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Supplement of

Storm Erwin: societal and energy impacts in northern Europe on 7–9 January 2005

Anthony J. Kettle

Correspondence to: Anthony J. Kettle (ake3358@gmail.com)

SECTION S1. THEMATIC MAPS OF STORM IMPACTS

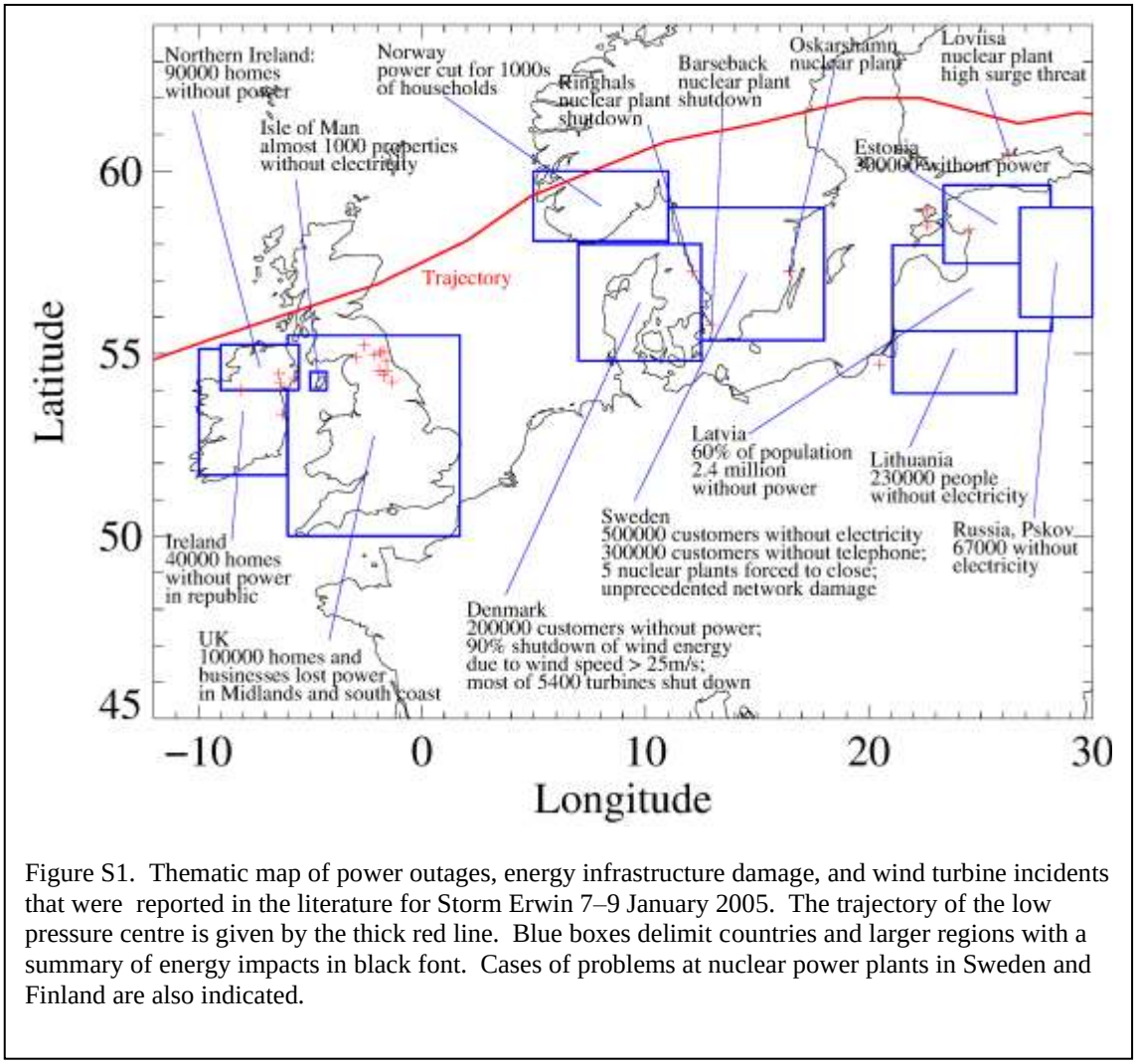

Figure S1. Thematic map of power outages, energy infrastructure damage, and wind turbine incidents that were reported in the literature for Storm Erwin 7–9 January 2005. The trajectory of the low pressure centre is given by the thick red line. Blue boxes delimit countries and larger regions with a summary of energy impacts in black font. Cases of problems at nuclear power plants in Sweden and Finland are also indicated.

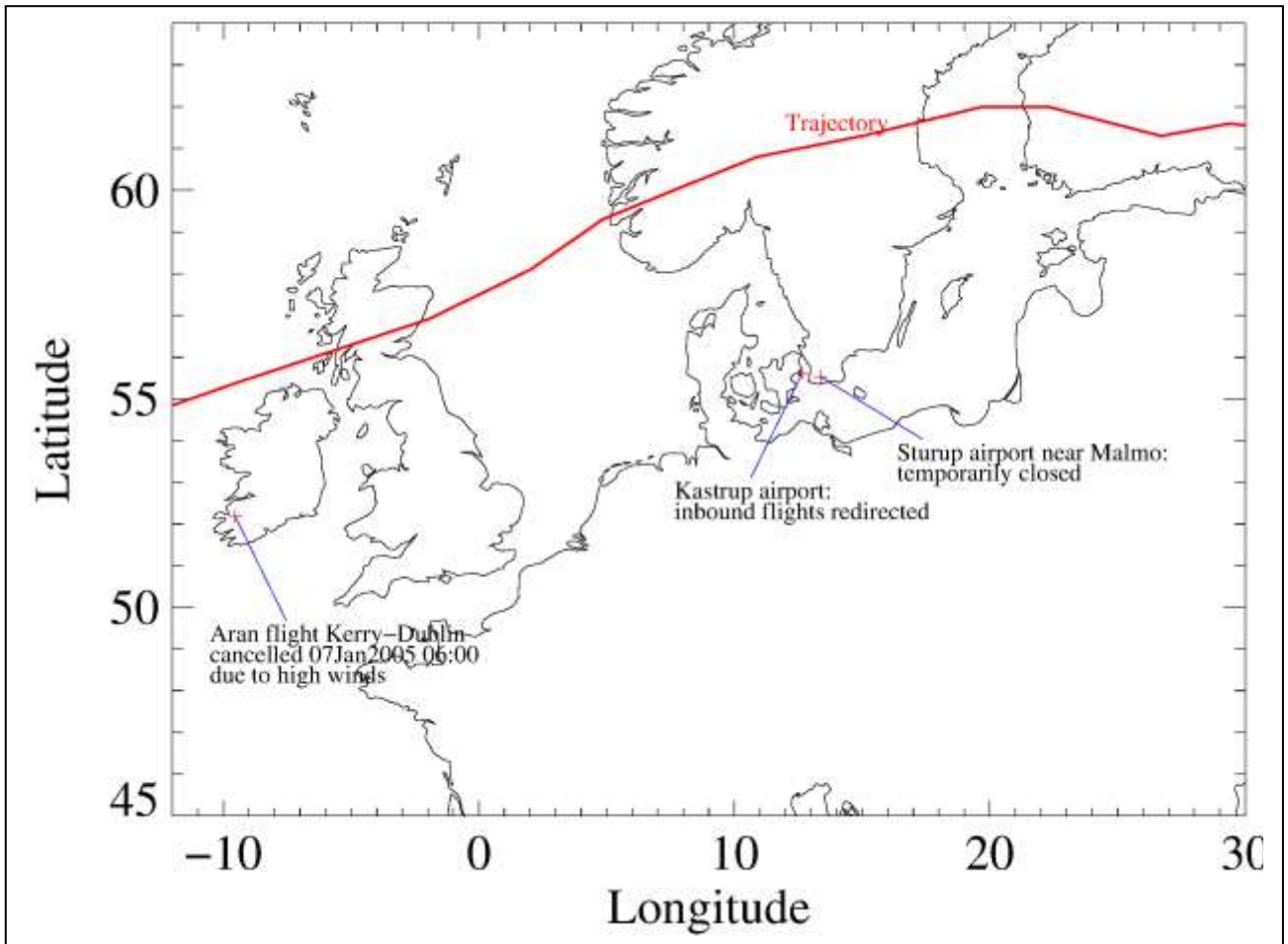

Figure S2 . Thematic map of flight cancellations and air transport incidents that were reported in the literature for Storm Erwin 7–9 January 2005. The trajectory of the low pressure centre is given by the thick red line.

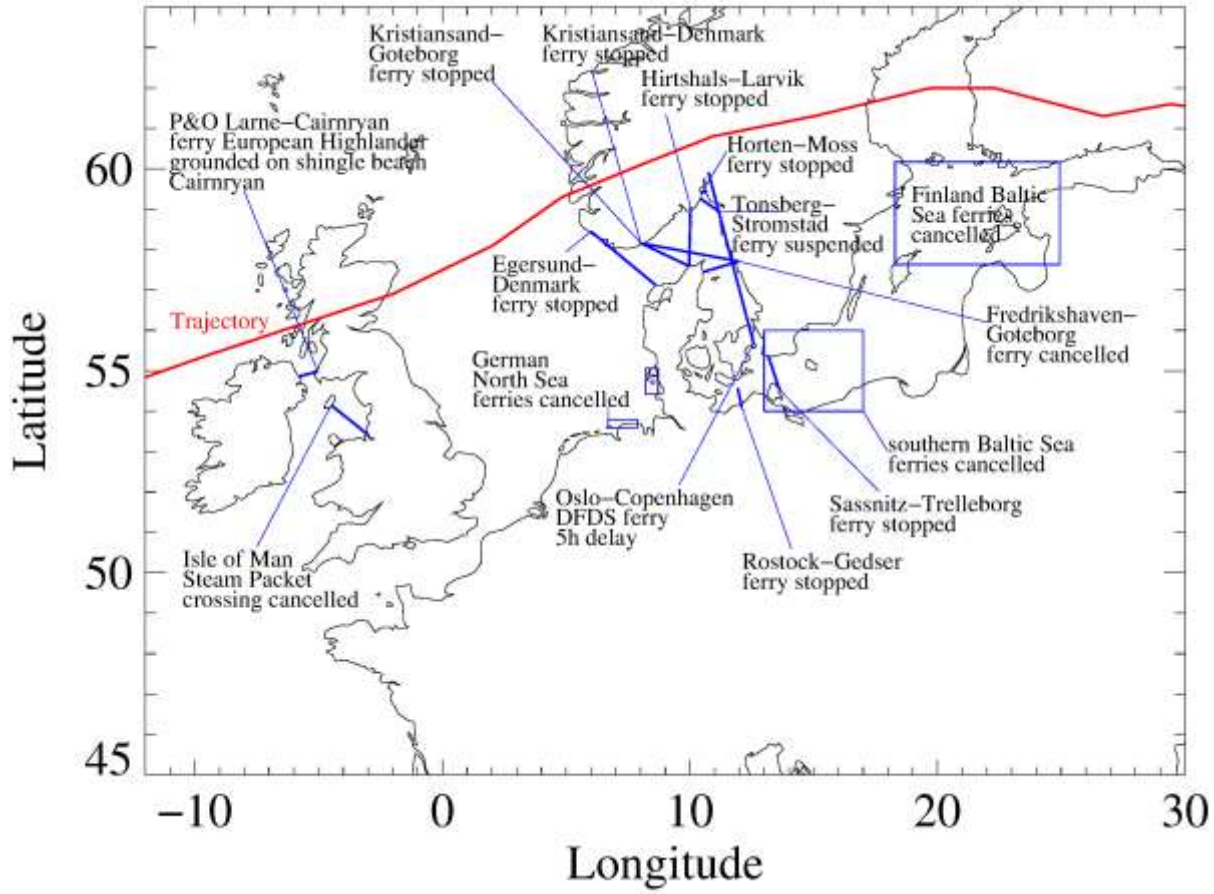

Figure S3. Thematic map of ferry and port interruptions that were reported in the literature for Storm Erwin 7–9 January 2005. The trajectory of the low pressure centre is given by the thick red line.

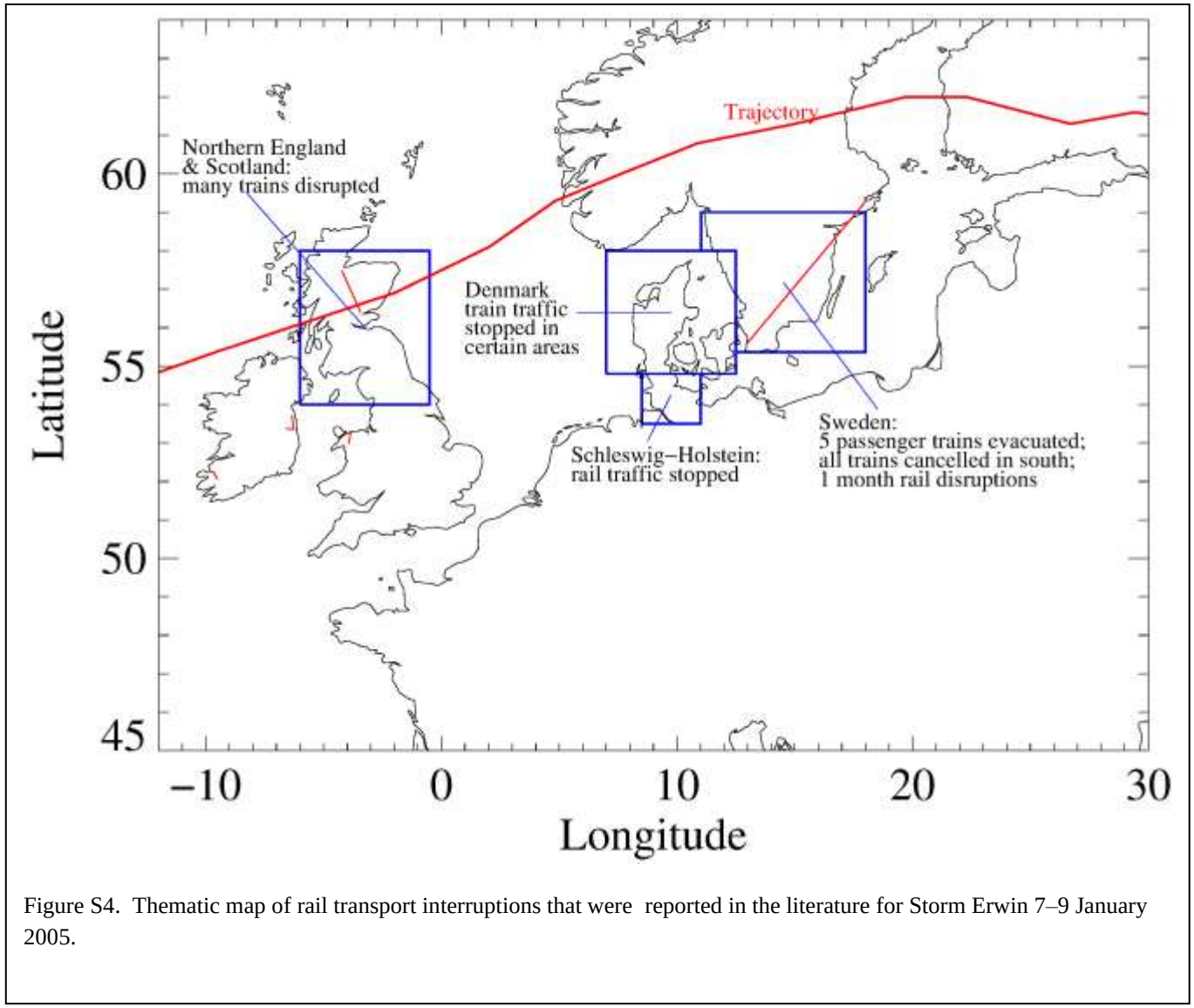

Figure S4. Thematic map of rail transport interruptions that were reported in the literature for Storm Erwin 7–9 January 2005.

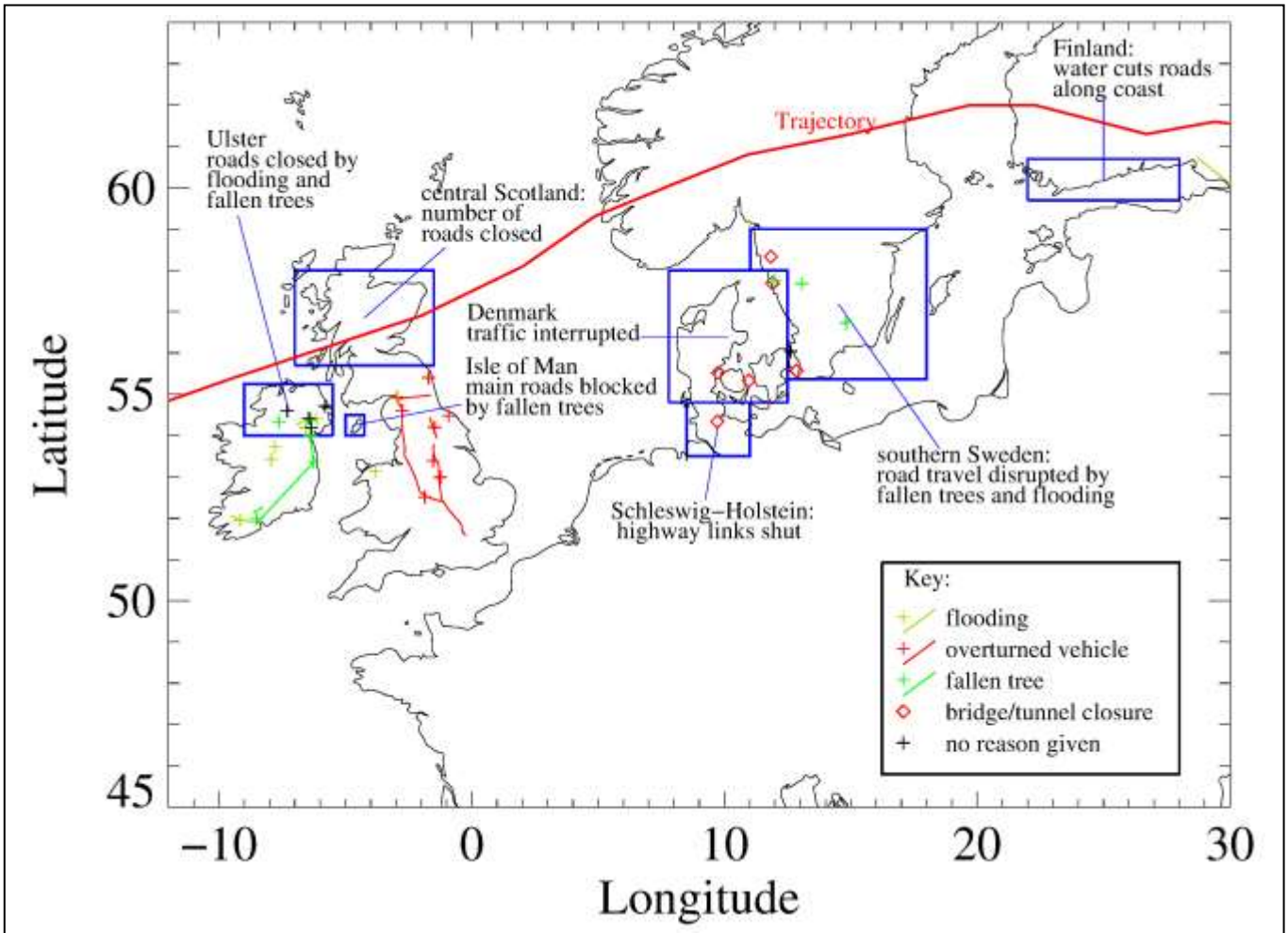

Figure S5. Thematic map of road transport interruptions that were reported in the literature for Storm Erwin 7–9 January 2005. The trajectory of the low pressure centre is given by the thick red line.

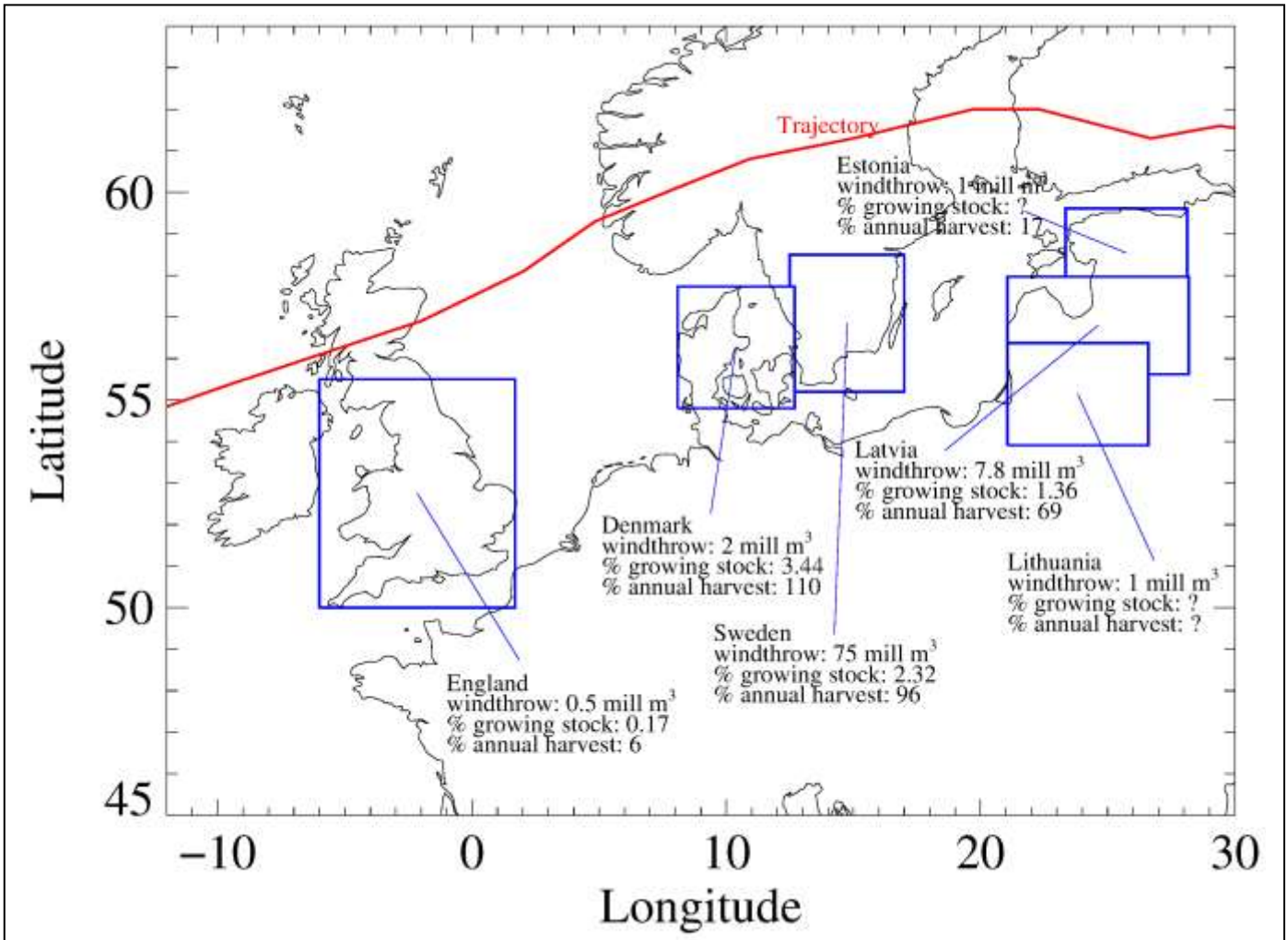

Figure S6. Thematic map of forest damage that was reported by Gardiner (2010) for storm Erwin 7–9 January 2005. The trajectory of the low pressure centre is given by the thick red line.

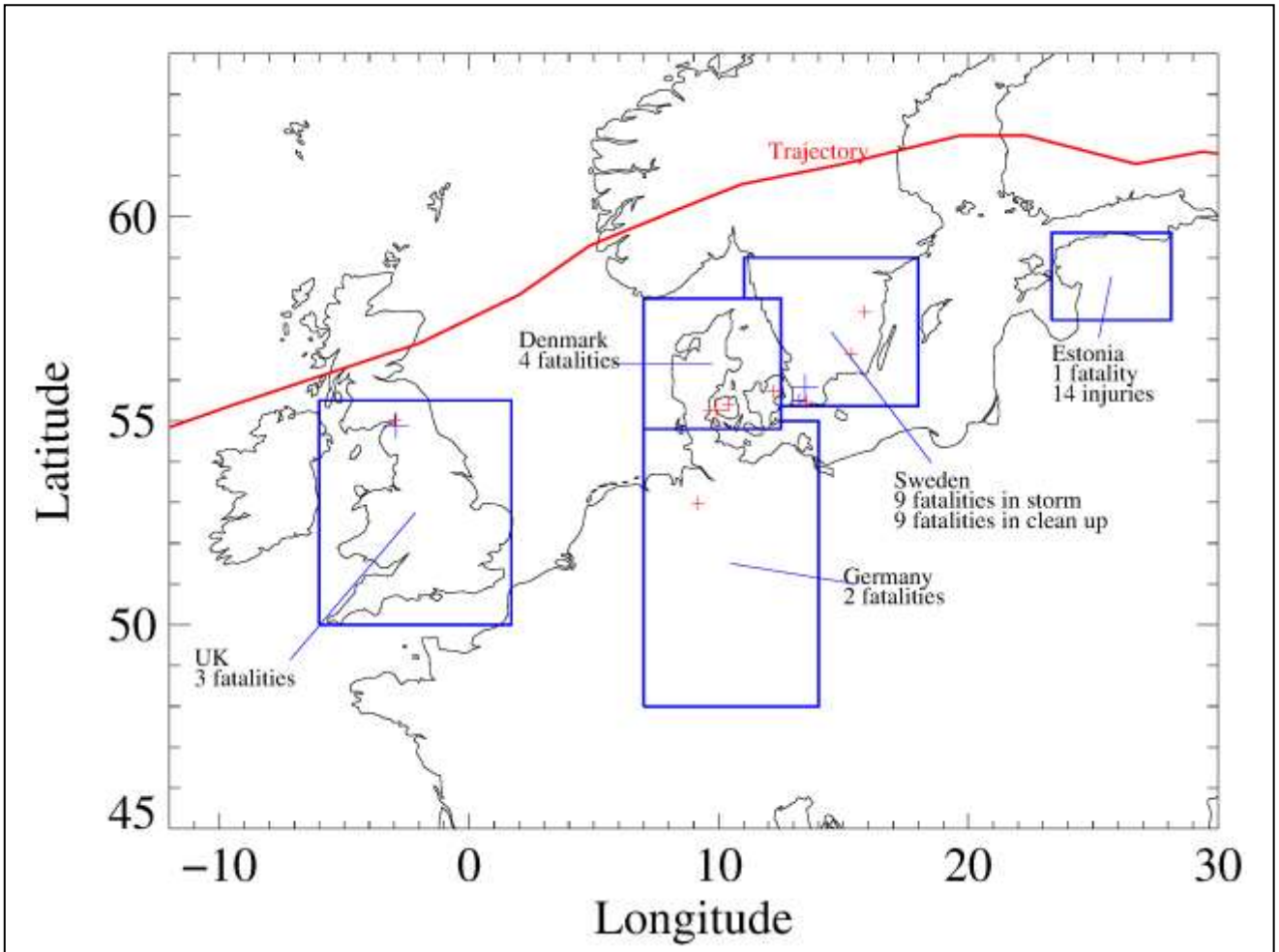

Figure S7. Thematic map of fatalities(red crosses) and injuries (blue crosses) that were reported in the literature for Storm Erwin 7–9 January 2005. The smaller symbol size denotes a single fatality or injury; the larger symbol denotes multiple casualties. The storm trajectory is plotted as a red line.

SECTION S2. STORM TRAJECTORY FROM XWS DATASET

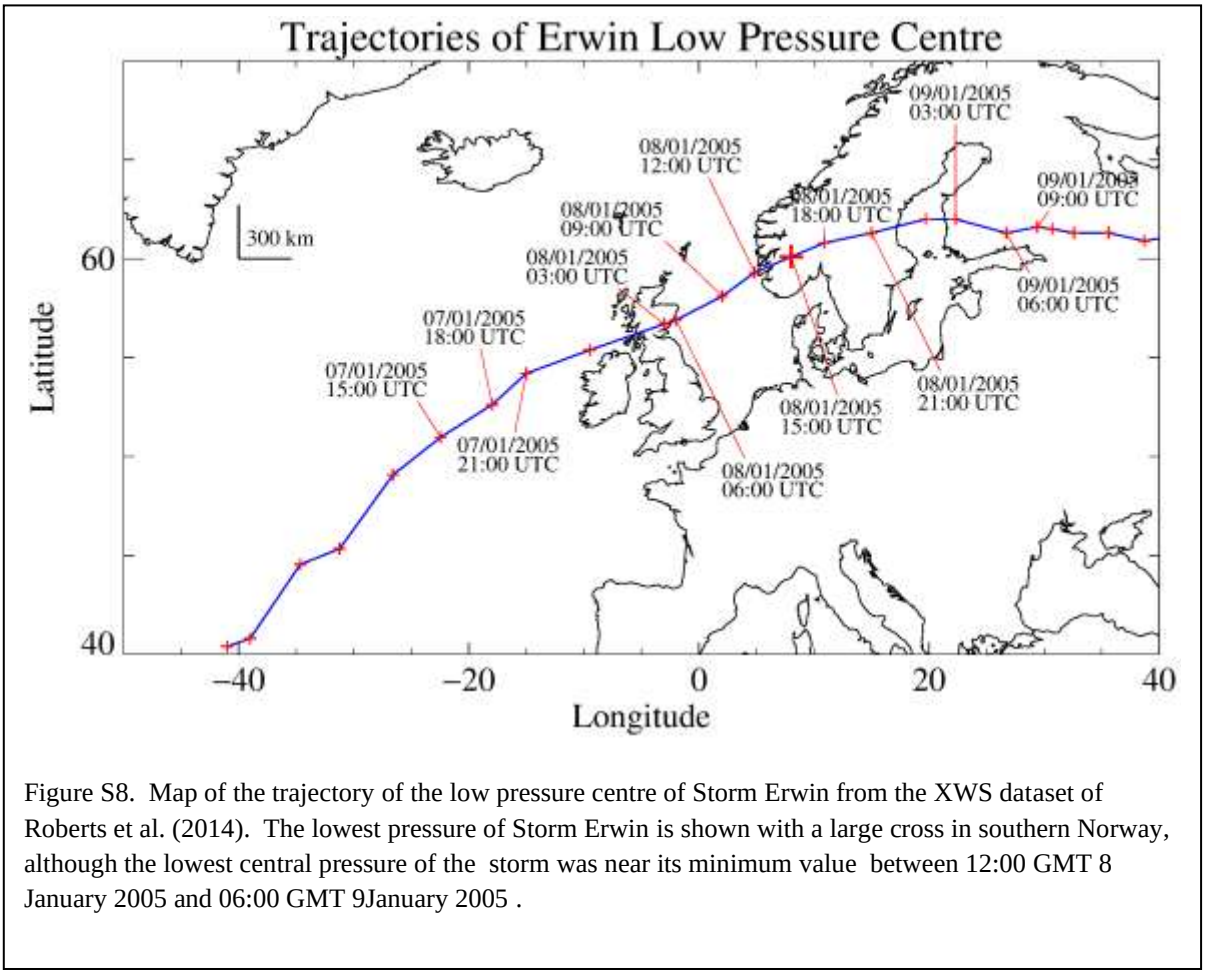

Figure S8. Map of the trajectory of the low pressure centre of Storm Erwin from the XWS dataset of Roberts et al. (2014). The lowest pressure of Storm Erwin is shown with a large cross in southern Norway, although the lowest central pressure of the storm was near its minimum value between 12:00 GMT 8 January 2005 and 06:00 GMT 9January 2005 .

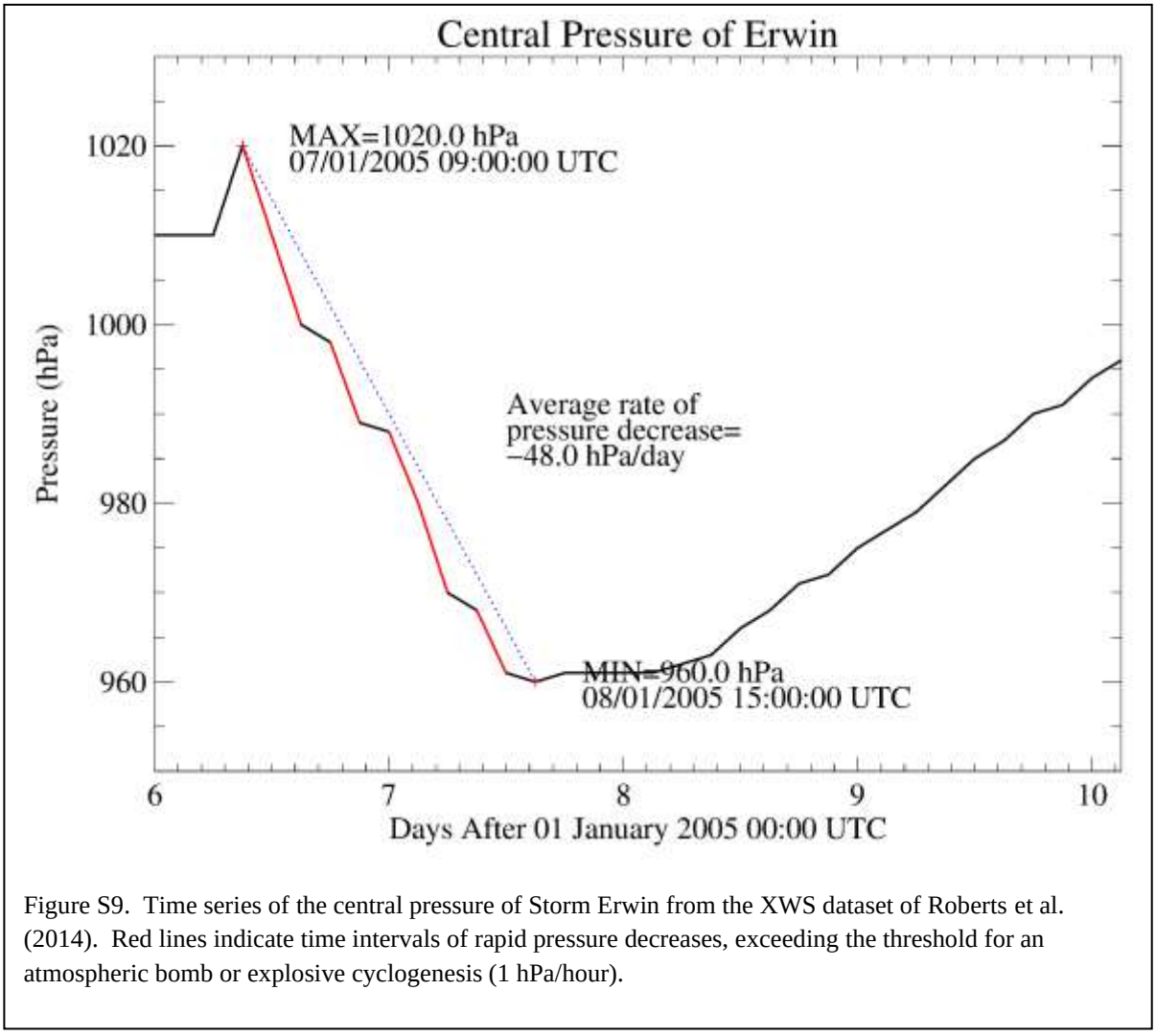

Figure S9. Time series of the central pressure of Storm Erwin from the XWS dataset of Roberts et al. (2014). Red lines indicate time intervals of rapid pressure decreases, exceeding the threshold for an atmospheric bomb or explosive cyclogenesis (1 hPa/hour).

SECTION S3. WIND MEASUREMENTS ACROSS THE PERIOD OF THE STORM

The following text is reproduced from the Supplement of Kettle (2024) as background information to understand the maps produced from the USAF data.

The USAF data set is described in the website 'U.S.A.F. DATSAV3 Surface observations, 1901–continuing' at https://rda.ucar.edu/datasets/ds463.2/. Data from the WMO, ICAO, and AFWA networks within the larger dataset forms an element of the Copernicus Climate Data Store product 'Global land surface atmospheric variables from 1755 to 2020 from comprehensive in-situ observations' at https://cds.climate.copernicus.eu/cdsapp#!/dataset/insitu-observations-surface-land?tab=overview'. The wind data from the WMO, ICAO, and AFWA networks have been used to compose the diagrams in this section. According to WMO reporting requirements, the wind speed report is a 10 minute average value and corrected for a 10 m standard height (CIMO guide, Chapter 5. Measurement of surface wind https://library.wmo.int/doc_num.php?explnum_id=3177/CIMO_Guide_2014_en_I_5.pdf).

Problems have been noted with some of the wind speed data passing into the international weather networks, which is most likely associated with a unit conversion error between knots and m/s (Gatey and Miller, 2007). The problem makes it difficult to trust the infrequent occurrence of high wind speed values in the raw data set. For this reason, a basic data buddy check was implemented for rejecting potentially bad data when drawing up the maps of this section. For a given reporting time, a wind speed value was compared with the nearest other reporting station and rejected if it was more than four times greater.

The trajectory information in the following maps is taken from the Extreme Winstorm Catalog (Roberts et al., 2014; XWS, 2025)

Reference:

Gatey, D.A. and Miller, C.A.: An investigation into 50-year return period wind speed differences for Europe, J .Wind Engineering and Industrial Aerodynamics, 95, 1040–1052, 2007.

Kettle, A. J.: Storm Daria: Societal and energy impacts in northwest Europe on 25–26 January 1990, Adv. Geosci., 65, 83– 101, 2024.

Roberts, J. F., Champion, A. J., Dawkins, L. C., Hodges, K. I., Shaffrey, L. C., Stephenson, D. B., Stringer, M. A., Thornton, H. E., and Youngman, D.B.: The XWS open access catalogue of extreme European windstorms from 1979 to 2012, Nat. Hazards Earth Syst. Sci, 14, 2487–2501, doi:10.5194/nhess-14-2487-2014, 2014.

XWS: https://www.europeanwindstorms.org/, last access: 7 June 2025.

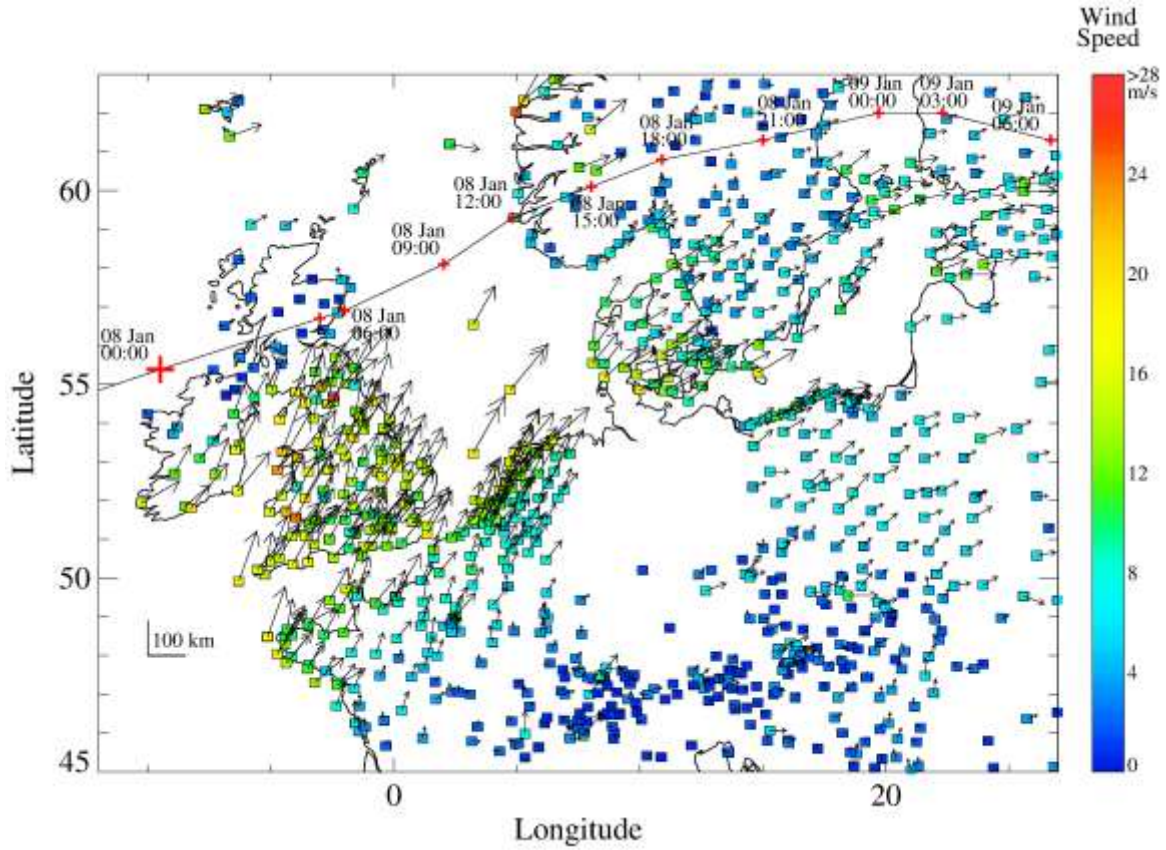

Figure S10. Wind speed and direction within 5 minutes of 00:00 UTC 8 January 2005 from selected stations of the USAF data set. The trajectory of low pressure centre is indicated by the black line with red crosses at 3 hour intervals (Roberts et al., 2014). The location of the pressure centre at the time of wind field is shown by a larger cross.

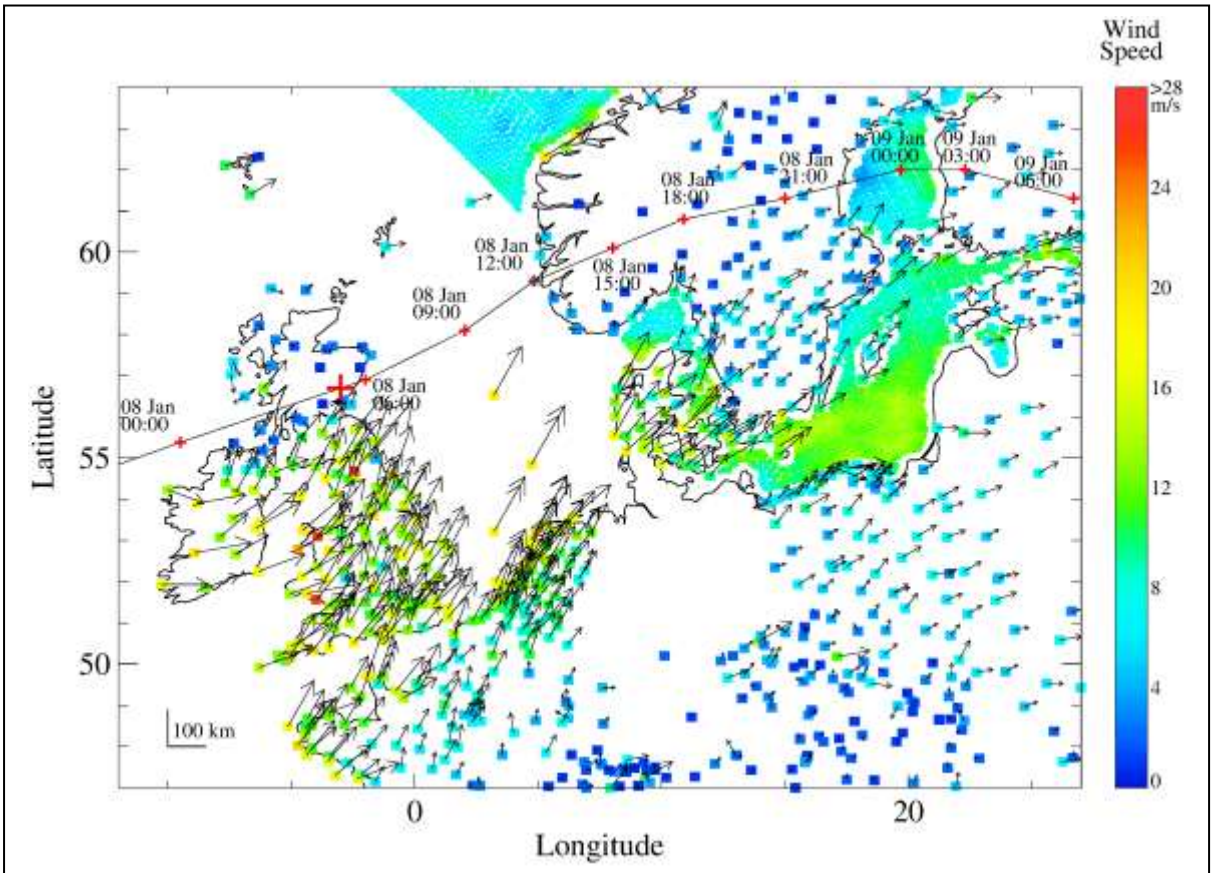

Figure S11. Wind speed and direction within 5 minutes of 03:00 UTC 8 January 2005 from selected stations of the USAF data set. The trajectory of low pressure centre is indicated by the black line with red crosses at 3 hour intervals (Roberts et al., 2014). The location of the pressure centre at the time of wind field is shown by a larger cross. The QuikSCAT sea surface wind speeds are shown for a satellite overpass at ~03:20 UTC or ~20 minutes after the synoptic station reports.

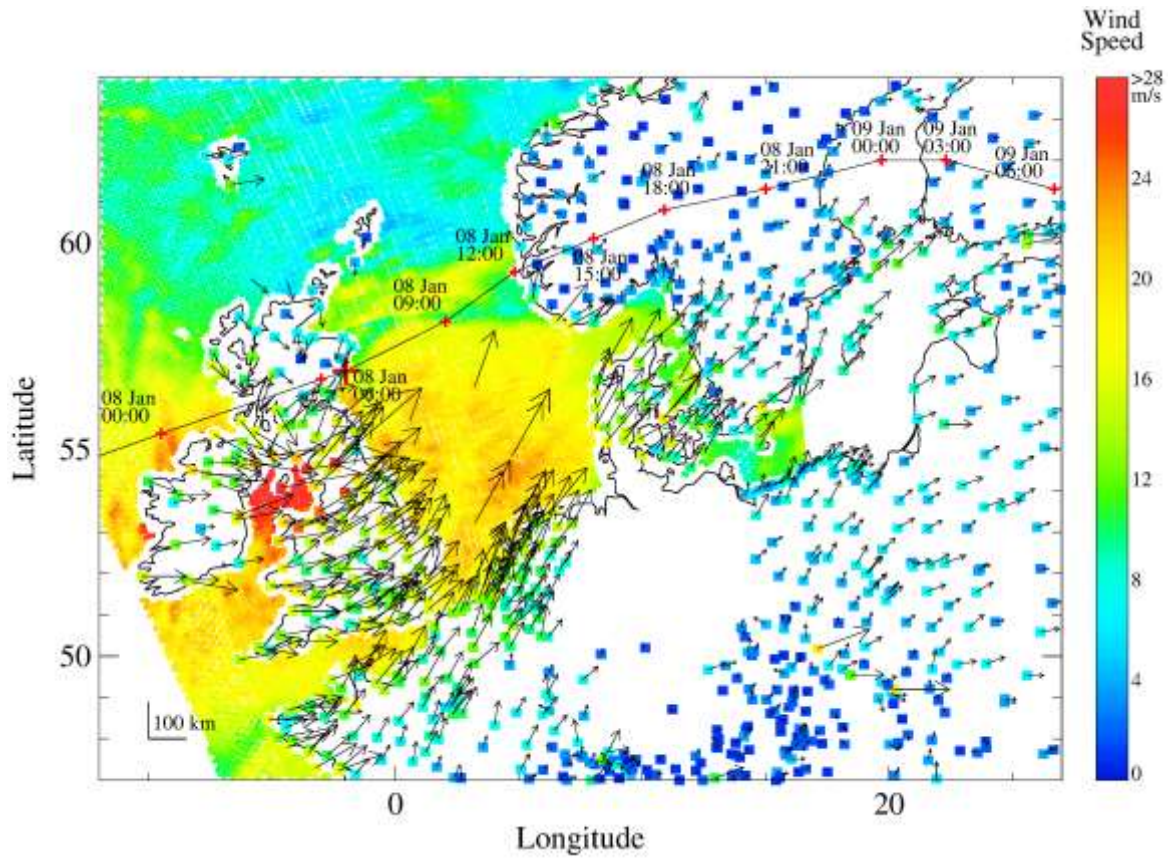

Figure S12. Wind speed and direction within 5 minutes of 06:00 UTC 8 January 2005 from selected stations of the USAF data set. The trajectory of low pressure centre is indicated by the black line with red crosses at 3 hour intervals (Lockwood et al., 2022). The location of the pressure centre at the time of wind field is shown by a larger cross. The QuikSCAT sea surface wind speeds are shown for a satellite overpass at ~05:00 UTC or ~60 minutes before the synoptic station reports.

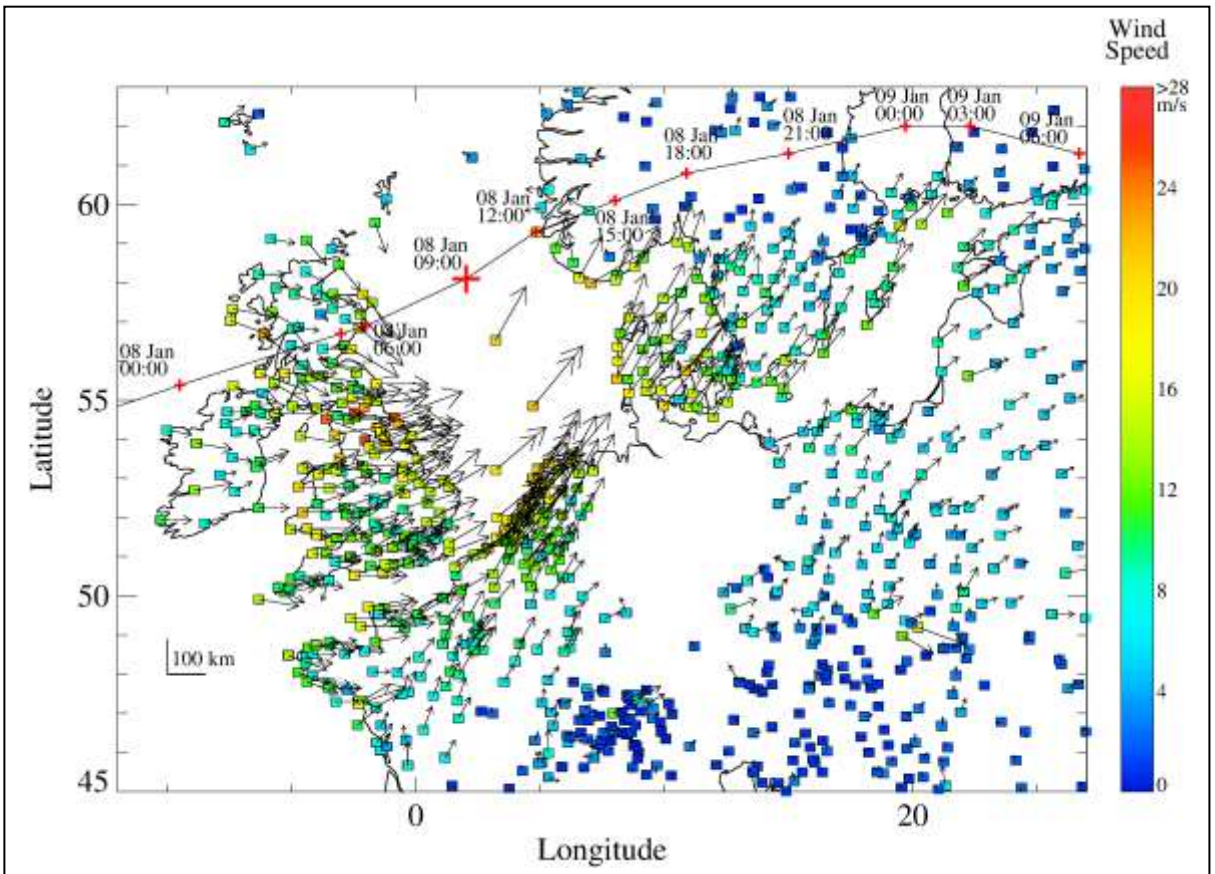

Figure S13. Wind speed and direction within 5 minutes of 09:00 UTC 8 January 2005 from selected stations of the USAF data set. The trajectory of low pressure centre is indicated by the black line with red crosses at 3 hour intervals (Roberts et al., 2014). The location of the pressure centre at the time of wind field is shown by a larger cross.

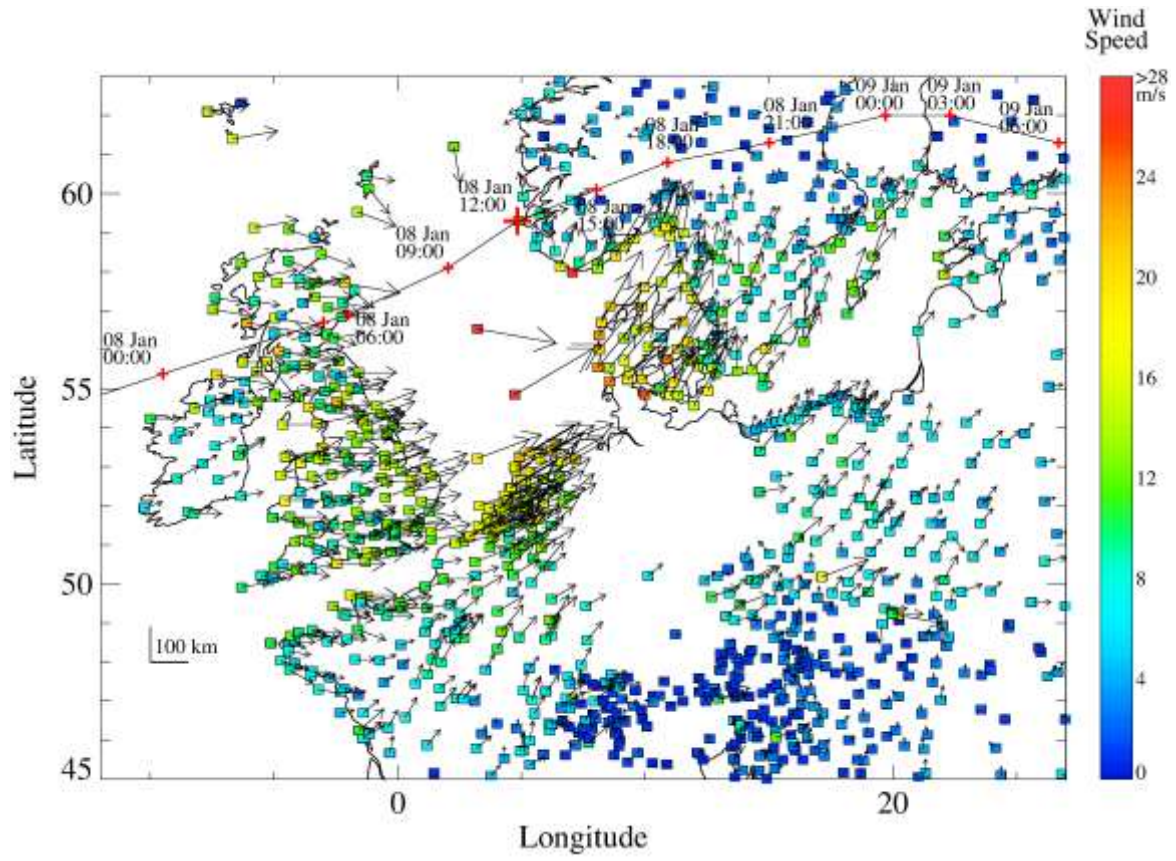

Figure S14. Wind speed and direction within 5 minutes of 12:00 UTC 8 January 2005 from selected stations of the USAF data set. The trajectory of low pressure centre is indicated by the black line with red crosses at 3 hour intervals (Roberts et al., 2014). The location of the pressure centre at the time of wind field is shown by a larger cross.

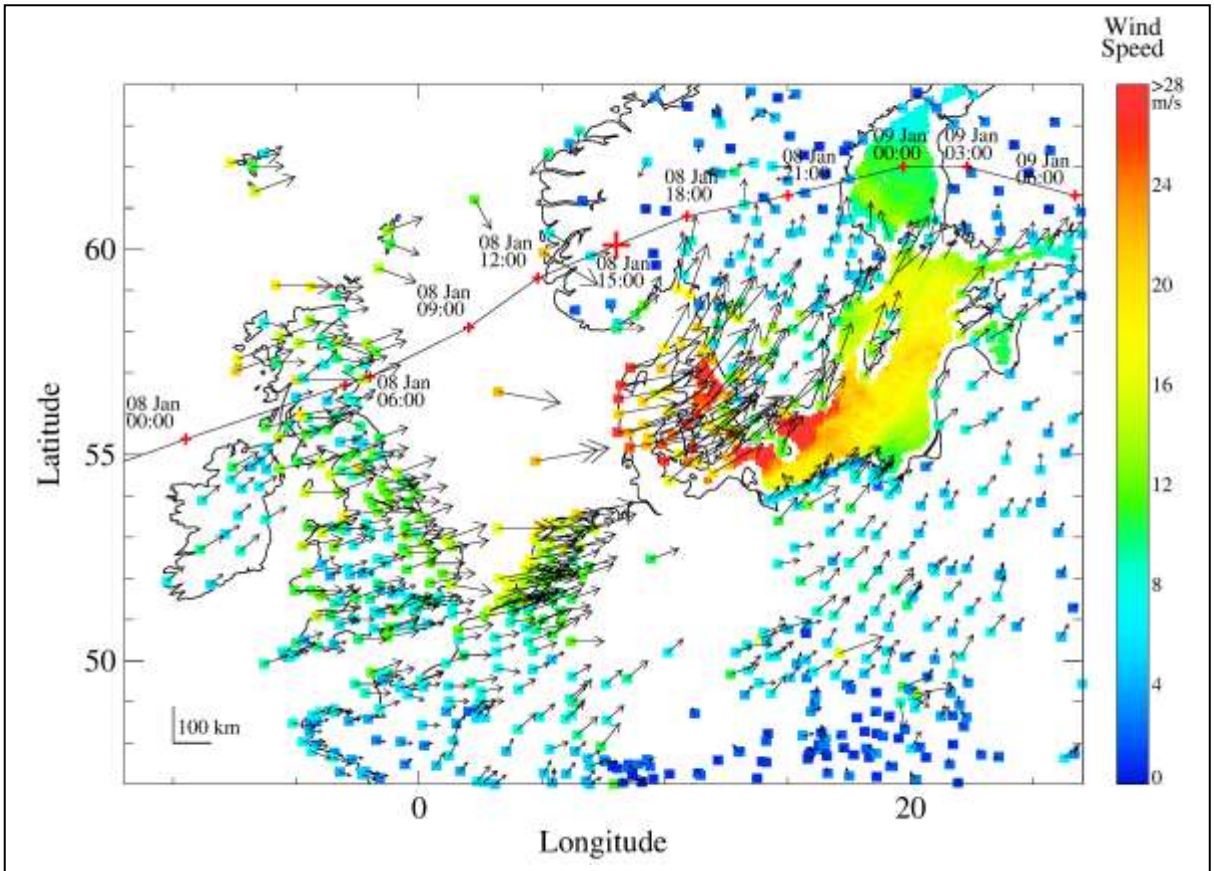

Figure S15. Wind speed and direction within 5 minutes of 15:00 UTC 8 January 2005 from selected stations of the USAF data set. The trajectory of low pressure centre is indicated by the black line with red crosses at 3 hour intervals (Roberts et al., 2014). The location of the pressure centre at the time of wind field is shown by a larger cross. The QuikSCAT sea surface wind speeds are shown for a satellite overpass at ~17:03 UTC or ~123 minutes after the synoptic station reports.

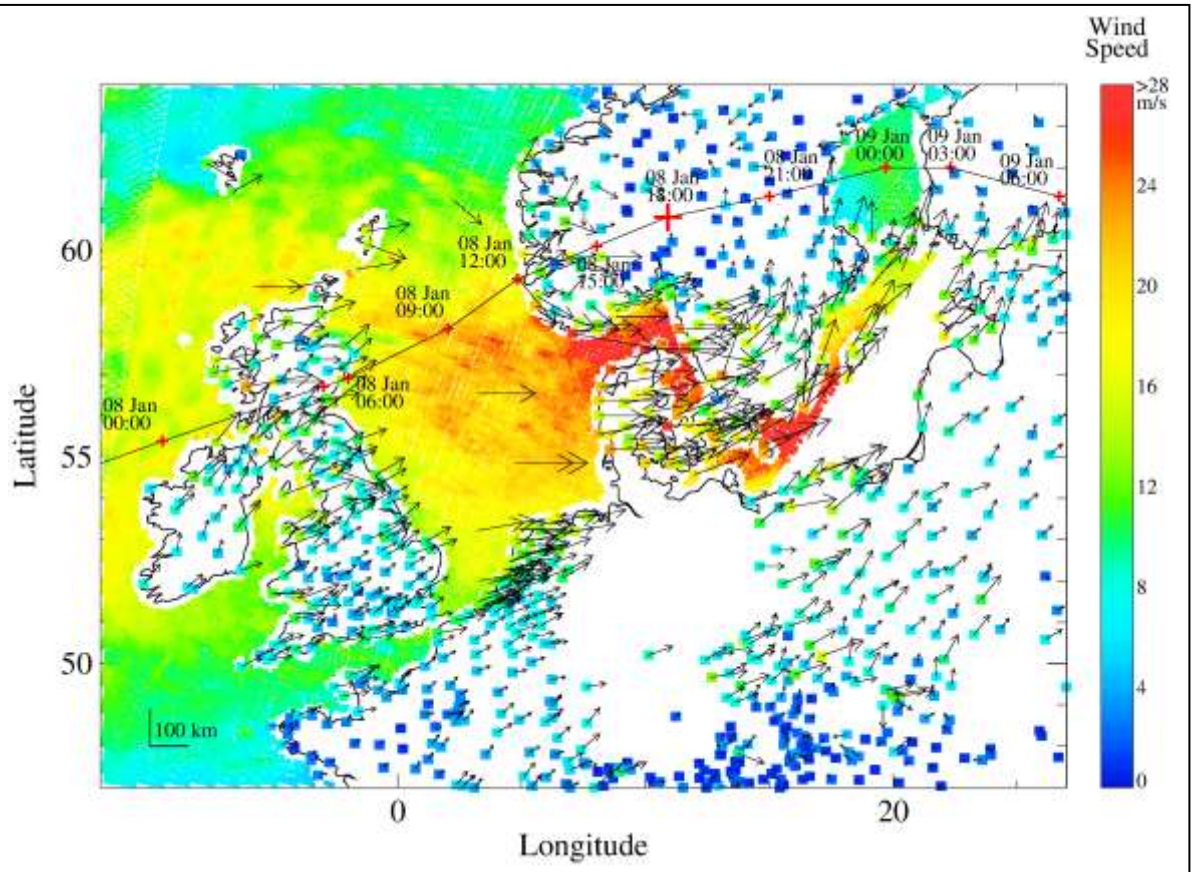

Figure S16. Wind speed and direction within 5 minutes of 18:00 UTC 8 January 2005 from selected stations of the USAF data set. The trajectory of low pressure centre is indicated by the black line with red crosses at 3 hour intervals (Roberts et al., 2014). The location of the pressure centre at the time of wind field is shown by a larger cross. The QuikSCAT sea surface wind speeds are shown for a satellite overpass at ~18:45 UTC or ~45 minutes after the synoptic station reports.

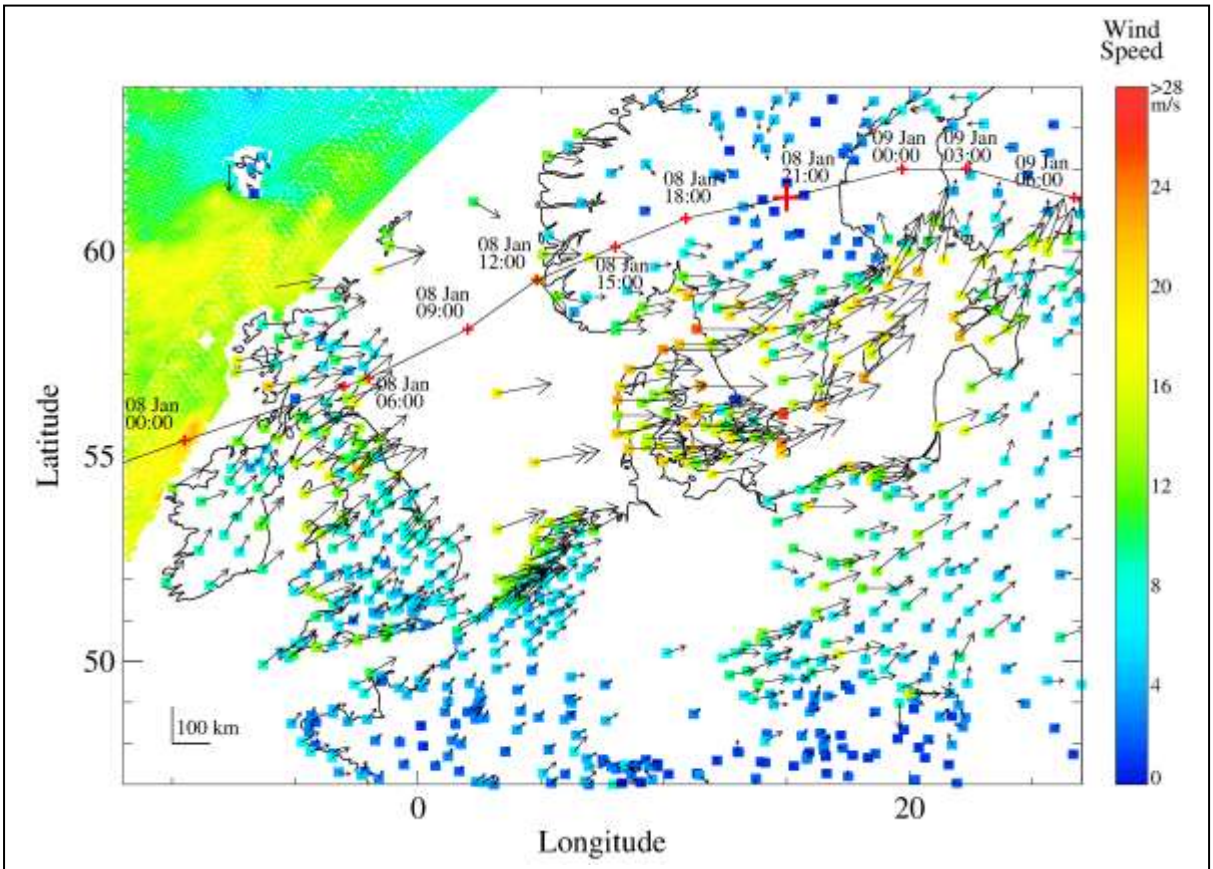

Figure S17. Wind speed and direction within 5 minutes of 21:00 UTC 8 January 2005 from selected stations of the USAF data set. The trajectory of low pressure centre is indicated by the black line with red crosses at 3 hour intervals (Roberts et al., 2014). The location of the pressure centre at the time of wind field is shown by a larger cross. The QuikSCAT sea surface wind speeds are shown for a satellite overpass at ~20:25 UTC or ~35 minutes before the synoptic station reports.

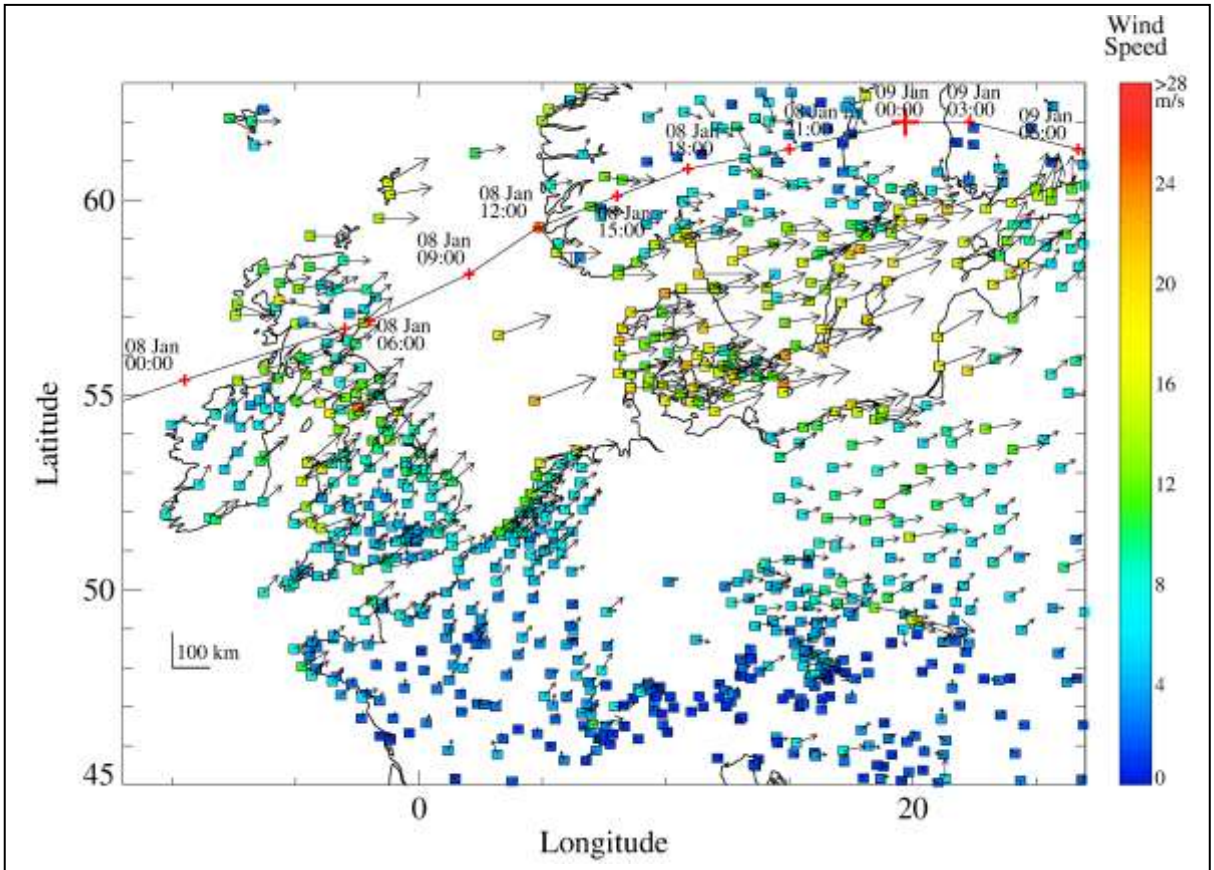

Figure S18. Wind speed and direction within 5 minutes of 00:00 UTC 9 January 2005 from selected stations of the USAF data set. The trajectory of low pressure centre is indicated by the black line with red crosses at 3 hour intervals (Roberts et al., 2014). The location of the pressure centre at the time of wind field is shown by a larger cross.

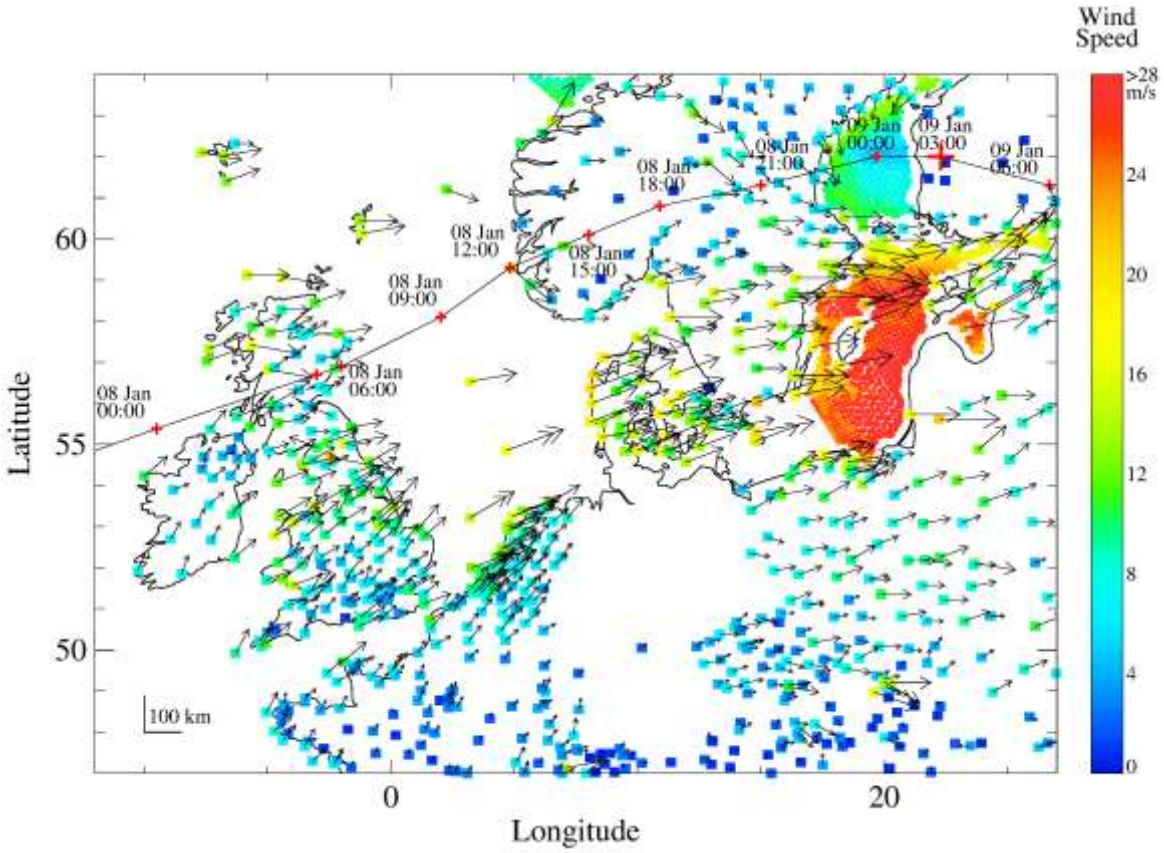

Figure S19. Wind speed and direction within 5 minutes of 03:00 UTC 9 January 2005 from selected stations of the USAF data set. The trajectory of low pressure centre is indicated by the black line with red crosses at 3 hour intervals (Roberts et al., 2014). The location of the pressure centre at the time of wind field is shown by a larger cross. The QuikSCAT sea surface wind speeds are shown for a satellite overpass at ~02:54 UTC or ~6 minutes before the synoptic station reports.

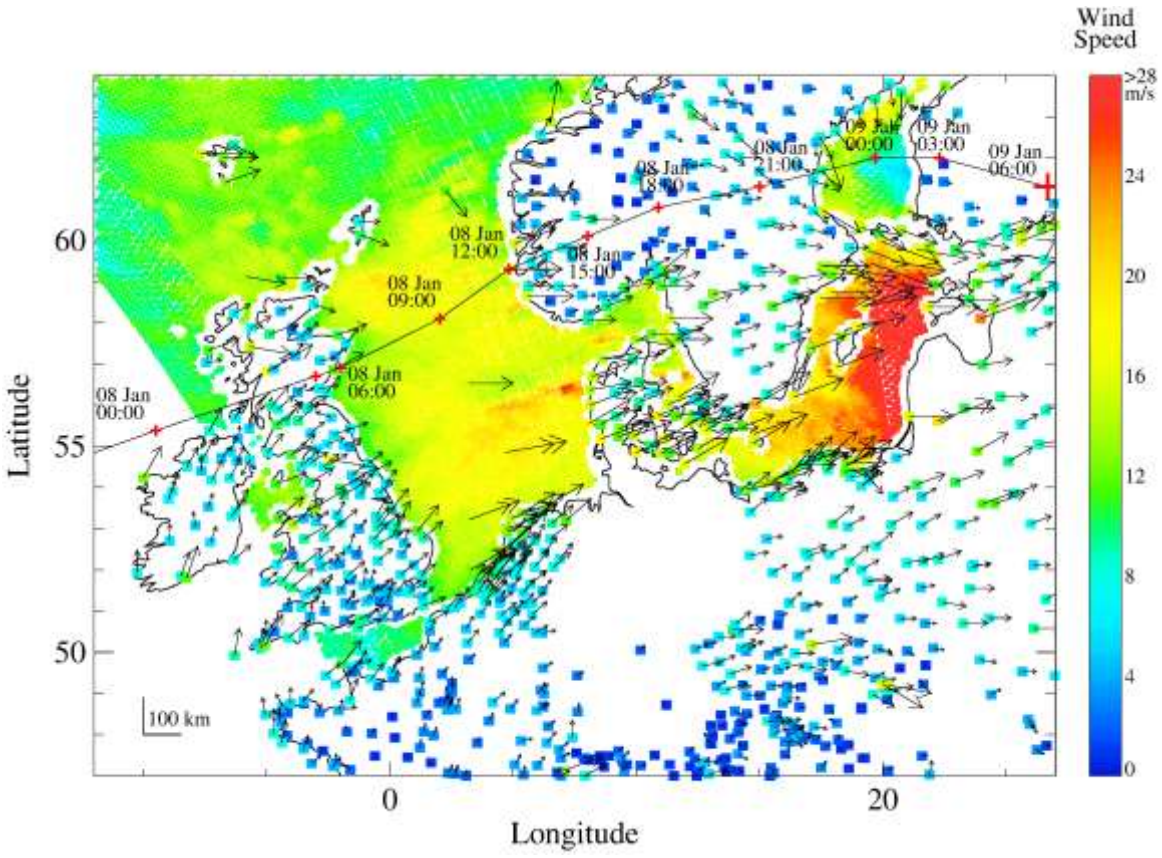

Figure S20. Wind speed and direction within 5 minutes of 06:00 UTC 9 January 2005 from selected stations of the USAF data set. The trajectory of low pressure centre is indicated by the black line with red crosses at 3 hour intervals (Roberts et al., 2014). The location of the pressure centre at the time of wind field is shown by a larger cross. SSM/I sea surface wind speeds are shown for a satellite overpass at about 04:34 UTC or ~86 minutes before the synoptic station reports.

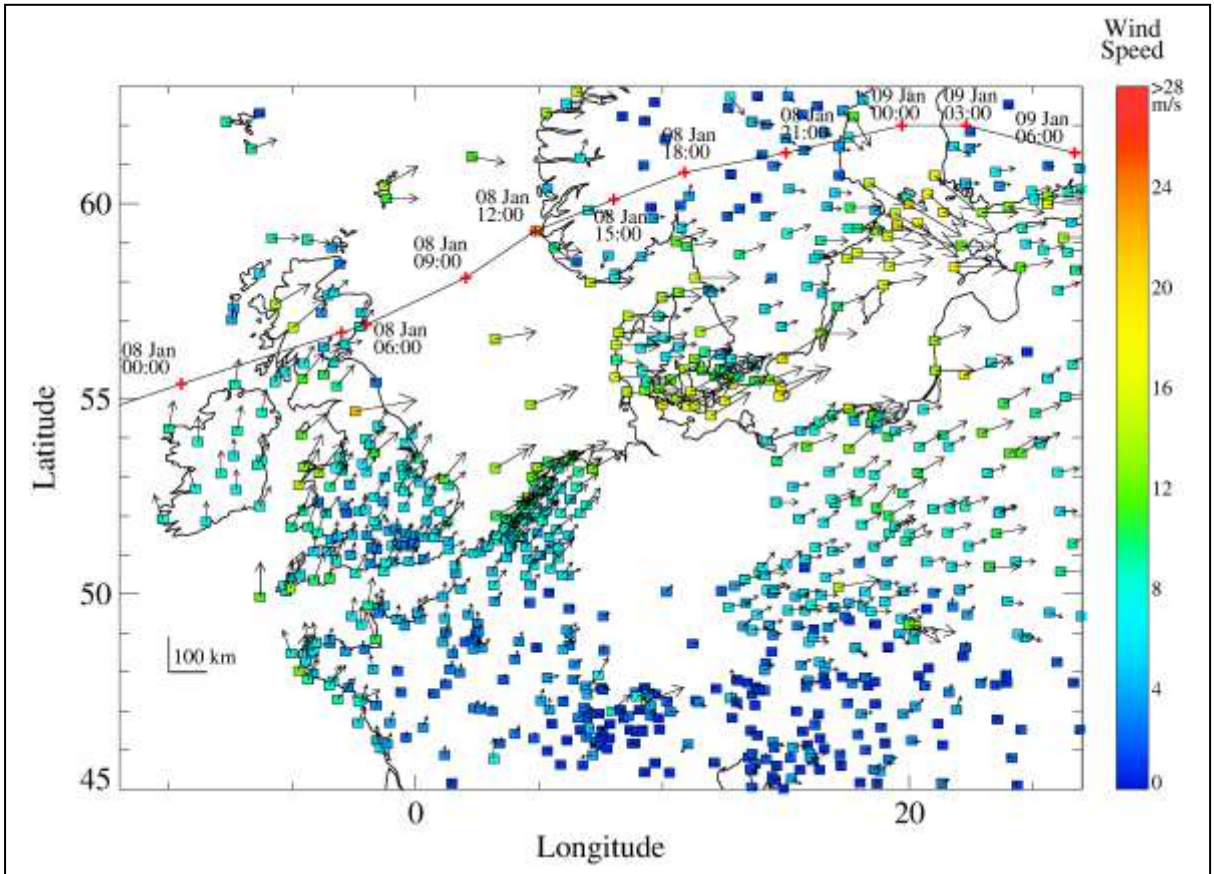

Figure S21. Wind speed and direction within 5 minutes of 09:00 UTC 8 January 2005 from selected stations of the USAF data set. The trajectory of low pressure centre is indicated by the black line with red crosses at 3 hour intervals (Roberts et al., 2014). The location of the pressure centre at the time of wind field is off the right edge of the figure.

SECTION S4. RADIOSONDE ANALYSIS ACROSS THE PERIOD OF THE STORM

The following description has been reproduced and modified from Kettle (2024).

Radiosonde data for Europe were downloaded from the University of Wyoming archival website at http://weather.uwyo.edu/upperair/sounding.html. The locations of the stations chosen for the analysis are shown in Fig. S22 (S4.1). The data for the time period 1–31 January 2005 were selected for analysis. Most of the stations had radiosonde ascents at 12 h intervals, although some had data at 6 h intervals. The original data sets included primary profile measurements (pressure, height, temperature, dew point temperature, wind speed, and wind direction), derived profile measurements (relative humidity, mixing ratio, and potential temperature) and a number of diagnostic values including convective available potential energy (CAPE) , level of free convection, equilibrium level, and SWEAT (Severe WEA Threat) index. Although the archival website does not present metadata or instrument specifications, information about the radiosonde instruments that have used by the different national meteorological services is given in Gaffen (1993).

A subset of information for height and wind speed is presented in this section. Time series of vertical profiles of wind speed are shown in Fig. S23, S24, S25 for stations at Lerwick, Stavanger, and Valencia. These show the highest upper tropospheric wind speeds at the time of Storm Erwin, which was registered for the radiosonde ascents on 8 January 2005 00:00 UTC. These stations were in the region of high surface wind speeds across north-western Europe. The upper tropospheric wind speeds of approximately 80 m/s for one station would have marked this storm as a category 5 hurricane if the wind speeds had been registered as a 10 minute sustained average at 10 m height above the ground surface.

Latitude-height profiles of wind speed are shown for stations in western Europe at 7 January 2005 at 12:00 UTC (Fig. S26), 8 January 2005 at 00:00 UTC (Fig. S27), 8 January 2005 at 12:00 UTC (Fig. S28), and 9 January 2005 at 00:00 UTC (Fig. S29). The figures emphasize that the highest tropospheric winds occurred at latitudes of about 50–60 N, south of the trajectory of the low pressure centre. The high level jets for Lerwick and Stavanger were centered at a height of about 10 km, and high winds for several stations penetrated down to about 5 km.

The spatial distribution of positive CAPE data calculated from the radiosonde profiles is shown in maps in Fig. S30 (7 January 2005 12:00 UTC), S31 (8 January 2005 00:00 UTC), S32 (8 January 2005 12:00 UTC), and S33 (9 January 2005 00:00 UTC). For the first two time periods, the maps show a small goup of stations with positive CAPE clustered mainly around the North Sea. The level of free convection and equilibrium level for these stations reveals that the convection systems were mainly shallow and close to the surface. For the last two time periods, the conection systems deepened. The time period indicates that the convection depth around the Baltic area extends almost to half othe depth of the troposphere. The spatial distribution of positive SWEAT index data calculated from radiosonde profiles is shown in maps in Fig. S34 (7 January 2005 12:00 UTC), S35 (8 January 2005 00:00 UTC), S36 (8 January 2005 12:00 UTC) and S37 (9 January 2005 00:00 UTC), along with the location of the one tornado report in northern Germany. The SWEAT index takes account of vertical wind shear and stability, and the important message from these plots is that the tornado potential in north-western Europe near the North Sea coast was comparable to a bad summertime convection system in the mid-western United States. During Storm Erwin, the SWEAT index reached its highest value in southern Sweden on 9 January 2005 00:00, near the locations of highest forest damage.

References:

Gaffen, Dian J.: Historical changes in radiosonde instruments and practices, World Meteorological Organization, Instruments and Observing Methods, Report No. 50. WMO/TD-No.541, 1993

Kettle, A. J.: Storm Daria: Societal and energy impacts in northwest Europe on 25–26 January 1990, Adv. Geosci., 65, 83– 101, 2024.

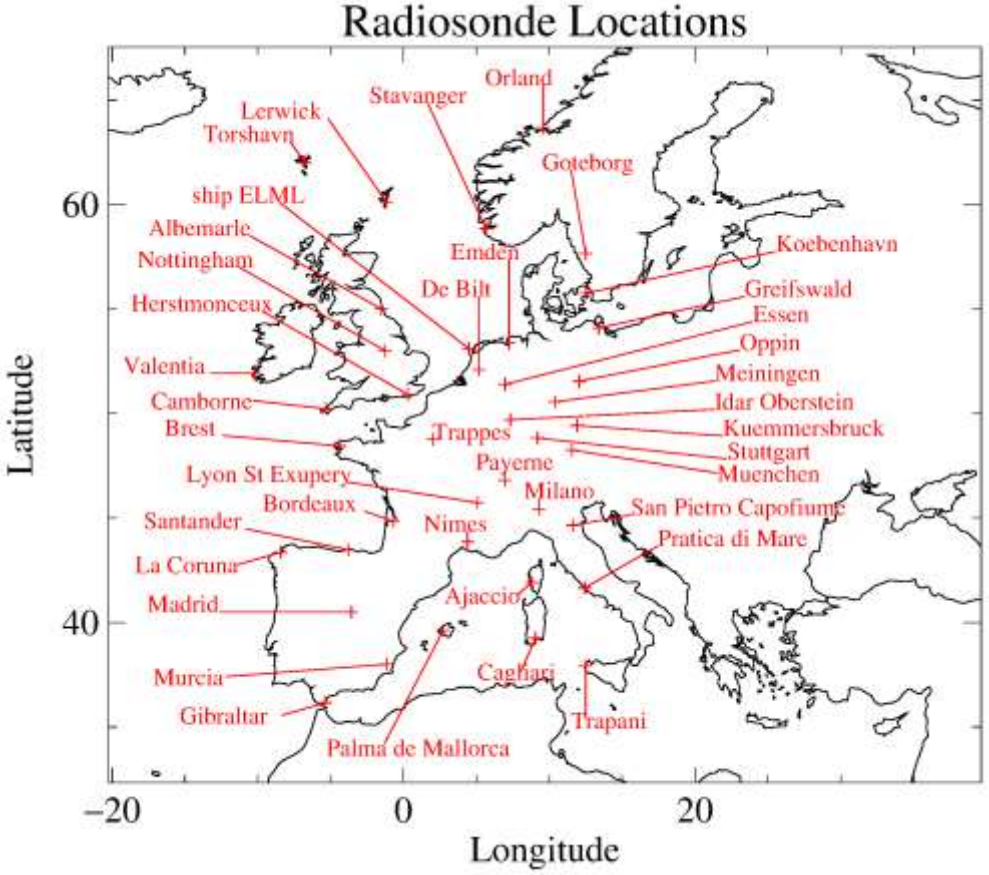

Figure S22. Map of radiosonde stations with data during the time period 1–31 January 2005.

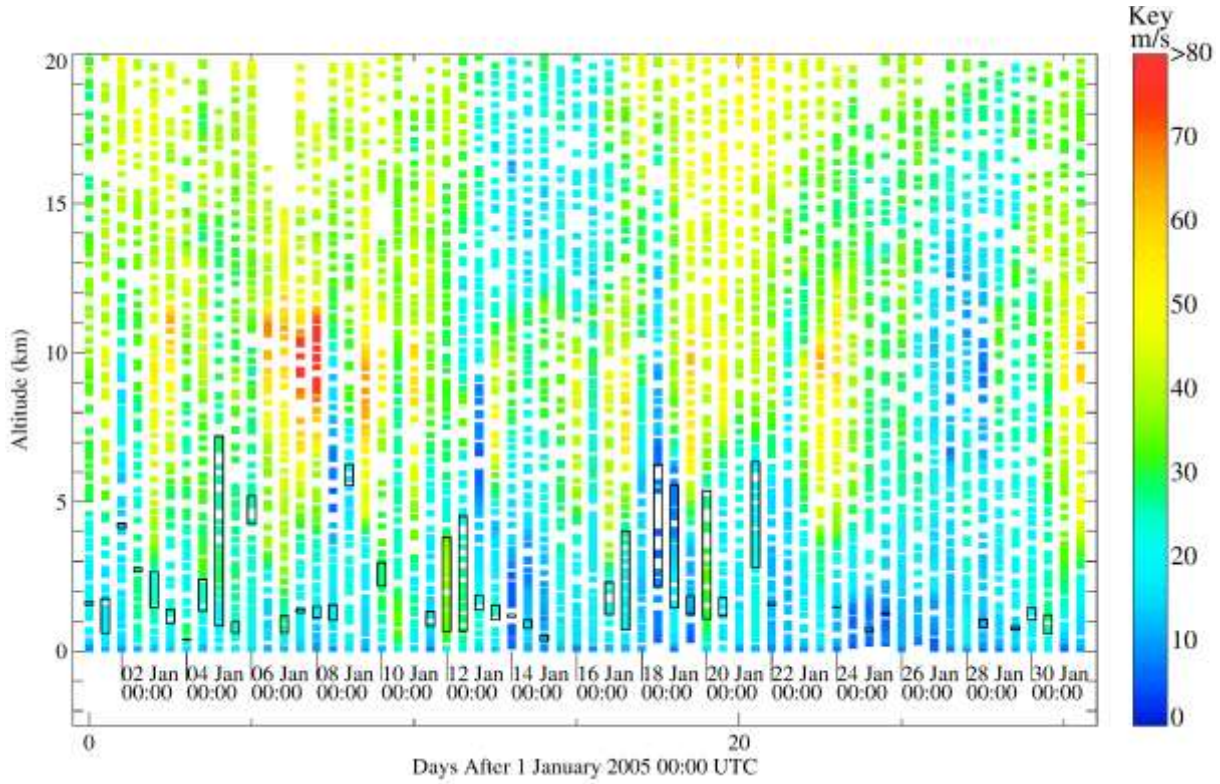

Figure S23. Time series of vertical profiles of wind speed for the radiosonde station at Lerwick in northern Scotland for the period 1–31 January 2005. Open boxes near the bottom of the figure (lower troposphere) indicate the vertical range between the level of free convection and the equilibium level for profiles showing positive values of convective available potential energy (CAPE).

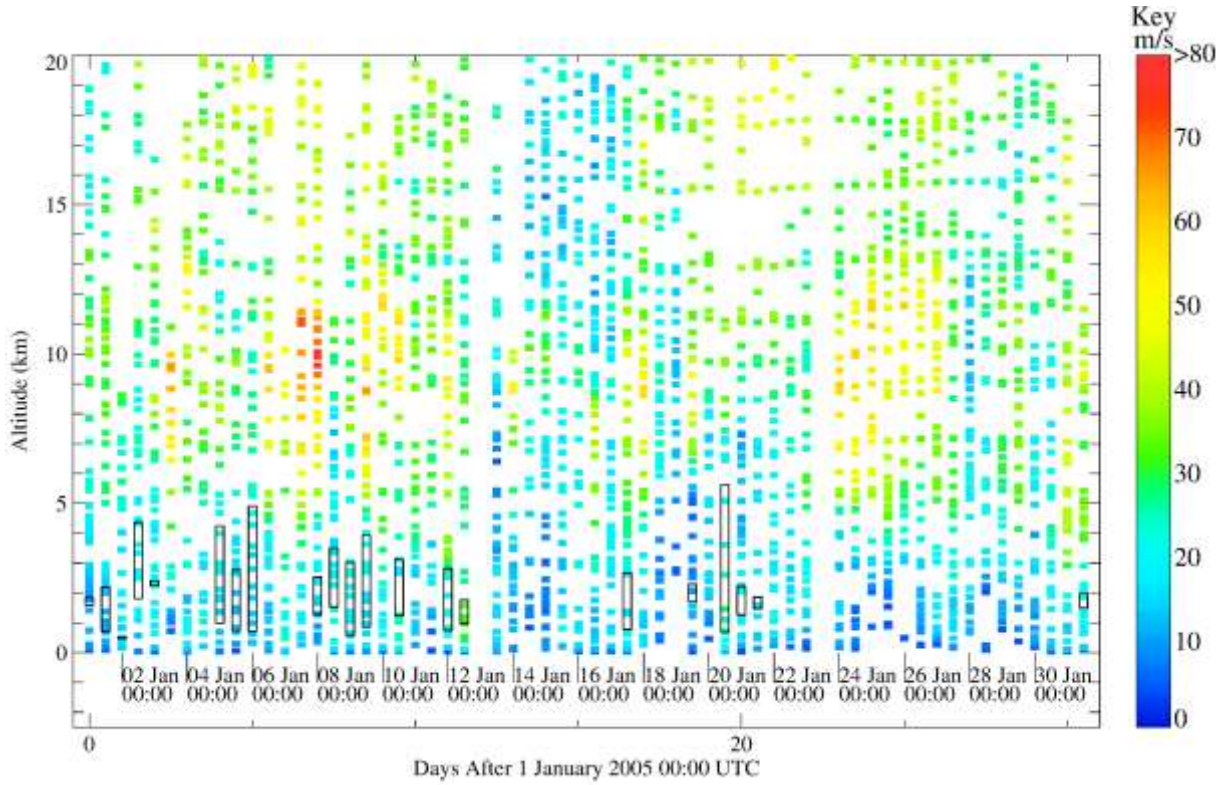

Figure S24. Time series of vertical profiles of wind speed for the radiosonde station at Stavanger in southern Norway for the period 1–31 January 2005. Open boxes near the bottom of the figure (lower troposphere) indicate the vertical range between the level of free convection and the equilibium level for profiles showing positive values of convective available potential energy (CAPE).

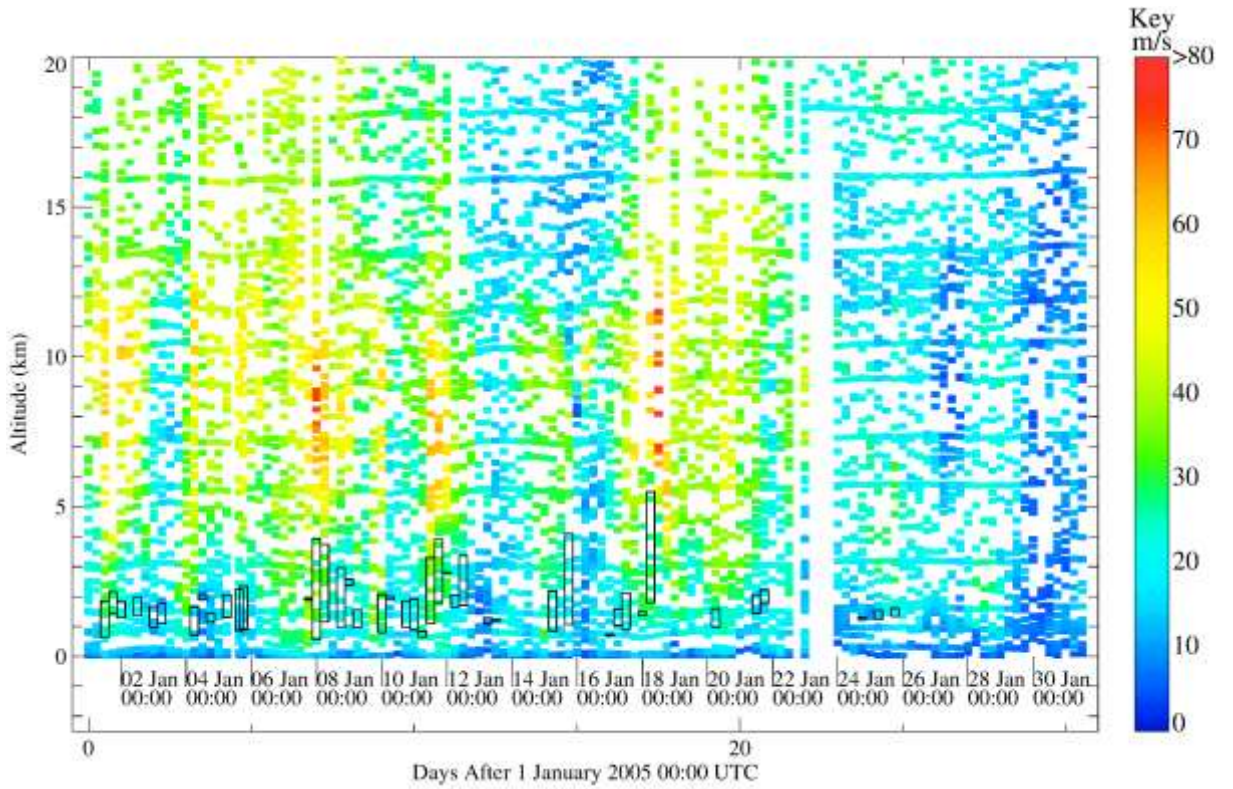

Figure S25. Time series of vertical profiles of wind speed for the radiosonde station at Valencia in south-western for the period 1–31 January 2005. Open boxes near the bottom of the figure (lower troposphere) indicate the vertical range between the level of free convection and the equilibium level for profiles showing positive values of convective available potential energy (CAPE).

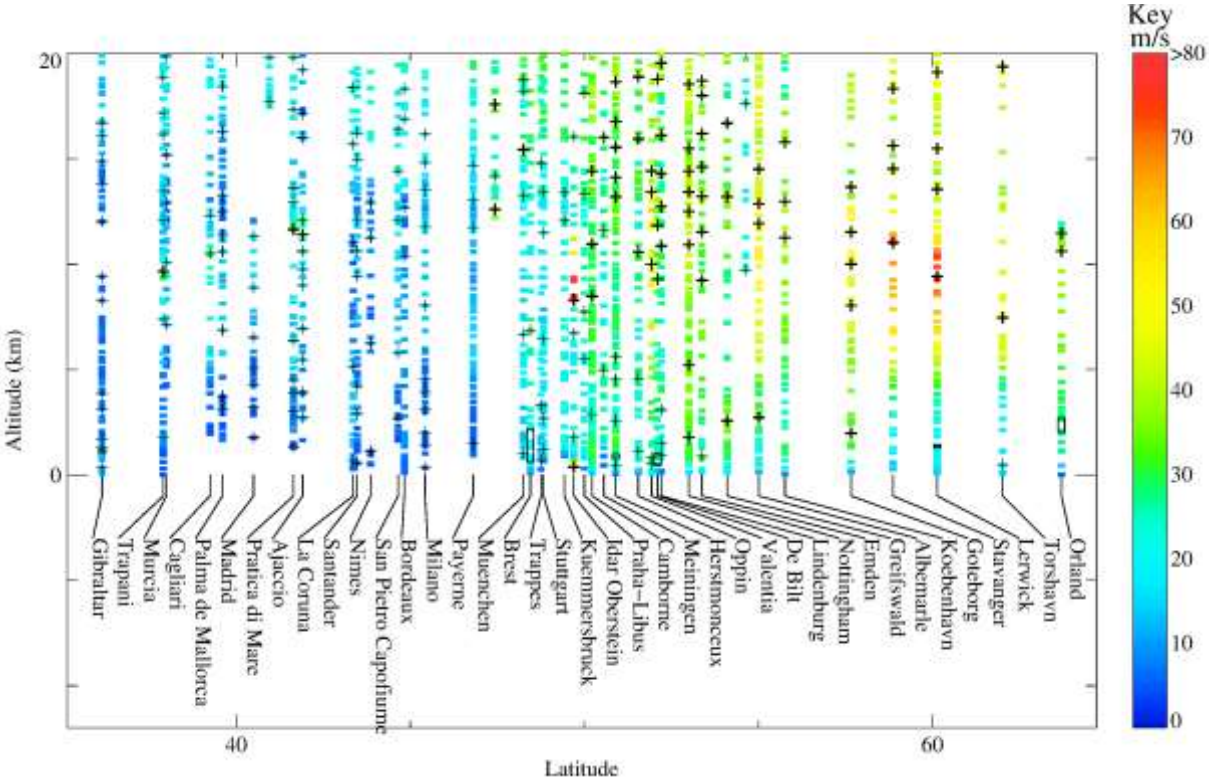

Figure S26. Latitude-height section of radiosonde wind speeds for stations in Europe on 7 January 2005 at 12:00 UTC. Crosses mark local maxima in the wind speed profiles, and bold crosses indicate local maximum wind speeds exceeding 32 m/s. Open boxes near the bottom of the figure (lower troposphere) indicate the vertical range between the level of free convection and the equilibrium level for profiles showing positive values of convective available potential energy (CAPE). The figure was constructed with a subset of stations west of 15°E.

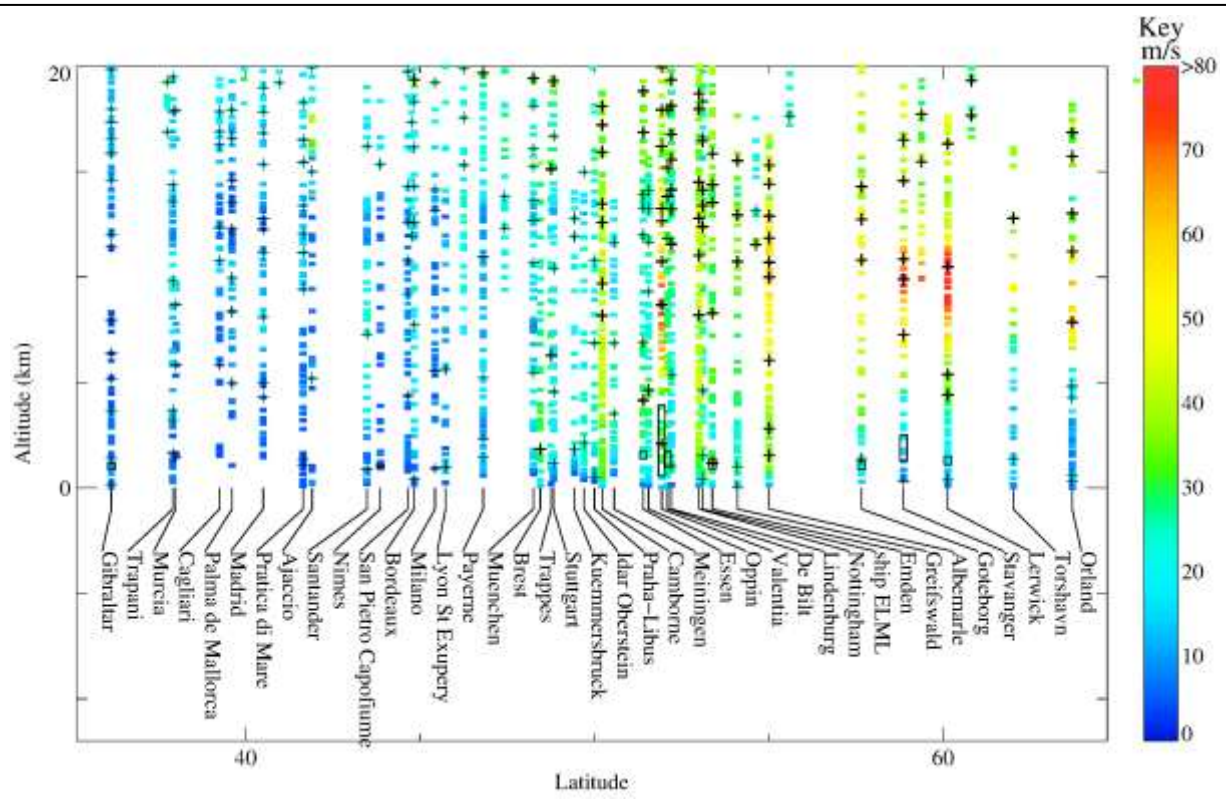

Figure S27. Latitude-height section of radiosonde wind speeds for stations in Europe on 8 January 2005 at 00:00 UTC. Crosses mark local maxima in the wind speed profiles, and bold crosses indicate local maximum wind speeds exceeding 32 m/s. Open boxes near the bottom of the figure (lower troposphere) indicate the vertical range between the level of free convection and the equilibrium level for profiles showing positive values of convective available potential energy (CAPE). The figure was constructed with a subset of stations west of 15°E.

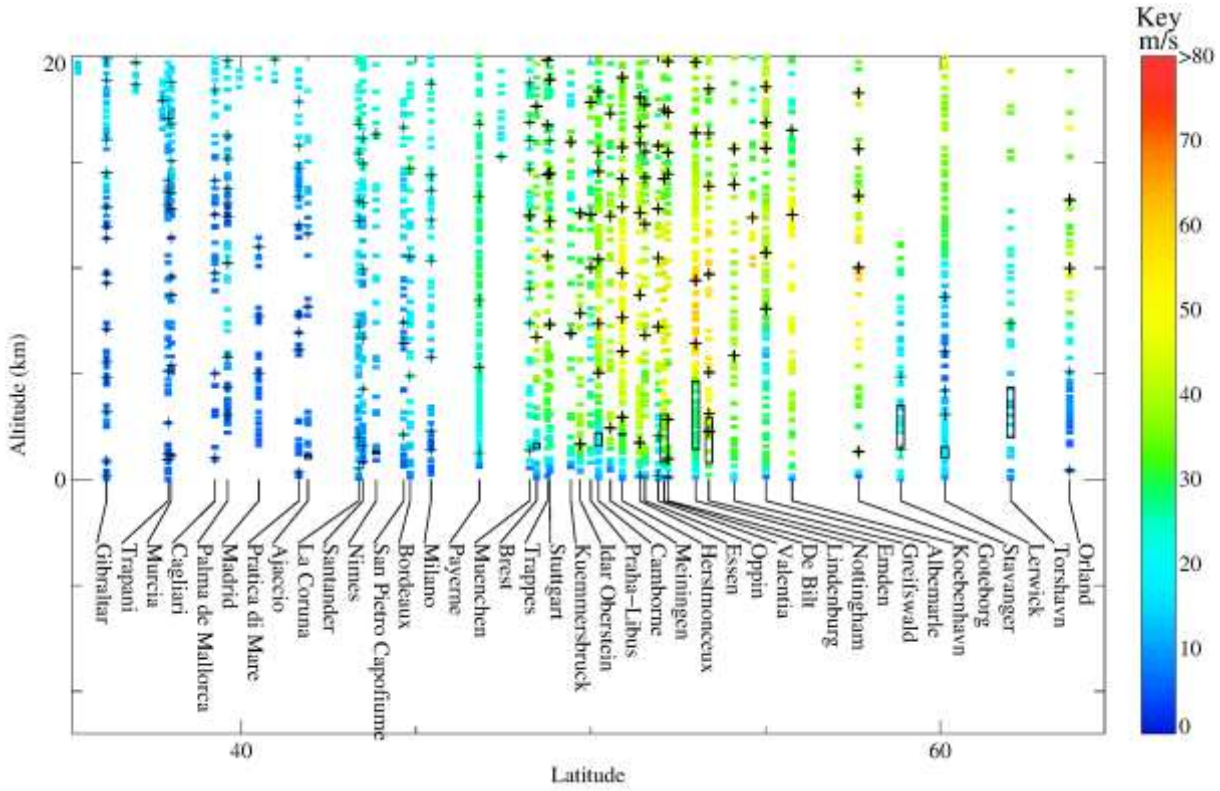

Figure S28. Latitude-height section of radiosonde wind speeds for stations in Europe on 8 January 2005 at 12:00 UTC. Crosses mark local maxima in the wind speed profiles, and bold crosses indicate local maximum wind speeds exceeding 32 m/s. Open boxes near the bottom of the figure (lower troposphere) indicate the vertical range between the level of free convection and the equilibrium level for profiles showing positive values of convective available potential energy (CAPE). The figure was constructed with a subset of stations west of 15°E.

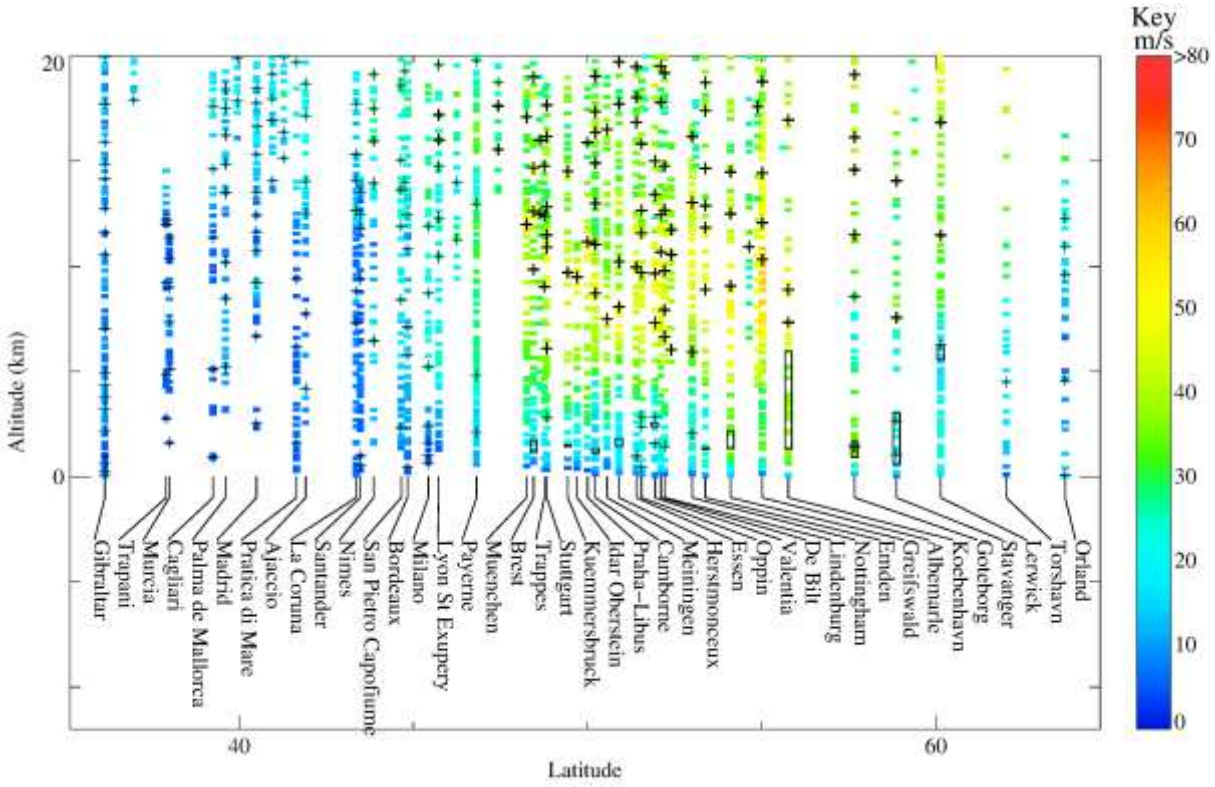

Figure S29. Latitude-height section of radiosonde wind speeds for stations in Europe on 9 January 2005 at 00:00 UTC. Crosses mark local maxima in the wind speed profiles, and bold crosses indicate local maximum wind speeds exceeding 32 m/s. Open boxes near the bottom of the figure (lower troposphere) indicate the vertical range between the level of free convection and the equilibrium level for profiles showing positive values of convective available potential energy (CAPE). The figure was constructed with a subset of stations west of 15°E.

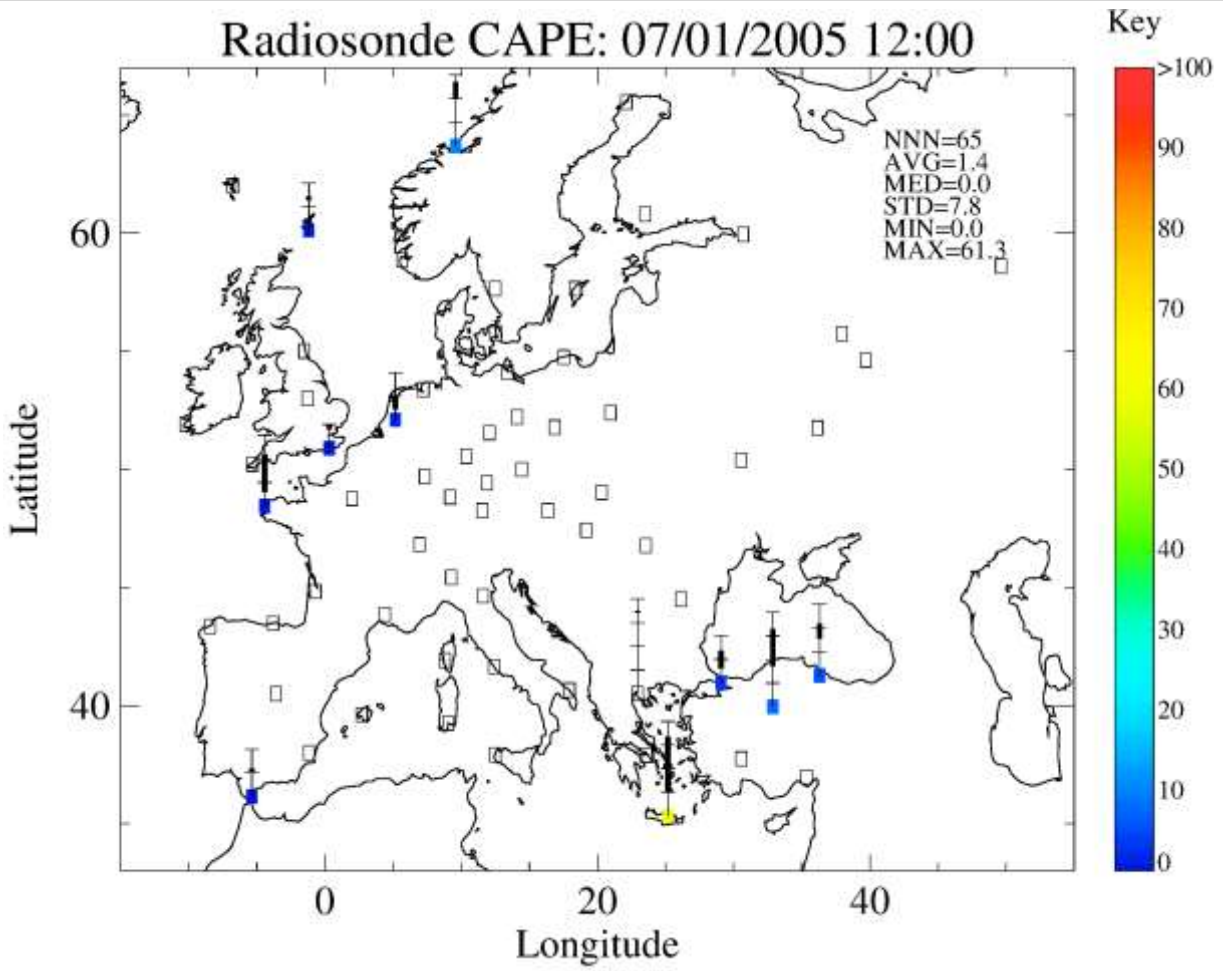

Figure S30. Map of convective available potential energy (CAPE, J/kg) for stations in Europe on 7 January 2005 at 12:00 UTC. The black vertical bars give the heights of the level of free convection and the equilibrium level for radiosonde profiles showing positive CAPE values, with horizontal tick marks at 1000 m intervals starting at the surface.

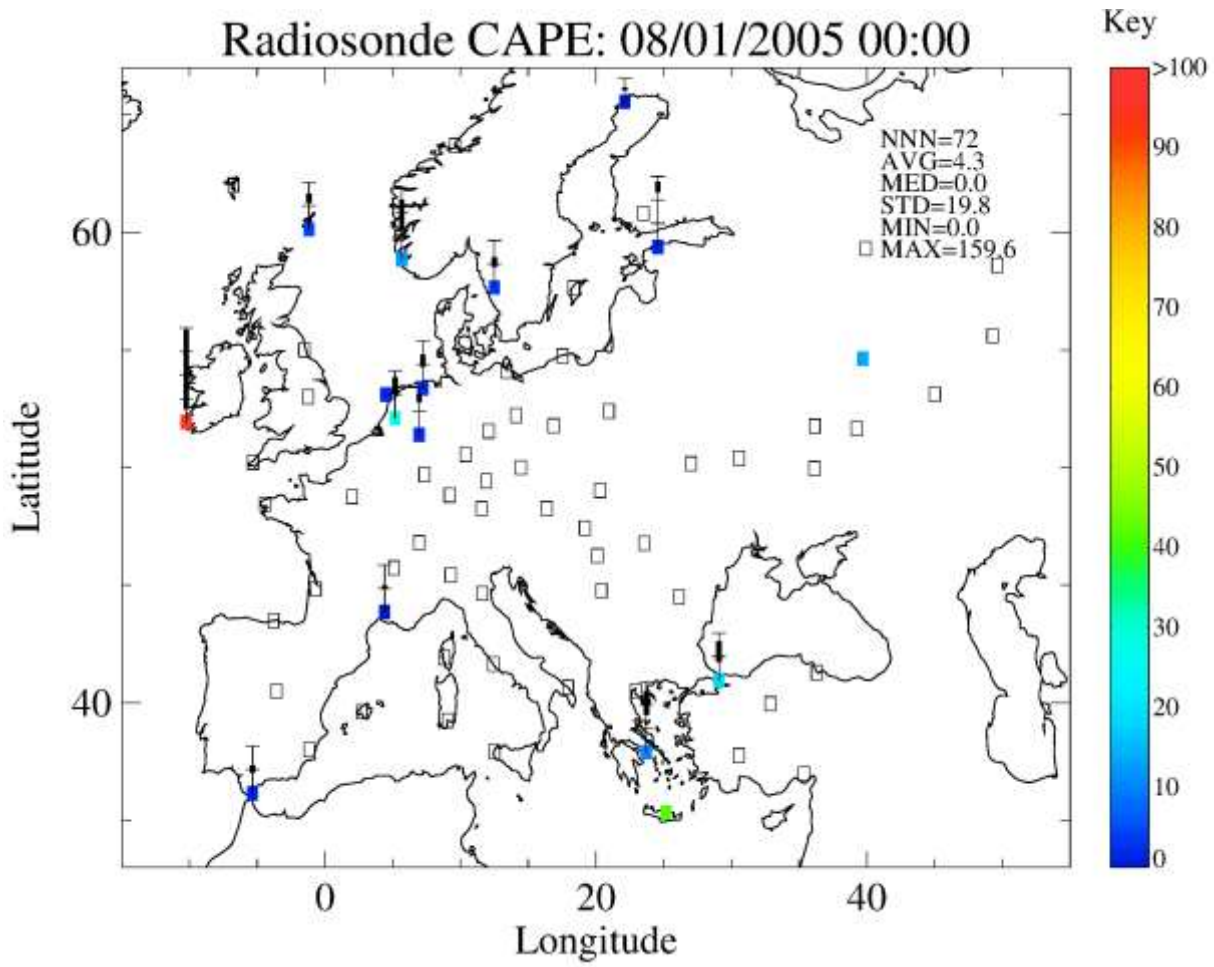

Figure S31. Map of convective available potential energy (CAPE, J/kg) for stations in Europe on 8 January 2005 at 00:00 UTC. The black vertical bars give the heights of the level of free convection and the equilibrium level for radiosonde profiles showing positive CAPE values, with horizontal tick marks at 1000 m intervals starting at the surface.

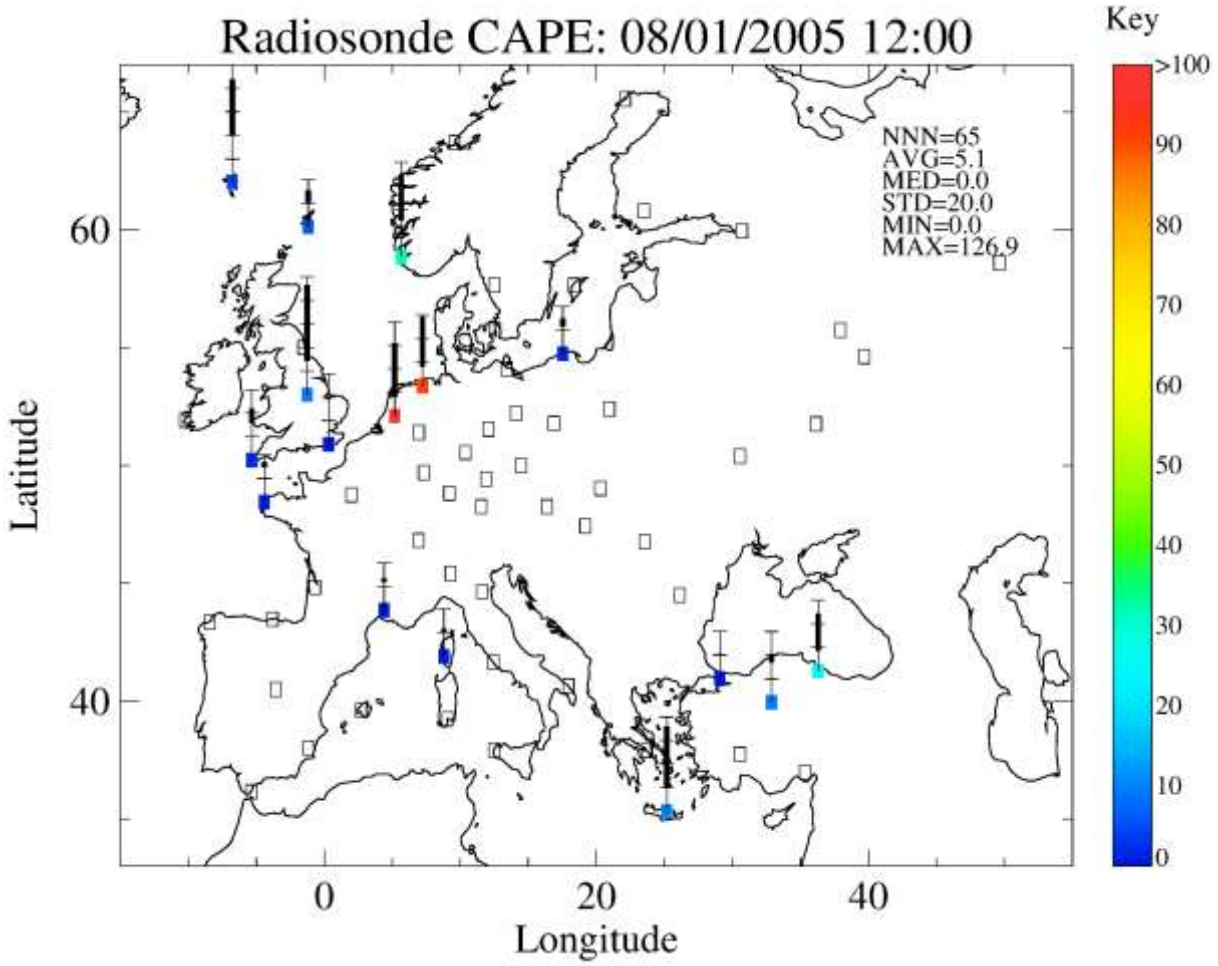

Figure S32. Map of convective available potential energy (CAPE, J/kg) for stations in Europe on 8 January 2005 at 12:00 UTC. The black vertical bars give the heights of the level of free convection and the equilibrium level for radiosonde profiles showing positive CAPE values, with horizontal tick marks at 1000 m intervals starting at the surface.

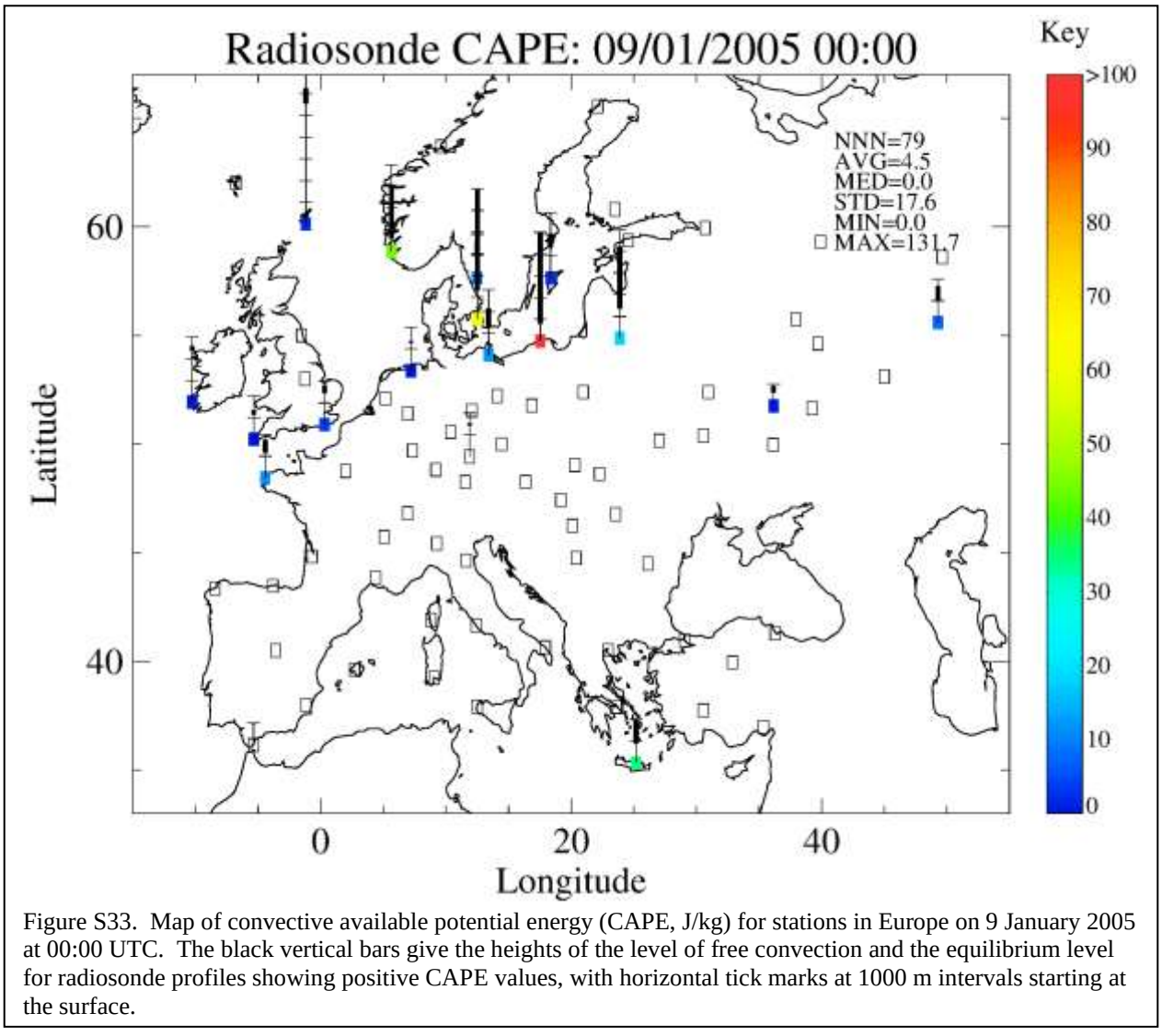

Figure S33. Map of convective available potential energy (CAPE, J/kg) for stations in Europe on 9 January 2005 at 00:00 UTC. The black vertical bars give the heights of the level of free convection and the equilibrium level for radiosonde profiles showing positive CAPE values, with horizontal tick marks at 1000 m intervals starting at the surface.

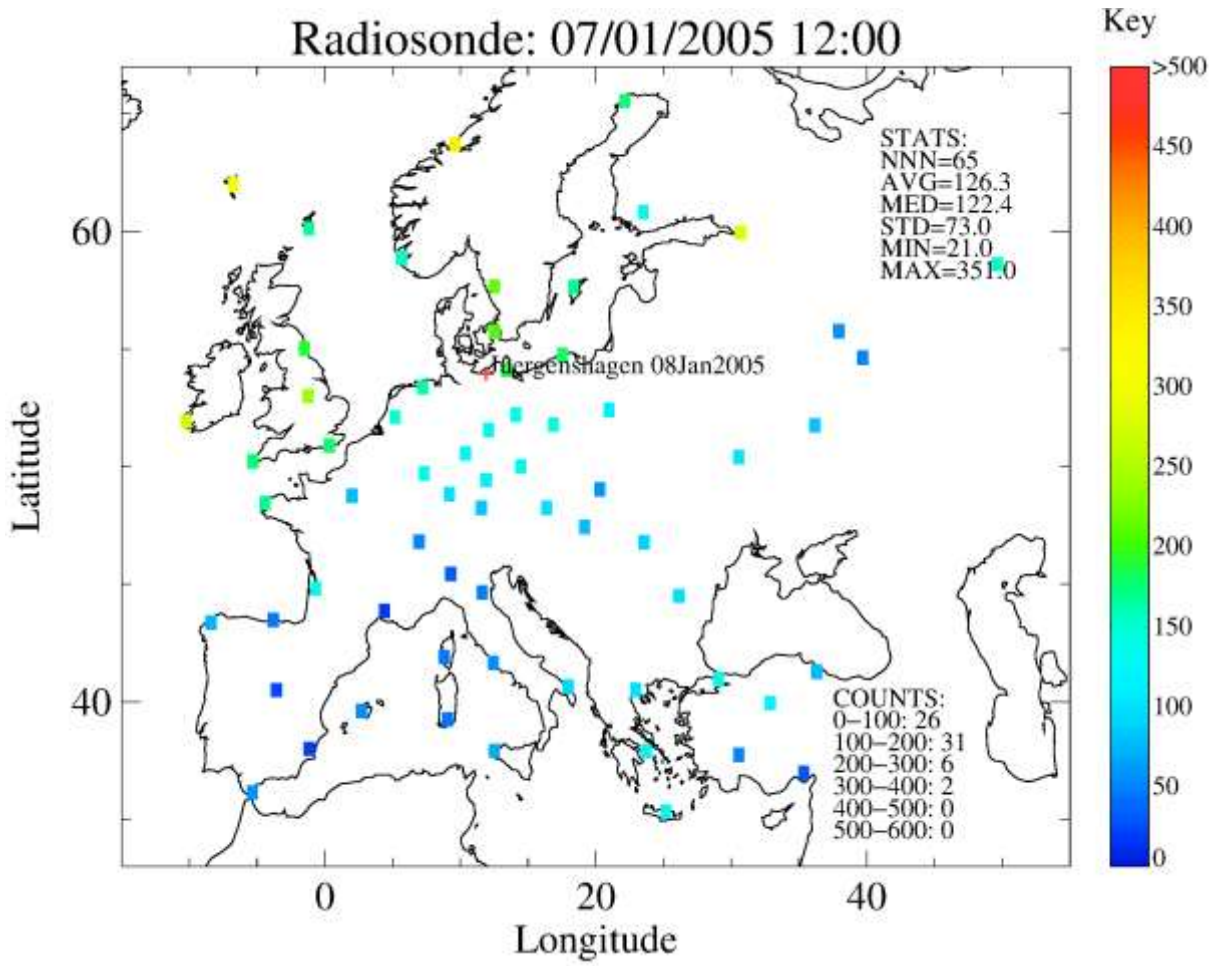

Figure S34. Map of SWEAT index for stations in Europe on 7 January 2005 at 12:00 UTC. Crosses mark the locations of tornadoes. The statistics of the displayed stations are printed on the map, along with a tabulated histogram distribution of values.

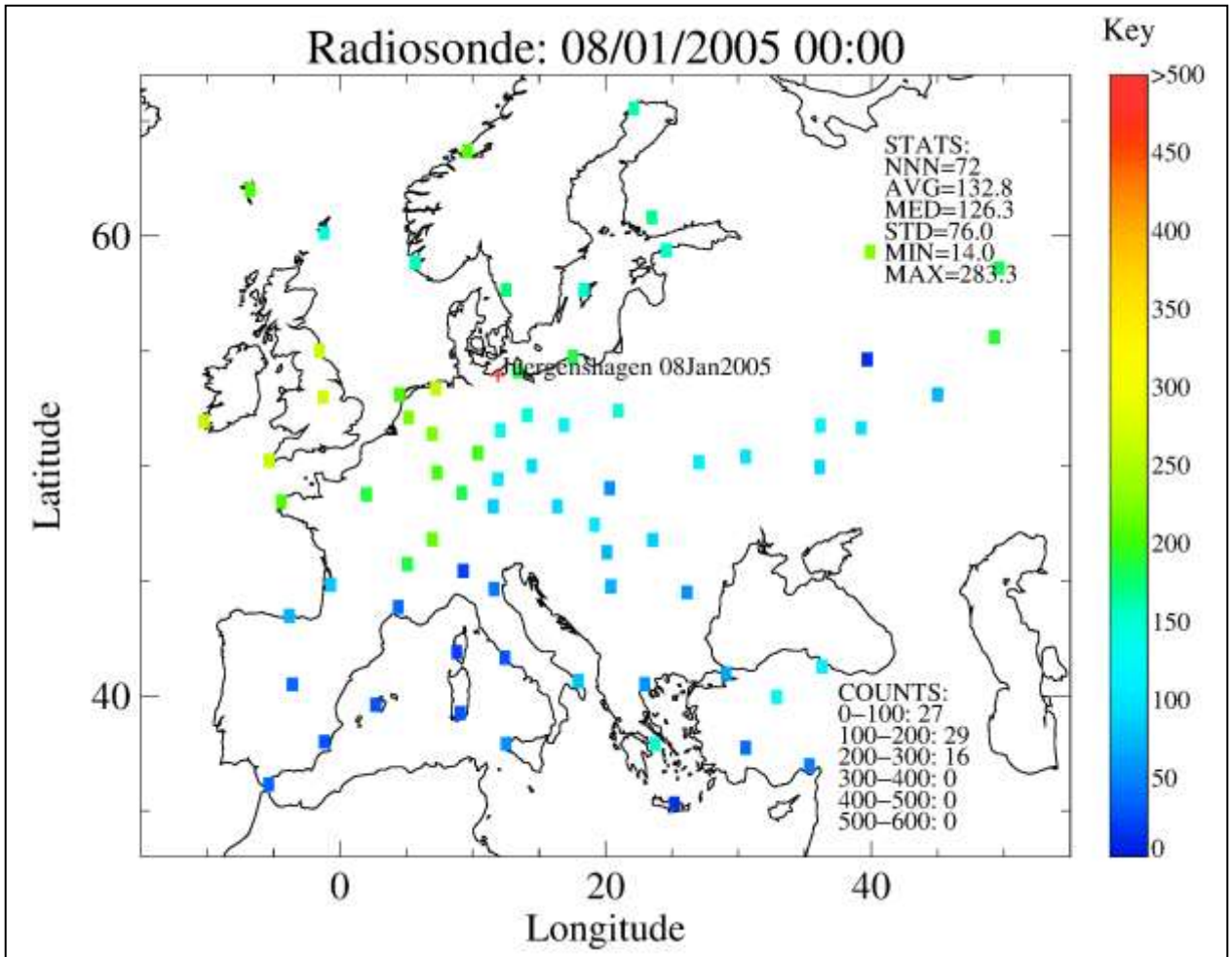

Figure S35. Map of SWEAT index for stations in Europe on 8 January 2005 at 00:00 UTC. Crosses mark the locations of tornadoes. The statistics of the displayed stations are printed on the map, along with a tabulated histogram distribution of values.

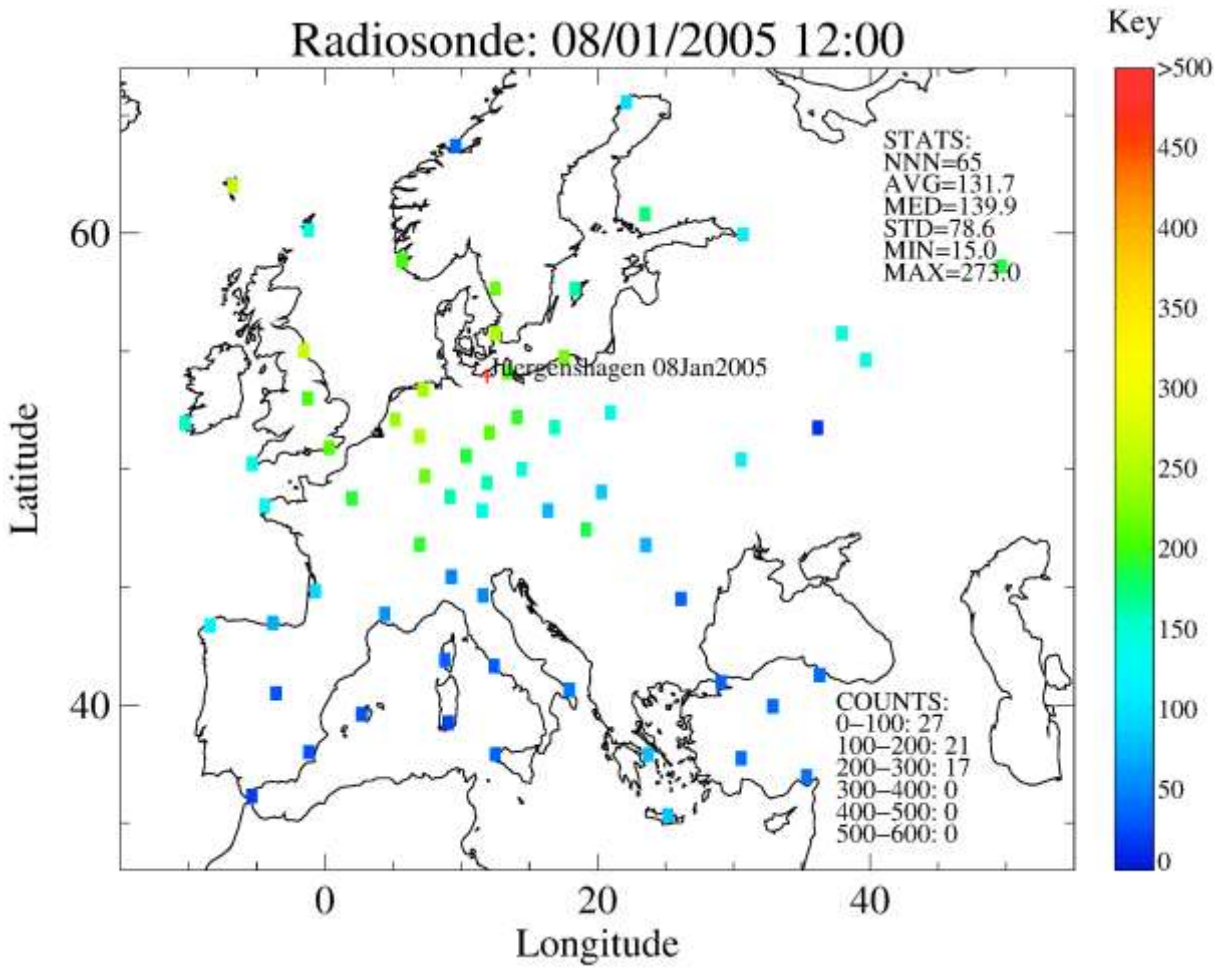

Figure S36. Map of SWEAT index for stations in Europe on 8 January 2005 at 12:00 UTC. Crosses mark the locations of tornadoes. The statistics of the displayed stations are printed on the map, along with a tabulated histogram distribution of values.

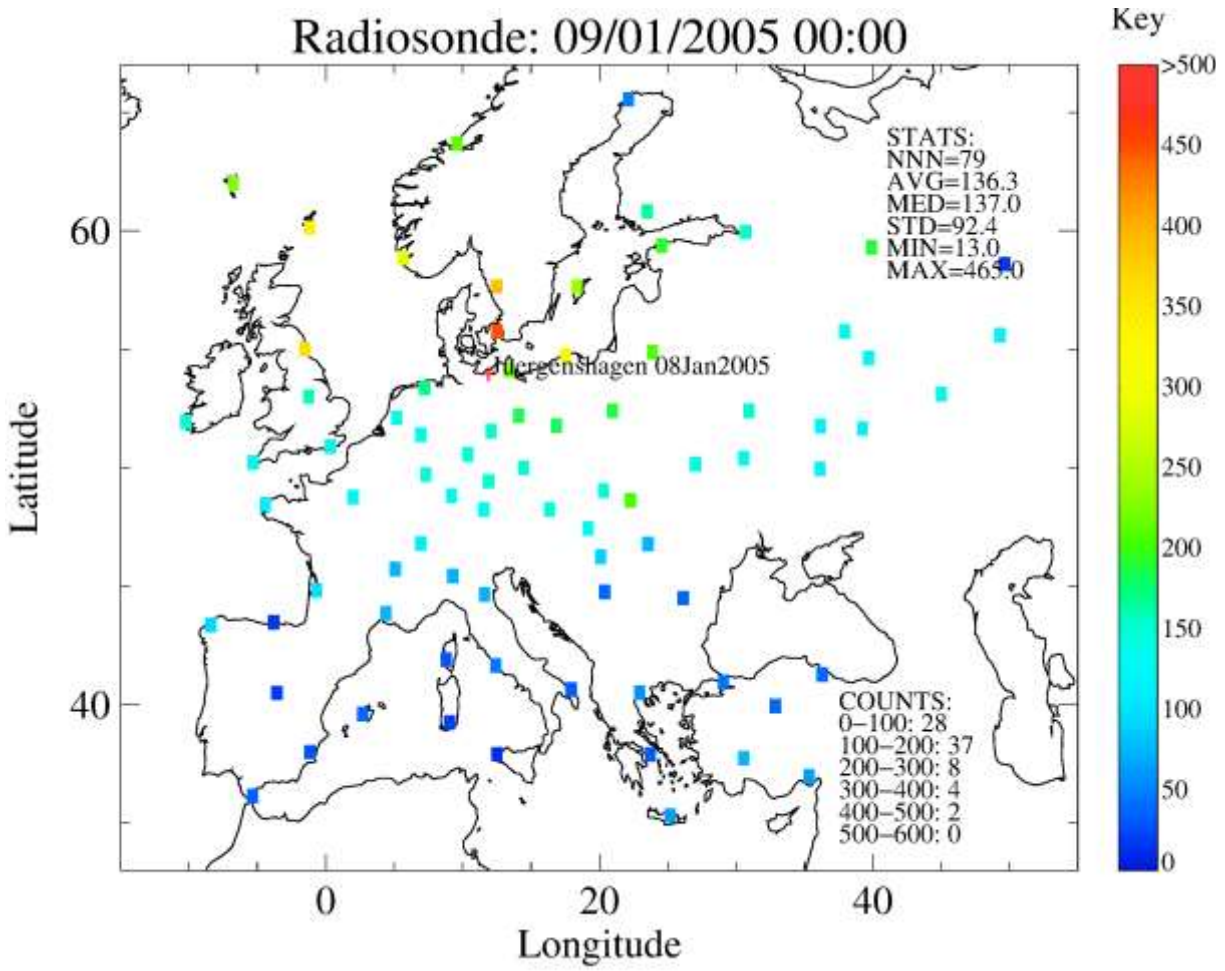

Figure S37. Map of SWEAT index for stations in Europe on 9 January 2005 at 00:00 UTC. Crosses mark the locations of tornadoes. The statistics of the displayed stations are printed on the map, along with a tabulated histogram distribution of values.

SECTION S5. WAVE MEASUREMENTS IN THE NORTH SEA

The following text is reproduced from Kettle (2024)

Measurements of significant wave height are presented for stations in the Norwegian Sea and North Sea. The data originate from different sources, which are given in Tables S1. The data providers are mostly governmental authorities, except CMEMS, which is a European Commission organization and has provided data from different sources. The quality control and data cleaning procedures for the different providers is not known. Referring to wave instrumental records from late 1990s and 2000s, Magnusson (2009) indicated that the data cleaning may be too vigorous in some instances and may remove valid wave data in extreme sea states.

Note that some of the wave recorders in the list may have a biased response to the wave field. In particular, the UK Light Ships Channel, Sevenstones, Greenwich, Sandettie systematically underestimate Hs and overestimate mean wave period and are thus not directly comparable with other types of wave recorders (Bidlot, 2025).

References:

Bidlot, J.: email communication on UK Light Ships Channel, Sevenstones, Greenwich, Sandettie, 26 May 2025.

Kettle, A. J.: Storm Daria: Societal and energy impacts in northwest Europe on 25–26 January 1990, Adv. Geosci., 65, 83– 101, 2024.

Magnusson, A.K.: What is true sea state? Proceedings of the 11th International Workshop on Wave Hindcasting and Forecasting and Coastal Hazard Symposium, JCOMM Halifax, Canada, Oct 18–23, 2009, Technical Report No 52, WMO/TD-No. 1533, IOC Workshop Report No. 232, 2009b.

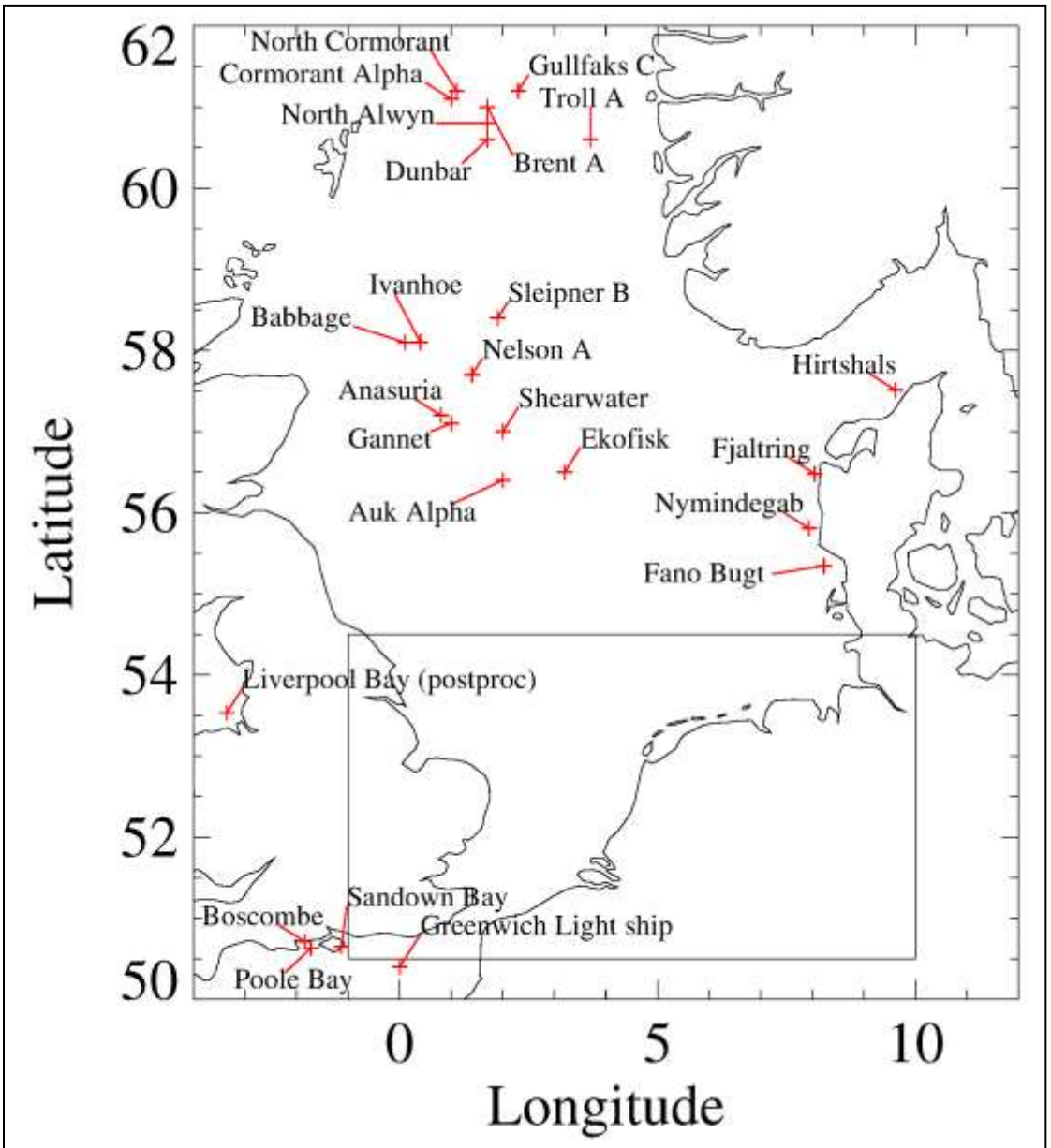

Figure S38. Location of wave measurement stations where significant wave height was measured. Wave recorders in the box in the southern North Sea are shown in Figure S39 for clarity.

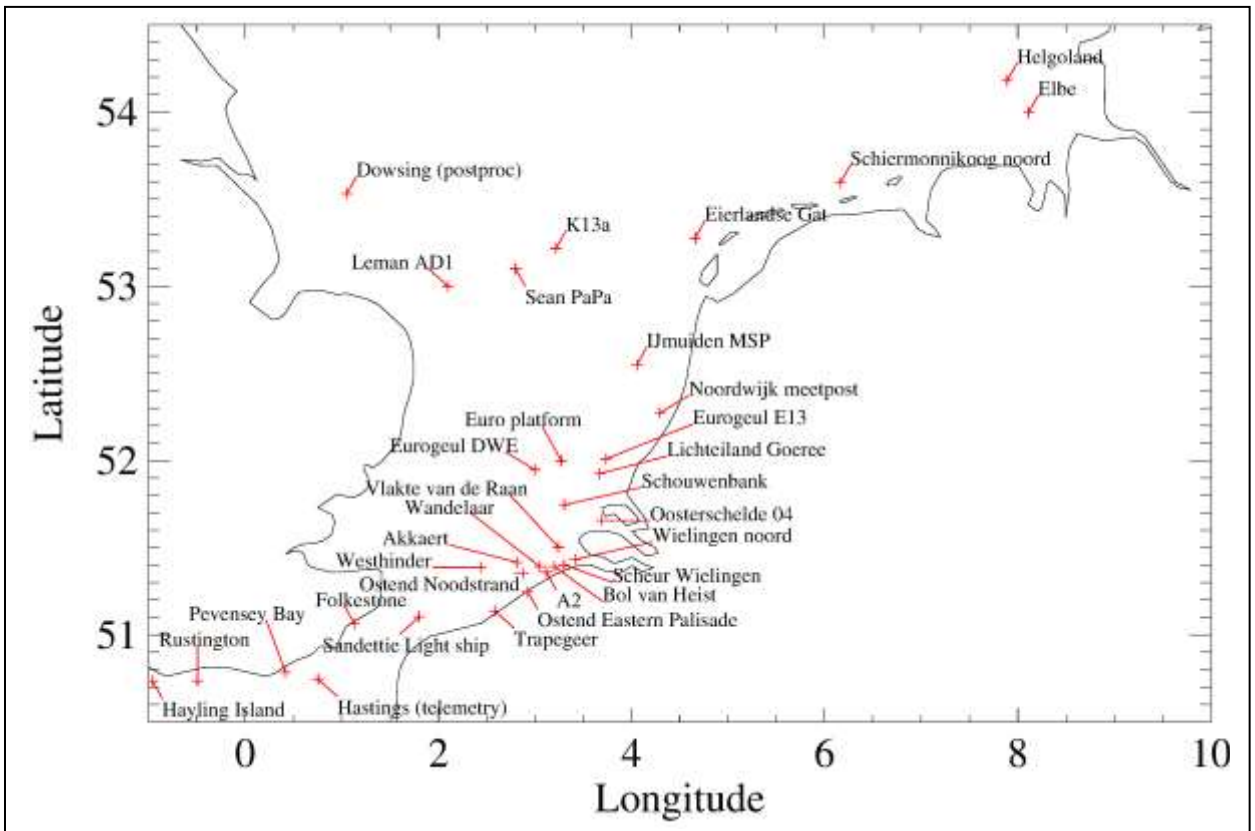

Figure S39. Location of wave measurement stations recording significant wave height in the southern North Sea.

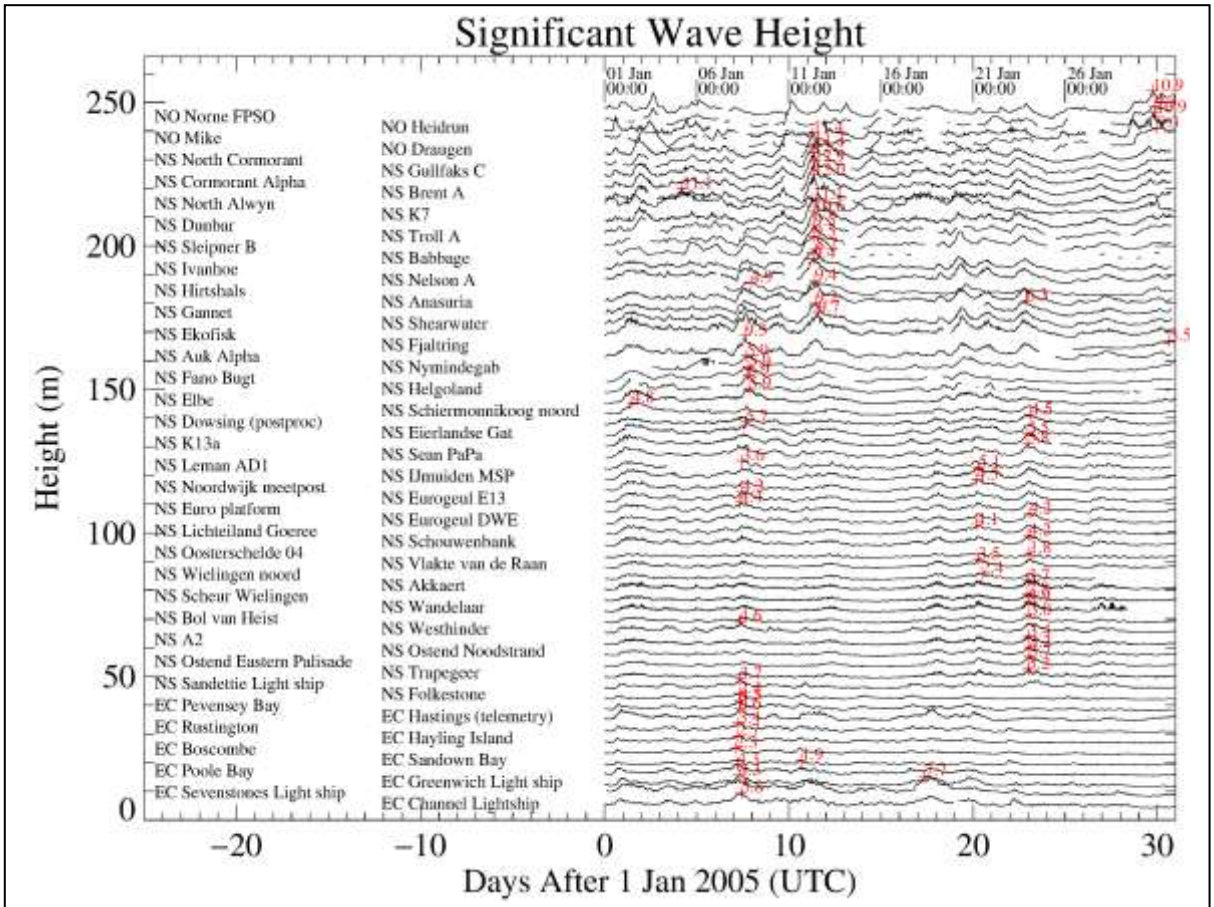

Figure S40. Time series of significant wave height for available stations in the English Channel, North Sea, and Norwegian Sea for the period January 2005. The time series have been vertically offset for clarity, and the stations have been arranged according to latitude. The highest value of each series is indicated by a red cross with the significant wave height printed in red font.

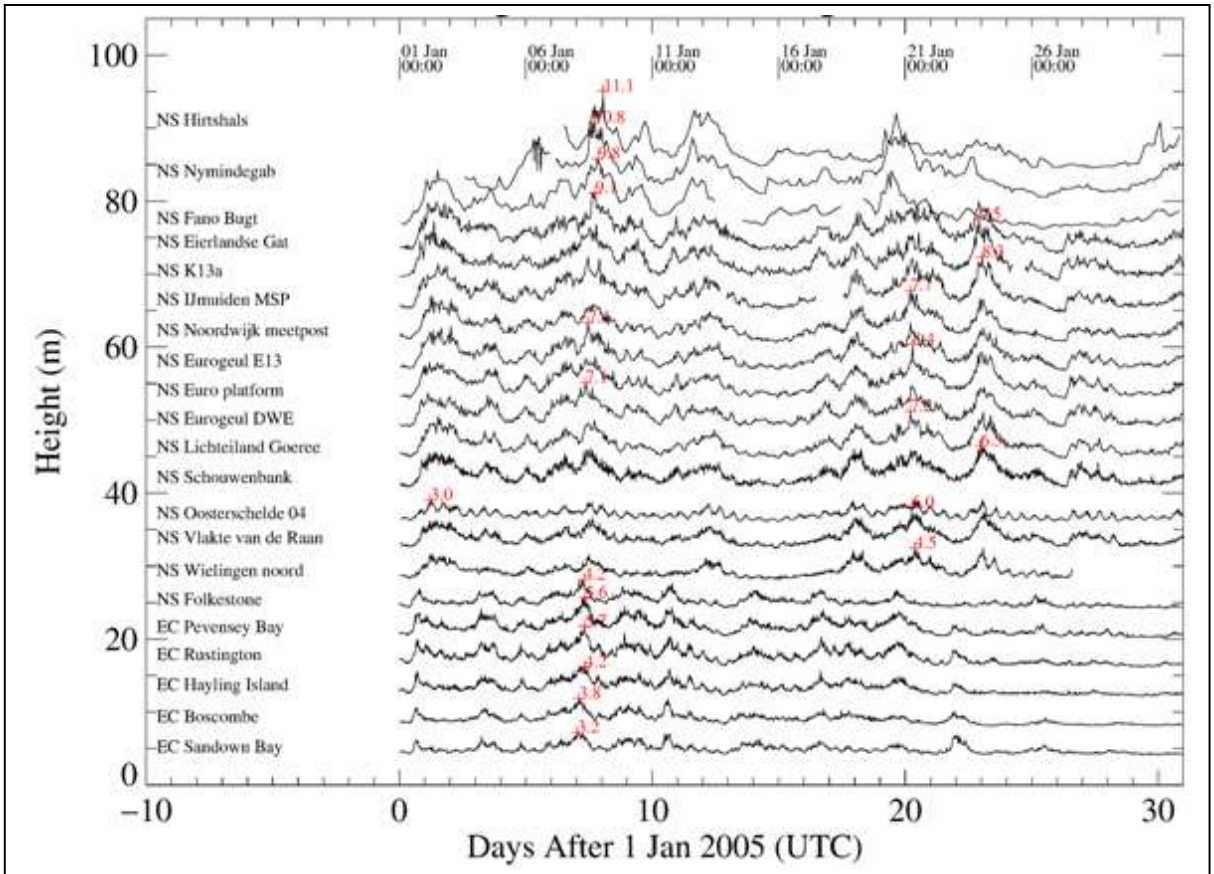

Figure S41. Time series of maximum wave height for available stations in the English Channel and North Sea for the period January 2005. The time series have been vertically offset for clarity, and the stations have been arranged according to latitude. The highest value of each series is indicated by a red cross with the highest value of the series printed in red font.

Table S1. Significant wave height information for the period January 2005. Information is presented for the highest significant wave height over the full period and for the two day period of the storm 8–9 January 2005.

Station name [1]	Land [2]	NNN [3]	Date & time series start [4]	Date & time series end [5]	Median Δt (min) [6]	Date/time peak full series [7]	Peak (m) [8]	Date/time peak 8–9Jan2005 [9]	Peak (m) [10]
K1	CME	739	01/01/2005 00:00	01/02/2005 00:00	60.5	18/01/2005 06:59	13.7	08/01/2005 00:59	7.8
Channel Lightship	CME	669	01/01/2005 00:00	01/02/2005 00:00	60.5	08/01/2005 09:59	5.8	08/01/2005 09:59	5.8
Sevenstones Light ship	CME	576	01/01/2005 03:00	01/02/2005 00:00	60.5	18/01/2005 09:00	7.7	08/01/2005 06:59	6.4
Greenwich Light ship	CME	737	01/01/2005 00:00	01/02/2005 00:00	60.5	08/01/2005 06:59	4.3	08/01/2005 06:59	4.3
Poole Bay	CEF	1488	01/01/2005 00:00	31/01/2005 23:30	30.0	08/01/2005 05:00	4.3	08/01/2005 05:00	4.3
Sandown Bay	CCO	1485	01/01/2005 00:00	31/01/2005 22:30	30.0	11/01/2005 16:00	1.9	08/01/2005 02:00	1.9
Boscombe	CCO	1485	01/01/2005 00:00	31/01/2005 22:30	30.0	08/01/2005 02:30	2.3	08/01/2005 02:30	2.3
Hayling Island	CCO	1485	01/01/2005 00:00	31/01/2005 22:30	30.0	08/01/2005 05:30	2.7	08/01/2005 05:30	2.7
Rustington	CCO	1477	01/01/2005 00:00	31/01/2005 22:30	30.0	08/01/2005 06:30	3.4	08/01/2005 06:30	3.4
Hastings (telemetry)	CEF	1485	01/01/2005 00:00	31/01/2005 23:30	30.0	08/01/2005 07:30	4.6	08/01/2005 07:30	4.6
Pevensey Bay	CCO	1486	01/01/2005 00:00	31/01/2005 22:30	30.0	08/01/2005 08:30	3.5	08/01/2005 08:30	3.5
K2	CME	724	01/01/2005 00:00	01/02/2005 00:00	60.5	18/01/2005 04:59	14.6	08/01/2005 07:59	8.4
Folkestone	CCO	1486	01/01/2005 00:00	31/01/2005 23:00	30.0	08/01/2005 07:30	2.4	08/01/2005 07:30	2.4
Sandettie Light ship	CME	728	01/01/2005 00:00	01/02/2005 00:00	60.5	08/01/2005 07:59	3.7	08/01/2005 07:59	3.7
Trapegeer	BE	2975	01/01/2005 00:00	31/01/2005 23:45	15.0	23/01/2005 23:45	3.2	08/01/2005 11:00	1.9
Ostend Eastern Palisade	BE	1472	01/01/2005 00:00	31/01/2005 23:30	30.0	24/01/2005 01:30	3.7	08/01/2005 12:00	1.6
Ostend Noodstrand	BE	1488	01/01/2005 00:00	31/01/2005 23:30	30.0	24/01/2005 01:30	3.2	08/01/2005 12:00	2.2
A2	BE	2975	01/01/2005 00:00	31/01/2005 23:45	15.0	24/01/2005 00:45	3.4	08/01/2005 11:30	2.1
Westhinder	BE	1462	01/01/2005 00:00	31/01/2005 23:30	30.0	08/01/2005 08:30	4.6	08/01/2005 08:30	4.6
Bol van Heist	BE	1454	01/01/2005 00:00	31/01/2005 23:30	30.0	24/01/2005 01:00	3.0	08/01/2005 09:30	2.3
Wandelaar	BE	2709	01/01/2005 00:00	29/01/2005 08:15	15.0	24/01/2005 00:45	3.9	08/01/2005 11:00	2.4
Scheur Wielingen	BE	2933	01/01/2005 00:00	31/01/2005 23:45	15.0	23/01/2005 23:00	2.8	08/01/2005 11:45	2.1
Akkaert	BE	2976	01/01/2005 00:00	31/01/2005 23:45	15.0	23/01/2005 23:15	3.7	08/01/2005 10:45	2.8
Wielingen noord	NE	1263	01/01/2005 01:00	27/01/2005 14:30	30.0	21/01/2005 11:00	2.4	08/01/2005 12:30	2.0
Vlakte van de Raan	NE	1476	01/01/2005 01:00	01/02/2005 00:00	30.0	21/01/2005 06:30	3.5	08/01/2005 12:00	2.8
Oosterschelde 04	NE	1476	01/01/2005 01:00	01/02/2005 00:00	30.0	24/01/2005 01:30	1.8	08/01/2005 12:00	1.6
Schouwenbank	NE	2210	01/01/2005 01:00	01/02/2005 00:00	30.0	24/01/2005 01:30	4.2	08/01/2005 11:00	3.8
Lichteiland Goeree	NE	744	01/01/2005 01:00	01/02/2005 00:00	60.0	21/01/2005 05:00	4.1	08/01/2005 12:00	3.6
Eurogeul DWE	NE	742	01/01/2005 01:00	01/02/2005 00:00	60.0	24/01/2005 02:00	4.2	08/01/2005 09:00	4.1
Euro platform	NE	743	01/01/2005 01:00	01/02/2005 00:00	60.0	08/01/2005 09:00	4.4	08/01/2005 09:00	4.4
Eurogeul E13	NE	744	01/01/2005 01:00	01/02/2005 00:00	60.0	08/01/2005 11:00	4.2	08/01/2005 11:00	4.2
Noordwijk meetpost	NE	744	01/01/2005 01:00	01/02/2005 00:00	60.0	21/01/2005 05:00	4.5	08/01/2005 11:00	3.8
IJmuiden MSP	NE	1062	01/01/2005 01:00	01/02/2005 00:00	59.9	21/01/2005 07:00	5.1	08/01/2005 22:00	4.6
Leman AD1	BID	627	01/01/2005 00:00	31/01/2005 18:00	60.0	08/01/2005 11:00	3.6	08/01/2005 11:00	3.6
Scan PaPa	BID	731	01/01/2005 01:00	31/01/2005 18:00	60.0	23/01/2005 23:00	5.8	08/01/2005 06:00	5.2

Table S1. (continued)

Station name [1]	Land [2]	NNN [3]	Date & time series start [4]	Date & time series end [5]	Median Δt (min) [6]	Date/time peak full series [7]	Peak (m) [8]	Date/time peak 8–9Jan2005 [9]	Peak (m) [10]
K13a	NE	727	01/01/2005 01:00	01/02/2005 00:00	60.0	23/01/2005 23:00	5.5	08/01/2005 13:00	5.2
Eierlandse Gat	NE	744	01/01/2005 01:00	01/02/2005 00:00	60.0	08/01/2005 16:00	5.7	08/01/2005 16:00	5.7
M2	CEF	1488	01/01/2005 00:00	31/01/2005 23:30	30.0	08/01/2005 03:30	4.2	08/01/2005 03:30	4.2
Dowsing (postproc)	CEF	1488	01/01/2005 00:00	31/01/2005 23:30	30.0	24/01/2005 03:00	4.5	08/01/2005 12:30	3.6
Liverpool Bay (postproc)	CEF	1487	01/01/2005 00:00	31/01/2005 23:30	30.0	08/01/2005 11:30	4.6	08/01/2005 11:30	4.6
Schiermonnikoog noord	NE	744	01/01/2005 01:00	01/02/2005 00:00	60.0	02/01/2005 12:00	4.8	08/01/2005 16:00	3.6
Elbe	CME	1490	01/01/2005 00:02	31/01/2005 23:08	27.4	08/01/2005 20:15	5.9	08/01/2005 20:15	5.9
Helgoland	CME	657	01/01/2005 00:06	31/01/2005 18:41	53.3	08/01/2005 18:42	6.9	08/01/2005 18:42	6.9
K4	CME	582	01/01/2005 00:00	31/01/2005 22:59	60.5	11/01/2005 18:00	15.7	08/01/2005 15:59	8.1
Fano Bugt	DK	245	31/12/2004 23:00	31/01/2005 20:00	180.0	08/01/2005 19:30	5.9	08/01/2005 19:30	5.9
Nymindegab	DK	257	03/01/2005 14:15	31/01/2005 20:15	180.0	08/01/2005 16:45	5.9	08/01/2005 16:45	5.9
Auk Alpha	BID	707	01/01/2005 01:00	31/01/2005 18:00	60.0	08/01/2005 15:00	9.3	08/01/2005 15:00	9.3
Fjaltring	DK	206	26/01/2005 10:30	31/01/2005 22:30	30.0	31/01/2005 16:00	3.5		
Ekofisk	BID	723	01/01/2005 00:00	31/01/2005 18:00	60.0	12/01/2005 14:00	9.7	08/01/2005 15:00	9.5
Shearwater	BID	731	01/01/2005 00:00	31/01/2005 18:00	60.0	12/01/2005 11:00	9.2	08/01/2005 14:00	8.1
Gannet	BID	469	01/01/2005 01:00	31/01/2005 18:00	60.0	23/01/2005 21:00	6.3	08/01/2005 13:00	6.1
Anasuria	BID	709	01/01/2005 01:00	31/01/2005 18:00	60.0	12/01/2005 10:00	9.4	08/01/2005 13:00	6.5
Hirtshals	DK	209	07/01/2005 12:00	31/01/2005 20:00	180.0	08/01/2005 22:30	4.9	08/01/2005 22:30	4.9
Nelson A	BID	703	01/01/2005 01:00	31/01/2005 18:00	60.0	12/01/2005 08:00	9.4	08/01/2005 22:00	6.6
Ivanhoe	BID	714	01/01/2005 01:00	31/01/2005 18:00	60.0	12/01/2005 11:00	8.7	08/01/2005 18:00	5.2
Babbage	BID	69	01/01/2005 03:00	31/01/2005 03:00	360.0	12/01/2005 09:00	9.5	08/01/2005 15:00	7.1
Sleipner B	BID	223	01/01/2005 00:00	31/01/2005 18:00	180.0	12/01/2005 09:00	9.5	08/01/2005 15:00	6.0
K5	CME	692	01/01/2005 00:00	01/02/2005 00:00	60.5	05/01/2005 00:00	12.3	08/01/2005 19:59	8.3
Troll A	BID	211	01/01/2005 00:00	31/01/2005 18:00	180.0	12/01/2005 09:00	10.6	09/01/2005 09:00	5.2
Dunbar	BID	729	01/01/2005 01:00	31/01/2005 18:00	60.0	12/01/2005 07:00	11.1	09/01/2005 05:00	4.5
K7	CME	537	01/01/2005 00:00	31/01/2005 21:59	60.5	05/01/2005 04:59	11.1	09/01/2005 00:00	6.3
North Alwyn	BID	680	01/01/2005 01:00	31/01/2005 18:00	60.0	12/01/2005 09:00	12.0	09/01/2005 06:00	4.5
Brent A	BID	713	01/01/2005 00:00	31/01/2005 18:00	60.0	12/01/2005 09:00	12.9	08/01/2005 00:00	5.0
Cormorant Alpha	BID	730	01/01/2005 00:00	31/01/2005 18:00	60.0	12/01/2005 08:00	12.2	08/01/2005 00:00	5.0
Gullfaks C	BID	222	01/01/2005 00:00	31/01/2005 18:00	180.0	12/01/2005 09:00	11.3	08/01/2005 00:00	5.6
North Cormorant	BID	712	01/01/2005 01:00	31/01/2005 18:00	60.0	12/01/2005 07:00	11.4	08/01/2005 00:00	5.0
Draugen	BID	178	01/01/2005 00:00	31/01/2005 18:00	180.0	31/01/2005 00:00	9.3	09/01/2005 18:00	4.4
Mike	BID	575	01/01/2005 00:00	31/01/2005 18:00	60.0	30/01/2005 22:00	10.9	09/01/2005 19:00	4.2
Heidrun	BID	170	01/01/2005 00:00	31/01/2005 18:00	180.0	30/01/2005 21:00	9.3	08/01/2005 06:00	3.4
Norne FPSO	BID	229	01/01/2005 00:00	31/01/2005 18:00	180.0	30/01/2005 18:00	10.9	08/01/2005 00:00	5.1

Notes:
[1] Wave measuring station name
[2] Sources of wave data:
BE: Vlaams Instituut voor de Zee; https://meetnetvlaamsebanken.be
BID: Bidlot, Jean: email with wave measurement and ECMWF model data for Jan 2005, 15Dec2024.
CEF: digital files from Wavenet website hosted by CEFAS, https://wavenet.cefas.co.uk/
CEM: European Copernicus wave information, http://www.marineinsitu.eu/dashboard/
DK: digital files for Denmark from https://kyst.dk/soeterritoriet/maalinger-og-data/vandstandsmaalinger/
LSH: digital data files emailed by Maria Bluemel
NO: digital data from Norwegian offshore platforms downloaded from https://seklima.met.no,
NE: digital data file downloaded from RWS Waterinfo website https://waterinfo.rws.nl/#!/nav/expert/alle-groepen/
[3] Number of data points in time series
[4] Start date and time of time series (GMT)
[5] End date and time of time series (GMT)
[6] Median time interval
[7] Date and time of peak of full time series (GMT)
[8] Peak significant wave height of full time series.
[9] Date and time of peak of 2 d time series during Storm Erwin 8–9 January 2005.
[10] Peak significant wave height of 2 d time series during Storm Erwin 8–9 January 2005.

SECTION S6. COASTAL RETREAT/ADVANCE ON SYLT DURING 2004/2005

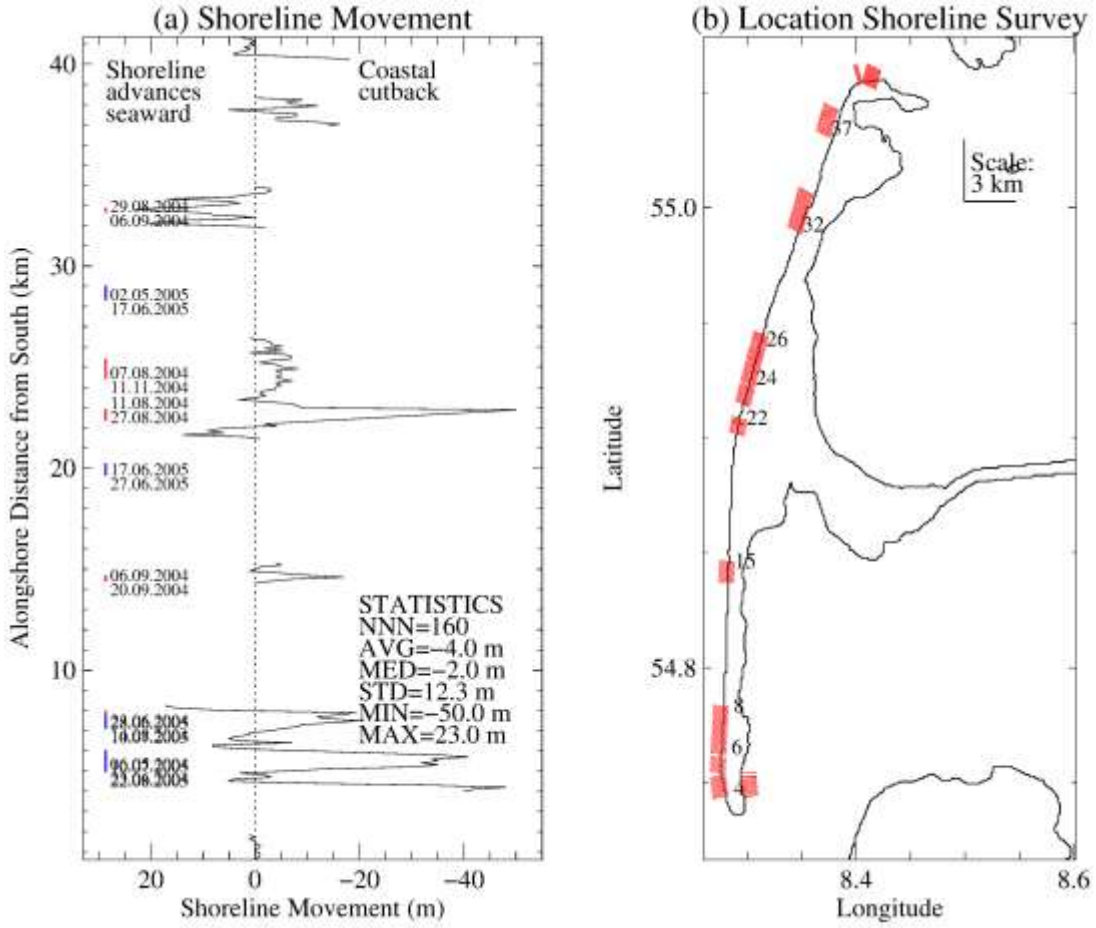

Figure S42. (a) Coastal retreat and advance (at the level +3.75 m above mean sea level) on the west coast of Sylt across the winter of 2004–2005. The profiles were measured on different dates in 2004 (ranging from 9 June to 7 December) and 2005 (ranging from 16 March to 15 August). During period there were 10 instances of beach nourishment along different sections of the coast, indicated by red and blue vertical bars and event dates. (b) Map of location of location of survey profiles from which coastal advance and retreat were calculated. The numbers give the alongshore distance in kilometres from the first profile in the south, for comparison with (a). The data for this plot were sent by Theide-Erk Woeffler of the Landesbetrieb für Küstenschutz, Nationalpark, und Meereschutz Schleswig-Holstein, Germany.

SECTION S7. TABLE OF TIDE GAUGE STATIONS USED IN THE INVESTIGATION

Table S2. Information on tide gauge data used in this study with source.

N	Station Name	Abb	Country	Latitude (degree)	Longitude (degree)	Δt orig (min)	Δt use (min)	Source
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
1	Tobermory	TB	UK	56.62	−6.06	15	15	BODC
2	Stornoway	ST	UK	58.21	−6.39	15	15	BODC
3	Ullapool	UL	UK	57.90	−5.16	15	15	BODC
4	Kinlochbervie	KB	UK	58.46	−5.05	15	15	BODC
5	Wick	WK	UK	58.44	−3.09	15	15	BODC
6	Aberdeen	AB	UK	57.14	−2.07	15	15	BODC
7	North Shields	NS	UK	55.01	−1.44	15	15	BODC
8	Immingham	IM	UK	53.63	−0.19	15	15	BODC
9	Cromer	CR	UK	52.93	1.30	15	15	BODC
10	Lowestoft	LT	UK	52.47	1.75	15	15	BODC
11	Harwich	HW	UK	51.95	1.28	15	15	BODC
12	Felixstowe	FE	UK	51.96	1.35	15	15	BODC
13	Sheerness	SH	UK	51.44	0.74	15	15	BODC
14	Dover	DV	UK	51.12	1.32	15	15	BODC
15	Scarborough	SR	UK	54.28	−0.39	10	10	NNRCMP
16	Herne Bay	HB	UK	51.38	1.12	10	10	NNRCMP
17	Nieuwpoort	NI	BE	51.15	2.73	5	5	VLIZ
18	Ostend	OE	BE	51.23	2.92	5	5	VLIZ
19	Zeebrugge	ZB	BE	51.35	3.20	5	5	VLIZ
20	Euro platform	EU	NE	52.00	3.28	10	10	RWS
21	Westkapelle	WL	NE	51.52	3.44	10	10	RWS
22	Cadzand	CZ	NE	51.38	3.38	10	10	RWS
23	Vlissingen	VL	NE	51.44	3.60	10	10	RWS
24	Roompot buiten	RM	NE	51.62	3.68	10	10	RWS
25	Hansweert	HT	NE	51.45	4.01	10	10	RWS
26	Bath	BA	NE	51.40	4.21	10	10	RWS
27	Bergse Diepsluis west	BD	NE	51.51	4.17	10	10	RWS
28	Brouwershavensche Gat 08	BH	NE	51.75	3.83	10	10	RWS
29	Lichteiland Goeree	LG	NE	51.92	3.67	10	10	RWS
30	Krammersluizen west	KM	NE	51.66	4.14	10	10	RWS
31	Stellendam buiten	SB	NE	51.83	4.03	10	10	RWS
32	Maassluis	MA	NE	51.92	4.25	10	10	RWS
33	Goidschalxoord	GX	NE	51.83	4.45	10	10	RWS
34	Hoek van Holland	HH	NE	51.98	4.12	10	10	RWS
35	Vlaardingen	VD	NE	51.90	4.35	10	10	RWS
36	Dordrecht	DD	NE	51.82	4.67	10	10	RWS
37	Rotterdam	RD	NE	51.92	4.50	10	10	RWS
38	Krimpen a/d Lek	KL	NE	51.89	4.63	10	10	RWS
39	Krimpen a/d IJssel	KI	NE	51.92	4.58	10	10	RWS
40	Scheveningen	SC	NE	52.10	4.26	10	10	RWS

Table S2 (continued).

N [1]	Station Name [2]	Abb [3]	Country [4]	Latitude (degree) [5]	Longitude (degree) [6]	Δt orig (min) [7]	Δt use (min) [8]	Source [9]
41	Schoonhoven	SO	NE	51.94	4.85	10	10	RWS
42	Noordwijk meetpost	NO	NE	52.27	4.29	10	10	RWS
43	IJmuiden buitenhaven	IJ	NE	52.46	4.55	10	10	RWS
44	Petten zuid	PZ	NE	52.77	4.65	10	10	RWS
45	Den Oever buiten	DO	NE	52.93	5.05	10	10	RWS
46	Oudeschild	OS	NE	53.04	4.85	10	10	RWS
47	Texel Noordzee	TX	NE	53.12	4.73	10	10	RWS
48	Kornwerderzand buiten	KW	NE	53.07	5.34	10	10	RWS
49	Harlingen	HL	NE	53.18	5.41	10	10	RWS
50	Vlieland haven	VH	NE	53.30	5.09	10	10	RWS
51	West–Terschelling	TL	NE	53.36	5.22	10	10	RWS
52	Terschelling Noordzee	TN	NE	53.44	5.33	10	10	RWS
53	Wierumergronden	WG	NE	53.52	5.96	10	10	RWS
54	Lauwersoog	LR	NE	53.41	6.20	10	10	RWS
55	Eemshaven	EE	NE	53.45	6.83	10	10	RWS
56	Delfzijl	DF	NE	53.33	6.93	10	10	RWS
57	Nieuwe Statenzijl	NZ	NE	53.23	7.21	10	10	RWS
58	Bremen–Grosse–Weserbruecke	BW	DE	53.07	8.80	10	10	BAFG
59	Huntebrueck	HK	DE	53.20	8.44	10	10	BAFG
60	Knock	KN	DE	53.33	7.04	10	10	BAFG
61	Emden–Neue–Seeschleuse	EM	DE	53.34	7.20	10	10	BAFG
62	Emshoern	EH	DE	53.49	6.84	10	10	BAFG
63	Zollenspieker	ZO	DE	53.40	10.19	10	10	BAFG
64	Borkum–Fischerbalje	BF	DE	53.56	6.75	10	10	BAFG
65	WHV–Alter–Vorhafen	WV	DE	53.51	8.14	10	10	BAFG
66	Hamburg–St–Pauli	HM	DE	53.55	9.97	10	10	BAFG
67	Hetlingen	HE	DE	53.61	9.54	10	10	BAFG
68	Stadersand	SD	DE	53.63	9.53	10	10	BAFG
69	Langeoog	LA	DE	53.73	7.51	10	10	BAFG
70	Pinnau–Sperrwerk	PI	DE	53.67	9.56	10	10	BAFG
71	Spiekeroog	SP	DE	53.75	7.68	10	10	BAFG
72	Wangerooge–West	WW	DE	53.78	7.86	10	10	BAFG
73	Mellumplate	MP	DE	53.77	8.09	10	10	BAFG
74	Kollmar	KO	DE	53.73	9.46	10	10	BAFG
75	Wangerooge–Nord	WN	DE	53.81	7.93	10	10	BAFG
76	Glueckstadt	GL	DE	53.78	9.41	10	10	BAFG
77	LT–Alte–Weser	AW	DE	53.86	8.13	10	10	BAFG
78	Cuxhaven–Steubenhoeft	CU	DE	53.87	8.72	10	10	BAFG
79	Brunsbuettel–Mole4	BR	DE	53.89	9.14	10	10	BAFG
80	Mittelgrund	MG	DE	53.94	8.63	10	10	BAFG

Table S2 (continued).

N	Station Name	Abb	Country	Latitude (degree)	Longitude (degree)	Δt orig (min)	Δt use (min)	Source
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
81	Scharhoern	SN	DE	53.97	8.46	10	10	BAFG
82	Zehnerloch	ZE	DE	53.95	8.66	10	10	BAFG
83	Buesum	BU	DE	54.12	8.86	10	10	BAFG
84	Helgoland–Suedhafen	HS	DE	54.18	7.90	10	10	BAFG
85	Helgoland–Binnenhafen	HF	DE	54.18	7.90	10	10	BAFG
86	Eider–Sperrwerk	EI	DE	54.26	8.84	10	10	BAFG
87	Husum	HU	DE	54.47	9.02	10	10	BAFG
88	Pellworm	PW	DE	54.50	8.70	10	10	BAFG
89	Wittduen	WI	DE	54.63	8.39	10	10	BAFG
90	Dagebuell	DA	DE	54.73	8.69	10	10	BAFG
91	Hoernum	HR	DE	54.76	8.31	10	10	BAFG
92	List	LS	DE	55.02	8.45	10	10	BAFG
93	Hojer	HO	DK	54.96	8.66	10	10	KDI
94	Havneby	HY	DK	55.09	8.57	10	10	KDI
95	Ribe	RI	DK	55.34	8.68	10	10	KDI
96	Esbjerg	EJ	DK	55.47	8.42	10	10	KDI
97	Hvide Sande (Havet)	HV	DK	56.00	8.11	10	10	KDI
98	Thorsminde (Havet)	TO	DK	56.37	8.11	10	10	KDI
99	Ferring	FR	DK	56.52	8.12	10	10	KDI
100	Thyboron (Havet hofde 58)	TY	DK	56.71	8.21	10	10	KDI
101	Hanstholm	HA	DK	57.12	8.59	10	10	KDI2
102	Hirtshals	HI	DK	57.60	9.96	10	10	KDI2
103	Tregde	TG	NO	58.00	7.56	10	10	Kartv
104	Stavanger	SV	NO	58.97	5.73	10	10	Kartv
105	Bergen	BG	NO	60.39	5.33	10	10	Kartv
106	Maloy	MY	NO	61.94	5.11	10	10	Kartv

Notes:
[1] Station running index
[2] Station name
[3] Station abbreviation used in figures of the main manuscript
[4] Country
[5] Latitude
[6] Longitude
[7] Data reporting interval in minutes
[8] Data time interval used in analysis
[9] Source:
BODC: British Oceanographic Data Centre; water level data from the primary tide gauge packed with the residual water level after subtraction of the BODC model tide; https://bodc.ac.uk/data/hosted_data_systems/sea_level/uk_tide_gauge_network/
NNRCMP: Network of regional coastal monitoring programs; Herne Bay, https://www.coastalmonitoring.org/realtimedata/?chart=89; Scarborough, https://www.coastalmonitoring.org/realtimedata/?chart=108.
VLIZ: Vlaams Instituut voor de Zee; https://meetnetvlaamsebanken.be
RWS: Rijkswatersaat Waterinfo; https://waterinfo.rws.nl/#!/nav/expert/alle-groepen/ (levels with respect common level reference of country)
RWS2: Rijkswatersaat Waterinfo; https://waterinfo.rws.nl/#!/nav/expert/alle-groepen/ (offshore stations whose levels have a local reference)
BAFG: Bundesanstalt fuer Gewaesserkunde; email communication with Wilfried Wiechmann at Datenstelle-M1@bafg.de
KDI: Kystdirektoratet; https://kystatlas.kyst.dk/public2/data/vandstand/vandstand.html

KDI2: Kystdirektoratet; data from gauges operated by Danish harbour authorities) email communication with Bjørn Frederiksen bfr@kyst.dk
Kartv: Kartverket; api.sehavniva.no/tideapi_en.html

Table S3. Summary of Rejected Stations

Station	Country	Reason
Islay	UK - BODC	Strong signal from Irish Sea?
Leith	UK - BODC	No data
Whitby	UK - BODC	Severely corrupted
Southend	UK - Environment Agency	Noise on 8 January unlike other stations
Brouwershavensche Gat, punt 02	Netherlands	16 point gap on 12 January
Haringvliet 10	Netherlands	Long gaps
Keizersveer	Netherlands	Time series looks different from others
Nes	Netherlands	Long gap on 15 January
Oosterschelde 11	Netherlands	Measured data absent
Schiermonnikoog	Netherlands	Long data gaps in period
Spikenisse	Netherlands	29 point data gap
Stavenisse	Netherlands	Long data gap
Terneuzen	Netherlands	Long data gaps
Vlakte van de Raan	Netherlands	16 point data gap
Yerseke	Netherlands	16 point data gap
Plaatform K13a	Netherlands	24 point data gap on 19 January
Bake-Z	Germany	Measurement series bad
Toenning	Germany	Measurement series bad
Norderney Riffgat	Germany	Extended data gaps
Bork Havn tryk	Denmark	Strange trends
Hvide Sand (Fjord)	Denmark	Strange trends
Thorsminde (Fjord)	Denmark	Strange trends
Ballum flyder	Denmark	Clipped tidal peaks during storm Erwin
Hvide Sand (Havn) tryk	Denmark	Data gaps
Ribe (Havet pa forlandet) tryk	Denmark	Data gaps
Thorsminde (havn)	Denmark	Data gaps
Thyboron (Havn) tryk	Denmark	Data gaps

SECTION S8. WATER LEVEL RANGE ACROSS 10-MINUTE INTERVALS: GERMANY

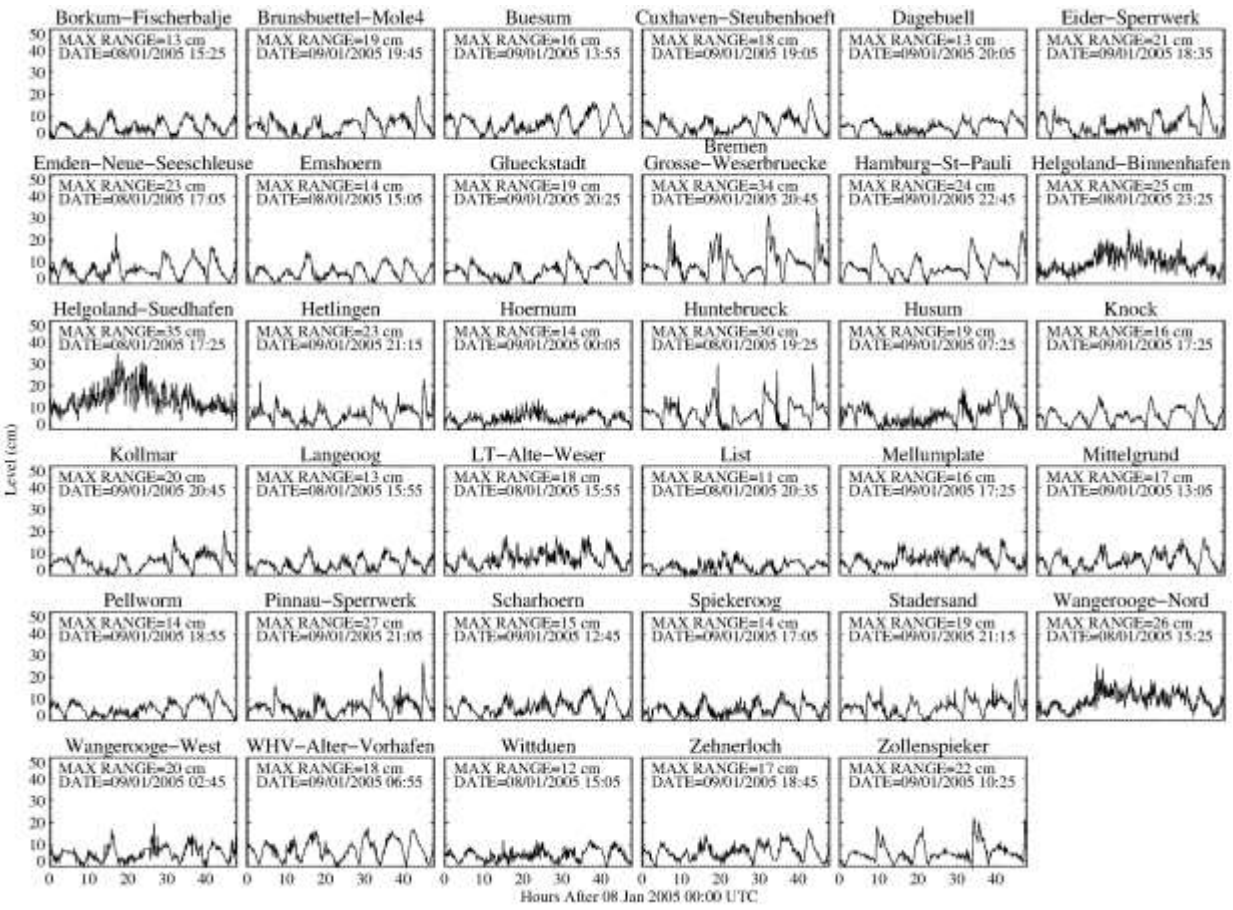

Figure S43. Range of water levels across 10-minute intervals, calculated from the original 1-minute time series data for Germany. The data for this graph was sent by Wilfried Wiechmann (Bundesanstalt für Gewasserkunde).

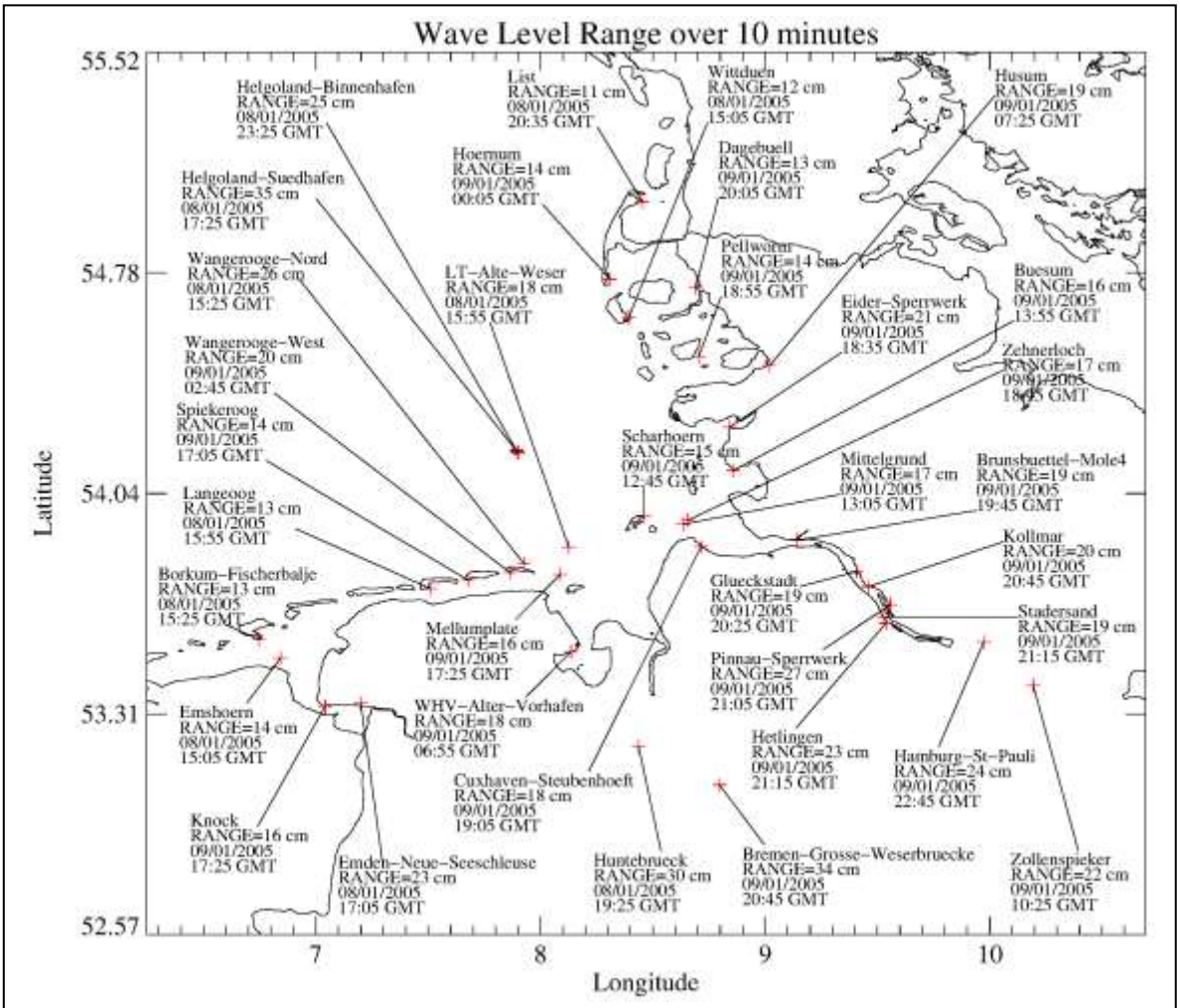

Figure S44. Map showing locations of the German tide gauge stations where the maximum range of water levels in 10-minute intervals were assessed.

SECTION S9. SAMPLE POWER SPECTRUM OF TIDE GAUGE WATER LEVEL DATA

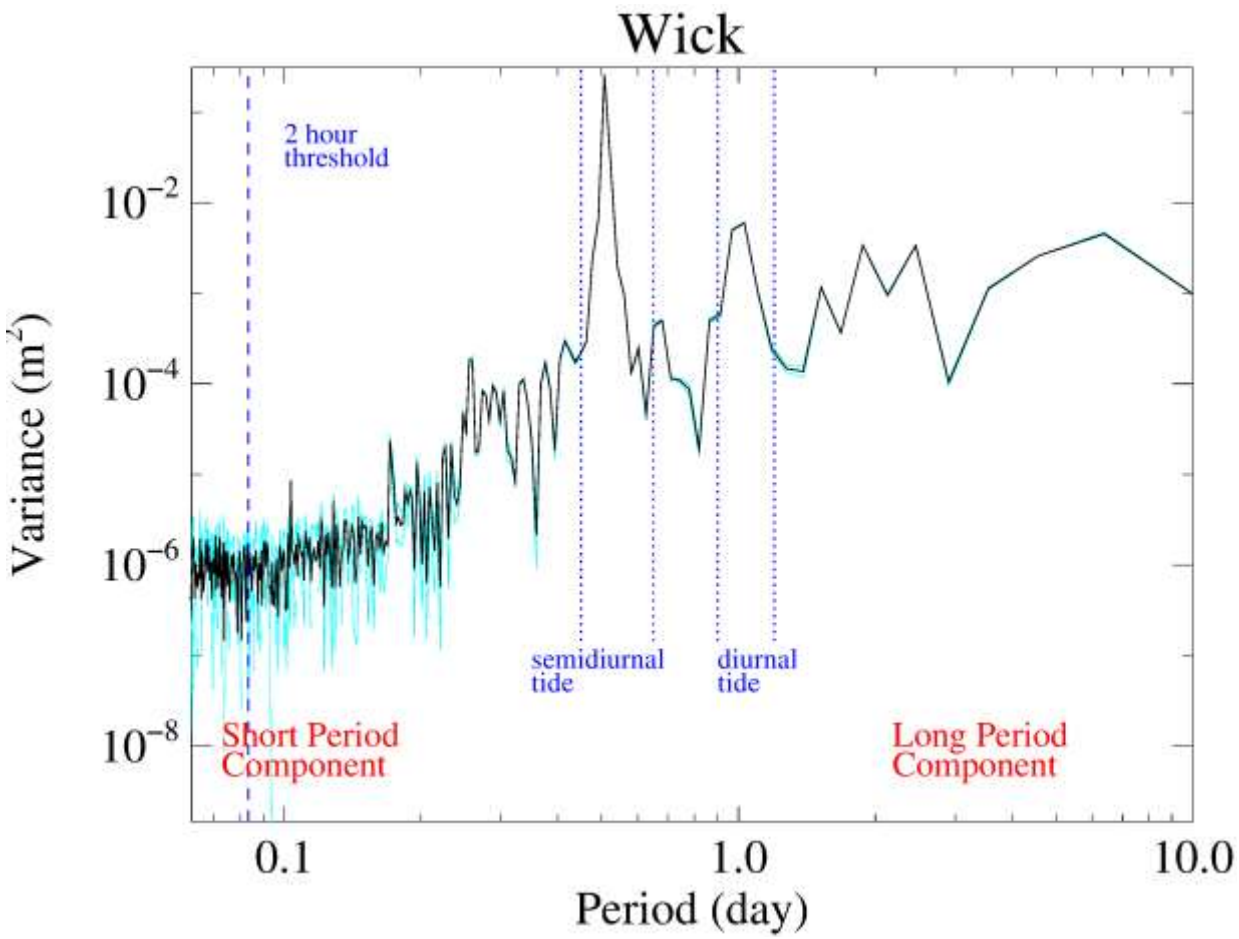

Figure S45. Sample spectrum of water level for Wick in the UK across the 16 day period 6–21 January 2005 (inclusive). The 2 hour threshold separating the short period and long period components of the time series reconstructions is shown, as well as the thresholds defining the diurnal and semidiurnal components that were used to de-tide the time series. The uncertainty in the spectrum (light blue line) calculated as the standard deviation of three spectra derived from re-sampling the time series at every third point.

SECTION S10. TIDE GAUGE LEVELLING DIFFERENCES AND SURGE CORRECTIONS

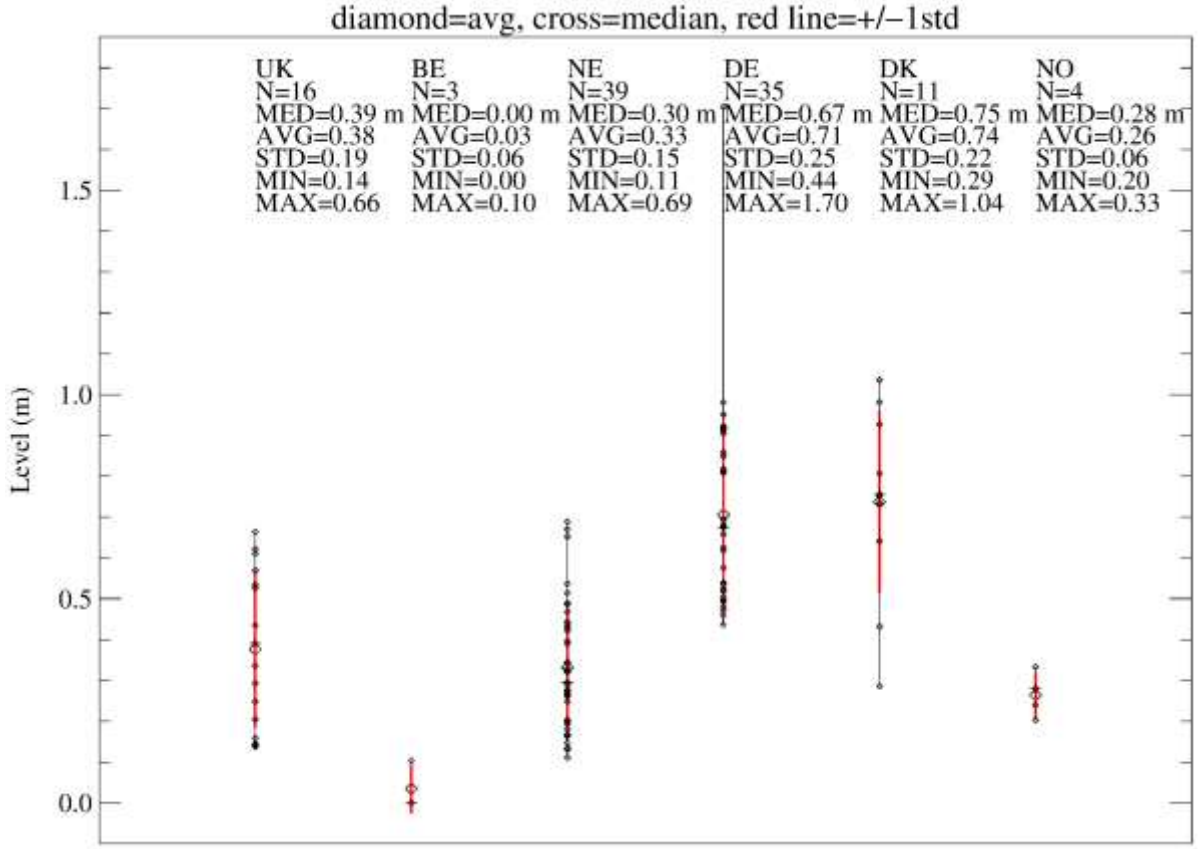

Figure S46. Difference of the reported mean sea level and the 16 day median level calculated from the tide gauge data for the period 6–21 January 2005. The station differences have been separated by country, and statistics from the country collections have been calculated. The reason for the apparent bias is not clear.

SECTION S11. MARITIME ACCIDENTS 8–9 JANUARY 2005

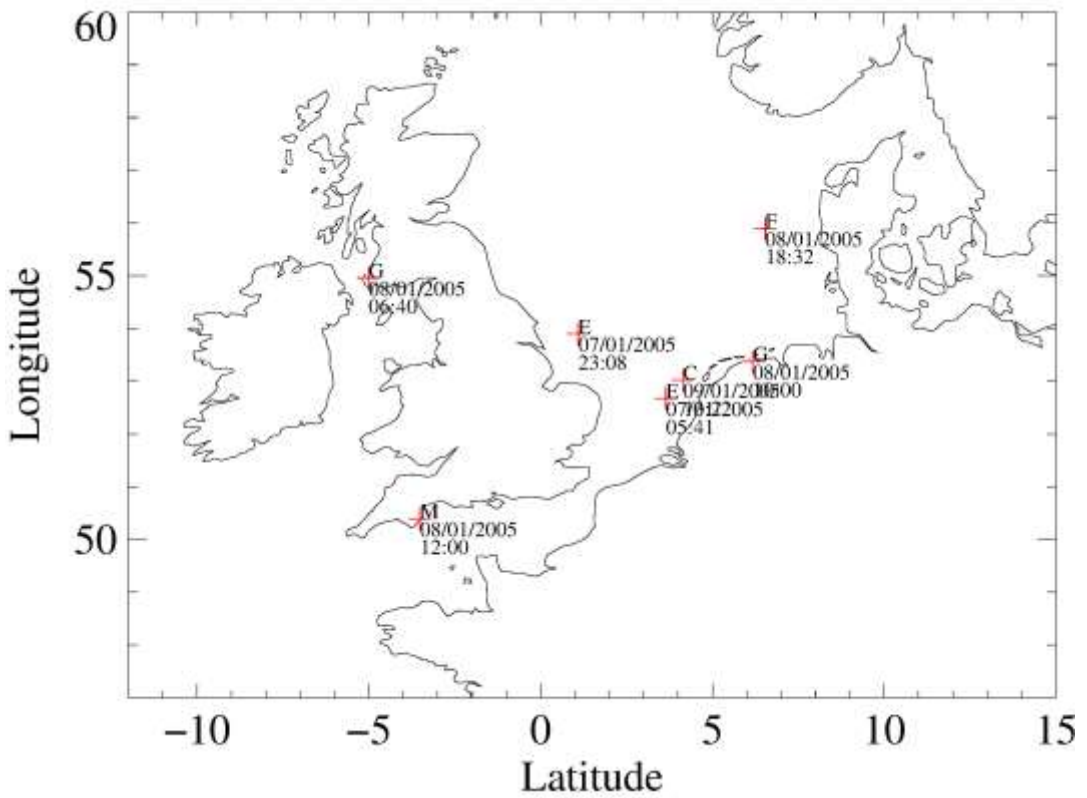

Figure S47. Locations of maritime casualties during Storm Erwin 7–9 January 2005. The information is mostly from Lloyds Casualty Week (20050121) with one record from the KNRM on the Netherlands coast. The highest profile accident was the grounding of the ferry European Highlander on the west coast of Scotland. Two accidents were registered in the North Sea during the main storm period 8–9 January 2005, although two others occurred on 7 January 2005.

Table S4. Information for the maritime accidents and offshore events in the North Sea for 8–9 January 2005.

N [1]	Ship/Platform Name or Incident [2]	Abb [3]	Latitude (deg) [4]	Longitude (deg) [5]	Date (UTC) dd/mm/yyyy [6]	Time UTC hh:mm [7]	Uncertainty (h) [8]	Source [9]
1	Sandettie	SAN	53.02	4.14	09/01/2005	13:22	0.0	LCW_20050121
2	Schieborg	SCH	55.90	6.54	08/01/2005	18:32	0.0	LCW_20050121
3	barges	BAR	53.37	6.17	08/01/2005	10:00	0.0	KNRM

SECTION S12. TABLE OF MAXIMA IN WAVE TIMES SERIES DATA 8–9 JANUARY 2005

Table S5. Information for maximum in the time series of significant wave height in the North Sea and Norwegian Sea for 8–9 January 2005.

N [1]	Ship/Platform Name or Incident [2]	Lati–tude (deg) [4]	Longi–tude (deg) [5]	Date (UTC) dd/mm/yyyy [6]	Time UTC hh:mm [7]	Uncer tainty (h) [8]	Source [9]
1	Folkestone	51.06	1.13	08/01/2005	07:30	0.0	CCO
2	Sandettie Light ship	51.10	1.80	08/01/2005	07:59	0.0	CMEMS
3	Trapegeer	51.14	2.58	08/01/2005	11:00	0.0	BE
4	Ostend Eastern Palisade	51.25	2.93	08/01/2005	12:00	0.0	BE
5	Ostend Noodstrand	51.35	2.88	08/01/2005	12:00	0.0	BE
6	A2	51.36	3.12	08/01/2005	11:30	0.0	BE
7	Westhinder	51.39	2.44	08/01/2005	08:30	0.0	BE
8	Bol van Heist	51.39	3.20	08/01/2005	09:30	0.0	BE
9	Wandelaar	51.39	3.05	08/01/2005	11:00	0.0	BE
10	Scheur Wielingen	51.40	3.30	08/01/2005	11:45	0.0	BE
11	Akkaert	51.42	2.82	08/01/2005	10:45	0.0	BE
12	Wielingen noord	51.43	3.41	08/01/2005	12:30	0.0	NE
13	Vlakte van de Raan	51.50	3.24	08/01/2005	12:00	0.0	NE
14	Oosterschelde 04	51.65	3.69	08/01/2005	12:00	0.0	NE
15	Schouwenbank	51.75	3.31	08/01/2005	11:00	0.0	NE
16	Lichteiland Goeree	51.92	3.67	08/01/2005	12:00	0.0	NE
17	Eurogeul DWE	51.95	3.00	08/01/2005	09:00	0.0	NE
18	Euro platform	52.00	3.28	08/01/2005	09:00	0.0	NE
19	Eurogeul E13	52.01	3.74	08/01/2005	11:00	0.0	NE
20	Noordwijk meetpost	52.27	4.30	08/01/2005	11:00	0.0	NE
21	IJmuiden MSP	52.55	4.06	08/01/2005	22:00	0.0	NE
22	Leman AD1	53.00	2.10	08/01/2005	11:00	0.0	BIDLOT
23	Sean PaPa	53.10	2.80	08/01/2005	06:00	0.0	BIDLOT
24	K13a	53.22	3.22	08/01/2005	13:00	0.0	NE
25	Eierlandse Gat	53.28	4.66	08/01/2005	16:00	0.0	NE
26	Dowsing (postproc)	53.53	1.05	08/01/2005	12:30	0.0	CEFAS
27	Schiermonnikoog noord	53.60	6.16	08/01/2005	16:00	0.0	NE
28	Elbe	54.00	8.11	08/01/2005	20:15	0.0	CMEMS
29	Helgoland	54.18	7.89	08/01/2005	18:42	0.0	CMEMS
30	Fano Bugt	55.34	8.23	08/01/2005	19:30	0.0	DK
31	Nymindegab	55.81	7.94	08/01/2005	16:45	0.0	DK
32	Auk Alpha	56.40	2.00	08/01/2005	15:00	0.0	BIDLOT
33	Ekofisk	56.50	3.20	08/01/2005	15:00	0.0	BIDLOT
34	Shearwater	57.00	2.00	08/01/2005	14:00	0.0	BIDLOT
35	Gannet	57.10	1.00	08/01/2005	13:00	0.0	BIDLOT
36	Anasuria	57.20	0.80	08/01/2005	13:00	0.0	BIDLOT
37	Hirtshals	57.51	9.61	08/01/2005	22:30	0.0	DK
38	Nelson A	57.70	1.40	08/01/2005	22:00	0.0	BIDLOT
39	Ivanhoe	58.10	0.40	08/01/2005	18:00	0.0	BIDLOT
40	Babbage	58.10	0.10	08/01/2005	15:00	0.0	BIDLOT
41	Sleipner B	58.40	1.90	08/01/2005	15:00	0.0	BIDLOT
42	Troll A	60.60	3.70	09/01/2005	09:00	0.0	BIDLOT
43	Dunbar	60.60	1.70	09/01/2005	05:00	0.0	BIDLOT
44	K7	60.70	–4.50	09/01/2005	00:00	0.0	CMEMS
45	North Alwyn	60.80	1.70	09/01/2005	06:00	0.0	BIDLOT
46	Brent A	61.00	1.70	08/01/2005	00:00	0.0	BIDLOT
47	Cormorant Alpha	61.10	1.00	08/01/2005	00:00	0.0	BIDLOT
48	Gullfaks C	61.20	2.30	08/01/2005	00:00	0.0	BIDLOT

Table S6. Information for maximum in time series of maximum wave height in the North Sea and Norwegian Sea for 8–9 January 2005.

N [1]	Ship/Platform Name or Incident [2]	Latitude (deg) [4]	Longitude (deg) [5]	Date (UTC) dd/mm/yyyy [6]	Time UTC hh:mm [7]	Uncertainty (h) [8]	Source [9]
1	Folkestone	51.06	1.13	08/01/2005	07:00	0.0	CCO
2	Wielingen noord	51.43	3.41	08/01/2005	12:00	0.0	NE
3	Vlakte van de Raan	51.50	3.24	08/01/2005	15:00	0.0	NE
4	Oosterschelde 04	51.65	3.69	08/01/2005	14:30	0.0	NE
5	Schouwenbank	51.75	3.31	08/01/2005	14:00	0.0	NE
6	Lichteiland Goeree	51.92	3.67	08/01/2005	17:00	0.0	NE
7	Eurogeul DWE	51.95	3.00	08/01/2005	09:00	0.0	NE
8	Euro platform	52.00	3.28	08/01/2005	18:00	0.0	NE
9	Eurogeul E13	52.01	3.74	08/01/2005	11:00	0.0	NE
10	Noordwijk meetpost	52.27	4.30	08/01/2005	16:00	0.0	NE
11	IJmuiden MSP	52.55	4.06	08/01/2005	11:00	0.0	NE
12	K13a	53.22	3.22	08/01/2005	19:00	0.0	NE
13	Eierlandse Gat	53.28	4.66	08/01/2005	18:00	0.0	NE
14	Fano Bugt	55.34	8.23	08/01/2005	20:30	0.0	DK
15	Nymindegab	55.81	7.94	08/01/2005	16:45	0.0	DK
16	Hirtshals	57.51	9.61	09/01/2005	01:30	0.0	DK

Notes:
[1] Running index of event
[2] Ship/platform name
[3] Abbreviation used in figures of main manuscript
[4] Latitude
[5] Longitude
[6] Date of incident
[7] Time of incident
[8] Source:
LCW_20050121: Lloyd's Casualty Week: Lloyd's of London Press Ltd., Sheepen Place, Colchester, Essex, CO3 3LP, 21/01/2005
BE: Vlaams Instituut voor de Zee; https://meetnetvlaamsebanken.be
BIDLOT:
CCO: National Network of Regional Coastal Monitoring Programmes (NNRCMP), https://coastalmonitoring.org/
DK: Kystdirektoratet; https://kystatlas.kyst.dk/public2/data/vandstand/vandstand.html
NE: Rijkswaterstaat Waterinfo; https://waterinfo.rws.nl/ (levels with respect common level reference of country)

SECTION S13. MAXIMUM SURGE RESIDUAL

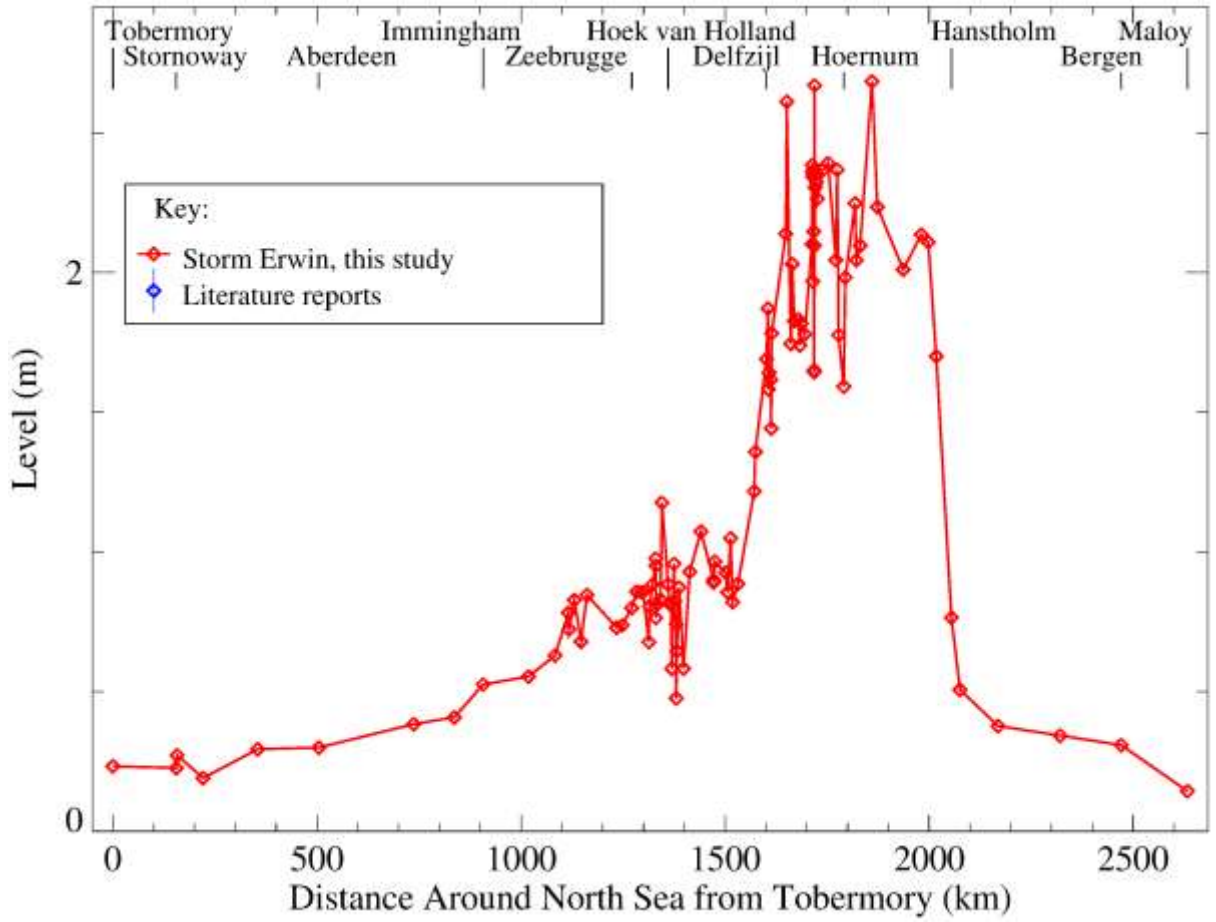

Figure S48. Maximum surge residual during Storm Erwin on 8–9 January 2005 versus coastal distance around the North Sea starting from Tobermory in Scotland.

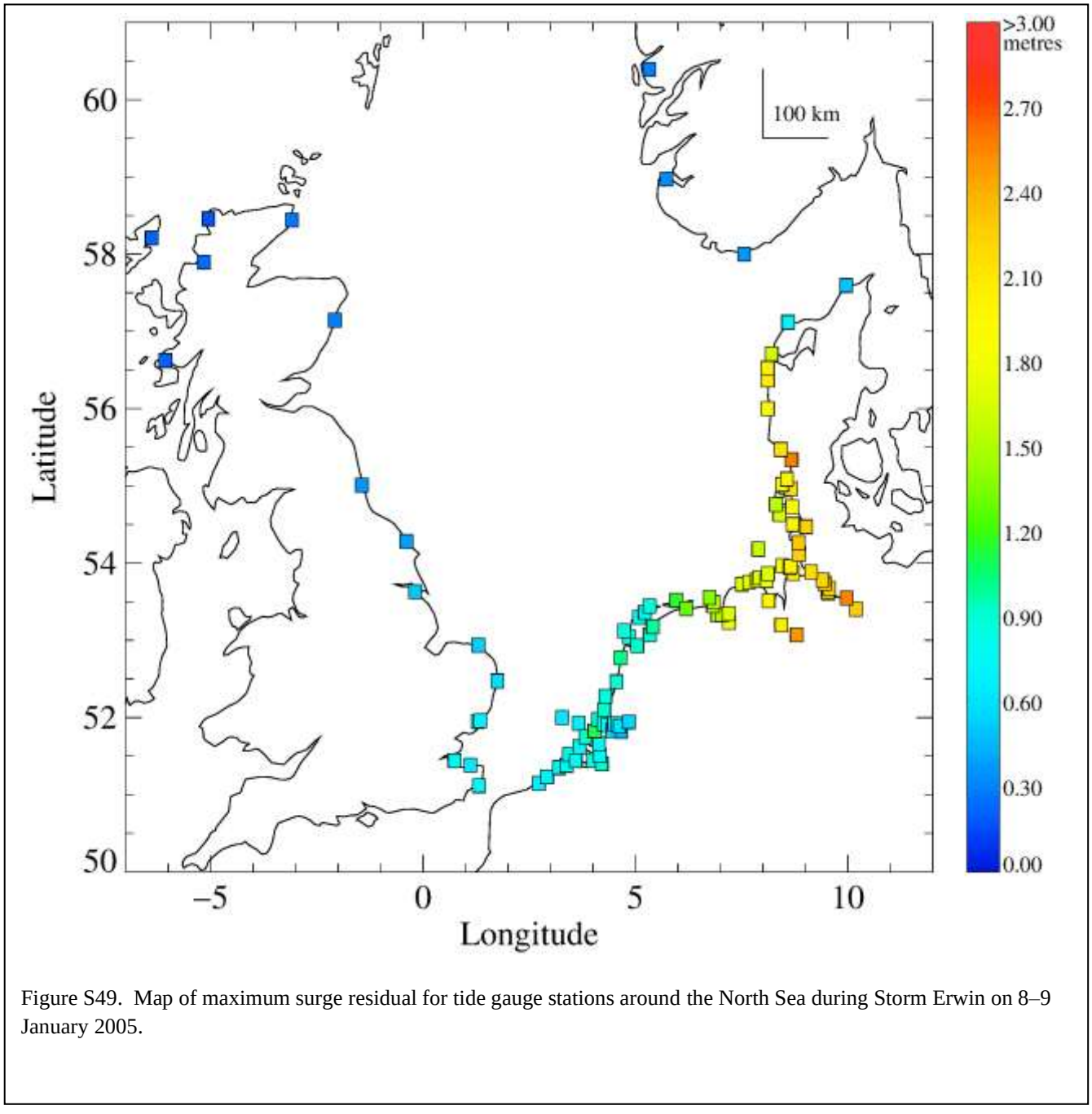

Figure S49. Map of maximum surge residual for tide gauge stations around the North Sea during Storm Erwin on 8–9 January 2005.

SECTION S14. RETURN PERIOD OF WATER LEVELS FROM THE LITERATURE

Table S7. Sorted list of return periods of highest water levels during Storm Erwin on 8–9 January 2005.

N [1]	Location [2]	Country [3]	Latitude (degree) [4]	Longitude (degree) [5]	Return Period (year) [6]	Case [7]
1	Varberg+Ringhals	SV	57.25	12.11	500	12:SMHI
2	Parnu	EE	58.38	24.48	414	8:W14
3	Logstor	DK	56.97	9.25	195	5:kdi18
4	Ferring	DK	56.52	8.12	177	5:kdi18
5	Ringkobing	DK	56.09	8.24	154	5:kdi18
6	Hanko	FI	59.82	22.98	123	3:RANK
7	Narva	EE	59.46	28.05	111	3:RANK
8	Tallinn	EE	59.45	24.78	111	3:RANK
9	Helsinki	FI	60.15	24.96	106	3:RANK
10	Thyboron Hav	DK	56.71	8.21	100	5:kdi18
11	Naarva–Joesuu	EE	59.46	28.05	83	3:RANK
12	Thorsminde Havn	DK	56.37	8.12	75	5:kdi18
13	Thyboron Havn	DK	56.71	8.22	71	5:kdi18
14	Lemvig	DK	55.55	8.31	68	5:kdi18
15	Hvide Sand Havn	DK	56.00	8.13	49	5:kdi18
16	Heltermaa	EE	58.86	23.03	40	3:RANK
17	Dirhami	EE	59.20	23.50	40	3:RANK
18	Skovlunde	DK	56.42	8.17	37	5:kdi18
19	Hvide Sand Hav	DK	56.00	8.11	34	5:kdi18
20	Kunda	EE	59.50	26.51	32	3:RANK
21	Gotaborg–Torhamnen	SV	57.68	11.79	30	12:SMHI
22	Skive	DK	56.57	9.05	29	5:kdi18
23	Helsinki	FI	60.15	24.96	26	8:W14
24	Liverpool	UK	53.45	−3.02	19	6:NTLSF13
25	Hirtshals	DK	57.59	9.96	18	5:kdi18
26	Skagen	DK	57.72	10.60	12	5:kdi18
27	Ribe	DK	55.34	8.68	12	5:kdi18
28	Esbjerg	DK	55.47	8.42	11	5:kdi18
29	Saint Petersburg	RU	59.94	30.31	10	3:RANK
30	Hanstholm	DK	57.12	8.60	9.6	5:kdi18
31	Simrishhamn	SV	55.56	14.36	7.2	11:RANKMIN
32	Kungsvik	SV	59.00	11.13	7.0	12:SMHI
33	Smogen	SV	58.35	11.22	7.0	12:SMHI
34	Oranmore Bridge	EI	53.27	−8.93	6.1	10:GUMBEL
35	Stenungsund	SV	58.09	11.83	6.0	12:SMHI

Table S7. (continued)

N [1]	Location [2]	Country [3]	Latitude (degree) [4]	Longitude (degree) [5]	Return Period (year) [6]	Case [7]
36	Llandudno	UK	53.33	−3.83	5.8	6:NTLSF13
37	Nibe/Sebbersund	DK	56.99	9.63	5.4	5:kdi18
38	Oskarshamn	SV	57.28	16.48	5.4	11:RANKMIN
39	Hojer Sluse	DK	54.96	8.66	5.3	5:kdi18
40	Hals	DK	56.99	10.31	5.3	5:kdi18
41	Visby	SV	57.64	18.28	5.0	12:SMHI
42	Marviken+Arko	SV	58.48	16.96	5.0	12:SMHI
43	Viken	SV	56.14	12.58	5.0	12:SMHI
44	Heysham	UK	54.03	−2.92	4.9	6:NTLSF13
45	Kloster	DK	56.30	8.28	4.8	5:kdi18
46	Havneby	DK	55.09	8.57	4.6	5:kdi18
47	Kobenhavn	DK	55.70	12.60	4.3	5:kdi18
48	Hornbaek	DK	56.09	12.46	4.1	5:kdi18
49	Olands Norra Udda	SV	57.37	17.10	4.0	12:SMHI
50	Ballum	DK	55.13	8.69	3.8	5:kdi18
51	Newport	UK	51.55	−2.99	3.6	6:NTLSF13
52	Norresundby	DK	57.06	9.92	3.4	5:kdi18
53	Hinkley Point	UK	51.22	−3.13	3.3	6:NTLSF13
54	Grenaa	DK	56.41	10.92	3.1	5:kdi18
55	Ilfracombe	UK	51.21	−4.11	3.0	6:NTLSF13
56	Mumbles	UK	51.57	−3.98	2.1	6:NTLSF13
57	Barseback	SV	55.76	12.90	2.0	12:SMHI
58	Klagshamn	SV	55.52	12.89	2.0	12:SMHI
59	Ferry Bridge	EI	52.47	−9.63	1.9	10:GUMBEL
60	Balls Bridge	EI	52.67	−8.62	1.6	10:GUMBEL
61	Sjaellands Odde	DK	55.97	11.37	1.6	5:kdi18
62	Tregde	NO	58.00	7.56	1.5	3:RANK
63	Delfzijl	NE	53.33	6.93	0.25	1:RP

Notes:

[1] Running index of data
[2] Station name
[3] Country
[4] Latitude
[5] Longitude
[6] Calculated return period in years
[7] Return period
[8] Description of calculation:
RP: return period presented in source
FREQ: source presents number of exceedances within a time interval; return period is taken as reciprocal
RANK: source presents rank of water level across a date range; return period is calculated as the number of years represented divided by the rank.

RANKMIN: as for RANK but applied to minimum surge levels during a storm

kdi18: Ditlevsen et al (2018) present the maximum water levels for the storm and tabulated values of standardized return periods versus water level that were interpolated to derive the return periods [Ditlevsen C, MM Ramos, C Sørensen, UR Ciocan, T Pionkowitz, Højvandsstatistikker 2017, Miljo- og Fødevareministeriet, Kystdirektoratet Lemvig, Februar, 2018]

NTLSF13: The National Tide and Sea Level Facility NTSLF presents web pages with ranked lists of the top 10 skew surge levels for selected tide gauges around the UK across specified date ranges up to 2013. The return period was calculated as the number of years of data divided by the rank of Storm Kyrill, if it was present [https://ntslf.org/storm-surges/skew-surges/scotland, https://ntslf.org/storm-surges/skew-surges/england-east, https://ntslf.org/storm-surges/skew-surges/england-south, https://ntslf.org/storm-surges/skew-surges/england-wales, https://ntslf.org/storm-surges/skew-surges/england_west, https://ntslf.org/storm-surges/skew-surges/isle-of-man, https://ntslf.org/storm-surges/skew-surges/northern-ireland, https://ntslf.org/storm-surges/skew-surges/channel-islands (accessed 10Nov2021)]

SMHI: return period read from extreme value return period graph using water levels read from an online time series graph (SMHI, Högvattenhändelser idag och i framtiden, https://www.smhi.se/klimat/stigande-havsnivaer/hogvattenhandelser-idag-och-i-framtiden, last access: 10Jan2025)

GUMBEL: return period calculated from Gumbel analysis of literature table of annual maximum water levels.

W14: return period calculated from water level and tabulated results of extreme value analysis presented in: T Wolski, B. Wisniewski, A. Giza, H. Kowalewska-Kalkowska, H. Boman, S. Grabbi-Kaiv, T. Hammarklint, J. Holfort, Z. Lydeikaite, Extreme sea levels at selected stations on the Baltic coast, Oceanologia, 56, 259-290, 2014.

SECTION S15. MAXIMUM AMPLITUDE AND RANGE OF SHORT PERIOD OSCILLATIONS

Table S8. List of maximum amplitude (in descending order) of down-crossing oscillations derived from the short period time series reconstructions for each North Sea tide gauge station.

N	Station Name	Max (cm)	Midpoint of Oscillation (h after 8 Jan 2005 00:00 UTC)	Duration of Oscillation (h)
1	Thorsminde (Havet)	22.9	11.75	1.83
2	Stellendam buiten	22.4	13.42	1.50
3	Ferring	21.2	15.08	1.50
4	Hanstholm	21.1	23.00	1.00
5	Thyboron (Havet hofde 58)	20.1	11.67	1.33
6	Brouwershavensche Gat 08	19.1	13.17	1.33
7	Ullapool	16.6	16.62	1.25
8	Bremen–Grosse–Weserbruecke	16.4	44.92	1.33
9	IJmuiden buitenhaven	14.0	15.50	0.67
10	Terschelling Noordzee	13.8	14.92	1.50
11	Huntebrueck	13.3	18.50	1.83
12	Hvide Sande (Havet)	12.7	15.67	1.67
13	Texel Noordzee	11.3	15.25	1.17
14	Pinnau–Sperrwerk	11.1	33.92	1.67
15	Nieuwe Statenzijl	10.4	16.83	1.33
16	Zollenspieker	10.2	34.50	1.50
17	Scheveningen	9.9	18.83	0.33
18	Zeebrugge	9.5	13.38	1.08
19	Kinlochbervie	9.4	15.88	0.75
20	Hirtshals	9.3	23.58	0.50
21	Ribe	8.5	19.50	1.33
22	Roompot buiten	8.3	13.25	1.50
23	Cadzand	7.3	13.42	1.17
24	Petten zuid	7.2	14.58	1.17
25	Stornoway	7.0	13.25	1.00
26	Scarborough	6.9	24.92	1.50
27	Ostend	6.9	27.75	1.00
28	Hojer	6.7	15.58	1.17
29	Esbjerg	6.6	20.50	1.33
30	Tobermory	6.6	13.38	1.25
31	Nieuwpoort	6.5	7.87	1.42
32	North Shields	6.3	9.75	1.00
33	Eemshaven	6.2	17.42	0.50
34	Delfzijl	6.1	17.00	1.00
35	Eider–Sperrwerk	6.0	20.50	1.17
36	Wangerooge–Nord	6.0	18.58	0.67
37	Hetlingen	5.9	45.42	1.33
38	Kollmar	5.9	44.75	1.33
39	Aberdeen	5.9	16.00	1.00
40	Kornwerderzand buiten	5.8	16.33	1.33

Table S8. (continued).

N	Station Name	Max (cm)	Midpoint of Oscillation (h after 8 Jan 2005 00:00 UTC)	Duration of Oscillation (h)
41	Krammersluizen west	5.8	32.08	1.83
42	West–Terschelling	5.7	15.17	1.33
43	Wierumergronden	5.7	20.58	0.83
44	Vlieland haven	5.6	15.25	0.83
45	Husum	5.6	20.00	1.50
46	Wangerooge–West	5.6	46.33	1.17
47	Tregde	5.5	18.17	0.33
48	Euro platform	5.4	12.33	1.33
49	Wittduen	5.4	15.42	1.33
50	Maloy	5.3	8.33	0.33
51	Glueckstadt	5.3	44.58	1.33
52	Cromer	5.2	12.25	1.50
53	Hoernum	5.1	18.58	1.33
54	Westkapelle	5.0	14.08	0.83
55	Maassluis	5.0	15.08	1.50
56	Vlissingen	4.9	13.75	1.50
57	Brunsbuettel–Mole4	4.9	18.75	1.33
58	Hoek van Holland	4.8	20.67	1.33
59	Lowestoft	4.6	14.63	1.25
60	Spiekeroog	4.6	14.83	1.17
61	Immingham	4.3	11.50	1.50
62	Bath	4.3	19.08	1.50
63	Noordwijk meetpost	4.2	13.58	1.50
64	Stadersand	4.1	45.33	1.50
65	LT–Alte–Weser	3.9	15.08	1.33
66	Lichteiland Goeree	3.9	13.00	0.67
67	Havneby	3.9	14.17	0.33
68	Zehnerloch	3.9	16.08	1.67
69	Den Oever buiten	3.8	38.17	1.67
70	Hansweert	3.8	11.67	1.33
71	Helgoland–Suedhafen	3.6	16.17	0.83
72	Scharhoern	3.6	25.08	1.00
73	Hamburg–St–Pauli	3.5	44.83	1.83
74	Emden–Neue–Seeschleuse	3.5	12.75	0.67
75	Helgoland–Binnenhafen	3.4	14.75	1.00
76	Cuxhaven–Steubenhoeft	3.3	18.00	1.17
77	List	3.2	16.33	1.50
78	Dagebuell	3.2	19.50	1.17
79	Herne Bay	3.1	9.75	1.83
80	Krimpen a/d IJssel	3.0	16.17	1.67

Table S8 (continued).

N	Station Name	Max (cm)	Midpoint of Oscillation (h after 8 Jan 2005 00:00 UTC)	Duration of Oscillation (h)
81	Dover	3.0	9.75	1.50
82	Felixstowe	3.0	27.50	0.50
83	Harlingen	3.0	17.67	0.67
84	WHV–Alter–Vorhafen	2.9	11.92	0.67
85	Pellworm	2.8	15.92	1.67
86	Rotterdam	2.8	14.50	1.33
87	Mittelgrund	2.8	17.67	1.50
88	Langeoog	2.8	14.92	1.00
89	Bergen	2.8	10.25	0.83
90	Mellumplate	2.8	16.75	1.00
91	Lauwersoog	2.8	23.50	1.33
92	Harwich	2.7	14.88	1.25
93	Oudeschild	2.7	38.83	1.33
94	Wick	2.6	22.13	1.75
95	Emshoern	2.6	16.33	1.17
96	Schoonhoven	2.4	11.17	1.00
97	Borkum–Fischerbalje	2.4	16.83	0.50
98	Dordrecht	2.3	25.92	1.83
99	Vlaardingen	2.2	21.08	1.17
100	Knock	2.1	15.92	1.33
101	Buesum	2.1	26.33	0.50
102	Goidschalxoord	2.0	36.42	1.50
103	Bergse Diepsluis west	1.9	31.00	0.67
104	Stavanger	1.8	10.33	1.67
105	Krimpen a/d Lek	1.7	14.83	1.33
106	Sheerness	1.6	14.63	1.75

Table S9. List of maximum range (in descending order) of down-crossing oscillations derived from the short period time series reconstructions for each North Sea tide gauge station.

N	Station Name	Range (cm)	Midpoint of Oscillation (h after 8 Jan 2005 00:00 UTC)	Duration of Oscillation (h)
1	Stellendam buiten	42.6	13.42	1.50
2	Hanstholm	36.7	23.00	1.00
3	Thorsminde (Havet)	34.7	11.75	1.83
4	Ferring	34.1	11.58	1.50
5	Thyboron (Havet hofde 58)	34.0	11.67	1.33
6	Bremen–Grosse–Weserbruecke	31.4	44.92	1.33
7	Ullapool	31.0	16.62	1.25
8	Nieuwe Statenzijl	27.1	30.83	1.33
9	Brouwershavensche Gat 08	25.7	13.17	1.33
10	Hvide Sande (Havet)	25.0	15.67	1.67
11	IJmuiden buitenhaven	24.0	15.50	0.67
12	Kinlochbervie	23.9	14.12	0.75
13	Huntebrueck	22.6	43.92	1.33
14	Zollenspieker	21.6	34.50	1.50
15	Terschelling Noordzee	20.7	14.92	1.50
16	Pinnau–Sperrwerk	19.8	45.25	1.33
17	Texel Noordzee	19.1	15.25	1.17
18	Hirtshals	18.3	30.83	0.33
19	Zeebrugge	15.5	13.38	1.08
20	Ribe	15.2	22.75	0.83
21	Hojer	15.1	18.67	1.67
22	Scheveningen	14.6	18.83	0.33
23	Petten zuid	14.6	14.58	1.17
24	Hetlingen	13.9	45.42	1.33
25	Scarborough	13.4	28.08	0.50
26	Roompot buiten	13.2	13.25	1.50
27	Den Oever buiten	13.2	38.17	1.67
28	Eider–Sperrwerk	13.1	42.75	1.33
29	Nieuwpoort	13.1	7.87	1.42
30	Stornoway	13.0	17.25	1.00
31	Tobermory	12.6	12.25	1.00
32	Wittduen	12.3	15.42	1.33
33	Cadzand	12.2	13.42	1.17
34	Kollmar	12.2	44.75	1.33
35	Krammersluizen west	12.0	32.08	1.83
36	Esbjerg	11.9	20.50	1.33
37	Tregde	11.8	16.58	0.83
38	Delfzijl	11.7	17.00	1.00
39	Eemshaven	11.7	17.42	0.50
40	Stadersand	10.8	45.33	1.50

Table S9. (continued).

N	Station Name	Range (cm)	Midpoint of Oscillation (h after 8 Jan 2005 00:00 UTC)	Duration of Oscillation (h)
41	Wangerooge–Nord	10.7	24.58	1.33
42	Cromer	10.6	12.25	1.50
43	Glueckstadt	10.5	44.58	1.33
44	Ostend	10.5	27.75	1.00
45	Wierumergronden	10.4	20.58	0.83
46	Husum	10.2	43.25	1.33
47	Aberdeen	9.9	17.25	0.50
48	Hoernum	9.8	16.50	1.17
49	Kornwerderzand buiten	9.6	16.33	1.33
50	Noordwijk meetpost	9.3	13.58	1.50
51	Brunsbuettel–Mole4	9.2	43.83	1.50
52	North Shields	9.2	9.75	1.00
53	Hoek van Holland	9.2	20.67	1.33
54	Maassluis	9.1	15.08	1.50
55	Maloy	9.0	8.33	0.33
56	Wangerooge–West	9.0	46.33	1.17
57	Vlissingen	8.9	13.75	1.50
58	Bath	8.9	19.08	1.50
59	Lowestoft	8.7	14.63	1.25
60	Immingham	8.7	22.87	1.75
61	Helgoland–Suedhafen	8.4	26.42	1.00
62	Euro platform	8.4	12.33	1.33
63	West–Terschelling	8.3	15.17	1.33
64	Vlieland haven	8.3	15.25	0.83
65	Spiekeroog	8.1	14.83	1.17
66	Westkapelle	7.7	14.08	0.83
67	LT–Alte–Weser	7.6	35.92	1.00
68	Hansweert	7.6	18.58	1.50
69	Herne Bay	7.0	9.75	1.83
70	Dagebuell	7.0	18.08	1.67
71	Zehnerloch	6.8	16.08	1.67
72	Scharhoern	6.7	25.08	1.00
73	Lauwersoog	6.5	39.58	1.17
74	Wick	6.4	17.88	1.25
75	Harlingen	6.2	17.67	0.67
76	List	6.2	14.92	1.33
77	Mittelgrund	6.2	17.67	1.50
78	Schoonhoven	6.0	37.17	1.33
79	Cuxhaven–Steubenhoeft	6.0	18.00	1.17
80	Rotterdam	5.9	21.83	1.67

Table S9 (continued).

N	Station Name	Range (cm)	Midpoint of Oscillation (h after 8 Jan 2005 00:00 UTC)	Duration of Oscillation (h)
81	Mellumplate	5.9	16.75	1.00
82	Helgoland–Binnenhafen	5.9	14.75	1.00
83	Felixstowe	5.8	16.13	1.75
84	Hamburg–St–Pauli	5.8	44.83	1.83
85	Oudeschild	5.5	37.33	1.67
86	Lichteiland Goeree	5.5	13.00	0.67
87	Havneby	5.4	23.25	0.50
88	Langeoog	5.4	24.75	0.67
89	Dover	5.4	9.75	1.50
90	Pellworm	5.2	15.92	1.67
91	Krimpen a/d IJssel	4.9	21.92	1.17
92	Bergen	4.8	11.08	0.83
93	Emshoern	4.7	12.33	1.17
94	Emden–Neue–Seeschleuse	4.6	17.75	1.33
95	Harwich	4.6	16.25	1.50
96	Knock	4.5	20.00	1.50
97	Borkum–Fischerbalje	4.5	16.83	0.50
98	WHV–Alter–Vorhafen	4.5	14.67	1.83
99	Dordrecht	4.4	9.75	1.83
100	Goidschalxoord	4.2	23.42	1.83
101	Vlaardingen	4.2	21.08	1.17
102	Bergse Diepsluis west	4.1	32.08	1.50
103	Buesum	3.5	24.33	1.50
104	Krimpen a/d Lek	3.4	14.83	1.33
105	Stavanger	3.3	23.75	1.50
106	Sheerness	3.2	14.63	1.75

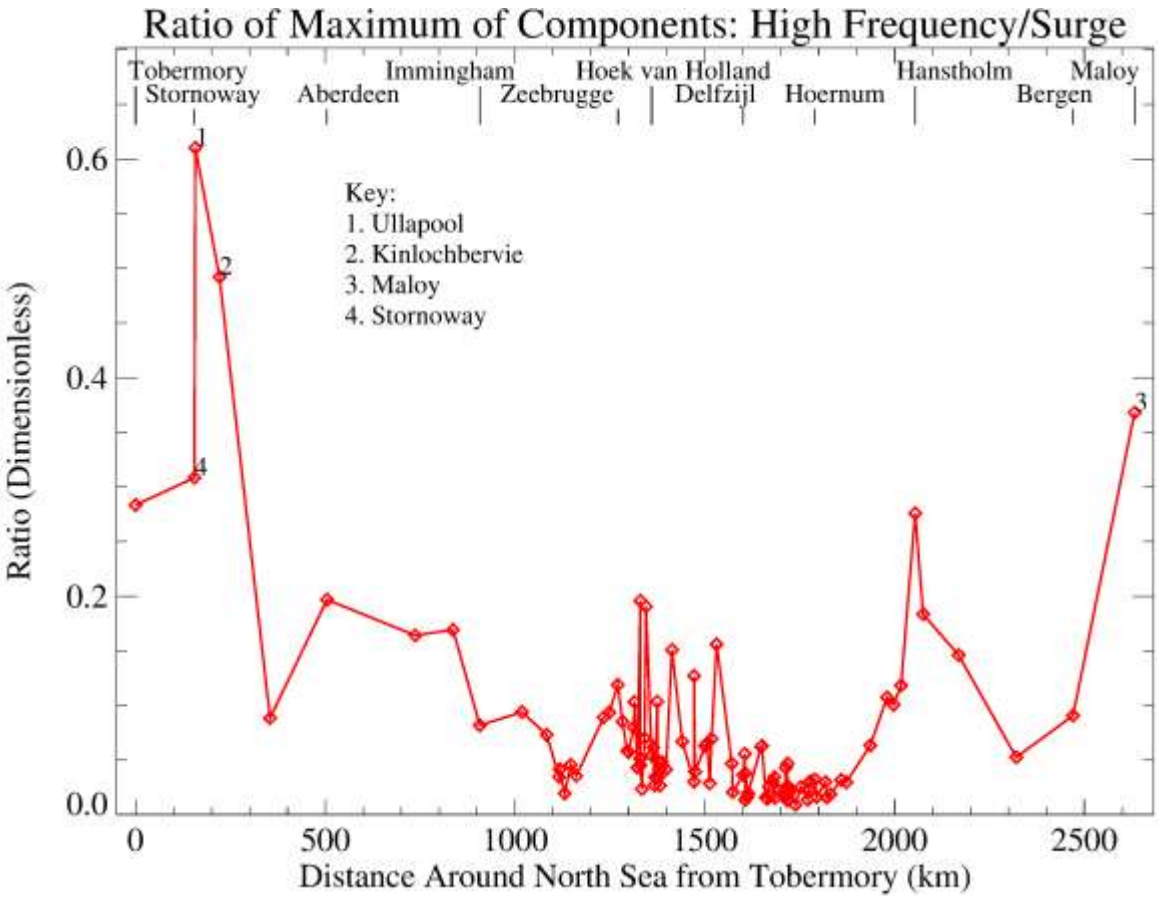

Figure S50. Ratio of maximum amplitude in the short period time series reconstruction to maximum surge residual in the interval 8–9 January 2005.

SECTION S16. TIMING OF TIDE, SURGE, AND INCIDENTS AROUND NORTH SEA COAST

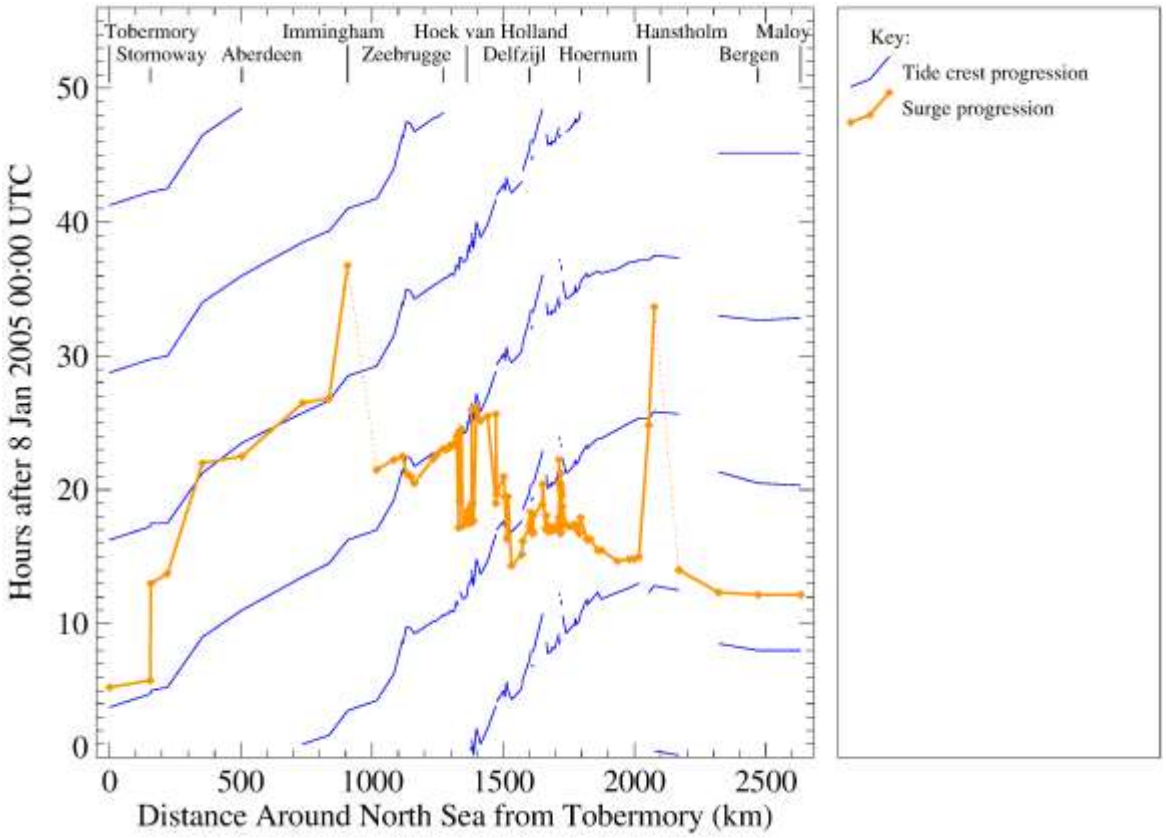

Figure S51. Summary of the progression of the tidal crests and storm surge peak around the North Sea on 8–9 January 2005. The data are plotted on axes of time versus counter-clockwise distance around the North Sea starting from Tobermory in Scotland.

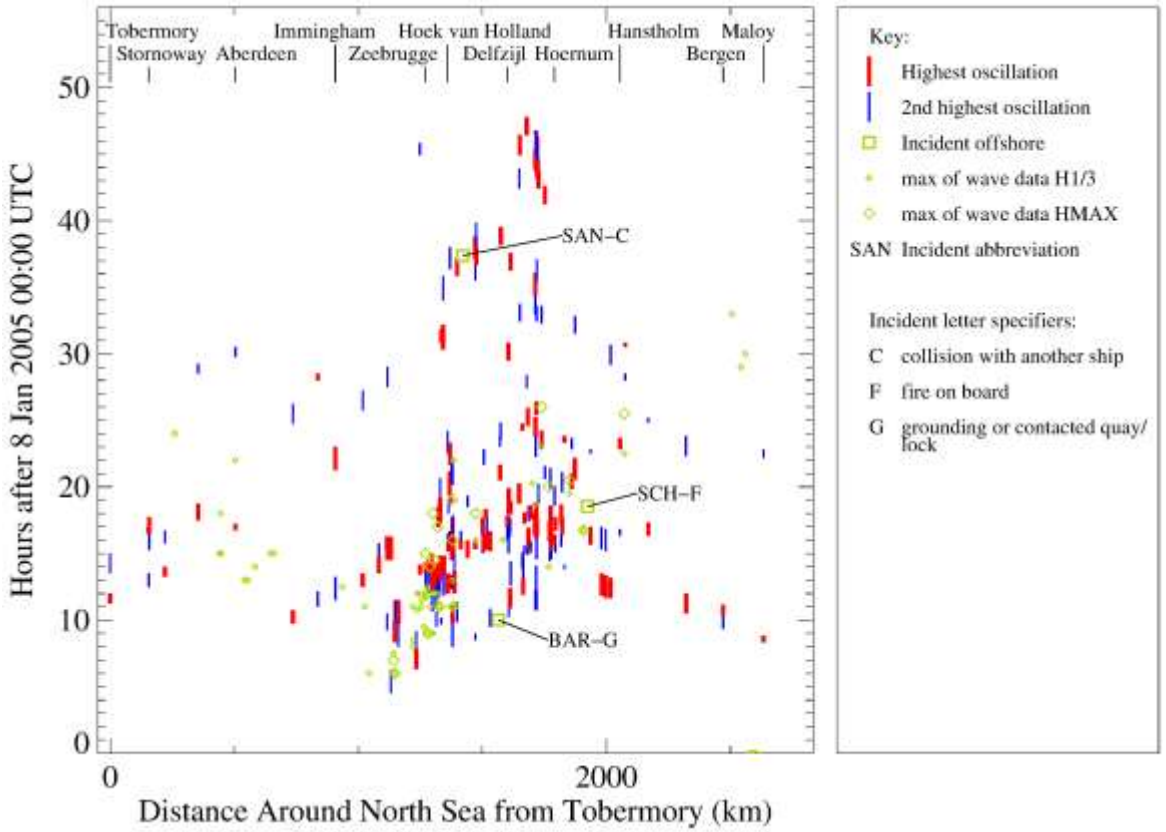

Figure S52. Summary of the spatial-temporal relationship of peak-to-trough range of the highest up-crossing short period oscillations in the tide gauge record, maritime incidents/accidents, and significant/maximum wave height across the two day storm period. The data are plotted on axes of time versus counter-clockwise distance around the North Sea starting from Tobermory in Scotland.

SECTION S17. THEMATIC TABLES OF STORM DESCRIPTION AND IMPACTS

Table S10. Master list of tables in working notes

Content
Table S11. List of sources reviewed for project (arranged by year and then alphabetically)
Table S12. List of sources that could not be obtained (arranged by year and then alphabetically)
Table S13. List of photos of event (arranged by year and then alphabetically)
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Table S11. List of sources reviewed for project (arranged by year and then alphabetically)

Source	Type[1]	Full Reference and Notes
Thompson (1980)	4	Thompson, K.R., An analysis of British monthly sea level, Geophys. J. R. astr. Soc., 63, 57-73, 1980.
Kjeldsen (1990)	4	Kjeldsen, Soren Peter: Breaking waves, in A. Torum and O.T. Gudmestad (eds.), Water Wave Kinematics, 453-473, Kluwer Academic Publishers, https://link.springer.com/chapter/10.1007/978-94-009-0531-3_29, 1990.
Elsinghorst et al (1998)	4	Elsinghorst C., P. Groeneboom, P. Jonathan, L. Smulders, P.H. Taylor, Extreme value analysis of North Sea storm severity, Journal of Offshore Mechanics and Arctic Engineering, 120, 177-183, 1998.
Alexandersson and Ivarsson (2005)	1	Alexandersson H and KI Ivarsson, Januaristormen 2005, Faktablad nr 25, SMHI, https://www.smhi.se/download/18.18f5a56618fc9f08e832d664/1717805946933/faktablad_janstorm%5B1%5D.pdf, November 2005.
Bancroft (2005)	3	Bancroft, George P., Weather Review - North Atlantic Area, January through April 2005, Mariners Weather Log, vol. 49, No. 2, Marine https://www.vos.noaa.gov/MWL/aug_05/north_atlantic.shtml, Aug 2005.
BBC (20050108)	1	BBC, Severe gales cause havoc on roads, http://news.bbc.co.uk/2/hi/uk_news/england/4157069.stm, 08January2005
BBC (20050110a)	1	BBC, Northern Europe shaken by storms, http://news.bbc.co.uk/2/hi/europe/4158809.stm, 10 January 2005a
BBC (20050110b)	1	BBC, No quick fix to flood problem, http://news.bbc.co.uk/2/hi/uk_news/wales/4159471.stm, 10Jan2005b
Belfast Telegraph (20050110a)	1	Belfast Telegraph, Ulster braced for more storms (contributor Maureen Coleman), p.1, 10Jan2005 (Monday)
Belfast Telegraph (20050110b)	1	Belfast Telegraph, More power from the pole man, p.2, 10Jan2005b (Monday)
Belfast Telegraph (20050110c)	1	Belfast Telegraph, Storms sweep northern Britain, p.6, 10Jan2005c (Monday)
Beredskapstyrelsen (2005)	1	Beredskabstyrelsen, Beredskabets indsats i forbindelse med orkanen 8. januar 2005, En tvaergaende erfaringsopsamling, Beredskabssstyrelsen, Datavej16, 3460 Birkerod, Oktober 2005
Blight (2005)	1	Blight, PJ: A discussion of the synoptic background and development of the 7-8Jan storm, https://user.eumetsat.int/resources/case-studies/rapid-cyclogenesis-in-the-north-atlantic, pdf time stamp 17/03/2005
Bradshaw et al (2005)	3	Bradshaw, E. (ed.): Annual Report for 2005 for the UK national tide gauge network and related sea level science, National Tidal and Sea level Facility, NERC 100017897, 2005
Brown (2005)	1	Brown, Paul R., The violent gale of 11-12 January 2005 in the north of Scotland, Journal of Meteorology, 30, 104-106, 2005
Cargolaw (2005)	1	Cargolaw: International Vessel Casualties & Pirates Database For Year 2005 - Jan. Through Dec. 2005 http://www.cargolaw.com/presentation_casualties.05.html (last access 21 July 2021)
CNN (20050109)	1	CNN, Weather. 13 killed as storm lashes Europe, http://edition.cnn.com/2005/WEATHER/01/09/europe.storm/, 09 Jan 2005.
Danish Energy Authority (2005)	3	Danish Energy Authority, Offshore Wind Power. Danish Experiences and Solutions. Danish Energy Authority, October, 2005.
DMI (2005)	1	DMI, Danmark ramt af landsdækkende storm, https://www.dmi.dk/nyheder/2005/danmark-ramt-af-landsdakkende-storm#:~:text=Stormen%20her%20i%20januar%202005,hen%20over%20den%20nordlige%20Nords%C3%B8. 10Jan2005
DWD (2005)	1	DWD, Orkan Erwin am 8. Januar 2005. https://www.dwd.de/DE/leistungen/besondereereignisse/stuerme/20050801_orkan_erwin.pdf?__blob=public

		ationFile&v=4, pdf timestamp: 07Feb2005
Eitrheim (2005)	1	Eitrheim, K:, Rapport etter stormen 'Gudrun' lordag 8.1.2005 for Rogaland fylke, met.no, 11 January 2005
EUMETSAT (2005)	1	EUMETSAT, Rapid cyclogenesis in the North Atlantic 6-8 January 2005, (contributors: Jochen Kerkmann and Gordon Bridge) https://www.eumetsat.int/rapid-cyclogenesis-north-atlantic published 06January2005, accessed 03Dec2022
Golmen and Stenstrom	3	Golmen, LG and P Stenstrom, Bryggen i Bergen; Vassinntrenging i fundament og bolverk; Resultat av maalinger vinter/vaaren 5005, Rapport 5047-2005, Norsk institutt for vannforskning NIVA, August, 2005.
Guardian (20050109)	1	Guardian, Thousands lose power in storms (contributor Henry McDonald), 9 January 2005.
Guardian (20050112)	1	Guardian, Storms claim at least five lives (contributor: Adam Jay), https://www.theguardian.com/environment/2005/jan/12/weather.climatechange1, 12 January 2005
Guy Carpenter (2005)	1	Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005 [ERWIN]
Hallands Nyheder (20050109)	1	Hallands Nyheder, Stormen staengde Ringhals (contributor Krister Svahn), 9 January 2005 https://www.hn.se/nyheter/varberg/stormen-stangde-ringhals.036d8cf7-2756-4206-b13c-6d03f504a264 [ERWIN]
Irish Times (20050108)	1	The Irish Times, Severe weekend weather leads to flooding (contributor James Fitzgerald), https://www.irishtimes.com/news/severe-weekend-weather-leads-to-flooding-1.404508, 8 January 2005 [ERWIN]
Irish Times (20050109)	1	The Irish Times, Seven die as storm hits southern Scandinavia, irishtimes.com/news/seven-die-as-storm-hits-southern-scandinavia-1.1295791, 9 January 2005 [ERWIN]
Irish Times (20050111)	1	The Irish Times, Man dies as storm causes power cuts and flooding (contributor Ciara O'Brien), https://www.irishtimes.com/news/man-dies-as-storm-causes-power-cuts-and-flooding-1.1295844, 11 January 2005 [GERO]
Jameson (2005)	1	Jameson D., Weather extremes 2005. January 7th-8th Severe storm development, https://user.eumetsat.int/resources/case-studies/rapid-cyclogenesis-in-the-north-atlantic, pdf timestamp: 17/03/2005 [ERWIN]
LCW (20050121)	3	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ
LCW (20050128)	3	Lloyds Casualty Week, 28Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ
LCW (20050204)	3	Lloyds Casualty Week, 04Feb2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ
Lindahl (2005)	1	Lindahl, Sture: The Storm Gudrun 2005-01-08, uploaded to Internet 19/10/2021, presentation 2005-05-12 [ERWIN]
Loginfo A/S (2005)	3	Loginfo A/S: Heidrun EMS-Data, Month report, January 2005, 19 February 2005 [ERWIN,GERO]
LKN.SH (200501)	2	LKN.SH, Sturmfluten 2005, Hydrologischer Bericht Sturmfluten Nordsee und Elbe, 6pp., Januar 2005. report emailed by Hauke Thiesen 20 June 2023. [ERWIN-GERO]
Met Eireann (200501)	3	Met Eireann, Monthly Weather Bulletin, No 225, Jan 2005
Met.no info (2005)	2	met.no info, Varsling av stormer og ekstremt vaer (contact information: KH Midtbo, M Lystad, D Kvamme), 10pp, No.18/2005, Oslo, 25 November 2005 [GUDRUN-HAAREK-INGA]
MIROS-Draugen (2005)	3	MIROS: Manedsrapport, januar 2005, Draugen - Naturdatainnsamling, ND/1022/05/01, 18 February 2005. [ERWIN,GERO]
MIROS-Ekofisk (2005)	3	MIROS, Ekofisk Monthly Report, January 2005, Doc No. ND/1024/05/01, MIROS, 29pp, 25February2005. [ERWIN,GERO]
MIROS-Heimdal (2005)	3	MIROS: Manedsapport, januar 2005, Heimdal - Naturdatainnsamling, ND/1047/05/01, 28 February 2005. [ERWIN,GERO]
MIROS-Sleipner (2005)	3	MIROS: Manedsrapport, januar 2005, Sleipner A - Naturdatainnsamling, ND/1017/05/01, 17 February 2005 [ERWIN,GERO]
MIROS-Troll (2005)	3	MIROS: Manedsrapport, januar 2005, Troll A - Naturdatainnsamling, ND/1012/05/01, 16 February 2005 [ERWIN,GERO]
NLWKN (20050111)	4	NLWKN, Experten vom NLWKN: Flache Nordsee schuetzt Niedersachsens Kueste vor einem Tsunami, https://www.nlwkn.niedersachsen.de/startseite/aktuelles/presse_und_offentlichkeitsarbeit/pressemitteilungen/-38655.html, 11 January 2005.
NLWKN (20050121)	4	NLWKN, Elfte Sturmflut bisher höchste des Winters (contributor Achim Stolz), Nds. Landesbetrieb für Wasserwirtschaft, Küsten- und Naturschutz, https://www.nlwkn.niedersachsen.de/startseite/aktuelles/presse_und_offentlichkeitsarbeit/pressemitteilungen/-38678.html, 21/01/2005 [INGO]
NRK (20050108)	1	NRK, Gudrun herjar i sor (contributor Bent J. Tandstad), 8Jan2005
Oceanor Sandnes - Norne (2005)	3	Oceanor Sandnes: Norne EMS-Data, Monthly Report January 2005, 16 February 2005.
Rosenorn (2005)	3	Rosenorn, Stig, Vintervejret 2004-2005, Vejret, 103, 23-25, 2005
RWS (2005a)	1	RWS, Stormvloedflits 2005-02. Zeer zware zuidwesterstorm veroorzaakt vrij hoge waterstanden langs de kust (contributor Jan Kroos). https://open.rijkswaterstaat.nl/open-overheid/onderzoeksrapporten/%40257045/stormvloedflitsen-wmcn-kust/, 2005a
RWS (2005b)	1	RWS, Stormvloedflits 2005-03. Stormtij en storm met orkankracht veroorzaken hoge waterstanden langs de kust (contributor Jan Kroos). https://open.rijkswaterstaat.nl/open-overheid/onderzoeksrapporten/%40257045/stormvloedflitsen-wmcn-kust/, 2005b
Verlaan et al (2005)	4	Verlaan M, A Zijderveld, H de Vries, J Kroos, Operational storm surge forecasting in the Netherlands: developments in the last decade, Phil. Trans. R. Soc. A, 363, 1441-1453, doi: 10.1098/rsta.2005.1578, 2005.
Argyriadis et al (2006)	3	Argyriadis, K., G. Fischer, P. Frohbose, D. Kindler, and F. Reher: Research platform FINO1 - Some measurement results, European Wind Energy Conference EWEC and Exhibition 2006, Athens, Greece, 27 February - 2 March 2006, Volume 2, pp. 906-915, ISBN: 978-1-62276-467-9, 2006.
Deutsche Rueck (2006)	3	Deutsche Rueck, Sturmdokumentation Deutschland 2005, (contributors: T. Axer, T. Bistry, S Fietze, M Mueller, M Prechtl), Deutsche Rueckversicherung, Aktiengesellschaft, Hansaallee 177, 40549, Duesseldorf, March, 2006.
Feix (2006)	4	Feix, O. (ed): Statistical Yearbook 2005, Secretariat of UCTE, https://eepublicdownloads.entsoe.eu/clean-

		documents/pre2015/publications/ce/Statistical_Yearbook_2005.pdf, pdf datestamp 12 October 2006.
Haanpaa et al (2006)	1	Haanpaa, Simo, Samuli Lehtonen, Lasse Peltonen, Elena Talockaite, Impacts of winter storm Gudrun of 7th-9th January 2005 and measures taken in the Baltic Sea region, Astra, www.astra-project.org, 43pp, 2006 [pdf properties: datestamp 13/06/2006]
Klee and Noren (2006)	3	Klee, I. and L Noren (ed): Annual Report 2005, Nordel Secretariat, Box 530, FI-00101 Helsinki, Finland, http://www.pfbach.dk/firma_pfb/historien/data_files/Nordel_ann_2005.pdf, pdf date stap: 3 May 2006, last access 8 October 2025
Nordel (2006)	4	Nordel: Annual Statistics 2005, https://www.entsoe.eu/news-events/former-associations/, pdf date stamp 21 June 2006
Petroleum Safety Authority (2006)	4	Petroleum Safety Authority Norway: Annual Report 2005, Stavanger, 2005 [pdf timestamp 28 April 2006]
Suursaar and Sooaar (2006)	1	Suursaar, U. and J. Sooaar, Storm surge induced by extratropical cyclone Gudrun: hydrodynamic reconstruction of the event, assessment of mitigation actions and analysis of future flood risks in Parnu, Estonia, WIT Transactions on Ecology and the Environment, vol.91, pp241-250, WIT Press, 2006.
Suursaar et al (2006)	1	Suursaar, U., T. Kullas, M. Otsmann, I. Saarmae, J. Kuik, M. Merilain, Cyclone Gudrun in January 2005 and modelling its hydrodyanamic consequences in the Estonian coastal waters, Boreal Environmental Research, 11, 143-159, 2006.
Dailey (2007)	3	Dailey, P., The 2006-2007 European winter storm season: winding down, Air Worldwide, http://www.air-worldwide.com/Publications/AIR-Currents/The-2006-2007-European-winter-storm-season, March 7, 2007 (last accessed July 9, 2014).
Dawson (2007)	1	Dawson AG, S Dawson, W Ritchie, Historical climatology and coastal change associated with the 'Great Storm' of January 2005, South Uist and Benbecula, Scottish Outer Hebrides, Scottish Geographical Journal, 123, 135-149, 2007 [GERO]
Financial Times (20070120)	3	Financial Times, Insurers play down scale of storm damage claims, (reporter: William MacNamara), 20Jan2007
Hasager et al (2007)	3	Hasager CB, P Astrup, M Nielsen, MB Christiansen, J Badger, P Nielsen, PB Soorensen, RJ Barthelmie, SC Pryor, H Bergstroom, SAT-WIND project Final Report, Riso-R-1586(EN), Riso National Laboratory, Technical University of Denmark, Roskilde, Denmark, April, 2007.
Hisscott (2007)	2	Hisscott, Alan, When NWP met climatology: storms over the Isle of Man during January 2005,'Weather, 62, 74-77, 2007
Johansson et al (2007)	1	Johansson J., S Lindahl, O. Samuelsson, H Ottoson, The storm Gudrun. A seven-week power outage in Sweden, CRIS, Third International Conference on Critical Infrastructure, Alexandria, Virginia, September, 2006. [ERWIN]
Magnusson (2007)	4	Magnusson, A.K.: Powerpoint presentation at the EXWW workmeeting 2006–2007 Hotel Admiral, Bergen, June 12–14th 2007.
Mueller-Westermeier (2007)	3	Mueller-Westermeier, Gerhard, Beschreibung un klimatologische Bewertung des Orkantiefs "Kyrill", pdf properties: Title: Deutscher Wetterdienst - Nationale Klimauberwachung, Author: Gerhard Mueller-Westermeier, Subjet: Orkan Kyrill, datestamp: 26Jan2007
Munich Re (2007)	3	Munich Re, Significant winter storms Europe 1980-2006. The 10 costliest storms listed by insured loss. MuenchenerRueck Munich Re Group, 2007 [pdf document time stamp: 26/01/2007]
Neumann (2007)	3	Neumann, T., FINO and the mast shadow effect, 52nd IEA Topical Expert Meeting, Wind and wave measurements at offshore locations, Berlin, Germany, February 2007, organized by TU Berlin and Germanischer Lloyd, International Energy Agency, Implementing Agreement for Co-operation in the Research, Development and Deployment of Wind Turbine Systems, Task 11.
Nilsson et al (2007)	3	Nilsson C, S Goyette, L Barring, Relating forest damage data to the wind field from high-resolution RCM simulations: case study of Anatol striking Sweden in December 1999, Global and Planetary Change, 57, 161-176, 2007.
Petroleum Safety Authority (2007)	4	Petroleum Safety Authority Norway: Annual Report 2006. Supervision and facts, Stavanger, 26 April 2007.
Soresen et al (2007)	3	Sorensen C, SM Ingvardsen, I Andersen, BB Kloster, KDI, Hojvandsstatistikker 2007, Extreme sea level statistics for Denmark, 2007, Kystdirektoratet, Dec, 2007.
Wolf (2007)	1	Wolf, J.: Modelling of waves and setup for the storm of 11-12 January 2005, Proudman Oceanographic Institute, report no. 181, March 2007. [GERO]
Fredsoe (2008)	3	Fredsoe, Jorgen, Report on field tests with the PEM-system at the West Coast of Jutland 2005-2008, Department of Mechanical Engineering, DTU, May 2008 [pdf properties: author: Jorgen Fredsoe; date stamp: 04Jun2008; 112pp]
Heipertz and Nickel (2008)	3	Heipertz, Martin and Christiane Nickel, Climate change brings stormy days: Case studies on the impact of extreme weather events on public finances, SSRN Electronic Journal, pp. 613-630, DOI: 10.2139/ssrn.1997256, April 2008 (In Fiscal Sustainability, Analytical Developments and Emerging Policy Issues, 3-5April2008)
Hellenberg and Kentala (2008)	1	Hellenberg, T. and J. Kentala, Chapter III. Sudden sea level rise in the Gulf of Finland in January 2005, in C. Pursiainen (ed), Early Warning and Civil Protection. When does it work and why does it fail? Nordregio report 2008:1
Horsburgh et al. (2008)	4	Horsburgh KJ, C Wilson, BJ Baptie, A Cooper, D Cresswell, RMW Musson, L Ottemoller, S Richardson, SL Sargeant, Impact of a Lisbon-type tsunami on the UK Coastline and the implications for tsunami propagation over broad continental shelves, J Geophys Res, 113, 15pp, C04007, doi:10.1029/2007JC04425, 2008.
Piontkowitz and Soerensen (2008)	3	Piontkowitz, Thorsten & Carlo Soerensen, Consequences of Climate Change along the Danish Coasts, Safecoast Action 5A, Danish Coastal Authority, Hojbovej 1, 7600 Lemvig, Denmark, kdi@kyst.dk, December 2008
Rantanen (2008)	2	Rantanen, H., Chapter IV. Coping with Power Disturbances, in C. Pursiainen (ed), Early Warning and Civil Protection. When does it work and why does it fail? Nordregio report 2008:1, p.95-119
Soomere et al (2008)	1	Soomere, T., A. Behrens, L. Toumi, J.W. Nielsen: Wave conditions in the Baltic proper and in the Gulf of Finland during windstorm Gudrun, Nat Hazards Earth Syst. Sci., 8, 37-46, 2008.

Tonisson et al. (2008)	1	Tonisson H, K Orviku, J Jaagus, U Suursaar, A Kont, R Rivis, Coastal damages on Saaremaa Island, Estonia, caused by the extreme storm and flooding on January 9, 2005, Journal of Coastal Research, 24, 602-614, 2008.
Baker (2009)	1	Baker, L., Sting jets in severe northern European wind storms, Weather, 64, 143-148, 2009
Behrens and Guenther (2009)	3	Behrens, A. and H. Guenther, Operational wave prediction of extreme storms in Northern Europe, Nat. Hazards, 49, 387-399, 2009
Emeis and Turk (2009)	2	Emeis, S. and M. Turk, Wind-driven wave heights in the German Bight, Ocean Dynamics, 59, 463-475, 2009
Magnusson (2009)	3	Magnusson, A.K.: What is true sea state? Powerpoint presentation at the 11th International Workshop on Wave Hindcasting and Forecasting and Coastal Hazard Symposium, JCOMM Halifax, Canada, 18–23 October 2009.
SMHI (2009)	3	SMHI, Per - Januaristormen 2007, 6Aug2009, https://www.smhi.se/kunskapsbanken/meteorologi/per-januaristormen-2007-1.5287
Tatge (2009)	3	Tatge, Yoern, Looking back, looking forward: Anatol, Lothar and Martin ten years later, 09Dec2009. https://www.air-worldwide.com/publications/air-currents/looking-back-looking-forward-anatol-lothar-and-martin-ten-years-later/
Tetzlaff (2009)	3	Tetzlaff, G., Extreme rain and wind storms in teh mid-latitudes I, Singapore, 21-22.04.2009. https://imsarchives.nus/edu.sg/oldwww/Programs/09fluidss/files/Gerd Tetzlaff.pdf (Spring School on Fluid Mechanics and Geophysics of Environmental Hazards, Singapore, April 19-May 2, 2009) [pdf datestamp: 14/05/2009] [GERO]
Walser and Wagner (2009)	4	Walser, M. and F. Wagner (ed.): The 50 year success story - Evolution of a European Interconnected Grid, Secretariat of UCTE, Boulevard Saint-Michel 15, B-1040 Brussels, Belgium, https://eepublicdownloads.entsoe.eu/clean-documents/pre2015/publications/ce/110422_UCPTE-UCTE_The50yearSuccessStory.pdf, 2009 last access: 6 October 2025
Averkiev and Klevannyy (2010)	3	Averkiev, A.S. and K.A. Klevannyy, A case study of the impact of cyclonic trajectories on sea-level extremes in the Gulf of Finland, Continental Shelf Research, 30, 707-714, 2010.
Bidlot (2010)	4	Bidlot, J-M, Intercomparison of operational wave forecasting systems against buoys: data from ECMWF, MetOffice, FNMOC, MSC, NCEP, MeteoFrance, DWD, BoM, SHOM, JMA, KMA, Puerto del Estado, DMI August 2010 to October 2010, 23Nov2010. https://www.oceanexpert.net/document/6353 (filename: SPA_ETWS_verification201009.pdf)
Brown et al. (2010)	3	Brown, J.M., A.J. Souza, J. Wolf: An investigation of recent decadal-scale storm events in eastern Irish Sea, J. Geophys. Res., 115, C05018, doi:10.1029/2009JC005662, 2010
Gardiner (2010)	3	Gardiner, Barry, Appendix 1: List of all Storms in Database, European Forest Institute, Atlantic European Regional Office - EFIAtlantic, 19 pp. [PDF properties: author=Barry Gardiner, datestamp=23Jul2010] https://ec.europa.eu/environment/forests/pdf/Final_Report_Appendix_1.pdf
Gardiner (2010)	3	Gardiner, Barry, Appendix 3: Background information on 11 storms selected for detailed analysis, European Forest Institute, Atlantic European Regional Office - EFIAtlantic, 161 pp. [PDF properties: datestamp 23Jul2010]
Olbert and Hartnett (2010)	4	Olbert, A.I. and M. Hartnett, Storms and surges in Irish waters, Ocean Modelling, 34, 50-62, 2010.
Gray et al. (2011)	3	Gray AL, O Martinez-Avarado, LH Baker, PA Clark, Conditional symmetric instability in sting-jet storms, QJRMS, 137, 1482-1500, 2011
Krzystyniak (2011)	3	Krzystyniak M, The relationship between extreme weather events and subsequent slide events in Norway, Master Thesis, Dept of Geosciences, University of Oslo, Sept. 2011 [ERWIN]
SMHI (20111013)	1	SMHI, Gudrun - Januaristormen 2005,, https://www.smhi.se/kunskapsbanken/meteorologi/stormar-i-sverige/enskilda-stormar-och-ovader/gudrun-januaristormen-2005-1.5300, 13 oktober 2011
Esurge_2005_erwin (2012)	1	Esurge_2005_erwin(2012), Winter storm Gudrun (2005), by Philip Harwood, 2012/11/11
Gardiner (2012)	3	Gardiner B, K Blennow, J-M Carnus, P Fleischer, F Ingemarson, G Landmann, M Lindner, M Marzano, B Nicoll, C Orazio, J-L Peyron, M-P Reviron, M-J Schelhaas, A Schuck, M Spielmann, T Usbeck, Destructive storm in European Forests: Past and Forthcoming Impacts, European Forest Institute, Atlantic European Regional Office - EFIAtlantic [pdf document properties: author=Barry Gardiner, datestamp=09Mar2012]
Sieber (2012)	3	Sieber, Jeanette, Impacts of extreme hydro-meteorological events on electricity generation and possible adaptation measures. A GIS-based approach for corporate risk management and enhanced climate mitigation concepts in Germany. Ph.D. thesis, Julius-Maximilians-Universitaet Wuerzburg - Institut fuer Geographie, Karlsruhe, November 2012
MIROS-Gullfaks (2013)	3	MIROS, Manedsrapport Gullfaks C, Januar 2005, ND/1013/05/01, 14 October 2013
AON Benfield (2013)	3	AON Benfield, Historie von 1703 bis 2012: Winterstuerme in Europa, Stand: Januar 2013
Pelt (2013)	3	Pelt, S., Kraftige storme med oprindelse i Nordatlanten, Vejret, 137, 44-47, 2013
Penna et al. (2013)	3	Penna NT, WE Featherstone, J Gazeaux, RJ Bingham, The apparent British sea slope is caused by systematic errors in the levelling-based vertical datum, Geophys. J. Int., 194, 772-786, 2013
Angus and Rennie (2014)	1	Angus, S. and A. Rennie, An Ataireachd Aird: The storm of January 2005 in the Uists, Scotland, Ocean & Coastal Management, 94, 22-29, 2014. [GERO]
Bitner-Gregersen and Magnusson (2014)	3	Bitner-Gregersen, E. and AK Magnusson, Effect of intrinsic and sampling variability on wave parameters and wave statistics, Ocean Dynamics, 64, 1643-1655, 2014
CH2MHill Halcrow (2014)	3	CH2MHill Halcrow, Cell 1 Regional Coastal Monitoring Programme, Wave Data Analysis Report 2: 2013-2014, Final Report, March 2014 [document properties: author=Andy.Parson@ch2m.com; datestamp; 04/04/2014]
Harwood (2014)	3	Harwood, Phillip, Esurge final report, 15Feb2015, copyright CGI Ltd 2014
Petroliagis and Pinson (2014)	3	Petroliagis TI and P Pinson, Early warnings of extreme winds using the ECMWF Extreme Forecast Index, Meteorological Applications, 21, 171-185, 2014.
Post and Kouts (2014)	3	Post, P. and T Kouts, Characteristics of cyclones causing extreme sea levels in the northern Baltic Sea, Oceanologia, 56, 241-258, 2014.

Roberts et al (2014)	3	Roberts JF, AJ Champion, LC Dawkins, KI Hodes, LC Shaffrey, DB Stephenson, MA Stringer, HE Thornton, DB Youngman, The XWS open access catalogue of extreme European windstorms from 1979 to 2012, Nat. Hazards Earth Syst. Sci, 14, 2487-2501, 2014
Wolski et al (2014)	3	Wolski, T., B. Wisniewski, A. Giza, H. Kowalewska-Kalkowska, H. Boman, S. Grabbi-Kaiv, T. Hammarklint, J. Holfort, Z. Lydeikaite, Extreme sea levels at selected stations on the Baltic coast, Oceanologia, 56, 259-290, 2014
Hewson and Neu (2015)	3	Hewson TD and U Neu, Cyclones, windstorms and the IMILAST project, Tellus A, 67, 27128, http://dx.doi.org/10.3402/tellusa.v67.27128, 2015
Spencer et al (2015)	4	Spencer T, SM Brooks, BR Evans, JA Tempest, I Moeller, Southern North Sea storm surge event of Dec.5, 2013: Water levels, waves, and coastal impacts, Earth Science Reviews, 146, 120-145, 2015.
Statistica (2015)	3	Statistica, The costliest winter storms ever to hit Europe. Fatalities and financial losses of Europe's 10 costliest winter storms (source Munich Re), 08Dec2015
Thejournal.ie (2015)	3	thejournal.ie, The deadliest storms to ever hit Europe, 14Dec2015 0610AM, https://www.thejournal.ie/europe-storms-2497164-Dec2015/, accessed 10Dec2020
Boettcher (2016)	3	Boettcher C., The cost of blackouts in Europe, record number 126674, 28Apr2016 https://cordis.europa.eu/article/id/126674-the-cost-of-blackouts-in-europe
DEA (2016)	3	Danish Energy Agency, Security of Electricity Supply in Denmark, 1st edition 2015, translated 2016, Danish Energy Agency, Amaliegade 44, 1256 Copenhagen K, ISBN 978-87-93180-15-4
Christensen et al (2017)	4	Christensen KH, A Carrasco, J-R Bidlot, O Breivik, The 'shallow-waterness' of the wave climate in European coastal regions, Ocean Sciences, 13, 589-597, 2017.
Expressen (20170204)	1	Expressen, Gudrun 2005: 20 doedas i den vaarsta storm, https://www.expressen.se/nyheter/inloggad/gudrun-2005-20-dodas-i-den-varsta-stormen/, published 04Feb2017 09:25
Haigh et al (2017)	3	Haigh, I.D., O. Ozsoy, M.P. Wadey, R.J. Nicholls, S.L. Gallup, T. Wahl, J.M. Brown, Data descriptor: An improved database of coastal flooding in the United Kingdom from 1915 to 2016, Scientific Data, 4: 170100, DOI: 10.1038/sdata.2017.100
Kulikov and Medvedev (2017)	3	Kulikov, E.A. and I.P. Medvedev, Extreme statistics of storm surges in the Baltic Sea, Oceanology, 57, 772-783, 2017. [ERWIN]
Pantillon et al (2017)	3	Pantillon, F., P. Knippertz, U. Corsmeier, Revisiting the synoptic-scale probability of severe European winter storms using ECMWF ensemble reforecasts, Nat. Hazards Earth Syst. Sci., 17, 1795-1810, 2017. [ERWIN-GERO]
Schold et al. (2017)	3	Schold S, S Hellstrom, C-L Ivarsson, P Kallberg, H Lindow, S. Nerheim, S Schimanke, J Sodling, L Wern, Vattenstandsdynamik langs Sveriges kust, SMHI, Oceanografi, Nr. 123, 82 pp, 2017
SurgeWatch (2017)	1	SurgeWatch, Storm Event 11th January 2005, in Haigh, I.D., O. Ozsoy, M.P. Wadey, R.J. Nicholls, S.L. Gallup, T. Wahl, J.M. Brown,Data descriptor: An improved database of coastal flooding in the United Kingdom from 1915 to 2016, Scientific Data, 4: 170100, DOI: 10.1038/sdata.2017.100, 2017 [GERO]
Cappelen (2018b)	3	Cappelen, John, Bodil og det beskidte dusin, https://www.dmi.dk/nyheder/2013/bodil-og-det-beskidte-dusin 11Dec2013, updated 2Oct2018b [ERWIN-GERO]
Clark et al. (2018)	3	Clark, PA and SL Gray, Sting jets in extratropical cyclones: a review, Quarterly Journal of the Royal Meteorological Society, 144, 943-969, 2018.
Palginomm et al (2018)	2	Palginomm V, K Orviku, U Suursaar, A Kont, H Tonnison, R Rivis, Lessons learned from record-high storm surges and associated inundations in Parnu, SW Estonia, Journal of Coastal Research, 85, 1-5, 2018.
Woodworth (2018)	4	Woodworth, PL: Sea level change in Great Britain between 1859 and the present, Geophys. J. Int., 213, 222-236, 2018.
Pellikka et al (2020)	4	Pellikka, H., TK Laurila, H Boman, A Karjalainen, J-V Bjorkqvist, KK Kahma, Meteotsunami occurrence in the Gulf of Finland over the past century, Nat. Hazards Earth Syst. Sci., 20, 2535-2546, https://doi.org/10.5194/nhess-20-2535-2020, 2020
Medvedev and Kulikov (2021)	3	Medvedev, I.P. and E.A. Kulikov, Extreme storm surges in the Gulf of Finland: Frequency-spectral properties and the influence of low-frequency sea level oscillations, Oceanology, 61, 459-468, 2021.
Lewis et al (2023)	4	Lewis C, T Smyth, D Williams, J Neuman, H Cloke, Meteotsunami in the United Kingdom: the hidden hazard, Nat Hazards Earth Syst Sci, 23, 2531-2546, 2023.
Nielsen (2023)	3	Nielsen, J.W., Stormfloden den 8. januar 2005, https://ocean.dmi.dk/case_studies/surges/2005-01-08.php, last access:21Feb2023.
Bidlot (20241215)	4	Bidlot, Jean: email with wave measurement and ECMWF model data for Jan 2005, 15Dec2024.
ESWD (20240803)	1	European Severe Weather Database, 7-9Jan2005, https://eswd.eu (last access 03Aug2024)
ClimateChangePost (20241124)	1	ClimateChangePost, Denmark Storms, https://www.climatechangepost.com/countries/denmark/storms/, last acces 24Nov2024
FMI (20241129)	3	Finnish Meteorological Institute, Sea level statistics, https://en.ilmatieteenlaitos.fi/sealevelstatistics, date stamp 29 November 2024 (last access: 19 December 2024)
Kartverket (2024)	3	Kartverket, Top 10 storm surges for Tregde, Stavanger, Bergen, Maloy, data lists emailed by Aksel Voldsund, 20 July 2024
NTSLF (2024)	3	NTSLF, Skew surge history, https://ntslf.org/storm-surges/skew-surges, https://ntslf.org/storm-surges/skew-surges/scotland, https://ntslf.org/storm-surges/skew-surges/england-east, https://ntslf.org/storm-surges/skew-surges/england-south, https://ntslf.org/storm-surges/skew-surges/england-wales, https://ntslf.org/storm-surges/skew-surges/england_west, https://ntslf.org/storm-surges/skew-surges/isle-of-man, https://ntslf.org/storm-surges/skew-surges/northern-ireland, https://ntslf.org/storm-surges/skew-surges/channel-islands, (accessed 28Dec2024)
Rantanen et al (2024)	1	Rantanen M, D van den Broek, J Corner, VA Sinclair, MM Johansson, J Sarkka, TK Laurila, and K Jylha, The impact of serial cyclone clustering on extremelyhigh sea levels in the Baltic Sea, Geophysical Research Letters, 51, e2023GL107203, https://doi.org/10.1029/2023GL107203, 2024.
Seewetter - Kiel (2024)	1	Seewetter - Kiel: Orkantief Erwin, http://www.seewetter-kiel.de/seewetter/orkan_erwin.htm, last access: 10Dec2024
SMHI (2024a)	3	SMHI, Rekord: Vattenstand, https://www.smhi.se/data/oceanografi/havsvattenstand/rekord-havsvattenstand-1.2269, updated 26 November 2024a, last access: 06 January 2025.
SMHI (2024b)	3	SMHI, Stationslista vattenstand, https://www.smhi.se/kunskapsbanken/stationslista-havsvattenstand-

		1.13981, 27Nov2024b, (last access: 8Jan2025)
Bioenergy International (2025)	1	Bioenergy International, The aftermath and legacy of Storm Gudrun - 20 years on (contributor Alan Sherrard), https://bioenergyinternational.com/the-aftermath-and-legacy-of-storm-gudrun-20-years-on/, 11 January 2025.
ENTSOE (2025)	4	ENTSOE, https://www.entsoe.eu/news-events/former-associations/, last access 12 October 2025/
ISC (2025)	4	International Seismic Centre, ISC Bulletin, https://www.isc.ac.uk/, last access 10Aug2025.
Lorenz et al (2025)	3	Lorenz M, K Viigand, U Grawe, Untangling the waves: decomposing extreme sea levels in a non-tidal basin, the Baltic Sea, Nat. Hazards Earth Syst. Sci., 25, 1439-1458, 2025.
Myhr (2025)	1	Myhr, K.J.: Storm puts focus on security, https://history.vattenfall.com/stories/power-to-the-people/storm-puts-focus-on-security/, last access: 24Jan2025.
NNRCMP (2025)	4	NNRCMP, Welcome, National Network of Regional Coastal Monitoring Programmes, https://coastalmonitoring.org/, last access: 2 January 2025
OPW (2025)	3	OPW, Hydrometric, https://waterlevel.ie/hydro-data/#/overview/Waterlevel/station/, Office of Public Works, last access: 11/02/2025.
SMHI (2025)	3	SMHI, Högvattenhändelser idag och i framtiden, https://www.smhi.se/klimat/stigande-havsnivaer/hogvattenhandelser-idag-och-i-framtiden, last access: 10Jan2025
Wikipedia (20250124)	3	Wikipedia, Floods in Saint Petersburg, https://en.wikipedia.org/wiki/Floods_in_Saint_Petersburg, 24Jan2025
Wikipedia (20250429)	1	Wikipedia, Ekstremveret Gudrun, https://nn.wikipedia.org/wiki/Ekstremv%C3%AAret_Gudrun, last access: 29Apr2025

Notes:
[1] Type: 1=storm is main focus (or used as key example in general discussion); 2=1-4 case studies including the storm; 3=the storm is one of many case studies or mentioned only; 4=storm not mentioned; reference is included for background information

Table S12. List of sources that could not be obtained (arranged by year and then alphabetically)

Source	Full Reference and Notes
Anderson (2005)	Anderson, P, 2005,Da stormen tog stod mollene af [When the stormincreased the turbines switched off], Eltra magasinet, 1, February.
Anderson (2006)	Anderson, P. (2006), When the storm increased the turbines switched off, EnergiNet.dk, http://www.elvest.energinet.dk/media(16383.1033)/Da_stormen_tog_til_GB.pdf
Longseth (2006)	Lonseth, L, Ekofisk Reference Data Set 1980-2005, Fugro Oceanor Report No C55060/4026/R2, 2006.

Table S13. List of normal photos of event (arranged by year and then alphabetically)

Source	Full Reference and Notes
Alexandersson and Ivarsson (2005)	Alexandersson H and KI Ivarsson, Januaristormen 2005, Faktablad nr 25, SMHI, https://www.smhi.se/download/18.18f5a56618fc9f08e832d664/1717805946933/faktablad_janstorm%5B1%5D.pdf, November 2005. -FIG11. [PHOTO] Photos of forest damage outhern Sweden -FIG14. [PHOTO] photos of forest damage in southern Sweden
BBC (20050110a)	BBC, Northern Europe shaken by storms, http://news.bbc.co.uk/2/hi/europe/4158809.stm, 10 January 2005a -FIG. [PHOTO] Trees were uprooted with fatal consequences in some countries
BBC (20050110b)	BBC, No quick fix to flood problem, http://news.bbc.co.uk/2/hi/uk_news/wales/4159471.stm, 10Jan2005b -FIG. [PHOTO] Many roads closed or had speed restrictions -FIG. [PHOTO] Flooding in the Conwy Valley on Sunday (9Jan2005)
DMI (2005)	DMI, Danmark ramt af landsdækkende storm, https://www.dmi.dk/nyheder/2005/danmark-ramt-af-landsdakkende-storm#:~:text=Stormen%20her%20i%20januar%202005,hen%20over%20den%20nordlige%20Nords%C3%B8. 10Jan2005 -FIG. [PHOTO] Whole country marked by storm in form of toppled trees, toppled power lines, lost roof tiles, storm-damaged buildings. Short distance NW of Silkeborg, this house received serious damage that it can not be saved. Nothing was damaged in the house [Jesper Gronne]
DWD (2005)	DWD, Orkan Erwin am 8. Januar 2005. https://www.dwd.de/DE/leistungen/besondereereignisse/stuerme/20050801_orkan_erwin.pdf?__blob=publicationFile&v=4, pdf timestamp: 07Feb2005 FIG1. [PHOTO] Impacts of Hurricane Erwin (a) Hexham in UK, (b) Esbjerg Hafen in Denmark [source Spiegel Online]
Golmen and Stenstrom (2005)	Golmen, LG and P Stenstrom, Bryggen i Bergen; Vassinntrenging i fundament og bolverk; Resultat av maalinger vinter/vaaren 5005, Rapport 5047-2005, Norsk institutt for vannforskning NIVA, August, 2005. -FIG2. [PHOTO] Bryggen during record spring tide 27Feb1990 and 12Jan2005 [Norges Sjokartverk/BT] -FIG3. [PHOTO] From fish store during spring tide 12Jan2005. -FIG10. [PHOTO] Photo from drapefallet on north side of Bredgaarden during spring tide 12Jan2005
Guardian (20050112)	Guardian, Storms claim at least five lives (contributor: Adam Jay), https://www.theguardian.com/environment/2005/jan/12/weather.climatechange1, 12 January 2005 FIG. [PHOTO] A lorry lies beneath the Foyle Bridge, Derry, after being blown off by gale-force winds [Paul Faith]
Guy Carpenter (2005)	Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005 -FIG9. [MAP] Carlisle in northwest England was hit by the worst floods in 100 years -FIG10-12.[PHOTO] Scenes in Carlisle after the flood waters started to subside -FIG14. [PHOTO] Example of forest damage in Smaaland, southern Sweden (source: Smaalandsposten) -FIG15. [PHOTO] Storm damage to a residential building in Vaxjo, southern Sweden (source: Smaalandsposten)
Lindahl (2005)	Lindahl, Sture: The Storm Gudrun 2005-01-08, uploaded to Internet 19/10/2021, presentation 2005-05-12 -FIG. [PHOTO] Photo of trees fallen onto houses -FIG. [PHOTO] Photo of trees fallen on road

	-FIG. [PHOTO] Photo of forest damage -FIG. [PHOTO] Photo of windfall over large tracts of forest -FIG. [PHOTO] Trees across power lines with caption: Severe damage to the 0.4kV and 10kV network. Half of the network in Smaaland was damaged -FIG. [PHOTO] Fallen mast with caption: significant damage on the 40kV and 50kV network. -FIG. [PHOTO] Electrical insulator with branches of fallen tree -FIG. [PHOTO] Tree fallen on house -FIG. [PHOTO] Tree fallen on house -FIG. [PHOTO] workers repair fallen lines in forest
NRK (20050108)	NRK, Gudrun herjar i sor (contributor Bent J. Tandstad), 8Jan2005 -FIG. [PHOTO] car has problem in water at Hvaler in Ostfold
Haanpaa et al (2006)	Haanpaa, Simo, Samuli Lehtonen, Lasse Peltonen, Elena Talockaite, Impacts of winter storm Gudrun of 7th-9th January 2005 and measures taken in the Baltic Sea region, Astra, www.astra-project.org, 43pp, 2006 [pdf properties: datestamp 13/06/2006] -FIG0. [PHOTO] Flooded square in large city (Helsinki?) FIG3. [PHOTO] storm damages on Estonian coast (photo: Sten Suuroja) FIG4. [PHOTO] People gathered to observed the rising sea level (photo: Kaisa Schmidt-Thorne) FIG5. [PHOTO] Forest damages were extensive in Sweden (photo: SMHI 2005) FIG8. [PHOTO] Eroded foredunes at Lemmeoja, Estonia (Photo: Sten Suuroja) FIG9. [PHOTO] Flooding in Parnu Estonia (Photo: Sten Suuroja) -FIG12. [PHOTO] Flooding streets in Helsinki (Samuli Lehtonen)
Dawson et al (2007)	Dawson AG, S Dawson, W Ritchie, Historical climatology and coastal change associated with the 'Great Storm' of January 2005, South Uist and Benbecula, Scottish Outer Hebrides, Scottish Geographical Journal, 123, 135-149, 2007 -FIG3. [PHOTO] Shingle ridge deposited during the Jan2005 storm at Pollochar, South Uist. The ridge lies 2-3 m above the highest astronomical tide. In fossil form, such ridges could be misinterpreted as evidence for sea level having been higher durig the Holocene -FIG5. [PHOTO] Tabular gneiss block rived from bedrock during 11Jan2005 storm near Stoneybridge. Note lichen cover of adjacent areas of bedrock showing that this area of rock surface lies above the reach of normal wave action.
Hisscott (2007)	Hisscott, Alan, When NWP met climatology: storms over the Isle of Man during January 2005,'Weather, 62, 74-77, 2007 -FIG5. [PHOTO] A large area of damage to the upper Tholt-y-Will plantation (as shown in FIG4) -FIG6. [PHOTO] An area of damage to the lower Tholt-y-Will plantation (shown as B in FIG4)
Piontkowitz and Soerensen (2008)	Piontkowitz, Thorsten & Carlo Soerensen, Consequences of Climate Change along the Danish Coasts, Safecoast Action 5A, Danish Coastal Authority, Hojbovej 1, 7600 Lemvig, Denmark, kdi@kyst.dk, December 2008 -FIG4.28. [PHOTO] Seaward dune top at Sondervig before and after the storm surge on 8-9Jan2005
Tonisson et al (2008)	Tonisson H, K Orviku, J Jaagus, U Suursaar, A Kont, R Rivis, Coastal damages on Saaremaa Island, Estonia, caused by the extreme storm and flooding on January 9, 2005, Journal of Coastal Research, 24, 602-614, 2008. -FIG5. [PHOTO] The leaning Kiipsaare lighthouse is in the sea near the mean shoreline today FIG6. [PHOTO] Cape Sorve before (July2004) and after (Jan2005) the storm FIG8. [PHOTO] Substantial recession of the sandy scarp at the Jarve study site after the storm FIG14. [PHOTO] Sandy scarp in Kiipsaare before and after the storm FIG15. [PHOTO] The sand from the beach has been transported up to 50m inland from the edge of the dunes by the swash
SMHI (20111013)	SMHI, Gudrun - Januaristormen 2005,, https://www.smhi.se/kunskapsbanken/meteorologi/stormar-i-sverige/enskilda-stormar-och-ovader/gudrun-januaristormen-2005-1.5300, 13 oktober 2011 -FIG3. [PHOTO] a week after the storm most routes were cleared as her at Navjokulla, Vastra Torsas Smaaland 17Jan2005
Pelt (2013)	Pelt, S., Kraftige storme med oprindelse i Nordatlanten, Vejret, 137, 44-47, 2013 FIG4. [PHOTO] Extensive forest falls in Skane after the powerful storm Gudrun 8Jan2005
Angus and Rennie (2014)	Angus, S. and A. Rennie, An Ataireachd Aird: The storm of January 2005 in the Uists, Scotland, Ocean & Coastal Management, 94, 22-29, 2014. FIG3. [PHOTO] Aerial image of the shingle overwash extending 20-30m inland of the road at Stoneybridge FIG4. [PHOTO] Gualan showing breaches in centre [photograph by Johanne Ferguson 17.2.2005] FIG5. [PHOTO] Fence ripped from ground by wave action and Teanna Mhachair, Baile Sear. Note vegetation on fence 08.02.2005 [photograph by Stewart Angus] FIG6. [PHOTO] Ministry of Defence building Vadette 1 in July 2002 and same building on 7 February 2005. Note loss of machair to seaward [photograph by Stewart Angus] FIG7. [PHOTO] Seasonal lochs jusst inland of the dune ridge on machair west of west Loch Ollay, South Uist. Note the two sandy areas on the right of the picture: these may represent breaches in the dunes where sea water gained access to the machair. [photograph Stwart Angus 17/02.2005]
Expressen (20170204)	Expressen, Gudrun 2005: 20 doedas i den vaarsta storm, https://www.expressen.se/nyheter/inloggad/gudrun-2005-20-dodas-i-den-varsta-stormen/, published 04Feb2017 09:25 -FIG. [PHOTO] when storm reached Sweden there were hurricane winds that caused destruction [credit: Niklas Larsson/Bildbyraan] NOTE: tree fallen across a car -FIG [PHOTO] Sven Agren from Klippan was sitting in car backing onto a road when a birch tree fell on his car roof. If I had been sitting 20cm behind I would not have survived [PHOTO: Magnus Torle] -FIG. [PHOTO] on picture taken from flying plane? one recieves a idea of the almost incomprehensible damage that Grudrun caused in the forest. Value of more than 23 bill SEK Impacted area equivalent to 275000 football fields

	-FIG. [PHOTO] Carl XVI Gustaf travelled to impacted area for perception of destruction [credit: Niklas Larsson/Bildryan] -FIG. [PHOTO] Sixten Svensson became front figure for rebellion against electricity companies [credit: OKAND] -FIG. [PHOTO] Wind strength at more than 40m/s pushed water levels up and caused flooding, including at Feskakorka in Goteborg [credit: Leif Jacobsson] -FIG. [PHOTO] trees fell like skittles in many places when Gudrun passed. Roads were blocked and power lines blown down, trains stood still, and many forest owners hit by economic catastrophe [credit: Lennart Rehnman]
Palginomm et al (2018)	Palginomm V, K Orviku, U Suursaar, A Kont, H Tonnison, R Rivis, Lessons learned from record-high storm surges and associated inundations in Parnu, SW Estonia, Journal of Coastal Research, 85, 1-5, 2018. FIG2. [PHOTO] Inundation of Parnu City on 9Jan2005 [credit J. Ramez]
Seewetter - Kiel (2024)	Seewetter - Kiel: Orkantief Erwin, http://www.seewetter-kiel.de/seewetter/orkan_erwin.htm, last access: 10Dec2024 -FIG3. [PHOTO] Series of photos of Kiel Fjord during storm Erwin 8Jan2005, including ferry
Bioenergy International (2025)	Bioenergy International, The aftermath and legacy of Storm Gudrun - 20 years on (contributor Alan Sherrard), https://bioenergyinternational.com/the-aftermath-and-legacy-of-storm-gudrun-20-years-on/, 11 January 2025. -FIG1. [PHOTO] Storm Gudrun which hit S Sweden on 8-9Jan2005 felled for forest in Sweden than any other known storm [Sodra] -FIG2. [MAP] Damaged forest after stom Gudrun in m3 per hectare (Swedeish Forest Agency) with Sveakog's forest estates marked [Sveakog] -FIG3. [PHOTO] High stumps left from tree stems that snapped during storm Gudrun [E.ON] -FIG4. [PHOTO] January 2005, a cleared road in Kronoberg County after Storm Gudrun [Bengt Henriksson, Swedish Forest Agency] -FIG5. [PHOTO] Transport of Sveaskog's harvesters, forwarders, and service trailers from Bergslagen to the storm-stricken areas in Gotland, 16Jan2005 [Sveaskog] -FIG6. [PHOTO] manual salvage logging in a storm-felled forest is a hard and hazardous job for forest owners and contractors alike [Sveakog] -FIG7. [PHOTO] View of the forest around Stockaryd, Jul2005. The clearing work after storm Gudrun has resulted in a visual tree shaped in the landscape. The photo was awarded picture of the year in 2006 [Joakim Berglund/Expressen] -FIG8. [PHOTO] Storage areas for storm Gudrun timber in Knislinge, Skaane [Staffan Andresson/IBL] -FIG9. [PHOTO] At its peak, Byholma stored around 1 million m3 of wood, corresponding to 4 million logs making it one of the world's larges log storage facilities and inadvertently, a major tourist destination [Ola Nilsson/Sydsenskan/IBL] FIG10. [PHOTO] 05Feb2005 salvage logging at a site in Kronoberg County after storm Gudrun [Bengt Henriksson/Swedish Forest Agency] FIG11. [PHOTO] 2005: Felled trees at one of the entrances to Sodra's Toftaholm property [Sodra] FIG12. [PHOTO] 2025: Regrown forest at same entrance to Toftaholm [Sodra] FIG13. [PHOTO] Many roads were impassable after storm Gudrun, which meant it took longer to reach downed power lines [E.ON] FIG14. [PHOTO] The electricity grid was built up piece by piece after 8Jan 2005 to secure future electricity grids for storms and severe weather events [E.ON] FIG15. [PHOTO] View of the forest in Vartorp, 20y after storm Gudrun [Sveaskog]
Myhr (2025)	Myhr, K.J.: Storm puts focus on security, https://history.vattenfall.com/stories/power-to-the-people/storm-puts-focus-on-security/, last access: 24Jan2025. -FIG1. [PHOTO] storm Gudrun. Aerial photo over Dunevallen/Trollhatten, the day after clearing up the effects from the storm Gudrun [credit: Joachim Nywall] -FIG2. [PHOTO] The storm Gudrun. Havoc in the woods after the storm Gudrun 2005 [credit: Joachim Nywall] -FIG3. [PHOTO] Gudrun forest damage Sweden 2005 -FIG4. [PHOTO] The storm Gudrun. Service technicians soing work after the storm Gudrun at Trollhatten [credit: Joachim Nywall] -FIG5. [PHOTO] Onshore cable ducts at Stor-Rotiden wind farm 2010. The highest point of the area is about 570m above sea level and the terrain consists of low-growing northern Swedish forest. [credit: Anna-Karin Drugge]

Table S14. Ranking of storm among events; assessing importance of storm (arranged by year and then alphabetically)

Source	Full Reference and Notes
Alexandersson and Ivarsson (2005)	Alexandersson H and KI Ivarsson, Januaristormen 2005, Faktablad nr 25, SMHI, https://www.smhi.se/download/18.18f5a56618fc9f08e832d664/1717805946933/faktablad_janstorm%5B1%5D.pdf, November 2005. -highest ever tree fall in post-1900 Sweden history -Sweden tree fall about same as all other 20C storms combined -record flood level Carlisle with water levels 1m higher than previous record -record water level Ringhals on Hallands coast in time series back to 1887
BBC (20050110a)	BBC, Northern Europe shaken by storms, http://news.bbc.co.uk/2/hi/europe/4158809.stm, 10 January 2005a -worst storm to hit Baltic states in 40 years
BBC (20050110b)	BBC, No quick fix to flood problem, http://news.bbc.co.uk/2/hi/uk_news/wales/4159471.stm, 10Jan2005b -ERWIN; Conwy valley flooding -Phil Jones (EA, Wales): 2 of biggest floods in living memory happened within 11 months -floods might not recur for 50y; extreme events rare
Beredskabstyrelsen (2005)	Beredskabstyrelsen, Beredskabets indsats i forbindelse med orkanen 8. januar 2005, En tvaergaende erfaringsopsamling, Beredskabssstyrelsen, Datavej16, 3460 Birkerod, Oktober 2005 -Erwin ranks at one of top 10 storms Denmark over last 100y

	-Logstor had highest water level ever at 2.26m over normal -Gudrun: Sweden worst storm in 80 years -Gudrun caused worst-in-history damage to regional and local electricity network
Blight (2005)	Blight, PJ: A discussion of the synoptic background and development of the 7-8Jan storm, https://user.eumetsat.int/resources/case-studies/rapid-cyclogenesis-in-the-north-atlantic, pdf time stamp 17/03/2005 -Erwin: strongest winds inthe UK for several years
CNN (20050109)	CNN, Weather. 13 killed as storm lashes Europe, http://edition.cnn.com/2005/WEATHER/01/09/europe.storm/, 09 Jan 2005. -Logstor Denmark: highest water ever in harbour (2.5m) 100s people evacuated
DMI (2005)	DMI, Danmark ramt af landsdækkende storm, https://www.dmi.dk/nyheder/2005/danmark-ramt-af-landsdakkende-storm#:~:text=Stormen%20her%20i%20januar%202005,hen%20over%20den%20nordlige%20Nords%C3%B8. 10Jan2005 -DMI issued 5 warnings at same time; never happened previously -storm Jan2005 belongs among top-10 -Logstor: highest ever water levels; 2.26m over daily levels
DWD (2005)	DWD, Orkan Erwin am 8. Januar 2005. https://www.dwd.de/DE/leistungen/besondereereignisse/stuerme/20050801_orkan_erwin.pdf?__blob=publicationFile&v=4, pdf timestamp: 07Feb2005 -gusts at List/Sylt assessed at 20y return period level
Eitrheim (2005)	Eitrheim, K:, Rapport etter stormen 'Gudrun' lordag 8.1.2005 for Rogaland fylke, met.no, 11 January 2005 -previous worst storm with comparable winds in Norway Nov1981
Golmen and Stenstrom (2005)	Golmen, LG and P Stenstrom, Bryggen i Bergen; Vassinntrenging i fundament og bolverk; Resultat av maalinger vinter/vaaren 5005, Rapport 5047-2005, Norsk institutt for vannforskning NIVA, August, 2005. -GERO water levels just few cm below all time maximum on 27Feb1990 (VIVIAN)
Guardian (20050112)	Guardian, Storms claim at least five lives (contributor: Adam Jay), https://www.theguardian.com/environment/2005/jan/12/weather.climatechange1, 12 January 2005 -Duncan Mackay of Stornaway CG: worst he has experienced in several years
Guy Carpenter (2005)	Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005 -ERWIN/GUDRUN: -England: Carlisle in Cumbria hit by worse floods in 100years -EA: Carlisle floods worst for over 100y; last major flood 1968 with water levels ~1m lower -Sweden: most serious storm in 35 years (wind speed) -Sweden: record number of trees fallen -Denmark: Erwin not as severe as Anatol in 1999 -DMI: Erwin ranks with 10 largest storms ever experienced
Hallands Nyheder (20050109)	Hallands Nyheder, Stormen staengde Ringhals (contributor Krister Svahn), 9 January 2005 https://www.hn.se/nyheter/varberg/stormen-stangde-ringhals.036d8cf7-2756-4206-b13c-6d03f504a264 -Gudrun was first time storm winds forced Ringhals to such an extensive stop
LCW (20050121)	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -ERWIN: Cumbria worst weather in almost 40 years -ERWIN: meteorologists described storm as one of worst to hit Scandinavia in years -ERWIN: early 9Jan water level Helsinki 151cm above avg; previous Helsinki record 136cm -ERWIN: meteorologists say storm was worst to hit Baltic states in 40 years
LCW (20050128)	Lloyds Casualty Week, 28Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -ERWIN: damage to the power line network in Sweden was unprecedented
LCW (20050204)	Lloyds Casualty Week, 04Feb2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -Erwin/Gero was worst insurance storm in the UK since Oct 2000
Lindahl (2005)	Lindahl, Sture: The Storm Gudrun 2005-01-08, uploaded to Internet 19/10/2021, presentation 2005-05-12 -longest ever power outages in Sweden
Met Eireann (200501)	Met Eireann, Monthly Weather Bulletin, No 225, Jan 2005 -Storm Erwin & Gero had maximum 10 min avg wind speed and gust of month -highest daily total rainfall for most stations in Ireland on 7Jan2005 -Malin Head had lowest pressure of month on 8Jan
Met.no info (2005)	met.no info, Varsling av stormer og ekstremt vaer (contact information: KH Midtbo, M Lystad, D Kvamme), 10pp, No.18/2005, Oslo, 25 November 2005 -the most damage was caused by Inga
Rosenorn (2005)	Rosenorn, Stig, Vintervejret 2004-2005, Vejret, 103, 23-25, 2005 -Erwin/Gudrun was worst storm of winter for Denmark
Argyriadis et al (2006)	Argyriadis, K., G. Fischer, P. Frohbose, D. Kindler, and F. Reher: Research platform FINO1 - Some measurement results, European Wind Energy Conference EWEC and Exhibition 2006, Athens, Greece, 27 February - 2 March 2006, Volume 2, pp. 906-915, ISBN: 978-1-62276-467-9, 2006. -worst storm at FINO1 in the 2003-2005 period
Deutsche Rueck (2006)	Deutsche Rueck, Sturmdokumentation Deutschland 2005, (contributors: T. Axer, T. Bistry, S Fietze, M Mueller, M Prechtl), Deutsche Rueckversicherung, Aktiengesellschaft, Hansaallee 177, 40549, Duesseldorf, March, 2006. -ERWIN -return period of extreme winds Sweden assessed at 40y return period
Haanpaa et al (2006)	Haanpaa, Simo, Samuli Lehtonen, Lasse Peltonen, Elena Talockaite, Impacts of winter storm Gudrun of 7th-9th January 2005 and measures taken in the Baltic Sea region, Astra, www.astra-project.org, 43pp, 2006 [pdf properties: datestamp 13/06/2006] -Gudrun given by Norwegian Meteorological Institute (AKA Erwin) -storm worst since 1969 based on area and damage -impact of Gudrun did not reach level Lothar/Martin 1999 or Jeanett 2002 -Lothar/Martin 1999 still most expensive storms ever recorded with 125 fatalities; 4 mill impacted -EEA (2003): storms like Lothar/Martin 1999 have a return period of only 10y

	-storms with insurance loss >1 bill EUR (e.g. Jeanett 2002) occur every 2-3 years -FOREST LOSS one most significant environmental impacts of Gudrun -FOREST LOSS Sweden: record damage for over 30y -WATER LEVEL: Tallinn had record water level 152cm 6h before max height Helsinki (Suursaar et al 2006)
Suursaar and Sooaar (2006)	Suursaar, U. and J. Sooaar, Storm surge induced by extratropical cyclone Gudrun: hydrodynamic reconstruction of the event, assessment of mitigation actions and analysis of future flood risks in Parnu, Estonia, WIT Transactions on Ecology and the Environment, vol.91, pp241-250, WIT Press, 2006. -Gudrun resulted in new highest storm surge Parnu (275cm) -losses reached 0.7% Estona GDP -most influential natural disaster in Estonia for century
Suursaar et al (2006)	Suursaar, U., T. Kullas, M. Otsmann, I. Saarmae, J. Kuik, M. Merilain, Cyclone Gudrun in January 2005 and modelling its hydrodyanamic consequences in the Estonian coastal waters, Boreal Environmental Research, 11, 143-159, 2006. -SMHI Gudrun most serious storm of 35y; costs 2X higher than Anatol 1999 -DMI: Gudrun among top 10 storms; not as serious as Anatol 3-4Dec1999 -Estonia: Gudrun same rank as 23Jan1995 storm; close to storms 6-7Aug1967 & 18Oct1967 (hurr strength) -Gudrun had highest impact for Estonia; among 5 strongest; new sea level record -Estonia: Gudrun worst for property damage from wind and flooding
Dailey (2007)	Dailey, P., The 2006-2007 European winter storm season: winding down, Air Worldwide, http://www.air-worldwide.com/Publications/AIR-Currents/The-2006-2007-European-winter-storm-season, March 7, 2007 (last accessed July 9, 2014). -storm Per in Jan 2007 was worst storm for Sweden since storm Erwin 2005
Dawson et al (2007)	Dawson AG, S Dawson, W Ritchie, Historical climatology and coastal change associated with the 'Great Storm' of January 2005, South Uist and Benbecula, Scottish Outer Hebrides, Scottish Geographical Journal, 123, 135-149, 2007 -GERO worst storm in living memory -Benbecula: no storm of comparable magnitude has taken place in this area for 150y
Financial Times (20070120)	Financial Times, Insurers play down scale of storm damage claims, (reporter: William MacNamara), 20Jan2007 -for Storm Kyrill 18Jan2007: insurers say impossible to estimate scale of storm damage; 12 killed UK, 27 across Europe -Royal and Sun Alliance: not as bad as 1987 or 1990 (2bill GBP at time) -Royal and Sum Alliance: closest equivalent Carlisle storm of 2005; 250 mill GBP
Hisscott (2007)	Hisscott, Alan, When NWP met climatology: storms over the Isle of Man during January 2005,'Weather, 62, 74-77, 2007 -Storm Erwin had highest storm gust since winter storm in winter 1998-9 -maximum gust for Anatol in Dec1999 was comparable but lower -Storm GERO: one of most intense depressions to affect W coast Scotland for many years
Mueller-Westermeier (2007)	Mueller-Westermeier, Gerhard, Beschreibung un klimatologische Bewertung des Orkantiefs "Kyrill", pdf properties: Title: Deutscher Wetterdienst - Nationale Klimauberwachung, Author: Gerhard Mueller-Westermeier, Subjet: Orkan Kyrill, datestamp: 26Jan2007 -storm Erwin highest wind gust at Brocken rank 14 of 26 storms from 1990-2007
Munich Re (2007)	Munich Re, Significant winter storms Europe 1980-2006. The 10 costliest storms listed by insured loss. MuenchenerRueck Munich Re Group, 2007 [pdf document time stamp: 26/01/2007] -Storm Erwin 2005 rank 7/10 insurance loss for European winter storms in period 1980-2006
Neumann (2007)	Neumann, T., FINO and the mast shadow effect, 52nd IEA Topical Expert Meeting, Wind and wave measurements at offshore locations, Berlin, Germany, February 2007, organized by TU Berlin and Germanischer Lloyd, International Energy Agency, Implementing Agreement for Co-operation in the Research, Development and Deployment of Wind Turbine Systems, Task 11. -Storm Erwin 08/01/2005 was 2nd ranked storm at FINO1 in 3y period 2004-2006 after storm on 31/12/2006; Britta may have been rank 3
Nilsson et al (2007)	Nilsson C, S Goyette, L Barring, Relating forest damage data to the wind field from high-resolution RCM simulations: case study of Anatol striking Sweden in December 1999, Global and Planetary Change, 57, 161-176, 2007. Gudrun 2005 had a similar magnitude as Anatol 1999 but passed on a more northerly path over largely forested regions, causing devastating forest damage
Behrens and Guenther (2009)	Behrens, A. and H. Guenther, Operational wave prediction of extreme storms in Northern Europe, Nat. Hazards, 49, 387-399, 2009 -Erwin in list of top 10 storms in North Sea/Baltic Sea area in period 1999-2008
Heipertz and Nickel (2008)	Heipertz, Martin and Christiane Nickel, Climate change brings stormy days: Case studies on the impact of extreme weather events on public finances, SSRN Electronic Journal, pp. 613-630, DOI: 10.2139/ssrn.1997256, April 2008 (In Fiscal Sustainability, Analytical Developments and Emerging Policy Issues, 3-5April2008) -EU Solidarity Fund Estonia (report damage 48 mill EUR or 0.43% GDP), Latvia (193 mill EUR or 1.48% GDP), Sweden (2297 mill EUR or 0.80% GDP)
Piontkowitz and Soerensen (2008)	Piontkowitz, Thorsten & Carlo Soerensen, Consequences of Climate Change along the Danish Coasts, Safecoast Action 5A, Danish Coastal Authority, Hojbovej 1, 7600 Lemvig, Denmark, kdi@kyst.dk, December 2008 -storm ERWIN 2005 -Houvig site near Hvide Sand & Nymindegab: -8-9Jan2005 severe storm surge occurred along Danish West coast; return period >50y -p.82: The highest ever recorded water level at Logstor occurred on the evening of 8Jan2005 reaching 2.05m (water level may have been locally 15-20cm higher according to some reports) and large parts of the town were flooded and inhabitants evacuated. Several other locations along the fjord were flooed as the water rose and dikes breached.
Soomere et al (2008)	Soomere, T., A. Behrens, L. Toumi, J.W. Nielsen: Wave conditions in the Baltic proper and in the Gulf of Finland during windstorm Gudrun, Nat Hazards Earth Syst. Sci., 8, 37-46, 2008. -wave field at FIMR buoy 1 in Baltic Sea was 4th occurrence >7m SWH in 12 year deployment -highest recorded storm surge in Parnu 275cm over mean sea level -new water level records west Estonia coast and Gulf of Finland
Magnusson (2009)	Magnusson, A.K.: What is true sea state? Powerpoint presentation at the 11th International Workshop on Wave Hindcasting and Forecasting and Coastal Hazard Symposium, JCOMM Halifax, Canada, 18–23 October 2009.

	-Storm Erwin 2005 was probably one of list of EXWW storms.
SMHI (2009)	SMHI, Per - Januaristormen 2007, 6Aug2009, https://www.smhi.se/kunskapsbanken/meteorologi/per-januaristormen-2007-1.5287 -Gudrun worst storm ever in Sweden for destroyed forest: 75 million m3 timber -storm 22Sep1969 rank2, storm 3Jan1954 rank3, storm 14Jan2007 (Per) rank4
Tatge (2009)	Tatge, Yoern, Looking back, looking forward: Anatol, Lothar and Martin ten years later, 09Dec2009. https://www.air-worldwide.com/publications/air-currents/looking-back-looking-forward-anatol-lothar-and-martin-ten-years-later/ -Erwin part of group of defining extratropical cyclones since 1999: Anatol-Lothar-Martin (Dec 1999), Jeanette (Oct 2002), Kyrill (Jan 2007), Emma (Mar 2008), Klaus (Jan2009)
Tetzlaff (2009)	Tetzlaff, G., Extreme rain and wind storms in the mid-latitudes I, Singapore, 21-22.04.2009. https://imsarchives.nus/edu.sg/oldwww/Programs/09fluidss/files/Gerd Tetzlaff.pdf (Spring School on Fluid Mechanics and Geophysics of Environmental Hazards, Singapore, April 19-May 2, 2009) [pdf datestamp: 14/05/2009] -remarkable offshore gust in northeast Atlantic (highest ever?)
Averkiev and Klevannyy (2010)	Averkiev, A.S. and K.A. Klevannyy, A case study of the impact of cyclonic trajectories on sea-level extremes in the Gulf of Finland, Continental Shelf Research, 30, 707-714, 2010. -rank 1 storm surge water levels for stations in Finland and Estonia: Turku, Hanko , Helsinki, Hamina, Vyborg , Narva, Toila, Suurpaa, Tallinn, Ristna, Parnu
SMHI (20111013)	SMHI, Gudrun - Januaristormen 2005,, https://www.smhi.se/kunskapsbanken/meteorologi/stormar-i-sverige/enskilda-stormar-och-ovader/gudrun-januaristormen-2005-1.5300, 13 oktober 2011 -forest damage during Gudrun was worse than autumn 1969 storm
Esurge_2005_erwin (2012)	Esurge_2005_erwin(2012), Winter storm Gudrun (2005), by Philip Harwood, 2012/11/11 -new water level record several places Baltic Sea
Petroliagis and Pinson (2014)	Petroliagis TI and P Pinson, Early warnings of extreme winds using the ECMWF Extreme Forecast Index, Meteorological Applications, 21, 171-185, 2014. -time series of daily max wind speed for Hanover airport 1Dec2003-31May2010 shows Erwin to have wind speed ~12.5 m/s and possibly in top 10 worst storms of period; worst is Kyrill Jan2007, 2nd is unidentified storm from Dec 2003
Post and Kouts (2014)	Post, P. and T Kouts, Characteristics of cyclones causing extreme sea levels in the northern Baltic Sea, Oceanologia, 56, 241-258, 2014. -storm Erwin 9Jan2005 had rank 1 surge level for Parnu and Tallinn
Roberts et al (2014)	Roberts JF, AJ Champion, LC Dawkins, KI Hodes, LC Shaffrey, DB Stephenson, MA Stringer, HE Thornton, DB Youngman, The XWS open access catalogue of extreme European windstorms from 1979 to 2012, Nat. Hazards Earth Syst. Sci, 14, 2487-2501, 2014 -ERWIN near top for max wspd in storm list 1987-2011; rak8 for footprint index; rank10 for insurance losses
Wolski et al (2014)	Wolski, T., B. Wisniewski, A. Giza, H. Kowalewska-Kalkowska, H. Boman, S. Grabbi-Kaiv, T. Hammarklint, J. Holfort, Z. Lydeikaite, Extreme sea levels at selected stations on the Baltic coast, Oceanologia, 56, 259-290, 2014 -6 stations in Baltic had highest ever water level during Storm Erwin
Statistica (2015)	Statistica, The costliest winter storms ever to hit Europe. Fatalities and financial losses of Europe's 10 costliest winter storms (source Munich Re), 08Dec2015 -ERWIN rank 5 for insurance loss; rank10 for fatalities for storms since 1987
Thejournal.ie (2015)	thejournal.ie, The deadliest storms to ever hit Europe, 14Dec2015 0610AM, https://www.thejournal.ie/europe-storms-2497164-Dec2015/, accessed 10Dec2020 -ERWIN rank 5 for insurance loss; rank10 for fatalities for storms since 1987
Expressen (20170204)	Expressen, Gudrun 2005: 20 doedas i den vaarsta storm, https://www.expressen.se/nyheter/inloggad/gudrun-2005-20-dodas-i-den-varsta-stormen/, published 04Feb2017 09:25 -Sweden natural catastrophe of 8Jan2005 was one of the most destructive ever -Gudrun worst Swedish storm for timber windfall
Kulikov and Medvedev (2017)	Kulikov, E.A. and I.P. Medvedev, Extreme statistics of storm surges in the Baltic Sea, Oceanology, 57, 772-783, 2017 -Storm Erwin: rank 1 storm surge at Parnu Estonia
SurgeWatch (2017)	SurgeWatch, Storm Event 11th January 2005, in Haigh, I.D., O. Ozsoy, M.P. Wadey, R.J. Nicholls, S.L. Gallup, T. Wahl, J.M. Brown,Data descriptor: An improved database of coastal flooding in the United Kingdom from 1915 to 2016, Scientific Data, 4: 170100, DOI: 10.1038/sdata.2017.100, 2017 [GERO] -GERO -event had highest record return period water levels for 5 sites in Scotland -highest return period Tobermory: 71y event (highest skew surge 1.51m) -second largest return period Kinlochbervie: 70y (1 in 5y threshold exceeded in 2 high tide cycles) -in affected parts of Scotland, storm considered worst in living memory -more severe storm occurred 11-12Nov1877
Cappelen (2018b)	Cappelen, John, Bodil og det beskidte dusin, https://www.dmi.dk/nyheder/2013/bodil-og-det-beskidte-dusin 11Dec2013, updated 2Oct2018b -Erwin/Gudrun: DMI Denmark natonal category 3 storm near threshold to category 4; whole country hit by storm with hurricane strength gusts -Gero: storm of N Ireland and Scotland: central pressure down to 944hPa
Palginomm et al (2018)	Palginomm V, K Orviku, U Suursaar, A Kont, H Tonnison, R Rivis, Lessons learned from record-high storm surges and associated inundations in Parnu, SW Estonia, Journal of Coastal Research, 85, 1-5, 2018. -Gudrun was a rank 1 surge for Parnu in tide gauge record from 1924
Medvedev and Kulikov (2021)	Medvedev, I.P. and E.A. Kulikov, Extreme storm surges in the Gulf of Finland: Frequency-spectral properties and the influence of low-frequency sea level oscillations, Oceanology, 61, 459-468, 2021. *-event Jan2005 (Gudrun/Erwin); strongest storm in 50y * -Parnu Bay sea level record
Nielsen (2023)	Nielsen, J.W., Stormfloden den 8. januar 2005, https://ocean.dmi.dk/case_studies/surges/2005-01-08.php, last access:21Feb2023. -record water level in Limfjord at Logstor & Skive
FMI (20241219)	Finnish Meteorological Institute, Sea level statistics, https://en.ilmatieteenlaitos.fi/sealevelstatistics, date stamp 29 November 2024 (last access: 19 December 2024)

	-record surge wter levels Turku, Hanko, Helsinki, Hamina
Rantanen et al (2024)	Rantanen M, D van den Broek, J Corner, VA Sinclair, MM Johansson, J Sarkka, TK Laurila, and K Jylha, The impact of serial cyclone clustering on extremelyhigh sea levels in the Baltic Sea, Geophysical Research Letters, 51, e2023GL107203, https://doi.org/10.1029/2023GL107203, 2024. -record high sea levels were observed in Estonia and Finland
SMHI (2024)	SMHI, Rekord: Vattenstand, https://www.smhi.se/data/oceanografi/havsvattenstand/rekord-havsvattenstand-1.2269, updated 26 November 2024, last access: 06 January 2025. -rank1 storm surge for Sweden tide gauge station Ringhals
Bioenergy International (2025)	Bioenergy International, The aftermath and legacy of Storm Gudrun - 20 years on (contributor Alan Sherrard), https://bioenergyinternational.com/the-aftermath-and-legacy-of-storm-gudrun-20-years-on/, 11 January 2025. -ERWIN/GUDRUN: -felled more trees than any known storm Gudrun felled more forest in Sweden than any other known storm
Lorenz et al (2025)	Lorenz M, K Viigand, U Grawe, Untangling the waves: decomposing extreme sea levels in a non-tidal basin, the Baltic Sea, Nat. Hazards Earth Syst. Sci., 25, 1439-1458, 2025. -storm Erwin rank 1 surge at Parnu
Myhr (2025)	Myhr, K.J.: Storm puts focus on security, https://history.vattenfall.com/stories/power-to-the-people/storm-puts-focus-on-security/, last access: 24Jan2025. -Sat evening 8Jan2005, Sweden hit by storm Gudrun, worst natural disaster ever in Sweden
OPW (2025)	OPW, Hydrometric, https://waterlevel.ie/hydro-data/#/overview/Waterlevel/station/, Office of Public Works, last access: 11/02/2025. -Erwin was Ireland rank 7 surge
SMHI (2025)	SMHI, Högvattenhändelser idag och i framtiden, https://www.smhi.se/klimat/stigande-havsnivaer/hogvattenhandelser-idag-och-i-framtiden, last access: 10Jan2025 -water level at Ringhals at 500y return period; Gotaborg at 30y return period
Wikipedia (20250124)	Wikipedia, Floods in Saint Petersburg, https://en.wikipedia.org/wiki/Floods_in_Saint_Petersburg, 24Jan2025 -Erwin/Gudrun had rank 29 surge water level at St Petersburg Russia

Table S15. Severe forecast (arranged by year and then alphabetically)

Source	Full Reference and Notes
Beredskabstyrelesen (2005)	Beredskabstyrelsen, Beredskabets indsats i forbindelse med orkanen 8. januar 2005, En tvaergaende erfaringsopsamling, Beredskabssstyrelsen, Datavej16, 3460 Birkerod, Oktober 2005 -record of weather warnings issued by DMI
Blight (2005)	Blight, PJ: A discussion of the synoptic background and development of the 7-8Jan storm, https://user.eumetsat.int/resources/case-studies/rapid-cyclogenesis-in-the-north-atlantic, pdf time stamp 17/03/2005 -ERWIN -models oscillating over previous days if active wave would develop night to Saturday -Thur model indications of deeper development
DMI (2005)	DMI, Danmark ramt af landsdækkende storm, https://www.dmi.dk/nyheder/2005/danmark-ramt-af-landsdakkende-storm#:~:text=Stormen%20her%20i%20januar%202005,hen%20over%20den%20nordlige%20Nords%C3%B8. 10Jan2005 -DMI issued 5 warnings at same time; never happened previously
Eitrheim (2005)	Eitrheim, K:, Rapport etter stormen 'Gudrun' lordag 8.1.2005 for Rogaland fylke, met.no, 11 January 2005 -met.no issued a series of warning for strong winds and surge starting from 7Jan2005 1300
Jameson (2005)	Jameson D., Weather extremes 2005. January 7th-8th Severe storm development, https://user.eumetsat.int/resources/case-studies/rapid-cyclogenesis-in-the-north-atlantic, pdf timestamp: 17/03/2005 -ERWIN: UK Met Office issued 'emergency severe weather warning'; first for some time
Met.no info (2005)	met.no info, Varsling av stormer og ekstremt vaer (contact information: KH Midtbo, M Lystad, D Kvamme), 10pp, No.18/2005, Oslo, 25 November 2005 -special extreme weather forecast for Gudrun-Haarek-Inga and post-storm evaluation
Deutsche Rueck (2006)	Deutsche Rueck, Sturmdokumentation Deutschland 2005, (contributors: T. Axer, T. Bistry, S Fietze, M Mueller, M Prechtl), Deutsche Rueckversicherung, Aktiengesellschaft, Hansaallee 177, 40549, Duesseldorf, March, 2006. -DWD issued early storm warmings, with Schleswig-Holstein at highest level
Haanpaa et al (2006)	Haanpaa, Simo, Samuli Lehtonen, Lasse Peltonen, Elena Talockaite, Impacts of winter storm Gudrun of 7th-9th January 2005 and measures taken in the Baltic Sea region, Astra, www.astra-project.org, 43pp, 2006 [pdf properties: datestamp 13/06/2006] -quick response, DMI storm warning 8Jan2005 1223UTC -SMHI storm forecasts accurate; difficulty getting info to public; 'background media noise' -forest owners aware of risks; few plan forest practices to minimize risks -Lithuanian Hydrometeorological Service and Klaipeda Division issued early warning 10:52UTC 8Jan but only for Lithuanian coastal region & Klaipeda port/Baltic Sea/Curonian Lagoon -warning that next 12-15h would have water levels expected to increase 1.1-1.3m -weather forecasts with 5,4,3,2,1 day lead times -Estonian Meteorological and Hydrlogical Institute: hurricane warnings 1-1.5d prior to event -individual scientists provided unofficial warnings of surge up to 2.4m; no official warnings -advanced preparation based on experience from Dec2004 storm -Finnish Institute of Maritime Research alerts frm 1350UTC 7Jan2005
Suursaar and Sooaar (2006)	Suursaar, U. and J. Sooaar, Storm surge induced by extratropical cyclone Gudrun: hydrodynamic reconstruction of the event, assessment of mitigation actions and analysis of future flood risks in Parnu, Estonia, WIT Transactions on Ecology and the Environment, vol.91, pp241-250, WIT Press, 2006. -EMHI warnings 1.5d prior to onset Estonia -no ENHI warnings for surge; surge forecast from DMI
Suursaar et al (2006)	Suursaar, U., T. Kullas, M. Otsmann, I. Saarmae, J. Kuik, M. Merilain, Cyclone Gudrun in January 2005 and

	modelling its hydrodyanamic consequences in the Estonian coastal waters, Boreal Environmental Research, 11, 143-159, 2006. -EMHI web warning surge 1.5d prior to Estonia onset -FIMR warning of 150cm flood Helsinki
Hisscott (2007)	Hisscott, Alan, When NWP met climatology: storms over the Isle of Man during January 2005,'Weather, 62, 74-77, 2007 -FIG7 shows forecast charts 0000UTC 8Jan2005 from UK Met Office NWP model runs initiated 72,60,48,36h before -all runs predicted large depression with main centre S to SE of Iceland with strong W flow -rund T60,T48,T36 also suggested small secondary centre around 982-984mb west of Scotland -analysis in FIG1 shows secondary centre further SW than any prediction, near W coast Ireland
Hellenberg and Kentala (2008)	Hellenberg, T. and J. Kentala, Chapter III. Sudden sea level rise in the Gulf of Finland in January 2005, in C. Pursiainen (ed), Early Warning and Civil Protection. When does it work and why does it fail? Nordregio report 2008:1 -surge warnings issued from 7Jan2005 -surge flooding up the 240cm forecast for Helsinki -expected Helsinki level over 120cm and up to 150cm; max level predicted 140cm or 4cm over record -earlier Helsinki record height 27Jan1990 in record starting 1904
Averkiev and Klevannyy (2010)	Averkiev, A.S. and K.A. Klevannyy, A case study of the impact of cyclonic trajectories on sea-level extremes in the Gulf of Finland, Continental Shelf Research, 30, 707-714, 2010. -operation storm surge model for St. Petersburg predicts much higher water level than what actually occurred
Nielsen (2013)	Nielsen, J.W., Stormfloden den 8. januar 2005, https://ocean.dmi.dk/case_studies/surges/2005-01-08.php, last access:21Feb2023. -surge models run and flood warnings issued 7Jan2005

Table S16. Storm not as bad as expected; not as bad as it could have been (arranged by year and then alphabetically)

Source	Full Reference and Notes
Beredskabstyrelsen (2005)	Beredskabstyrelsen, Beredskabets indsats i forbindelse med orkanen 8. januar 2005, En tvaergaende erfaringsopsamling, Beredskabsstyrelsen, Datavej16, 3460 Birkerod, Oktober 2005 -Erwin had 5 fatalities Denmark compared with 7 fatalities for Anatol 3Dec1999 -Denmark 200000 customers without power at some point during storm Erwin 8Jan2005 -for Anatol Dec1999: 400000 customers without power
Eitrheim (2005)	Eitrheim, K:, Rapport etter stormen 'Gudrun' lordag 8.1.2005 for Rogaland fylke, met.no, 11 January 2005 -as far as we know, no reports of serious damage after storm Gudrun -due to several reason -Nov1981 storm was as strong as Gudrun; weaker constructions during earlier storm -modern buildings and similar constructions seem to be able to withstand Gudrun winds -people secured property and stayed indoors during storm
Hallands Nyheder (20050109)	Hallands Nyheder, Stormen staengde Ringhals (contributor Krister Svahn), 9 January 2005 https://www.hn.se/nyheter/varberg/stormen-stangde-ringhals.036d8cf7-2756-4206-b13c-6d03f504a264 -Gudrun struck on weekend so power demand from industry low; also temperatures warm (no heating requirement?)
RWS (2005a)	RWS, Stormvloedflits 2005-02. Zeer zware zuidwesterstorm veroorzaakt vrij hoge waterstanden langs de kust (contributor Jan Kroos). https://open.rijkswaterstaat.nl/open-overheid/onderzoeksrapporten/%40257045/stormvloedflitsen-wmcn-kust/, 2005a -surge levels low; only pre-warnings for West Holland (Hoek van Holland) and Delfzijl
Haanpaa et al (2006)	Haanpaa, Simo, Samuli Lehtonen, Lasse Peltonen, Elena Talockaite, Impacts of winter storm Gudrun of 7th-9th January 2005 and measures taken in the Baltic Sea region, Astra, www.astra-project.org, 43pp, 2006 [pdf properties: datestamp 13/06/2006] -SWEDEN: mild weather; no one harmed by outages -Finland: highest storm gusts in Lemland & Rauma with 24m/s on afternoon 9Jan2005 -most severe storm of winter 2004-5 for Finland was Rafael (Finn in Sweden/Norway) 22-23Dec04 -Finland: no direct forest damage because of weakened storm -harvesting hindered by wet ground; sawmills suffering lack of supply
Saarsuur et al (2006)	Suursaar, U., T. Kullas, M. Otsmann, I. Saarmae, J. Kuik, M. Merilain, Cyclone Gudrun in January 2005 and modelling its hydrodyanamic consequences in the Estonian coastal waters, Boreal Environmental Research, 11, 143-159, 2006. -water level at Parnu could have been higher if wind direction slightly different; slightly different trajectory
Soomere et al (2008)	Soomere, T., A. Behrens, L. Toumi, J.W. Nielsen: Wave conditions in the Baltic proper and in the Gulf of Finland during windstorm Gudrun, Nat Hazards Earth Syst. Sci., 8, 37-46, 2008. -wind direction W to WSW oblique to long axis of Baltic -short fetch between Gotland and Saaremaa
Averkiev and Klevannyy (2010)	Averkiev, A.S. and K.A. Klevannyy, A case study of the impact of cyclonic trajectories on sea-level extremes in the Gulf of Finland, Continental Shelf Research, 30, 707-714, 2010. -presentation of detailed modelling investigation of cyclone conditions for much worse storm surge in the eastern Baltic
Wikipedia (20250429)	Wikipedia, Ekstremveret Gudrun, https://nn.wikipedia.org/wiki/Ekstremv%C3%AAret_Gudrun, last access: 29Apr2025 -ERWIN: -Norway: high water with flooding Sandefjord-Mandal but without large effects like UK & Denmark

Table S17. Storm worse than expected; unusual damage or emergency services actions (arranged by year and then alphabetically)

Source	Full Reference and Notes
BBC (20050108)	BBC, Severe gales cause havoc on roads, http://news.bbc.co.uk/2/hi/uk_news/england/4157069.stm,

	08January2005 -storm Erwin 8Jan2005 -no safe routes in or out of Carlisle -rain caused flooding in Haydon Bridge with 40 homes evacuated -police evacuating people at Warden Paper Mill, 3 miles east of Hayden Bridge -North Yorkshire police: dozen lorries overturned on A1 between Scotch Corner & Wetherby
BBC (20050110)	BBC, Northern Europe shaken by storms, http://news.bbc.co.uk/2/hi/europe/4158809.stm, 10 January 2005 -southern Sweden, 2 nuclear reactors shut down & 220000 homes in regions without electricity -Latvia governemnt declared energy crisis after 60% of population of 2.4 million without power -Monday: 40% of country still without power
Belfast Telegraph (20050110c)	Belfast Telegraph, Storms sweep northern Britain, p.6, 10Jan2005c (Monday) -Carlisle schools closed, hospital operations cancelled; 1000s waiting to return to homes without power
Beredskabstyrelsen (2005)	Beredskabstyrelsen, Beredskabets indsats i forbindelse med orkanen 8. januar 2005, En tvaergaende erfaringsopsamling, Beredskabssstyrelsen, Datavej16, 3460 Birkerod, Oktober 2005 -surge flooding of Logstor and evacuations unexpected
DMI (2005)	DMI, Danmark ramt af landsdækkende storm, https://www.dmi.dk/nyheder/2005/danmark-ramt-af-landsdakkende-storm#:~:text=Stormen%20her%20i%20januar%202005,hen%20over%20den%20nordlige%20Nords%C3%B8. 10Jan2005 -police advised whole country against going outside -Helsingor police stopped all traffic on roads
Hallands Nyheder (20050109)	Hallands Nyheder, Stormen staengde Ringhals (contributor Krister Svahn), 9 January 2005 https://www.hn.se/nyheter/varberg/stormen-stangde-ringhals.036d8cf7-2756-4206-b13c-6d03f504a264 -shut-down of 3 of 4 Ringhalds nuclear reactors -Gudrun was first time storm winds forced Ringhals to such an extensive stop
Guardian (20050112)	Guardian, Storms claim at least five lives (contributor: Adam Jay), https://www.theguardian.com/environment/2005/jan/12/weather.climatechange1, 12 January 2005 -GERO -emergency services in Scotland overwhelmed by calls
Guy Carpenter (2005)	Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005 -ERWIN/GUDRUN -UK: Carlisle: power cut to ~30000 homes; ~3000 people evacuated -UK: EA: Carlisle floods worst for over 100y; last major flood 1968 with water levels ~1m lower -SWEDEN: more than 400000 households lost power & phone lines in Sweden from falling trees -SWEDEN: estimated several weeks needed before power back in all affected areas -SWEDEN: in some areas elderly evacuated from unheated houses -LATVIA: national energy crisis declared after 1000s electricity poles downed; 1.4 million people or 60% population without power at height of storm -LATVIA: surge flooding Riga; military evacuating people from capital
Irish Times (20050111)	The Irish Times, Man dies as storm causes power cuts and flooding (contributor Ciara O'Brien), https://www.irishtimes.com/news/man-dies-as-storm-causes-power-cuts-and-flooding-1.1295844, 11 January 2005 -GERO -unsual traffic accident: lorry driver killed when vehicle blown off Derry's Foyle Bridge by gale winds -lorry fell 100s feet from bridge onto mudflats
Jameson (2005)	Jameson D., Weather extremes 2005. January 7th-8th Severe storm development, https://user.eumetsat.int/resources/case-studies/rapid-cyclogenesis-in-the-north-atlantic, pdf timestamp: 17/03/2005 -UK Met Office issued 'emergency severe weather warning'; first for some time
LCW (20050121)	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -ERWIN: Carlisle flooded when River Eden burst banks; military helicopters call to evacuate 15 people from flooded homes. -ERWIN: fire and police stations flooded & operating from temporary headquarters -ERWIN: all 65 city buses damaged by water -ERWIN: at Srninen Harbour in Helsinki, 100s of newly imported cars (Audi & Volkswagens) had water damage when protective barrier of sand & stone breached -ERWIN: Latvia: 60% of population 2.4 million without power; government declares energy crisis
LCW (20050128)	Lloyds Casualty Week, 28Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -ERWIN: 50000 people in Sweden still without power a week after storm; several more weeks of repair necessary
Lindahl (2005)	Lindahl, Sture: The Storm Gudrun 2005-01-08, uploaded to Internet 19/10/2021, presentation 2005-05-12 -restoration of power in 6 weeks after storm required workers from other countries
NRK (20050108)	NRK, Gudrun herjar i sor (contributor Bent J. Tandstad), 8Jan2005 -ERWIN/GUDRUN -sivelforsvaret in Vest-Agder called in 40-60 extra personnel
Haanpaa et al (2006)	Haanpaa, Simo, Samuli Lehtonen, Lasse Peltonen, Elena Talockaite, Impacts of winter storm Gudrun of 7th-9th January 2005 and measures taken in the Baltic Sea region, Astra, www.astra-project.org, 43pp, 2006 [pdf properties: datestamp 13/06/2006] -Denmark: ~5400 turbines; with winds > 25 m/s western Denmark, 4000 Eltra machines shut down -local energy production reduced to 1/20th full capacity of 2380 MW -SWEDEN: power demand filled power bought abroad (N Europe); but with difficult because storm extensive -reactors at Barseback & Ringhals had problems with salty water on switchboards and cable hammer -affected reactors account for 1/5 energy peoduction Sweden (Ringhals, 2005) -uprooted trees downed 30000 km cables

	-Finnish nuclear reactor Loviisa -problem with water rising to level that would disable cooling system (WNA 2005) -Estonian Meteorological and Hydrlogical Institute: hurricane warnings 1-1.5d prior to event -individual scientists provided unofficial warnings of surge up to 2.4m; no official warnings * -evacuations in middle of surge
Johansson et al (2006)	Johansson J., S Lindahl, O. Samuelsson, H Ottoson, The storm Gudrun. A seven-week power outage in Sweden, CRIS, Third International Conference on Critical Infrastructure, Alexandria, Virginia, September, 2006. -ERWIN -power outage in Sweden lasted 7 weeks in some places -Stockholm-Malmo train stopped running for 2 weeks -for electricity network repairs: workers brought in from Germany, Poland & Swedish army -spare electricity parts brought in from northern Sweden
Suursaar and Sooaar (2006)	Suursaar, U. and J. Sooaar, Storm surge induced by extratropical cyclone Gudrun: hydrodynamic reconstruction of the event, assessment of mitigation actions and analysis of future flood risks in Parnu, Estonia, WIT Transactions on Ecology and the Environment, vol.91, pp241-250, WIT Press, 2006. -no public understanding of 2.4m sea level rise -flooding: 775 houses with 5097 inhabitants in Parnu; 159 houses Haapsalu -294 cars damaged by floods or fallen trees -600 people evacuated; 400 in Paarnu -1 senior citizen perished
Dawson et al (2007)	Dawson AG, S Dawson, W Ritchie, Historical climatology and coastal change associated with the 'Great Storm' of January 2005, South Uist and Benbecula, Scottish Outer Hebrides, Scottish Geographical Journal, 123, 135-149, 2007 -GERO: sand deposits in Western Isles up to 2-3m above high water mark
Hisscott (2007)	Hisscott, Alan, When NWP met climatology: storms over the Isle of Man during January 2005,'Weather, 62, 74-77, 2007 -Isle of Man bus network shut down for Storm Erwin
Hellenberg and Kentala (2008)	Hellenberg, T. and J. Kentala, Chapter III. Sudden sea level rise in the Gulf of Finland in January 2005, in C. Pursiainen (ed), Early Warning and Civil Protection. When does it work and why does it fail? Nordregio report 2008:1 -FIGIII-1. [MAP] Place names mentioned in the test of Chapter_III NOTE: insufficient resources available to authorities in impacted areas in southern Sweden -port of Sornainen in Helsinki: 400-500 newly imported cars damaged by seawater -Estonia: clear failings in the preparedness of authorities -Estonia met dept did not storm forecasts seriously on Friday -Estonian rescue dept responded to met inst warnings after 26h delay -people had no idea what streets would be flooded by 2m flood -last comparable Estonia flood 1964 -flood peak would be at night so people would not be warned
Rantanen (2008)	Rantanen, H., Chapter IV. Coping with Power Disturbances, in C. Pursiainen (ed), Early Warning and Civil Protection. When does it work and why does it fail? Nordregio report 2008:1, p.95-119 -SMHI wather warning 7Jan2005 at 23:18 -night Sat to Sun, rescue units pulled back due to risk of falling trees -Impacts on emergency services -larger popluation centres (cities) had functional electricity during storm -larger commend and communication centres operational -fire stations in countrysde blacked out by power failure -stations had loss of heating; if there were low temperatures & snow stns would have been useless -Telecommunications -lack of comms far more serious problem than power blackouts -critical bas stations with backup power; batteries failed and fuel depleted -mobile and fixed telephone networks suffered from disturbances; 300000 customers without telephone -2 days after storm 90% of mobile network operational -several customers lacked land lines for several weeks -some fire stations with backup power acted as warm cottages -some areas had water distribution problems -availability of fuel for vehicles not affected; majority of population had no power blackout
Soomere et al (2008)	Soomere, T., A. Behrens, L. Toumi, J.W. Nielsen: Wave conditions in the Baltic proper and in the Gulf of Finland during windstorm Gudrun, Nat Hazards Earth Syst. Sci., 8, 37-46, 2008. -unexpectedly long and highwaves in Gulf of Finland
Angus and Rennie (2014)	Angus, S. and A. Rennie, An Ataireachd Aird: The storm of January 2005 in the Uists, Scotland, Ocean & Coastal Management, 94, 22-29, 2014. -GERO -12t fire tender washed off causeway in Uists with water level 4.6m -5 fatalities
Expressen (20170204)	Expressen, Gudrun 2005: 20 doedas i den vaarsta storm, https://www.expressen.se/nyheter/inloggad/gudrun-2005-20-dodas-i-den-varsta-stormen/, published 04Feb2017 09:25 -Ljungby: roads covered in tree drifts 6-7m high; 6 days before roads passable -after Svensson was without power for 17d diesel generator was placed in home town Kylen to provide electr -electricity restored in surrounding towns after almost a month
SurgeWatch (2017)	SurgeWatch, Storm Event 11th January 2005, in Haigh, I.D., O. Ozsoy, M.P. Wadey, R.J. Nicholls, S.L. Gallup, T. Wahl, J.M. Brown,Data descriptor: An improved database of coastal flooding in the United Kingdom from 1915 to 2016, Scientific Data, 4: 170100, DOI: 10.1038/sdata.2017.100, 2017 [GERO] -GERO

	-5 people killed when 2 cars swept from causeway on South Uist (Cramb, 2014)
Bioenergy International (2025)	Bioenergy International, The aftermath and legacy of Storm Gudrun - 20 years on (contributor Alan Sherrard), https://bioenergyinternational.com/the-aftermath-and-legacy-of-storm-gudrun-20-years-on/, 11 January 2025. -ERWIN/GUDRUN: -felled more trees than any known storm Gudrun felled more forest in Sweden than any other known storm -Forest History Society: Gudrun downed two-times forest as 2 1969 storms -VIDA procured former military airstrip outside Ljungby for gigantic wet storage facility -site had up to 1000 visitors per day during first year operations -processing stored timber started Jan2008; 29Apr2010 last truckload left Byholma -at peak Byholma stored 1 mill m3 wood (4 million logs) -FIG9. [PHOTO] At its peak, Byholma stored around 1 million m3 of wood, corresponding to 4 million logs making it one of the world's larges log storage facilities and inadvertently, a major tourist destination [Ola Nilsson/Sydsenskan/IBL] -E.ON decided built new grid after 20000 km of grid badly damaged
Lorenz et al (2025)	Lorenz M, K Viigand, U Grawe, Untangling the waves: decomposing extreme sea levels in a non-tidal basin, the Baltic Sea, Nat. Hazards Earth Syst. Sci., 25, 1439-1458, 2025. -water level at Parnu described as being statistical outlier
Myhr (2025)	Myhr, K.J.: Storm puts focus on security, https://history.vattenfall.com/stories/power-to-the-people/storm-puts-focus-on-security/, last access: 24Jan2025. -natural disaster put spotlight on vulnerability of Swedish society -electrical outage stopped all activity -Vattenfall & other grid operators significantly increased rate of investment to make network secure in all weather -nuclear power plants at Ringhals & Barseback halted production due to grid failures; switchgear unusable due to large amounts of salt from sea -society ceased to function for several days -communication problems; Vattenfall received 40000 calls on 30 lines -Vattenfall decided 1 year earlier to invest 10 bill SEK over 5y to insulate & weatherproof grid -burying lines became more common

Table S18. Storm duration; extended period bad weather (arranged by year and then alphabetically)

Source	Full Reference and Notes
Belfast Telegraph (20050108)	Belfast Telegraph, Ulster braced for more storms (contributor Maureen Coleman), p.1, 10Jan2005 (Monday) -10Jan2005 Ulster bracing for more severe gales & torrential rain; storms continue to cause havoc across province -up to 3000 householders in Co Down & Armagh still without power morning 10Jan2005; severe weather hampered repairs -storm set to continue this week with break Wednesday 12Jan2005; gales & heavy rain later in week -PA WeatherCentre in London: overnight stormy; 11Jan2005 severe gales of up to 80mph
Beredskabstyrelsen (2005)	Beredskabstyrelsen, Beredskabets indsats i forbindelse med orkanen 8. januar 2005, En tvaergaende erfaringsopsamling, Beredskabssstyrelsen, Datavej16, 3460 Birkerod, Oktober 2005 -DMI warnings from 7Jan2005 13:23 CET to 9Jan2005 19:56
Brown (2005)	Brown, Paul R., The violent gale of 11-12 January 2005 in the north of Scotland, Journal of Meteorology, 30, 104-106, 2005 -storm Gero started 11Jan and lasted through 12Jan
Eitrheim (2005)	Eitrheim, K:, Rapport etter stormen 'Gudrun' lordag 8.1.2005 for Rogaland fylke, met.no, 11 January 2005 -full storm conditions in western Norway for only 2-3h period from 1700 8Jan2005
Hallands Nyheder (20050109)	Hallands Nyheder, Stormen staengde Ringhals (contributor Krister Svahn), 9 January 2005 https://www.hn.se/nyheter/varberg/stormen-stangde-ringhals.036d8cf7-2756-4206-b13c-6d03f504a264 -Ringhals reactors restarted on Sunday after being sut-down on Saturday
RWS (2005a)	RWS, Stormvloedflits 2005-02. Zeer zware zuidwesterstorm veroorzaakt vrij hoge waterstanden langs de kust (contributor Jan Kroos). https://open.rijkswaterstaat.nl/open-overheid/onderzoeksrapporten/%40257045/stormvloedflitsen-wmcn-kust/, 2005a -high winds noted only for afternoon 8Jan2005
RWS (2005b)	RWS, Stormvloedflits 2005-03. Stormtij en storm met orkankracht veroorzaken hoge waterstanden langs de kust (contributor Jan Kroos). https://open.rijkswaterstaat.nl/open-overheid/onderzoeksrapporten/%40257045/stormvloedflitsen-wmcn-kust/, 2005b -high winds lasted about 18h
Haanpaa et al (2006)	Haanpaa, Simo, Samuli Lehtonen, Lasse Peltonen, Elena Talockaite, Impacts of winter storm Gudrun of 7th-9th January 2005 and measures taken in the Baltic Sea region, Astra, www.astra-project.org, 43pp, 2006 [pdf properties: datestamp 13/06/2006] -Lithuanian Hydrometeorological Service and Klaipeda Division issued early warning 10:52UTC 8Jan but only for Lithuanian coastal region & Klaipeda port/Baltic Sea/Curonian Lagoon -warning that next 12-15h would have water levels expected to increase 1.1-1.3m
Dawson et al (2007)	Dawson AG, S Dawson, W Ritchie, Historical climatology and coastal change associated with the 'Great Storm' of January 2005, South Uist and Benbecula, Scottish Outer Hebrides, Scottish Geographical Journal, 123, 135-149, 2007 -storm affected Benbecula & South Uist coastlines in 2 ways -11Jan2005 0500: hurricane force winds from S lasting 15h -11Jan2005 evening: winds reduced to gale force but shift to be from W until late moring 12Jan
Hisscott (2007)	Hisscott, Alan, When NWP met climatology: storms over the Isle of Man during January 2005,'Weather, 62, 74-77, 2007 -0000UTC 8Jan secondary low P 980mb approaching W coast Ireland with EXPLOSIVE DEEPENING -low P travelled across Ireland & N Irish Sea to S Scotland by 0536UTC -winds Isle of Man strongest in period 0430-0700UTC

Hellenberg and Kentala (2008)	Hellenberg, T. and J. Kentala, Chapter III. Sudden sea level rise in the Gulf of Finland in January 2005, in C. Pursiainen (ed), Early Warning and Civil Protection. When does it work and why does it fail? Nordregio report 2008:1 -Monday 10Jan water level continued to be higher than normal
Piontkowitz and Soerensen (2008)	Piontkowitz, Thorsten & Carlo Soerensen, Consequences of Climate Change along the Danish Coasts, Safecoast Action 5A, Danish Coastal Authority, Hojbovej 1, 7600 Lemvig, Denmark, kdi@kyst.dk, December 2008 -storm ERWIN 2005 -p.83: The wind was approximately 10m/s from westerly directions for six days prior to the main event and this persistent wind forcing lead to high general water levels 70-100cm in the fjord. The narrowing of the fjord east of Logstor Bredning meant that the water could not be transported away fast enough. Conditions were ideal for a major surge at Logstor with a large wind setup over the shoals and an atmospheric pressure that dropped from 1015hPa to 980hPa as the storm peaked.
Tonisson et al (2008)	Tonisson H, K Orviku, J Jaagus, U Suursaar, A Kont, R Rivis, Coastal damages on Saaremaa Island, Estonia, caused by the extreme storm and flooding on January 9, 2005, Journal of Coastal Research, 24, 602-614, 2008. -flooding in Parnu lasted 12 h
Averkiev and Klevannyy (2010)	Averkiev, A.S. and K.A. Klevannyy, A case study of the impact of cyclonic trajectories on sea-level extremes in the Gulf of Finland, Continental Shelf Research, 30, 707-714, 2010. -presentation of characteristic time scale of cyclone development (deepening and filling) on order of 1 day
Palginomm et al (2018)	Palginomm V, K Orviku, U Suursaar, A Kont, H Tonnison, R Rivis, Lessons learned from record-high storm surges and associated inundations in Parnu, SW Estonia, Journal of Coastal Research, 85, 1-5, 2018. -flooding in Parnu lasted 12h
Medvedev and Kulikov (2021)	Medvedev, I.P. and E.A. Kulikov, Extreme storm surges in the Gulf of Finland: Frequency-spectral properties and the influence of low-frequency sea level oscillations, Oceanology, 61, 459-468, 2021. -Erwin/Gudrun high water levels in St Petersburg -strong sea level variations in Gulf of Finland as early as 24-27Dec2004 with seiche 0.7-1.1 cycle/d -freq structure of water level oscillations changed by 6Jan2005; comp 0.45-0.55, 0.56-0.65,0.66-0.9 -7Jan2005 23:00 St Petersburg flood at 165cm; 9Jan 09:00 water level at 238cm at head Glulf Finland -sea level St Petersburg exceeded 160cm for 10.5h
Rantanen et al (2023)	Rantanen M, D van den Broek, J Corner, VA Sinclair, MM Johansson, J Sarkka, TK Laurila, and K Jylha, The impact of serial cyclone clustering on extremelyhigh sea levels in the Baltic Sea, Geophysical Research Letters, 51, e2023GL107203, https://doi.org/10.1029/2023GL107203, 2024. -Gudrun was 4th of series of cycles from 1-9Jan2005
Myhr (2025)	Myhr, K.J.: Storm puts focus on security, https://history.vattenfall.com/stories/power-to-the-people/storm-puts-focus-on-security/, last access: 24Jan2025. -within few hours, wind blew down 1y harvest of trees (200 mill trees) & power lines, poles, power stations

Table S19. Names of the storm1 - Erwin/Gudrun (arranged by year and then alphabetically)

Name	Full Reference and Notes
Erwin (Gemrnay, central Europe)	Beredskabstyrelsen, Beredskabets indsats i forbindelse med orkanen 8. januar 2005, En tvaergaende erfaringsopsamling, Beredskabssstyrelsen, Datavej16, 3460 Birkerod, Oktober 2005 DMI, Danmark ramt af landsdækkende storm, https://www.dmi.dk/nyheder/2005/danmark-ramt-af-landsdakkende-storm#:~:text=Stormen%20her%20i%20januar%202005,hen%20over%20den%20nordlige%20Nords%C3%B8. 10Jan2005 Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005 Suursaar, U. and J. Sooaar, Storm surge induced by extratropical cyclone Gudrun: hydrodynamic reconstruction of the event, assessment of mitigation actions and analysis of future flood risks in Parnu, Estonia, WIT Transactions on Ecology and the Environment, vol.91, pp241-250, WIT Press, 2006. Baker, L., Sting jets in severe northern European wind storms, Weather, 64, 143-148, 2009 Averkiev, A.S. and K.A. Klevannyy, A case study of the impact of cyclonic trajectories on sea-level extremes in the Gulf of Finland, Continental Shelf Research, 30, 707-714, 2010.
Gudrun (Nordic countries)	Alexandersson H and KI Ivarsson, Januaristormen 2005, Faktablad nr 25, SMHI, https://www.smhi.se/download/18.18f5a56618fc9f08e832d664/1717805946933/faktablad_janstorm%5B1%5D.pdf, November 2005. Beredskabstyrelsen, Beredskabets indsats i forbindelse med orkanen 8. januar 2005, En tvaergaende erfaringsopsamling, Beredskabssstyrelsen, Datavej16, 3460 Birkerod, Oktober 2005 DMI, Danmark ramt af landsdækkende storm, https://www.dmi.dk/nyheder/2005/danmark-ramt-af-landsdakkende-storm#:~:text=Stormen%20her%20i%20januar%202005,hen%20over%20den%20nordlige%20Nords%C3%B8. 10Jan2005 Eitrheim, K:, Rapport etter stormen 'Gudrun' lordag 8.1.2005 for Rogaland fylke, met.no, 11 January 2005 Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005 met.no info, Varsling av stormer og ekstremt vaer (contact information: KH Midtbo, M Lystad, D Kvamme), 10pp, No.18/2005, Oslo, 25 November 2005 NRK, Gudrun herjar i sor (contributor Bent J. Tandstad), 8Jan2005 Haanpaa, Simo, Samuli Lehtonen, Lasse Peltonen, Elena Talockaite, Impacts of winter storm Gudrun of 7th-9th January 2005 and measures taken in the Baltic Sea region, Astra, www.astra-project.org, 43pp, 2006 [pdf properties: datestamp 13/06/2006] Hellenberg, T. and J. Kentala, Chapter III. Sudden sea level rise in the Gulf of Finland in January 2005, in C. Pursiainen (ed), Early Warning and Civil Protection. When does it work and why does it fail? Nordregio report 2008:1 Soomere, T., A. Behrens, L. Toumi, J.W. Nielsen: Wave conditions in the Baltic proper and in the Gulf of Finland during windstorm Gudrun, Nat Hazards Earth Syst. Sci., 8, 37-46, 2008.

	Tonisson H, K Orviku, J Jaagus, U Suursaar, A Kont, R Rivis, Coastal damages on Saaremaa Island, Estonia, caused by the extreme storm and flooding on January 9, 2005, Journal of Coastal Research, 24, 602-614, 2008. Baker, L., Sting jets in severe northern European wind storms, Weather, 64, 143-148, 2009 Krzystyniak M, The relationship bewteen extreme weather events and subsequent slide events in Norway, Master Thesis, Dept of Geosciences, University of Oslo, Sept. 2011 SMHI, Gudrun - Januaristormen 2005,, https://www.smhi.se/kunskapsbanken/meteorologi/stormar-i-sverige/enskilda-stormar-och-ovader/gudrun-januaristormen-2005-1.5300, 13 oktober 2011 Expressen, Gudrun 2005: 20 doedas i den vaarsta storm, https://www.expressen.se/nyheter/inloggad/gudrun-2005-20-dodas-i-den-varsta-stormen/, published 04Feb2017 09:25 Myhr, K.J.: Storm puts focus on security, https://history.vattenfall.com/stories/power-to-the-people/storm-puts-focus-on-security/, last access: 24Jan2025. Wikipedia, Ekstremveret Gudrun, https://nn.wikipedia.org/wiki/Ekstremv%C3%AAret_Gudrun, last access: 29Apr2025

Table S20. Names of the storm2 - Haarek (arranged by year and then alphabetically)

Name	Full Reference and Notes
Haarek	met.no info, Varsling av stormer og ekstremt vaer (contact information: KH Midtbo, M Lystad, D Kvamme), 10pp, No.18/2005, Oslo, 25 November 2005
	Krzystyniak M, The relationship bewteen extreme weather events and subsequent slide events in Norway, Master Thesis, Dept of Geosciences, University of Oslo, Sept. 2011

Table S21. Names of the storm3 - Gero/Inga(arranged by year and then alphabetically)

Name	Full Reference and Notes
Gero	Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005 Tetzlaff, G., Extreme rain and wind storms in teh mid-latitudes I, Singapore, 21-22.04.2009. https://imsarchives.nus/edu.sg/oldwww/Programs/09fluidss/files/Gerd Tetzlaff.pdf (Spring School on Fluid Mechanics and Geophysics of Environmental Hazards, Singapore, April 19-May 2, 2009) [pdf datestamp: 14/05/2009] SurgeWatch, Storm Event 11th January 2005, in Haigh, I.D., O. Ozsoy, M.P. Wadey, R.J. Nicholls, S.L. Gallup, T. Wahl, J.M. Brown,Data descriptor: An improved database of coastal flooding in the United Kingdom from 1915 to 2016, Scientific Data, 4: 170100, DOI: 10.1038/sdata.2017.100, 2017 [GERO]
Inga	met.no info, Varsling av stormer og ekstremt vaer (contact information: KH Midtbo, M Lystad, D Kvamme), 10pp, No.18/2005, Oslo, 25 November 2005 Krzystyniak M, The relationship bewteen extreme weather events and subsequent slide events in Norway, Master Thesis, Dept of Geosciences, University of Oslo, Sept. 2011
Great storm of Jan2005	Dawson AG, S Dawson, W Ritchie, Historical climatology and coastal change associated with the 'Great Storm' of January 2005, South Uist and Benbecula, Scottish Outer Hebrides, Scottish Geographical Journal, 123, 135-149, 2007

Table S22. Satellite pictures (arranged by year and then alphabetically)

Source	Full Reference and Notes
Alexandersson and Ivarsson (2005)	Alexandersson H and KI Ivarsson, Januaristormen 2005, Faktablad nr 25, SMHI, https://www.smhi.se/download/18.18f5a56618fc9f08e832d664/1717805946933/faktablad_janstorm%5B1%5D.pdf, November 2005. FIG1. [SATELLITE] forodande stormen seen from satellite NOAA-16 13:50 8Jan2005. Low pressure centre just off SW Norway; part of North Sea coast outline seen to SW including part of England [Karl-Goran Karlsson, SMHI] FIG4. [SATELLITE] NOAA channel 4 22:59UTC 7Jan2005 [Satellite pictures from Dundee] FIG5. [SATELLITE] NOAA channel 4 06:36UTC 8Jan2005 FIG6. [SATELLITE] NOAA channel 4 20:57UTC 8Jan2005; cold front across S Germany
Bancroft (2005)	Bancroft, George P., Weather Review - North Atlantic Area, January through April 2005, Mariners Weather Log, vol. 49, No. 2, Marine https://www.vos.noaa.gov/MWL/aug_05/north_atlantic.shtml, Aug 2005. -GERO -FIG4. [SATELLITE] METEOSAT-7 infrared satellite image valid 1800UTC 11Jan2005. Satellite senses temperature on a scale from back (warm) to white (cold) in imagery. The stormin FIG3 is shown near max intensity, with the time of the image 6h later than FIG3b. -FIG6. [SATELLITE] Quikscat scatterometer image of satellite-sensed widns valid about seven hours before FIG3b [NOAA-NESDIS]
Blight (2005)	Blight, PJ: A discussion of the synoptic background and development of the 7-8Jan storm, https://user.eumetsat.int/resources/case-studies/rapid-cyclogenesis-in-the-north-atlantic, pdf time stamp 17/03/2005 FIG1. [MAP] WV image 12Z 7Jan. Jet streak had just founded base of the upper trough and about to engage cold front. Sharp therma contrast across NE Atlantic FIG2. [MAP] WV image at 22Z 7Jan. Marked cyclogenesis underway. Dry slot and baroclinic leaf with classic shap Marked dry intrusion & cooling cloud tops on baroclinic leaf indicate marked cyclogenesis underway with colder polar air mass starting to warp western flank FIG3. [MAP] WV image at 8Jan 06Z; classic swirl of cloud with lowP center over borders; bent back occlusion coming across Irish Sea into Cumbria with gusts >100mph
DMI (2005)	DMI, Danmark ramt af landsdækkende storm, https://www.dmi.dk/nyheder/2005/danmark-ramt-af-landsdakkende-storm#:~:text=Stormen%20her%20i%20januar%202005,hen%20over%20den%20nordlige%20Nords%C3%B8. 10Jan2005 -FIG. [SATELLITE] MSG1 ch-12 20050108 1300. Cloud picture from METEOSAT-8

	with storm over Stavanger
DWD (2005)	DWD, Orkan Erwin am 8. Januar 2005. https://www.dwd.de/DE/leistungen/besondereereignisse/stuerme/20050801_orkan_erwin.pdf?__blob=publicationFile&v=4, pdf timestamp: 07Feb2005 FIG5. [SATELLITE] TERRA Satellite of NASA 08Jan2005 12:00?, showing cold front passing across Germany
EUMETSAT (2005)	EUMETSAT, Rapid cyclogenesis in the North Atlantic 6-8 January 2005, (contributors: Jochen Kerkmann and Gordon Bridge) https://www.eumetsat.int/rapid-cyclogenesis-north-atlantic published 06January2005, accessed 03Dec2022 -FIG1. [MAP] Initial Stage 1: Meteosat-8 Difference Image IR9.7-IR10.8, 7Jan2005 03:00UTC -FIG2. [MAP] Initial Stage 2: Meteosat-8 Difference Image IR9.7-IR10.8, 7Jan2005 09:00UTC -FIG3. [MAP] Advanced Stage 1: Meteosat-8 Difference Image IR9.7-IR10.8, 7Jan2005 15:00UTC -FIG4. [MAP] Advanced Stage 2: Meteosat-8 Difference Image IR9.7-IR10.8, 7Jan2005 22:00UTC -FIG5. [MAP] Mature Stage 1: Meteosat-8 Difference Image IR9.7-IR10.8, 8Jan2005 06:00UTC -FIG6. [MAP] Mature Stage 2: Meteosat-8 Difference Image IR9.7-IR10.8, 8Jan2005 12:00UTC -FIG7. [MAP] Meteosat-8 RGB Composite NIR1.6, VIS0.8, VIS0.6, 7Jan2005 15:00UTC -FIG8. [MAP] Meteosat-8 RGB Composite NIR1.6, VIS0.8, VIS0.6, 8Jan2005 09:00UTC
Guy Carpenter (2005)	Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005 -FIG6. [MAP] Satellite pic for 12:00 on Saturday 8Jan2005. Pic is composite of 3 satellite channels. White & green areas show cloudiness; brown region mostly cloud free. Surface low and fronts superimposed for reference (Danish Met Office) NOTE: SOUTHWARD MOVINGCLOUD STREET BETWEEN UK & ICELAND
Met Eireann (2005)	Met Eireann, Monthly Weather Bulletin, No 225, Jan 2005 -GERO FIG_p1. [SATELLITE] infrared satellite impact at 11Jan2005 1540UTC
Met.no info (2005)	met.no info, Varsling av stormer og ekstremt vaer (contact information: KH Midtbo, M Lystad, D Kvamme), 10pp, No.18/2005, Oslo, 25 November 2005 -FIG2. [MAP] Low pressure trajectory for storm Gudrun that developed 7-8Jan2005. blue points are storm pressure centre every 6h; red cross is low pressure center at time of satellite image at 03:00UTC 8Jan; white area just west for low pressure center is skyhatt and indicates sudden development of storm NOAA-16 Ekstrem 4 2005-01-08 02:55 -FIG3. [MAP] Low pressure trajectory for storm Gudrun that developed 7-8Jan2005. blue points are storm pressure centre every 6h; red cross is low pressure center at time of satellite image at 10:00UTC 8Jan; the image in FIG2 shows the same storm 7h earlier. The storm has gone through an explosive development in only 7h; note that the cloud system now is rolled up around the centre and that the skyhatten is not seen as a separate cloud cloud system -FIG4. Low pressure trajectory for storm Haarek (above) and for Inga (below) that developed in the period 10-14 Janaury 2005. Points on the blue curve give the low pressure centre every 6h. Red cross is the low pressure centre at the same time as the satellite picture
RWS (2005a)	RWS, Stormvloedflits 2005-02. Zeer zware zuidwesterstorm veroorzaakt vrij hoge waterstanden langs de kust (contributor Jan Kroos). https://open.rijkswaterstaat.nl/open-overheid/onderzoeksrapporten/%40257045/stormvloedflitsen-wmcn-kust/, 2005a -FIG2. [PHOTO Satellite] Meteosat 8 Europea IR (channells 9-10-11) Sat 8Jan2005 1900 CST (met.no)
RWS (2005b)	RWS, Stormvloedflits 2005-03. Stormtij en storm met orkankracht veroorzaken hoge waterstanden langs de kust (contributor Jan Kroos). https://open.rijkswaterstaat.nl/open-overheid/onderzoeksrapporten/%40257045/stormvloedflitsen-wmcn-kust/, 2005b FIG2. [SATELLITE IMAGE] Meteosat 8 Europa VIS (channels 1 2 3) Wed 12Jan2005 13:00 CST NOTE: patchy cloud street W of Scotland; streaming feature north of Scotland
Hisscott (2007)	Hisscott, Alan, When NWP met climatology: storms over the Isle of Man during January 2005,'Weather, 62, 74-77, 2007 -FIG2. [SATELLITE IR IMAGE] AVHRR channel 4 (infrared) satellite image over the British Isles at 0536UTC on 8Jan2005 (Satellite Receiving Station, University of Dundee) NOTE: CLOUD STREET SOUTHWEST OF CENTRE OVER SOUTHERN IRELAND
Baker (2009)	Baker, L., Sting jets in severe northern European wind storms, Weather, 64, 143-148, 2009 -FIG3. [SATELLITE] Infrared images from Meteosat Second Generation satellite at (a) 1800UTC 7Jan, (b) 2200UTC 7Jan, (c) 0300UTC 8Jan, (d) 0800UTC 8Jan NOTE: cloud street on W side of centre
Angus and Rennie (2014)	Angus, S. and A. Rennie, An Ataireachd Aird: The storm of January 2005 in the Uists, Scotland, Ocean & Coastal Management, 94, 22-29, 2014. -GERO: mention of high wind speed from TOPEX near maximum value recorded over 12y deployment
Clark and Gray (2018)	Clark, PA and SL Gray, Sting jets in extratropical cyclones: a review, Quarterly Journal of the Royal Meteorological Society, 144, 943-969, 2018. FIG5. IR satellite images taken from the operational METEOSAT satellite at the time. Dates are given in ddmmyyyy format and times in UTC. Grey scale is arbitrary in each case and has been chosen to render the cloud features most clearly [EUMETSAT & UKMO]: Great Storm 16Oct1987, Oratia 30Oct2000, Anna 26Feb2002, Jeanette 25Oct2002, Gudrun 08Jan2005, Friedhelm 08Dec2011, Ulli 03Jan2012, St Jude Storm 28Oct2013, Tini 12Feb2014
Seewetter - Kiel (2024)	Seewetter - Kiel: Orkantief Erwin, http://www.seewetter-kiel.de/seewetter/orkan_erwin.htm, last access: 10Dec2024 -FIG1. [SATELLITE] Development of satellite images (NOAA,IR):

	07/01/2005 00:00UT, 07/01/2005 12:10UT, 07/01/2005 21:59UT, 08/01/2005 05:36UT, 08/01/2005 11:47UT, 08/01/2005 15:24UT, 08/01/2005 19:57UT 09/01/2005 05:11UT

Table S23. Weather radar, radar reflectivity (arranged by year and then alphabetically)

Source	Full Reference and Notes
Met.no info (2005)	met.no info, Varsling av stormer og ekstremt vaer (contact information: KH Midtbo, M Lystad, D Kvamme), 10pp, No.18/2005, Oslo, 25 November 2005 -5 weather radar in operation in Norway; 4 with ocean cover for storms approaching coast from west

Table S24. Meteorological data maps or surface analysis (arranged by year and then alphabetically)

Source	Full Reference and Notes
Bancroft (2005)	Bancroft, George P., Weather Review - North Atlantic Area, January through April 2005, Mariners Weather Log, vol. 49, No. 2, Marine https://www.vos.noaa.gov/MWL/aug_05/north_atlantic.shtml, Aug 2005. -FIG1. [MAP] OPC North Atlantic Surface Analysis charts (Part1 east) valid 1200UTC 7Jan and 8Jan2005 NOTE: ERWIN/GUDRUN -FIG2. [MAP] OPC North Atlantic 500hPa analysis valid 00UTC 8Jan2005 or halfway between the valid times of the two analysis charts in FIG`1. The chart is computer generated with short wave troughs (heavy broken lines) manually added -FIG3. [MAP] OPC North Atlantic Surface Analysis charts (Part1) valid 1200UTC valid 1200UTC 10Jan & 11Jan2005
Brown (2005)	Brown, Paul R., The violent gale of 11-12 January 2005 in the north of Scotland, Journal of Meteorology, 30, 104-106, 2005 -GERO -FIG1. [MAP] Surface analysis for 0000GMT 12Jan2005 showing previous and subsequent depths and positions of the major depression north of Scotland -FIG2. [MAP] Highest gust in knots reported during the night of 11-12Jan2005. Values in brackets indicate incomplete data; underlined station at high latitude
DMI (2005)	DMI, Danmark ramt af landsdækkende storm, https://www.dmi.dk/nyheder/2005/danmark-ramt-af-landsdakkende-storm#:~:text=Stormen%20her%20i%20januar%202005,hen%20over%20den%20nordlige%20Nords%C3%B8. 10Jan2005 -FIG. [MAP] highest 10-min avg wind in m/s (blue) during storm 8Jan2005. For most stations there is also max gust (red). Graph is updated with new and corrected values Monday 10Jan 14:00
DWD (2005)	DWD, Orkan Erwin am 8. Januar 2005. https://www.dwd.de/DE/leistungen/besondereereignisse/stuerme/20050801_orkan_erwin.pdf?__blob=publicationFile&v=4, pdf timestamp: 07Feb2005 FIG7. [MAP] measured wind speeds gusts in N Germany & Denmark 8Jan2005 12:00 FIG8. [MAP] measured wind speeds gusts in N Germany & Denmark 8Jan2005 18:00 FIG9. [MAP] measured wind speeds in N Germany & Denmark 8Jan2005 12:00 FIG10. [MAP] measured wind speeds in N Germany & Denmark 8Jan2005 18:00
Met Eireann (200501)	Met Eireann, Monthly Weather Bulletin, No 225, Jan 2005 FIG_p1. [MAP] Synoptic chart 11Jan2005; sea level pressure & fronts; first half of January brought very disturbed weather, as Atlantic storms passed over or near country. On 11Jan2005 storm centre passed near N coast, deepening to 952 hPa N of Scotland early on 12Jan. Belmullet recorded gust 80kt (148 km/h) late morning 11Jan; most other stations meas gusts of 55kt or more
Hisscott (2007)	Hisscott, Alan, When NWP met climatology: storms over the Isle of Man during January 2005,'Weather, 62, 74-77, 2007 -FIG1. [MAP] Synptic chart for 0000UTC on 8Jan2005 (analysis UK Met Office, Exeter)
Angus and Rennie (2014)	Angus, S. and A. Rennie, An Ataireachd Aird: The storm of January 2005 in the Uists, Scotland, Ocean & Coastal Management, 94, 22-29, 2014. FIG1. [MAP] Synoptic weather charts for the development of the storm [Met Office]
Wolski et al (2014)	Wolski, T., B. Wisniewski, A. Giza, H. Kowalewska-Kalkowska, H. Boman, S. Grabbi-Kaiv, T. Hammarklint, J. Holfort, Z. Lydeikaite, Extreme sea levels at selected stations on the Baltic coast, Oceanologia, 56, 259-290, 2014 -FIG10. [MAP] Weather map of northern Europe for 8-10Jan2005 (UKMO)
Nielsen (2023)	Nielsen, J.W., Stormfloden den 8. januar 2005, https://ocean.dmi.dk/case_studies/surges/2005-01-08.php, last access:21Feb2023. -FIG2. [MAP] Highest 10min avg wspd in m/s (blue) during 8Jan2005; most stations also have most powerful gust (red)

Table S25. Model fields (arranged by year and then alphabetically)

Source	Full Reference and Notes
Alexandersso n and Ivarsson (2005)	Alexandersson H and KI Ivarsson, Januaristormen 2005, Faktablad nr 25, SMHI, https://www.smhi.se/download/18.18f5a56618fc9f08e832d664/1717805946933/faktablad_janstorm%5B1%5D.pdf, November 2005. FIG2. [MAP] Prognosis from ECMWF with issuing time 02UTC 7Jan205 for 20:00UTC 8Jan2005 FIG3. [MAP] Analysis of pressure field and wind 20UTC 8Jan2005 -FIG7. [MAP] Maximum gust winds at 10m height 8-9Jan2005
Bancroft (2005)	Bancroft, George P., Weather Review - North Atlantic Area, January through April 2005, Mariners Weather Log, vol. 49, No. 2, Marine https://www.vos.noaa.gov/MWL/aug_05/north_atlantic.shtml, Aug 2005. -FIG2. [MAP] OPC North Atlantic 500hPa analysis valid 00UTC 8Jan2005 or halfway between the valid times of the two analysis charts in FIG`1. The chart is computer generated with short wave troughs (heavy broken lines) manually added

DWD (2005)	DWD, Orkan Erwin am 8. Januar 2005. https://www.dwd.de/DE/leistungen/besondereereignisse/stuerme/20050801_orkan_erwin.pdf?__blob=publicationFile&v=4, pdf timestamp: 07Feb2005 FIG3. [MAP] Map 07Jan2005 12:00? or 18:00? Berliner Wetterkarte; height of 500hPa surface FIG4. [MAP] Map 08Jan2005 00:00 Berliner Wetterkarte
Guy Carpenter (2005)	Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005 -FIG2. [MAP] Surface weather map for 18:00 on Friday 7Jan2005. Black dashed lines isobars; full red lines isotherms 1500m altitude. The surface low and fronts of Erwin shown (Danish Met Office) NOTE: Color field surface wind speed? -FIG3. [MAP] Weather conditions at an altitude of around 9 km for 18:00 Friday 7Jan2005. The black dashed lines are surface isobars, superimposed for reference. The regions of constant wind are indicated by coloring usinng the dark red colors to represent areas with wind speeds higher than 80m/s (Danish Met Office) NOTE: extremely high winds W of Scotland & over Sogne fjord -FIG4. [MAP] Surface weather map for 06:00 on Saturday 8Jan2005. The black dashed lines are isobars and full red lines isotherms at 1500m. The surface low and fronts of Erwin are also shown (Danish Met Office) -FIG5. [MAP] Weather conditions at an altitude of ~9km for 06:00 Saturday 8Jan2005. Black dashed lines isobars, superimposed for reference. Regions of constant wind indicated by coloring with dark red areas representing wind speeds > 80m/s (source: Danish Met Office) -FIG7. [MAP] Surface weather map for 18:00 on Sat 8Jan2005. Black dashed lines isobases. full red lines isotherms at 1500m. Surface low and fronts of Erwin also shown NOTE: MATURE STORM STAGE -FIG8. [MAP] Weather conditions at altitude of ~9km for 18:00 on Sat 8Jan2005. Black dashed lines surfae isobars for reference. Regions of constant wind in color with red indicating wspd>80m/s
Lindahl (2005)	Lindahl, Sture: The Storm Gudrun 2005-01-08, uploaded to Internet 19/10/2021, presentation 2005-05-12 -FIG. [MAP] Map of southern Sweden with contoured gust speeds
Met.no info (2005)	met.no info, Varsling av stormer og ekstremt vaer (contact information: KH Midtbo, M Lystad, D Kvamme), 10pp, No.18/2005, Oslo, 25 November 2005 -FIG1. [MAP] (top) sea level pressure for storm Inga 12Jan2005 12UTC; (bottom) 36h forecast at the same time; some differences but really good prognosis
RWS (2005a)	RWS, Stormvloedflits 2005-02. Zeer zware zuidwesterstorm veroorzaakt vrij hoge waterstanden langs de kust (contributor Jan Kroos). https://open.rijkswaterstaat.nl/open-overheid/onderzoeksrapporten/%40257045/stormvloedflitsen-wmcn-kust/, 2005a -FIG1. [MAP] Surface analysis Sat 8Jan2005 12UTC showing low P over coast W Norway -FIG3. [MAP] wind and pressure forecast at 8Jan2005 1500GMT (3h after analysis)
RWS (2005b)	RWS, Stormvloedflits 2005-03. Stormtij en storm met orkankracht veroorzaken hoge waterstanden langs de kust (contributor Jan Kroos). https://open.rijkswaterstaat.nl/open-overheid/onderzoeksrapporten/%40257045/stormvloedflitsen-wmcn-kust/, 2005b FIG1. [MAP] Analysis for Wed 12Jn2005 18UTC; surface pressure showing Gero low P over central Norway (Trondheim) & cold front across central France, Germany, Poland, Baltic States [KNMI] FIG3. [MAP] Model field of wind and pressure KNMI for 12Jan2005 00:00GMT (0h after analysis) NOTE: low P center closest to Stornaway with 30m/s west winds at location
Deutsche Rueck (2006)	Deutsche Rueck, Sturmdokumentation Deutschland 2005, (contributors: T. Axer, T. Bistry, S Fietze, M Mueller, M Prechtl), Deutsche Rueckversicherung, Aktiengesellschaft, Hansaallee 177, 40549, Duesseldorf, March, 2006. FIG1. [MAP] Surface pressure for Storm Erwin 08Jan2005 00:00UTC FIG2. [MAP] Surface pressure for Storm Erwin 09Jan2005 00:00UTC FIG3. [MAP] Maximum gust field; storm Erwin; 08Jan2005
Wolf (2007)	Wolf, J.: Modelling of waves and setup for the storm of 11-12 January 2005, Proudman Oceanographic Institute, report no. 181, March 2007. [GERO] -FIG1. [MAP] Mesoscale winds at time of maximum wind stress at South Uist (11Jan2005 22:00) -FIG2. [MAP] Met Office synoptic chart for 12Jan2005 00:00 -FIG9. [MAP] Mesoscale winds at time of altimeter pass 11Jan2005 15:00 -FIG11. [MAP] SWAN wave height and mean wave direction (using corrected windspeed) for 11Jan2005 15:00 -FIG15. [MAP] NEA model wave height at time of maximum modelled waves at South Uist -FIG16. [MAP] CS3 model wave height at time of maximum modelled waves at SOuth Uist -FIG17. [MAP] wave setup at peak of storm 11Jan2005 23:00
Soomere et al (2008)	Soomere, T., A. Behrens, L. Toumi, J.W. Nielsen: Wave conditions in the Baltic proper and in the Gulf of Finland during windstorm Gudrun, Nat Hazards Earth Syst. Sci., 8, 37-46, 2008. -FIG2. [MAP] Modelled wind speed (m/s) and direction 10m above water surface at 06:00GMT on 9Jan2005 in the DMI 54h forecast valid at 00:00GMT 9Jan -FIG3. [MAP] Modelled Hs (m) and wave propagation direction (arrow) at 06:00 GMT on 9Jan2005 in the DMI forecast valid at 00:00 GMT on 9Jan2005
Baker (2009)	Baker, L., Sting jets in severe northern European wind storms, Weather, 64, 143-148, 2009 -FIG4. [MAP] Cloud top temperature for the model system (defined at the temperature of the uppermost surface of 90% relative humidity at (a) 1800UTC 7Jan, (b) 2200UTC 7Jan, (c) 0300UTC 8Jan, (d) 0800UTC 8Jan, overplotted with contours of 950mb theta_w -FIG5. Model derived fields at 0400UTC 8Jan. (a) Earth-relative wind speed at 850mb with contours of 600mb RH

	(b) System-relative wind speed at 850mb with 3 selected contours of 850 mb theta_w (c) vertical east-west cross section along 56N showing system -relative wind strength, with red contours of RH and black contour of PV. Black and red boxes show the terminating regions of the back trajectories (d) origin points of the trajectories at 1800UTC 7Jan with black and red circles approximately enclosing trajectoreis that terminate inthe regions of black & red boxes in (c). Colour scale is pressure in mb. Contours of relh at 650mb are black and PV at 350mb in red -FIG7. [MAP] Model derived fields at 0900UTC 8Jan. System-relative wind strength at 850mb (shaded) with 3 selected contours of 850mb teta_w
Gardiner (2010)	Gardiner, Barry, Appendix 3: Background information on 11 storms selected for detailed analysis, European Forest Institute, Atlantic European Regional Office - EFIAtlantic, 161 pp. [PDF properties: datestamp 23Jul2010] -FIG9.2. [MAP] Maximum gust wind speed on 8-9Jan2005 (Alexandersson and Ivarsson, 2005)
SMHI (20111013)	SMHI, Gudrun - Januaristormen 2005,, https://www.smhi.se/kunskapsbanken/meteorologi/stormar-i-sverige/enskilda-stormar-och-ovader/gudrun-januaristormen-2005-1.5300, 13 oktober 2011 -FIG4. [MAP] Maximum gusts at 10m height for 8-9Jan2005. It should be underlined that gusts of 30m/s in forest areas of south and central Gotland caused significantly more damage than gusts of 35 m/s in coast regions where vegetation much thinner. Few measurements from 1969 indicate gusts >30m/s in north Gotland
SurgeWatch (2017)	SurgeWatch, Storm Event 11th January 2005, in Haigh, I.D., O. Ozsoy, M.P. Wadey, R.J. Nicholls, S.L. Gallup, T. Wahl, J.M. Brown,Data descriptor: An improved database of coastal flooding in the United Kingdom from 1915 to 2016, Scientific Data, 4: 170100, DOI: 10.1038/sdata.2017.100, 2017 [GERO] FIG1. [MAP] Met conditions at time of maximum water level (11/01/2005 18:00); trajectory overplotted FIG2. [MAP] Met conditions during event
Nielsen (2023)	Nielsen, J.W., Stormfloden den 8. januar 2005, https://ocean.dmi.dk/case_studies/surges/2005-01-08.php, last access:21Feb2023. -FIG3. [MAP] HIRLAM-S prognosis valid for 8Jan2005 kl 15Z [/Amstrup, DMI] -FIG4. [MAP] HIRLAM-S prognosis valid for 9Jan2005 kl 0Z [/Amstrup, DMI]
Seewetter - Kiel (2024)	Seewetter - Kiel: Orkantief Erwin, http://www.seewetter-kiel.de/seewetter/orkan_erwin.htm, last access: 10Dec2024 -FIG2. [MAP] Development of ground level charts [source: Wetterzentrale; Mario Lehwald] (a) analysis 07Jan2005 12:00UTC (b) analysis 07Jan2005 18:00UTC (c) analysis 08Jan2005 00:00UTC (d) analysis 08Jan2005 06:00UTC (e) analysis 08Jan2005 12:00UTC (f) analysis 08Jan2005 18:00UTC (g) analysis 09Jan2005 00:00UTC

Table S26. Satellite altimeter strip maps (arranged by year and then alphabetically)

Source	Full Reference and Notes
Wolf (2007)	Wolf, J.: Modelling of waves and setup for the storm of 11-12 January 2005, Proudman Oceanographic Institute, report no. 181, March 2007. -use of Jason & TOPEX altimeter data for wind speed and significant wave height to compare with model results -FIG7. Wind speed along JASON track at 11Jan2005 15:00 -FIG8. Wind speed along TOPEX track at 11Jan2005 15:00

Table S27. Meteorological data (arranged by year and then alphabetically)

Data type	Location	Time Interval	Full Reference and Notes
[TABLE, ERWIN] maximum average wind speed and 3-second gust	Southern Sweden stations	7-9Jan2005	Alexandersson H and KI Ivarsson, Januaristormen 2005, Faktablad nr 25, SMHI, https://www.smhi.se/download/18.18f5a56618fc9f08e832d664/1717805946933/faktablad_janstorm%5B1%5D.pdf, November 2005.
[FIGURE, ERWIN] maximum 3 second gust during hour	Hano, Maseskar, Vaxjo	8-9Jan2005	Alexandersson H and KI Ivarsson, Januaristormen 2005, Faktablad nr 25, SMHI, https://www.smhi.se/download/18.18f5a56618fc9f08e832d664/1717805946933/faktablad_janstorm%5B1%5D.pdf, November 2005.
[FIGURE, ERWIN] pressure, wind direction, air temperature	Vaxjo	8-9Jan2005	Alexandersson H and KI Ivarsson, Januaristormen 2005, Faktablad nr 25, SMHI, https://www.smhi.se/download/18.18f5a56618fc9f08e832d664/1717805946933/faktablad_janstorm%5B1%5D.pdf, November 2005.
[TEXT, ERWIN, GERO] maximum wind speeds	North Atlantic ships and offshore buoys	7-8Jan2005 and 10-11Jan2005	Bancroft, George P., Weather Review - North Atlantic Area, January through April 2005, Mariners Weather Log, vol. 49, No. 2, Marine https://www.vos.noaa.gov/MWL/aug_05/north_atlantic.shtml, Aug 2005.
[MAP, GERO] highest gusts	Scotland and Northern Ireland stations	11-12Jan2005	Brown, Paul R., The violent gale of 11-12 January 2005 in the north of Scotland, Journal of Meteorology, 30, 104-106, 2005
[TEXT, GERO] highest gusts	Belmullet, Buoy K4, North Rona, Sule Skerry, Aonach Mor, Cairngorm, Ullapool	11-12Jan2005	Brown, Paul R., The violent gale of 11-12 January 2005 in the north of Scotland, Journal of Meteorology, 30, 104-106, 2005

[TABLE, ERWIN] maximum wind speed and gust	Denmark stations	8Jan2005	DMI, Danmark ramt af landsdækkende storm, https://www.dmi.dk/nyheder/2005/danmark-ramt-af-landsdakkende-storm#:~:text=Stormen%20her%20i%20januar%202005,hen%20over%20den%20nordlige%20Nords%C3%B8. 10Jan2005
[FIGURE, ERWIN] gust and average wind speed	Stations in northern Germany and Denmark	8Jan2005 12:00 & 18:00	DWD, Orkan Erwin am 8. Januar 2005. https://www.dwd.de/DE/leistungen/besondereereignisse/stuerme/20050801_orkan_erwin.pdf?__blob=publicationFile&v=4, pdf timestamp: 07Feb2005
[FIGURE, ERWIN] average wind speed and gust	List/Sylt, Arkona/Ruegen, Brocken/Harz, Muenchen-Stadt, Wendelstein	7-10Jan2005	DWD, Orkan Erwin am 8. Januar 2005. https://www.dwd.de/DE/leistungen/besondereereignisse/stuerme/20050801_orkan_erwin.pdf?__blob=publicationFile&v=4, pdf timestamp: 07Feb2005
[TEXT, GERO] maximum wind speed	North Rona, Barra	11Jan2005	Guardian, Storms claim at least five lives (contributor: Adam Jay), https://www.theguardian.com/environment/2005/jan/12/weather.climatechange1, 12 January 2005
[TABLE, ERWIN] maximum gust	Great Dun Fell (Cumbria), St. Bees Head (Cumbria), Loftus (Cleveland), Warcop (Cumbria), Leeming, Albermarle, Dishforth, Crosby	8-9Jan2005	Jameson D., Weather extremes 2005. January 7th-8th Severe storm development, https://user.eumetsat.int/resources/case-studies/rapid-cyclogenesis-in-the-north-atlantic, pdf timestamp: 17/03/2005
[TEXT, GERO] Maximum wind speed	North Rona, Barra	11Jan2005	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ
[FIGURE] 10 minute average wind speed, gust	Heidrun	1-31Jan2005	Loginfo A/S: Heidrun EMS-Data, Month report, January 2005, 19 February 2005
[TABLE, ERWIN, GERO] maximum 10 min average wind speed of month	Ireland stations	11Jan2005	Met Eireann, Monthly Weather Bulletin, No 225, Jan 2005
[TABLE, ERWIN, GERO] maximum gust of month	Ireland stations	?	Met Eireann, Monthly Weather Bulletin, No 225, Jan 2005
[TABLE] Maximum wind speed	Ekofisk , Utsira, Stromtangen	10 min?	met.no info, Varsling av stormer og ekstremt vaer (contact information: KH Midtbo, M Lystad, D Kvamme), 10pp, No.18/2005, Oslo, 25 November 2005
[TEXT,FIGURE; ERWIN,GERO] mean wind speed, gust, wind direction, pressure	Draugen	1-31Jan2005	MIROS: Manedsrapport, januar 2005, Draugen - Naturdatainnsamling, ND/1022/05/01, 18 February 2005.
[TEXT,FIGURE; ERWIN,GERO] mean wind speed, gust, wind direction, pressure	Ekofisk	1-31Jan2005	MIROS, Ekofisk Monthly Report, January 2005, Doc No. ND/1024/05/01, MIROS, 29pp, 25February2005.
[TEXT,FIGURE; ERWIN,GERO] mean wind speed, gust, wind direction, pressure	Heimdal	1-31Jan2005	MIROS: Manedsapport, januar 2005, Heimdal - Naturdatainnsamling, ND/1047/05/01, 28 February 2005.
[FIGURE; ERWIN,GERO] mean wind speed, gust, wind direction, pressure	Sleipner	1-31Jan2005	MIROS: Manedsrapport, januar 2005, Sleipner A - Naturdatainnsamling, ND/1017/05/01, 17 February 2005
[FIGURE; ERWIN,GERO] mean wind speed, gust, wind direction, pressure	Troll	1-31Jan2005	MIROS: Manedsrapport, januar 2005, Troll A - Naturdatainnsamling, ND/1012/05/01, 16 February 2005
[FIGURE; ERWIN,GERO] mean wind speed, gust, wind direction, pressure	Norne	1-31Jan2005	Oceanor Sandnes: Norne EMS-Data, Monthly Report January 2005, 16 February 2005.
[FIGURE, ERWIN] 10 min wind speed at 100m, 1s gust	FINO1	8Jan2005	Argyriadis, K., G. Fischer, P. Frohbose, D. Kindler, and F. Reher: Research platform FINO1 - Some measurement results, European Wind Energy Conference EWEC and Exhibition 2006, Athens, Greece, 27 February - 2 March 2006, Volume 2, pp. 906-915, ISBN: 978-1-62276-467-9, 2006.
[FIGURE, ERWIN] wind speed, gust, wind direction	Ruhnu	1-11Jan2005	Suursaar, U. and J. Sooaar, Storm surge induced by extratropical cyclone Gudrun: hydrodynamic reconstruction of the event, assessment of mitigation actions and analysis of future flood risks in Parnu, Estonia, WIT Transactions on Ecology and the Environment, vol.91, pp241-250, WIT Press, 2006.
[FIGURE, ERWIN] wind speed, gust, wind direction	Ruhnu, Vilsandi	1-11Jan2005	Suursaar, U., T. Kullas, M. Otsmann, I. Saarmae, J. Kuik, M. Merilain, Cyclone Gudrun in January 2005 and modelling its hydrodyanamic consequences in the Estonian coastal waters, Boreal Environmental

			Research, 11, 143-159, 2006.
[FIGURE, ERWIN,GERO] Average wind speed	Hovsore 80m mast	Jan-Feb, 2005	Hasager CB, P Astrup, M Nielsen, MB Christiansen, J Badger, P Nielsen, PB Soorensen, RJ Barthelmie, SC Pryor, H Bergstroom, SAT-WIND project Final Report, Riso-R-1586(EN), Riso National Laboratory, Technical University of Denmark, Roskilde, Denmark, April, 2007.
[TEXT, ERWIN] gust	Ronaldsway on Isle of Man	instanteous	Hisscott, Alan, When NWP met climatology: storms over the Isle of Man during January 2005,'Weather, 62, 74-77, 2007
[TABLE] maximum gust	Brocken	8Jan2005	Mueller-Westermeier, Gerhard, Beschreibung un klimatologische Bewertung des Orkantiefs "Kyrill", pdf properties: Title: Deutscher Wetterdienst - Nationale Klimauberwachung, Author: Gerhard Mueller-Westermeier, Subjet: Orkan Kyrill, datestamp: 26Jan2007
[FIGURE, ERWIN] maximum average wind speed and gust	FINO1 mast	Jan2005	Neumann, T., FINO and the mast shadow effect, 52nd IEA Topical Expert Meeting, Wind and wave measurements at offshore locations, Berlin, Germany, February 2007, organized by TU Berlin and Germanischer Lloyd, International Energy Agency, Implementing Agreement for Co-operation in the Research, Development and Deployment of Wind Turbine Systems, Task 11.
[FIGURE, ERWIN,GERO] wind speed	Buoys K5,M1, M2,M3,M4,M5	1-16 Jan2005	Wolf, J.: Modelling of waves and setup for the storm of 11-12 January 2005, Proudman Oceanographic Institute, report no. 181, March 2007.
[FIGURE, ERWIN] wind speed, gust, direction	Ruhnu & Vilsandi inEstonia	1-12Jan2005	Tonisson H, K Orviku, J Jaagus, U Suursaar, A Kont, R Rivis, Coastal damages on Saaremaa Island, Estonia, caused by the extreme storm and flooding on January 9, 2005, Journal of Coastal Research, 24, 602-614, 2008.
[FIGURE, ERWIN] wind speed	FINO1	8Jan2005	Emeis, S. and M. Turk, Wind-driven wave heights in the German Bight, Ocean Dynamics, 59, 463-475, 2009
[TABLE, GERO] gust	North east Atlantic buoy	Instantaneous on 12Jan2005	Tetzlaff, G., Extreme rain and wind storms in the mid-latitudes I, Singapore, 21-22.04.2009. https://imsarchives.nus/edu.sg/oldwww/Programs/09fluidss/files/Gerd Tetzlaff.pdf (Spring School on Fluid Mechanics and Geophysics of Environmental Hazards, Singapore, April 19-May 2, 2009) [pdf datestamp: 14/05/2009]
[FIGURE, ERWIN] maximum gust (in hour?)	Hano, Maseskare, Vaxjo	8-9Jan2005	Gardiner, Barry, Appendix 3: Background information on 11 storms selected for detailed analysis, European Forest Institute, Atlantic European Regional Office - EFIAtlantic, 161 pp. [PDF properties: datestamp 23Jul2010]
[FIGURE, ERWIN] maximum hourly gust	Hano, Maasekaar, Vaaxjoo	1 hour maximum	SMHI, Gudrun - Januaristormen 2005,, https://www.smhi.se/kunskapsbanken/meteorologi/stormar-i-sverige/enskilda-stormar-och-ovader/gudrun-januaristormen-2005-1.5300, 13 oktober 2011
[FIGURE; ERWIN,GERO] mean wind speed, gust, wind direction, pressure	Gullfaks C	1-31Jan2005	MIROS, Manedsrapport Gullfaks C, Januar 2005, ND/1013/05/01, 14 October 2013
[TEXT, ERWIN] maximum wind speed and gust	Hanstholm	8Jan2005	Pelt, S., Kraftige storme med oprindelse i Nordatlanten, Vejret, 137, 44-47, 2013
[TEXT, GERO] maximum wind speed , gust and direction	Benbecula, Barra, North Rona, Rueval South Uist	instantaneous	Angus, S. and A. Rennie, An Ataireachd Aird: The storm of January 2005 in the Uists, Scotland, Ocean & Coastal Management, 94, 22-29, 2014.
[FIGURE] wind speed and direction	Skanor, Gedser, Kiel, Swinoujscie, Klaipeda, Ristna, Hamina, Kemi	7-10Jan2005	Wolski, T., B. Wisniewski, A. Giza, H. Kowalewska-Kalkowska, H. Boman, S. Grabbi-Kaiv, T. Hammarklint, J. Holfort, Z. Lydeikaite, Extreme sea levels at selected stations on the Baltic coast, Oceanologia, 56, 259-290, 2014
[TEXT, GERO] maximum gust	Great Dun Fell in Cumbria	instantaneous	SurgeWatch, Storm Event 11th January 2005, in Haigh, I.D., O. Ozsoy, M.P. Wadey, R.J. Nicholls, S.L. Gallup, T. Wahl, J.M. Brown,Data descriptor: An improved database of coastal flooding in the United Kingdom from 1915 to 2016, Scientific Data, 4: 170100, DOI: 10.1038/sdata.2017.100, 2017 [GERO]
[FIGURE, ERWIN] wind speed	Thyboron, Gniben	7-10Jan2005	Nielsen, J.W., Stormfloden den 8. januar 2005, https://ocean.dmi.dk/case_studies/surges/2005-01-08.php, last access:21Feb2023.
[TEXT, ERWIN] maximum gust	Stations in UK, Poland	7-9Jan2005	European Severe Weather Database, 7-9Jan2005, https://eswd.eu (last access 03Aug2024)
[TABLE, ERWIN]	Norway stations	7-9Jan2005	Wikipedia, Ekstremveret Gudrun,

maximum wind speed & gust			https://nn.wikipedia.org/wiki/Ekstremv%C3%AAret_Gudrun, last access: 29Apr2025
[TABLE, ERWIN] maximum wind speed and gust	Sweden stations	7-9Jan2005	Wikipedia, Ekstremveret Gudrun, https://nn.wikipedia.org/wiki/Ekstremv%C3%AAret_Gudrun, last access: 29Apr2025
[TABLE, ERWIN] maximum wind speed or gust	Hanstholm in Denmark, St. Bees Head in Cumbria UK	7-8Jan2005	Wikipedia, Ekstremveret Gudrun, https://nn.wikipedia.org/wiki/Ekstremv%C3%AAret_Gudrun, last access: 29Apr2025

Table S28. Significant wave height and sea state (arranged by year and then alphabetically)

Data type	Location	Time Interval	Full Reference and Notes
[TEXT, ERWIN, GERO] significant wave height	North Atlantic ships and offshore buoys	7-8Jan2005 and 10-11Jan2005	Bancroft, George P., Weather Review - North Atlantic Area, January through April 2005, Mariners Weather Log, vol. 49, No. 2, Marine https://www.vos.noaa.gov/MWL/aug_05/north_atlantic.shtml, Aug 2005.
[TEXT,FIGURE; ERWIN,GERO] significant and maximum wave height	Heidrun	1-31Jan2005	Loginfo A/S: Heidrun EMS-Data, Month report, January 2005, 19 February 2005
[TABLE] Maximum significant wave height	Ekofisk , Utsira	30 min?	met.no info, Varsling av stormer og ekstremt vaer (contact information: KH Midtbo, M Lystad, D Kvamme), 10pp, No.18/2005, Oslo, 25 November 2005
[TEXT,FIGURE; ERWIN,GERO] significant and maximum wave height	Draugen	1-31Jan2005	MIROS: Manedsrapport, januar 2005, Draugen - Naturdatainnsamling, ND/1022/05/01, 18 February 2005.
[TEXT,FIGURE; ERWIN,GERO] significant and maximum wave height	Ekofisk	1-31Jan2005	MIROS, Ekofisk Monthly Report, January 2005, Doc No. ND/1024/05/01, MIROS, 29pp, 25February2005.
[TEXT,FIGURE; ERWIN,GERO] significant and maximum wave height	Heimdal	1-31Jan2005	MIROS: Manedsapport, januar 2005, Heimdal - Naturdatainnsamling, ND/1047/05/01, 28 February 2005.
[FIGURE; ERWIN,GERO] significant and maximum wave height	Sleipner	1-31Jan2005	MIROS: Manedsrapport, januar 2005, Sleipner A - Naturdatainnsamling, ND/1017/05/01, 17 February 2005
[FIGURE; ERWIN,GERO] significant and maximum wave height	Troll	1-31Jan2005	MIROS: Manedsrapport, januar 2005, Troll A - Naturdatainnsamling, ND/1012/05/01, 16 February 2005
[FIGURE; ERWIN,GERO] significant and maximum wave height	Norne	1-31Jan2005	Oceanor Sandnes: Norne EMS-Data, Monthly Report January 2005, 16 February 2005.
[FIGURE, ERWIN] significant and maximum wave height	FINO1	8 Jan 2005	Argyriadis, K., G. Fischer, P. Frohbose, D. Kindler, and F. Reher: Research platform FINO1 - Some measurement results, European Wind Energy Conference EWEC and Exhibition 2006, Athens, Greece, 27 February - 2 March 2006, Volume 2, pp. 906-915, ISBN: 978-1-62276-467-9, 2006.
[FIGURE, ERWIN, GERO] significant wave height	Buoy M1,M2,M3,M4,M5, Liverpool Bay	8-13Jan2005	Wolf, J.: Modelling of waves and setup for the storm of 11-12 January 2005, Proudman Oceanographic Institute, report no. 181, March 2007.
[FIGURE, ERWIN] significant wave height	Nymindegab	7-11Jan2005	Piontkowitz, Thorsten & Carlo Soerensen, Consequences of Climate Change along the Danish Coasts, Safecoast Action 5A, Danish Coastal Authority, Hojbovej 1, 7600 Lemvig, Denmark, kdi@kyst.dk, December 2008
[FIGURE] Significant wave height	FIMR buoy 1 in Baltic Sea, buoy 3 near island of Naisaar, near Helsinki	7-13 Jan 2005	Soomere, T., A. Behrens, L. Toumi, J.W. Nielsen: Wave conditions in the Baltic proper and in the Gulf of Finland during windstorm Gudrun, Nat Hazards Earth Syst. Sci., 8, 37-46, 2008.
[FIGURE, ERWIN] significant wave height	FINO1	8Jan2005	Emeis, S. and M. Turk, Wind-driven wave heights in the German Bight, Ocean Dynamics, 59, 463-475, 2009
[TABLE, ERWIN]	Liverpool	8Jan2005	Brown, J.M., A.J. Souza, J. Wolf: An investigation of recent decadal-scale storm events in eastern Irish Sea, J. Geophys. Res., 115, C05018, doi:10.1029/2009JC005662, 2010
[FIGURE; ERWIN,GERO] significant and maximum wave height	Gullfaks C	1-31Jan2005	MIROS, Manedsrapport Gullfaks C, Januar 2005, ND/1013/05/01, 14 October 2013

[FIGURE, ERWIN] high frequency waverider recording	Ekofisk	20 minute recrd from 8Jan2008	Bitner-Gregersen, E. and AK Magnusson, Effect of intrinsic and sampling variability on wave parameters and wave statistics, Ocean Dynamics, 64, 1643-1655, 2014

Table 29. Wave period and other wave data (arranged by year and then alphabetically)

Data type	Location	Time Interval	Full Reference and Notes
[FIGURE; ERWIN,GERO] mean zero upcrossing wave period	Heidrun	1-31Jan2005	Loginfo A/S: Heidrun EMS-Data, Month report, January 2005, 19 February 2005
[FIGURE; ERWIN,GERO] mean and peak wave period; wave direction	Draugen	1-31Jan2005	MIROS: Manedsrapport, januar 2005, Draugen - Naturdatainnsamling, ND/1022/05/01, 18 February 2005.
[TEXT,FIGURE; ERWIN,GERO] mean period	Ekofisk	1-31Jan2005	MIROS, Ekofisk Monthly Report, January 2005, Doc No. ND/1024/05/01, MIROS, 29pp, 25February2005.
[FIGURE; ERWIN,GERO] mean and peak wave period; wave direction	Heimdal	1-31Jan2005	MIROS: Manedsapport, januar 2005, Heimdal - Naturdatainnsamling, ND/1047/05/01, 28 February 2005.
[FIGURE; ERWIN,GERO] mean and peak wave period; wave direction	Sleipner	1-31Jan2005	MIROS: Manedsrapport, januar 2005, Sleipner A - Naturdatainnsamling, ND/1017/05/01, 17 February 2005
[FIGURE; ERWIN,GERO] mean and peak wave period; wave direction	Troll	1-31Jan2005	MIROS: Manedsrapport, januar 2005, Troll A - Naturdatainnsamling, ND/1012/05/01, 16 February 2005
[FIGURE; ERWIN,GERO] mean wave period	Norne	1-31Jan2005	Oceanor Sandnes: Norne EMS-Data, Monthly Report January 2005, 16 February 2005.
[FIGURE] Peak period	FIMR buoy 1 in Baltic Sea, buoy 3 near island of Naisaar, near Helsinki	7-13 Jan 2005	Soomere, T., A. Behrens, L. Toumi, J.W. Nielsen: Wave conditions in the Baltic proper and in the Gulf of Finland during windstorm Gudrun, Nat Hazards Earth Syst. Sci., 8, 37-46, 2008.
[FIGURE; ERWIN,GERO] mean and peak wave period; wave direction	Gullfaks C	1-31Jan2005	MIROS, Manedsrapport Gullfaks C, Januar 2005, ND/1013/05/01, 14 October 2013

Table S30. Surge reports and quantitative water levels (arranged by year and then alphabetically)

Data type	Location	Time Interval	Full Reference and Notes
[TEXT, ERWIN] extreme water level	Ringhals, Gotaborg, Smogen, Skanor (minimum)	8Jan2005	Alexandersson H and KI Ivarsson, Januaristormen 2005, Faktablad nr 25, SMHI, https://www.smhi.se/download/18.18f5a56618fc9f08e832d664/1717805946933/faktablad_janstorm%5B1%5D.pdf, November 2005.
[TEXT] Maximum water level	Logstor	8Jan2005	Beredskabstyrelsen, Beredskabets indsats i forbindelse med orkanen 8. januar 2005, En tvaergaende erfaringsopsamling, Beredskabssstyrelsen, Datavej16, 3460 Birkerod, Oktober 2005
[TABLE] Highest surge and highest water level (ERWIN, GERO)	UK tide gauge stations	8Jan2005 and 12Jan2005	Bradshaw, E. (ed.): Annual Report for 2005 for the UK national tide gauge network and related sea level science, National Tidal and Sea level Facility, NERC 100017897, 2005
[TEXT] Maximum water level	Bergen	7Jan2005, 12Jan2005	Golmen, LG and P Stenstrom, Bryggen i Bergen; Vassinntrenging i fundament og bolverk; Resultat av maalinger vinter/vaaren 5005, Rapport 5047-2005, Norsk institutt for vannforskning NIVA, August, 2005.
[TEXT] Highest water level	West Jutland, Limfjord	Instantaneous	Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005
[TEXT] Highest water level (ERWIN)	Helsinki	8Jan2005	Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005
[TEXT] Highest water level (ERWIN)	St. Petersburg	8Jan2005	Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005
[TABLE] water level (ERWIN, GERO)	List, Hoernum, Wittduen, Dagebuell, Hooge Anleger, Pellworm Anleger, Husum, Eidersperrwerk, Buesum, Helgoland, Cuxhaven, Brunsbuettel, Glueckstadt, Schulau, Hamburg St. Pauli	8Jan2005 and 12Jan2005	LKN.SH, Sturmfluten 2005, Hydrologischer Bericht Sturmfluten Nordsee und Elbe, 6pp., Januar 2005. report emailed by Hauke Thiesen 20 June 2023. [ERWIN-GERO]
[TEXT] Highest water level in nontidal Baltic Sea (ERWIN)	Helsinki, Loviisa nuclear power plant, St. Petersburg	8Jan2005	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ
[TEXT] Highest water level in nontidal Baltic Sea (ERWIN)	St. Petersburg	9Jan2005	Lloyds Casualty Week, 28Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ
[TABLE] probably highest water level, presented for seekart null for Bergen and	Ekofisk , Bergen, Oscarsberg	Instantaneous?	met.no info, Varsling av stormer og ekstremt vaer (contact information: KH Midtbo, M Lystad, D Kvamme), 10pp, No.18/2005, Oslo, 25 November 2005

Oscarsberg			
[TEXT,FIGURE; ERWIN,GERO] water level	Draugen	1-31Jan2005	MIROS: Manedsrapport, januar 2005, Draugen - Naturdatainnsamling, ND/1022/05/01, 18 February 2005.
[TEXT,FIGURE; ERWIN,GERO] water level	Ekofisk	1-31Jan2005	MIROS, Ekofisk Monthly Report, November 2007, Doc No. ND/1024/05/01, MIROS, 29pp, 25February2005.
[TEXT,FIGURE; ERWIN,GERO] water level	Heimdal	1-31Jan2005	MIROS: Manedsapport, januar 2005, Heimdal - Naturdatainnsamling, ND/1047/05/01, 28 February 2005.
[TABLE] highest water level and skew surge (ERWIN)	Hoek van Holland, Delfzijl	8Jan2005	RWS, Stormvloedflits 2005-02. Zeer zware zuidwesterstorm veroorzaakt vrij hoge waterstanden langs de kust (contributor Jan Kroos). https://open.rijkswaterstaat.nl/open-overheid/onderzoeksrapporten/%40257045/stormvloedflitsen-wmcn-kust/, 2005a
[TABLE] highest water level and skew surge (GERO)	Den Helder, Delfzijl, Vlissingen, Hoek van Holland	12Jan2005	RWS, Stormvloedflits 2005-03. Stormtij en storm met orkankracht veroorzaken hoge waterstanden langs de kust (contributor Jan Kroos). https://open.rijkswaterstaat.nl/open-overheid/onderzoeksrapporten/%40257045/stormvloedflitsen-wmcn-kust/, 2005b
[FIGURE] sea level (ERWIN, GERO)	Parnu	1-11Jan2005	Suursaar, U. and J. Sooaar, Storm surge induced by extratropical cyclone Gudrun: hydrodynamic reconstruction of the event, assessment of mitigation actions and analysis of future flood risks in Parnu, Estonia, WIT Transactions on Ecology and the Environment, vol.91, pp241-250, WIT Press, 2006.
[FIGURE] sea level (ERWIN, GERO)	Parnu	1-11Jan2005	Suursaar, U., T. Kullas, M. Otsmann, I. Saarmae, J. Kuik, M. Merilain, Cyclone Gudrun in January 2005 and modelling its hydrodyanamic consequences in the Estonian coastal waters, Boreal Environmental Research, 11, 143-159, 2006.
[TABLE] maximum water level (ERWIN)	Narva-Joesuu, Haapsalu, Dirhami, Virtsu, Heltermaa, Parnu, Kunda, Ristna, Toila, Port of Tallinn	9Jan2005	Suursaar, U., T. Kullas, M. Otsmann, I. Saarmae, J. Kuik, M. Merilain, Cyclone Gudrun in January 2005 and modelling its hydrodyanamic consequences in the Estonian coastal waters, Boreal Environmental Research, 11, 143-159, 2006.
[TABLE] highest water level (ERWIN)	Hojer Sluse, Havneby, Ballum, Ribe, Esberg, Hvide Sande Havn, Hvide Sand Havet, Thorsminde Havn, Ferring, Thyboron Havn, Thyboron Hav, Hanstholm, Hirtshals, Skagen, Ringkobing, Kloster, Skovlunde, Lemvig, Skive, Logstor, Nibe/Sebbersund, Norresundby, Hals, Grenaa, Sjaellands Odde, Hornbaek, Kobenhavn	8Jan2005	Sorensen C, SM Ingvardsen, I Andersen, BB Kloster, KDI, Hojvandsstatistikker 2007, Extreme sea level statistics for Denmark, 2007, Kystdirektoratet, Dec, 2007.
[FIGURE] water level (ERWIN)	Logstor	1-16Jan2005	Piontkowitz, Thorsten & Carlo Soerensen, Consequences of Climate Change along the Danish Coasts, Safecoast Action 5A, Danish Coastal Authority, Hojbovej 1, 7600 Lemvig, Denmark, kdi@kyst.dk, December 2008
[FIGURE] water level (ERWIN)	Hvide Sand	6-11Jan2005	Tonisson H, K Orviku, J Jaagus, U Suursaar, A Kont, R Rivis, Coastal damages on Saaremaa Island, Estonia, caused by the extreme storm and flooding on January 9, 2005, Journal of Coastal Research, 24, 602-614, 2008.
[FIGURE] water level (ERWIN, GERO)	Parnu	20Dec2004-20Jan2005	Tonisson H, K Orviku, J Jaagus, U Suursaar, A Kont, R Rivis, Coastal damages on Saaremaa Island, Estonia, caused by the extreme storm and flooding on January 9, 2005, Journal of Coastal Research, 24, 602-614, 2008.
[MAP] highest water level (ERWIN)	Turku, Hanko , Helsinki, Hamina, Vyborg , Narva, Toila, Suurpaa, Tallinn, Ristna, Parnu	9Jan2005	Averkiev, A.S. and K.A. Klevannyy, A case study of the impact of cyclonic trajectories on sea-level extremes in the Gulf of Finland, Continental Shelf Research, 30, 707-714, 2010.
[TABLE, ERWIN]	Liverpool, Heysham	8Jan2005	Brown, J.M., A.J. Souza, J. Wolf: An investigation of recent decadal-scale storm events in eastern Irish Sea, J. Geophys. Res., 115, C05018, doi:10.1029/2009JC005662, 2010
[MAP] highest water level (GERO)	North Uist and Benbecula	11-12Jan2005	Angus, S. and A. Rennie, An Ataireachd Aird: The storm of January 2005 in the Uists, Scotland, Ocean & Coastal Management, 94, 22-29, 2014.
[TABLE] highest water level (GERO)	Scarborough	12Jan2005	CH2MHill Halcrow, Cell 1 Regional Coastal Monitoring Programme, Wave Data Analysis Report 2: 2013-2014, Final Report, March 2014 [document properties: author=Andy.Parson@ch2m.com; datestamp; 04/04/2014]
[FIGURE] water level (ERWIN,GERO)	Hvide Sande	1-21Jan2005	Harwood, Phillip, Esurge final report, 15Feb2015, copyright CGI Ltd 2014
[TABLE] highest water level	Tallinn, Parnu	9Jan2005	Post, P. and T Kouts, Characteristics of cyclones causing extreme sea levels in the northern Baltic Sea, Oceanologia, 56,

			241-258, 2014.
[FIGURE] water level	Parnu	Jan2005	Post, P. and T Kouts, Characteristics of cyclones causing extreme sea levels in the northern Baltic Sea, Oceanologia, 56, 241-258, 2014.
[FIGURE] water level	Skanor, Gedser, Kiel, Swinoujscie, Klaipeda, Ristna, Hamina, Kemi	7-10Jan2005	Wolski, T., B. Wisniewski, A. Giza, H. Kowalewska-Kalkowska, H. Boman, S. Grabbi-Kaiv, T. Hammarklint, J. Holfort, Z. Lydeikaite, Extreme sea levels at selected stations on the Baltic coast, Oceanologia, 56, 259-290, 2014
[TABLE] highest water level	Ristna, Helsinki, Hanko, Hamina, Narva, Parnu	9Jan2005	Wolski, T., B. Wisniewski, A. Giza, H. Kowalewska-Kalkowska, H. Boman, S. Grabbi-Kaiv, T. Hammarklint, J. Holfort, Z. Lydeikaite, Extreme sea levels at selected stations on the Baltic coast, Oceanologia, 56, 259-290, 2014
[TEXT] highest water level (ERWIN)	Parnu	09Jan2005	Kulikov, E.A. and I.P. Medvedev, Extreme statistics of storm surges in the Baltic Sea, Oceanology, 57, 772-783, 2017
[TABLE] highest water level (ERWIN)	Ringhals	08Jan2005	Schold S, S Hellstrom, C-L Ivarsson, P Kallberg, H Lindow, S. Nerheim, S Schimanke, J Sodling, L Wern, Vattenstandsdynamik langs Sveriges kust, SMHI, Oceanografi, Nr. 123, 82 pp, 2017
[TABLE] highest water level, skew surge (GERO)	UK stations	12Jan2005	SurgeWatch, Storm Event 11th January 2005, in Haigh, I.D., O. Ozsoy, M.P. Wadey, R.J. Nicholls, S.L. Gallup, T. Wahl, J.M. Brown,Data descriptor: An improved database of coastal flooding in the United Kingdom from 1915 to 2016, Scientific Data, 4: 170100, DOI: 10.1038/sdata.2017.100, 2017
[TEXT, GRAPH] highest water level (ERWIN)	Parnu	09Jan2005	Palginomm V, K Orviku, U Suursaar, A Kont, H Tonnison, R Rivis, Lessons learned from record-high storm surges and associated inundations in Parnu, SW Estonia, Journal of Coastal Research, 85, 1-5, 2018.
[TABLE] Highest water level (ERWIN)	Turku, Hanko, Helsinki, Hamina	8Jan2005	Finnish Meteorological Institute, Sea level statistics, https://en.ilmatieteenlaitos.fi/sealevelstatistics, date stamp 29 November 2024 (last access: 19 December 2024)
[TABLE] Highest water level	Maloy (GERO), Bergen (GERO), Tregde (ERWIN)	8Jan2005 and 12Jan2005	Kartverket, Top 10 storm surges for Tregde, Stavanger, Bergen, Maloy, data lists emailed by Aksel Voldsund, 20 July 2024
[TABLE] Top 10 skew surge	Aberdeen (GERO), North Shields (GERO), Ilfracombe (ERWIN), Hinkley Point (ERWIN), Mumbles (ERWIN), Llandudno (ERWIN), Liverpool (ERWIN), Heysham (ERWIN), Portrush (GERO), Port Ellen (GERO), Tobermory (GERO), Kinlochbervie (GERO)	8Jan2005 and 12Jan2005	NTSLF, Skew surge history, https://ntslf.org/storm-surges/skew-surges, https://ntslf.org/storm-surges/skew-surges/scotland, https://ntslf.org/storm-surges/skew-surges/england-east, https://ntslf.org/storm-surges/skew-surges/england-south, https://ntslf.org/storm-surges/skew-surges/england-wales, https://ntslf.org/storm-surges/skew-surges/england_west, https://ntslf.org/storm-surges/skew-surges/isle-of-man, https://ntslf.org/storm-surges/skew-surges/northern-ireland, https://ntslf.org/storm-surges/skew-surges/channel-islands, (accessed 28Dec2024)
[TABLE] maximum water level	Ringhals (ERWIN)	8Jan2005	SMHI, Rekord: Vattenstand, https://www.smhi.se/data/oceanografi/havsvattenstand/rekord-havsvattenstand-1.2269, updated 26 November 2024, last access: 06 January 2025.
[TEXT] maximum water level	Ringhals (ERWIN)	8Jan2005	SMHI, Högvattenhändelser idag och i framtiden, https://www.smhi.se/klimat/stigande-havsnivaer/hogvattenhandelser-idag-och-i-framtiden, last access: 10Jan2025
[TEXT] maximum water level	Parnu Estonia	9Jan2005	Soomere, T., A. Behrens, L. Toumi, J.W. Nielsen: Wave conditions in the Baltic proper and in the Gulf of Finland during windstorm Gudrun, Nat Hazards Earth Syst. Sci., 8, 37-46, 2008.
[FIGURE] water level	Hirtshals, Skive, Thyboron, Esbjerg (ERWIN)	7-10Jan2005	Nielsen, J.W., Stormfloden den 8. januar 2005, https://ocean.dmi.dk/case_studies/surges/2005-01-08.php, last access:21Feb2023.
[TABLE] maximum water level	Denmark stations	8-9Jan2005	Nielsen, J.W., Stormfloden den 8. januar 2005, https://ocean.dmi.dk/case_studies/surges/2005-01-08.php, last access:21Feb2023.
[FIGURE] water level	Kemi, Helsinki, Landsort, Parnu	1-22Jan2005	Rantanen M, D van den Broek, J Corner, VA Sinclair, MM Johansson, J Sarkka, TK Laurila, and K Jylha, The impact of serial cyclone clustering on extremelyhigh sea levels in the Baltic Sea, Geophysical Research Letters, 51, e2023GL107203, https://doi.org/10.1029/2023GL107203, 2024.
[TABLE] maximum water level	Saint Petersburg	9Jan2005	Wikipedia, Floods in Saint Petersburg, https://en.wikipedia.org/wiki/Floods_in_Saint_Petersburg, 24Jan2025
[TABLE] maximum water level	Ireland: Ferry Bridge, Balls Bridge, Oranmore Bridge	8Jan2005	OPW, Hydrometric, https://waterlevel.ie/hydro-data/#/overview/Waterlevel/station/, Office of Public Works,

			last access: 11/02/2025.
[TABLE] maximum water level	Ballina	12Jan2005	OPW, Hydrometric, https://waterlevel.ie/hydro-data/#/overview/Waterlevel/station/, Office of Public Works, last access: 11/02/2025.

Table S31. Water current information (arranged by year and then alphabetically)

Data type	Location	Time Interval	Full Reference and Notes
[TEXT,FIGURE; ERWIN,GERO] current	Ekofisk	1-31Jan2005	MIROS, Ekofisk Monthly Report, November 2007, Doc No. ND/1024/05/01, MIROS, 29pp, 25February2005.

Table S32. Return period of water level; ranking of water level

Source	Full Reference and Notes
Alexandersson and Iversson (2005)	Alexandersson H and KI Ivarsson, Januaristormen 2005, Faktablad nr 25, SMHI, https://www.smhi.se/download/18.18f5a56618fc9f08e832d664/1717805946933/faktablad_janstorm%5B1%5D.pdf, November 2005. -rank 1 water level Ringhals & Smogen
Beredskabstyrelsen (2005)	Beredskabstyrelsen, Beredskabets indsats i forbindelse med orkanen 8. januar 2005, En tvaergaende erfaringsopsamling, Beredskabssstyrelsen, Datavej16, 3460 Birkerod, Oktober 2005 -highest water level ever in Logstor
CNN (20050109)	CNN, Weather. 13 killed as storm lashes Europe, http://edition.cnn.com/2005/WEATHER/01/09/europe.storm/, 09 Jan 2005. -Logstor Denmark: highest water ever in harbour (2.5m) 100s people evacuated
RWS (2005a)	RWS, Stormvloedflits 2005-02. Zeer zware zuidwesterstorm veroorzaakt vrij hoge waterstanden langs de kust (contributor Jan Kroos). https://open.rijkswaterstaat.nl/open-overheid/onderzoeksrapporten/%40257045/stormvloedflitsen-wmcn-kust/, 2005a -return period skew surge Delfzijl at 2X/y -return period water level at Delfzijl at 4X/year
RWS (2005b)	RWS, Stormvloedflits 2005-03. Stormtij en storm met orkankracht veroorzaken hoge waterstanden langs de kust (contributor Jan Kroos). https://open.rijkswaterstaat.nl/open-overheid/onderzoeksrapporten/%40257045/stormvloedflitsen-wmcn-kust/, 2005b -return period surg residual at Vlissengen 3X/year -return period water level at Vlissingen 2X/year
Suursaar and Sooaar (2006)	Suursaar, U. and J. Sooaar, Storm surge induced by extratropical cyclone Gudrun: hydrodynamic reconstruction of the event, assessment of mitigation actions and analysis of future flood risks in Parnu, Estonia, WIT Transactions on Ecology and the Environment, vol.91, pp241-250, WIT Press, 2006. -highest Parnu surges of 253cm & 275cm have theoretical recurrence periods of 500-1000y -2 highest surges occur as anomalies like tornado in wind speed record or tsunamis in sea level data
Suursaar et al (2006)	Suursaar, U., T. Kullas, M. Otsmann, I. Saarmae, J. Kuik, M. Merilain, Cyclone Gudrun in January 2005 and modelling its hydrodyanamic consequences in the Estonian coastal waters, Boreal Environmental Research, 11, 143-159, 2006. -Estonia record surge levels: Haapsalu, Virtsu, Parnu, Ristna, Toila, Port of Tallinn
Sorensen et al (2007)	Sorensen C, SM Ingvardsen, I Andersen, BB Kloster, KDI, Hojvandsstatistikker 2007, Extreme sea level statistics for Denmark, 2007, Kystdirektoratet, Dec, 2007. -ERWIN Hojer Sluse, rank=23, data period=87.2 year Havneby, rank=13, data period=46 year Ballum, rank=19, data period=72.2 years Ribe, rank=11, data period=87.7 years Esberg, rank=16, data period=133.8 years Hvide Sande Havn, rank=3, data period=75.2 years Hvide Sand Havet, rank=1, data period=21.3 years Thorsminde Havn, rank=1, data period=58.1 years Ferring, rank=1, data period=13.4 years Thyboron Havn, rank=1, data period=72.1 years Thyboron Hav, rank=1, data period=25.5 years Hanstholm, rank=4, data period=37.2 years Hirtshals, rank=4, data period=41.2 years Skagen, rank=7, data period=60.7years Ringkobing, rank=1, data period=36.2 years Kloster, rank=9, data period=35 years Skovlunde, rank=1, data period=35 years Lemvig, rank=1, data period=43.1 years Skive, rank=1, data period=11.2 years Logstor, rank=1, data period=76.1 years Nibe/Sebbersund, rank=13, data period=31.5 years Norresundby, rank=11, data period=34.4 years Hals, rank=8, data period=35.5 years Grenaa, rank=8, data period=29.8 years Sjaellands Odde, rank=9, data period=14 years Hornbaek, rank=40, data period=115.9 years Kobenhavn, rank=40, data period=119 years
Soomere et al (2008)	Soomere, T., A. Behrens, L. Toumi, J.W. Nielsen: Wave conditions in the Baltic proper and in the Gulf of Finland during windstorm Gudrun, Nat Hazards Earth Syst. Sci., 8, 37-46, 2008. -highest recorded storm surge in Parnu 275cm over mean sea level

	-new water level records west Estonia coast and Gulf of Finland
Tonisson et al (2008)	Tonisson H, K Orviku, J Jaagus, U Suursaar, A Kont, R Rivis, Coastal damages on Saaremaa Island, Estonia, caused by the extreme storm and flooding on January 9, 2005, Journal of Coastal Research, 24, 602-614, 2008. -Parnu had record surge at 275cm
Angus and Rennie (2014)	Angus, S. and A. Rennie, An Ataireachd Aird: The storm of January 2005 in the Uists, Scotland, Ocean & Coastal Management, 94, 22-29, 2014. -mention that significant coastal erosion in Uists by major storms would have occurred 9 times in 144 years.
Kulikov and Medvedev (2017)	Kulikov, E.A. and I.P. Medvedev, Extreme statistics of storm surges in the Baltic Sea, Oceanology, 57, 772-783, 2017 -Parnu water level during Storm Erwin at 1000 y return period level according to Gumbel analysis -description of graphical method to fit parameters for Gumbel/Frechet/Weibull distributions
SurgeWatch (2017)	SurgeWatch, Storm Event 11th January 2005, in Haigh, I.D., O. Ozsoy, M.P. Wadey, R.J. Nicholls, S.L. Gallup, T. Wahl, J.M. Brown,Data descriptor: An improved database of coastal flooding in the United Kingdom from 1915 to 2016, Scientific Data, 4: 170100, DOI: 10.1038/sdata.2017.100, 2017 -GERO Tide_gauge Date_time RP_y Watlev_mCD Tide_mCD Skew_m Newhaven 13/01/2005 01:00 <1 7.26 6.9 0.36 Portsmouth 13/01/2005 01:00 <1 5.13 4.76 0.38 Bournemouth 11/01/2005 09:00 <1 2.52 2.29 0.23 Weymouth 11/01/2005 07:15 <1 2.55 2.37 0.19 Newlyn 11/01/2005 05:00 <1 5.83 5.65 0.18 St. Mary's 11/01/2005 05:00 <1 5.9 5.79 0.11 Ilfracombe 11/01/2005 06:15 <1 9.59 9.38 0.21 Hinkley Point 11/01/2005 07:15 <1 12.15 11.95 0.2 Newport 12/01/2005 08:15 <1 12.54 12.52 0.02 Mumbles 11/01/2005 06:45 <1 9.83 9.62 0.22 Milford Haven 11/01/2005 06:45 <1 7.34 7.15 0.2 Fishguard 11/01/2005 07:30 <1 5.21 5 0.21 Holyhead 11/01/2005 23:00 <1 6.3 5.66 0.65 Llandudno 11/01/2005 23:30 <1 8.3 7.68 0.62 Liverpool 11/01/2005 23:45 <1 10.4 9.41 1 Heysham 12/01/2005 00:00 2 10.85 9.81 1.03 Workington 12/01/2005 00:15 <1 9.26 8.36 0.9 Port Erin 12/01/2005 00:00 <1 6.01 5.32 0.69 Portpatrick 12/01/2005 00:15 1 4.62 3.84 0.78 Millport 12/01/2005 01:30 <1 4.17 3.36 0.81 Port Ellen 11/01/2005 18:45 2 1.81 0.7 1.11 Tobermory 11/01/2005 19:00 71 6.06 4.55 1.51 Stornaway 12/01/2005 08:00 17 5.89 5.19 0.7 Ullapool 12/01/2005 08:15 57 6.44 5.52 0.93 Kinlochbervie 12/01/2005 08:30 70 6.28 5.22 1.06 Lerwick 12/01/2005 12:00 5 2.86 2.39 0.47 Wick 12/01/2005 12:30 65 4.5 3.74 0.76 Aberdeen 12/01/2005 14:30 57 5.31 4.54 0.76 North Shields 12/01/2005 16:45 16 6.11 5.38 0.73 Immingham 12/01/2005 19:00 4 8.29 7.42 0.87 Cromer 12/01/2005 20:00 4 6.13 5.32 0.81 Lowestoft 12/01/2005 22:30 3 3.68 2.67 1.01 Harwich 13/01/2005 01:30 1 4.7 4.06 0.64 Sheerness 13/01/2005 02:00 <1 6.31 5.81 0.49 Dover 13/01/2005 00:30 2 7.55 6.85 0.7
OPW (2025)	OPW, Hydrometric, https://waterlevel.ie/hydro-data/#/overview/Waterlevel/station/, Office of Public Works, last access: 11/02/2025. Station Nr Date Rk Retper_y Ferry Bridge 23061 08/01/2005 25 1.9 Balls Bridge 25061 08/01/2005 41 1.6 Oranmore Bridge 29015 08/01/2005 7 6.1 Ballina 34061 12/01/2005 17 3.3
Palginomm et al (2018)	Palginomm V, K Orviku, U Suursaar, A Kont, H Tonnison, R Rivis, Lessons learned from record-high storm surges and associated inundations in Parnu, SW Estonia, Journal of Coastal Research, 85, 1-5, 2018. -critical level 1.6m has 56 month return period (20 exceedances) -FIG3. Empirical return period graph based on monthly max sea levels at Parnu gauge 1924-2016
SMHI (2025)	SMHI, Högvattenhändelser idag och i framtiden, https://www.smhi.se/klimat/stigande-havsnivaer/hogvattenhandelser-idag-och-i-framtiden, last access: 10Jan2025 -return periods of water level in on Sweden west coast and souther Sweden can be read from GEV graphs

Table S33. Return period of wind speed; ranking of wind speed

Source	Full Reference and Notes
Blight (2005)	Blight, PJ: A discussion of the synoptic background and development of the 7-8Jan storm, https://user.eumetsat.int/resources/case-studies/rapid-cyclogenesis-in-the-north-atlantic, pdf time stamp 17/03/2005 -ERWIN: stongest winds in the UK for several years
DWD (2005)	DWD, Orkan Erwin am 8. Januar 2005.

	https://www.dwd.de/DE/leistungen/besondereereignisse/stuerme/20050801_orkan_erwin.pdf?__blob=publicationFile&v=4, pdf timestamp: 07Feb2005 -ERWIN -measured gust on List/Sylt assessed at 20y return period level
Guy Carpenter (2005)	Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005 -ERWIN/GUDRUN -most serious storm in 35 years
Deutsche Rueck (2006)	Deutsche Rueck, Sturmdokumentation Deutschland 2005, (contributors: T. Axer, T. Bistry, S Fietze, M Mueller, M Prechtl), Deutsche Rueckversicherung, Aktiengesellschaft, Hansaallee 177, 40549, Duesseldorf, March, 2006. -ERWIN -return period extreme winds Sweden at 40y return period level
Hiscott (2007)	Hisscott, Alan, When NWP met climatology: storms over the Isle of Man during January 2005,'Weather, 62, 74-77, 2007 -worst wind storm Isle of Man since Dec1999
SMHI (20111013)	SMHI, Gudrun - Januaristormen 2005,, https://www.smhi.se/kunskapsbanken/meteorologi/stormar-i-sverige/enskilda-stormar-och-ovader/gudrun-januaristormen-2005-1.5300, 13 oktober 2011 -FIG6. [MAP] Calculated return period for gusts during Storm Gudrun NOTE: gusts past 50y threshold near Goteborg -in worst-affected area return period >50y -in large pars of Smaaland, Haland, Skane gusts during Gudrun were at 20-50y level -locally in east Sveland winds gusts exceeded 20y level
Expressen (20170204)	Expressen, Gudrun 2005: 20 doedas i den vaarsta storm, https://www.expressen.se/nyheter/inloggad/gudrun-2005-20-dodas-i-den-varsta-stormen/, published 04Feb2017 09:25 -storms with same magnitude as Gudrun have average return period 30y -1969 storm of similar power passed over S Sweden with 37 million m3 timber fallen -Gudrun destroyed 75 million m3 timber

Table S34. Return period of significant wave height; ranking

Source	Full Reference and Notes
Emeis and Turk (2009)	Emeis, S. and M. Turk, Wind-driven wave heights in the German Bight, Ocean Dynamics, 59, 463-475, 2009 -extreme significant wave height Erwin had return period of 1-3 y -extreme significant wave height Britta had return period 20y

Table S35. Return period of insurance loss; ranking of insurance loss

Source	Full Reference and Notes
LCW (20050204)	Lloyds Casualty Week, 04Feb2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -Erwin/Gero was worst insurance storm in UK since Oct2000

Table S36. Storm trajectory map (arranged by year and then alphabetically)

Source	Full Reference and Notes
Alexandersson and Iversson (2005)	Alexandersson H and KI Ivarsson, Januaristormen 2005, Faktablad nr 25, SMHI, https://www.smhi.se/download/18.18f5a56618fc9f08e832d664/1717805946933/faktablad_janstorm%5B1%5D.pdf, November 2005. -FIG13. [MAP] Low pressure path at 3h intervals from 22CET 7Jan to 16CET 9Jan
Brown (2005)	Brown, Paul R., The violent gale of 11-12 January 2005 in the north of Scotland, Journal of Meteorology, 30, 104-106, 2005 -GERO storm trajectory
DWD (2005)	DWD, Orkan Erwin am 8. Januar 2005. https://www.dwd.de/DE/leistungen/besondereereignisse/stuerme/20050801_orkan_erwin.pdf?__blob=publicationFile&v=4, pdf timestamp: 07Feb2005 FIG2. [MAP] Trajectory of Hurricane ERWIN on 7-8Jan2005
Guy Carpenter (2005)	Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005 -FIG1. [MAP] Map showing affected areas and storm track Erwin; trajectory NOTE: AFFECTED CITIES: Carlisle, Logstor, Kobenhavn, Halmstad, Ljungby, Riga, Helsinki, St. Petersburg
Lindahl (2005)	Lindahl, Sture: The Storm Gudrun 2005-01-08, uploaded to Internet 19/10/2021, presentation 2005-05-12 -FIG. [MAP] Map of trajectory with affected regions and impacted cities: Carlisle, Logstor, Kobenhavn, Halmstad, Ljungby, Riga, Helsinki, St. Petersburg (this is the trajecotry map from the Guy Carpenter 2005 report)
Met.no info (2005)	met.no info, Varsling av stormer og ekstremt vaer (contact information: KH Midtbo, M Lystad, D Kvamme), 10pp, No.18/2005, Oslo, 25 November 2005 -FIG2. [MAP] Low pressure trajectory for storm Gudrun that developed 7-8Jan2005. blue points are storm pressure centre every 6h; red cross is low pressure center at time of satellite image at 03:00UTC 8Jan; white area just west for low pressure center is skyhatt and indicates sudden development of storm NOAA-16 Ekstrem 4 2005-01-08 02:55 -FIG3. [MAP] Low pressure trajectory for storm Gudrun that developed 7-8Jan2005. blue points are storm pressure centre every 6h; red cross is low pressure center at time of satellite image at 10:00UTC 8Jan; the image in FIG2 shows the same storm 7h earlier. The storm has gone through an explosive development in only 7h; note that the cloud system now is rolled up around the centre and that the skyhatten is not seen as a separate cloud cloud system

	-FIG4. Low pressure trajectory for storm Haarek (above) and for Inga (below) that developed in the period 10-14 Janaury 2005. Points on the blue curve give the low pressure centre every 6h. Red cross is the low pressure centre at the same time as the satellite picture
Haanpaa et al (2006)	Haanpaa, Simo, Samuli Lehtonen, Lasse Peltonen, Elena Talockaite, Impacts of winter storm Gudrun of 7th-9th January 2005 and measures taken in the Baltic Sea region, Astra, www.astra-project.org, 43pp, 2006 [pdf properties: datestamp 13/06/2006] -ERWIN FIG2. A map of the Baltic Sea region indicating the effects of Gudrun in the analyzed countries and case study areas: insured loss, power cut, storm trajectory, storm surge, coastal erosion
Suursaar and Sooaar (2006)	Suursaar, U. and J. Sooaar, Storm surge induced by extratropical cyclone Gudrun: hydrodynamic reconstruction of the event, assessment of mitigation actions and analysis of future flood risks in Parnu, Estonia, WIT Transactions on Ecology and the Environment, vol.91, pp.241-250, WIT Press, 2006. FIG1. [MAP] (a) The trajectory of the cyclone's eye on 7-10 January 2005 (b) study area
Suursaar et al (2006)	Suursaar, U., T. Kullas, M. Otsmann, I. Saarmae, J. Kuik, M. Merilain, Cyclone Gudrun in January 2005 and modelling its hydrodyanamic consequences in the Estonian coastal waters, Boreal Environmental Research, 11, 143-159, 2006. -FIG2. [MAP] The trajectory of the cyclone's eye on 7-9Jan2005
Tonisson et al (2008)	Tonisson H, K Orviku, J Jaagus, U Suursaar, A Kont, R Rivis, Coastal damages on Saaremaa Island, Estonia, caused by the extreme storm and flooding on January 9, 2005, Journal of Coastal Research, 24, 602-614, 2008. -FIG2. [MAP] The trajectory of the cyclone eye on January 7-10 2005 (after Carpenter 2005; Suursaar et al, 2006)
Baker (2009)	Baker, L., Sting jets in severe northern European wind storms, Weather, 64, 143-148, 2009 -FIG2. Track of model-derived cyclone centre every 4h between 1600 UTC 7Jan and 0800 UTC 8Jan, with mean sea-level pressure values (mbar) marked at each point
Averkiev and Klevannyy (2010)	Averkiev, A.S. and K.A. Klevannyy, A case study of the impact of cyclonic trajectories on sea-level extremes in the Gulf of Finland, Continental Shelf Research, 30, 707-714, 2010. -trajectories of cyclones that result in the worst storm surge flooding for different cities around the Gulf of Mexico
Brown et al (2010)	Brown, J.M., A.J. Souza, J. Wolf: An investigation of recent decadal-scale storm events in eastern Irish Sea, J. Geophys. Res., 115, C05018, doi:10.1029/2009JC005662, 2010 -FIG3. [MAP] Storm tracks generating the 5 largest surge events at Heysham. The track number relating it to a surge event is given in Tab1. The storm position is plotted every hour and the location at peak surge is marked by open circles.
Gardiner (2010)	Gardiner, Barry, Appendix 3: Background information on 11 storms selected for detailed analysis, European Forest Institute, Atlantic European Regional Office - EFIAtlantic, 161 pp. [PDF properties: datestamp 23Jul2010] -FIG9.1. [MAP] Storm track and affected regions. Swedish meteorological institute (2006)
SMHI (20111013)	SMHI, Gudrun - Januaristormen 2005,, https://www.smhi.se/kunskapsbanken/meteorologi/stormar-i-sverige/enskilda-stormar-och-ovader/gudrun-januaristormen-2005-1.5300, 13 oktober 2011 -ERWIN -FIG1. [MAP] low pressure location every 3h from 07Jan 22:00 to 09Jan 16:00; trajectory -FIG2. [MAP] Lines show the lowest air pressure (hPa) during passage of low pressure 8-9Jan2005. Trajectory of low pressure across central Sweden shown NOTE: isobars closer together on south side
Gardiner (2012)	Gardiner B, K Blennow, J-M Carnus, P Fleischer, F Ingemarson, G Landmann, M Lindner, M Marzano, B Nicoll, C Orazio, J-L Peyron, M-P Reviron, M-J Schelhaas, A Schuck, M Spielmann, T Usbeck, Destructive storm in European Forests: Past and Forthcoming Impacts, European Forest Institute, Atlantic European Regional Office - EFIAtlantic [pdf document properties: author=Barry Gardiner, datestamp=09Mar2012] FIG3a. [MAP] Paths of low pressure centres for selected storms. (Most tracks are derived from the NASA re-analysis of extratropical storms 1953 storm, Feb1967 storm, Sep1969 storm, Nov1972 storm, Oct1987 storm, Daria 1990, Vivian 1990, Lothar 1999, Martin 1999, Gudrun 2005, Kyrill 2007, Klaus 2009 FIG3b. [MAP] Estimated areas affected by selected storms. (The areas have been derived from reports and publications in Appendix 3 and are only prvided to allow an impressure of the impact area) 1953 storm, Feb1967 storm, Sep1969 storm, Nov1972 storm, Oct1987 storm, Daria 1990, Vivian 1990, Lothar 1999, Martin 1999, Gudrun 2005, Kyrill 2007, Klaus 2009
Post and Kouts (2014)	Post, P. and T Kouts, Characteristics of cyclones causing extreme sea levels in the northern Baltic Sea, Oceanologia, 56, 241-258, 2014. -FIG2. [MAP] Truncated trajectories of cyclones associated with the most extreme sea levels at Parnu: 18Oct1967 (green) and 9Jan2005 (red). The 2 blue lines encompass the sector for the trajectories of all other cyclones that causes at least +150cm sea levels at Parnu -FIG3. [MAP] Trajectories of cyclones causing extreme sea levels at Parnu: 18Oct1967 and 9Jan2005. Six tracks from the same cluster are shown for both periods; the longest ones are truncated at both ends. The numbers on the lines show the date and time of the cyclone's position.
Schold et al (2017)	Schold S, S Hellstrom, C-L Ivarsson, P Kallberg, H Lindow, S. Nerheim, S Schimanke, J Sodling, L Wern, Vattenstandsdynamik langs Sveriges kust, SMHI, Oceanografi, Nr. 123, 82 pp, 2017 FIG1_p68. [MAP] Air pressure 2005/01/08 1700Z. Storm Gudrun. Color field gives highest gust field during the entire storm. Hourly location of low pressure centre shown by blue crosses. Lowest pressure during storm shown by contour field

SurgeWatch (2017)	SurgeWatch, Storm Event 11th January 2005, in Haigh, I.D., O. Ozsoy, M.P. Wadey, R.J. Nicholls, S.L. Gallup, T. Wahl, J.M. Brown,Data descriptor: An improved database of coastal flooding in the United Kingdom from 1915 to 2016, Scientific Data, 4: 170100, DOI: 10.1038/sdata.2017.100, 2017 -GERO FIG1. [MAP] Met conditions at time of maximum water level (11/01/2005 18:00); trajectory overplotted
Rantanen et al (2023)	Rantanen M, D van den Broek, J Corner, VA Sinclair, MM Johansson, J Sarkka, TK Laurila, and K Jylha, The impact of serial cyclone clustering on extremelyhigh sea levels in the Baltic Sea, Geophysical Research Letters, 51, e2023GL107203, https://doi.org/10.1029/2023GL107203, 2024. -FIG1. [MAP] Location of the tide gauges used in the study. Black circle shows the 700km radius used to define SCC in Parnu. Background shading depicts MSLP on 9Jan2005 at 00:00UTC when Storm Gudrun hit the Baltic Sea. Dotted lines indicate tracks of the 4 ETCs preceding the January 2005 flooding with the track of Storm Gudrun in red. Legend shows the minimum MSLP of the ETCs and the dots of the tracks indicated the location of the ETC center every 3 h.

Table S37. Unusual pressure drop; time series central pressure; explosive characteristics; bomb; unusually low central pressure (arranged by year and then alphabetically)

Source	Full Reference and Notes
Bancroft (2005)	Bancroft, George P., Weather Review - North Atlantic Area, January through April 2005, Mariners Weather Log, vol. 49, No. 2, Marine https://www.vos.noaa.gov/MWL/aug_05/north_atlantic.shtml, Aug 2005. -explosive deepening of Erwin and Gero -Erwin pressure drop 41 hPa in 24 h -Gero pressure drop 45 hPa in 24h
Blight (2005)	Blight, PJ: A discussion of the synoptic background and development of the 7-8Jan storm, https://user.eumetsat.int/resources/case-studies/rapid-cyclogenesis-in-the-north-atlantic, pdf time stamp 17/03/2005 -ERWIN * -low deepening explosively under diffluence aloft -7Jan evening: pressure falls in 6-7mb/3h over Ireland -Erwin 7-8Jan developed over 18h; explosive cyclogenesis from upper air pattern -highest UK winds for several years.
Brown (2005)	Brown, Paul R., The violent gale of 11-12 January 2005 in the north of Scotland, Journal of Meteorology, 30, 104-106, 2005 -ERWIN: 8Jan2005: Erwin moved NE across Scotland, deepening rapidly 980-962 mb -GERO: next 30h moved steadily NE; gradually deepened to 985mb N of Azores by 1800GMT 10Jan -then rapid development: deepened by 10mb in next 6h; 19mb in following 6h; then 11 mb -midday 11Jan NW of Ireland with central pressure 945 mb
DWD (2005)	DWD, Orkan Erwin am 8. Januar 2005. https://www.dwd.de/DE/leistungen/besondereereignisse/stuerme/20050801_orkan_erwin.pdf?__blob=publicationFile&v=4 , pdf timestamp: 07Feb2005 -ERWIN -midday 8Jan2005 low P in Norwegian Sea; central P decrease 10hPa in 3h to 960hPa
Eitrheim (2005)	Eitrheim, K:, Rapport etter stormen 'Gudrun' lordag 8.1.2005 for Rogaland fylke, met.no, 11 January 2005 *-Saturday 0700: low pressure at east coast Scotland; dropped to 968hPa (16hPa in 6h)
EUMETSAT (2005)	EUMETSAT, Rapid cyclogenesis in the North Atlantic 6-8 January 2005, (contributors: Jochen Kerkmann and Gordon Bridge) https://www.eumetsat.int/rapid-cyclogenesis-north-atlantic published 06January2005, accessed 03Dec2022 -storm Erwin rapid cyclogenesis -7Jan2005 22:00UTC WV6.2 image shows dark stripe between cloud head & cloudiness from warm conveyor belt -dry intrusion from advection of dry sinking air from stratosph lower levels along cyclonic side of stream -already visible at 1500UTC -RGB composite that combines best 3 MSG features for early detection of rapid cyclogeneisis: WV6.2, WV6.2-7.3 BTD, IR9.7-10.8 BTD
Guy Carpenter (2005)	Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005 -ERWIN/GUDRUN -7Jan2005 18GMT pressure of storm centre just below 995mb; system hardly visible -next 12h storm moved rapidly NE, deepening 25mb (EXPLOSIVE DEEPENING) -06:00 08Jan2005 (Sat) central pressure below 970mb; located east of UK
Met Eireann (2005010)	Met Eireann, Monthly Weather Bulletin, No 225, Jan 2005 -lowest pressure of month on 8Jan at Malin Head
RWS (2005a)	RWS, Stormvloedflits 2005-02. Zeer zware zuidwesterstorm veroorzaakt vrij hoge waterstanden langs de kust (contributor Jan Kroos). https://open.rijkswaterstaat.nl/open-overheid/onderzoeksrapporten/%40257045/stormvloedflitsen-wmcn-kust/, 2005a -ERWIN -low pressure center deepened very rapidly over the North Sea
RWS (2005b)	RWS, Stormvloedflits 2005-03. Stormtij en storm met orkankracht veroorzaken hoge waterstanden langs de kust (contributor Jan Kroos). https://open.rijkswaterstaat.nl/open-overheid/onderzoeksrapporten/%40257045/stormvloedflitsen-wmcn-kust/, 2005b -GERO -low pressure centre deepened rapidly north of Scotland
Suursaar et al (2006)	Suursaar, U., T. Kullas, M. Otsmann, I. Saarmae, J. Kuik, M. Merilain, Cyclone Gudrun in January 2005 and modelling its hydrodyanamic consequences in the Estonian coastal waters, Boreal Environmental Research, 11, 143-159, 2006. -decrease in air pressure by 30hPa during 1day indicated energy & intensity

	-pressure nadir 960hPa NE of Oslo 20:00UTC 8Jan2005 -after nadir travelling speed of the low pressure centre decreased somewhat -pressure increase very slowly 962hPa over Finland & 970hPa above lake Onega Russia
Hisscott (2007)	Hisscott, Alan, When NWP met climatology: storms over the Isle of Man during January 2005,'Weather, 62, 74-77, 2007 -ERWIN -0000UTC 8Jan secondary low P 980mb approaching W coast Ireland with EXPLOSIVE DEEPENING -low P travelled across Ireland & N Irish Sea to S Scotland by 0536UTC -winds Isle of Man strongest in period 0430-0700UTC
Baker (2009)	Baker, L., Sting jets in severe northern European wind storms, Weather, 64, 143-148, 2009 -system passed over UK 1800UTC 7Jan to 1300UTC 8Jan -pressure decrease of 40 mb; similar to rapid decrease during Oct1987 storm (26mb in 12h) -satisfies Sanders & Gyakum (1980) definition meteorological bomb
SMHI (20111013)	SMHI, Gudrun - Januaristormen 2005,, https://www.smhi.se/kunskapsbanken/meteorologi/stormar-i-sverige/enskilda-stormar-och-ovader/gudrun-januaristormen-2005-1.5300, 13 oktober 2011 -storm deepened explosively; very mild moist air NW British Isles
Angus and Rennie (2014)	Angus, S. and A. Rennie, An Ataireachd Aird: The storm of January 2005 in the Uists, Scotland, Ocean & Coastal Management, 94, 22-29, 2014. -GERO: mention of unuusually low air pressure comparable with worst historical cases -low P value of 944 lower than other storms: 952 mb for Oct1987, 968mb for 31Jan1953 storm -925.5mb meas Ochtertyre, Perth & Kinross on 26Jan1884 -2 cases 19th century when Monach isles lighkeepers recorded air P less than 944mb -lower record 936.3mb on 12Nov1887
Post and Kouts (2014)	Post, P. and T Kouts, Characteristics of cyclones causing extreme sea levels in the northern Baltic Sea, Oceanologia, 56, 241-258, 2014. -Storm Erwin Jan2005 highest sea level on record since 1923 for Parnu & since 1842 for Tallinn -Erwin classified as explosive cyclone or bomb from Bergeron's definition (Roebber 1984)
Wikipedia (20250429)	Wikipedia, Ekstremveret Gudrun, https://nn.wikipedia.org/wiki/Ekstremv%C3%AAret_Gudrun, last access: 29Apr2025 -Low pressure developed W of Ireland 7Jan2005 -powerful jet stream contributed to explosive deepening as storm moved N_Ireland to Scotland

Table S38. Rapid increase of surface pressure after passage of low (arranged by year and then alphabetically)

Source	Full Reference and Notes
Blight (2005)	Blight, PJ: A discussion of the synoptic background and development of the 7-8Jan storm, https://user.eumetsat.int/resources/case-studies/rapid-cyclogenesis-in-the-north-atlantic, pdf time stamp 17/03/2005 -ERWIN -huge pressure rises during morning over N England and S Scotland in strong confluence behind upper trough (near 20mb in 3h up to 10Z, return rate 50y)
Brown (2005)	Brown, Paul R., The violent gale of 11-12 January 2005 in the north of Scotland, Journal of Meteorology, 30, 104-106, 2005 -ERWIN: abnormal rapid rise of pressure to rear
Suursaar et al (2006)	Suursaar, U., T. Kullas, M. Otsmann, I. Saarmae, J. Kuik, M. Merilain, Cyclone Gudrun in January 2005 and modelling its hydrodynamic consequences in the Estonian coastal waters, Boreal Environmental Research, 11, 143-159, 2006. -pressure increase very slowly 962hPa over Finland & 970hPa above lake Onega Russia

Table S39. Horizontal pressure gradient

Source	Full Reference and Notes
Alexandersson and Iversson (2005)	Alexandersson H and KI Ivarsson, Januaristormen 2005, Faktablad nr 25, SMHI, https://www.smhi.se/download/18.18f5a56618fc9f08e832d664/1717805946933/faktablad_janstorm%5B1%5D.pdf, November 2005. -discussion of horizontal pressure gradient in comparison of most serious storms for Gotaland -FIG10. [MAP] Surface air pressure analysis for the severe storms 25Dec1902, 22Sep1969, 8Jan2005
Blight (2005)	Blight, PJ: A discussion of the synoptic background and development of the 7-8Jan storm, https://user.eumetsat.int/resources/case-studies/rapid-cyclogenesis-in-the-north-atlantic, pdf time stamp 17/03/2005 -ERWIN: -gust St Bees Head at extreme end of scale >100mph; powerful indication of gradient
Brown (2005)	Brown, Paul R., The violent gale of 11-12 January 2005 in the north of Scotland, Journal of Meteorology, 30, 104-106, 2005 -GERO -pressure gradient on S flank extreme with geostrophic winds 175kt -pressure maintained similar depth passing between Scotland & Faroes -began to fill on entering Norwegian Sea 12Jan
Jameson (2005)	Jameson D., Weather extremes 2005. January 7th-8th Severe storm development, https://user.eumetsat.int/resources/case-studies/rapid-cyclogenesis-in-the-north-atlantic, pdf timestamp: 17/03/2005 -ERWIN -pressure gradient tightened as storm centre moved closer to strong high over central Europe -forecast of strong low moving across N Ireland & later Scotland; tight press grad at south -prediction of gusts to 70mph across parts of UK
Wikipedia (20250429)	Wikipedia, Ekstremveret Gudrun, https://nn.wikipedia.org/wiki/Ekstremv%C3%AAret_Gudrun, last access: 29Apr2025 -large differences in pressure between N & S Sweden led to strong wind with storm on night to 9Jan

Table S40. Low level jet

Source	Full Reference and Notes

Baker (2009)	Baker, L., Sting jets in severe northern European wind storms, Weather, 64, 143-148, 2009 -Erwin -low level jets associated with cold conveyor belt and warm conveyor belt
Clark and Gray (2018)	Clark, PA and SL Gray, Sting jets in extratropical cyclones: a review, Quarterly Journal of the Royal Meteorological Society, 144, 943-969, 2018. -sting jet storm also have low level jets associated with cold conveyor belt and warm conveyor belt.

Table S41. Sting Jet

Source	Full Reference and Notes
Blight (2005)	Blight, PJ: A discussion of the synoptic background and development of the 7-8Jan storm, https://user.eumetsat.int/resources/case-studies/rapid-cyclogenesis-in-the-north-atlantic, pdf time stamp 17/03/2005 -ERWIN -gust St Bees Head at extreme end of scale >100mph; powerful indication of gradient wind dragged down to sfc in typical sting jet scenario; gusts elsewhere 70-80mph
Guy Carpenter (2005)	Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005 -ERWIN/GUDRUN -indications that high winds of Denmark, S Sweden, N Britain due to STING JET -sting jets known to occur in low P systems like Erwin & cause damaging winds at surface -sting jet occurs when stream of strong upper air winds descends to ground at bent back tip
Haanpaa et al (2006)	Haanpaa, Simo, Samuli Lehtonen, Lasse Peltonen, Elena Talockaite, Impacts of winter storm Gudrun of 7th-9th January 2005 and measures taken in the Baltic Sea region, Astra, www.astra-project.org, 43pp, 2006 [pdf properties: datestamp 13/06/2006] -STING JET: dry air rushed downwards
Suursaar et al (2006)	Suursaar, U., T. Kullas, M. Otsmann, I. Saarmae, J. Kuik, M. Merilain, Cyclone Gudrun in January 2005 and modelling its hydrodyanamic consequences in the Estonian coastal waters, Boreal Environmental Research, 11, 143-159, 2006. -ERWIN/GUDRUN -sting jet within cyclone caused damaging winds at surface -sting jet when very strong upper level winds descends to ground at centre of low pressure
Hisscott (2007)	Hisscott, Alan, When NWP met climatology: storms over the Isle of Man during January 2005,'Weather, 62, 74-77, 2007 -timing and direction of winds consistent with sting jet phenomenon (Browning et al 2003); Gray (2003) gives overview process -secondary low had much more developed circulation with occluding warm air; Isle of Man sting jet
Baker (2009)	Baker, L., Sting jets in severe northern European wind storms, Weather, 64, 143-148, 2009 -analysis of sting jet associated with Storm Gudrun -sting jet originate in cloud head; air exits at tip of cloud head & descends -Gronas (1995) -very few cases of storms with sting jets identified in literature -Great storm 15-16Oct1987 with peak gusts>50m/s -Parton (2007): potential sting jet cases from MST mesosphere-stratopshere-troposphere radar -Parton (2009): windstorm Jeanette 27Oct2002 -paper focusses on Erwin/Gudrun 7-9Jan2005 -surface gusts to 40m/s -Carlisle flooding -strong surface winds & banded cloud-head structure suggest sting jet
Gray et al (2011)	Gray AL, O Martinez-Avarado, LH Baker, PA Clark, Conditional symmetric instability in sting-jet storms, QJRMS, 137, 1482-1500, 2011 -list of publications where the high wind field of certain storms has been linked to sting jets
Hewson and Neu (2015)	Hewson TD and U Neu, Cyclones, windstorms and the IMILAST project, Tellus A, 67, 27128, http://dx.doi.org/10.3402/tellusa.v67.27128, 2015 -ERWIN identified as a sting jet storm
Clark and Gray (2018)	Clark, PA and SL Gray, Sting jets in extratropical cyclones: a review, Quarterly Journal of the Royal Meteorological Society, 144, 943-969, 2018. -review of sting jet storm with Gudrun as example

Table S42. Radiosonde analysis

Source	Full Reference and Notes

Table S43. Stable/unstable atmospheric boundary layer

Source	Full Reference and Notes
Emeis and Turk (2009)	Emeis, S. and M. Turk, Wind-driven wave heights in the German Bight, Ocean Dynamics, 59, 463-475, 2009 -Storm Erwin: stable atmospheric boundary layer at FINO1 resulting from warm west wind; this resulted in low significant wave height compared with Storm Britta 2006
MIROS - Ekofisk (2005)	MIROS, Ekofisk Monthly Report, November 2007, Doc No. ND/1024/05/01, MIROS, 29pp, 25February2005.
MIROS - Heimdal (2005)	MIROS: Manedsapport, januar 2005, Heimdal - Naturdatainnsamling, ND/1047/05/01, 28 February 2005.
MIROS - Draugen (2005)	MIROS: Manedsrapport, januar 2005, Draugen - Naturdatainnsamling, ND/1022/05/01, 18 February 2005.
Oceanor Sandnes - Norne (2005)	Oceanor Sandnes: Norne EMS-Data, Monthly Report January 2005, 16 February 2005. -unstable atmospheric boundary layer conditions at Norne

Table S44. Problems with drag coefficient & forecasting wind setup at high wind speeds > 25m/s

Source	Full Reference and Notes
Averkiev and Klevannyy (2010)	Averkiev, A.S. and K.A. Klevannyy, A case study of the impact of cyclonic trajectories on sea-level extremes in the Gulf of Finland, Continental Shelf Research, 30, 707-714, 2010. -wind stress parameterization had to be adjusted to get the correct storm surge water level for certain historical storms -statement that spray and foam may reduce wind stress

Table S45. Strong jet stream & Rossby wave breaking

Source	Full Reference and Notes
Bancroft (2005)	Bancroft, George P., Weather Review - North Atlantic Area, January through April 2005, Mariners Weather Log, vol. 49, No. 2, Marine https://www.vos.noaa.gov/MWL/aug_05/north_atlantic.shtml, Aug 2005. -mention of stron jet in relation to Erwin
Guy Carpenter (2005)	Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005 -winds in upper troposphere at 9km shown in FIG3; jet stream in red -very strong upper level winds further accelerating to NE just aloft of storm initial phase -location of jet stream & large temperature difference between air masses allows storm to generate large amounts of energy, affecting intensity/speed/direction -highest winds of jet streak moved further NE -jet still located above low P system, helping further intensification
Haanpaa et al (2006)	Haanpaa, Simo, Samuli Lehtonen, Lasse Peltonen, Elena Talockaite, Impacts of winter storm Gudrun of 7th-9th January 2005 and measures taken in the Baltic Sea region, Astra, www.astra-project.org, 43pp, 2006 [pdf properties: datestamp 13/06/2006] -JET STREAM: located over low pressure centre; intensified condensation for the clouds & ppt
Wikipedia (20250429)	Wikipedia, Ekstremveret Gudrun, https://nn.wikipedia.org/wiki/Ekstremv%C3%AAret_Gudrun, last access: 29Apr2025 -Low pressure developed W of Ireland 7Jan2005 -powerful jet stream contributed to explosive deepening as storm moved N_Ireland to Scotland

Table S46. Storm clustering; upstream/downstream cyclogenesis (arranged by year and then alphabetically)

Source	Full Reference and Notes
Brown (2005)	Brown, Paul R., The violent gale of 11-12 January 2005 in the north of Scotland, Journal of Meteorology, 30, 104-106, 2005 -cluster of 3 storms : Erwin, Haarek, Gero
Guy Carpenter (2005)	Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005 -Gero crossed UK on way to Nordic region; storm track to N of Erwin -major disruption Scotland & N Ireland with wind speeds >54m/s -twin storm events common in Europe: Vivian and Wiebke (Germany, 1990), 25-25Dec1997 storms UK, and Lothar/Martin Dec1999
Suursaar et al (2006)	Suursaar, U., T. Kullas, M. Otsmann, I. Saarmae, J. Kuik, M. Merilain, Cyclone Gudrun in January 2005 and modelling its hydrodyanamic consequences in the Estonian coastal waters, Boreal Environmental Research, 11, 143-159, 2006. -min pressure Parnu 972hPa & Ristna 968hPa; 30hPa lower than lows 2,5,7,January & 10-11Jan -Gero followed Gudrun on 10-11Jan2005 with lowest air pressure N of Scotland 948hPa -pressure filled quickly after nadir -mild at Estonia; wspd 15m/s at Vilsandi & Ruhnu
Tonisson et al (2008)	Tonisson H, K Orviku, J Jaagus, U Suursaar, A Kont, R Rivis, Coastal damages on Saaremaa Island, Estonia, caused by the extreme storm and flooding on January 9, 2005, Journal of Coastal Research, 24, 602-614, 2008. -cyclones frequently come in pairs or as a series; preconditioning for high levels -FIG4. [TIMESERIES] Comparison of sea level variations during the two historically highest storm surges in Parnu
Pelt (2013)	Pelt, S., Kraftige storme med oprindelse i Nordatlanten, Vejret, 137, 44-47, 2013 -like end Dec1999, 2 storms developed Jan2005 within short period -first storm Gudrun 8Jan2005 -three days later Storm Gero hit N Ireland and Scotland
Post and Kouts (2014)	Post, P. and T Kouts, Characteristics of cyclones causing extreme sea levels in the northern Baltic Sea, Oceanologia, 56, 241-258, 2014. -Suursaar et al (2010) conclude 2 events with highest sea levels Parnu in 1967 & 2005 (+250 & +275 cm) are outliers or elements of other populations in ensemble of maxima -cause of sea level extrems in 1967 & 2005 could be the properties of a series of cyclones crossing the Baltic Sea rather than parameters of a single cyclone -clustering of cyclone tracks produces extreme cases that do not belong to ensemble of high surges -FIG1. [TIMESERIES] Two cases of extreme sea level max recorded at the Parnu coastal station on 17Oct1967 0800Z +250cm and 9Jan2005 0700Z +275cm. The horizontal axis shows time in days before and after the highest water level in Parnu -FIG3. [MAP] Trajectories of cyclones causing extreme sea levels at Parnu: 18Oct1967 and 9Jan2005. Six tracks from the same cluster are shown for both periods; the longest ones are truncated at both ends. The numbers on the lines show the date and time of the cyclone's position. -hypothesis that extreme sea level events might be caused not by one intense

	extra-tropical cyclone, but by temporal clustering of cyclones in trajectory corridor -sequence of 5 cyclones building up to extreme sea level with about 10 days similar in structure & periodicity
Medvedev and Kulikov (2021)	Medvedev, I.P. and E.A. Kulikov, Extreme storm surges in the Gulf of Finland: Frequency-spectral properties and the influence of low-frequency sea level oscillations, Oceanology, 61, 459-468, 2021. -chain of cyclones in Baltic Sea can cause resonant rocking effect
Rantanen et al (2023)	Rantanen M, D van den Broek, J Corner, VA Sinclair, MM Johansson, J Sarkka, TK Laurila, and K Jylha, The impact of serial cyclone clustering on extremelyhigh sea levels in the Baltic Sea, Geophysical Research Letters, 51, e2023GL107203, https://doi.org/10.1029/2023GL107203, 2024. -Gudrun was 4th of sequence of cyclones across Baltic region in period 1-9Jan2005
Wikipedia (20250429)	Wikipedia, Ekstremveret Gudrun, https://nn.wikipedia.org/wiki/Ekstremv%C3%AAret_Gudrun, last access: 29Apr2025 -Gudrun was 1st of 3 storms in 5 days; Haarek hit Nord Trondelag-Lofoten; Inga hit Vestlandet

Table S47. Squall line, convective thunderstorms, tornadoes (arranged by year and then alphabetically)

Source	Full Reference and Notes
DWD (2005)	DWD, Orkan Erwin am 8. Januar 2005. https://www.dwd.de/DE/leistungen/besondereereignisse/stuerme/20050801_orkan_erwin.pdf?__blob=publicationFile&v=4, pdf timestamp: 07Feb2005 -ERWIN FIG5. [SATELLITE] TERRA Satellite of NASA 08Jan2005 12:00?, showing cold front passing across Germany
ESWD (20240803)	European Severe Weather Database, 7-9Jan2005, https://eswd.eu (last access 03Aug2024) TORNADO Location LA Latitud Longitu Date Day Time Uncertainty ND --- Jürgenshagen Mecklenburg-Vorpomm DE 53.95 N 11.90 E 08-01-2005 sat 12:00 UTC (+/- 12 hrs.) tornado
Wikipedia (20250429)	Wikipedia, Ekstremveret Gudrun, https://nn.wikipedia.org/wiki/Ekstremv%C3%AAret_Gudrun, last access: 29Apr2025 -powerful ppt followed front, south of storm centre and flooded several places, mainly by overflow rivers

Table S48. Derecho (arranged by year and then alphabetically)

Source	Full Reference and Notes

Table S49. Cold air outbreak (arranged by year and then alphabetically)

Source	Full Reference and Notes
Alexandersson and Iversson (2005)	Alexandersson H and KI Ivarsson, Januaristormen 2005, Faktablad nr 25, SMHI, https://www.smhi.se/download/18.18f5a56618fc9f08e832d664/1717805946933/faktablad_janstorm%5B1%5D.pdf, November 2005. -NOAA satellite images showing cloud streets in cold air mass to west of storm center
Jameson (2005)	Jameson D., Weather extremes 2005. January 7th-8th Severe storm development, https://user.eumetsat.int/resources/case-studies/rapid-cyclogenesis-in-the-north-atlantic, pdf timestamp: 17/03/2005 -ERWIN -cold air behind low turned rain to sleet/snow -few cm covering higher routes; blizzards

Table S50. Unusual warm air temperature (arranged by year and then alphabetically)

Source	Full Reference and Notes
CNN (20050109)	CNN, Weather. 13 killed as storm lashes Europe, http://edition.cnn.com/2005/WEATHER/01/09/europe.storm/, 09 Jan 2005. -northern Germany: Germany had highest nighttime temp during storm (>10C) in more than 100y
DWD (2005)	DWD, Orkan Erwin am 8. Januar 2005. https://www.dwd.de/DE/leistungen/besondereereignisse/stuerme/20050801_orkan_erwin.pdf?__blob=publicationFile&v=4, pdf timestamp: 07Feb2005 -ERWIN -night to 8Jan parts of N Germany had highest day-minimum temperatures in 100y record
Guy Carpenter (2005)	Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005 -ERWIN/GUDRUN -Swedenforest damage: damage contribution from moist ground from mild and wet winter
Jameson (2005)	Jameson D., Weather extremes 2005. January 7th-8th Severe storm development, https://user.eumetsat.int/resources/case-studies/rapid-cyclogenesis-in-the-north-atlantic, pdf timestamp: 17/03/2005 -mild,moist SW airflow over UK first week 2005 -spells of heavy rainfall & gusty winds -south dry-bright-mild; temp well above average; 15C at Coningsby Lincolnshire
Suursaar and Sooaar (2006)	Suursaar, U. and J. Sooaar, Storm surge induced by extratropical cyclone Gudrun: hydrodynamic reconstruction of the event, assessment of mitigation actions and analysis of future flood risks in Parnu, Estonia, WIT Transactions on Ecology and the Environment, vol.91, pp.241-250, WIT Press, 2006. -unusually warm: temp Parnu -1C to +6C; met norm at -5C
Suursaar et al (2006)	Suursaar, U., T. Kullas, M. Otsmann, I. Saarmae, J. Kuik, M. Merilain, Cyclone Gudrun in January 2005 and modelling its hydrodyanamic consequences in the Estonian coastal waters, Boreal Environmental Research, 11, 143-159, 2006. -air temperatures well above norm since Dec2004
Rantanen (2005)	Rantanen, H., Chapter IV. Coping with Power Disturbances, in C. Pursiainen (ed), Early Warning and Civil Protection. When does it work and why does it fail? Nordregio report 2008:1, p.95-119 -stations had loss of heating; if there were low temperatures & snow stns would have been useless

	-mild weather meant situation not life-threatening; if cold weather siuation would be bad
Tonisson et al (2008)	Tonisson H, K Orviku, J Jaagus, U Suursaar, A Kont, R Rivis, Coastal damages on Saaremaa Island, Estonia, caused by the extreme storm and flooding on January 9, 2005, Journal of Coastal Research, 24, 602-614, 2008. -before storm air temp -1C to +5C in Parnu; met norm is -5C
Emeis and Turk (2009)	Emeis, S. and M. Turk, Wind-driven wave heights in the German Bight, Ocean Dynamics, 59, 463-475, 2009 -Storm Erwin: warm air temperatures at FINO1 create stable atmospheric conditions low significant wave height
Gardiner (2010)	Gardiner, Barry, Appendix 3: Background information on 11 storms selected for detailed analysis, European Forest Institute, Atlantic European Regional Office - EFIAtlantic, 161 pp. [PDF properties: datestamp 23Jul2010] -SWEDEN: storm preceded by period of mild weather -SWEDEN damage: situation mitigated by mild weather
Krzystyniak (2011)	Krzystyniak M, The relationship between extreme weather events and subsequent slide events in Norway, Master Thesis, Dept of Geosciences, University of Oslo, Sept. 2011 -warm temperatures registered during landslide events for Erwin & Gero

Table S51. Lightning (arranged by year and then alphabetically)

Source	Full Reference and Notes
Met Eireann (200501)	Met Eireann, Monthly Weather Bulletin, No 225, Jan 2005 -thunderstorm activity noted for 8Jan & 11Jan

Table S52. Meso-vortex or secondary low pressure centre (arranged by year and then alphabetically)

Source	Full Reference and Notes
Blight (2005)	Blight, PJ: A discussion of the synoptic background and development of the 7-8Jan storm, https://user.eumetsat.int/resources/case-studies/rapid-cyclogenesis-in-the-north-atlantic, pdf time stamp 17/03/2005 -ERWIN -8Jan 06Z elongated low P center from NE Scotland to off coast Berwick on Tweed; 2nd low appeared -elongation resulted in exceptionally strong pressure gradient North Channel to N England
Eitrheim (2005)	Eitrheim, K:, Rapport etter stormen 'Gudrun' lordag 8.1.2005 for Rogaland fylke, met.no, 11 January 2005 -Saturday 1300: low pressure split with main centre 958hPa ca 100km W of Jaren; secondary pressure 959 hPa just W of Bergen
Guy Carpenter (2005)	Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005 -Erwin began as perturb on polar front just W of Ireland -7Jan2005 18GMT pressure of storm centre just below 995mb; system hardly visible -cold air mass Greenland started to move southward colliding with warm moist air mass
Hisscott (2005)	Hisscott, Alan, When NWP met climatology: storms over the Isle of Man during January 2005,'Weather, 62, 74-77, 2007 -7Jan2005 large complex area low pressure from Denmark Strait to Scandinavia -slow moving frontal system over N of British Isles with prolonged heavy rain over Ronaldsway; 32mm or almost half of Jan 2005 amount -0000UTC 8Jan secondary low P 980mb approaching W coast Ireland with EXPLOSIVE DEEPENING -low P travelled across Ireland & N Irish Sea to S Scotland by 0536UTC

Table S53. Meteotsunami and unusual surges; double surges (arranged by year and then alphabetically)

Source	Full Reference and Notes
Suursaar and Sooaar (2006)	Suursaar, U. and J. Sooaar, Storm surge induced by extratropical cyclone Gudrun: hydrodynamic reconstruction of the event, assessment of mitigation actions and analysis of future flood risks in Parnu, Estonia, WIT Transactions on Ecology and the Environment, vol.91, pp.241-250, WIT Press, 2006. -reference to Parnu high surge level like tsunami in water level record; completely above expected trend
SurgeWatch (2007)	SurgeWatch, Storm Event 11th January 2005, in Haigh, I.D., O. Ozsoy, M.P. Wadey, R.J. Nicholls, S.L. Gallup, T. Wahl, J.M. Brown,Data descriptor: An improved database of coastal flooding in the United Kingdom from 1915 to 2016, Scientific Data, 4: 170100, DOI: 10.1038/sdata.2017.100, 2017 -GERO -wave study (Wolf, 2007; Wolf, 2009) -local wave setup very high 0.5m at South Uist due to large wave heights (14.3m) shoaling nearshore
Piontkowitz and Soerensen (2008)	Piontkowitz, Thorsten & Carlo Soerensen, Consequences of Climate Change along the Danish Coasts, Safecoast Action 5A, Danish Coastal Authority, Hojbovej 1, 7600 Lemvig, Denmark, kdi@kyst.dk, December 2008 -storm ERWIN 2005: double surge on Jutland west coast -max sea level 303cm reached 15:00; 2nd peak surge occurred few hours later 21:30-01:00 8Jan
Harwood (2014)	Harwood, Phillip, Esurge final report, 15Feb2015, copyright CGI Ltd 2014 -tide gauge water level time series for Hvide Sande 1-21Jan2005, showing double surge peak

Table S54. Maximum surface gusts noted (arranged by year and then alphabetically)

Source	Full Reference and Notes
Alexandersson and Iversson (2005)	Alexandersson H and KI Ivarsson, Januaristormen 2005, Faktablad nr 25, SMHI, https://www.smhi.se/download/18.18f5a56618fc9f08e832d664/1717805946933/faktablad_janstorm%5B1%5D.pdf, November 2005. -storm gusts in Sweden and Denmark as cause of remarkable timber fall -FIG7. [MAP] Maximum gust winds at 10m height 8-9Jan2005
Beredskabstyrelsen (2005)	Beredskabstyrelsen, Beredskabets indsats i forbindelse med orkanen 8. januar 2005, En tvaergaende erfaringsopsamling, Beredskabssstyrelsen, Datavej16, 3460 Birkerod, Oktober 2005 -highest water level ever in Logstor -storm trajectory from west to east; highest wind strength at Hanstholm avg=35m/s, gust to 46m/s

	-entire country with hurricane gusts
Blight (2005)	Blight, PJ: A discussion of the synoptic background and development of the 7-8Jan storm, https://user.eumetsat.int/resources/case-studies/rapid-cyclogenesis-in-the-north-atlantic, pdf time stamp 17/03/2005 -ERWIN -gust St Bees Head at extreme end of scale >100mph; powerful indication of gradient wind dragged down to sfc in typical sting jet scenario; gusts elsewhere 70-80mph -WV loops showed dry upper tropospheric air extending down to sfc, ensuring v strong gusts to SW of bent back occlusion -strongests winds now over North Sea; oil platforms reporting 100mph gusts; storm reaches Baltic
Brown (2005)	Brown, Paul R., The violent gale of 11-12 January 2005 in the north of Scotland, Journal of Meteorology, 30, 104-106, 2005 -GERO -high gusts on certain headlands & mountains -North Rona 116kt, mean 94kt -Sule Skerry 100kt -Aonach Mor 123kt -Cairngorm 117kt -Ullapool 110kt -FIG2. [MAP] Highest gust in knots reported during the night of 11-12Jan2005. Values in brackets indicate incomplete data; underlined station at high latitude
DMI (2005)	DMI, Danmark ramt af landsdækkende storm, https://www.dmi.dk/nyheder/2005/danmark-ramt-af-landsdakkende-storm#:~:text=Stormen%20her%20i%20januar%202005,hen%20over%20den%20nordlige%20Nords%C3%B8. 10Jan2005 -FIG. [MAP] highest 10-min avg wind in m/s (blue) during storm 8Jan2005. For most stations there is also max gust (red). Graph is updated with new and corrected values Monday 10Jan 14:00
DWD (2005)	DWD, Orkan Erwin am 8. Januar 2005. https://www.dwd.de/DE/leistungen/besondereereignisse/stuerme/20050801_orkan_erwin.pdf?__blob=publicationFile&v=4, pdf timestamp: 07Feb2005 -ERWIN -presentation of maps & time series of average wind speed and gusts in Germany and Denmark -sustained hurricane winds only at Brocken/Harz -hurricane gusts in coastal areas North Sea and Baltic Sea
Jameson (2005)	Jameson D., Weather extremes 2005. January 7th-8th Severe storm development, https://user.eumetsat.int/resources/case-studies/rapid-cyclogenesis-in-the-north-atlantic, pdf timestamp: 17/03/2005 -ERWIN -prediction of gusts to 70mph across parts of UK -slight potential of severe storm winds with gusts to 90mph across S Scotland & Cumbria -UK Met Office issued 'emergency severe weather warning'; first for some time -midnight low P just off W Ireland with central pressure 980hPa & mean wind40mph -low P continue to track ENE across Irish Sea & Scotland, wind incr & gusting >80mph * -small area of exceptionally strong winds on back edge of back-bent occlusion moving through border region with top gust 104mph at St. BeesHead on W coast Cumbria * & 130mph at Great Dun Fell; part of swath of damaging winds across N England -12Z depression moved out into North Sea & still deepening on approach to Norway/Denmark/Sweden bring further heavy rain & severe gales -Ekofisk reported gust 107mph -Rosnaes, Denmark reported 103mph gust -Hanstholm, Denmark reported 104mph gust at 16Z -widespread reports of gusts near 90mph in N Denmark & Baltic areas of Germany
Lindahl (2005)	Lindahl, Sture: The Storm Gudrun 2005-01-08, uploaded to Internet 19/10/2021, presentation 2005-05-12 -FIG. [MAP] Map of southern Sweden with contoured gust speeds -avg wspd 10-20ms; gusts to 42m/s -FIG. [MAP] Map of southern Sweden showing gust areas
Rosenorn (2005)	Rosenorn, Stig, Vintervejret 2004-2005, Vejret, 103, 23-25, 2005 -Storm Erwin/Gudrun had hurricane gusts in afternoon and evening 8Jan
Deutsche Rueck (2006)	Deutsche Rueck, Sturmdokumentation Deutschland 2005, (contributors: T. Axer, T. Bistry, S Fietze, M Mueller, M Prechtl), Deutsche Rueckversicherung, Aktiengesellschaft, Hansaallee 177, 40549, Duesseldorf, March, 2006. -ERWIN -stn List/Sylt reported peak gust of 148km/h; significantly over hurricane threshold Bf12 118km/h -in Germany highest wind speed German Bight -other stations NE Germany reported Bf12; Kap Arkon/Ruegen 126km/h & Schwerin 122km/h -wind reached hurricane strength at mountain stations -peak values at Brocken 166km/h -lowland stations like Aachen, Berlin-Dahlem, Flughafen Muenster/Osnabrueck had gusts around 100km/h -S Germany values under storm level except for mountain stations
Suursaar and Sooaar (2006)	Suursaar, U. and J. Sooaar, Storm surge induced by extratropical cyclone Gudrun: hydrodynamic reconstruction of the event, assessment of mitigation actions and analysis of future flood risks in Parnu, Estonia, WIT Transactions on Ecology and the Environment, vol.91, pp.241-250, WIT Press, 2006. -Saffir-Simpson classification: cyclone reasched hurricane strength; max wspd DK & SE -DMI: highest wind speed reached 34m/s -parts of Estonia in zone of cyclone highest wind speed -highest wind speed few 100 km on right hand side of cyclone trajectory -Estonia meas avg wspd up to 28m/s; gusts to 38m/s on west Estonia coast -malfunctioning instruments with gaps among highest wspds

Dawson et al (2007)	Dawson AG, S Dawson, W Ritchie, Historical climatology and coastal change associated with the 'Great Storm' of January 2005, South Uist and Benbecula, Scottish Outer Hebrides, Scottish Geographical Journal, 123, 135-149, 2007 -11Jan2005 hurricane winds blowing Nwards in advance of occluded front of frontal cyclone with central pressure 953mb, tracking SW-NE with gusts to 47m/s
Tonisson et al (2008)	Tonisson H, K Orviku, J Jaagus, U Suursaar, A Kont, R Rivis, Coastal damages on Saaremaa Island, Estonia, caused by the extreme storm and flooding on January 9, 2005, Journal of Coastal Research, 24, 602-614, 2008. -Saffir-Simpson scale cyclone reached hurricane strength from max wspd Denmark -max mean wspd 34m/s W coast Denmark & S Sweden -Estonia strong winds few 100 km S of cyclone center trajectory -gusts reached 38m/s Kihnu; 33-34m/s Ruhnu, Sorve, Vilsandi
Baker (2009)	Baker, L., Sting jets in severe northern European wind storms, Weather, 64, 143-148, 2009 -surface gusts to 40m/s in UK
Gardiner (2010)	Gardiner, Barry, Appendix 3: Background information on 11 storms selected for detailed analysis, European Forest Institute, Atlantic European Regional Office - EFIAtlantic, 161 pp. [PDF properties: datestamp 23Jul2010] -Great Britain -max gust 45m/s at lighthous St. Bees, Cumbria, NW England -Sweden -max 10m min wspd at coasta station Hanno at 33m/s & highest gusts 42m/s -inland stations max wsd/gust 15/33 m/s at Ljungby and 17/33m/s at Vaxjo -Ljungby station experienced power failure from storm -storm preceded by period of mild weather -storm 22Sep1969 had similar wspd but smaller in geographical extent & further north -Denmark -highest wspd during storm at Hanstholm in NW Jutland witn avg 35m/s & gust of 46m/s -Latvia -highest gust 38m/s -FIG9.2. [MAP] Maximum gust wind speed on 8-9Jan2005 (Alexandersson and Ivarsson, 2005) -FIG9.3. [TIMESERIES] Maximum gust wind speed on 8-9Jan2005 at the meteorological stations Hano, Masekar, Vaxjo
Angus and Rennie (2014)	Angus, S. and A. Rennie, An Ataireachd Aird: The storm of January 2005 in the Uists, Scotland, Ocean & Coastal Management, 94, 22-29, 2014. -GERO: surface gusts in Outer Hebrides
Nielsen (2023)	Nielsen, J.W., Stormfloden den 8. januar 2005, https://ocean.dmi.dk/case_studies/surges/2005-01-08.php, last access:21Feb2023. -FIG2. [MAP] Highest 10min avg wspd in m/s (blue) during 8Jan2005; most stations also have most powerful gust (red)
ESWD (20240803)	European Severe Weather Database, 7-9Jan2005, https://eswd.eu (last access 03Aug2024) SEVERE WIND Location LA Latitud Longitu Date Day Time Uncertainty ND --- Leba Pomorskie PL 54.75 N 17.54 E 07-01-2005 fri 20:30 UTC (+/- 30 min.) severe wind; wind speed: 25 m/s Ustka Pomorskie PL 54.75 N 17.54 E 07-01-2005 fri 17:30 UTC (+/- 30 min.) severe wind; wind speed: 26 m/s Leba Pomorskie PL 54.75 N 17.54 E 07-01-2005 fri 06:30 UTC (+/- 30 min.) severe wind; wind speed: 25 m/s Aberdaron Wales UK 52.82 N 4.70 W 08-01-2005 sat 12:00 UTC (+/- 1 day) severe wind; wind speed: 46 m/s Linton-on-Ouse Northern Ireland UK 54.05 N 1.25 W 08-01-2005 sat 12:00 UTC (+/- 1 day) severe wind; wind speed: 35.5 m/s Dishforth UK 54.14 N 1.41 W 08-01-2005 sat 12:00 UTC (+/- 1 day) severe wind; wind speed: 36.5 m/s Killowen Northern Ireland UK 54.07 N 6.16 W 08-01-2005 sat 12:00 UTC (+/- 1 day) severe wind; wind speed: 38.5 m/s Leeming UK 54.30 N 1.55 W 08-01-2005 sat 12:00 UTC (+/- 1 day) severe wind; wind speed: 38 m/s Loftus UK 54.55 N 0.88 W 08-01-2005 sat 12:00 UTC (+/- 1 day) severe wind; wind speed: 40 m/s Ronaldsway (Isle of Man) UK 54.08 N 4.63 W 08-01-2005 sat 12:00 UTC (+/- 1 day) severe wind; wind speed: 40.5 m/s Point of Ayre (Isle of Man) UK 54.41 N 4.37 W 08-01-2005 sat 12:00 UTC (+/- 1 day) severe wind; wind speed: 43.5 m/s St. Bees Head UK 54.52 N 3.63 W 08-01-2005 sat 12:00 UTC (+/- 1 day) severe wind; wind speed: 45.5 m/s Gdansk (Port Polnocny) Pomorskie PL 54.40 N 18.70 E 08-01-2005 sat 20:30 UTC (+/- 30 min.) severe wind; wind speed: 26 m/s Ustka Pomorskie PL 54.59 N 16.85 E 08-01-2005 sat 19:30 UTC (+/- 30 min.) severe wind; wind speed: 31 m/s Kolobrzeg (Uzdrowiska) Pomorskie PL 54.19 N 15.59 E 08-01-2005 sat 19:30 UTC (+/- 30 min.) severe wind; wind speed: 25 m/s Leba Pomorskie PL 54.75 N 17.54 E 08-01-2005 sat 18:30 UTC (+/- 30 min.) severe wind; wind speed: 31 m/s Gdynia-Kosakowo Pomorskie PL 54.57 N 18.52 E 08-01-2005 sat 18:30 UTC (+/- 30 min.) severe wind; wind speed: 27 m/s Chojnice Pomorskie PL 53.72 N 17.53 E 08-01-2005 sat 17:30 UTC (+/- 30 min.) severe wind; wind speed:

	25 m/s Swidwin Zachodniopomorskie PL 53.78 N 15.84 E 08-01-2005 sat 16:30 UTC (+/- 30 min.) severe wind; wind speed: 25 m/s Leba Pomorskie PL 54.75 N 17.54 E 09-01-2005 sun 12:30 UTC (+/- 30 min.) severe wind; wind speed: 27 m/s Ustka Pomorskie PL 54.59 N 16.86 E 09-01-2005 sun 12:30 UTC (+/- 30 min.) severe wind; wind speed: 25 m/s Hel Pomorskie PL 54.60 N 18.81 E 09-01-2005 sun 03:30 UTC (+/- 30 min.) severe wind; wind speed: 27 m/s Ustka Pomorskie PL 54.59 N 16.85 E 09-01-2005 sun 03:30 UTC (+/- 30 min.) severe wind; wind speed: 27 m/s Leba Pomorskie PL 54.75 N 17.54 E 09-01-2005 sun 01:30 UTC (+/- 30 min.) severe wind; wind speed: 31 m/s Siedlce Mazowieckie PL 52.18 N 22.25 E 09-01-2005 sun 01:30 UTC (+/- 30 min.) severe wind; wind speed: 28 m/s Gdynia-Kosakowo Pomorskie PL 54.57 N 18.52 E 09-01-2005 sun 00:30 UTC (+/- 30 min.) severe wind; wind speed: 30 m/s
Seewetter - Kiel (2024)	Seewetter - Kiel: Orkantief Erwin, http://www.seewetter-kiel.de/seewetter/orkan_erwin.htm, last access: 10Dec2024 -Erwin had gusts 130-180km/h in all of north that caused damage -Leuchturm Kiel gusts of almost 140km/h measured; Flensburg almost 160km/h; on west coast single gusts over 180km/s
Myhr (2025)	Myhr, K.J.: Storm puts focus on security, https://history.vattenfall.com/stories/power-to-the-people/storm-puts-focus-on-security/, last access: 24Jan2025.
Wikipedia (20250429)	Wikipedia, Ekstremveret Gudrun, https://nn.wikipedia.org/wiki/Ekstremv%C3%AAret_Gudrun, last access: 29Apr2025 -ERWIN -tabulated wind speed and gust data for Norway & Sweden; mention of highest winds at Hanstholm Denmark & St. Bees Head Cumbria UK

Table S55. Hurricane gusts/strongest winds on south (right) side of pressure center (arranged by year and then alphabetically)

Source	Full Reference and Notes
Brown (2005)	Brown, Paul R., The violent gale of 11-12 January 2005 in the north of Scotland, Journal of Meteorology, 30, 104-106, 2005 -pressure gradient on S flank extreme with geostrophic winds 175kt
DMI (2005)	DMI, Danmark ramt af landsdækkende storm, https://www.dmi.dk/nyheder/2005/danmark-ramt-af-landsdakkende-storm#:~:text=Stormen%20her%20i%20januar%202005,hen%20over%20den%20nordlige%20Nords%C3%B8. 10Jan2005 -Erwin: strongest winds N Jutland when low pressure centre over S Norway -Anatol: strongest winds southern Denmark when low P centre passed over N Jutland
Guy Carpenter (2005)	Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005 -very soon after storm formed strong winds developed in large areas S of centre -gales to N Germany, Denmark, W Sweden, North Sea
RWS (2005b)	RWS, Stormvloedflits 2005-03. Stormtij en storm met orkankracht veroorzaken hoge waterstanden langs de kust (contributor Jan Kroos). https://open.rijkswaterstaat.nl/open-overheid/onderzoeksrapporten/%40257045/stormvloedflitsen-wmcn-kust/, 2005b -GERO -on south side of depression, winds reached hurricane strength Bf12
Haanpaa et al (2006)	Haanpaa, Simo, Samuli Lehtonen, Lasse Peltonen, Elena Talockaite, Impacts of winter storm Gudrun of 7th-9th January 2005 and measures taken in the Baltic Sea region, Astra, www.astra-project.org, 43pp, 2006 [pdf properties: datestamp 13/06/2006] * -trajectory: Scotland-S Norway-S Sweden-Finland-Russian Karelia -highest winds S of trajectory because of vector averaging
Suursaar and Sooaar (2006)	Suursaar, U. and J. Sooaar, Storm surge induced by extratropical cyclone Gudrun: hydrodynamic reconstruction of the event, assessment of mitigation actions and analysis of future flood risks in Parnu, Estonia, WIT Transactions on Ecology and the Environment, vol.91, pp.241-250, WIT Press, 2006. -highest wind speed few 100 km on right hand side of cyclone trajectory
Suursaar et al (2006)	Suursaar, U., T. Kullas, M. Otsmann, I. Saarmae, J. Kuik, M. Merilain, Cyclone Gudrun in January 2005 and modelling its hydrodyanamic consequences in the Estonian coastal waters, Boreal Environmental Research, 11, 143-159, 2006. -zone of highest winds usually remains righthand from the cyclone eye track -local wind speed as vector sum of pressure gradient winds and travelling velocity of low P
Tonisson et al (2008)	Tonisson H, K Orviku, J Jaagus, U Suursaar, A Kont, R Rivis, Coastal damages on Saaremaa Island, Estonia, caused by the extreme storm and flooding on January 9, 2005, Journal of Coastal Research, 24, 602-614, 2008. -Estonia strong winds few 100 km S of cyclone center trajectory
Averkiev and Klevannyy (2010)	Averkiev, A.S. and K.A. Klevannyy, A case study of the impact of cyclonic trajectories on sea-level extremes in the Gulf of Finland, Continental Shelf Research, 30, 707-714, 2010. -storm surge for idealized storm always on right hand side of trajectory
SMHI (20111013)	SMHI, Gudrun - Januaristormen 2005,, https://www.smhi.se/kunskapsbanken/meteorologi/stormar-i-sverige/enskilda-stormar-och-ovader/gudrun-januaristormen-2005-1.5300, 13 oktober 2011 -FIG2. [MAP] Lines show the lowest air pressure (hPa) during passage of low pressure 8-9Jan2005. Trajectory of low pressure across central Sweden shown NOTE: isobars closer together on south side

Table S56. Wind direction, fetch and wave size in German Bight

Source	Full Reference and Notes
Emeis and Turk (2009)	Emeis, S. and M. Turk, Wind-driven wave heights in the German Bight, Ocean Dynamics, 59, 463-475, 2009 -Storm Erwin: investigation of dependence of significant wave height on wind speed, fetch & atmospheric stability -low significant wave height compared with storm Britta 2006

Table S57. Culmination time and location determines damage properties of storm

Source	Full Reference and Notes
Brown (2005)	Brown, Paul R., The violent gale of 11-12 January 2005 in the north of Scotland, Journal of Meteorology, 30, 104-106, 2005 -GERO -pressure maintained similar depth passing between Scotland & Faroes -began to fill on entering Norwegian Sea 12Jan
Guy Carpenter (2005)	Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005 -ERWIN/GUDRUN *-CULMINATION: nadir point 960mb on Sat afternoon NE of Oslo -after climax storm filled slowly but retained strength for 12h while moving east -on Sunday, when storm reached Baltic countries & Russia, winds continued to decline further.
Met.no info (2005)	met.no info, Varsling av stormer og ekstremt vaer (contact information: KH Midtbo, M Lystad, D Kvamme), 10pp, No.18/2005, Oslo, 25 November 2005 -this last storm different from first two: larger area and reached its max strength before reaching Norwegian coast -Inga continued strong at the Norwegian coast even if it had begun to decrease in strength
RWS (2005b)	RWS, Stormvloedflits 2005-03. Stormtij en storm met orkankracht veroorzaken hoge waterstanden langs de kust (contributor Jan Kroos). https://open.rijkswaterstaat.nl/open-overheid/onderzoeksrapporten/%40257045/stormvloedflitsen-wmcn-kust/, 2005b -GERO -night 11-12Jan around midnight, central pressure culminated at ca 950hPa
Dailey (2007)	Dailey, P., The 2006-2007 European winter storm season: winding down, Air Worldwide, http://www.air-worldwide.com/Publications/AIR-Currents/The-2006-2007-European-winter-storm-season, March 7, 2007 (last accessed July 9, 2014). -Franz -quite strong when it crossed British coast: min central pressure 950mb -weakened significantly by the time it reached central Europe; storm culmination time
Hisscott (2007)	Hisscott, Alan, When NWP met climatology: storms over the Isle of Man during January 2005,'Weather, 62, 74-77, 2007 -11Jan2005 low developed over Natl & tracked toward N Scotland -culmination: estimated central pressured reached 940mb as it passed close to NW Scotland -one of most intense depressions to affect W coast Scotland for many years
Averkiev and Klevannyy (2010)	Averkiev, A.S. and K.A. Klevannyy, A case study of the impact of cyclonic trajectories on sea-level extremes in the Gulf of Finland, Continental Shelf Research, 30, 707-714, 2010. -FIG5. [MAP] The most dangerous cyclone trajectories, velocities and positions of the cyclone centers at the moments of their maximum deepness for different points in the Gulf of Finland and Parnu. -model study shows that highest possible storm surge for cyclones that culminate just after maximum flood area
SMHI (20111013)	SMHI, Gudrun - Januaristormen 2005,, https://www.smhi.se/kunskapsbanken/meteorologi/stormar-i-sverige/enskilda-stormar-och-ovader/gudrun-januaristormen-2005-1.5300, 13 oktober 2011 -culmination? later on Saturday or night to Sunday as low P passed Sweden -lowest central pressure 960hPa at Norwegian border on Saturday evening
Post and Kouts (2014)	Post, P. and T Kouts, Characteristics of cyclones causing extreme sea levels in the northern Baltic Sea, Oceanologia, 56, 241-258, 2014. -latitude & longitude of the lowest pressure as a determining factor for extreme surges at Tallinn and Parnu

Table S58. Blocking high pressure system (arranged by year and then alphabetically)

Source	Full Reference and Notes
Suursaar et al (2006)	Suursaar, U., T. Kullas, M. Otsmann, I. Saarmae, J. Kuik, M. Merilain, Cyclone Gudrun in January 2005 and modelling its hydrodyanamic consequences in the Estonian coastal waters, Boreal Environmental Research, 11, 143-159, 2006. -cyclones from N or S do not produce extreme surges -strongest eastward winds during anticyclone blockage over Russia eg Dev1959 with -123cm at Parnu

Table S59. Infragravity wave, rogue wave, green water incidents (arranged by year and then alphabetically)

Source	Full Reference and Notes

Table S60. Seismic signature of storm; microseism (arranged by year and then alphabetically)

Source	Full Reference and Notes
ISC (2025)	International Seismic Centre, ISC Bulletin, https://www.isc.ac.uk/, last access 10Aug2025. -only 1 seismic even in northern Italy on 8-9Jan2005 during period of Storm Erwin

Table S61. Wave dynamics and dike breaches; wave runup studies (arranged by year and then alphabetically)

Source	Full Reference and Notes

Table S62. Precipitation, river level, river dike breaches, landslides (arranged by year and then alphabetically)

Source	Full Reference and Notes
Alexandersson and Ivarsson (2005)	Alexandersson H and KI Ivarsson, Januaristormen 2005, Faktablad nr 25, SMHI, https://www.smhi.se/download/18.18f5a56618fc9f08e832d664/1717805946933/faktablad_janstorm%5B1%5D.pdf, November 2005. -ERWIN -Friday: powerful convection cells in N part GB -Carlisle: 2900 properties with flooding damage -227mm rain in 72h with 120 mm on 7Jan to morning 8Jan -water level 1m higher than previous record
BBC (20050108)	BBC, Severe gales cause havoc on roads, http://news.bbc.co.uk/2/hi/uk_news/england/4157069.stm, 08January2005 -ERWIN -rain caused flooding in Haydon Bridge with 40 homes evacuated -no safe routes in or out of Carlisle -Andy Fraser, Environment Agency: >600 properties flooded in Cumbria -police evacuating people at Warden Paper Mill, 3 miles east of Hayden Bridge -flood warnings for River Tees & River Wear in Durham
BBC (20050110a)	BBC, Northern Europe shaken by storms, http://news.bbc.co.uk/2/hi/europe/4158809.stm, 10 January 2005a -ERWIN -UK flooding forced thousands to leave homes -Carlisle in NW England: 1000s moved to temporary accomodation as some 70000 homes lost power -northern England: man crushed by barn falling on caravan; 2 elderly women died in flooded properties
BBC (20050110b)	BBC, No quick fix to flood problem, http://news.bbc.co.uk/2/hi/uk_news/wales/4159471.stm, 10Jan2005b -ERWIN -some householders in Conwy valley facing financial ruin -some houses had flood damage Feb2004 & 8-9Jan2005 -Phil Jones (EA, Wales): 2 of biggest floods in living memory happened within 11 months -floods might not recur for 50y; extreme events rare -Coney burst banks on Saturday & damaged houses
Belfast Telegraph (20050110a)	Belfast Telegraph, Ulster braced for more storms (contributor Maureen Coleman), p.1, 10Jan2005 (Monday) -ERWIN -10Jan2005 Ulster bracing for more severe gales & torrential rain; storms continue to cause havoc across province -storm set to continue this week with break Wednesday 12Jan2005; gales & heavy rain later in week -many roads closed by flooding; worst cases Dromore & Newtown-hamilton; main Armagh road to Monaghan closed S of Middleton
Belfast Telegraph (20050110c)	Belfast Telegraph, Storms sweep northern Britain, p.6, 10Jan2005c (Monday) -ERWIN -motorists warned about travelling in Carlisle because of floods -rains to continue evening 11Jan-12Jan -several roads in the city remained closed -63y man killed barn blew down in Scottish border; bodies 2 elderly women found in flooded homes Carlisle -2 people missing in W Yorkshire & Morayshire Scotland; swept away in swollen rivers
Blight (2005)	Blight, PJ: A discussion of the synoptic background and development of the 7-8Jan storm, https://user.eumetsat.int/resources/case-studies/rapid-cyclogenesis-in-the-north-atlantic, pdf time stamp 17/03/2005 -Thu 6Jan2005, active conveyor belt system with frontal system across North Atlantic -heavy orographic rainfall stationary during day across Highland & Argyll; 50mm in higher region
CNN (20050109)	CNN, Weather. 13 killed as storm lashes Europe, http://edition.cnn.com/2005/WEATHER/01/09/europe.storm/, 09 Jan 2005. -Carlisle, UK: worst flooding in 40y -most access roads still underwater Sunday
EUMETSAT (2005)	EUMETSAT, Rapid cyclogenesis in the North Atlantic 6-8 January 2005, (contributors: Jochen Kerkmann and Gordon Bridge) https://www.eumetsat.int/rapid-cyclogenesis-north-atlantic published 06January2005, accessed 03Dec2022 -mountain observatory Capel Curig (Snowdonia) reported 225mm rain -more than 100 flood warnings issued by UK Environment Agency; -flooding Cumbria in Carlisle; water reached 2nd floor of some houses -Keswick badly flooded; residents evacuated by inflatable boats
Guardian (20050109)	Guardian, Thousands lose power in storms (contributor Henry McDonald), 9 January 2005. -ERWIN -worst affected counties Republic Cavan & Monaghan, with flooding -Galway: road Claddagh junction-Seapoint closed by flooding -Britain: gale winds and heavy rain caused problems: motorways closed, evacuations from flooded homes, power cuts -RAF evacuated people in Carlisle
Guardian (20050112)	Guardian, Storms claim at least five lives (contributor: Adam Jay), https://www.theguardian.com/environment/2005/jan/12/weather.climatechange1, 12 January 2005 -GERO -Scottish Environment Protection Agency issued 21 flood watches & 13 flood warnings during storms -Fort William coast guard: 4 elderly residents evacuated from housing complex -Oban coast guard: rescued man floating away in camper

	-recurrence of flooding in Cumbria; CG rescued couple from car in floodwater near Easton
Guy Carpenter (2005)	Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005 -ERWIN/GUDRUN -powerful winds and heavy rain caused widespread damage 7-8Jan2005 -power cuts across many regions & forcing 1000s people to be evacuated from flooded homes -Ireland: -several rivers burst banks & flooded roads -flood warning for River Shannon -UK: worst hit areas north of England, Wales, southern Scotland -most dramatic events in Carlisle with severe flooding -225mm rain northern England over weekend (8-9Jan) -storm caused rivers in regions to burst banks -Environment Agency: 7 severe flood warnings & 100 flood warnings -Carlisle in Cumbria hit by worse floods in 100years -2900 homes in city flooded according to EA -flooding also in Keswick, Kendall, Penrith; evacuations in Appleby, Longtown, Shap -torrential rain swelled River Eden with tributaries Petteril and Caldew -EA: 8km of Carlisle flood defenses breached -Carlisle cut off by flooding; 1000s people moved to temporary accommodation -Shap (high on River Eden catchment) 227 mm rain in 72 hours and 95mm on 7Jan -in parts of Carlisle, water levels reached 1.8m but receded on 9Jan -at height of storm: people rescued by helicopter from rooftop or picked up in boats -150 people evacuated from Warwick road -staff as Tesco store trapped inside building by rising water -schools across Carlisle closed & hospital operations cancelled -local Stagecoach fleet of 87 buses put out of action by floodwaters up to 1.2m at Willowholme depot -2 large industrial estates in city flooded -River Eden catchment covers 2300 km2 of NW England; drains lake district -precipitation behind Carlisle flood caused by warm, moisture laden air mid-Atlantic being forced over Cumbrian Mountains and Pennines -unusual to receive large amounts of ppt at both Lake District and Pennines -ground waterlogged -other flood factors: 80% of wetlands in Eden catchment lost since 1950s -areas drained to improve grazing potential of land -since 1968, substantial building taken place close to River Eden, including floodplain -EA: Carlisle floods worst for over 100y; last major flood 1968 with water levels ~1m lower -SWEDEN: road travel disrupted by fallen trees and flooding
Irish Times (20050108)	The Irish Times, Severe weekend weather leads to flooding (contributor James Fitzgerald), https://www.irishtimes.com/news/severe-weekend-weather-leads-to-flooding-1.404508, 8 January 2005 [ERWIN] -worst weather expected in south and southwest; 50 mm rain already fallen in some places -Bus Eireann last night reported delays up to 1h on some routes -problems with much water on roads; Athlone & Longford worst affected -railway: Iarnrod Eireann; -flooding forced Dublin-Tralee train to terminate Killarney; with replacement bus service -Cork: flooding on main Cork-Killarney road near Ballyvourney -severe flooding Foynes, County Limerick (Shannon estuary)
Irish Times (20050111)	The Irish Times, Man dies as storm causes power cuts and flooding (contributor Ciara O'Brien), https://www.irishtimes.com/news/man-dies-as-storm-causes-power-cuts-and-flooding-1.1295844, 11 January 2005 -GERO -Co Down: flooding closed dual-carriageway Newry to Warrenpoint (estuary road)
Jameson (2005)	Jameson D., Weather extremes 2005. January 7th-8th Severe storm development, https://user.eumetsat.int/resources/case-studies/rapid-cyclogenesis-in-the-north-atlantic, pdf timestamp: 17/03/2005 -ERWIN -wave formed on cold front over N Scotland 6Jan -rain fell over NW for 2 days until early Saturday 8Jan -parts of NW Scotland & N Wales had >100m in 72h to 8Jan2005 0600 -Capel Curig in Snowdonia reported 225mm rain ->100 flood warnings issued by EA -flooding Carlisle Cumbria to 2nd floor of some houses; peoplelifted off farmhouses -Keswick badly hit by flooding TAB1. 72h selected rainfall total to 8Jan2005 06Z Capel Curig, N Wales 225.4mm Loch Glascarnoch, NW Scotland 129.0 mm Eskdalemuir, SW Scotland 122.6 Keswick, Lake District 120.0 Tulloch Bridge, Scotland 98.0
LCW (20050121)	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -ERWIN: widespread flooding in UK with high winds & torrential rain -ERWIN: homes deluged in parts of Wales, Scotland, N England; some houses evacuated -ERWIN: Carlisle in Cumbria awash with water; cut off with no safe routes in or out -ERWIN: Keswick resident evacuations with inflatable boats -ERWIN: River South Tyne burst banks; 40 residents at Haydon Bridge evacuated

	-ERWIN: Llanrwst: several houses flooded; main A470 road flooded on either side of town -ERWIN: Scotland: severe warnings: -ERWIN: River Tay, between Kenmore and Dunkeld & Dunkeld and Perth -ERWIN: River Isla, between Bridge of Ruthven to the Tay -ERWIN: River Teith, Callendar -ERWIN: West Yorkshire: residents evacuated from handful of properties after River Wharfe broke banks at Otley & Ilkley -ERWIN: North Yorkshire: police said heavy rain causing problems at Wensleydale & Swaledale -ERWIN: floods inundated parts of Britain and left one ferry stranded -ERWIN: more than 100 flood warnings across England, Scotland & Wales -ERWIN: Carlisle flooded when River Eden burst banks; military helicopters call to evacuate 15 people from flooded homes. -ERWIN: flooding in Carlisle left schools, roads, police stations closed; court & hospital running on skeleton services -ERWIN: Carlisle to have less rain today but but could be affected by fresh gales Jan12 -ERWIN: schools in Carlisle, Wigton, Dalston are closed today -ERWIN: fire and police stations flooded & operating from temporary headquarters -ERWIN: 0545 UTC Jan10 24 flood warnings in England & Wales, 77 additional flood watches -ERWIN: two severe flood warnings of imminent danger to life and property: River Eden in Carlisle & River Caldrew in Denton Holme -ERWIN: Scottish EPA issued 8 severe flood warnings, 12 flood warnings, 25 flood watches -ERWIN: England: flooding forced 1000s to leave homes -ERWIN: Carlisle: 1000s of people moved into temp accommodation as 70000 homes lost power in flooding -ERWIN: northern England: man crushed when barn collapsed on caravan; 2 elderly women died in flooded properties -ERWIN: Southern Scotland also with bad flooding; forecast of gusts of up to 90mph before end of week -ERWIN: on Jan10 2230UTC seven flood warning in place for England and Wales and 30 flood watches -ERWIN: Scottish EPA: 3 severe flood warnings, 15 flood warnings, 19 flood watches -ERWIN: Wales: 50 properties in Conwy Valley, Llanrwst and Trefriw areas flooded -ERWIN: UK: 2 British men swept away in northern rivers and missing since Saturday -ERWIN: UK: 10000 homes in NE England without running water; weekend storms caused flooding -ERWIN: UK: police warned people against returning to homes in Carlisle; contaminated water & damaged cabling -GERO: SEPA Scottish Environmental Protection Agency: rain of wet ground; flooding warning
Met Eireann (200501)	Met Eireann, Monthly Weather Bulletin, No 225, Jan 2005 -highest day accumulation rainfall of Jan 2005 occurred on 7 Jan 2005 for most stations; values up to 40.0mm -heavy rain 7-8Jan2005 caused some severe flooding W half of country
NRK (20050108)	NRK, Gudrun herjar i sor (contributor Bent J. Tandstad), 8Jan2005 -ERWIN Rasfare -local large landslides in mountains in S Norway, especially in west -reports of difficult driving conditions in S inland areas in S Norway and in mountains in S Norway because of wind and ppt.
Detsche Rueck (2006)	Deutsche Rueck, Sturmdokumentation Deutschland 2005, (contributors: T. Axer, T. Bistry, S Fietze, M Mueller, M Prechtl), Deutsche Rueckversicherung, Aktiengesellschaft, Hansaallee 177, 40549, Duesseldorf, March, 2006. -ERWIN -dramatic photos of Carlisle flooding; several thousand people evacuated
Gardiner (2010)	Gardiner, Barry, Appendix 3: Background information on 11 storms selected for detailed analysis, European Forest Institute, Atlantic European Regional Office - EFIAtlantic, 161 pp. [PDF properties: datestamp 23Jul2010] -storm ERWIN -UK -night of 6-7Jan very strong thunder storms formed -Carlisle, river Eden flooded with damage to 2900 houses -upper parts of catchment had 227mm rain in 72h with 120mm in 24h to 8AM on 8an -river higher than 1m above previous record
Krzystyniak (2011)	Krzystyniak M, The relationship between extreme weather events and subsequent slide events in Norway, Master Thesis, Dept of Geosciences, University of Oslo, Sept. 2011 -high rainfalls registered for landslide events in Rogaland & Agder for Storm Erwin & Egersun-Kristiansund for Gero
ESWD (20240803)	European Severe Weather Database, 7-9Jan2005, https://eswd.eu (last access 03Aug2024) EXTREME RAIN Location LA Latitud Longitu Date Day Time Uncertainty ND --- Rydal Hall No 2 UK 54.45 N 2.98 W 07-01-2005 Fri 21:00 UTC (+/- 12 hrs.) precipitation: 180 mm duration of precipitation: 24 hours Honister UK 54.51 N 3.20 W 07-01-2005 Fri 12:00 UTC (+/- 12 hrs.) precipitation: 173 mm duration of precipitation: 24 hours
Wikipedia (20050429)	Wikipedia, Ekstremveret Gudrun, https://nn.wikipedia.org/wiki/Ekstremv%C3%AAret_Gudrun, last access: 29Apr2025 -ERWIN -powerful ppt followed front, south of storm centre and flooded several places, mainly by overflow rivers -UK evacuations from floods -Cappel Curig in Snowdona received 144 mm ppt in 24h 7Jan -Shap in Cumbria received 227mm in 72h

Table S63. Unusual peak of significant wave height in northern North Sea (arranged by year and then alphabetically)

Source	Full Reference and Notes

Table S64. Very low coastal water levels (arranged by year and then alphabetically)

Source	Full Reference and Notes
Alexandersson and Ivarsson (2005)	Alexandersson H and KI Ivarsson, Januaristormen 2005, Faktablad nr 25, SMHI, https://www.smhi.se/download/18.18f5a56618fc9f08e832d664/1717805946933/faktablad_janstorm%5B1%5D.pdf, November 2005. -on S coast very low water levels: Skanor at -134cm below avg; record -152cm for Anatol Dec1999
Suursaar et al (2006)	Suursaar, U., T. Kullas, M. Otsmann, I. Saarmae, J. Kuik, M. Merilain, Cyclone Gudrun in January 2005 and modelling its hydrodyanamic consequences in the Estonian coastal waters, Boreal Environmental Research, 11, 143-159, 2006. -along Sweden coast of Baltic Sea, relative sea level drop of up 150cm in Skanor and Simrishamn
Nielsen (2023)	Nielsen, J.W., Stormfloden den 8. januar 2005, https://ocean.dmi.dk/case_studies/surges/2005-01-08.php, last access:21Feb2023. -low water levels wester Baltic
SMHI (2025)	SMHI, Högvattenhändelser idag och i framtiden, https://www.smhi.se/klimat/stigande-havsnivaer/hogvattenhandelser-idag-och-i-framtiden, last access: 10Jan2025 -low water levels along Sweden Baltic coast during Storm Erwin: Simrishamn, Oscarshamn

Table S65. Modelled turbulence kinetic energy in ocean wave model (arranged by year and then alphabetically)

Source	Full Reference and Notes

Table S66. Classification of storm surges/storm (arranged by year and then alphabetically)

Source	Full Reference and Notes
Averkiev and Klevannyy (2010)	Averkiev, A.S. and K.A. Klevannyy, A case study of the impact of cyclonic trajectories on sea-level extremes in the Gulf of Finland, Continental Shelf Research, 30, 707-714, 2010. -demonstration of different trajectories needed for worst storm surges at different locations around Gulf of Finland.
Olbert and Hartnett (2010)	Olbert, A.I. and M. Hartnett, Storms and surges in Irish waters, Ocean Modelling, 34, 50-62, 2010. -5 families of storm trajectories causes surges in Ireland; most important characteristics location & direction of movement
Medvedev and Kulikov (2021)	Medvedev, I.P. and E.A. Kulikov, Extreme storm surges in the Gulf of Finland: Frequency-spectral properties and the influence of low-frequency sea level oscillations, Oceanology, 61, 459-468, 2021. -analysis of spectral characteristics of storm surges in Gulf of Finland and St Petersburg

Table S67. Fatalities & injuries (arranged by year and then alphabetically)

Source	Full Reference and Notes
Alexandersson and Iversson (2005)	Alexandersson H and KI Ivarsson, Januaristormen 2005, Faktablad nr 25, SMHI, https://www.smhi.se/download/18.18f5a56618fc9f08e832d664/1717805946933/faktablad_janstorm%5B1%5D.pdf, November 2005. -UK 3 fatalities Carlisle -Denmark: 4 fatalities -Germany : 2 fatalities
BBC (20050110)	BBC, Northern Europe shaken by storms, http://news.bbc.co.uk/2/hi/europe/4158809.stm, 10 January 2005 -7 died Sweden, 3 in England -Sweden: 4 motorists killed by trees blown onto cars; 3 others dies in winds up to 150km/h -Germany: 2X20y men missing when kayak capsized near Landwedel -Denmark: 2 killed by trees on vehicles; 2 killed by dislodged roof -northern England: man crushed by barn falling on caravan; 2 elderly women died in flooded properties
Beredskabstyrelsen (2005)	Beredskabstyrelsen, Beredskabets indsats i forbindelse med orkanen 8. januar 2005, En tvaergaende erfaringsopsamling, Beredskabssstyrelsen, Datavej16, 3460 Birkerod, Oktober 2005 -total fatalities 17 Europe -Denmark 5 fatalities; 2 fatalities Fyn (hit by roof from apartment); 2 died Fyn & Sjaelland by tree on cars -Anatol 3Dec1999 with 7 fatalites is rank 1
Belfast Telegraph (20050110c)	Belfast Telegraph, Storms sweep northern Britain, p.6, 10Jan2005c (Monday) -ERWIN -63y man killed barn blew down in Scottish border; bodies 2 elderly women found in flooded homes Carlisle -2 people missing in W Yorkshire & Morayshire Scotland; swept away in swollen rivers
Brown (2005)	Brown, Paul R., The violent gale of 11-12 January 2005 in the north of Scotland, Journal of Meteorology, 30, 104-106, 2005 -family of 5 drowned in car trying to escape South Uist
CNN (20050109)	CNN, Weather. 13 killed as storm lashes Europe, http://edition.cnn.com/2005/WEATHER/01/09/europe.storm/, 09 Jan 2005. -6 fatalities Sweden from falling trees & other debris -4 died Denmark; 2 died Assens when roof of house fell on them -Germany: 2 canoeists missing after strong gust capsized boat on lake -UK: 63y oldman killed when barn blew down -UK: bodies of 2 elderly women in flooded houses
DMI (2005)	DMI, Danmark ramt af landsdækkende storm, https://www.dmi.dk/nyheder/2005/danmark-ramt-af-landsdakkende-storm#:~:text=Stormen%20her%20i%20januar%202005,hen%20over%20den%20nordlige%20Nords%C3%B8. 10Jan2005 -4 fatalies in Denmark; 3 fatalities on Fyn

	-2 fatalies in Assens when roof came from apartment building -1 fatality Odense when motorist hit by toppled tree -1 fatality Ostrup at Roskilde; also tree falls on car -S Sweden hit hard by storm; 7 fatalities; > 200 000 households without electricity Sat even
Guardian (20050112)	Guardian, Storms claim at least five lives (contributor: Adam Jay), https://www.theguardian.com/environment/2005/jan/12/weather.climatechange1, 12 January 2005 -GERO -at least 5 people died in hurricane strength winds that hit Scotland, N_Ireland, N England -Western Isles: police recovered body from car in sea off Benbecula; man's body nearby -4 people missing from village of Creagorry the island -strongest winds recorded in Western Isles; 124mph North Rona & 105mph on Barra -Scottish mainland: car driver killed in collision with lorry on A1 N of Berwick -Tayside: van driver killed in collision with lorry on A90 near Forfar -N Ireland: lorry blown off Foyle Bridge in Derry, killing driver FIG. [PHOTO] A lorry lies beneath the Foyle Bridge, Derry, after being blown off by gale-force winds [Paul Faith]
Guy Carpenter (2005)	Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005 -ERWIN/GUDRUN -17 fatalities -Carlisle: 3 dead and 100 injured -Denmark: 4 people killed -Sweden: 9 people killed -Germany: 2 people missing after kayak overturned in high winds -Latvia: no deaths or injuries reported -Estonia: 14 people injured & needed hospital treatment
Irish Times (20050109)	The Irish Times, Seven die as storm hits southern Scandinavia, irishtimes.com/news/seven-die-as-storm-hits-southern-scandinavia-1.1295791, 9 January 2005 -ERWIN -Denmark:2 men killed when struck by roof torn off cottage on island of Funan -Denmark: 2 others killed by falling trees -Sweden: 3 died during storm force winds; 2 motorists whose cars hit by falling trees
Irish Times (20050111)	The Irish Times, Man dies as storm causes power cuts and flooding (contributor Ciara O'Brien), https://www.irishtimes.com/news/man-dies-as-storm-causes-power-cuts-and-flooding-1.1295844, 11 January 2005 -GERO -another lorry overturned & collided with car while crossing Faughn Bridge on Limavady Road near Derry; 2 injuries
Johansson et al (2006)	Johansson J., S Lindahl, O. Samuelsson, H Ottoson, The storm Gudrun. A seven-week power outage in Sweden, CRIS, Third International Conference on Critical Infrastructure, Alexandria, Virginia, September, 2006. -ERWIN -10 fatalities in storm and clean-up
LCW (20050121)	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -ERWIN: at least 3 dead Denmark, 2 in Sweden -ERWIN: Denmark: man in Odense killed when tree smashed into car -ERWIN: 3 killed & 2 missing after torrential rain & gales swept northern England -ERWIN: deaths: man crushed in caravan by collapsed barn in Cumbria; 2 elderly women died in flooded properties -ERWIN: two people missing in West Yorkshire and Morayshire -ERWIN: 7 died Sweden, 4 in Denmark, 3 in N England -ERWIN: Sweden: 4 motorists killed when trees blew onto cars; 3 others died in winds to 94mph -ERWIN: Germany: 2X20y men missing when kayak capsized; presumed dead near Landwebel -ERWIN: Denmark: 2 died when uprooted trees flung onto vehicles; 2 killed due to dislodged roof -ERWIN: northern England: man crushed when barn collapsed on caravan; 2 elderly women died in flooded properties -ERWIN: Sweden: another person reported killed in fierce storms that struck N Europe over weekend Jan8-9; death toll 17 -ERWIN: Sweden: in S Sweden 7 people killed; police said another person found dead & another missing -ERWIN: UK: 2 British men swept away in northern rivers and missing since Saturday -ERWIN: UK: 3 people died in Carlisle area during weekend storms -GERO: Scotland: 2 drivers killed, 60000 people without without power in overnight gales up to 124mph -GERO: winds blew over lorry killing motorist on A1 near Burnmouth -GERO: Tayside: van driver killed in collision on A90 -GERO: no injuries in Norway
LCW (20050128)	Lloyds Casualty Week, 28Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -ERWIN: 14 people killed in storm; 7 in Sweden
Deutsche Rueck (2006)	Deutsche Rueck, Sturmdokumentation Deutschland 2005, (contributors: T. Axer, T. Bistry, S Fietze, M Mueller, M Prechtl), Deutsche Rueckversicherung, Aktiengesellschaft, Hansaallee 177, 40549, Duesseldorf, March, 2006. -ERWIN -Germany: at least 7 people injured -Germany: 2 young paddle boaters on Brahsee S of Kiel capsized in storm & drowned
Haanpaa et al (2006)	Haanpaa, Simo, Samuli Lehtonen, Lasse Peltonen, Elena Talockaite, Impacts of winter storm Gudrun of 7th-9th January 2005 and measures taken in the Baltic Sea region, Astra, www.astra-project.org, 43pp, 2006 [pdf properties: datestamp 13/06/2006] -GUDRUN/ERWIN: fatalities: 17 with Sweden (7), Denmark (4) -SMHI: 20 people died after storm, working on damage

Suursaar and Sooaar (2006)	Suursaar, U. and J. Sooaar, Storm surge induced by extratropical cyclone Gudrun: hydrodynamic reconstruction of the event, assessment of mitigation actions and analysis of future flood risks in Parnu, Estonia, WIT Transactions on Ecology and the Environment, vol.91, pp.241-250, WIT Press, 2006. -1 fatality Estonia
Suursaar et al (2006)	Suursaar, U., T. Kullas, M. Otsmann, I. Saarmae, J. Kuik, M. Merilain, Cyclone Gudrun in January 2005 and modelling its hydrodyanamic consequences in the Estonian coastal waters, Boreal Environmental Research, 11, 143-159, 2006. -17 fatalities, including 1 in Estonia
Hellenberg and Kentala (2007)	Hellenberg, T. and J. Kentala, Chapter III. Sudden sea level rise in the Gulf of Finland in January 2005, in C. Pursiainen (ed), Early Warning and Civil Protection. When does it work and why does it fail? Nordregio report 2008:1 -11 Estonions taken to hospital because of hypothermia
Soomere et al (2008)	Soomere, T., A. Behrens, L. Toumi, J.W. Nielsen: Wave conditions in the Baltic proper and in the Gulf of Finland during windstorm Gudrun, Nat Hazards Earth Syst. Sci., 8, 37-46, 2008. -18 fatalities
Gardiner (2010)	Gardiner, Barry, Appendix 3: Background information on 11 storms selected for detailed analysis, European Forest Institute, Atlantic European Regional Office - EFIAtlantic, 161 pp. [PDF properties: datestamp 23Jul2010] 9.6. Casualties -UK: 3 deaths, 100 injured -Denmark: 4 deaths -Sweden: 11 deaths in storm and through salvage work; 1600 accidents -Germany: 2 killed
SMHI (20111013)	SMHI, Gudrun - Januaristormen 2005,, https://www.smhi.se/kunskapsbanken/meteorologi/stormar-i-sverige/enskilda-stormar-och-ovader/gudrun-januaristormen-2005-1.5300, 13 oktober 2011 -ERWIN -7 fatalities as direct consequence of storm
Gardiner (2012)	Gardiner B, K Blennow, J-M Carnus, P Fleischer, F Ingemarson, G Landmann, M Lindner, M Marzano, B Nicoll, C Orazio, J-L Peyron, M-P Reviron, M-J Schelhaas, A Schuck, M Spielmann, T Usbeck, Destructive storm in European Forests: Past and Forthcoming Impacts, European Forest Institute, Atlantic European Regional Office - EFIAtlantic [pdf document properties: author=Barry Gardiner, datestamp=09Mar2012] -19 fatalies due to storm
AON Benfield (2013)	AON Benfield, Historie von 1703 bis 2012: Winterstuerme in Europea, Stand: Januar 2013 -2fatalities northern Germany; northern Europe 11 fatalities
Angus and Rennie (2014)	Angus, S. and A. Rennie, An Ataireachd Aird: The storm of January 2005 in the Uists, Scotland, Ocean & Coastal Management, 94, 22-29, 2014. -GERO: 5 fatalities
Thejournal.ie (2015)	thejournal.ie, The deadliest storms to ever hit Europe, 14Dec2015 0610AM, https://www.thejournal.ie/europe-storms-2497164-Dec2015/, accessed 10Dec2020 -ERWIN had 18 fatalities in Europe
Expressen (20170204)	Expressen, Gudrun 2005: 20 doedas i den vaarsta storm, https://www.expressen.se/nyheter/inloggad/gudrun-2005-20-dodas-i-den-varsta-stormen/, published 04Feb2017 09:25 -in south and middle Sweden, 9 fatalities -later 11 people died in events related to cleaning up after the storm -clearing work lasted over a year -between Jan2005-Jan2006 11 people died clearing up fallen timber -last victim was forest worker from Estland while clearing forest at Varohalvon in Halland -141 work-accidents in following Gudrun -Gudrun fatalities during evening, night, morning when storm hit Sweden -91y old man in Skane blown into forest? and died when he tried to fix his blown off veranda roof -60y old man driving with his hjullastare? outside Vaxjo hit by falling tree; died on way to hospital -man from Landskrona also died by a falling tree -57y old man on way home to Vaxjo who lamnar his car when he was compelled to stop by tree blocking the road -Vimmerby: 68y old died .. under fallen tree -a lantbrukara (farm) in Skurup died under hay bale -Sturups airfield 30y man died when his car hit a toppled tree -total of 9 people died during weekend
SurgeWatch (2017)	SurgeWatch, Storm Event 11th January 2005, in Haigh, I.D., O. Ozsoy, M.P. Wadey, R.J. Nicholls, S.L. Gallup, T. Wahl, J.M. Brown,Data descriptor: An improved database of coastal flooding in the United Kingdom from 1915 to 2016, Scientific Data, 4: 170100, DOI: 10.1038/sdata.2017.100, 2017 -GERO -5 people killed when 2 cars swept from causeway on South Uist (Cramb, 2014)
European Severe Weather Database (20240803)	European Severe Weather Database, 7-9Jan2005, https://eswd.eu (last access 03Aug2024) FATALITIES Location LA Latitud Longitu Date Day Time Uncertainty ND --- Longtown UK 55.01 N 2.97 W 08-01-2005 sat 12:00 UTC (+/- 1 day) wall of barn fell on caravan; 1 dead Eriksmåla Kronobergs Län SV 56.63 N 15.32 E 09-01-2005 sun 18:02 UTC (+/- 1 hrs.) man killed by falling tree; Vimmerby Kalmar Län SV 57.67 N 15.85 E 09-01-2005 sun 16:43 UTC (+/- 1 hrs.) man killed by falling tree

	Snogeröd Skåne län SV 55.83 N 13.47 E 09-01-2005 sun 16:39 UTC (+/- 1 hrs.) Number of people injured: 3. Number of people dead: 1. Svedala Skåne län SV 55.50 N 13.23 E 09-01-2005 sun 14:49 UTC (+/- 1 hrs.) Number of people injured: 1. Number of people dead: 1. Skurup Skåne län SV 55.47 N 13.50 E 09-01-2005 sun 14:00 UTC (+/- 1 hrs.) person killed by falling debris INJURIES Location LA Latitud Longitu Date Day Time Uncertainty ND --- Värnamo Jönköpings Län SV 57.19 N 14.04 E 09-01-2005 sun 21:20 UTC (+/- 1 hrs.) 1. woman injured; car hit by falling tree; Vaggeryd Jönköpings Län SV 57.50 N 14.12 E 09-01-2005 sun 20:20 UTC (+/- 1 hrs.) 1. woman injured by falling tree;
Bioenergy International (2025)	Bioenergy International, The aftermath and legacy of Storm Gudrun - 20 years on (contributor Alan Sherrard), https://bioenergyinternational.com/the-aftermath-and-legacy-of-storm-gudrun-20-years-on/, 11 January 2025. -ERWIN/GUDRUN -9 people killed -final death toll attributed to Gudrun doubled to 18 people
Myhr (2025)	Myhr, K.J.: Storm puts focus on security, https://history.vattenfall.com/stories/power-to-the-people/storm-puts-focus-on-security/, last access: 24Jan2025. -ERWIN/GUDRUN -7 killed (Sweden)
Wikipedia (20250429)	Wikipedia, Ekstremveret Gudrun, https://nn.wikipedia.org/wiki/Ekstremv%C3%AAret_Gudrun, last access: 29Apr2025 -ERWIN -Denmark: 5 fatalities -Sweden: 5 fatalities -17 fatalities in total

Table S68. Coastal flooding, dike breaks, and evacuations (arranged by year and then alphabetically)

Source	Full Reference and Notes
Alexandersson and Iversson (2005)	Alexandersson H and KI Ivarsson, Januaristormen 2005, Faktablad nr 25, SMHI, https://www.smhi.se/download/18.18f5a56618fc9f08e832d664/1717805946933/faktablad_janstorm%5B1%5D.pdf, November 2005. -Lettland: extremely high water levels at coast; flooding in some communities
BBC (20050110)	BBC, Northern Europe shaken by storms, http://news.bbc.co.uk/2/hi/europe/4158809.stm, 10 January 2005 -Baltic states: flooding in many coastal towns
Beredskabstyrelsen (2005)	Beredskabstyrelsen, Beredskabets indsats i forbindelse med orkanen 8. januar 2005, En tvaergaende erfaringsopsamling, Beredskabssstyrelsen, Datavej16, 3460 Birkerod, Oktober 2005 -storm surge Jutland west coast & Limfjord -Logstor had highest water level ever at 2.26m over normal -Skive & Logstor flooded; several 100 people evacuated -Thy dikes broke which led to evacuations
Brown (2005)	Brown, Paul R., The violent gale of 11-12 January 2005 in the north of Scotland, Journal of Meteorology, 30, 104-106, 2005 -GERO: flooding proble South Uist because surge at same time as new moon tide
CNN (20050109)	CNN, Weather. 13 killed as storm lashes Europe, http://edition.cnn.com/2005/WEATHER/01/09/europe.storm/, 09 Jan 2005. -Logstor Denmark: highest water ever in harbour (2.5m) 100s people evacuated -St Peterburg Russia water receded on Sunday -Neva river level rose to within 30cm of the flooding mark of 2.6m -embankments closed to traffic & 6 subway stations shut down
DMI (2005)	DMI, Danmark ramt af landsdækkende storm, https://www.dmi.dk/nyheder/2005/danmark-ramt-af-landsdakkende-storm#:~:text=Stormen%20her%20i%20januar%202005,hen%20over%20den%20nordlige%20Nords%C3%B8. 10Jan2005 -high west wind cause high surge and flooding large parts of west coast; worst at Limfjord -flooding in Logstor & Skive required evacuation of several 100 people -Logstor: highest ever water levels; 2.26m over daily levels -dike breaks at Krik Vig and Hilligso Drag in Thy region with evacuations
DWD (2005)	DWD, Orkan Erwin am 8. Januar 2005. https://www.dwd.de/DE/leistungen/besondereereignisse/stuerme/20050801_orkan_erwin.pdf?__blob=publicationFile&v=4, pdf timestamp: 07Feb2005 -ERWIN -mention of flooding in St. Petersburg
Guy Carpenter (2005)	Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005 -ERWIN/GUDRUN -Denmark: all areas affected with NW Jutland reachin 45m/s -heavy flooding W Jutland and Limfjorden: sea level rose >2m above normal -storm moved across Baltic Sea to S Finland and Baltic states 9Jan2005 -flooding in coastal areas with record 1.5m above sea level Helsinki -Latvia: surge flooding Riga; military evacuating people from capital

	-Estonia: 600 people evacuated -Lithuania: flooding reported -Russia, St. Petersburg: 6 subway stations closed by rising water levels -water levels reached 2.5m above normal at one point -insurance losses limited except for cargo loss of cars flooded in Helsinki Harbour (3.5mGBP) -similar car loss in Halmstad in Sweden (7.7mGBP)
Irish Times (20050111)	The Irish Times, Man dies as storm causes power cuts and flooding (contributor Ciara O'Brien), https://www.irishtimes.com/news/man-dies-as-storm-causes-power-cuts-and-flooding-1.1295844, 11 January 2005 -GERO -in Malahide Co Dublin high tide caused flooding Bissets Strand, Strand Road, Estuary Road -Co Down: flooding closed dual-carriageway Newry to Warrenpoint (estuary road)
LCW (20050121)	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -ERWIN: Finland: Helsinki expected sea level to rise; sandbags & large paper rolls on waterfront -ERWIN: Finland: winds in S Baltic pushed sea level along south and southwest coasts of Finland to record high; flooding in many areas Saturday night (8Jan) and yesterday (9Jan)) -ERWIN: Finland: early 9Jan water level Helsinki 151cm above avg; previous Helsinki record 136cm -ERWIN: Finland: senior citizens evac from homes in Virolahti & Pyht -ERWIN: Finland: at Srninen Harbour in Helsinki, 100s of newly imported cars (Audi & Volkswagens) had water damage when protective barrier of sand & stone breached -ERWIN: Finland: water cut a number of roads & highways along coast; also centre of Helsinki where Market Square flooded -ERWIN: Finland: water pumped out of many cellars near shore -ERWIN: Finland: concern at Loviisa nuclear power plant with two of Finland's 4 nuclear reactors -ERWIN: Finland: with water levels reaching 171cm above long-term avg, energy utility Fortum geared up for shut down if water levels rose further; water level came down afternoon 9 Jan ERWIN: Finland: water level highest in Hamina and Kotka in eastern part of Gulf of Finland (nearly 2m above normal) -ERWIN: Finland: in Turku SW Finland water flooded into lobby of Seaport Hotel -ERWIN: Baltic states: coastal towns had flooding -ERWIN: Russia: on Jan9 flooding occurred St. Petersburg with water levels rising 2.39m -ERWIN: Russia:Petrogradskiy district of St Petersburg affected most -ERWIN: Russia:alot of industrial facilities flooded -ERWIN: Russia:all shore cranes in St. Petersburg port stopped work when electric supply switched off following flooding of berths -ERWIN: Russia:river Sleleznyovka overflowed in Vyborg district Leningrad region & suspension of traffic on Finland-Russian highway between 1800 Jan 9 and 1200 Jan10 -ERWIN: Russia:flood subsided in evening Jan 9 Sunday; further flooding expected
LCW (20050128)	Lloyds Casualty Week, 28Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -St Petersburg flooded during storm -2 hospitalized -7 embankments covered in water -6 metro stations closed for safety on Sunday 9Jan -water reached 2.39m above avg -St Petersburg Meteorological Centre: water 1m over avg on Monday -Vice Governor Viktor Lobko: city saved from worse flooding by uncompleted flood defense -Met Alexander Rodionov: Jan flood unusual, floods normally autumn & spring -no serious damage in city and not victims
NRK (20050108)	NRK, Gudrun herjar i sor (contributor Bent J. Tandstad), 8Jan2005 -coast from Egersund to Swedish border has risk of extr high water level 80-100cm over normal Farleg strandsone -met.no advises people to avoid shore -Ostfold: Gudrun led to riksveg 108 to Hvaler being closed; 3700 people isolated on islands -FIG. [PHOTO] car has problem in water at Hvaler in Ostfold
Deutsche Rueck (2006)	Deutsche Rueck, Sturmdokumentation Deutschland 2005, (contributors: T. Axer, T. Bistry, S Fietze, M Mueller, M Prechtl), Deutsche Rueckversicherung, Aktiengesellschaft, Hansaallee 177, 40549, Duesseldorf, March, 2006. -ERWIN -Halligen reported 'Land Unter' from surge driven by WSW winds -Sylt reported significant coastal damage -coastal dune retreat 20m at Hornumer Odde on southern tip of island -winds in Finnischen Meerbussen caused 1.5m storm surge in Helsinki & St. Petersburg
Haanpaa et al (2006)	Haanpaa, Simo, Samuli Lehtonen, Lasse Peltonen, Elena Talockaite, Impacts of winter storm Gudrun of 7th-9th January 2005 and measures taken in the Baltic Sea region, Astra, www.astra-project.org, 43pp, 2006 [pdf properties: datestamp 13/06/2006] -Denmark with 150000-200000 affected; 135 households evacuated -Estonia: numerous houses in Parnu & Haapsalu affected by surge flooding -Estonia: 600 people evacuated due to severe weather conditions -max sea levels Parnu Estonia +275cm morning 9Jan2005; water penetrated 1km inland -orientation of winds matched Parnu/Haapsalu/Matsala Bays -Tallinn had record water level 152cm 6h before max height Helsinki (Suursaar et al 2006) -Parnu: 775 houses flooded; only 1/3 homeowners had insurance -Helsinki, Finland -metro tunnels threatened -outlet pipes of sewers had to be manually blocked to prevent inflow seawater

	-water treatment plant flooded; 63000m3 sewage water released to sea -Finland storm costs 15-20 mill EUR (Federation of Finnish insurance companies) -damage from cellar flooding and summer house damage -much damage from Turku harbour from several hundred destroyed imported cars at harbour -Loviisa: rising water threatened functioning of cooling water system of nuclear power plant; unit was almost shut down -Estonian Meteorological and Hydrlogical Institute: hurricane warnings 1-1.5d prior to event -individual scientists provided unofficial warnings of surge up to 2.4m; no official warnings * -evacuations in middle of surge
Suursaar and Sooaar (2006)	Suursaar, U. and J. Sooaar, Storm surge induced by extratropical cyclone Gudrun: hydrodynamic reconstruction of the event, assessment of mitigation actions and analysis of future flood risks in Parnu, Estonia, WIT Transactions on Ecology and the Environment, vol.91, pp.241-250, WIT Press, 2006. -coastal damage and coastline retreat in Estonia -flooding: 775 houses with 5097 inhabitants in Parnu; 159 houses Haapsalu -294 cars damaged by floods or fallen trees -600 people evacuated; 400 in Paarnu
Suursaar et al (2006)	Suursaar, U., T. Kullas, M. Otsmann, I. Saarmae, J. Kuik, M. Merilain, Cyclone Gudrun in January 2005 and modelling its hydrodyanamic consequences in the Estonian coastal waters, Boreal Environmental Research, 11, 143-159, 2006. -main financial losses Gudrun from flooding urban areas Parnu, Haapsalu, Kuresaare -Gudrun had highest impact for Estonia; among 5 strongest; new sea level record -Estonia: Gudrun worst for property damage from wind and flooding -EMHI web warning surge 1.5d prior to Estonia onset -FIMR warning of 150cm flood Helsinki -consequences of 2.4m surge not appreciated -flooding 1km inland -Estonia damage 50 mill EUR from flooding urban areas Parnu & Haapsalu
Hellenberg and Kentala (2007)	Hellenberg, T. and J. Kentala, Chapter III. Sudden sea level rise in the Gulf of Finland in January 2005, in C. Pursiainen (ed), Early Warning and Civil Protection. When does it work and why does it fail? Nordregio report 2008:1 -road E18 closed to traffic Sunday afternoon in Viipuri/Vyborg (Russia) & Vaalimaa frontier -water rose over E18 from Vaalimaa to Viipuri/Vyborg -St. Petersburg: 6 metro stations because of flood risk 8. Floods in South and Southest Finland -traffic cut off in many places in Helsinki region -cut in main circle roads Keha I in Otaniemi & intersection of Keha III/Itavayli -water closed roads throughout the coastal region -dozens of houses flooded Helsinki -port of Sornainen in Helsinki: 400-500 newly imported cars damaged by seawater -Virolahti: evacuations from 2 terraces of houses -Pyhtaa: evacuations -Tammissaari, Loviisa: water flooded buildings along the shore -some streets closed in towns neara Helsinki: Espoo, Kotka, Kirkkonummi, Sipoo, Raisio, Porvoo -Turki: whole passenger port under water on Sunday morning -Monday 10Jan water level continued to be higher than normal
Piontkowitz and Soerensen (2008)	Piontkowitz, Thorsten & Carlo Soerensen, Consequences of Climate Change along the Danish Coasts, Safecoast Action 5A, Danish Coastal Authority, Hojbovej 1, 7600 Lemvig, Denmark, kdi@kyst.dk, December 2008 -p.81: The water level variations at Logstor have been investigated with special emphasis on the Jan2005 surge that lead to severe flooding of the low-lying parts of the town -p.82: The highest ever recorded water level at Logstor occurred on the evening of 8Jan2005 reaching 2.05m (water level may have been locally 15-20cm higher according to some reports) and large parts of the town were flooded and inhabitants evacuated. Several other locations along the fjord were flooed as the water rose and dikes breached. -p.83: The flood protection wall was overtopped at a water level of 190 cm, and even before then some flooding had occurred. At the peak of the storm the water level in the town reached approx 205cm and after the peak it took a while for the water to recede due to the persistent wind force on the water. No exact water levelling of the water level in the streets was carried out but from the extent of the flooding and from local observations of bot the max water level and water flows in the narrow streets; a detailed picture has been gained. In the lower lying parts of the town the water level reached 60-100cm in the streets. Refer to Jensen (2007) for a more detailed desription and mapping of the flooding.
Tonisson et al (2008)	Tonisson H, K Orviku, J Jaagus, U Suursaar, A Kont, R Rivis, Coastal damages on Saaremaa Island, Estonia, caused by the extreme storm and flooding on January 9, 2005, Journal of Coastal Research, 24, 602-614, 2008. -sea level reached 275cm 0500GMT 9Jan2005 -Parnu & Haapsalu flooded for 12h; shoreline recession 1km -previous comparable surge 253cm on 18Oct1967
Angus and Rennie (2014)	Angus, S. and A. Rennie, An Ataireachd Aird: The storm of January 2005 in the Uists, Scotland, Ocean & Coastal Management, 94, 22-29, 2014. -GERO: coastal flooding in Outer Hebrides -dune overwash & sediment fans
Expressen (20170204)	Expressen, Gudrun 2005: 20 doedas i den vaarsta storm, https://www.expressen.se/nyheter/inloggad/gudrun-2005-20-dodas-i-den-varsta-stormen/, published 04Feb2017 09:25

	-Halmstad -1650 newly manufactured cars linedup in Halmstad totally destroyed in storm; value 230 million SEK -FIG. [PHOTO] Wind strength at more than 40m/s pushed water levels up and caused flooding, including at Feskakorka in Goteborg [credit: Leif Jacobsson]
SurgeWatch (2017)	SurgeWatch, Storm Event 11th January 2005, in Haigh, I.D., O. Ozsoy, M.P. Wadey, R.J. Nicholls, S.L. Gallup, T. Wahl, J.M. Brown,Data descriptor: An improved database of coastal flooding in the United Kingdom from 1915 to 2016, Scientific Data, 4: 170100, DOI: 10.1038/sdata.2017.100, 2017 -GERO -5 people killed when 2 cars swept from causeway on South Uist (Cramb, 2014) -school in Balivanich damaged & later relocated (Richards and Phipps, 2007) -considerable erosion in some places (Dawson et al, 2007); causeway damage Benbecula, N/S Uist -in N of England, quayside areas of Newcastle flooded when River Tyne burst banks (BBC 2005) -during unspecified time in January 2005 coastal flooding Warkworth Northumberland; likely on 12Jan -coastal flooding at Bryggen, Norway (Vannstand.no 2014)
Palginomm et al (2018)	Palginomm V, K Orviku, U Suursaar, A Kont, H Tonnison, R Rivis, Lessons learned from record-high storm surges and associated inundations in Parnu, SW Estonia, Journal of Coastal Research, 85, 1-5, 2018. -coastal flooding in Parnu during Gudrun pentrated 1km inland
Nielsen (2023)	Nielsen, J.W., Stormfloden den 8. januar 2005, https://ocean.dmi.dk/case_studies/surges/2005-01-08.php, last access:21Feb2023. -flooding in Limfjord area with some evacuations from Logstor & Skive
Wikipedia (20250429)	Wikipedia, Ekstremveret Gudrun, https://nn.wikipedia.org/wiki/Ekstremv%C3%AAret_Gudrun, last access: 29Apr2025 -2m storm surge Denmark with flooding in several places -Norway: high water with flooding Sandefjord-Mandal but without large effects like UK & Denmark -Helsinki: water level 9Jan 146cm above normal -St Petersburg: water from Neva river so high that 6 metro stations had to close -town of Abo seen under water -Parnu in Estonia: highest water level 280cm over normal; 25% of streets in town flooded

Table S69. Coastal dike heights and protection levels (arranged by year and then alphabetically)

Source	Full Reference and Notes
NLWKN (20050111)	NLWKN, Experten vom NLWKN: Flache Nordsee schuetzt Niedersachsens Kueste vor einem Tsunami, https://www.nlwkn.niedersachsen.de/startseite/aktuelles/presse_und_offentlichkeitsarbeit/pressemitteilungen/-38655.html, 11 January 2005. -coast protected against winter storms -dikes 6 to almost 9 m over NN; 1 m higher than earlier
Averkiev and Klevannyy (2010)	Averkiev, A.S. and K.A. Klevannyy, A case study of the impact of cyclonic trajectories on sea-level extremes in the Gulf of Finland, Continental Shelf Research, 30, 707-714, 2010. -coastline of Gulf of Finland undergoing extensive construction -new port terminals in St. Petersburg, Primorsk, Ust'-Luga, Batareinya Bay, Vistino, Vysotsk, -second block of Leningrad power station -St. Petersburg Flood protection barrier to be completed in next few years -projects designed for 10000y extreme event

Table S70. Surge barrier closures (arranged by year and then alphabetically)

Source	Full Reference and Notes
RWS (2005a)	RWS, Stormvloedflits 2005-02. Zeer zware zuidwesterstorm veroorzaakt vrij hoge waterstanden langs de kust (contributor Jan Kroos). https://open.rijkswaterstaat.nl/open-overheid/onderzoeksrapporten/%40257045/stormvloedflitsen-wmcn-kust/, 2005a -no surge barriers closed in Netherlands for ERWIN
RWS (2005b)	RWS, Stormvloedflits 2005-03. Stormtij en storm met orkankracht veroorzaken hoge waterstanden langs de kust (contributor Jan Kroos). https://open.rijkswaterstaat.nl/open-overheid/onderzoeksrapporten/%40257045/stormvloedflitsen-wmcn-kust/, 2005b -no surge barriers closed in Netherlands for GERO

Table S71. Beach damage and coastal issues; salt water contamination of groundwater; sewer systems (arranged by year and then alphabetically)

Source	Full Reference and Notes
Alexandersson and Ivarsson (2005)	Alexandersson H and KI Ivarsson, Januaristormen 2005, Faktablad nr 25, SMHI, https://www.smhi.se/download/18.18f5a56618fc9f08e832d664/1717805946933/faktablad_janstorm%5B1%5D.pdf, November 2005. -extreme high water levels contributed to the coastal damage Hallandskusten -sand dune erosion Falkenberg
Deutsche Rueck (2006)	Deutsche Rueck, Sturmdokumentation Deutschland 2005, (contributors: T. Axer, T. Bistry, S Fietze, M Mueller, M Prechtl), Deutsche Rueckversicherung, Aktiengesellschaft, Hansaallee 177, 40549, Duesseldorf, March, 2006. -ERWIN -Sylt reported significant coastal damage -coastal dune retreat 20m at Hornumer Odde on southern tip of island
Haanpaa et al (2006)	Haanpaa, Simo, Samuli Lehtonen, Lasse Peltonen, Elena Talockaite, Impacts of winter storm Gudrun of 7th-9th January 2005 and measures taken in the Baltic Sea region, Astra, www.astra-project.org, 43pp, 2006 [pdf properties: datestamp 13/06/2006] 3.4.2. Coastal erosion.

	-shoreline affected throughout southern coasts of study -destruction most severe Latvia -water level & waves affected coastlines Germany, Poland, Lithuania -reduced sediment from river discharge had impact on coastal damage FIG8. [PHOTO] Eroded foredunes at Lemmeoja, Estonia (Photo: Sten Suuroja) 3.4.2.1. Coastal processes enhanced by storms a threat to tourism -westernmost point of coastal erosion: Isle of Sylt -99 km2 with 40 km of western coastline being eroded -one of few locations in Germany hit by storm -impact of tourist sector -Eurosion: 1.0 mill m3 sediment lost annually because of storms -storm Jan2005 20m of coastline eroded -21000 people on island, mainly living from tourism -Sylt: rising sea level & stormier winters increased rate of erosion over past 35y -hard protection versus nourishing -beach nourishments of 30 mill m3 (30 times annual erosion) every 5 years 3.4.2.2. Human processes enhances erosion and vulnerability of the near-shore communities -Poland Hel peninsula, 39km long & 300m wide; 20000 inhabitants working in tourism -Jan2005 storm washed away 4000m3 sand from 15km stretch 3.4.2.3. Number of extreme storm events on the rise -erosion on Hel peninsula Poland stopped 1940s by construction groins -harbour system constructed at base of peninsula 1936 -most of groins destroyed 1996; beach nourishment adopted every second year (much more than Sylt) -total loss sediments on Lithuanian coast 0.57 mio m3 for Jan2005 event -normal erosion loss 0.1-0.5 mio m3 -Klaipeda tanker accident 1981 required removal of 0.5 mill m3 polluted soil -Lithuanian coast mainly sand -area experience 73 storm day annually with wind speeds higher that 15m/s -Lithuania met with 10 major storms in past 50y; each one a 100y event: 1983, 1986, 1990, 1992 3.4.2.4. River-sea interaction important in sustaining coastal mass-balance -Latvia: 200km of coastline affected (40% of total); 3.1 mill m3 volume washed away -coastal cutback 3-6 to 8-10m; near Kolka maximum values 15-21 and even 28m -Latvia coast in south end of gulf of Riga susceptible to erosion -following storm of 1969 some foredunes fixed with concrete base 3.4.2.5. Natural and soft means of coastal protection provide good results -Estonia: coastal erosion extensive but mainly uninhabited beaches -around Saarema island & Parnu beaches receded by 10s of meters -Valgeranna in Estonia had camping site buildings destroyed -beach already eroded from powerful 1999 storm (Anatol) 3.4.2.6. Lessons of Gudrun on coastal erosion and tourism -extreme storm like Jan2005 can many times more damage than normal storms -lack of sea ice during mild winters makes effects of storms more severe -anticipate more problems southern Baltic
Suursaar and Sooaar (2006)	Suursaar, U. and J. Sooaar, Storm surge induced by extratropical cyclone Gudrun: hydrodynamic reconstruction of the event, assessment of mitigation actions and analysis of future flood risks in Parnu, Estonia, WIT Transactions on Ecology and the Environment, vol.91, pp.241-250, WIT Press, 2006. -coastal damage during storm; changes during storm worse than 10-15y of ordinary storms
Suursaar et al (2006)	Suursaar, U., T. Kullas, M. Otsmann, I. Saarmae, J. Kuik, M. Merilain, Cyclone Gudrun in January 2005 and modelling its hydrodyanamic consequences in the Estonian coastal waters, Boreal Environmental Research, 11, 143-159, 2006. -damage to harbours and beach facilities reported in Estonia media -work done by near bottom currents proportional to velocity cubed; wave energy prop amplitude squared
Dawson et al (2007)	Dawson AG, S Dawson, W Ritchie, Historical climatology and coastal change associated with the 'Great Storm' of January 2005, South Uist and Benbecula, Scottish Outer Hebrides, Scottish Geographical Journal, 123, 135-149, 2007 -Gero 4. Coastal impacts of the January 2005 'Great Storm' -severe erosion along coastal areas west of causeways -in some areas coastal dunes subject to significant retreat -in some dune areas waves broke through & over dunes

	-FIG2. [MAP] Map of South Uist and Benbecula showing locations mentioned in text. Major areas of coastal flooding associated with the January 2005 storm indicated, together with coastal areas that experienced the most severe coastal damage.
Fredsoe (2008)	Fredsoe, Jorgen, Report on field tests with the PEM-system at the West Coast of Jutland 2005-2008, Department of Mechanical Engineering, DTU, May 2008 [pdf properties: author: Jorgen Fredsoe; date stamp: 04Jun2008; 112pp] -report on system for monitoring coastal erosion at Nymindegab in Denmark over period 2005-2008 -Daria 1990 reported to be most severe storm -Erwin 2005 in list of severe storms 2003-2008 -FIG3.13.[TIMESERIES] 15 most severe storms Dec2003-Jan2008 Nymindegab storm Dec2003 Nymindegab storm Nov2004 Nymindegab storm Jan2005 Nymindegab storm Oct-Nov2006 Nymindegab storm Jan2007 Nymindegab storm Mar2007 Nymindegab storm Nov2007 Nymindegab storm Dec2007
Hellenberg and Kentala (2008)	Hellenberg, T. and J. Kentala, Chapter III. Sudden sea level rise in the Gulf of Finland in January 2005, in C. Pursiainen (ed), Early Warning and Civil Protection. When does it work and why does it fail? Nordregio report 2008:1 -Helsinki 63000 m3 untreated waste water dumped into sea -Parnu: salty water flooded the city and its wells
Piontkowitz and Soerensen (2008)	Piontkowitz, Thorsten & Carlo Soerensen, Consequences of Climate Change along the Danish Coasts, Safecoast Action 5A, Danish Coastal Authority, Hojbovej 1, 7600 Lemvig, Denmark, kdi@kyst.dk, December 2008 -storm ERWIN 2005 -Houvig near Hvide Sand: -TAB4.11. Coastal retreat in survey line 55100 due to the storm surge 8-9Jan2005 Elevation mDVR90 Retreat_m 0 30.95 4.80 22.27 10 13.72 -FIG4.27. Coastal profle of survey line 5510 before and after storm surge 8-9Jan2005 -Logstor: -p.79: on average 50000 m3/y are beign dredged from the canal, and following the Jan2005 storm the amount was 160 000 m3
Soomere et al (2008)	Soomere, T., A. Behrens, L. Toumi, J.W. Nielsen: Wave conditions in the Baltic proper and in the Gulf of Finland during windstorm Gudrun, Nat Hazards Earth Syst. Sci., 8, 37-46, 2008. -substantial beach damage at places (Orviku, 2006)
Tonisson et al (2008)	Tonisson H, K Orviku, J Jaagus, U Suursaar, A Kont, R Rivis, Coastal damages on Saaremaa Island, Estonia, caused by the extreme storm and flooding on January 9, 2005, Journal of Coastal Research, 24, 602-614, 2008. -significant changes in coastal geomorphology Saaremaa study area -Kelba elongation of spit by 75m -largest change sandy beach at Kiipsaare; scarp receded 10-20m -total recession 1980-2004 50-70m -big changes Erwin also on shores of Gulf of Livonia -Jarve changes for Erwin about same as for severe storm Feb1990; no effect storms between -Gudrun caused much larger changes to depositional shores west Estonia than prev storms 10-15y
Angus and Rennie (2014)	Angus, S. and A. Rennie, An Ataireachd Aird: The storm of January 2005 in the Uists, Scotland, Ocean & Coastal Management, 94, 22-29, 2014. -GERO: dune overwash and sediment fans -flooded inland lakes have lower salinity than expected due to groundwater fluxing
Expressen (20170204)	Expressen, Gudrun 2005: 20 doedas i den vaarsta storm, https://www.expressen.se/nyheter/inloggad/gudrun-2005-20-dodas-i-den-varsta-stormen/, published 04Feb2017 09:25 -Kronobergs island? hit hardest by storm. Here infrastructure knocked out for 1000s poeple -fixed and mobile telephone knocked out; also electricity -sewer system disabled
SurgeWatch (2017)	SurgeWatch, Storm Event 11th January 2005, in Haigh, I.D., O. Ozsoy, M.P. Wadey, R.J. Nicholls, S.L. Gallup, T. Wahl, J.M. Brown,Data descriptor: An improved database of coastal flooding in the United Kingdom from 1915 to 2016, Scientific Data, 4: 170100, DOI: 10.1038/sdata.2017.100, 2017 -GERO -considerable erosion in some places (Dawson et al, 2007); causeway damage Benbecula, N/S Uist

Table S72. Power interruptions; telephone poles/lines down; oil pipeline flow stopped due to electricity loss (arranged by year and then alphabetically)

Source	Full Reference and Notes
Alexandersson and Ivarsson (2005)	Alexandersson H and KI Ivarsson, Januaristormen 2005, Faktablad nr 25, SMHI, https://www.smhi.se/download/18.18f5a56618fc9f08e832d664/1717805946933/faktablad_janstorm%5B1%5D.pdf, November 2005. -Denmark: N half Jylland extensive tree fall; 60000 households without electricity -Baltic states hit hard, especially Lettland; -Lettland: electricity network collapse with 1.4 mill people without power -SW Norway -extensive power outage in storm path
BBC (20050108)	BBC, Severe gales cause havoc on roads, http://news.bbc.co.uk/2/hi/uk_news/england/4157069.stm,

	08January2005 -power outages in South Durham, Hexham, Ponteland, Stamfordham, Kielder in Northumberland -Northern Electrical Distribution Network (NEDL): electricity affected in Richmond, Thirske, Barnard Castle, Durham, Darlington
BBC (20050110)	BBC, Northern Europe shaken by storms, http://news.bbc.co.uk/2/hi/europe/4158809.stm, 10 January 2005 -100s of thousands homes Scandinavia, Latvia, Estonia, Lithuania without power -southern Sweden, 2 nuclear reactors shut down & 220000 homes in regions without electricity -Carlisle in NW England: 1000s moved to temporary accomodation as some 70000 homes lost power -Denmark & Norway: many thousands of household suffered power cuts -Estonia suffered power cuts -Latvia government declared energy crisis after 60% of population of 2.4 million without power -Monday: 40% of country still without power -government minister said power to be restored at end of day
Belfast Telegraph (20050110b)	Belfast Telegraph, More power from the pole man, p.2, 10Jan2005b (Monday) -ERWIN: FIG. [PHOTO] NIE engineers restore electricity supplies at Leitrim village near Castlewellan, Co. Down, yesterday after Northern Ireland was battered by storms
Belfast Telegraph (20050110c)	Belfast Telegraph, Storms sweep northern Britain, p.6, 10Jan2005c (Monday) -ERWIN: 1000s waiting to return to homes without power
Belfast Telegraph (20050110)	Belfast Telegraph, Ulster braced for more storms (contributor Maureen Coleman), p.1, 10Jan2005 (Monday) -ERWIN -1000s householders without power: Newry, Craigavon, Downpatrick; 90mph winds damage supplies -height of storms 90000 homes/businesses without power -NIE engineers & linesmen work to replace broken lines and poles -up to 3000 householders in Co Down & Armagh still without power morning 10Jan2005; severe weather hampered repairs -NIE spokeman: customers to be taken off supplies to facilitate permanent repairs
Beredskabstyrelsen (2005)	Beredskabstyrelsen, Beredskabets indsats i forbindelse med orkanen 8. januar 2005, En tvaergaende erfaringsopsamling, Beredskabsstyrelsen, Datavej16, 3460 Birkerod, Oktober 2005 -(Sweden or Europe?) 500000 power loss cases & 300000 telephone loss cases -power loss lasted more than a month for some -Denmark 200000 customers without power at some point during storm Erwin 8Jan2005 -for Anatol Dec1999: 400000 customers without power -Gudrun: Sweden worst storm in 80 years -500000 electricity customers without power; 300000 without telephone -some electricity outages lastes more than a month -Gudrun caused worst-in-history damage to regional and local electricity network -during hurricane overhead transmission lines broken by toppled trees, transformers flooded by storm surge -damage in one event normally takes place over 10y -Sjaelland beredskabsstyrelsen: 400kV lines buried; system robust -number of customers with power loss in Erwin2005 half as many as Anatol 1999 -since 1999 hurricane, 9000km of low-voltage (87%) had been moved to underground cables
Brown (2005)	Brown, Paul R., The violent gale of 11-12 January 2005 in the north of Scotland, Journal of Meteorology, 30, 104-106, 2005 -GERO: mention of power outages Scotland
CNN (20050109)	CNN, Weather. 13 killed as storm lashes Europe, http://edition.cnn.com/2005/WEATHER/01/09/europe.storm/, 09 Jan 2005. -Carlisle, UK: 100000 residents spent night without electricity
Danish Energy Authority (2005)	Danish Energy Authority, Offshore Wind Power. Danish Experiences and Solutions. Danish Energy Authority, October, 2005. -90% shutdown of wind energy during Erwin because wind speeds >25m/s -forecasts up to evening 7Jan2005 indicated full production during storm -later forecasts after evening 7Jan2005 indicated indicated wind power shutdown -maximum wind power loss 16:00 8Jan2005; turbine shutdowns started 10:00 -wind turbine recovery much slower than forecast with 50% by end of day
DMI (2005)	DMI, Danmark ramt af landsdækkende storm, https://www.dmi.dk/nyheder/2005/danmark-ramt-af-landsdakkende-storm#:~:text=Stormen%20her%20i%20januar%202005,hen%20over%20den%20nordlige%20Nords%C3%B8. 10Jan2005 -electricity loss at several places in country -S Sweden hit hard by storm; 7 fatalities; > 200 000 households without electricity Sat evening
Guardian (20050109)	Guardian, Thousands lose power in storms (contributor Henry McDonald), 9 January 2005. -ERWIN -around 90000 homes still without power across Ireland morning 9Jan2005 ->40000 homes republic Ireland; almost 50000 homes Northern Ireland -winds >50mph struck Irish coastline, pulling down power lines -Electricity Supply Board: emergency crews returned power to >20000 customers -Northern Ireland Electricity, Julie Carson: 400 engineers out to restore power in north -damage from trees and branches on lines; flying debris damaging poles & equipment -100000 homes & businesses lost power in Midlands and down south coast for part of day
Guardian (20050112)	Guardian, Storms claim at least five lives (contributor: Adam Jay), https://www.theguardian.com/environment/2005/jan/12/weather.climatechange1, 12 January 2005 -GERO -Scottish Hydro Electric: 60000 customers cut off by freak weather in Argyll, Western Isles, Highlands -45000 still cut off

	-150 major faults on network acrss Scotland; dangerous for staff to work in high winds -Northern Ireland: 26000 homes lost electricity overnight; 1000 still not restored -N England: 10000 homes in Hexham, Northumberland remain without water
Guy Carpenter (2005)	Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005 -ERWIN/GUDRUN -floods & winds cut power to 500000 homes -Sweden: disruption power supplies, phone lines, rail traffic -Norway: power cut households, hampered oil production -Ireland: powerful winds left ~150000 homes without electricity -UK: further south 1000s homes & businesses lost power for part of day -UK; Carlisle: power cut to ~30000 homes; ~3000 people evacuated -Denmark: 60000 households without power N Jutland -Sweden: 5 nuclear power plants forced to close when saltwater blown on electricity distrib plants -Sweden: more than 400000 households lost power & phone lines in Sweden from falling trees -Latvia: national energy crisis declared after 1000s electricity poles downed; 1.4 million people or 60% population without power at height of storm -Estonia: 10s of 1000s people without power -Lithuania: widespread power cuts
Hallands Nyheder (20050109)	Hallands Nyheder, Stormen staengde Ringhals (contributor Krister Svahn), 9 January 2005 https://www.hn.se/nyheter/varberg/stormen-stangde-ringhals.036d8cf7-2756-4206-b13c-6d03f504a264 -strong winds in Varberg forced Ringhals nuclear station to stop 3 of 4 reactors -system flush switches of salt build up made unusable in hurricane -Saturday evening: power plant forced to sharply reduce output; salt fog cause shorting -Reactor 2 & 3 storm completely; reactor 1 reduced before being stopped -Reactor 4 producing at lower level -start Sunday: Ringhals 1 & 4 on way to full power; others to be started -Gudrun was first time storm winds forced Ringhals to such an extensive stop -loss of Ringhals compensated from Norrland and Norway -weekend storm reduced industry operational demand; also warm weather -short circuits from wires visible as flashes in Varo area -Barseback: reactor stopped on Saturday 8Jan2005; restarted night Sunday 9Jan2005
Irish Times (20050108)	The Irish Times, Severe weekend weather leads to flooding (contributor James Fitzgerald), https://www.irishtimes.com/news/severe-weekend-weather-leads-to-flooding-1.404508, 8 January 2005 [ERWIN] -ESB crews on standby to restore electricity in case of power cuts
Irish Times (20050109)	The Irish Times, Seven die as storm hits southern Scandinavia, irishtimes.com/news/seven-die-as-storm-hits-southern-scandinavia-1.1295791, 9 January 2005 -ERWIN -Danish news agency Ritzau: 15000 households without power -Sweden: 200 000 households in S Sweden without electricity (TT) -5 passenger trains stuck without heat & light evacuated
Irish Times (20050111)	The Irish Times, Man dies as storm causes power cuts and flooding (contributor Ciara O'Brien), https://www.irishtimes.com/news/man-dies-as-storm-causes-power-cuts-and-flooding-1.1295844, 11 January 2005 -GERO -high winds cause electricity outage for 5000 households -ESB: reported 5000 homes without power -emergency crews on standby along west coast where worst damage expected
Jameson (2005)	Jameson D., Weather extremes 2005. January 7th-8th Severe storm development, https://user.eumetsat.int/resources/case-studies/rapid-cyclogenesis-in-the-north-atlantic, pdf timestamp: 17/03/2005 -ERWIN -40000 customers without power in flooded Carlisle; 60000 in Dublin
Klee and Noren (2006)	Klee, I. and L Noren (ed): Annual Report 2005, Nordel Secretariat, Box 530, FI-00101 Helsinki, Finland, http://www.pfbach.dk/firma_pfb/historien/data_files/Nordel_ann_2005.pdf, pdf date stap: 3 May 2006, last access 8 October 2025 -'The year began dramatically when hurricane Gudrun moved in over Eastern Denmark and Southern Sweden and left 860000 customers without electricity. No damage to the grid was reported but 20000km of Sweden's local networks were damaged. Nieghboring countries helped in the relief efforts as did other countries in other parts of the world' -8-9January: Hurricane Gudrun hits Denmark and Southern/Western Sweden. The grid copes well but thousands of homes are without electricity
LCW (20050121)	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -ERWIN, UK: 50000 homes without power in north & west of country -ERWIN: S Sweden> more than 100000 households without power -ERWIN: thousands of home without electricity in central & southern England -ERWIN, Carlisle: engineers restoring power supplies -ERWIN: power lost for whole of Carlisle and some of surrounding countryside -ERWIN: concern at Loviisa nuclear power plant with two of Finland's 4 nuclear reactors -ERWIN: southern Sweden: two nuclear reactors temporarily shut down; 220 000 homes in region without electricity -ERWIN: Carlisle: 1000s of people moved into temp accommodation as 70000 homes lost power in flooding -ERWIN: Denmark and Norway: many thousands of households had power cuts -ERWIN: Estonia: power cuts -ERWIN: Latvia: 60% of population 2.4 million without power; government declares energy crisis; 40% of population without power on Jan10 -ERWIN: Carlisle: 1000s resident unable to return home; 1000s of homes still without power

	-ERWIN: Northumbria Water: some supplies will be restored by Jan12; rest by Friday Jan14 -ERWIN: Power had been lost for whole of Carlisle & some of surrounding countryside -ERWIN: United Utilities: 3000 homes still without power nighto Jan10; Energywatch North West said probably 7000 -ERWIN: Russian Ministry for Emergency Situations told Itar-TASS: hurricane left >1500 inhabited localities without electricity in Pskov region of Russia -ERWIN: as many as 296 electric transmission lines damaged & 4000 transformer stations de-energized -ERWIN: 24 districts with population 67000 left without electricity -ERWIN: electricity supply restored in 1906 inhabited localities only this morning; >32000 have electricity again; planned to complete all restoration jobs by 20Jan. -ERWIN: Sweden: more than 150000 people without power today -ERWIN: Sweden: Swedish utilities Sydkraft AB and Vattenfall AB: 150000 households without electricity, 180000 no telephone -ERWIN: Sweden: Swedish utilities Sydkraft AB and Vattenfall AB: 150000 households without electricity, 180000 no telephone -ERWIN: Latvia-Estonia-Lithuania: power restored to 1000s residents -GERO: Scotland: 2 drivers killed, 60000 people without without power in overnight gales up to 124mph -GERO: Scottish Hydro Electric: 60000 customers cut off by freak weather; 150 major faults across Scotland; staff stood down because work too dangerous in high winds -GERO: storms with winds up to 120mph hit Scotland & Norway disrupting port & terminal operations, halting crude oil operations, cancelling ferries -GERO: 2 Scottish oil terminals & 1 Norwegian terminal closed due to coastal storms -GERO: Sullom Voe in Shetlands & Flotta in Orkneys closed to tanker loadings -GERO: production still flowing through northern North Sea pipeline -GERO: Sullom Voe to remain closed until 1800 Jan13; might be re-opened in weather good -GERO: shuttle tanker Loch Rannoch will call with Schiehallion -GERO: Teekay's suezmax African Spirit will be loaded with Brent export -GERO: Statoil: oil shipments from Mongstad and offshore loadings at Statfjord were halted -GERO: harsh weather has delayed repair & inspection on 2 Norwegian production platforms since year start at Statoil's Snorre &Shell's Draugen fields, closing in 345000 barrels of daily output -GERO: Norway: power lines damaged by blown down trees & poles -GERO: Norway: Agder county: 12000 customers without power most of afternoon -GERO: Norway: Oestfold area: lines down
LCW (20050128)	Lloyds Casualty Week, 28Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -week after Erwin (14 killed), 50000 people Sweden (hardest hit) remain without power -Sydkraft company (hardest hit): some customers to remain without power for several more weeks -45429 households still without power -including all Swedish companies 51000 households without power noon 15Jan -Sydkraft spokesman Johan Aspegren -damage to lines unprecedented in Sweden -Sydkraft has 2000 people on power grid repairs; people called in from Norway, Danmark, Finland, Germany
Lindahl (2005)	Lindahl, Sture: The Storm Gudrun 2005-01-08, uploaded to Internet 19/10/2021, presentation 2005-05-12 S14. The effect on the electric networks -FIG. [PHOTO] Trees across power lines with caption: Severe damage to the 0.4kV and 10kV network. Half of the network in Smaaland was damaged -FIG. [PHOTO] Fallen mast with caption: significant damage on the 40kV and 50kV network. S15. The effect on overhead lines -FIG. [PHOTO] Electrical insulator with branches of fallen tree S16. Effects on the electricity supply -600000 customers in Sweden affected -Sydkraft alone: 258000 customers affected S17. Number of customers Province N_customers N_affected Skane 334200 49000 Halland 42900 22000 Blekinge 33500 23000 Kronoberg 65000 55000 Kalmar 84300 45000 Jonkoping 59000 24000 Orebro 103500 10600 Other 1030000 258600 S18. Effects on other infrastructure -250000 customers in Sweden without fixed telephone service ->800 telephone exchange stations lost normal power & exhausted backup batteries -after 1 week 39000 customers did not have access to fixed telephone service
Deutsche Rueck	Deutsche Rueck, Sturmdokumentation Deutschland 2005, (contributors: T. Axer, T. Bistry, S Fietze, M Mueller,

(2006)	M Prechtl), Deutsche Rueckversicherung, Aktiengesellschaft, Hansaallee 177, 40549, Duesseldorf, March, 2006. -ERWIN -500000 households in Denmark & Sweden without electricity -several Swedish nuclear reactors removed from network on safety ground
Haanpaa et al (2006)	Haanpaa, Simo, Samuli Lehtonen, Lasse Peltonen, Elena Talockaite, Impacts of winter storm Gudrun of 7th-9th January 2005 and measures taken in the Baltic Sea region, Astra, www.astra-project.org, 43pp, 2006 [pdf properties: datestamp 13/06/2006] -ERWIN/GUDRUN Power_cut Denmark 300000 Sweden 730000 Lithuania 230000 Latvia 400000 Estonia 300000 Finland * 3.5.2. Energy production -100000 households without power in Denmark and Estonia -30000km power lines damaged in Sweden -Latvia: power cutoffs affected 60% territory; 400000 customers without electricity -Lithuania: 230000 residents without electricity -Latvia communications cuts 3.5.2.1. Strong winds stall wind farms in Denmark (Bulow, 2006; Andersen, 2006) -Denmark: ~5400 turbines; with winds > 25 m/s western Denmark, 4000 Eltra machines shut down -local energy production reduced to 1/20th full capacity of 2380 MW -power demand filled power bought abroad (N Europe); but with difficult because storm extensive -main transmission grid only few damages; public not affected by power cuts -low voltage overhead cables hit with impact on 150000 customers -no wind turbines harmed; scraping policy & renewal of old wind turbines -turbines had to be restarted manually (Andersen 2006) -100s of customers still without electricity 11Jan 3.5.2.2. Nuclear energy production in trouble in Sweden -Sweden: power cuts affected 730 000 people; half restored within day -total power cut days 2.3 million with cost 274 mill EUR -forced closing down of 4 nuclear reactors; downscaling fifth (WNA, 2005) -reactors at Barseback & Ringhals had problems with salty water on switchboards and cable hammer -affected reactors account for 1/5 energy peoduction Sweden (Ringhals, 2005) -uprooted trees downed 30000 km cables -mild weather; no one harmed by outages -10s thousands without electricity for more than week after storm (KBM, 2005) -supplies for electricity repairs ran out; falling trees created access problems -Finnish nuclear reactor Loviisa -problem with water rising to level that would disable cooling system (WNA 2005) -Gudrun highlighted problems with country unilateral energy production 3.5.2.3. Storm damage especially high on low-voltage lines -Lithuania: energy network almost collapsed night 8Jan2005 causing power loss for 1.4mill peo -main reason for power cuts trees falling on lines -1 case of collapsed high voltage mast -quick repairs but defect on main lines reduced reliability of grid -repaired by 15Jan -Latvia: effects very severe; 54000 km distribution lines damaged -23 day emergency situation -main reason treesfallen on lines; 3 transmission masts collapsed & 34 damaged * -largest mobilization ever of Latvian electricity businesses -6000 people working on clearance & repair -schools & hospitals repaired -20000 companies without electricity 3.5.2.4. Returning energy supply for remote areas slow -Latvia power returned quickly for customers -Sweden: main road network soon opened; clearing less important roads took days -FIG11. Latvenergo customers without electricity by day after Gudrun (Latvenergo na) NOTE: final connections took until start February 3.5.2.5. Warm weather unfortunate to forests, blessing for people -fallen trees most critical factor in network durability

	-Latvia: electicity lines less vulnerable if trees cut 20-30m from lines -Finland: trees cut 26-30m from 110kV lines, >40m from 400kV lines -effects to public may have been greater if weather colder -however, ground frosts would have prevented some trees falling -sheer number of trees greatly slowed repair work 3.5.2.6. Lessons of Gudrun on energy sector: extreme wather can cause nationwide impact energy -Denmark & Sweden had problem dependent on some form of electricity production -after Gudrun power in most places restored in couple of days -warm weather helped avoid serious consequences for people
Johansson et al (2006)	Johansson J., S Lindahl, O. Samuelsson, H Ottoson, The storm Gudrun. A seven-week power outage in Sweden, CRIS, Third International Conference on Critical Infrastructure, Alexandria, Virginia, September, 2006. -ERWIN -night 8-9Jan power supply interrupted for 650000 people -restoring power supply took 7 weeks -investment after storm: 1600km of overhead lines with bare conductors will be replaced by power cables -development program for extensive use of power cables for distribution -11 nuclear units in operation when storm his S Sweden -Barseback 2 disconnected from transmission network 8Jan2005 because of faults in adjac400kV substation -7h later possible to synchronize generator to network -Ringhals nuclear station: salt deposition on insulators in switchgear & transmission lines forced operators to reduce power output -1 of 2 turbine generators in Ringhals 1 tripped because of flashover in adj 400kV substation -other turbine tripped to house turbine operation -few minutes lter operators of Ringhals 2 started to reduce power & disconnected 1 of 2 turbine generators within about 2 minutes -connection to 400kV network lost less than hou later -400kV overhead line energized just before 06:00 9Jan2005 -plant ready to start up afternoon 9Jan2005. -Ringhals 3 disconnected from transmission network 08Jan2005 18:35 -both turbines tripped to house turbine operation; one operated for 4min, other for 1h -Ringhals 4 connected to transmitted network by gas-insulated switchgear; not disconnected from transmission -output reduced to 25% at 19:27 -fixed & mobile phones in Oskarshamn nuclear plant failed 09Jan2005 07:30; still possible to use mobile phones in conference room Oskarshamn 1 & 2 -widespread outages that lasted long time -transmission corridors should be wide enough to prevent trees falling on conductors -corridors too narrow; large portions of distribution system damaged beyond repair -distribution networks with large % underground cable not as badly affected as overhead cable -overhead cables with covered conducted damaged when poles toppled by falling trees -660 000 customers without electricity supply -20 000 of distribution lines owned by Sydkraft damaged; 2000 km completely replaced -customers affected: Sydkraft 300 000; Vattenfall 260 000; Fortum 50 000 -operators eestimated overall cost of storm 257 mill EUR -Sydkraft ->1000 small mobile generation units connected to network at important points -special project organisation for restoration -10Jan2005 1400 people in team; 600 added next day -15Jan2005 2400 people in total after personnel brought in from Germany, Poland, Swedish army -Hercules aircraft transported spare parts from N Sweden -Vattenfall -special organisation for large disturbances on 8Jan2005 with 200 people -repair work not started during storm -1300 people working when storm ended -15 helicopters used -special resources from N Sweden -Fortnum -special organisation for repair work -300-400 people engaged in restoration of power supply -4-5 helicopters used
Suursaar and Sooaar (2006)	Suursaar, U. and J. Sooaar, Storm surge induced by extratropical cyclone Gudrun: hydrodynamic reconstruction of the event, assessment of mitigation actions and analysis of future flood risks in Parnu, Estonia, WIT Transactions on Ecology and the Environment, vol.91, pp.241-250, WIT Press, 2006. -15% housholds has power cuts: 100% Hiiumaa, 78% in Saaremaa, 64% in Parnu county
Suursaar et al (2006)	Suursaar, U., T. Kullas, M. Otsmann, I. Saarmae, J. Kuik, M. Merilain, Cyclone Gudrun in January 2005 and modelling its hydrodyanamic consequences in the Estonian coastal waters, Boreal Environmental Research, 11, 143-159, 2006. -Estonian Energy: 32% households lost power; 100% Hiiumaa, 78% Saaremaa, 64% Parnu
Hisscott (2007)	Hisscott, Alan, When NWP met climatology: storms over the Isle of Man during January 2005,'Weather, 62, 74-77, 2007 -ERWIN -falling trees caused disruption to overhead power lines in rural parts of island; poles blown down -almost a 1000 properties with electricity loss; 100s not connected for several days

	-Manx Electricity Authority had to enlist contractors in England & Scotland to complete repairs over several weeks -electricity supplies disrupted for island water treatment works and pumping stations
Hellenberg and Kentala (2008)	Hellenberg, T. and J. Kentala, Chapter III. Sudden sea level rise in the Gulf of Finland in January 2005, in C. Pursiainen (ed), Early Warning and Civil Protection. When does it work and why does it fail? Nordregio report 2008:1 -Kaliningrad: wind caused much damage to roofs & power lines -Sunday night 15% Estonian homes without electricity 7. Nuclear factor -Sunday morning 09:00 Loviisa sea level 171cm; 200cm is critical point above which closure -sea level had never been so high in Lovissa before -previous sea level Loviisa record 1.6m -other nuclear power plant Olkiluoto; no need for special measures -sea level rose to 0.8m with danger limit of 2.3m -Russian nuclear power plant Sosnovyi Bor; sea level 140cm with risk limit of 325cm
Rantanen (2008)	Rantanen, H., Chapter IV. Coping with Power Disturbances, in C. Pursiainen (ed), Early Warning and Civil Protection. When does it work and why does it fail? Nordregio report 2008:1, p.95-119 -after storm 663000 network customers without electricity -more than half of customers had power back within 24h -159000 customers had to wait 1-3 days -82000 customers without power 4-7days -56000 customers without power 8-20days -12000 customers without power >20days -last customers without power 34days -Impacts on emergency services -larger popluation centres (cities) had functional electricity during storm -larger command and communication centres operational -fire stations in countryside blacked out by power failure -stations had loss of heating; if there were low temperatures & snow stns would have been useless -Telecommunications -lack of comms far more serious problem than power blackouts -critical bas stations with backup power; batteries failed and fuel depleted -mobile and fixed telephone networks suffered from disturbances; 300000 customers without telephone -2 days after storm 90% of mobile network operational -several customers lacked land lines for several weeks -some fire stations with backup power acted as warm cottages -some areas had water distribution problems -availability of fuel for vehicles not affected; majority of population had no power blackout
Soomere et al (2008)	Soomere, T., A. Behrens, L. Toumi, J.W. Nielsen: Wave conditions in the Baltic proper and in the Gulf of Finland during windstorm Gudrun, Nat Hazards Earth Syst. Sci., 8, 37-46, 2008. -wide area power outages Sweden, Norway, Baltic
Gardiner (2010)	Gardiner, Barry, Appendix 3: Background information on 11 storms selected for detailed analysis, European Forest Institute, Atlantic European Regional Office - EFIAtlantic, 161 pp. [PDF properties: datestamp 23Jul2010] -storm ERWIN -Denmark -northern half of Jutland had 60000 households without electricity -Sweden -landscape dramatically changed -roads blocked, electricity supply & telecomm out of order, trans stopped -730000 subscribers without electricity from wind damage -urban areas had power back in 1 day; some households had 45d delay -300000 subscribers nonmobile telecomms not functioning after storm -event after 2 months large number of subscribers without telecomms -Baltic States -Latvia: electricity supply almost collapsed & 1.4 million people without power -extremely high sea levels along coast with severe flooding -Norway -fairly extensive power failure
SMHI (20111013)	SMHI, Gudrun - Januaristormen 2005,, https://www.smhi.se/kunskapsbanken/meteorologi/stormar-i-sverige/enskilda-stormar-och-ovader/gudrun-januaristormen-2005-1.5300, 13 oktober 2011 -ERWIN/GUDRUN -on Sunday morning, wind decreased and landscape in many places unrecognizable -routes closed, power and telephone networks knocked out, train traffic stopped, and people shocked at the enormous damage -415000 households without power -a week later 50000 households still without power -worst cases remained isolated farms and villages -meteorological data from automatic weather stations lost because of electricity and telephone line breaks
Gardiner (2012)	Gardiner B, K Blennow, J-M Carnus, P Fleischer, F Ingemarson, G Landmann, M Lindner, M Marzano, B Nicoll, C Orazio, J-L Peyron, M-P Reviron, M-J Schelhaas, A Schuck, M Spielmann, T Usbeck, Destructive storm in European Forests: Past and Forthcoming Impacts, European Forest Institute, Atlantic European Regional

	Office - EFIAtlantic [pdf document properties: author=Barry Gardiner, datestamp=09Mar2012] -electricity outages Sweden, Denmark, Latvia, Estonia -telecomms systems destroyed -Sweden: some places 45days without electricity, but mild weather
Sieber (2012)	Sieber, Jeanette, Impacts of extreme hydro-meteorological events on electricity generation and possible adaptation measures. A GIS-based approach for corporate risk management and enhanced climate mitigation concepts in Germany. Ph.D. thesis, Julius-Maximilians-Universitaet Wuerzburg - Institut fuer Geographie, Karlsruhe, November 2012 -TAB5. Damages to electricity generation and distribution structures after severe storms in Europe Storm date Effect --- Anatol 03Dec1999 electricity supply 165000 households failed Lothar/Martin 25-26Dec1999 200 electricity pylons Jeanette 27Oct2002 at least 1 wind turbine broken Erwin 7-9Jan2005 shut down 5 nuclear stations Sweden Thorsten 25-27Nov2005 bending of network masts Karla 30-31Dec2006 loss of electricity supply Lotte 31Dec2006-01Jan2007 loss of electricity supply Franz 12Jan2007 loss of electricity supply Kyrill 18-20Jan2007 2 million households /wo electricity Annette 22Feb2008 loss of electricity supply Emma 01Mar2008 damage to 5000 transformer stations Klaus Jan2009 interruption supply 1.5million households Xynthia 26-28Feb2010 loss of electricity
AON Benfield (2013)	AON Benfield, Historie von 1703 bis 2012: Winterstuerme in Europea, Stand: Januar 2013 -night to 9Jan2005 341000 households without power; 4 day after 100000; 2 weeks after 25000
Boettcher (2016)	Boettcher C., The cost of blackouts in Europe, record number 126674, 28Apr2016 https://cordis.europa.eu/article/id/126674-the-cost-of-blackouts-in-europe -Jan2005 storm power loss 500000 homes Denmark & S Sweden -5 nuclear power plants shut down due to saltwater in electricity distrib plants
DEA (2016)	Danish Energy Agency, Security of Electricity Supply in Denmark, 1st edition 2015, translated 2016, Danish Energy Agency, Amaliegade 44, 1256 Copenhagen K, ISBN 978-87-93180-15-4 -ERWIN: 'around 200000 households scross Denmark lost electricity when a storm with hurricane -strength winds hit Denmark. ' Majority of outages from distribution lines damaged by fallen trees and flying objects.
Expressen (20170204	Expressen, Gudrun 2005: 20 doedas i den vaarsta storm, https://www.expressen.se/nyheter/inloggad/gudrun-2005-20-dodas-i-den-varsta-stormen/, published 04Feb2017 09:25 -Kronobergs island? hit hardest by storm. Here infrastructure knocked out for 1000s poeple -fixed and mobile telephone knocked out; also electricity -sewer system disabled -Sixten Svensson, ten 67y old, lived in one of ~415000 households that lost power in storm .... -after Svensson was without power for 17d diesel generator was placed in home town Kylen to provide electr -electricity restored in surrounding towns after almost a month
SurgeWatch (2017)	SurgeWatch, Storm Event 11th January 2005, in Haigh, I.D., O. Ozsoy, M.P. Wadey, R.J. Nicholls, S.L. Gallup, T. Wahl, J.M. Brown,Data descriptor: An improved database of coastal flooding in the United Kingdom from 1915 to 2016, Scientific Data, 4: 170100, DOI: 10.1038/sdata.2017.100, 2017 -GERO -60000 people without electricity (Weathermaster 2011)
ClimateChangePost (20241124)	ClimateChangePost, Denmark Storms, https://www.climatechangepost.com/countries/denmark/storms/, last acces 24Nov2024 -ERWIN/GUDRUN -storm hit Denmark afternoon 8Jan -worry if Denmarks 5400 wind turbines would stand storm -as wind speed rose >25m/s across W Denmark, most of 4000 Eltra turbines automatically shut -electricity production reduced to <1/20 full capacity -power demand filled by energy from abroad -forced closing down of Sweden 4 nuclear reactors and downscaling of 5th -Finnish nuclear units at Loviisa encountered problems -during extreme weather event, acquiring capacity from abroad may be difficult
ESWD (20240803)	European Severe Weather Database, 7-9Jan2005, https://eswd.eu (last access 03Aug2024) POWER/ELECTRICITY Location LA Latitud Longitu Date Day Time Uncertainty ND --- Cumbria UK 54.60 N 2.75 W 08-01-2005 sat 12:00 UTC (+/- 1 day) Power transmission damaged or destroyed Hexham UK 54.97 N 2.10 W 08-01-2005 sat 12:00 UTC (+/- 1 day) Power transmission damaged or destroyed; power cuts reported Ponteland UK 55.05 N 1.75 W 08-01-2005 sat 12:00 UTC (+/- 1 day) Power transmission damaged or destroyed; power cuts reported Stamfordham UK 55.03 N 1.87 W 08-01-2005 sat 12:00 UTC (+/- 1 day) Power transmission damaged or destroyed; power cuts reported Kielder UK 55.23 N 2.59 W 08-01-2005 sat 12:00 UTC (+/- 1 day) Power transmission damaged

	or destroyed; power cuts reported Durham UK 54.77 N 1.57 W 08-01-2005 sat 12:00 UTC (+/- 1 day) Power transmission damaged or destroyed; power cuts reported Richmond UK 54.40 N 1.73 W 08-01-2005 sat 12:00 UTC (+/- 1 day) Power transmission damaged or destroyed; power cuts reported Thirsk UK 54.22 N 1.33 W 08-01-2005 sat 12:00 UTC (+/- 1 day) Power transmission damaged or destroyed; power cuts reported Darlington UK 54.53 N 1.57 W 08-01-2005 sat 12:00 UTC (+/- 1 day) Power transmission damaged or destroyed; power cuts reported Barnard Castle UK 54.53 N 1.92 W 08-01-2005 sat 12:00 UTC (+/- 1 day) Power transmission damaged or destroyed; power cuts reported
Bioenergy International (2025)	Bioenergy International, The aftermath and legacy of Storm Gudrun - 20 years on (contributor Alan Sherrard), https://bioenergyinternational.com/the-aftermath-and-legacy-of-storm-gudrun-20-years-on/, 11 January 2025. -GUDRUN/ERWIN -730000 households & businesses without electricity -during Gudrun 10000 power poles broken & needed replacing -mobile gensets brought in from military stores, power companies, from abroad -lack of electricity meant schools & healthcare facilities closed -power supply restored for some people 35 days after storm -E.ON (formerly Sydkraft) largest utility & power grid owner in affected region: Gudrun one of worst in company history -260 000 E.ON clients without power; Vattenfall El distribution 180 000 without power -E.ON decided built new grid after 20000 km of grid badly damaged -installers flown in from other subsidiaries: Germany, UK, Finland -electrical equipment, backup generators brought in from China, India, Mexico -since Gudrun E.ON invested SEK 38 bill into weatherproofing 33000 km of power lines in Sweden, burying 75% underground -in S Sweden 1700km of uninsolated overhead lines initially buried & then replaced with insulated overhead lines -Vattenfall Eldistribution mustered 1600 people (1150 in field) with fleet 15 helicopters, 20 tracked carriers & 20 harvesters to locate and fis faults -year before Gudrun Vattenfall decided to invest SEK 10 bill over 5y to insulate & weatherproof grid -during first 10y after Gudrun, Vattenfall invested additional SEK 17bill in weatherproofing measures: widening & clearing lines, insulating overhead cables, burying lines where appropriate -Vattenfall investment in grid annually SEK 8-10 bill until 2030
Myhr (2025)	Myhr, K.J.: Storm puts focus on security, https://history.vattenfall.com/stories/power-to-the-people/storm-puts-focus-on-security/, last access: 24Jan2025. -ERWIN/GUDRUN -nuclear power plants at Ringhals & Barseback halted production due to grid failures; switchgear unusable due to large amounts of salt from sea -storm damage estimated at 10 bill SEK -780000 subscribers without electricity -30000 km power lines damaged; 9% required total replacement -underground network undamaged -power line corridors for local networks not tree-safe -total number of interruption days 2.3 million -grid company costs at 2.5 billion SEK -Sweden Energy Agency: Sweden & economy had weak points -society ceased to function for several days -180000 subscribers without power morning 9Jan2005 -power restored to half by 07:00PM -2days layer 10% or 18000 still without power -21Jan2005, power completely restored -during storm Vattenfall had up to 1600 people working with power disruptions; 1150 in field, 450 indoors & power station -15 helicopters, 20 tracked vehicles, 20 harvesters to locate & fix problems -communication problems; Vattenfall received 40000 calls on 30 lines
Wikipedia (20250429)	Wikipedia, Ekstremveret Gudrun, https://nn.wikipedia.org/wiki/Ekstremv%C3%AAret_Gudrun, last access: 29Apr2025 -ERWIN -UK evacuations from floods; 70000 without electricity -Denmark: 60000 households without power -night to 9Jan 341000 Sweden households without electricity -Ringhals and Barseback nuclear plants had to stop production because of broken power lines and large amounts of salt from sea 'saltstorm' leading to short circuits -Sweden hardest hit country in storm -4 days after storm 100000 households without power -2 weeks later 25000 households still without power -3 weeks later 10000 households without power -also loss of telephone communications

Table S73. List bridge closures, cancelled ferry crossings, port closures, airport cancellations, rail interruptions, traffic accidents (arranged by year and then alphabetically)

Source	Full Reference and Notes

Alexandersson and Ivarsson (2005)	Alexandersson H and KI Ivarsson, Januaristormen 2005, Faktablad nr 25, SMHI, https://www.smhi.se/download/18.18f5a56618fc9f08e832d664/1717805946933/faktablad_janstorm%5B1%5D.pdf, November 2005. -ERWIN -Schleswig-Holstein: train and ferry traffic stopped
BBC (20050108)	BBC, Severe gales cause havoc on roads, http://news.bbc.co.uk/2/hi/uk_news/england/4157069.stm, 08January2005 -A1 closed northbound from Stannington -police had to rescue stranded lorry drivers Northumberland early 8Jan2005 -no safe routes in or out of Carlisle -lorries overturned on M6 -jackknifed lorries A69 in Northumbria -Cleveland police: overturned lorry at Greystones roundabout -number of trees blown over in Stockton & Thornaby -North Yorkshire police: dozen lorries overturned on A1 between Scotch Corner & Wetherby
BBC (20050110a)	BBC, Northern Europe shaken by storms, http://news.bbc.co.uk/2/hi/europe/4158809.stm, 10 January 2005a -airports, rail networks, bridges, roads closed; dozens North Sea ferry routes cancelled -Scotland west coast: ferry ran aground; 100 on board remained there overnight
BBC (20050110b)	BBC, No quick fix to flood problem, http://news.bbc.co.uk/2/hi/uk_news/wales/4159471.stm, 10Jan2005b -railway closed between Llandudno Junction & Blaenau Ffestiniog -spokeswoman: line closed until further notice; relacement buses
Belfast Telegraph (20050110a)	Belfast Telegraph, Ulster braced for more storms (contributor Maureen Coleman), p.1, 10Jan2005 (Monday) -ERWIN -10Jan2005 Ulster bracing for more severe gales & torrential rain; storms continue to cause havoc across province -roads closed by flooding & fallen trees -Roads Service staff out in force to remove hundreds of fallen trees -many roads closed across province: Fermanagh worst hit -trees removed Saintfield Road Dublin & Gilford Co Down -many roads closed by flooding; worst cases Dromore & Newtown-hamilton; main Armagh road to Monaghan closed S of Middleton
Belfast Telegraph (20050110c)	Belfast Telegraph, Storms sweep northern Britain, p.6, 10Jan2005c (Monday) -ERWIN -motorists warned about travelling in Carlisle because of floods -several roads in the city remained closed
Beredskabstyrelsen (2005)	Beredskabstyrelsen, Beredskabets indsats i forbindelse med orkanen 8. januar 2005, En tvaergaende erfaringsopsamling, Beredskabssstyrelsen, Datavej16, 3460 Birkerod, Oktober 2005 -4000 people stranded by shutdown of bus network -traffic interrupted in large part of country -bridges closed: Storebaeltsbroen & Lillebaeltbro -train, metro & bus traffic stopped in certain areas -all plane traffic redirected to Germany or Sweden -police advised people from going outside
CNN (20050109)	CNN, Weather. 13 killed as storm lashes Europe, http://edition.cnn.com/2005/WEATHER/01/09/europe.storm/, 09 Jan 2005 -Germany: train services halted in N Germany -Carlisle, UK: worst flooding in 40y -most access roads still underwater Sunday -numerous ferry lines in North & Baltic Sea suspended; -ferry grounded near Cairnryan; refloated after 30h on high tide with 2 tug boats -high winds overturned 25 lorries on highways in northern England -numerous highways & bridges closed -northern Germany: Germany had highest nighttime temp during storm (>10C) in more than 100y -ferries Rostock Germany to Gedser Denmark cancelled on Saturday but running Sunday -ferry suspended Sassnitz on Ruegen in Germany to Trelleborg Sweden -ferry suspended Hirtshals Denmark to Larvik Norway on Saturday
DMI (2005)	DMI, Danmark ramt af landsdækkende storm, https://www.dmi.dk/nyheder/2005/danmark-ramt-af-landsdakkende-storm#:~:text=Stormen%20her%20i%20januar%202005,hen%20over%20den%20nordlige%20Nords%C3%B8. 10Jan2005 -violent weather meant traffic impaired for whole country. -bridge Storebaeltsbroen already closed 14:30 -bridge Lillebaeltsbroen also shut in running of day; very unusual; openend 21:00 -in several parts of the country train & bus traffic stopped -all air traffic redirected to Germany & Sweden at certain time -police advised whole country against going outside -Helsingor police stopped all traffic on roads
Guardian (20050109)	Guardian, Thousands lose power in storms (contributor Henry McDonald), 9 January 2005. -ERWIN -roads to south blocked by fallen trees including a main route to Cork -Cork festival for official launch of city as European Capital of Culture -Dublin: trees blocked roads to Swords -Galway: road Claddagh junction-Seapoint closed by flooding -M1 motorway at Dundalk interrupted by fallen trees -Ireland railway: lines closed: Dublin-Maynooth, Dublin-Drogheda -Northern Ireland roads: worst affected in Omagh, Newry, Portadown, Carrickfergus -ferry from N ireland run aground off W coast Scotland with 100 passengers

	-P&O ferry European Highlander stranded on shingle beach with winds >100mph -43 passengers & 53 crew not in immediate danger -tugs to arrive morning 9Jan2005 to tow ship to Cairnryan harbour -Britain: gale winds and heavy rain caused problems: motorways closed, evacuations from flooded homes, power cuts -dozens of lorries overturned, motorists in floodes airlifted -train services disrupted in N England & Scotland
Guy Carpenter (2005)	Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005 -ERWIN/GUDRUN -severe disruptions sea/air/land transport -UK: P&O European Highlander ferry ran aground SW Scotland; 100 passengers & crew stranded -dozens of lorries overturned; motorists in floods airlifted away -Highways Agency: do not drive unless journey essential -many train services disrupted, particularly north of England and Scotland -Carlisle: local Stagecoach fleet of 87 buses put out of action by floodwaters up to 1.2m at Willowholme depot -Denmark/Sweden: airports in Denmark and S Sweden temporarily closed -S Baltic ferries suspended -road & rail communications badly disrupted -Sweden: all rail traffic to/from south stopped -Sweden: road travel disrupted by fallen trees and flooding -Germany: Schleswig-Holstein: shut down trains, highway links, ferry bridges -Russia, St. Petersburg: 6 subway stations closed by rising water levels
Irish Times (20050108)	The Irish Times, Severe weekend weather leads to flooding (contributor James Fitzgerald), https://www.irishtimes.com/news/severe-weekend-weather-leads-to-flooding-1.404508, 8 January 2005 -ERWIN -Bus Eireann last night reported delays up to 1h on some routes -problems with much water on roads; Athlone & Longford worst affected -several ferry services cancelled -railway: Iarnrod Eireann; -flooding forced Dublin-Tralee train to terminate Killarney; with replacement bus service -trees on line Coolmine-Clonsilla on Dublin-Maynooth route with delays night 7Jan2005 -Aer Aran flight Kerry-Dublin cancelled 07Jan2005 06:00 cancelled due to high winds -Cork: flooding on main Cork-Killarney road near Ballyvourney -reports of fallen trees on main Mallo-Mitchelstown road near Whitechurch
Irish Times (20050109)	The Irish Times, Seven die as storm hits southern Scandinavia, irishtimes.com/news/seven-die-as-storm-hits-southern-scandinavia-1.1295791, 9 January 2005 -ERWIN -Denmark: DMI issued severe storm warning for entire country -widespread disruption trains & ferry transport -Denmark: Copenhagen airport: number of departing flights cancelled or delayed -Denmark: Kastrup airport: inbound flights redirected -Sweden: Sturup airport near Malmo temporarily closed -Sweden: ferry traffic stopped -Sweden: 5 passenger trains stuck without heat & light evacuated
Irish Times (20050111)	The Irish Times, Man dies as storm causes power cuts and flooding (contributor Ciara O'Brien), https://www.irishtimes.com/news/man-dies-as-storm-causes-power-cuts-and-flooding-1.1295844, 11 January 2005 -GERO -fallen trees & flooding blocked a number of roads -lorry driver killed when vehicle blown off Derry's Foyle Bridge by gale winds -lorry fell 100s feet from bridge onto mudflats -another lorry overturned & collided with car while crossing Faughn Bridge on Limavady Road near Derry; 2 injuries -emergency crews on standby along west coast where worst damage expected -in Malahide Co Dublin high tide caused flooding Bissets Strand, Strand Road, Estuary Road -ferry services to offshore islands cancelled -fallen tree at Millicent Bridge blocked road at Sallins -N20 between Croom & Banogue in Limerick partially blocked by tree -Clare: telephone pole blown down on Sandfield Road in Ennis -Co Down: flooding closed dual-carriageway Newry to Warrenpoint (estuary road) -flight cancellations: -Aer Arann cancelled some Galway and Kerry services with flights from Cork & Sligo affected -Aer Lingus cancelled flight from London Heathrow at 05:35PM -Ryanair cancelled some flights to/from London -Stena & Irish Ferries sailings running on schedule
Jameson (2005)	Jameson D., Weather extremes 2005. January 7th-8th Severe storm development, https://user.eumetsat.int/resources/case-studies/rapid-cyclogenesis-in-the-north-atlantic, pdf timestamp: 17/03/2005 -considerable damage UK; numerable report fallen trees & overturned vehicles on major routes -Scotland P&O European Highland ran aground on shingle in Cairnryan (Dumfries & Galloway); all 100 passengers safe
LCW (20050121)	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -ERWIN: UK: Carlisle in Cumbria awash with water; cut off with no safe routes in or out -ERWIN: UK: spate of accidents shut parts of M1 (northbound at jc26; southbound at jc 26-27) and M6 -ERWIN: UK: major bridges across UK closed or restricted; some train service severely disrupted

	-ERWIN: UK: Llanrwst: several houses flooded; main A470 road flooded on either side of town -ERWIN: UK: motorists advised not to journey unless necessary -ERWIN: UK: M6 near Carlisle: overturned lorries, closed southbound between jc44 & jc43; care advised between jc20 & jc22 in Cheshire -ERWIN: UK: M6 closed northbound between Jc5 & Jc6 near Birmingham -ERWIN: UK: central Scotland police: number of roads in the region were closed or passable only with care -ERWIN: UK: parts of rail line between Inverness and Perth were closed -ERWIN: Denmark: key bridges and airports were closed; all ferry and rail traffic suspended -ERWIN: ferry traffic between Sweden, Denmark and Germany heavily disrupted; dozens of delays and cancellations -ERWIN: Schleswig-Holstein: winds damaged houses & forced train and ferry links and highway bridges to shut down -ERWIN: DK: airports in Copenhagen & Malmo closed & inbound flights rerouted to Stockholm -ERWIN: SE: many roads in southern Sweden flooded; people urged to stay indoors -ERWIN: DK: bridges between island of Funen (Odense) and Zealand (Copenhagen) closed -ERWIN: DK: bridge between Copenhagen & Malmoe closed -ERWIN: SE: virtually all trains cancelled in S Sweden -ERWIN: UK: Carlisle: all 65 city buses damaged by water -ERWIN: Finland: water cut a number of roads & highways along coast; also centre of Helsinki where Market Square flooded -ERWIN: airports, rail networks, bridges, roads closed -ERWIN: dozens of N Sea ferry routes cancelled -ERWIN: Russia: St. Petersburg: river Sleleznyovka overflowed in Vyborg district Leningrad region & suspension of traffic on Finland-Russia highway between 1800 Jan 9 and 1200 Jan10 -GERO: Scotland: many roads in rural areas closed; drivers urged to take extra care in high winds -GERO: Scotland: bridges closed: Tay Road, Erskine, Forth Road, Kessock, Skye -GERO: Scotland: Ferry cancellations: -GERO: Scotland: CalMac: suspended all 26 routes between Scottish Islands & mainland -GERO: Scotland: P&O ferry suspended service from Scotland to N Ireland -GERO: Scotland: Northlink ferry suspended from Aberdeen to Orkney & Shetland -GERO: Scotland: First ScotRail cancelled all services -GERO: Scotland: Caledonian MacBrayne's ferry ops between Scottish ports & islands closed down, except 'Hebridean Isles' that left Kennacraig for Port Askaig on Islay -GERO: Storm Jan12 that hit southern & estern Norway caused problems for sea, air, road traffic -GERO: W Norway: most flights cancelled at Haugesund & Floroe airports -GERO: Hurtigruten had to bypass stops -GERO: ferries between Kristiansand & continent had sailing cancelled morning 12Jan
Lindahl (2005)	Lindahl, Sture: The Storm Gudrun 2005-01-08, uploaded to Internet 19/10/2021, presentation 2005-05-12 -2 major roads blocked more than 1 week -train service between Stockholm and Malmo disrupted for more than 2 weeks -local railways more than 3 weeks
NRK (20050108)	NRK, Gudrun herjar i sor (contributor Bent J. Tandstad), 8Jan2005 -ERWIN -Color Lines Prinsesse Ragnild using propeller to against waves -a couple of ropes are frayed; being considered if ferry should leave key -all ferries between Vestfold & Denmark suspended -ferries suspended from Egersund & Kristiansand to Denmark -no ferry between Kristiansand & Goteborg -ferry suspended between Tonsberg & Stromstad -Stena Line cancelled several ferries; hope to sail Fredrikshavn ferry in evening -Color Line ferries departing from Kiel and Oslo normal -DFDS says ferry Oslo-Copenhagen delayed from 17:00 to 20:00 -ferry route Horten-Moss impacted by storm; ferry traffic stopped on this route -Ostfold: Gudrun led to riksveg 108 to Hvaler being closed; 3700 people isolated on islands -FIG. [PHOTO] car has problem in water at Hvaler in Ostfold Rasfare -local large landslides in mountains in S Norway, especially in west -reports of difficult driving conditions in S inland areas in S Norway and in mountains in S Norway because of wind and ppt.
Deutsche Rueck (2006)	Deutsche Rueck, Sturmdokumentation Deutschland 2005, (contributors: T. Axer, T. Bistry, S Fietze, M Mueller, M Prechtl), Deutsche Rueckversicherung, Aktiengesellschaft, Hansaallee 177, 40549, Duesseldorf, March, 2006. -ERWIN -many areas had large trees broken or uprooted; interrupted traffic -Saturday afternoon whole train network of Schleswig-Holstein stopped from falling trees breaking power lines or falling on tracks -road traffic interrupted -high bridge of A7 over Kiel canal closed on safety grounds -hurricane gusts toppled several trucks and created dangerous flying objects -Ferry connections to German North Sea islands stopped -traffic suspended for a period -ferry traffic on Baltic suspended

	-several train links broken -bridges across Grossen Belt & Oresund closed on safety grounds -ferry stranded on W coast Scotland
Haanpaa et al (2006)	Haanpaa, Simo, Samuli Lehtonen, Lasse Peltonen, Elena Talockaite, Impacts of winter storm Gudrun of 7th-9th January 2005 and measures taken in the Baltic Sea region, Astra, www.astra-project.org, 43pp, 2006 [pdf properties: datestamp 13/06/2006] 3.5.3. Transport and communications -transport & commun damage severe in Denmark, Sweden, Lithuania, Estonia -Estonia state highway damage 729814EUR -other damage to roads, street lighting, culverts, tree clearance 870808 EUR -Finland: effects minor -all major ferry operators cancelled some departures -Finnish Road Administration: poor driving conditions -no effects rail traffic (VR state railways), flights from Helsinki-Vantaa airport (Finnair) -FIG12. [PHOTO] Flooding streets in Helsinki (Samuli Lehtonen)
Johansson et al (2006)	Johansson J., S Lindahl, O. Samuelsson, H Ottoson, The storm Gudrun. A seven-week power outage in Sweden, CRIS, Third International Conference on Critical Infrastructure, Alexandria, Virginia, September, 2006. -ERWIN - Malmo-Stockholm rail line stopped for 2 weeks,
Hisscott (2007)	Hisscott, Alan, When NWP met climatology: storms over the Isle of Man during January 2005,'Weather, 62, 74-77, 2007 -ERWIN: -overnight Isle of Man Steam Packet ferry and flights to airport delayed morning 8Jan -considerable disruption road transport -many main roads blocked by fallen trees and debris, including access to island hospital -all bus services cancelled for the day
Hellenberg and Kentala (2008)	Hellenberg, T. and J. Kentala, Chapter III. Sudden sea level rise in the Gulf of Finland in January 2005, in C. Pursiainen (ed), Early Warning and Civil Protection. When does it work and why does it fail? Nordregio report 2008:1 -ERWIN/GUDRUN -road E18 closed to traffic Sunday afternoon in Viipuri/Vyborg (Russia) & Vaalimaa frontier -water rose over E18 from Vaalimaa to Viipuri/Vyborg -St. Petersburg: 6 metro stations because of flood risk -traffic cut off in many places in Helsinki region -cut in main circle roads Keha I in Otaniemi & intersection of Keha III/Itavayli -water closed roads throughout the coastal region -some streets closed in towns neara Helsinki: Espoo, Kotka, Kirkkonummi, Sipoo, Raisio, Porvoo -Turki: whole passenger port under water on Sunday morning
Gardiner (2010)	Gardiner, Barry, Appendix 3: Background information on 11 storms selected for detailed analysis, European Forest Institute, Atlantic European Regional Office - EFIAtlantic, 161 pp. [PDF properties: datestamp 23Jul2010] -storm ERWIN -Sweden -landscape dramatically changed -roads blocked, electricity supply & telecomm out of order, trains stopped -all railways to/from S Sweden at standstill -20Jan some traffic on main rail; 12 Feb rail traffic normal -Germany -Schleswig-Holstein: many houses damaged; ferry & train traffic cancelled
SMHI (20111013)	SMHI, Gudrun - Januaristormen 2005, https://www.smhi.se/kunskapsbanken/meteorologi/stormar-i-sverige/enskilda-stormar-och-ovader/gudrun-januaristormen-2005-1.5300, 13 oktober 2011 -late Friday night 7Jan2005 new low P centre NW of Ireland -day later deepened to destructve storm; treefall, outages electricity & telephone, halted train traffic -on Sunday morning, wind decreased and landscape in many places unrecognizable -routes closed, power and telephone networks knocked out, train traffic stopped, and people shocked at the enormous damage
Expressen (2017)	Expressen, Gudrun 2005: 20 doedas i den vaarsta storm, https://www.expressen.se/nyheter/inloggad/gudrun-2005-20-dodas-i-den-varsta-stormen/, published 04Feb2017 09:25 -roads around south and middle Sweden blocked by fallen trees; power cables broken at same time -Ljungby: roads covered in tree drifts 6-7m high; 6 days before roads passable -completely destroyed buildings, railways knocked out, road system disabled
SurgeWatch (2017)	SurgeWatch, Storm Event 11th January 2005, in Haigh, I.D., O. Ozsoy, M.P. Wadey, R.J. Nicholls, S.L. Gallup, T. Wahl, J.M. Brown,Data descriptor: An improved database of coastal flooding in the United Kingdom from 1915 to 2016, Scientific Data, 4: 170100, DOI: 10.1038/sdata.2017.100, 2017 -GERO -Sumbergh airport in Shetlands closed for 3 days & key road links out of action (Ball et al, 2008) -roads/bridges, ferry, rail services affected
ESWD (20240803)	European Severe Weather Database, 7-9Jan2005, https://eswd.eu (last access 03Aug2024) BLOCKED ROAD Location LA Latitud Longitu Date Day Time Uncertainty ND --- Cumbria UK 54.60 N 2.75 W 08-01-2005 sat 12:00 UTC (+/- 1 day) lorries overturned on highway "M6"

	Northumberland UK 55.40 N 1.70 W 08-01-2005 sat 12:00 UTC (+/- 1 day) highway "A1" closed north of Stannington Thirsk UK 54.20 N 1.47 W 08-01-2005 sat 12:00 UTC (+/- 1 day) Truck(s) and/or trailer(s) overturned lorries overturned on highway "A1" between Wetherby and Scotch Corner Målsryd Västra Götaland SV 57.68 N 13.05 E 09-01-2005 sun 20:30 UTC (+/- 1 hrs.) roads blocked Lärje Västra Götaland SV 57.77 N 11.98 E 09-01-2005 sun 19:04 UTC (+/- 1 hrs.) car hit by falling tree Stenslanda Kronobergs Län SV 56.73 N 14.82 E 09-01-2005 sun 16:57 UTC (+/- 1 hrs.) several cars damaged by falling trees
Bioenergy International (2025)	Bioenergy International, The aftermath and legacy of Storm Gudrun - 20 years on (contributor Alan Sherrard), https://bioenergyinternational.com/the-aftermath-and-legacy-of-storm-gudrun-20-years-on/, 11 January 2025. -ERWIN/GUDRUN -fallen trees & power lines blocked roads & rail
Myhr (2025)	Myhr, K.J.: Storm puts focus on security, https://history.vattenfall.com/stories/power-to-the-people/storm-puts-focus-on-security/, last access: 24Jan2025. -ERWIN/GUDRUN -roads blocked by fallen trees -railways stopped -Sturup & Kastrup airports closed -bridges closed: Oresund, Alvsborg, Uddevalla
Wikipedia (20250429)	Wikipedia, Ekstremveret Gudrun, https://nn.wikipedia.org/wiki/Ekstremv%C3%AAret_Gudrun, last access: 29Apr2025 -ERWIN -Ireland, UK, Norway, Denmark, Sweden storm damaged infrastructure; traffic interruptions air-sea-land -St Petersburg: water from Neva river so high that 6 metro stations had to close -Sweden: all rail traffic returned to normal 1 month after storm

Table S74. Structural damage to wind farms and wind energy impacts (arranged by year and then alphabetically)

Source	Full Reference and Notes
Haanpaa et al (2006)	Haanpaa, Simo, Samuli Lehtonen, Lasse Peltonen, Elena Talockaite, Impacts of winter storm Gudrun of 7th-9th January 2005 and measures taken in the Baltic Sea region, Astra, www.astra-project.org, 43pp, 2006 [pdf properties: datestamp 13/06/2006] 3.5.2.1. Strong winds stall wind farms in Denmark (Bulow, 2006; Andersen, 2006) -Denmark: ~5400 turbines; with winds > 25 m/s western Denmark, 4000 Eltra machines shut down -local energy production reduced to 1/20th full capacity of 2380 MW -power demand filled power bought abroad (N Europe); but with difficult because storm extensive -main transmission grid only few damages; public not affected by power cuts -low voltage overhead cables hit with impact on 150000 customers -no wind turbines harmed; scraping policy & renewal of old wind turbines -turbines had to be restarted manually (Andersen 2006) -100s of customers still without electricity 11Jan

Table S75. Hydropower impacts (arranged by year and then alphabetically)

Source	Full Reference and Notes

Table S76. Structural damage to buildings, piers, and cultural monuments; flooded buildings (arranged by year and then alphabetically)

Source	Full Reference and Notes
Alexandersson and Ivarsson (2005)	Alexandersson H and KI Ivarsson, Januaristormen 2005, Faktablad nr 25, SMHI, https://www.smhi.se/download/18.18f5a56618fc9f08e832d664/1717805946933/faktablad_janstorm%5B1%5D.pdf, November 2005. -Schleswig-Holstein in N Germany -many houses damaged
DMI (2005)	DMI, Danmark ramt af landsdækkende storm, https://www.dmi.dk/nyheder/2005/danmark-ramt-af-landsdakkende-storm#:~:text=Stormen%20her%20i%20januar%202005,hen%20over%20den%20nordlige%20Nords%C3%B8. 10Jan2005 -4 fatalies in Denmark; 3 fatalities on Fyn -2 fatalies in Assens when roof came from apartment building -N Germany: roof tiles started falling; train & ferry traffic stopped
Eitrheim (2005)	Eitrheim, K.: Rapport etter stormen 'Gudrun' lordag 8.1.2005 for Rogaland fylke, met.no, 11 January 2005 -as far as we know, no reports of serious damage after storm Gudrun -due to several reason -Nov1981 storm was as strong as Gudrun; weaker constructions during earlier storm -modern buildings and similar constructions seem to be able to withstand Gudrun winds -people secured property and stayed indoors during storm
Guardian (20050109)	Guardian, Thousands lose power in storms (contributor Henry McDonald), 9 January 2005. -ERWIN -reports of fallen trees & flying bricks from broken chimneys in gusts to 90mph
Guy Carpenter (2005)	Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005 -ERWIN/GUDRUN -houses deroofed/property damage -UK, Carlisle: -2 large industrial estates in city flooded -insurance loss adjuster & disaster restoration companies (Servicemaster & Munters on scene

	-local utility companies working long hours to restore electricity to enable dehumidifiers -wall plaster stripped 1m above flood level -drying out and restoration slow; 4-8 months before residents can return to homes -Denmark: heavy damage to property -Sweden: heavy damage to property and forests -Norway affected by storm but little damage reported -Germany, Schleswig-Holstein: strong winds damaged houses -Latvia: houses deroofed -Latvia: property damage in Ventspils, Liepaja, Valka, Jekabspils -Estonia: damage greatest along west coasts
Irish Times (20050109)	The Irish Times, Seven die as storm hits southern Scandinavia, irishtimes.com/news/seven-die-as-storm-hits-southern-scandinavia-1.1295791, 9 January 2005 -ERWIN -Denmark: 2 men killed when struck by roof torn off cottage on island of Funan
Irish Times (20050111)	The Irish Times, Man dies as storm causes power cuts and flooding (contributor Ciara O'Brien), https://www.irishtimes.com/news/man-dies-as-storm-causes-power-cuts-and-flooding-1.1295844, 11 January 2005 -GERO -roof blown off Catholic Church at Tulsk Co Roscommon
LCW (20050121)	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -ERWIN: UK: deaths: man crushed in caravan by collapsed barn in Cumbria; 2 elderly women died in flooded properties -ERWIN: UK: up to 10000 households in Hexham in Northumberland enduring third day without water after weekend storms -ERWIN: UK: two water mains washed away & unlikely to be repaired before end of week -ERWIN: UK: Hexham schools to remain closed until end of week -ERWIN: UK: weekend winds of 145 kph that ripped roofs from homes & caused property damage on coast; insurance cost 10s mill EUR -ERWIN: Denmark: 2 died when uprooted trees flung onto vehicles; 2 killed due to dislodged roof -ERWIN: Schleswig-Holstein: winds damaged houses & forced train and ferry links and highway bridges to shut down -GERO: several large roofs blown off in eastern & western Norway
NRK (20050108)	NRK, Gudrun herjar i sor (contributor Bent J. Tandstad), 8Jan2005 -stat meteorologist Terje Alsvik Walloe: weather can cause destruction -roof tiles and loose objects can be taken by the wind; can be forest damage
Deutsche Rueck (2006)	Deutsche Rueck, Sturmdokumentation Deutschland 2005, (contributors: T. Axer, T. Bistry, S Fietze, M Mueller, M Prechtl), Deutsche Rueckversicherung, Aktiengesellschaft, Hansaallee 177, 40549, Duesseldorf, March, 2006. -ERWIN -worst damage in Schleswig-Holstein & Mecklenburg-Vorpommern -many house roofs significantly damaged; sometimes completely deroofed; case of 1000m2 deroofing Kiel
Hiscott (2007)	Hisscott, Alan, When NWP met climatology: storms over the Isle of Man during January 2005,'Weather, 62, 74-77, 2007 ERWIN: -strong winds caused widespread damage across Isle of Man -large sectors of residential estates and vehicles damaged by flying debris -property damage at 10 mill GBP -damage caused by gusts over 50kt increases non-linearly with peak wind speed -Browning et al (2003): for severe storm 25% increase in wspd causes 6-8times amount damage
Hellenberg and Kentala (2008)	Hellenberg, T. and J. Kentala, Chapter III. Sudden sea level rise in the Gulf of Finland in January 2005, in C. Pursiainen (ed), Early Warning and Civil Protection. When does it work and why does it fail? Nordregio report 2008:1 -GUDRUN -FIGIII-2. [MAP] The Helsinki region with selected places affected by flash flooding -dozens of houses flooded Helsinki -port of Sornainen in Helsinki: 400-500 newly imported cars damaged by seawater -Virolahti: evacuations from 2 terraces of houses -Pyhtaa: evacuations -Tammissaari, Loviisa: water flooded buildings along the shore -some streets closed in towns neara Helsinki: Espoo, Kotka, Kirkkonummi, Sipoo, Raisio, Porvoo -Turki: whole passenger port under water on Sunday morning
Gardiner (2010)	Gardiner, Barry, Appendix 3: Background information on 11 storms selected for detailed analysis, European Forest Institute, Atlantic European Regional Office - EFIAtlantic, 161 pp. [PDF properties: datestamp 23Jul2010] -storm ERWIN -Germany -Schleswig-Holstein: many houses damaged; ferry & train traffic cancelled
Expressen (20170204)	Expressen, Gudrun 2005: 20 doedas i den vaarsta storm, https://www.expressen.se/nyheter/inloggad/gudrun-2005-20-dodas-i-den-varsta-stormen/, published 04Feb2017 09:25 -completely destroyed buildings, railways knocked out, road system disabled -Malmo -hockey game ended when skating rink roof shaken powerfully in wind; arena evacuated
SurgeWatch (2017)	SurgeWatch, Storm Event 11th January 2005, in Haigh, I.D., O. Ozsoy, M.P. Wadey, R.J. Nicholls, S.L. Gallup, T. Wahl, J.M. Brown,Data descriptor: An improved database of coastal flooding in the United Kingdom from 1915 to 2016, Scientific Data, 4: 170100, DOI: 10.1038/sdata.2017.100, 2017 -GERO -Scotland: roofs damaged, trees blown down -school in Balivanich damaged & later relocated (Richards and Phipps, 2007)

ESWD (20240803)	European Severe Weather Database, 7-9Jan2005, https://eswd.eu (last access 03Aug2024) BUILDING DAMAGE Location LA Latitud Longitu Date Day Time Uncertainty ND --- Visby Gotlands Län SV 57.63 N 18.30 E 09-01-2005 Sun 20:50 UTC (+/- 1 hrs.) roof blown off

Table S77. Forest damage and tree falls (arranged by year and then alphabetically)

Source	Full Reference and Notes
Alexandersson and Ivarsson (2005)	Alexandersson H and KI Ivarsson, Januaristormen 2005, Faktablad nr 25, SMHI, https://www.smhi.se/download/18.18f5a56618fc9f08e832d664/1717805946933/faktablad_janstorm%5B1%5D.pdf, November 2005. -ERWIN -storm that hit Gotland & SE Svealand 8-9Jan2005 caused enormous damage to forest & indirectly also electricity & telecom network -approx 75 mill m3 timber fell; 3 times more than prevous worst storm 22Sep1969 -85% losses branches; 15% tall? -south & middle parts Smaland & Halland & southernmost Vastergotland & parts Skane/Blekinge hit worst -75 million m3 timber fallen or 250 mill trees -number about same as tree fall for all storms in 20th century -TAB2. List of fallen timber by storm -FIG12. [MAP] Volume of storm-damaged timber per ha 8-9Jan2005 -Lettland: 5 mill m3 timber fell -Denmark: N half Jylland extensive tree fall;
BBC (20050108)	BBC, Severe gales cause havoc on roads, http://news.bbc.co.uk/2/hi/uk_news/england/4157069.stm, 08January2005 -number of trees blown over in Stockton & Thornaby
Beredskabsstyrelsen (2005)	Beredskabstyrelsen, Beredskabets indsats i forbindelse med orkanen 8. januar 2005, En tvaergaende erfaringsopsamling, Beredskabsstyrelsen, Datavej16, 3460 Birkerod, Oktober 2005 -2 mill m3 trees fallen in Denmark forest most in Jutland north of line Skjern-Horsens -toppled trees over large areas; Sweden lose 75 mill m3 wood; worst for many years
Guy Carpenter (2005)	Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005 -ERWIN/GUDRUN -Danish forests: 20-30km2 loss woods with value 300 mill DKK -Sweden: -forest industry badly damaged: record number of trees fallen -estimated 75 million m3 trees felled with value 1.6-2.3 billion GBP -yearly production Sweden 85 mill m3 -in affected areas 3-4 years of production lost -net loss to forest industry several billion SEK -Sweden: Erwin wind speed about same as Anatol but larger area affected from trajectory path -forests hit by unusually strong winds inland -1969, Sweden hit by 2 storm with forest damage of 25 and 10 million m3 -since 1969 population of spruce increased -damage contribution from moist ground from mild and wet winter -Latvia: 5 million m3 wood toppled -Estonia: 1 million m3 timber toppled or 30 million EUR damage
Irish Times (20050108)	The Irish Times, Severe weekend weather leads to flooding (contributor James Fitzgerald), https://www.irishtimes.com/news/severe-weekend-weather-leads-to-flooding-1.404508, 8 January 2005 -ERWIN -trees on line Coolmine-Clonsilla on Dublin-Maynooth route with delays night 7Jan2005 -Cork: flooding on main Cork-Killarney road near Ballyvourney -reports of fallen trees on main Mallo-Mitchelstown road near Whitechurch
Irish Times (20050109)	The Irish Times, Seven die as storm hits southern Scandinavia, irishtimes.com/news/seven-die-as-storm-hits-southern-scandinavia-1.1295791, 9 January 2005 -ERWIN -Denmark: 2 others killed by falling trees -Sweden: 3 died during storm force winds; 2 motorists whose cars hit by falling trees
Irish Times (20050111)	The Irish Times, Man dies as storm causes power cuts and flooding (contributor Ciara O'Brien), https://www.irishtimes.com/news/man-dies-as-storm-causes-power-cuts-and-flooding-1.1295844, 11 January 2005 -GERO -fallen tree at Millicent Bridge blocked road at Sallins -N20 between Croom & Banogue in Limerick partially blocked by tree
LCW (20050121)	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -ERWIN: Northern Ireland: heavy gales uprooted trees across province; Enniskillen & Downpatrick particularly affected -ERWIN: Sweden: National Board of Forestry: hurricane strength winds felled >50 million cubic metres of trees; 2y harvest -ERWIN: Estonia: state forestry service: storm toppled nearly 1 million cubic metres timber, damage of USD39.31 million -ERWIN: UK: weekend winds of 145 kph that ripped roofs from homes & caused property damage on coast; insurance cost 10s mill EUR
LCW (20050128)	Lloyds Casualty Week, 28Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ

	-ERWIN: -Federation of Forest Owners Skogsaegarna estimates 75 million m3 forest wood uprooted or damaged
LCW (20050204)	Lloyds Casualty Week, 04Feb2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -ERWIN -Latvian Agric Minister: Latvian timber industry loses 100 million eur from Erwin (100-128 mill EUR) -at least 7.3 million m3 wood fallen -Latvian government declared national energy crisis; all emergency services deployed
Lindahl (2005)	Lindahl, Sture: The Storm Gudrun 2005-01-08, uploaded to Internet 19/10/2021, presentation 2005-05-12 -S7. The effects in the forests -75 million m3 timber damaged by storm -corresponds to 4y production -previous record (1969): 33 million m3 S20. Repair task for Sydkraft Nat -19350km damaged overhead lines to be repaired; 2180 km destroyed overhead lines to be replaced -FIG. [PHOTO] workers repair fallen lines in forest S21. Operation Gudrun -duration: 6 weeks -max size repair crew: 2716 persons -personnel involved 4520 persons -600 lines workers from 100 Swedish companies -400 lines workers from 35 companies in other countries (Finland, Norway, Denmark, Poland, Germany, UK) S22. Amount of work -10000 poles -1500 km of underground cable -70000 cable joints -120 distribution substations S23. Restoration after the storm -FIG. [TIMESERIES] customers without electricity in Sweden S24. Reliability of power supply -FIG. [TIMESERIES] Average outage time (total outage time/number of customers) Gudrun 2005 shows 35h/customer; 1999 (unidentified event) shows 10h/year S25. Reliability of power supply -FIG. [TIMESERIES] Outage time for MV (medium voltage?) delivery points - Vattenfall Graph shows downward from late 1930s to 1983 with 280 minute spike in 1969 S26. Reliability of power supply -FIG. [TIMESERIES] Equivalent outage time for MV (medium volatage?) supply - Sydkraft Graph shows 245 minute outage in 1983 S27. Reliability of power supply -FIG. Interruption time S28. Results and Plans -immediately after the storm, power supply was fixed by means of temporary installations -during rest of 2005 temporary installations will be replaced by permanent installations with normal or better reliability -lines will be upgraded with covered conductor -during 2005 the amount of new underground cable in Sydkraft area estimated at 1600km S29. MV and LV distribution system -total length: 172500km -power cable (Sydkraft 2005): 57000 km or 33% -planned construction (2005): 1600km -construction (2004): 1000km -construction (2003): 980km -construction (2002): 880km -in 2000 Sydkraft started to replace conventional overhead lines with bare conductors by overhead lines with covered conductors

	-in 2001 Sydkraft started to plow down underground cable when local conditions permit
Met.no info (2005)	met.no info, Varsling av stormer og ekstremt vaer (contact information: KH Midtbo, M Lystad, D Kvamme), 10pp, No.18/2005, Oslo, 25 November 2005 -from January 2005 we remember Gudrun, Haarek, Inga within one week; caused large damage along the coast and on forest inland
Deutsche Rueck (2006)	Deutsche Rueck, Sturmdokumentation Deutschland 2005, (contributors: T. Axer, T. Bistry, S Fietze, M Mueller, M Prechtl), Deutsche Rueckversicherung, Aktiengesellschaft, Hansaallee 177, 40549, Duesseldorf, March, 2006. -ERWIN -Saturday afternoon whole train network of Schleswig-Holstein stopped from falling trees breaking power lines or falling on tracks
Haanpaa et al (2006)	Haanpaa, Simo, Samuli Lehtonen, Lasse Peltonen, Elena Talockaite, Impacts of winter storm Gudrun of 7th-9th January 2005 and measures taken in the Baltic Sea region, Astra, www.astra-project.org, 43pp, 2006 [pdf properties: datestamp 13/06/2006] Windfall mill_m3 Denmark 1 Sweden 75 Lithuania 1 Latvia 7 Estonia 1 Finland 3.4.1. Forest losses -one most significant environmental impacts of Gudrun -Sweden: record damage over 30y -Latvia,Denmark,Estonia,Lithuania: significant forest damage -Poland: much lower forest damage than other countries 3.4.1.1. Spruce forest found susceptible to storm damages in Sweden -Sweden: 75 million m3 trees; equal to annual harvest of whole country -air masses may have accelerated in Denmark & Sweden while passing Norway obstale -Finland: mean wspd 15m/s & 30m/s gust critical threshold for forest damage -structure of forest had big impact on damage -SMHI (2005): large spruce plantations vulnerable to storm winds -Sweden forests were 30-40 years old; younger than last big storm from 1960s -coniferous forest makes up large fraction of total timber havest -spruce has shallower root structure compared to pine -forest management practices increase storm vulnerability: thinning & plantations -Finland: mean return period of the major wind damage to forest is 2-3y -with climate change, harmful storm event seen to rise -spruce growth rate next 100y will drop due to drought FIG5. [PHOTO] Forest damages were extensive in Sweden (photo: SMHI 2005) FIG6. Forest losses in the Baltic Sea Region after Gudrun FIG7. Comparison of the storm loses, annual harvest and share of coniferous timber in the countries of the BSR 3.4.1.2. Sturdier tree species introduced to Denmark lessen forest damage -Denmark: felled forest was 1.5-2.0 mill m3 or 1.5-2 times annual conifer harvest -cost forest damage 300 mill DKK or 40 mill EUR -impact mainly conifer; confier main forest type Denmark -after Anatol 1999, forest owners got support for clearing & replanting sturdier trees -planting trees in acidic soils from drained marshlands 3.4.1.3. Timber prices fall in Latvia as storm-felled timber reaches markets -Latvia losses >7mill m3; more than normal annual harvest -agricultural vancant lands used for forestry -damage concentrated in western part of country between Baltic Sea & Gulf of Riga -windblown timber sent ot market suddenly; price impact -normal harvest was delayed 3.4.1.4. Lessons learned from Gudrun on wind-induced forest damage -storm damage to European forest on increase a) forests have been planted on former agricultural areas b) forest monocultures common; spruce is weak because of root structure and evergreen foliage c) rougher harvesting techniques increase root damage d) trees planted on unsuitable soils -relapse period between storm events 3.5.1. Forestry and agriculture -forestry effects: prime growing age forests destroyed; heavy load on timber markets -agriculture: providing farms with spare power

	3.5.1.1. Reforestation only one part of cost of storms -Estonian forest damage: 8 mill EUR damage of which 3.2 mill EUR -Sweden: reforestation cost 240-725 mill EUR for destroyed 160000 ha -more than 1y after storm in Feb2006 10-15% fallen timber waits tbe handled -total cost forest damage Sweden 2 bill EUR; possible additional cost for insect damage -forest fire risk increased considerably -Finland: no direct forest damage because of weakened storm -harvesting hindered by wet ground; sawmills suffering lack of supply FIG10. Winter storm Gudrun: Damages to state-owned forests in Estonia
Johansson et al (2006)	Johansson J., S Lindahl, O. Samuelsson, H Ottoson, The storm Gudrun. A seven-week power outage in Sweden, CRIS, Third International Conference on Critical Infrastructure, Alexandria, Virginia, September, 2006. -ERWIN -mension of large number of fallen trees bringdown power lines and poles
Suursaar and Sooaar (2006)	Suursaar, U. and J. Sooaar, Storm surge induced by extratropical cyclone Gudrun: hydrodynamic reconstruction of the event, assessment of mitigation actions and analysis of future flood risks in Parnu, Estonia, WIT Transactions on Ecology and the Environment, vol.91, pp.241-250, WIT Press, 2006. -1.1 million m3 forest broken Estonia -forest losses in Latvia, Lithuania, Sweden, Denmark
Suursaar et al (2006)	Suursaar, U., T. Kullas, M. Otsmann, I. Saarmae, J. Kuik, M. Merilain, Cyclone Gudrun in January 2005 and modelling its hydrodyanamic consequences in the Estonian coastal waters, Boreal Environmental Research, 11, 143-159, 2006. -nearly 1 million m3 timber toppled Estonia
Hisscott (2007)	Hisscott, Alan, When NWP met climatology: storms over the Isle of Man during January 2005,'Weather, 62, 74-77, 2007 -ERWIN: -Pollard (2005): >300 deciduous trees and >20000 conifers felled during storm -7000m3 of timber felled; more than normal annual harvest -17 ha plantation destroyed; island does not have facility to process hardwood -The most severe plantation damage at Tholt-y-Will (Pollard 2007) & Ballaugh plantation -for damaged trees; half uprooted & half cracked off; contiguous areas of uprooting & cracking -snapped trees show twisting failure -2 damage sites aligned with wind -FIG3. [MAP] A map of the Isle of Man showing plantations (shaded) and the area of FIG4. (black rectangle) -FIG4. [MAP] The map of the Tholt-y-Will area. The location of the area of felled trees in FIG5 is shown as A and the location of FIG6 is shown as B. -FIG5. [PHOTO] A large area of damage to the upper Tholt-y-Will plantation (as shown in FIG4) -FIG6. [PHOTO] An area of damage to the lower Tholt-y-Will plantation (shown as B in FIG4)
Nilsonn et al (2007)	Nilsson C, S Goyette, L Barring, Relating forest damage data to the wind field from high-resolution RCM simulations: case study of Anatol striking Sweden in December 1999, Global and Planetary Change, 57, 161-176, 2007. -Gudrun destroyed 75 million m3 timber in Sweden
Rantanen (2008)	Rantanen, H., Chapter IV. Coping with Power Disturbances, in C. Pursiainen (ed), Early Warning and Civil Protection. When does it work and why does it fail? Nordregio report 2008:1, p.95-119 -night Sat to Sun, rescue units pulled back due to risk of falling trees
Soomere et al (2008)	Soomere, T., A. Behrens, L. Toumi, J.W. Nielsen: Wave conditions in the Baltic proper and in the Gulf of Finland during windstorm Gudrun, Nat Hazards Earth Syst. Sci., 8, 37-46, 2008. -largest forest damage ever reported in Sweden (Bengtsson and Nilsson, 2007)
SMHI (2009)	SMHI, Per - Januaristormen 2007, 6Aug2009, https://www.smhi.se/kunskapsbanken/meteorologi/per-januaristormen-2007-1.5287 -75 million m3 stimber lost Sweden during storm Erwin
Gardiner (2010)	Gardiner, Barry, Appendix 1: List of all Storms in Database, European Forest Institute, Atlantic European Regional Office - EFIAtlantic, 19 pp. [PDF properties: author=Barry Gardiner, datestamp=23Jul2010] https://ec.europa.eu/environment/forests/pdf/Final_Report_Appendix_1.pdf Event ID Year-Number//Month-Day// Storm Name //Country //Primary damage (Mm3)//Secondary damage (Mm3)//Estimated Growing Stock (Mm3)//% of Growing Stock damaged//Removals (Mm3)//Maximum Wind Speed (ms-1)//Value (M€) in Year of forest damage 2005-01 January 8 Gudrun (Erwin) UK 0.5 300 0.17 9.9 46 2005-01 January 9 Gudrun (Erwin) Denmark 2 58.2 3.44 1.84 46 2005-01 January 8-9 Gudrun (Erwin) Sweden 75 3233 2.32 78.13 42 1890 2005-01 January 8-9 Gudrun (Erwin) Latvia 7.8 573 1.36 11.29 40 2005-01 January 9 Gudrun (Erwin) Estonia 1 5.73 37 2005-01 January 9 Gudrun

	(Erwin) Lithuania 1 2005-02 January 11- 12 Gero Ireland, UK 49
Gardiner (2010)	Gardiner, Barry, Appendix 3: Background information on 11 storms selected for detailed analysis, European Forest Institute, Atlantic European Regional Office - EFIAtlantic, 161 pp. [PDF properties: datestamp 23Jul2010] 9.3. Primary damage -Sweden -total volume approx 75 million m3 forest damaged in Gotaland & Svealand over 270 000 ha. -damage most estensive in spruce except in Ostergotlands Ian for all Gotaland approx 80% damage made up of spruce -more damage done to spruce than other tree species -damaged acreage largest for mature forest; no severely damaged acreage for young forest -Denmark -northern Denmark wind damage to forest at 2 million m3 -Norway -Skogbrand (2010): no extensive damage to forest in Norway -Latvia -5 million m3 forest damaged -FIG9.4. [MAP] Damaged volume in southern Sweden after the 8Jan2005 wind damage event based on ocular inspection from aircraft 9.4. Secondary damage -Sweden -large efforts in Sweden to clear up storm impacts to prevent buildup of insect pests like spruce bark beetle & prevent reduction in quality harvested timber -large volumes spruce remained in forest over summer 2005; incr beetle popul & tree mortality -second wind felling Jan2007, partly in same area as 2005 -extensive efforts to salvage fallen timber before beetle flight spring 2007 -many trees remained in forest over the summer, led to production of new beetwles -altogether 3 mill m3 trees during 3 years -also in 2009 population of spruce bark beetle still high 9.5. Tertiary damage -Sweden -salvage of felled forest progressed more quickly than anticipated -approax 87% of wind-felled volume salvaged by end 2005 -forest owner Sodra reports 4000 extra people hired to deal with wind damage; normal Sodra employees 3900
SMHI (20111013)	SMHI, Gudrun - Januaristormen 2005,, https://www.smhi.se/kunskapsbanken/meteorologi/stormar-i-sverige/enskilda-stormar-och-ovader/gudrun-januaristormen-2005-1.5300, 13 oktober 2011 -areas with extensive forest damage: Smaaland, Halland, north Skana, Blekinga, south Vastergotland -forestry management estimates approx 75 million m3 timeber fell during storm -timber fall significantly greater than 37 million m3 for 1969 autumn storm -it should be added that fir plantations had increased greatly in 2005 at expense of mixed forests -FIG4. [MAP] Maximum gusts at 10m height for 8-9Jan2005. It should be underlined that gusts of 30m/s in forest areas of south and central Gotland caused significantly more damage than gusts of 35 m/s in coast regions where vegetation much thinner. Few measurements from 1969 indicate gusts >30m/s in north Gotland
Gardiner (2012)	Gardiner B, K Blennow, J-M Carnus, P Fleischer, F Ingemarson, G Landmann, M Lindner, M Marzano, B Nicoll, C Orazio, J-L Peyron, M-P Reviron, M-J Schelhaas, A Schuck, M Spielmann, T Usbeck, Destructive storm in European Forests: Past and Forthcoming Impacts, European Forest Institute, Atlantic European Regional Office - EFIAtlantic [pdf document properties: author=Barry Gardiner, datestamp=09Mar2012] -Forest Condition -S Sweden worst affected area -77% forest privately owned with small forest blocks -much of forest past age it would normally be harvested -80% damaged area Norway spruce; 12% scots pine; 2% deciduous trees -Impact of Storm -Sweden: 75 million m3 timber damaged; approx annual harvest of whole country -in some forestry districts, tree loss about same as 20y harvest -less damage Latvia, Denmark, UK, Estonia, Lithuania -outbreaks of bark beetles in spite efforts to clear storm damage; made worse by 2nd storm Jan2007 -tree mortality by beetles lower than expected (3 mill m3); beetle population still high 2009 -increased leaching from soil: nitrates, mercury, methyl mercury

	-avg price of logs in S & central Sweden reduced immedialtely after storm (38%) prices recovered in 2007 & 2008 before global economic slowdown in 2009
AON Benfield (2013)	AON Benfield, Historie von 1703 bis 2012: Winterstuerme in Europea, Stand: Januar 2013 -worst storm damage in S Sweden in Halland & Smaland; worst storm in 35y -165000 hectare forest destroyed; 75 million m3 timeber lost
Expressen (20170204)	Expressen, Gudrun 2005: 20 doedas i den vaarsta storm, https://www.expressen.se/nyheter/inloggad/gudrun-2005-20-dodas-i-den-varsta-stormen/, published 04Feb2017 09:25 -along route 30 near? Lammhult fallen trees hanging over power cables -during night 300 millions trees fallen; equivalent ot clear-cut area of 275000 football fields -Ljungby: roads covered in tree drifts 6-7m high; 6 days before roads passable -FIG. [PHOTO] Carl XVI Gustaf travelled to impacted area for perception of destruction [credit: Niklas Larsson/Bildryan] -74000 of 77000 forest owners impacted in storm area -worst impacted had 10y of harvest gone in one night -clearing work lasted over a year -between Jan2005-Jan2006 11 people died clearing up fallen timber -last victim was forest worker from Estland while clearing forest at Varohalvon in Halland -141 work-accidents in following Gudrun -summer 2005 runway between Ljungby & Halmstad became Europe's largest storage; 23000 truckloads of windfall timber -FIG. [PHOTO] trees fell like skittles in many places when Gudrun passed. Roads were blocked and power lines blown down, trains stood still, and many forest owners hit by economic catastrophe [credit: Lennart Rehnman]
SurgeWatch (2017)	SurgeWatch, Storm Event 11th January 2005, in Haigh, I.D., O. Ozsoy, M.P. Wadey, R.J. Nicholls, S.L. Gallup, T. Wahl, J.M. Brown,Data descriptor: An improved database of coastal flooding in the United Kingdom from 1915 to 2016, Scientific Data, 4: 170100, DOI: 10.1038/sdata.2017.100, 2017 -GERO -Scotland: roofs damaged, trees blown down
Cappelen (2018b)	Cappelen, John, Bodil og det beskidte dusin, https://www.dmi.dk/nyheder/2013/bodil-og-det-beskidte-dusin 11Dec2013, updated 2Oct2018b -Gudrun: great damage to forest of S Sweden
ClimateChangePost (20241124)	ClimateChangePost, Denmark Storms, https://www.climatechangepost.com/countries/denmark/storms/, last acces 24Nov2024 -Denmark: felled forest was 1.5-2 mill m3 timber or 1.52 annual conifer harvest -cost 300 mill DKK or 40 mill EUR -conifers hit mainly (main forest type Denmark)
ESWD (20240803)	European Severe Weather Database, 7-9Jan2005, https://eswd.eu (last access 03aug2024) TREE DAMAGE OR UPROOTED Location LA Latitud Longitu Date Day Time Uncertainty ND --- Stockton-on-Tees UK 54.58 N 1.34 W 08-01-2005 sat 12:00 UTC (+/- 1 day) Tree(s) uprooted or snapped; multiple trees downed Thornaby on Tees UK 54.54 N 1.30 W 08-01-2005 sat 12:00 UTC (+/- 1 day) Tree(s) uprooted or snapped; multiple trees downed Målsryd Västra Götaland SV 57.68 N 13.05 E 09-01-2005 sun 20:30 UTC (+/- 1 hrs.) trees downed
Bioenergy International (2025)	Bioenergy International, The aftermath and legacy of Storm Gudrun - 20 years on (contributor Alan Sherrard), https://bioenergyinternational.com/the-aftermath-and-legacy-of-storm-gudrun-20-years-on/, 11 January 2025. -ERWIN/GUDRUN -felled more trees than any known storm -200-250 million trees blown over or snapped in Gotaland & S Svealand -forest disturbance from storms, insect infestation, wildfire not uncommon; Gudrun felled more forest in Sweden than any other known storm -Swedish Forest Agency: wspd avg 33m/s felled 10% all forest in Gotaland -75 million m3 of timber downed; 1y of harvest for entire country; 3y harvest Gotaland -270000 ha forest damaged by storm -110000-130000 ha so devastated that there were reforestaion obligations; equivalent to clear cut -final death toll attributed to Gudrun doubled to 18 people -previous severe storm 25-26Dec1902; newspaper report Pjungby in Smaaland -in living memory Swedish forest damage benchmarked to 1969 -Forest History Society: Gudrun downed two-times forest as 2 1969 storms -Dec1931 c.2 mill m3 -Feb1932 c.2 mill m3 -Feb&Mar 1943 c.6 mill m3 -Jan1954 c.18 mill m3 -Oct1967 c.10 mill m3 -Sep&Nov 1969 c.36 mill m3 -Nov-Dec 1999 c. 5 mill m3 -priority after storm: roads passable, restoring electricity, telecommunications -800 military personnel called to assist utilities with emergency clearing, transporation -Ove Ohlsson, Sveaskog felling manager for Gotaland -followon task: to salvage & extract as much fallen timber as possible -existing resources not enough; labor & contractors from all over country & Europe

	-Sodra: by spring doubled number of logging crews; crewsfrom 15 countries -Sveasskog mobilized resources from central & northern parts of country -even if salvage logging and extraction done overnight for 75 mill m3 timber, Swedish forest industry could not process year's worth of industrial roundwood -long term log storage 2-6y needs water sprinkled on wood stacks -Nov2009 (almost 5y after storm) last load of storm-felled timber collected from terminal in Asige in Halland for Sodra industry processing -VIDA procured former military airstrip outside Ljungby for gigantic wet storage facility -site had up to 1000 visitors per day during first year operations -processing stored timber started Jan2008; 29Apr2010 last truckload left Byholma -at peak Byholma stored 1 mill m3 wood (4 million logs) -despite forest damage, Gudrun not extreme storm; several follow-on storms had higher winds -Jan2005 Storm Per 12 mill m3 -Dec2011 Storm Dagmar 4.5 mill m3 -autumn2013 Simone/Hilde/Sven/Ivar 14 mill m3 -Jan2015 Egon 3 mill m3 -Nov2015 Gorm 2 mill m3 -Sodra completed salvage logging/extraction Jun2006 -foreign personnel who cleared trees, took on reforestation -80% of trees snapped in storm Gudrun Norway spruce; more susceptible to storm damage than Scotspine -immediately after Gudrun, few receptive to advice to shift away from spruce; 87% of storm-affected forest replanted with spruce
Myhr (2025)	Myhr, K.J.: Storm puts focus on security, https://history.vattenfall.com/stories/power-to-the-people/storm-puts-focus-on-security/, last access: 24Jan2025. -within few hours, wind blew down 1y harvest of trees (200 mill trees)
Wikipedia (20250429)	Wikipedia, Ekstremveret Gudrun, https://nn.wikipedia.org/wiki/Ekstremv%C3%AAret_Gudrun, last access: 29Apr2025 -ERWIN -approx 70 million m3 timber fallen in Gotaland -largest destruction in forests -area of forest razed equivalent to 1 year harvest; large economic problem for forest owners -windfall created environmental problem; water quality decreased because of runoff

Table S78. General ship/rig emergency reports/offshore incidents/platform evacuations (arranged by year and then alphabetically)

Source	Full Reference and Notes
Guy Carpenter (2005)	Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005 -ERWIN/GUDRUN: P&O European Highlander ferry ran aground SW Scotland; 100 passengers & crew stranded
Cargolaw (2005)	Cargolaw: International Vessel Casualties & Pirates Database For Year 2005 - Jan. Through Dec. 2005 http://www.cargolaw.com/presentation_casualties.05.html (last access 21 July 2021) 06Jan2005 Thu: MV Sea Fox (2219t; Latvia), Riga for Liverpool with timber caught in force 9 gale 6Jan off Castlebay on island Barra with 50deg port list from cargo shift 06Jan2005 Thu: ship tied up 1441 in port Castle Bay, Isle of Barra under own power
Cargolaw (2005)	Cargolaw: International Vessel Casualties & Pirates Database For Year 2005 - Jan. Through Dec. 2005 http://www.cargolaw.com/presentation_casualties.05.html (last access 21 July 2021) 07Jan2005 Fri: MV Alianca Sao Paulo (25703 gt, 2003, Brazil) aground Elbe estuary 0525 on Scharhoern reef; ship freed 1625; escorted to Hamburg
Cargolaw (2005)	Cargolaw: International Vessel Casualties & Pirates Database For Year 2005 - Jan. Through Dec. 2005 http://www.cargolaw.com/presentation_casualties.05.html (last access 21 July 2021) 08Jan2005 Sat: RoRo MV Schieborg (21005 gt, 2000) afire lat N55d54m lon E06d32.3m; drifting in extreme bad weather off Danish coast; crew abandon ship 09Jan2005 Sun: burning ship taken in tow by tug/supply MV Esvagt Gamma 12Jan2005 Wed: salvage experts tackling fire
Cargolaw (2005)	Cargolaw: International Vessel Casualties & Pirates Database For Year 2005 - Jan. Through Dec. 2005 http://www.cargolaw.com/presentation_casualties.05.html (last access 21 July 2021) 08Jan2005 Sat: PO ro-ro ferry MV European Highlander, Larne for Cairnryan, 43 pass/57crew beached on shingle bank 09Jan2005 Sun: tugs refloated ferry 10:30GMT; passengers onboard for 30h
Cargolaw (2005)	Cargolaw: International Vessel Casualties & Pirates Database For Year 2005 - Jan. Through Dec. 2005 http://www.cargolaw.com/presentation_casualties.05.html (last access 21 July 2021) 10Jan2005 Mon: MV CCNI Chages (1998, 28148gt), Europe for Chile, carrying out investigation of location of 30 containers lost upon bad weather during voyage
Cargolaw (2005)	Cargolaw: International Vessel Casualties & Pirates Database For Year 2005 - Jan. Through Dec. 2005 http://www.cargolaw.com/presentation_casualties.05.html (last access 21 July 2021) 10Jan2005 Mon: MV Kieler Sprotte (1905, 22 mt) grounded 10Jan in Kiel harbour (report date 12Jan)
Cargolaw (2005)	Cargolaw: International Vessel Casualties & Pirates Database For Year 2005 - Jan. Through Dec. 2005 http://www.cargolaw.com/presentation_casualties.05.html (last access 21 July 2021) 12Jan2005 Wed: MT Havtank (Norway) in collection with buoy off Cuxhaven; MV Mellum and rescue MV Hermann Helms came to aid; ship continued to Hamburg
Cargolaw (2005)	Cargolaw: International Vessel Casualties & Pirates Database For Year 2005 - Jan. Through Dec. 2005 http://www.cargolaw.com/presentation_casualties.05.html (last access 21 July 2021) 12Jan2005 Wed: Unidentitified Spanish fishing vessel lost power 120nm off Scotland during storm with 100mph gusts

Cargolaw (2005)	Cargolaw: International Vessel Casualties & Pirates Database For Year 2005 - Jan. Through Dec. 2005 http://www.cargolaw.com/presentation_casualties.05.html (last access 21 July 2021) 12Jan2005 Wed: MV Annegret in collision with Kiel-Holtenau lock gate of Kiel canal; damaged on starboard side (report date 12Jan2005); Storm Erwin event
Cargolaw (2005)	Cargolaw: International Vessel Casualties & Pirates Database For Year 2005 - Jan. Through Dec. 2005 http://www.cargolaw.com/presentation_casualties.05.html (last access 21 July 2021) 07Jan2005 Fri: container MV OOCL Neva struck Bruensbuettel lock of Kiel canal & hit stern of German coastal in same lock (report date 12Jan2005); Strom Erwin event
Cargolaw (2005)	Cargolaw: International Vessel Casualties & Pirates Database For Year 2005 - Jan. Through Dec. 2005 http://www.cargolaw.com/presentation_casualties.05.html (last access 21 July 2021) 09Jan2005 Sun: M/V Baumwall (Gibraltar) in collision with lock & MV Anja Funk on entering Bruensbuettel lock of Kiel Canal (report date 12Jan2005); storm Erwin event
Cargolaw (2005)	Cargolaw: International Vessel Casualties & Pirates Database For Year 2005 - Jan. Through Dec. 2005 http://www.cargolaw.com/presentation_casualties.05.html (last access 21 July 2021) 12Jan2005 Wed: MV Sandetti (17.86gt, 2004), Norway for Harlingen, in collision with FV Volharding (371gt, 1987); both vessels headed to harbour with bow damage
Cargolaw (2005)	Cargolaw: International Vessel Casualties & Pirates Database For Year 2005 - Jan. Through Dec. 2005 http://www.cargolaw.com/presentation_casualties.05.html (last access 21 July 2021) 13Jan2005 Thu: Liverpool FV Siskin capsized 10nm west of St Bees Head; crew rescued by Workington lifeboat
Guardian (20050112)	Guardian, Storms claim at least five lives (contributor: Adam Jay), https://www.theguardian.com/environment/2005/jan/12/weather.climatechange1, 12 January 2005 -Spanish fishing boat off western Isles found at dawn by RAF Nimrod with all 19 crew -Cibeles, 290 km W of Lewis trigerred distress beacon night 11-12Jan; due to be towed
Jameson (2005)	Jameson D., Weather extremes 2005. January 7th-8th Severe storm development, https://user.eumetsat.int/resources/case-studies/rapid-cyclogenesis-in-the-north-atlantic, pdf timestamp: 17/03/2005 -Scotland P&O European Highland ran aground on shingle in Cairnryan (Dumfries & Galloway); all 100 passengers safe
LCW (20050121)	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -C.c. Alianca Sao Paulo (Liberia), Rotterdam for Hamburg ran aground off Scharhornriff in Elbe mouth yesterday monring 4AM during high tide
LCW (20050121)	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -Ro/ro Baumwall (3999gt, 1995, Gibraltar) struck lock gate Kiel Canal 09Jan due to trougble with variable pitch propeller
LCW (20050121)	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -Fishing Cibeles (240gt,1970,UK) with 19people issued distress alert 2327UTC 11Jan at lat N58d18.21m lon W12d47.40m; adrift and without power; winds WSW gale-force, with very rough seas
LCW (20050121)	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -Ro/ro ferry European Highlander (21200gt,2002,Bahamas), Larne to Cairnryan /100 persons, reported in distress hurricane Bf12 wind, grounded Loch Ryan N54d57.6m W05d00.7m at 06:40UTC
LCW (20050121)	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -Understood bulk Father F. began to drag anchor yesterday in strong winds
LCW (20050121)	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -bulk Great Moon (75905gt,1984,South Korea) N53d54m E01d05.8m with crankcase problem; winds SW Bf8, forecast to increase storm Bf11
LCW (20050121)	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -general cargo Henriette (2900gt,1971,NIS), Iceland to Forsand in ballast, grounded N of Haugesund, refloated by own means
LCW (20050121)	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -ferry Miyuki Maru (59gt) in lat N51d24m,lon E00d33.3m, entrance to CHatham Dock, River Medway, on fire
LCW (20050121)	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -C.c. MSC Rafaela (42307gt,1996,Panama), outward bound from Antwerp, touched quay at Boudewijnlock; ship's plating cracked 3-4m above waterline
LCW (20050121)	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -at 04:36UTC ro/ro Muirneag (5801gt, 1979, UK) ran aground in Stornaway harbour while berthing
LCW (20050121)	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -General cargo Sandettie (1786gt,2004,Netherlands), Norway to Greece, in collision with Volharding (371gt,1987) at N53d01.46m E04d08.6m at 13:22UTC
LCW (20050121)	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -Ro/ro Schieborg (21005gt,2000,Netherlands) on fire at N55d54m E06d32.3m ... on fire and drifting in extremely bad weather off the Danish coast
LCW (20050121)	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -General cargo Sea Fox (2219gt,1976,Latvia), Riga for Liverpool, port list 35deg at 10:02UTC, wind severe gale 9, lost 40m3 wood packets N56d20m W07d15m, then 20-30m3 wood packets N56d55.5m W07d25.7m
LCW (20050121)	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -Passenger ro/ro Normandy (25745gt,1982) broke aft mooring during S winds up to 48kt & made contact iwth port bow of product tanker Severn Fisher (6892gt,1983,Gibraltar)
LCW (20050121)	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -Ro/ro Taipan Scan (7591gt,1982,Autigua & Barbuda) and supply North Vanguard (2637gt,1990) in contact Esbjerg 14:15L 08Jan; moorings of Taipan Scan broke in heavy winds
LCW (20050121)	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -General cargo Terningen II (809gt,1982,Norway) grounded near Svolvaer at 0850 today; refloated under own power

LCW (20050121)	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -General cargo Union Topaz (1543gt,1985,Barbados), Rotterdam for Gunness, reported engine problems lat N52d40.5m lon E03d38.7m at 05:41UTC 07Jan
LCW (20050121)	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -General cargo Urkerland (852gt,1989,Netherlands), sailing through Wemeldinge-Hanswert canal early Jan 6, ran ashore near Postbrug (bridge) ,probably due to strong winds, and struck a dolphin

Table S79. Instrument failures during storm (arranged by year and then alphabetically)

Source	Full Reference and Notes
Alexandersson and Ivarsson (2005)	Alexandersson H and KI Ivarsson, Januaristormen 2005, Faktablad nr 25, SMHI, https://www.smhi.se/download/18.18f5a56618fc9f08e832d664/1717805946933/faktablad_janstorm%5B1%5D.pdf, November 2005. -inland stations Gotland: Ljungby 15m/s (instrument broken 19:00) & Vaxjo 17m/s -TAB1. Places where gusts reached hurricane strength at SMHI stations or airports. After gust, 10-min average wind reported Note: mast blew down Visingso; in many places meas stopped by electricity outage
Brown (2005)	Brown, Paul R., The violent gale of 11-12 January 2005 in the north of Scotland, Journal of Meteorology, 30, 104-106, 2005 -GERO -several stations in the NW failed at the height ofthe storm -West Gerinish reports ceased after 1500GMT -Barra down after recording gust 92kt at 1700GMT -Aultbea failed after 1800GMT -Benbecula & Skye had a few breaks during the night -Stornoway operational throughout
MROS-Draugen (2005)	MIROS: Manedsrapport, januar 2005, Draugen - Naturdatainnsamling, ND/1022/05/01, 18 February 2005. -data gap all met-ocean data 7-8 Jan 2005
Johansson et al (2006)	Johansson J., S Lindahl, O. Samuelsson, H Ottoson, The storm Gudrun. A seven-week power outage in Sweden, CRIS, Third International Conference on Critical Infrastructure, Alexandria, Virginia, September, 2006. -ERWIN: mention of the collapsed anemeter Sweden
Suursaar and Sooaar (2006)	Suursaar, U. and J. Sooaar, Storm surge induced by extratropical cyclone Gudrun: hydrodynamic reconstruction of the event, assessment of mitigation actions and analysis of future flood risks in Parnu, Estonia, WIT Transactions on Ecology and the Environment, vol.91, pp.241-250, WIT Press, 2006. -Estonia meas avg wspd up to 28m/s; gusts to 38m/s on west Estonia coast -malfunctioning instruments with gaps among highest wspds
Suursaar et al (2006)	Suursaar, U., T. Kullas, M. Otsmann, I. Saarmae, J. Kuik, M. Merilain, Cyclone Gudrun in January 2005 and modelling its hydrodyanamic consequences in the Estonian coastal waters, Boreal Environmental Research, 11, 143-159, 2006. -Vilsandi met station failed at height of storm -TAB2. Max sea levels (cm) measured at Estonian tide gauge stations during and prior to Gudrun. In Haapsalu and Virtsu, estimations based on subsequent level of water markings were performed; at some stations measurements were impossible due to waves or fouling. * station with episodic past measurements
Dawson et al (2007)	Dawson AG, S Dawson, W Ritchie, Historical climatology and coastal change associated with the 'Great Storm' of January 2005, South Uist and Benbecula, Scottish Outer Hebrides, Scottish Geographical Journal, 123, 135-149, 2007 -GERO: South Uist anemometer failed at height of storm
Gardiner (2010)	Gardiner, Barry, Appendix 3: Background information on 11 storms selected for detailed analysis, European Forest Institute, Atlantic European Regional Office - EFIAtlantic, 161 pp. [PDF properties: datestamp 23Jul2010] -inland stations max wsd/gust 15/33 m/s at Ljungby and 17/33m/s at Vaxjo -Ljungby station experienced power failure from storm
SMHI 20111013)	SMHI, Gudrun - Januaristormen 2005,, https://www.smhi.se/kunskapsbanken/meteorologi/stormar-i-sverige/enskilda-stormar-och-ovader/gudrun-januaristormen-2005-1.5300, 13 oktober 2011 -meteorological data from automatic weather stations lost because of electricity and telephone line breaks -of stations with data Hano outside of vastra Blekinge had highest avg wind (33m/s, hurricane) and most power wind gusts (42m/s)
Nielsen (2012)	Nielsen, J.W., Stormfloden den 8. januar 2005, https://ocean.dmi.dk/case_studies/surges/2005-01-08.php, last access:21Feb2023. -water level guage malfunction at Logstor and THorsminde
Pelt (2013)	Pelt, S., Kraftige storme med oprindelse i Nordatlanten, Vejret, 137, 44-47, 2013 -three days later Storm Gero hit N Ireland and Scotland -lowest central pressure 944hPa -several anemometers destroyed
Angus and Rennie (2014)	Angus, S. and A. Rennie, An Ataireachd Aird: The storm of January 2005 in the Uists, Scotland, Ocean & Coastal Management, 94, 22-29, 2014. -Benbecula winds so strong that recording/reporting equipment failed
Cappelen (2018b)	Cappelen, John, Bodil og det beskidte dusin, https://www.dmi.dk/nyheder/2013/bodil-og-det-beskidte-dusin 11Dec2013, updated 2Oct2018b -Gero: some anemometers in Scotland blown to pieces

Table S80. Nonhomogeneous data sets (arranged by year and then alphabetically)

Source	Full Reference and Notes

Table S81. Climatological background of storm; unusual preceding weather events (arranged by year and then alphabetically)

Source	Full Reference and Notes
Jameson (2005)	Jameson D., Weather extremes 2005. January 7th-8th Severe storm development, https://user.eumetsat.int/resources/case-studies/rapid-cyclogenesis-in-the-north-atlantic, pdf timestamp: 17/03/2005 -mild,moist SW airflow over UK first week 2005 -spells of heavy rainfall & gusty winds -south dry-bright-mild; temp well above average; 15C at Coningsby Lincolnshire
Met Eireann (200501)	Met Eireann, Monthly Weather Bulletin, No 225, Jan 2005 * -mean air temperatures well above normal for 3rd successive month by 2C * -first 10days of month particularly mild; only 3-4 frosts at inland stns on 9-11Jan -very mild conditions for most of January -FIG_p12. [MAP] January mean temperature difference from 1961-1990 normal NOTE values range from 1.7-2.5C -FIG_p15. [MAP] January mean temperature (difference from 1961-1990 normal) [data: NOAA] NOTE: all northern Europe with 1-3C higher temperatures
Met.no info (2005)	met.no info, Varsling av stormer og ekstremt vaer (contact information: KH Midtbo, M Lystad, D Kvamme), 10pp, No.18/2005, Oslo, 25 November 2005 -unusual weather events during year: -we have been witness to a summer & autumn with extra many hurricanes that have impacted central America and southern USA -autumn 2005 we have experienced the remains of tropical hurricanes with considerable power -example is violent rain weather in Bergen 13-14Sep2005 (Kristin) -two months later 13-14Nov2005 record precipitation on Vestlandet from Loke
Rosenorn (2005)	Rosenorn, Stig, Vintervejret 2004-2005, Vejret, 103, 23-25, 2005 -January 2005 temperature uncommon with avg temperature 3.7C above 1961-1990 climate norm and average of daily maximum temperatures also 3.7C above climate norm
Haanpaa et al (2006)	Haanpaa, Simo, Samuli Lehtonen, Lasse Peltonen, Elena Talockaite, Impacts of winter storm Gudrun of 7th-9th January 2005 and measures taken in the Baltic Sea region, Astra, www.astra-project.org, 43pp, 2006 [pdf properties: datestamp 13/06/2006] 3.5.2.5. Warm weather unfortunate to forests, blessing for people -fallen trees most critical factor in network durability -Latvia: electicity lines less vulnerable if trees cut 20-30m from lines -Finland: trees cut 26-30m from 110kV lines, >40m from 400kV lines -effects to public may have been greater if weather colder -however, ground frosts would have prevented some trees falling -sheer number of trees greatly slowed repair work
Suursaar and Sooaar (2006)	Suursaar, U. and J. Sooaar, Storm surge induced by extratropical cyclone Gudrun: hydrodynamic reconstruction of the event, assessment of mitigation actions and analysis of future flood risks in Parnu, Estonia, WIT Transactions on Ecology and the Environment, vol.91, pp.241-250, WIT Press, 2006. -avg Baltic Sea level high since Dec2004 from strong cyclone activity -high background values of Baltic Sea level +70cm
Suursaar et al (2006)	Suursaar, U., T. Kullas, M. Otsmann, I. Saarmae, J. Kuik, M. Merilain, Cyclone Gudrun in January 2005 and modelling its hydrodyanamic consequences in the Estonian coastal waters, Boreal Environmental Research, 11, 143-159, 2006. -min pressure Parnu 972hPa & Ristna 968hPa; 30hPa lower than lows 2,5,7,January & 10-11Jan -air temperatures well above norm since Dec2004 -background sea level before storm was +70cm in Estonia coastal waters; similar to all Baltic -cyclone with wind speed 20m/s would cause exceedance of threshold levels -critical sea level Parnu 170cm; Haapsalu 140cm -Parnu Bay nomogram
Hisscott (2007)	Hisscott, Alan, When NWP met climatology: storms over the Isle of Man during January 2005,'Weather, 62, 74-77, 2007 -Erwin first severe storm after Anatol Dec1999 (74kt) for Ronaldsway wind gusts after Erwin (79kt) -3 significant wet winters in interval Anatol-Erwin -2002 (calendar) was wettest in Ronaldsway record since 1947 (record max for Oct & Nov) -annual total 1118.2mm exceeded previous max 1086.5mm in 1954 -winters 2003 & 2004 were dry -temperature: whole period 1995-2005 warmer than avg; winter 2001/2 noticeably warm and wet -warm mild conditions without extreme winds would have positive effect of tree growth -destabilizing conditions very wet wind 2002/3 to dry conditions could destabilize ground -increased incidence of land slips in high locations
Hellenberg and Kentala (2008)	Hellenberg, T. and J. Kentala, Chapter III. Sudden sea level rise in the Gulf of Finland in January 2005, in C. Pursiainen (ed), Early Warning and Civil Protection. When does it work and why does it fail? Nordregio report 2008:1 -overall risk perception affected by tsunami SE Asia 26Dec2004; upgraded readiness
Piontkowitz and Soerensen (2008)	Piontkowitz, Thorsten & Carlo Soerensen, Consequences of Climate Change along the Danish Coasts, Safecoast Action 5A, Danish Coastal Authority, Hojbovej 1, 7600 Lemvig, Denmark, kdi@kyst.dk, December 2008 -p.83: The wind was approximately 10m/s from westerly directions for six days prior to the main event and this persistent wind forcing lead to high general water levels 70-100cm in the fjord. The narrowing of the fjord east of Logstor Bredning meant that the water could not be transported away fast enough. Conditions were ideal for a major surge at Logstor with a large wind setup over the shoals and an atmospheric pressure that dropped from 1015hPa to 980hPa as the storm peaked. Furthermore, local wave set-up added centimeters to the unusually high water levels

Tonisson et al (2008)	Tonisson H, K Orviku, J Jaagus, U Suursaar, A Kont, R Rivis, Coastal damages on Saaremaa Island, Estonia, caused by the extreme storm and flooding on January 9, 2005, Journal of Coastal Research, 24, 602-614, 2008. -Baltic Sea level high since Dec2004 from strong cyclonic activity -background sea level before storm +70cm in Estonia waters -cyclones frequently come in pairs or as a series; preconditioning for high levels -gently sloping bathymetry contributed to high surge -before storm air temp -1C to +5C in Parnu; met norm is -5C -FIG4. [TIMESERIES] Comparison of sea level variations during the two historically highest storm surges in Parnu
Post and Kouts (2014)	Post, P. and T Kouts, Characteristics of cyclones causing extreme sea levels in the northern Baltic Sea, Oceanologia, 56, 241-258, 2014. -series of cyclones on a similar trajectory preceeded the Erwin storm surge at Tallinn and Parnu
Medvedev and Kulikov (2021)	Medvedev, I.P. and E.A. Kulikov, Extreme storm surges in the Gulf of Finland: Frequency-spectral properties and the influence of low-frequency sea level oscillations, Oceanology, 61, 459-468, 2021. -strong sea level variations in Gulf of Finland as early as 24-27Dec2004 with seiche 0.7-1.1 cycle/d -freq structure of water level oscillations changed by 6Jan2005; comp 0.45-0.55, 0.56-0.65,0.66-0.9 -7Jan2005 23:00 St Petersburg flood at 165cm; 9Jan 09:00 water level at 238cm at head Glulf Finland -sea level St Petersburg exceeded 160cm for 10.5h
Nielsen (2023)	Nielsen, J.W., Stormfloden den 8. januar 2005, https://ocean.dmi.dk/case_studies/surges/2005-01-08.php, last access:21Feb2023. -water level along west coast Jutland and Limfjord already 1 m high from preceding weather events

Table S82. Storm timing compared with spring tide; phase of surge and tide (arranged by year and then alphabetically)

Source	Full Reference and Notes
Brown (2005)	Brown, Paul R., The violent gale of 11-12 January 2005 in the north of Scotland, Journal of Meteorology, 30, 104-106, 2005 -GERO -coastal flooding because surge at same time as new moon tide
Hellenberg and Kentala (2008)	Hellenberg, T. and J. Kentala, Chapter III. Sudden sea level rise in the Gulf of Finland in January 2005, in C. Pursiainen (ed), Early Warning and Civil Protection. When does it work and why does it fail? Nordregio report 2008:1 -GUDRUN -Finland storm surge -record high forecast for sea level rise would be due to storm related 'bathtub effect'

Table S83. Tide analysis (arranged by year and then alphabetically)

Source	Full Reference and Notes
Suursaar et al (2006)	Suursaar, U., T. Kullas, M. Otsmann, I. Saarmae, J. Kuik, M. Merilain, Cyclone Gudrun in January 2005 and modelling its hydrodyanamic consequences in the Estonian coastal waters, Boreal Environmental Research, 11, 143-159, 2006. -Baltic tide neglected in Estonia model; only 2cm amplitude
Medvedev and Kulikov (2021)	Medvedev, I.P. and E.A. Kulikov, Extreme storm surges in the Gulf of Finland: Frequency-spectral properties and the influence of low-frequency sea level oscillations, Oceanology, 61, 459-468, 2021. -FIG1. (a) Map of stations: (1) Foglo, (2) Hanko, (3) Helsinki, (4) Vyborg, (5) Kronstadt, (6) Gorny Institute; (b) spectral of sea level oscillations; SD=semidiurnal peak -spectral analysis of hourly water level data from Gulf of Finland -characteristic perids 25-35h; semidiurnal tide, 8h for some stations -application of low-pass filter to isolate eustatic sea level changes due to flow from North Sea

Table S84. Data filtering and discretization issues (arranged by year and then alphabetically)

Source	Full Reference and Notes

Table S85. Difficulties in meteorological model of storm (arranged by year and then alphabetically)

Source	Full Reference and Notes
Blight (2005)	Blight, PJ: A discussion of the synoptic background and development of the 7-8Jan storm, https://user.eumetsat.int/resources/case-studies/rapid-cyclogenesis-in-the-north-atlantic, pdf time stamp 17/03/2005 -ERWIN -models oscillating over previous days if active wave would develop night to Saturday -Thur model indications of deeper development -GFS model forecast storm well on Tuesday 5Jan2005 18Z; quality dropped for runs on Wednesday -all models run on Thursday forecast storm; UKMO global model & GFS model best
Met.no info (2005)	met.no info, Varsling av stormer og ekstremt vaer (contact information: KH Midtbo, M Lystad, D Kvamme), 10pp, No.18/2005, Oslo, 25 November 2005 -for the 3 extreme weather events Gudrun, Haarek, Inga that passed S Norway 7-14Jan2005 good forecast -one exception: one of the forecasts registered on the evening before Gudrun entered Skagerak gave storm conditions on a trajectory too far north -meteorologists disregarded this & were justified after the event -other prognoses had correct trajectory but shifted the low P center too strongly to east -for the last of the 3 storms, Inga, prognosis was very good far in advance -one of the 2day advance forecasts placed the low P center too far east and registered record wave heights in the N North Sea

Hisscott (2007)	Hisscott, Alan, When NWP met climatology: storms over the Isle of Man during January 2005,'Weather, 62, 74-77, 2007 -FIG7 shows forecast charts 0000UTC 8Jan2005 from UK Met Office NWP model runs initiated 72,60,48,36h before -all runs predicted large depression with main centre S to SE of Iceland with strong W flow -rund T60,T48,T36 also suggested small secondary centre around 982-984mb west of Scotland -analysis in FIG1 shows secondary centre further SW than any prediction, near W coast Ireland -secondary low had more developed circ with central pressure 980mb at 0000UTC; deepended to 970mb as it tracked toward Norwegian Sea -secondary low had much more developed circulation with occluding warm air; Isle of Man sting jet
Expressen (20170204)	Expressen, Gudrun 2005: 20 doedas i den vaarsta storm, https://www.expressen.se/nyheter/inloggad/gudrun-2005-20-dodas-i-den-varsta-stormen/, published 04Feb2017 09:25 -23:15 Friday night SMHI warned of hurricane winds for Sweden -winds even more powerful than model forecasts
Pantillon et al (2017)	Pantillon, F., P. Knippertz, U. Corsmeier, Revisiting the synoptic-scale probability of severe European winter storms using ECMWF ensemble reforecasts, Nat. Hazards Earth Syst. Sci., 17, 1795-1810, 2017. -ECMWF reforecast analysis for 25 storms 1995-2015 -'The storm are well predicted by the whole ensemble up to 2-4 days ahead. At longer lead times, the number of members predicting the observed storms decreases and the ensemble average is not clearly defined for the track and intensity.' -among sample 25 storms, some outliers (e.g., Gero) exhibit particularly low predictability -these exhibit explosive cyclogenesis or extending over small area

Table S86. Difficulties in modelling water levels and surge (arranged by year and then alphabetically)

Source	Full Reference and Notes
Suursaar et al (2006)	Suursaar, U., T. Kullas, M. Otsmann, I. Saarmae, J. Kuik, M. Merilain, Cyclone Gudrun in January 2005 and modelling its hydrodyanamic consequences in the Estonian coastal waters, Boreal Environmental Research, 11, 143-159, 2006. -2D surge model for Estonia mostly reported good -no operational surge model in place at time of ERWIN/GUDRUN
Hellenberg and Kentala (2008)	Hellenberg, T. and J. Kentala, Chapter III. Sudden sea level rise in the Gulf of Finland in January 2005, in C. Pursiainen (ed), Early Warning and Civil Protection. When does it work and why does it fail? Nordregio report 2008:1 -FIMR operational sea level model since autumn 2003; no routine forecasts before Jan2005 -Finnish & foreign sea level model forecasts compared: Helsinki range +240cm to +95cm -man-made forecast sea level up to 150cm where previous record +136cm -forecast indicated flooding would last long several hours & have 2 peaks -expected Helsinki level over 120cm and up to 150cm; max level predicted 140cm or 4cm over record -earlier Helsinki record height 27Jan1990 in record starting 1904 -record high forecast for sea level rise would be due to storm related 'bathtub effect' -at 20:00 8Jan2005, FIMR expert Kahma estimated record sea level rise would not reach Helsinki
Averkiev and Klevannyy (2010)	Averkiev, A.S. and K.A. Klevannyy, A case study of the impact of cyclonic trajectories on sea-level extremes in the Gulf of Finland, Continental Shelf Research, 30, 707-714, 2010. -operational storm surge model for St. Petersburg gave flood water level predictions much higher than observations; due to incorrect placement of storm trajectory

Table S87. Future sea level rise and flooding effects; future climate and storm return period (arranged by year and then alphabetically)

Source	Full Reference and Notes
Haanpaa et al (2006)	Haanpaa, Simo, Samuli Lehtonen, Lasse Peltonen, Elena Talockaite, Impacts of winter storm Gudrun of 7th-9th January 2005 and measures taken in the Baltic Sea region, Astra, www.astra-project.org, 43pp, 2006 [pdf properties: datestamp 13/06/2006] -coastal erosion & flooding most threatening & expensive effects of climate change -cost of floods in 2080s could be >> than 10times values of today
Suursaar and Sooaar (2006)	Suursaar, U. and J. Sooaar, Storm surge induced by extratropical cyclone Gudrun: hydrodynamic reconstruction of the event, assessment of mitigation actions and analysis of future flood risks in Parnu, Estonia, WIT Transactions on Ecology and the Environment, vol.91, pp.241-250, WIT Press, 2006. -impact of isostasy and future sea level rise
Financial Times (20070120)	Financial Times, Insurers play down scale of storm damage claims, (reporter: William MacNamara), 20Jan2007 -ABI: global warming increasing threat to insurance industry ability to offer flood & weather insur -'high winds and heavy rain currently hitting much of UK looks set to occur more frequently and cause more expensive damage in the future unless action is taken now.'
Hellenberg and Kentala (2008)	Hellenberg, T. and J. Kentala, Chapter III. Sudden sea level rise in the Gulf of Finland in January 2005, in C. Pursiainen (ed), Early Warning and Civil Protection. When does it work and why does it fail? Nordregio report 2008:1 -Baltic Sea level expected to rise 20-40cm in next 100y due to climate change
Piontkowitz and Soerensen (2008)	Piontkowitz, Thorsten & Carlo Soerensen, Consequences of Climate Change along the Danish Coasts, Safecoast Action 5A, Danish Coastal Authority, Hojbovej 1, 7600 Lemvig, Denmark, kdi@kyst.dk, December 2008 -further sea level rise and coastal flooding implications for Denmark; expected 1m sea level rise by 2100
ClimateChangePost (20241124)	ClimateChangePost, Denmark Storms, https://www.climatechangepost.com/countries/denmark/storms/, last acces 24Nov2024 -not clear how climate change will affect characteristics of extratropical cyclones -extratropical cyclones to become less frequent; larger number of most intense storms -higher storm track density over northern Europe (UK and Scandinavia) -intensity of storms in Europe will increase

	-More hurricanes -tropical cyclones might become a serious threat for western Europe in 21st century warming -genesis region of hurricanes now in western tropical Atlantic with SST>27C -this will shift eastwards -future tropical storms that reach western Europe will originate in eastern part of tropical Atlantic with SST>27C -projected shift in severe storms from winter to autumn

Table S88. Isostatic rebound and tide gauge record corrections (arranged by year and then alphabetically)

Source	Full Reference and Notes
Suursaar and Sooaar (2006)	Suursaar, U. and J. Sooaar, Storm surge induced by extratropical cyclone Gudrun: hydrodynamic reconstruction of the event, assessment of mitigation actions and analysis of future flood risks in Parnu, Estonia, WIT Transactions on Ecology and the Environment, vol.91, pp.241-250, WIT Press, 2006. -reference to isostasy being comparable with sea level rise
Kulikov and Medvedev (2017)	Kulikov, E.A. and I.P. Medvedev, Extreme statistics of storm surges in the Baltic Sea, Oceanology, 57, 772-783, 2017. -isostatic uplift Scandinavia; tide gauge time series linearly detrended before assessing surface maxima
Palginomm et al (2018)	Palginomm V, K Orviku, U Suursaar, A Kont, H Tonnison, R Rivis, Lessons learned from record-high storm surges and associated inundations in Parnu, SW Estonia, Journal of Coastal Research, 85, 1-5, 2018. -Parnu land uplift 0.5 mm/y
Rantanen et al (2024)	Rantanen M, D van den Broek, J Corner, VA Sinclair, MM Johansson, J Sarkka, TK Laurila, and K Jylha, The impact of serial cyclone clustering on extremelyhigh sea levels in the Baltic Sea, Geophysical Research Letters, 51, e2023GL107203, https://doi.org/10.1029/2023GL107203, 2024. -long term tide gauge water levels in eastern Baltic detrended to remove glacial isostatic uplift

Table S89. Storm event as manifestation of climate change (arranged by year and then alphabetically)

Source	Full Reference and Notes
LCW (20050121)	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -Kimmo Kahma, special researcher at Finnish Inst of Mar Research: new records for water levels in Gulf of Finland -surge from convergence of factors: deep low, winds of severe gale & storm force, shift of water in Baltic Basin -storm related to NAO; NAO has increased in intensity over past 30y
Haanpaa et al (2006)	Haanpaa, Simo, Samuli Lehtonen, Lasse Peltonen, Elena Talockaite, Impacts of winter storm Gudrun of 7th-9th January 2005 and measures taken in the Baltic Sea region, Astra, www.astra-project.org, 43pp, 2006 [pdf properties: datestamp 13/06/2006] 1. Introduction -report produced in frame of project 'Developing policies and adaptation strategies to climate change in the Baltic Sea region (ASTRA)'; EU project Jun2005-Dec2007 -ASTRA project objective: assess regional impacts of ongoing global climate change & develop strategies for climate change adaptation -Gudrun selected as case study for ASTRA project
Averkiev and Klevannyy (2010)	Averkiev, A.S. and K.A. Klevannyy, A case study of the impact of cyclonic trajectories on sea-level extremes in the Gulf of Finland, Continental Shelf Research, 30, 707-714, 2010. -Baltic floods became more frequent after 1948 in the long water level time series spanning 2 centuries
Palginomm et al (2018)	Palginomm V, K Orviku, U Suursaar, A Kont, H Tonnison, R Rivis, Lessons learned from record-high storm surges and associated inundations in Parnu, SW Estonia, Journal of Coastal Research, 85, 1-5, 2018. -Parnu has gotten warmer over 50 y; annual ice cover changed from 150d to 80d

Table S90. Baltic Sea events (arranged by year and then alphabetically)

Source	Full Reference and Notes
Guy Carpenter (2005)	Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005 -review of storm damage for Finland, Baltic states
Haanpaa et al (2006)	Haanpaa, Simo, Samuli Lehtonen, Lasse Peltonen, Elena Talockaite, Impacts of winter storm Gudrun of 7th-9th January 2005 and measures taken in the Baltic Sea region, Astra, www.astra-project.org, 43pp, 2006 [pdf properties: datestamp 13/06/2006] -report produced in frame of project 'Developing policies and adaptation strategies to climate change in the Baltic Sea region (ASTRA)'; EU project Jun2005-Dec2007 -ASTRA project objective: assess regional impacts of ongoing global climate change & develop strategies for climate change adaptation -Gudrun selected as case study for ASTRA project
Suursaar and Sooaar (2006)	Suursaar, U. and J. Sooaar, Storm surge induced by extratropical cyclone Gudrun: hydrodynamic reconstruction of the event, assessment of mitigation actions and analysis of future flood risks in Parnu, Estonia, WIT Transactions on Ecology and the Environment, vol.91, pp.241-250, WIT Press, 2006. -Erwin storm impacts in Estonia
Suursaar et al (2006)	Suursaar, U., T. Kullas, M. Otsmann, I. Saarmae, J. Kuik, M. Merilain, Cyclone Gudrun in January 2005 and modelling its hydrodyanamic consequences in the Estonian coastal waters, Boreal Environmental Research, 11, 143-159, 2006. -analysis of Estonia surge with model
LCW (20070121)	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -coastal surge flooding Finland; 4 Finnish nuclear reactors threatened to close

	-Estonia: power cuts -Latvia: 60% of population 2.4 million without power; government declares energy crisis -40% of population without power on Jan10 -Latvian schools closed until Jan12 Wed -Russian Ministry for Emergency Situations told Itar-TASS: hurricane left >1500 inhabited localities without electricity in Pskov region of Russia -hurricane swept over Pskov region 09Jan2005
LCW (20070128)	Lloyds Casualty Week, 28Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -St Petersburg flooding
Hellenberg and Kentala (2008)	Hellenberg, T. and J. Kentala, Chapter III. Sudden sea level rise in the Gulf of Finland in January 2005, in C. Pursiainen (ed), Early Warning and Civil Protection. When does it work and why does it fail? Nordregio report 2008:1 -description of Erwin/Gudrun surge flooding events in theFinland & Estonia
Soomere et al (2008)	Soomere, T., A. Behrens, L. Toumi, J.W. Nielsen: Wave conditions in the Baltic proper and in the Gulf of Finland during windstorm Gudrun, Nat Hazards Earth Syst. Sci., 8, 37-46, 2008. -documentation of wave field in Baltic during Erwin
Tonisson et al (2008)	Tonisson H, K Orviku, J Jaagus, U Suursaar, A Kont, R Rivis, Coastal damages on Saaremaa Island, Estonia, caused by the extreme storm and flooding on January 9, 2005, Journal of Coastal Research, 24, 602-614, 2008. -coastal damage in Estonia during storm Erwin 2005
Averkiev and Klevannyy (2010)	Averkiev, A.S. and K.A. Klevannyy, A case study of the impact of cyclonic trajectories on sea-level extremes in the Gulf of Finland, Continental Shelf Research, 30, 707-714, 2010. -idealized model study of storm surges in Gulf of Finland
SMHI (20111013)	SMHI, Gudrun - Januaristormen 2005,, https://www.smhi.se/kunskapsbanken/meteorologi/stormar-i-sverige/enskilda-stormar-och-ovader/gudrun-januaristormen-2005-1.5300, 13 oktober 2011 -description of Gudrun impacts in southern Sweden
Post and Kouts (2014)	Post, P. and T Kouts, Characteristics of cyclones causing extreme sea levels in the northern Baltic Sea, Oceanologia, 56, 241-258, 2014. -analysis of Erwin storm surge at Tallinn and Parnu
Palginomm et al (2018)	Palginomm V, K Orviku, U Suursaar, A Kont, H Tonnison, R Rivis, Lessons learned from record-high storm surges and associated inundations in Parnu, SW Estonia, Journal of Coastal Research, 85, 1-5, 2018. -Parnu flood analysis
Medvedev and Kulikov (2021)	Medvedev, I.P. and E.A. Kulikov, Extreme storm surges in the Gulf of Finland: Frequency-spectral properties and the influence of low-frequency sea level oscillations, Oceanology, 61, 459-468, 2021. -spectral analysis of water level data from Gulf of Finland
Nielsen (2023)	Nielsen, J.W., Stormfloden den 8. januar 2005, https://ocean.dmi.dk/case_studies/surges/2005-01-08.php, last access:21Feb2023. -strong 4m E-W tilt across Baltic; fear of seiche flood in western Baltic did not materialize.
Rantanen et al (2024)	Rantanen M, D van den Broek, J Corner, VA Sinclair, MM Johansson, J Sarkka, TK Laurila, and K Jylha, The impact of serial cyclone clustering on extremelyhigh sea levels in the Baltic Sea, Geophysical Research Letters, 51, e2023GL107203, https://doi.org/10.1029/2023GL107203, 2024. -analysis of storm clustering that results in high surges in Baltic Sea
Lorenz et al (2025)	Lorenz M, K Viigand, U Grawe, Untangling the waves: decomposing extreme sea levels in a non-tidal basin, the Baltic Sea, Nat. Hazards Earth Syst. Sci., 25, 1439-1458, 2025. -analysis of Baltic extreme sea level envents in terms of filling, surge, seiche
SMHI (2025)	SMHI, Högvattenhändelser idag och i framtiden, https://www.smhi.se/klimat/stigande-havsnivaer/hogvattenhandelser-idag-och-i-framtiden, last access: 10Jan2025 -extreme tide gauge water levels along Baltic coast of Sweden during Erwin
Wikipedia (20250125)	Wikipedia, Floods in Saint Petersburg, https://en.wikipedia.org/wiki/Floods_in_Saint_Petersburg, 24Jan2025 -St Petersbur g high surge during Erwin/Gudrun
Wikipedia (20250429)	Wikipedia, Ekstremveret Gudrun, https://nn.wikipedia.org/wiki/Ekstremv%C3%AAret_Gudrun, last access: 29Apr2025 -storm weakened slowly; powerful wind & ppt Finland, Russia, Germany, Latvia, Estonia, Lithuania -Helsinki: water level 9Jan 146cm above normal -St Petersburg: water from Neva river so high that 6 metro stations had to close -town of Abo seen under water -Parnu in Estonia: highest water level 280cm over normal; 25% of streets in town flooded

Table S91. Irish Sea events (arranged by year and then alphabetically)

Source	Full Reference and Notes
Jameson (2015)	Jameson D., Weather extremes 2005. January 7th-8th Severe storm development, https://user.eumetsat.int/resources/case-studies/rapid-cyclogenesis-in-the-north-atlantic, pdf timestamp: 17/03/2005 -high rainfall North Wales, Cumbria, Scotland -Scotland P&O European Highland ran aground on shingle in Cairnryan (Dumfries & Galloway); all 100 passengers safe
Met Eireann (200501)	Met Eireann, Monthly Weather Bulletin, No 225, Jan 2005 -Storm Erwin & Gero; events in Ireland
Hiscott (2007)	Hisscott, Alan, When NWP met climatology: storms over the Isle of Man during January 2005,'Weather, 62, 74-77, 2007 -description of Erwin impacts on Isle of Man

Table S92. Bristol Channel/English Channel/Celtic Sea events (arranged by year and then alphabetically)

Source	Full Reference and Notes

Table S93. Aftermath: new defenses; new design criteria; assessment of climate change; model problems (arranged by year and then alphabetically)

Source	Full Reference and Notes
Beredskapstyrelsen (2005)	Beredskabstyrelsen, Beredskabets indsats i forbindelse med orkanen 8. januar 2005, En tvaergaende erfaringsopsamling, Beredskabssstyrelsen, Datavej16, 3460 Birkerod, Oktober 2005 -for Denmark, process of burying transmission line s for protection against storms had started after Anatol 3Dec1999
Guy Carpenter (2005)	Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005 3.2. Flood coverage in the UK -EA: 10% of UK population lives on natural floodplains -unlike most countries, flood cover standard part of UK household policies since 1960s -8Jan1990 3rd major flood event over last 10y; previous 2 events: -Oct-Nov2000: 10000 properties flooded; wettest autumn in 270years -Apr1998: central England; 5000 buildings flooded -Association of British Insurers: insurance if properties safe to 75y level -400000 UK properties are at greater than 1-in-75 year risk of flooding -UK government to increase spending on flood defences by more than 13%/year over 2002 review
Argyriadis et al (2006)	Argyriadis, K., G. Fischer, P. Frohbose, D. Kindler, and F. Reher: Research platform FINO1 - Some measurement results, European Wind Energy Conference EWEC and Exhibition 2006, Athens, Greece, 27 February - 2 March 2006, Volume 2, pp. 906-915, ISBN: 978-1-62276-467-9, 2006. -survey of worst storms at FINO1 in period 2003-2005 to assess design criteria and wind energy potential
Haanpaa et al (2006)	Haanpaa, Simo, Samuli Lehtonen, Lasse Peltonen, Elena Talockaite, Impacts of winter storm Gudrun of 7th-9th January 2005 and measures taken in the Baltic Sea region, Astra, www.astra-project.org, 43pp, 2006 [pdf properties: datestamp 13/06/2006] -Finnish officials informed evening 7Jan on possible record high water levels -water level reached +151cm around noon 9Jan -today lowest construction level Helsinki set to 3m above sea level -old buildings including historic centre (Marker Square & presidential palace) low-lying
Johansson (2006)	Johansson J., S Lindahl, O. Samuelsson, H Ottoson, The storm Gudrun. A seven-week power outage in Sweden, CRIS, Third International Conference on Critical Infrastructure, Alexandria, Virginia, September, 2006. 8. Modification of the distribution networks -Gudrun demonstrated distrib networks with overhead lines has higher risk very long interruptions supply -even overhead insulated cables at risk of collapse from tree fall on poles -problems with burying cables: almost all networks with nominal voltage of 70kV and lower are non-effectively earthed -Petersen coil 9. New legistlation -on 5Dec2005 Swedish parliament modifications to Electricity Law -consumers entitled to compensation if electricity interruption longer than 12h -no compensation if interruption by failure on network with voltage of 220kV or higher -Electricity Law came into force 1Jan2006; from 1Jan2011 network owner must ensure interruption level longer than 24h
Suursaar and Sooaar (2006)	Suursaar, U. and J. Sooaar, Storm surge induced by extratropical cyclone Gudrun: hydrodynamic reconstruction of the event, assessment of mitigation actions and analysis of future flood risks in Parnu, Estonia, WIT Transactions on Ecology and the Environment, vol.91, pp.241-250, WIT Press, 2006. -the once closed Department of Marine Prognoses to be restored in EMHI in 2006 -crisis website opened -previous Parnu sea level record 253cm on 18Oct1967; previous building standards had been discon -old buildings safe; new buildings not safe at 200cm level -risk map showing flooding at 1.5,2.5,3.5m levels published FIG3. [MAP] The areas of potential inundation in Paarnu City in case of 1.5,2.5,3.5m sea level rise.
Hellenberg and Kentala (2008)	Hellenberg, T. and J. Kentala, Chapter III. Sudden sea level rise in the Gulf of Finland in January 2005, in C. Pursiainen (ed), Early Warning and Civil Protection. When does it work and why does it fail? Nordregio report 2008:1 -FIMR operational sea level model since autumn 2003; no routine forecasts before Jan2005 -'One of the key concepts of early warning regards the information flows and the possibilities to extend and transmit the information through the 'noise' of different actors and channels.' -'the situation authorities from Finland and Estonia started to negotiate about better information sharing between the countries in this kind of situations and as we know information sharing is essential and can reduce damage.'
Rantanen (2008)	Rantanen, H., Chapter IV. Coping with Power Disturbances, in C. Pursiainen (ed), Early Warning and Civil Protection. When does it work and why does it fail? Nordregio report 2008:1, p.95-119 -Lessons learned -Gudrun showed biggest need for improvement independent energy supplies -radio communications problems to be solved using TETRA-based RAKEL network -measures to improve reliability of telephone for emergency dispatching -redundant communications links to overcome reliability of information systems

	-management problems: one fire station required to house local municipality coordination group -risk assessment inadequate; coordination between emergencies poor because of lack of communications -mild weather meant situation not life-threatening; if cold weather siuation would be bad
Averkiev and Klevannyy (2010)	Averkiev, A.S. and K.A. Klevannyy, A case study of the impact of cyclonic trajectories on sea-level extremes in the Gulf of Finland, Continental Shelf Research, 30, 707-714, 2010. -problems with Erwin storm surge model motivated study to assess most dangerous cyclone trajectories
Gardiner (2012)	Gardiner B, K Blennow, J-M Carnus, P Fleischer, F Ingemarson, G Landmann, M Lindner, M Marzano, B Nicoll, C Orazio, J-L Peyron, M-P Reviron, M-J Schelhaas, A Schuck, M Spielmann, T Usbeck, Destructive storm in European Forests: Past and Forthcoming Impacts, European Forest Institute, Atlantic European Regional Office - EFIAtlantic [pdf document properties: author=Barry Gardiner, datestamp=09Mar2012] -Response to storm -European Solidarity Fund provided 92.88 mill EUR to Sweden,Estonia,Latvia, Lithuania -not much change to recommended forestry practice -insurance companies changed policies following storm -increased leaching from soil: nitrates, mercury, methyl mercury -avg price of logs in S & central Sweden reduced immedialtely after storm (38%) prices recovered in 2007 & 2008 before global economic slowdown in 2009
DEA (2016)	Danish Energy Agency, Security of Electricity Supply in Denmark, 1st edition 2015, translated 2016, Danish Energy Agency, Amaliegade 44, 1256 Copenhagen K, ISBN 978-87-93180-15-4 -Danish power cables placed underground after storm damage Anstol 1999 and Erwin/Gudrun 2005.
Palginomm et al (2018)	Palginomm V, K Orviku, U Suursaar, A Kont, H Tonnison, R Rivis, Lessons learned from record-high storm surges and associated inundations in Parnu, SW Estonia, Journal of Coastal Research, 85, 1-5, 2018. -Parnu dike planned after Oct1967 coastal surge; plan shelved in 1980s -dike not viable solution in cost analysis
Medvedev and Kulikov (2021)	Medvedev, I.P. and E.A. Kulikov, Extreme storm surges in the Gulf of Finland: Frequency-spectral properties and the influence of low-frequency sea level oscillations, Oceanology, 61, 459-468, 2021. -309-320 floods in St. Petersburg since 1703 -1979: St Petersburg Flood Protection Structures Complex -since 12Aug2011 dam operating successfully & prevented about 25 floods, including 294cm flood in 2011 -0.27 cycles/day
Myhr (2025)	Myhr, K.J.: Storm puts focus on security, https://history.vattenfall.com/stories/power-to-the-people/storm-puts-focus-on-security/, last access: 24Jan2025. -Weatherproofing through burial -Vattenfall decided 1 year earlier to invest 10 bill SEK over 5y to insulate & weatherproof grid -burying lines became more common -better control on pinpointing weak points -in decade following storm Vattenfall invested 17 bill SEK to weatherproof electricity grid -17000km lines put underground or secured by new isolated air lines -continued investment in electricy grid during 2010 estimated at 3-4 bill SEK per year
Wikipedia (20250124)	Wikipedia, Floods in Saint Petersburg, https://en.wikipedia.org/wiki/Floods_in_Saint_Petersburg, 24Jan2025 -St. Petersburg dam -construction of complex of dams protecting St. Petersburg from floods began 1979 -halted 1990s when 60% complete; resumed 2005; inaugerated 12Aug2011 -first use of dam to hold back Baltic water 28NOv2011; water rose to 1.3m ASL -309th flood 27-28Dec2011; gates closed but water rose to 1.7mASL; -without gates water would have risen to 2.3m

Table S94. Worst case storm surge/storm situation (arranged by year and then alphabetically)

Source	Full Reference and Notes
Met.no info (2005)	met.no info, Varsling av stormer og ekstremt vaer (contact information: KH Midtbo, M Lystad, D Kvamme), 10pp, No.18/2005, Oslo, 25 November 2005 -the most damage was caused by Inga; unusually high water & waves fro SW and W toward outer coast; further inland damage significantly less -SWH 11m (Gullfaks 11.3m) -this means highest waves in toward coast could have approached 20m -wind also strong from from an uncommon direction SW -Fjord areas in from outer coast protected from ocean waves -waves cause extra setup of water in fjords -winds were not totally extreme; 25-30 m/s at lighthouse stations -inland stations registered <20m/s on avg & 30m/s in gusts -Kvamsoy in Hardangerfjord registered 25m/s avg wind -people in the area that it has been significantly worst several times in the last 10-20 years
Suursaar and Sooaar (2006)	Suursaar, U. and J. Sooaar, Storm surge induced by extratropical cyclone Gudrun: hydrodynamic reconstruction of the event, assessment of mitigation actions and analysis of future flood risks in Parnu, Estonia, WIT Transactions on Ecology and the Environment, vol.91, pp.241-250, WIT Press, 2006. -Parnu Bay subject to large amplication for 220deg wind -worst case: 300-350cm surges possible in Parnu Bay
Suursaar et al (2006)	Suursaar, U., T. Kullas, M. Otsmann, I. Saarmae, J. Kuik, M. Merilain, Cyclone Gudrun in January 2005 and modelling its hydrodyanamic consequences in the Estonian coastal waters, Boreal Environmental Research, 11, 143-159, 2006. -higher surge level in Estonia possible with small change in trajectory
Averkiev and Klevannyy (2010)	Averkiev, A.S. and K.A. Klevannyy, A case study of the impact of cyclonic trajectories on sea-level extremes in the Gulf of Finland, Continental Shelf Research, 30, 707-714, 2010. -problems with Erwin storm surge model motivated study to assess most dangerous cyclone trajectories

	-most dangerous cyclone for Gulf of Finland passes just north of flood area with speed 14-19m/s &culminates slightly to east flooding target
Bioenergy International (2025)	Bioenergy International, The aftermath and legacy of Storm Gudrun - 20 years on (contributor Alan Sherrard), https://bioenergyinternational.com/the-aftermath-and-legacy-of-storm-gudrun-20-years-on/, 11 January 2025. -GUDRUN/ERWIN -forests replanted mostly in Norway spruce even though recognized that it is susceptible to storms -E.ON decided built new grid after 20000 km of grid badly damaged -installers flown in from other subsidiaries: Germany, UK, Finland -electrical equipment, backup generators brought in from China, India, Mexico -since Gudrun E.ON invested SEK 38 bill into weatherproofing 33000 km of power lines in Sweden, burying 75% underground -in S Sweden 1700km of uninsolated overhead lines initially buried & then replaced with insulated overhead lines -Vattenfall Eldistribution mustered 1600 people (1150 in field) with fleet 15 helicopters, 20 tracked carriers & 20 harvesters to locate and fix faults -year before Gudrun Vattenfall decided to invest SEK 10 bill over 5y to insulate & weatherproof grid -during first 10y after Gudrun, Vattenfall inveted additional SEK 17bill in weatherproofing measures: widening & clearing lines, insulating overhead cables, burying lines where appropriate -Vattenfall investment in grid annually SEK 8-10 bill until 2030 -2024 warmest year ever; first to exceed 1.5C; storms like Gudrun to become worst

Table S95. Damage costs; insurance losses (arranged by year and then alphabetically)

Source	Full Reference and Notes
Beredskabstyrelsen (2005)	Beredskabstyrelsen, Beredskabets indsats i forbindelse med orkanen 8. januar 2005, En tvaergaende erfaringsopsamling, Beredskabssstyrelsen, Datavej16, 3460 Birkerod, Oktober 2005 -150000-200000 cases of insurance damage
Guy Carpenter (2005)	Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005 6. Loss estimates 6.1. UK -early reports suggest loss 150-200mill GBP -Association British Insurers: avg household claim for flooding 15-30000 GBP -vast majority of losses in UK from flooding -flooding losses following windstorms not included in commercial catastrophic models -loss estimates in continental Europe mainly from wind damage 6.2. Sweden -early estimates insured loss 232mGBP with forest and agricultural products largest part -Anatol loss was 1mill SEK (77 millGBP) affecting southern tip Sweden with agric & resid loss 6.3. Denmark -150000-200000 claims with value could exceed 325mGBP -Anatol loss owas 1.2bGBP with 350000 claims -wind speeds Anatol higher -flood losses Denmark covered by Danish Flood Pool starting in 1991 -RMS projecting insured loss Denmark at 433mGBP or 3bSEK -Anatol loss 1bSEK affecting southern tip of Sweden; damage mostely to agriculture & buildings -RMS loss estimate weden at 500mSEK or 39mGBP 6.4. Norway and Finland -insurance losses limited except for cargo loss of cars flooded in Helsinki Harbour (3.5mGBP) -similar car loss in Halmstad in Sweden (7.7mGBP) 6.5. Reinsurer losses -most reinsurers yet to publish loss estimates; Munich Re estimates 50-100 million EUR
Johansson et al (2006)	Johansson J., S Lindahl, O. Samuelsson, H Ottoson, The storm Gudrun. A seven-week power outage in Sweden, CRIS, Third International Conference on Critical Infrastructure, Alexandria, Virginia, September, 2006. -ERWIN -electricity operators eestimated overall cost of storm 257 mill EUR
LCW (20050121)	Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ -ERWIN: UK: weekend winds of 145 kph that ripped roofs from homes & caused property damage on coast; insurance cost 10s mill EUR
Haanpaa et al (2006)	Haanpaa, Simo, Samuli Lehtonen, Lasse Peltonen, Elena Talockaite, Impacts of winter storm Gudrun of 7th-9th January 2005 and measures taken in the Baltic Sea region, Astra, www.astra-project.org, 43pp, 2006 [pdf properties: datestamp 13/06/2006] Economic_loss mill_EUR Denmark 617

	Sweden 2300 Lithuania 15 Latvia 192 Estonia 48 Finland 20
Suursaar and Sooaar (2006)	Suursaar, U. and J. Sooaar, Storm surge induced by extratropical cyclone Gudrun: hydrodynamic reconstruction of the event, assessment of mitigation actions and analysis of future flood risks in Parnu, Estonia, WIT Transactions on Ecology and the Environment, vol.91, pp.241-250, WIT Press, 2006. -losses reached 0.7% Estona GDP -most influential natural disaster in Estonia for century
Suursaar et al (2006)	Suursaar, U., T. Kullas, M. Otsmann, I. Saarmae, J. Kuik, M. Merilain, Cyclone Gudrun in January 2005 and modelling its hydrodyanamic consequences in the Estonian coastal waters, Boreal Environmental Research, 11, 143-159, 2006. -main financial losses Gudrun from flooding urban areas Parnu, Haapsalu, Kuresaare -Estonian Energy: 32% households lost power; 100% Hiiumaa, 78% Saaremaa, 64% Parbu -50 million EUR loss or 0.7% country GDP; Parnu worst at 30 million EUR -nearly 1 million m3 timber toppled Estonia
Dailey (2007)	Dailey, P., The 2006-2007 European winter storm season: winding down, Air Worldwide, http://www.air-worldwide.com/Publications/AIR-Currents/The-2006-2007-European-winter-storm-season, March 7, 2007 (last accessed July 9, 2014). -winter storms in Europe must reach areas of insured assets in belt from S England to central Europe to have high insurance losses -critieria for large insurance losses: intensity, size, location
Hisscott (2007)	Hisscott, Alan, When NWP met climatology: storms over the Isle of Man during January 2005,'Weather, 62, 74-77, 2007 -property damage at 10 mill GBP -damage caused by gusts over 50kt increases non-linearly with peak wind speed -Browning et al (2003): for severe storm 25% increase in wspd causes 6-8times amount damage
Munich Re (2007)	Munich Re, Significant winter storms Europe 1980-2006. The 10 costliest storms listed by insured loss. MuenchenerRueck Munich Re Group, 2007 [pdf document time stamp: 26/01/2007] -insurance loss info: Erwin(Gudrun) 7-9/01/2005 Denmark, Sweden 2.0 billion euro (adjusted for Jan2007)
Heipertz and Nickel (2008)	Heipertz, Martin and Christiane Nickel, Climate change brings stormy days: Case studies on the impact of extreme weather events on public finances, SSRN Electronic Journal, pp. 613-630, DOI: 10.2139/ssrn.1997256, April 2008 (In Fiscal Sustainability, Analytical Developments and Emerging Policy Issues, 3-5April2008) -EU Solidarity Fund Estonia (report damage 48 mill EUR or 0.43% GDP), Latvia (193 mill EUR or 1.48% GDP), Sweden (2297 mill EUR or 0.80% GDP)
Roberts et al (2014)	Roberts JF, AJ Champion, LC Dawkins, KI Hodes, LC Shaffrey, DB Stephenson, MA Stringer, HE Thornton, DB Youngman, The XWS open access catalogue of extreme European windstorms from 1979 to 2012, Nat. Hazards Earth Syst. Sci, 14, 2487-2501, 2014 -ERWIN had 2.2 bill USD insurance loss
Statistica (2015)	Statistica, The costliest winter storms ever to hit Europe. Fatalities and financial losses of Europe's 10 costliest winter storms (source Munich Re), 08Dec2015 -ERWIN financial loss 5.5 bill EUR
Thejournal.ie (2015)	thejournal.ie, The deadliest storms to ever hit Europe, 14Dec2015 0610AM, https://www.thejournal.ie/europe-storms-2497164-Dec2015/, accessed 10Dec2020 -ERWIN financial loss 5.5 bill EUR
Expressen (20170204)	Expressen, Gudrun 2005: 20 doedas i den vaarsta storm, https://www.expressen.se/nyheter/inloggad/gudrun-2005-20-dodas-i-den-varsta-stormen/, published 04Feb2017 09:25 -destruction valued at 23.3 bill SEK -storms costs 23.3 bill SEK for fallen timber and infrastructure
Myhr (2025)	Myhr, K.J.: Storm puts focus on security, https://history.vattenfall.com/stories/power-to-the-people/storm-puts-focus-on-security/, last access: 24Jan2025. -storm damage estimated at 10 bill SEK -total number of interruption days 2.3 million -grid company costs at 2.5 billion SEK
Wikipedia (20250429)	Wikipedia, Ekstremveret Gudrun, https://nn.wikipedia.org/wiki/Ekstremv%C3%AAret_Gudrun, last access: 29Apr2025 -Gudrun was 1st of 3 storms in 5 days; Haarek hit Nord Trondelag-Lofoten; Inga hit Vestlandet -3 storms causes 160 million NOK damage

Table S96. Online data sets (alphabetically)

Source	Full Reference and Notes
Belgium VLIZ	Belgium tide gauge and wave information with some associated meteorology: https://meetnetvlaamsebanken.be
Bidlot, Jean	Bidlot, Jean: email with wave measurement and ECMWF model data for Jan 2005, 15Dec2024.
Caithness Wind Farm	Caithness wind farm list of wind energy accidents: https://scotlandagainstspin.org/turbine-accident-statistics/ https://scotlandagainstspin.org/wp-content/uploads/2023/04/Detailed-incidents-to-31-Mar2023.pdf https://sctlandagainstspin.org/turbine-accident-statistics/
CMEMS	European Copernicus wave information http://www.marineinsitu.eu/dashboard/
Danish Energy Agency (20230719)	Danish Energy Agency, Overview of the Energy Sector, last access 19Jul2023 https://ens.dk/en/our-services/statistics-data-key-figures-and-energy-maps/overview-energy-sector -excel files of operating and decommissioned turbines in Denmark -monthly wind energy production in Denmark from 2002

Denmark tide gauge data	https://kyst.dk/soeterritoriet/maalinger-og-data/vandstandsmaalinger/
Denmark tide gauge metadata	Information sent by Christoffer Grupe for location of Danmark tide gauges https://kyst.dk/hav-og-anlaeg/maalinger-og-data/boelgemaalinger/kort-over-kystdirektoratets-boelgemaalere https://kyst.dk/hav-og-anlaeg/maalinger-og-data/vandstandsmaalinger/kort-over-kystdirektoratets-vandstandsmaalere. https://vandportalen.dk/.
DWD (2022)	DWD archive of weather maps: www2.wetter3.de/Archiv/archiv_dwd.html
ENTSOE	ENTSOE, https://www.entsoe.eu/news-events/former-associations/, last access 12 October 2025/ -website with former European electricity network companies with documents. https://transparency.entsoe.eu/content/static_content/Static%20content/legacy%20data/year%20selection.html -archives of cross border electrocity flows for 2011-2015
ESWD (20220501)	European Severe Weather Database, https://eswd.eu (last access 01May2022)
Extreme Wind Storms Catalog	http://www.europeanwindstorms.org
Fink et al (2007)	Fink AH, T Brucher, V Ermert, A Kruger, JG Pinto, The European storm Kyrill in Jan 2007: synoptic evolution, meteorological impacts and some considerations with repect to climate change, Natural Hazards and Earth System Sciences, 9, 405-423, 2009. -'weather charts over North America were obtained from the California Regional Weather Server and Unisys Weather Information Services'
Gatzen et al (2020)	Gatzen CP, AH Fink, DM Schultz, JG Pinto, An 18-year climatology of derechos in Germany, Nat Hazards Earth Syst. Sci., 20, 1335-1351, 2020 -lightning used to identify and track European derechos 1997-2014 -'We used data from the Arrival Time Difference (ATD) system operated by the Met Office (Lee, 1986) available at wetterzentrale.de (2016) until the year 2000 and from the Siemens Blids lightning network (Siemens, 2019) for events after the year 2000'
Karlsruhe Institute of Technology KIT	KIT extreme weather descriptions: http://www.wettergefahren-fruehwarnung.de/Ereignis/archiv_sturm.html
Karlsruhe Institute of Tecnology KIT	KIT FDA reports: https://www.cedim.kit.edu/english/2850.php
Land-SH	http://www.umweltdaten.landsh.de/public/hsi/pegelsuche.html -information on the Land-SH tide gauges
NNRCMP	Other tide gauges and wave monitoring sites around UK: NNRCMP, Welcome, National Network of Regional Coastal Monitoring Programmes, https://coastalmonitoring.org/, last access: 2 January 2025
NOAA Mariners Weather Log	NOAA: back issues of Mariners Weather Log https://repository.library.noaa.gov/
Norway Kartverket (20220301)	Kartverket website https://api.sehavniva.no/tideapi_en.html (last access 1Mar2022) https://www.kartverket.no/til-sjos/se-havniva/resultat?id=1082308&location=Bergen%20vannstandsm%C3%A5ler (last access 5 Feb 2025)
Norway SEklima	Norway wave information https://seklima.met.no
Netherlands RWS Waterinfo	RWS: (Rijkswatersaat Waterinfo) https://waterinfo.rws.nl/#!/nav/expert/alle-groepen/
North East Coastal Observatory	Reports on tide gauge and wave data for the North Sea coast of England (Halcrow), North East Coastal Observatory, http://northeastcoastalobservatory.org.uk/data/reports/20_cell_1_monitoring_reports/26_wave_&_tide_reports/ (last access: 18Dec2024)
Primavera	PRIMAVERA European winter windstorm event https://zenodo.org/record/6492182#.YzRjCqTMJPY
Quikscat	qscat data product information site https://podaac.jpl.nasa.gov/dataset/QSCAT_LEVEL_2B_OWV_COMP_12 qscact ftp download site https://podaac-tools.jpl.nasa.gov/drive/files/allData/quikscat/L2B12/v3/2007/011 Fore, A.G., Stiles, B.W., Chau, A.H., Williams, B.A., Dunbar, R.S., and Rodriguez, E.: Point-wise wind retrieval and ambiguity removal improvements for the QuikSCAT climatological data set, IEEE Transactions on Geoscience and Remote Sensing, 52, 51–59, 10.1109/TGRS.2012.2235843, 2014. PO.DAAC: QuikSCAT Level 2B Version 3, Guide Document, 7 March 2013, Version 1.0, Physical Oceanography Distributed Active Archive Centre (PO.DAAC), 2013.
Sweden SMHI tide gauge	SMHI tide gauge information page: SMHI, Stationslista vattenstand, https://www.smhi.se/kunskapsbanken/stationslista-havsvattenstand-1.13981, 27Nov2024, (last access: 8Jan2025)
Sweden SMHI return period of surge	Return period of surge water levels for 20-30 Sweden tide gauge station https://www.smhi.se/klimat/framtidens-klimat/stigande-havsnivaer/hogvattenhandelser-idag-och-i-framtiden
Sweden SMHI lowest & highest surge levels along coast	List of stations with highest/lowest surge water levels https://www.smhi.se/kunskapsbanken/oceanografi/vattenstand-i-havet/rekord-vattenstand
XWS	https://www.europeanwindstorms.org/ Roberts JF, AJ Champion, LC Dawkins, KI Hodges, LC Shaffrey, DB Stephenson, MA Stringer, HE Thornton, DB Youngman, The XWS open access catalogue of extreme European windstorms from 1979 to 2012, Nat. Hazards Earth Syst. Sci, 14, 2487-2501, doi:10.5194/nhess-14-2487-2014, 2014
UK BODC tide gauge	https://www.bodc.ac.uk/data/hosted_data_systems/sea_level/uk_tide_gauge_network/processed/
UK CEFAS Wavenet	https://wavenet.cefas.co.uk/
UKMO (2021) Daily	UKMO, personal communication with Catherine Ross, UKMO, 2 Mar 2021. UKMO daily weather summaries at

Weather Summary	Digital Library and archive: https://digital.nmla.metoffice.gov.uk/collection_86058de1-8d55-4bc5-8305-5698d0bd7e13/
UKMO (2022) Marine Observer	Back issues of Marine Observer, https://digitial.nmla.metoffice.gov.uk/SO_Oafb8f96-434b-42c3-8082-056623702322/
UKMO Meteorological Magazine	Back issues of Meteorological Magazine https://digital.nmla.metoffice.gov.uk/SO_31c4215d-460a-4ce3-bdac-12c775f5c92d/
University of Wyoming radiosonde archive	https://weather.uwyo.edu/upperair/sounding.html, https://weather.uwyo.edu/upperair/sounding_legacy.html

Table S97. Storm animations (alphabetically)

Source	Full Reference and Notes
EUMETSAT (2005)	EUMETSAT, Rapid cyclogenesis in the North Atlantic 6-8 January 2005, (contributors: Jochen Kerkmann and Gordon Bridge) https://www.eumetsat.int/rapid-cyclogenesis-north-atlantic published 06January2005, accessed 03Dec2022 -geostationary satellite image animation with several IR bins for coding false color-scale
Nielsen et al (2023)	Nielsen, J.W., Stormfloden den 8. januar 2005, https://ocean.dmi.dk/case_studies/surges/2005-01-08.php, last access:21Feb2023. -animation of wind speed maps

Table S98. Onshore/offshore wind energy policy and historical development

Source	Full Reference and Notes
Danish Energy Authority (2005)	Danish Energy Authority, Offshore Wind Power. Danish Experiences and Solutions. Danish Energy Authority, October, 2005. -historical development of Denmark wind power and offshore wind power -energy crisis mid-1970s; acidification rain 1980s -government research program for large MW turbines late 1970s -feed in tariffs promote from start 1980s promote development of small turbines -government plan for large offshore wind fars from 1997; earlier pilot plants
Rantanen (2008)	Rantanen, H., Chapter IV. Coping with Power Disturbances, in C. Pursiainen (ed), Early Warning and Civil Protection. When does it work and why does it fail? Nordregio report 2008:1, p.95-119. -historical development of cross border electricity networks in Europe -map Nordic transmission grid (Nordel 2007a)

Table S99. Context and background information where storm not mentioned (arranged by year and then alphabetically)

Source	Full Reference and Notes
Thompson (1980)	Thompson, K.R., An analysis of British monthly sea level, Geophys. J. R. astr. Soc., 63, 57-73, 1980. -recommended article by Phil Woodworth to understand annual variation of monthly mean sea level for UK tide gauge stations.
Kjeldsen (1990)	Kjeldsen, Soren Peter: Breaking waves, in A. Torum and O.T. Gudmestad (eds.), Water Wave Kinematics, 453-473, Kluwer Academic Publishers, https://link.springer.com/chapter/10.1007/978-94-009-0531-3_29, 1990. -Ekofisk platform 2/4a hit by wave with crest >20m high; control room damaged & flooded; production halted for 24 h
Elsinghorst et al (1998)	Elsinghorst C., P. Groeneboom, P. Jonathan, L. Smulders, P.H. Taylor, Extreme value analysis of North Sea storm severity, Journal of Offshore Mechanics and Arctic Engineering, 120, 177-183, 1998. -NESS data set 1964-1989 -return period of extreme wave heights in North Sea region with return periods 100-500y -offshore structures designed for extreme ocean environments with return period 100-10000 years
Nordel (2006)	Nordel: Annual Statistics 2005, https://www.entsoe.eu/news-events/former-associations/, pdf date stamp 21 June 2006 -Nordel annual statistics 2005 -maximum loads on system: Denmark/Finland/Iceland/Norway/Sweden
Magnusson (2007)	Magnusson, A.K.: Powerpoint presentation at the EXWW workmeeting 2006–2007 Hotel Admiral, Bergen, June 12–14th 2007. -background information on EXWW Ekofisk storm procedures
NLWKN (20050111)	NLWKN, Experten vom NLWKN: Flache Nordsee schuetzt Niedersachsens Kueste vor einem Tsunami, https://www.nlwkn.niedersachsen.de/startseite/aktuelles/presse_und_offentlichkeitsarbeit/pressemitteilungen/-38655.html, 11 January 2005.
NLWKN (20050121)	NLWKN, Elfte Sturmflut bisher höchste des Winters (contributor Achim Stolz), Nds. Landesbetrieb für Wasserwirtschaft, Küsten- und Naturschutz, https://www.nlwkn.niedersachsen.de/startseite/aktuelles/presse_und_offentlichkeitsarbeit/pressemitteilungen/-38678.html, 21/01/2005 [INGO]
NNRCMP (2005)	NNRCMP, Welcome, National Network of Regional Coastal Monitoring Programmes, https://coastalmonitoring.org/, last access: 2 January 2025 -list of tide gauge and wave datasets around UK that might contain references to Jan 2005 storms: Scarborough tide gauge, Herne Bay Tide gauge, Newbiggin waves, Whitby waves, Scarborough waves, Brighton Marina waves, Sandown Bay waves, Rustington waves, Pevensey Bay waves, Milford-on-Sea waves, Lymington waves, Herne Bay waves, Hayling Island waves, Folkstone waves, Deale pier waves, Boscombe waves
Verlaan et al (2005)	Verlaan M, A Zijderveld, H de Vries, J Kroos, Operational storm surge forecasting in the Netherlands: developments in the last decade, Phil. Trans. R. Soc. A, 363, 1441-1453, doi: 10.1098/rsta.2005.1578, 2005. -development of Netherlands numerical model for storm surge forecasting

	-tidal Kelvin wave -UK & Netherlands tide gauge data used for forecasting -first numerical model from early 1980s; Kalman filter implemented early 1990s -calibration by modifying depths; last calibration from 1997 -increased resolution atmospheric model does not increase skill of surge forecast
Feix (2006)	Feix, O. (ed): Statistical Yearbook 2005, Secretariat of UCTE, https://eepublicdownloads.entsoe.eu/clean-documents/pre2015/publications/ce/Statistical_Yearbook_2005.pdf, pdf datestamp 12 October 2006. -2005 statistical yearbook for UCTE power netowrk in Europe, showing grid damage by month on maps -list of maximum load and date for each European country; none correpsond to Storm Erwin 8Jan2005
Petroleum Safety Authority (2006)	Petroleum Safety Authority Norway: Annual Report 2005, Stavanger, 2005 [pdf timestamp 28 April 2006] -construction standard for offshore structions: 100y storm; changed to 10000y storm in 1984 -evacuation procedures -climate change: corrosion & winterization
Petroleum Safety Authority (2007)	Petroleum Safety Authority Norway: Annual Report 2006. Supervision and facts, Stavanger, 26 April 2007. -overview of storm damage to Valhal,Ekofisk,Eldfisk during Storm Britta/Borgny 2006 -3 comparable storms over past 3 years -platforms originally built to withstand 100y wave -implementation of procedures to evacuate platforms durign severe storms
Horsburgh et al (2008)	Horsburgh KJ, C Wilson, BJ Baptie, A Cooper, D Cresswell, RMW Musson, L Ottemoller, S Richardson, SL Sargeant, Impact of a Lisbon-type tsunami on the UK Coastline and the implications for tsunami propagation over broad continental shelves, J Geophys Res, 113, 15pp, C04007, doi:10.1029/2007JC04425, 2008. -model analysis of 1Nov1755 Lisbon earthquake and tsunami to assess tsunami catastrophe potential for coastal areas UK -highest coastal water levels Cornwall 3.5m; similar to winter storm surge -20 minute tsunami period -ringing effects and amplification on continental shelf
Walser and Wagner (2009)	Walser, M. and F. Wagner (ed.): The 50 year success story - Evolution of a European Interconnected Grid, Secretariat of UCTE, Boulevard Saint-Michel 15, B-1040 Brussels, Belgium, https://eepublicdownloads.entsoe.eu/clean-documents/pre2015/publications/ce/110422_UCPTE-UCTE_The50yearSuccessStory.pdf, 2009 last access: 6 October 2025 -Nordel electricity network for Scandinavia -FIG_p47. [SCHEMATIC] Electricity exchanges on 15Dec1999 11:00 (MW)
Bidlot (2010)	Bidlot, J-M, Intercomparison of operational wave forecasting systems against buoys: data from ECMWF, MetOffice, FNMOC, MSC, NCEP, MeteoFrance, DWD, BoM, SHOM, JMA, KMA, Puerto del Estado, DMI August 2010 to October 2010, 23Nov2010. https://www.oceanexpert.net/document/6353 (filename: SPA_ETWS_verification201009.pdf) -information of offshore wave measurement sites in northwest Europe and eastern Atlantic -SWH and wind speed reported; peak period almost never -rapid increase in GTS wave reports after mid-1990s
Olbert and Hartnett (2010)	Olbert, A.I. and M. Hartnett, Storms and surges in Irish waters, Ocean Modelling, 34, 50-62, 2010. -Ireland storm surge modelling study -tide-surge interaction -external propagation of tides into Irish Sea -coincidence of tide and surge peaks at differnt locations -7 floods in 50 years for Cork -target case study for Jeanette on 27Oct2002
Penna et al. (2013)	Penna NT, WE Featherstone, J Gazeaux, RJ Bingham, The apparent British sea slope is caused by systematic errors in the levelling-based vertical datum, Geophys. J. Int., 194, 772-786, 2013 -information on latitude slope error of Ordnance Datum Newlyn; arising from systematic error in Second Geodetic Survey of Britain
Spencer et al. (2015)	Spencer T, SM Brooks, BR Evans, JA Tempest, I Moeller, Southern North Sea storm surge event of Dec.5, 2013: Water levels, waves, and coastal impacts, Earth Science Reviews, 146, 120-145, 2015. -description of significant wave runup water levels in exposed locations on East Anglia coast during Storm Xaver 2013
Chrstensen et al (2017)	Christensen KH, A Carrasco, J-R Bidlot, O Breivik, The 'shallow-waterness' of the wave climate in European coastal regions, Ocean Sciences, 13, 589-597, 2017. -shallow water wave effects can extend far offshore in North Sea during winter storms
Woodworth (2018)	Woodworth, PL: Sea level change in Great Britain between 1859 and the present, Geophys. J. Int., 213, 222-236, 2018. -sea level rise in Great Britain since mid-19th century.
Pellikka et al. (2020)	Pellikka, H., TK Laurila, H Boman, A Karjalainen, J-V Bjorkqvist, KK Kahma, Meteotsunami occurrence in the Gulf of Finland over the past century, Nat. Hazards Earth Syst. Sci., 20, 2535-2546, https://doi.org/10.5194/nhess-20-2535-2020, 2020 -meteotsunami data base for Hanko, Hamina, Helsinki from paper records, digital recording -atmospheric pressure time series -meteotsunami summertiem event linked to small atmospheric pressure changes and
Lewis et al (2023)	Lewis C, T Smyth, D Williams, J Neuman, H Cloke, Meteotsunami in the United Kingdom: the hidden hazard, Nat Hazards Earth Syst Sci, 23, 2531-2546, 2023. -list of UK meteotsunamis including instrument analysis 2010-2022
ENTSOE (2025)	ENTSOE, https://www.entsoe.eu/news-events/former-associations/, last access 12 October 2025/ -website with list of former electricity netowrk companies with documents

Table S100. Errors/typos in source reports for storm (arranged by year and then alphabetically)

Source	Full Reference and Notes

Gardiner (2012)	Gardiner B, K Blennow, J-M Carnus, P Fleischer, F Ingemarson, G Landmann, M Lindner, M Marzano, B Nicoll, C Orazio, J-L Peyron, M-P Reviron, M-J Schelhaas, A Schuck, M Spielmann, T Usbeck, Destructive storm in European Forests: Past and Forthcoming Impacts, European Forest Institute, Atlantic European Regional Office - EFIAtlantic [pdf document properties: author=Barry Gardiner, datestamp=09Mar2012] -Erwin stated to form northwest of Iceland; it was northwest of Ireland
SurgeWatch (2017)	SurgeWatch, Storm Event 11th January 2005, in Haigh, I.D., O. Ozsoy, M.P. Wadey, R.J. Nicholls, S.L. Gallup, T. Wahl, J.M. Brown,Data descriptor: An improved database of coastal flooding in the United Kingdom from 1915 to 2016, Scientific Data, 4: 170100, DOI: 10.1038/sdata.2017.100, 2017 -Carlisle river flood linked to GERO instead of ERWIN

Table S101. Abbreviations used in manuscript (alphabetical)

Abbreviation	Full name
BODC	British Oceanographic Data Centre
CAPE	Convective available potential energy
ESWD	European Severe Weather Database
EXWW	Ekofisk Extreme Wave Warning
FINO1	Forschungsplattformen in Nord- und Ostsee
KDI	Kystdirektoratet
KNRM	Koninklijke Nederslandse Redding Maatschappij
NNRCMP	National Network of Regional Coastal Monitoring Programmes
QuikSCAT	Quick Scatterometer
RWS	Rijkswaterstaat
SWEAT	Severe WEAther Threat
UTC	Universal Time Coordinated
VLIZ	Vlaams Instituut voor de Zee

Table S102. People contacted for information about storm (alphabetical)

Name	Affilation and contact information
Bidlot, Jean	jean.bidlot@ecmwf.int European Centre for Medium range Weather Forecasts (ECMWF) Shinfield Park RG2 9AX Reading United Kingdom Tel: +44-118-9499-708
Blümel, Maria	Maria.Bluemel@lkn.landsh.de Landesbetrieb fuer Kuestenschutz, Nationalpark, und Meereschutz Schleswig-Holstein, Fachbereich Hydrologie, Mess- und Beobachtungsdients Betriebssitz Husum Herzog-Adolf-Str. 1 25813 Husum Tel: 04841 667 357 Mobil: 0151 64325708 Fax: 04841 667 115 De-mail: poststelle@lkn.landsh.de-mail.de
Carr, Ramona	Ramona.Carr@marine.ie Data Request Service Data Management Group Marine Institute Rinville, Oranmore Co. Galway H91 R673 Ireland
Frederiksen, Bjorn	bfr@kyst.dk Kysttekniker Vejledning – Klima og Kystbeskyttelse +45 20 93 35 92 Miljo- of Fodevareministeriet Kystdirektoratet, Hojbovej 1 7620 Lemvig Tel: +45 99 63 63 63 kdi@kyst.dk www.kyst.dk
Hull, Tom	CEFAS Tom.hull@cefas.gov.uk
Kalén, Ola	SMHI/Swedish Meteorological and Hydrological Institute Community Planning, Water, Oceanography Goteborgseskaderns Plats 3 SE-426 71 Vastra Frolunda

	Sweden Ola.Kalen@smhi.se Tel: +46 (0) 11 495 80 00 Mob: +46 (0) 31 751 8986 Street address: SvenKallfeltsgata 15
Matthews, Robin	Robin.matthews@environment-agency.gov.uk Forecasting and Response Technical Advisor Thames Tidal Defences Environment Agency Thames Barrier Eastmoor Street Charlton London SE7 8LX Mob: +44 7780107484
Newport, Peter	Hydrometric Office of Public Works Main Street, Headford, Co. Galway, H91 RX79 Mob: +353 86 383 5589 Tel: +353 46 942 2351 peter.newport@opw.ie
Perez-Gonzalez, Irene	Irene.PerezGonzalez@bsh.de BSH
Skaland, Reidun Gangstø	reidung@met.no Scientist Climate Services MET Norway, Forskar Avdeling for Klimatenester Meteorologisk institutt (MET) Tel: +47 96 62 36 75
Thiesen, Hauke	Hauke.Thiesen@lkn.landsh.de Sachbereich 2120: Kuestenhydrologie Betriebssitz Husum Herzog-Adolf-Strasse 1 25813 Husum Tel: 04841 667-246 Fax: 04841 667-115
Warwick-Champion, Elizabeth	E.warwick-champion@soton.ac.uk Hydrodynamics Project Manager Channel Coastal Observatory European Way Southampton SO14 3ZH UK Tel: +44(0) 23 8235 41166 Tel: +44(0) 7919 395679
Wiechmann, Wilfried	wiechmann@bafg.de datenstelle-M1@bafg.de Federal Institute of Hydrology Am Mainzer Tor 1 Postfach 20 02 53 56002 Koblenz Germany Tel: 0261 1306 5340 Fax: 0261 1306 5363
Woeffler, Theide-Erk	Theide-Erk.Woeffler@lkn.landsh Landesbetrieb fuer Kuestenschutz, Nationalpark und Meeresschutz Schleswig-Holstein Fachbereich Konzeptionelle Planungen, Analysen, Informationssystemes Betreibssitz Husum Hezog-Adolf-Str. 1 25813 Husum Tel: 04861/667-187 Fax: 04841/667-115

References

Alexandersson H and KI Ivarsson, Januaristormen 2005, Faktablad nr 25, SMHI, https://www.smhi.se/download/18.18f5a56618fc9f08e832d664/1717805946933/faktablad_janstorm%5B1%5D.pdf, November 2005.

Angus, S. and A. Rennie, An Ataireachd Aird: The storm of January 2005 in the Uists, Scotland, Ocean & Coastal Management, 94, 22-29, 2014.
AON Benfield, Historie von 1703 bis 2012: Winterstuerme in Europa, Stand: Januar 2013
Argyriadis, K., G. Fischer, P. Frohbose, D. Kindler, and F. Reher: Research platform FINO1 - Some measurement results, European Wind Energy Conference EWEC and Exhibition 2006, Athens, Greece, 27 February - 2 March 2006, Volume 2, pp. 906-915, ISBN: 978-1-62276-467-9, 2006.
Averkiev, A.S. and K.A. Klevannyy, A case study of the impact of cyclonic trajectories on sea-level extremes in the Gulf of Finland, Continental Shelf Research, 30, 707-714, 2010.
Baker, L., Sting jets in severe northern European wind storms, Weather, 64, 143-148, 2009
Bancroft, George P., Weather Review - North Atlantic Area, January through April 2005, Mariners Weather Log, vol. 49, No. 2, Marine https://www.vos.noaa.gov/MWL/aug_05/north_atlantic.shtml, Aug 2005.
BBC, Northern Europe shaken by storms, http://news.bbc.co.uk/2/hi/europe/4158809.stm, 10 January 2005a
BBC, Severe gales cause havoc on roads, http://news.bbc.co.uk/2/hi/uk_news/england/4157069.stm, 08January2005
BBC, No quick fix to flood problem, http://news.bbc.co.uk/2/hi/uk_news/wales/4159471.stm, 10Jan2005b
Behrens, A. and H. Guenther, Operational wave prediction of extreme storms in Northern Europe, Nat. Hazards, 49, 387-399, 2009
Belfast Telegraph, Ulster braced for more storms (contributor Maureen Coleman), p.1, 10Jan2005a (Monday)
Belfast Telegraph, More power from the pole man, p.2, 10Jan2005b (Monday)
Belfast Telegraph, Storms sweep northern Britain, p.6, 10Jan2005c (Monday)
Beredskabstyrelsen, Beredskabets indsats i forbindelse med orkanen 8. januar 2005, En tvaergaende erfaringsopsamling, Beredskabssstyrelsen, Datavej16, 3460 Birkerod, Oktober 2005
Bidlot, J-M, Intercomparison of operational wave forecasting systems against buoys: data from ECMWF, MetOffice, FNMOC, MSC, NCEP, MeteoFrance, DWD, BoM, SHOM, JMA, KMA, Puerto del Estado, DMI August 2010 to October 2010, 23Nov2010. https://www.oceanexpert.net/document/6353 (filename: SPA_ETWS_verification201009.pdf)
Bidlot, Jean: email with wave measurement and ECMWF model data for Jan 2005, 15Dec2024.
Bioenergy International, The aftermath and legacy of Storm Gudrun - 20 years on (contributor Alan Sherrard), https://bioenergyinternational.com/the-aftermath-and-legacy-of-storm-gudrun-20-years-on/, 11 January 2025.
Bitner-Gregersen, E. and AK Magnusson, Effect of intrinsic and sampling variability on wave parameters and wave statistics, Ocean Dynamics, 64, 1643-1655, 2014
Blight, PJ: A discussion of the synoptic background and development of the 7-8Jan storm, https://user.eumetsat.int/resources/case-studies/rapid-cyclogenesis-in-the-north-atlantic, pdf time stamp 17/03/2005
Boettcher C., The cost of blackouts in Europe, record number 126674, 28Apr2016 https://cordis.europa.eu/article/id/126674-the-cost-of-blackouts-in-europe
Bradshaw, E. (ed.): Annual Report for 2005 for the UK national tide gauge network and related sea level science, National Tidal and Sea level Facility, NERC 100017897, 2005
Brown, J.M., A.J. Souza, J. Wolf: An investigation of recent decadal-scale storm events in eastern Irish Sea, J. Geophys. Res., 115, C05018, doi:10.1029/2009JC005662, 2010
Brown, Paul R., The violent gale of 11-12 January 2005 in the north of Scotland, Journal of Meteorology, 30, 104-106, 2005
Cappelen, John, Bodil og det beskidte dusin, https://www.dmi.dk/nyheder/2013/bodil-og-det-beskidte-dusin 11Dec2013, updated 2Oct2018b
Cargolaw: International Vessel Casualties & Pirates Database For Year 2005 - Jan. Through Dec. 2005 http://www.cargolaw.com/presentation_casualties.05.html (last access 21 July 2021)
Clark, PA and SL Gray, Sting jets in extratropical cyclones: a review, Quarterly Journal of the Royal Meteorological Society, 144, 943-969, 2018.
CH2MHill Halcrow, Cell 1 Regional Coastal Monitoring Programme, Wave Data Analysis Report 2: 2013-2014, Final Report, March 2014 [document properties: author=Andy.Parson@ch2m.com; datestamp; 04/04/2014]
Christensen KH, A Carrasco, J-R Bidlot, O Breivik, The 'shallow-waterness' of the wave climate in European coastal regions, Ocean Sciences, 13, 589-597, 2017.
ClimateChangePost, Denmark Storms, https://www.climatechangepost.com/countries/denmark/storms/, last acces 24Nov2024.
CNN, Weather. 13 killed as storm lashes Europe, http://edition.cnn.com/2005/WEATHER/01/09/europe.storm/, 09 Jan 2005.
Dailey, P., The 2006-2007 European winter storm season: winding down, Air Worldwide, http://www.air-worldwide.com/Publications/AIR-Currents/The-2006-2007-European-winter-storm-season, March 7, 2007 (last accessed July 9, 2014).
Danish Energy Authority, Offshore Wind Power. Danish Experiences and Solutions. Danish Energy Authority, October, 2005.
Danish Energy Agency, Security of Electricity Supply in Denmark, 1st edition 2015, translated 2016, Danish Energy Agency, Amaliegade 44, 1256 Copenhagen K, ISBN 978-87-93180-15-4
Dawson AG, S Dawson, W Ritchie, Historical climatology and coastal change associated with the 'Great Storm' of January 2005, South Uist and Benbecula, Scottish Outer Hebrides, Scottish Geographical Journal, 123, 135-149, 2007
Deutsche Rueck, Sturmdokumentation Deutschland 2005, (contributors: T. Axer, T. Bistry, S Fietze, M Mueller, M Prechtl), Deutsche Rueckversicherung, Aktiengesellschaft, Hansaallee 177, 40549, Duesseldorf, March, 2006.
DMI, Danmark ramt af landsdækkende storm, https://www.dmi.dk/nyheder/2005/danmark-ramt-af-landsdakkende-storm#:~:text=Stormen%20her%20i%20januar%202005,hen%20over%20den%20nordlige%20Nords%C3%B8. 10Jan2005
DWD, Orkan Erwin am 8. Januar 2005. https://www.dwd.de/DE/leistungen/besondereereignisse/stuerme/20050801_orkan_erwin.pdf?__blob=publicationFile&v=4, pdf timestamp: 07Feb2005
Eitrheim, K:, Rapport etter stormen 'Gudrun' lordag 8.1.2005 for Rogaland fylke, met.no, 11 January 2005
Elsinghorst C., P. Groeneboom, P. Jonathan, L. Smulders, P.H. Taylor, Extreme value analysis of North Sea storm severity, Journal of Offshore Mechanics and Arctic Engineering, 120, 177-183, 1998.
Emeis, S. and M. Turk, Wind-driven wave heights in the German Bight, Ocean Dynamics, 59, 463-475, 2009
ENTSOE, https://www.entsoe.eu/news-events/former-associations/, last access 12 October 2025/
Esurge_2005_erwin(2012), Winter storm Gudrun (2005), by Philip Harwood, 2012/11/11
EUMETSAT, Rapid cyclogenesis in the North Atlantic 6-8 January 2005, (contributors: Jochen Kerkmann and Gordon Bridge) https://www.eumetsat.int/rapid-cyclogenesis-north-atlantic published 06January2005, accessed 03Dec2022
European Severe Weather Database, 7-9Jan2005, https://eswd.eu (last access 03Aug2024)
Expressen, Gudrun 2005: 20 doedas i den vaarsta storm, https://www.expressen.se/nyheter/inloggad/gudrun-2005-20-dodas-i-den-varsta-stormen/, published 04Feb2017 09:25

Feix, O. (ed): Statistical Yearbook 2005, Secretariat of UCTE, https://eepublicdownloads.entsoe.eu/clean-documents/pre2015/publications/ce/Statistical_Yearbook_2005.pdf, pdf datestamp 12 October 2006.
Financial Times, Insurers play down scale of storm damage claims, (reporter: William MacNamara), 20Jan2007
Finnish Meteorological Institute, Sea level statistics, https://en.ilmatieteenlaitos.fi/sealevelstatistics, date stamp 29 November 2024 (last access: 19 December 2024)
Fredsoe, Jorgen, Report on field tests with the PEM-system at the West Coast of Jutland 2005-2008, Department of Mechanical Engineering, DTU, May 2008 [pdf properties: author: Jorgen Fredsoe; date stamp: 04Jun2008; 112pp]
Gardiner, Barry, Appendix 1: List of all Storms in Database, European Forest Institute, Atlantic European Regional Office - EFIAtlantic, 19 pp. [PDF properties: author=Barry Gardiner, datestamp=23Jul2010] https://ec.europa.eu/environment/forests/pdf/Final_Report_Appendix_1.pdf
Gardiner, Barry, Appendix 3: Background information on 11 storms selected for detailed analysis, European Forest Institute, Atlantic European Regional Office - EFIAtlantic, 161 pp. [PDF properties: datestamp 23Jul2010]
Gardiner B, K Blennow, J-M Carnus, P Fleischer, F Ingemarson, G Landmann, M Lindner, M Marzano, B Nicoll, C Orazio, J-L Peyron, M-P Reviron, M-J Schelhaas, A Schuck, M Spielmann, T Usbeck, Destructive storm in European Forests: Past and Forthcoming Impacts, European Forest Institute, Atlantic European Regional Office - EFIAtlantic [pdf document properties: author=Barry Gardiner, datestamp=09Mar2012]
Golmen, LG and P Stenstrom, Bryggen i Bergen; Vassinntrenging i fundament og bolverk; Resultat av maalinger vinter/vaaren 5005, Rapport 5047-2005, Norsk institutt for vannforskning NIVA, August, 2005.
Gray AL, O Martinez-Avarado, LH Baker, PA Clark, Conditional symmetric instability in sting-jet storms, QJRMS, 137, 1482-1500, 2011
Guardian, Thousands lose power in storms (contributor Henry McDonald), 9 January 2005.
Guardian, Storms claim at least five lives (contributor: Adam Jay), https://www.theguardian.com/environment/2005/jan/12/weather.climatechange1, 12 January 2005
Guy Carpenter, Windstorm Erwin/Gudrun - January 2005, Specialty Practice Briefing, Issue No. 2, 17 January 2005
Haigh, I.D., O. Ozsoy, M.P. Wadey, R.J. Nicholls, S.L. Gallup, T. Wahl, J.M. Brown, Data descriptor: An improved database of coastal flooding in the United Kingdom from 1915 to 2016, Scientific Data, 4: 170100, DOI: 10.1038/sdata.2017.100
Haanpaa, Simo, Samuli Lehtonen, Lasse Peltonen, Elena Talockaite, Impacts of winter storm Gudrun of 7th-9th January 2005 and measures taken in the Baltic Sea region, Astra, www.astra-project.org, 43pp, 2006 [pdf properties: datestamp 13/06/2006]
Hallands Nyheder, Stormen staengde Ringhals (contributor Krister Svahn), 9 January 2005 https://www.hn.se/nyheter/varberg/stormen-stangde-ringhals.036d8cf7-2756-4206-b13c-6d03f504a264
Harwood, Phillip, Esurge final report, 15Feb2015, copyright CGI Ltd 2014
Hasager CB, P Astrup, M Nielsen, MB Christiansen, J Badger, P Nielsen, PB Soorensen, RJ Barthelmie, SC Pryor, H Bergstroom, SAT-WIND project Final Report, Riso-R-1586(EN), Riso National Laboratory, Technical University of Denmark, Roskilde, Denmark, April, 2007.
Heipertz, Martin and Christiane Nickel, Climate change brings stormy days: Case studies on the impact of extreme weather events on public finances, SSRN Electronic Journal, pp. 613-630, DOI: 10.2139/ssrn.1997256, April 2008 (In Fiscal Sustainability, Analytical Developments and Emerging Policy Issues, 3-5April2008)
Hellenberg, T. and J. Kentala, Chapter III. Sudden sea level rise in the Gulf of Finland in January 2005, in C. Pursiainen (ed), Early Warning and Civil Protection. When does it work and why does it fail? Nordregio report 2008:1
Hewson TD and U Neu, Cyclones, windstorms and the IMILAST project, Tellus A, 67, 27128, http://dx.doi.org/10.3402/tellusa.v67.27128, 2015
Hisscott, Alan, When NWP met climatology: storms over the Isle of Man during January 2005,'Weather, 62, 74-77, 2007
Horsburgh KJ, C Wilson, BJ Baptie, A Cooper, D Cresswell, RMW Musson, L Ottemoller, S Richardson, SL Sargeant, Impact of a Lisbon-type tsunami on the UK Coastline and the implications for tsunami propagation over broad continental shelves, J Geophys Res, 113, 15pp, C04007, doi:10.1029/2007JC04425, 2008.
International Seismic Centre, ISC Bulletin, last access 10Aug2025.
The Irish Times, Severe weekend weather leads to flooding (contributor James Fitzgerald), https://www.irishtimes.com/news/severe-weekend-weather-leads-to-flooding-1.404508, 8 January 2005
The Irish Times, Seven die as storm hits southern Scandinavia, irishtimes.com/news/seven-die-as-storm-hits-southern-scandinavia-1.1295791, 9 January 2005
The Irish Times, Man dies as storm causes power cuts and flooding (contributor Ciara O'Brien), https://www.irishtimes.com/news/man-dies-as-storm-causes-power-cuts-and-flooding-1.1295844, 11 January 2005
Jameson D., Weather extremes 2005. January 7th-8th Severe storm development, https://user.eumetsat.int/resources/case-studies/rapid-cyclogenesis-in-the-north-atlantic, pdf timestamp: 17/03/2005
Johansson J., S Lindahl, O. Samuelsson, H Ottoson, The storm Gudrun. A seven-week power outage in Sweden, CRIS, Third International Conference on Critical Infrastructure, Alexandria, Virginia, September, 2006.
Kartverket, Top 10 storm surges for Tregde, Stavanger, Bergen, Maloy, data lists emailed by Aksel Voldsund, 20 July 2024
Kjeldsen, Soren Peter: Breaking waves, in A. Torum and O.T. Gudmestad (eds.), Water Wave Kinematics, 453-473, Kluwer Academic Publishers, https://link.springer.com/chapter/10.1007/978-94-009-0531-3_29, 1990.
Klee, I. and L Noren (ed): Annual Report 2005, Nordel Secretariat, Box 530, FI-00101 Helsinki, Finland, http://www.pfbach.dk/firma_pfb/historien/data_files/Nordel_ann_2005.pdf, pdf date stap: 3 May 2006, last access 8 October 2025
Krzystyniak M, The relationship bewteen extreme weather events and subsequent slide events in Norway, Master Thesis, Dept of Geosciences, University of Oslo, Sept. 2011
Kulikov, E.A. and I.P. Medvedev, Extreme statistics of storm surges in the Baltic Sea, Oceanology, 57, 772-783, 2017.
Lewis C, T Smyth, D Williams, J Neuman, H Cloke, Meteotsunami in the United Kingdom: the hidden hazard, Nat Hazards Earth Syst Sci, 23, 2531-2546, 2023.
Lindahl, Sture: The Storm Gudrun 2005-01-08, uploaded to Internet 19/10/2021, presentation 2005-05-12
LKN.SH, Sturmfluten 2005, Hydrologischer Bericht Sturmfluten Nordsee und Elbe, 6pp., Januar 2005. report emailed by Hauke Thiesen 20 June 2023.
Lloyds Casualty Week, 21Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ
Lloyds Casualty Week, 28Jan2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ
Lloyds Casualty Week, 04Feb2005, Lloyd's MIU, Telephone House, 69-77 Paul Street, London, EC2A 4LQ
Loginfo A/S: Heidrun EMS-Data, Month report, January 2005, 19 February 2005
Lorenz M, K Viigand, U Grawe, Untangling the waves: decomposing extreme sea levels in a non-tidal basin, the Baltic Sea, Nat. Hazards Earth Syst. Sci., 25, 1439-1458, 2025.
Magnusson, A.K.: Powerpoint presentation at the EXWW workmeeting 2006–2007 Hotel Admiral, Bergen, June 12–14th 2007.

Magnusson, A.K.: What is true sea state? Powerpoint presentation at the 11th International Workshop on Wave Hindcasting and Forecasting and Coastal Hazard Symposium, JCOMM Halifax, Canada, 18–23 October 2009.
Medvedev, I.P. and E.A. Kulikov, Extreme storm surges in the Gulf of Finland: Frequency-spectral properties and the influence of low-frequency sea level oscillations, Oceanology, 61, 459-468, 2021.
Met Eireann, Monthly Weather Bulletin, No 225, Jan 2005
met.no info, Varsling av stormer og ekstremt vaer (contact information: KH Midtbo, M Lystad, D Kvamme), 10pp, No.18/2005, Oslo, 25 November 2005
MIROS: Manedsrapport, januar 2005, Draugen - Naturdatainnsamling, ND/1022/05/01, 18 February 2005.
MIROS, Ekofisk Monthly Report, November 2007, Doc No. ND/1024/05/01, MIROS, 29pp, 25 February 2005.
MIROS: Manedsapport, januar 2005, Heimdal - Naturdatainnsamling, ND/1047/05/01, 28 February 2005.
MIROS: Manedsrapport, januar 2005, Sleipner A - Naturdatainnsamling, ND/1017/05/01, 17 February 2005
MIROS: Manedsrapport, januar 2005, Troll A - Naturdatainnsamling, ND/1012/05/01, 16 February 2005
MIROS, Manedsrapport Gullfaks C, Januar 2005, ND/1013/05/01, 14 October 2013
Mueller-Westermeier, Gerhard, Beschreibung un klimatologische Bewertung des Orkantiefs "Kyrill", pdf properties: Title: Deutscher Wetterdienst - Nationale Klimauberwachung, Author: Gerhard Mueller-Westermeier, Subjet: Orkan Kyrill, datestamp: 26Jan2007
Munich Re, Significant winter storms Europe 1980-2006. The 10 costliest storms listed by insured loss. MuenchenerRueck Munich Re Group, 2007 [pdf document time stamp: 26/01/2007]
Myhr, K.J.: Storm puts focus on security, https://history.vattenfall.com/stories/power-to-the-people/storm-puts-focus-on-security/, last access: 24Jan2025.
Neumann, T., FINO and the mast shadow effect, 52nd IEA Topical Expert Meeting, Wind and wave measurements at offshore locations, Berlin, Germany, February 2007, organized by TU Berlin and Germanischer Lloyd, International Energy Agency, Implementing Agreement for Co-operation in the Research, Development and Deployment of Wind Turbine Systems, Task 11.
Nielsen, J.W., Stormfloden den 8. januar 2005, https://ocean.dmi.dk/case_studies/surges/2005-01-08.php, last access:21Feb2023.
Nilsson C, S Goyette, L Barring, Relating forest damage data to the wind field from high-resolution RCM simulations: case study of Anatol striking Sweden in December 1999, Global and Planetary Change, 57, 161-176, 2007.
NLWKN, Experten vom NLWKN: Flache Nordsee schuetzt Niedersachsens Kueste vor einem Tsunami, https://www.nlwkn.niedersachsen.de/startseite/aktuelles/presse_und_offentlichkeitsarbeit/pressemitteilungen/-38655.html, 11 January 2005.
NLWKN, Elfte Sturmflut bisher höchste des Winters (contributor Achim Stolz), Nds. Landesbetrieb für Wasserwirtschaft, Küsten- und Naturschutz, https://www.nlwkn.niedersachsen.de/startseite/aktuelles/presse_und_offentlichkeitsarbeit/pressemitteilungen/-38678.html, 21/01/2005
NNRCMP, Welcome, National Network of Regional Coastal Monitoring Programmes, https://coastalmonitoring.org/, last access: 2 January 2025
Nordel: Annual Statistics 2005, https://www.entsoe.eu/news-events/former-associations/, pdf date stamp 21 June 2006
North East Coastal Observatory, http://northeastcoastalobservatory.org.uk/data/reports/20_cell_1_monitoring_reports/26_wave_&_tide_reports/ (last access: 18Dec2024)
NRK, Gudrun herjar i sor (contributor Bent J. Tandstad), 8Jan2005
NTSLF, Skew surge history, https://ntslf.org/storm-surges/skew-surges, https://ntslf.org/storm-surges/skew-surges/scotland, https://ntslf.org/storm-surges/skew-surges/england-east, https://ntslf.org/storm-surges/skew-surges/england-south, https://ntslf.org/storm-surges/skew-surges/england-wales, https://ntslf.org/storm-surges/skew-surges/england_west, https://ntslf.org/storm-surges/skew-surges/isle-of-man, https://ntslf.org/storm-surges/skew-surges/northern-ireland, https://ntslf.org/storm-surges/skew-surges/channel-islands, (accessed 28Dec2024)
Oceanor Sandnes: Norne EMS-Data, Monthly Report January 2005, 16 February 2005.
Olbert, A.I. and M. Hartnett, Storms and surges in Irish waters, Ocean Modelling, 34, 50-62, 2010.
OPW, Hydrometric, https://waterlevel.ie/hydro-data/#/overview/Waterlevel/station/, Office of Public Works, last access: 11/02/2025.
Palginomm V, K Orviku, U Suursaar, A Kont, H Tonnison, R Rivis, Lessons learned from record-high storm surges and associated inundations in Parnu, SW Estonia, Journal of Coastal Research, 85, 1-5, 2018.
Pantillon, F., P. Knippertz, U. Corsmeier, Revisiting the synoptic-scale probability of severe European winter storms using ECMWF ensemble reforecasts, Nat. Hazards Earth Syst. Sci., 17, 1795-1810, 2017.
Pellikka, H., TK Laurila, H Boman, A Karjalainen, J-V Bjorkqvist, KK Kahma, Meteotsunami occurrence in the Gulf of Finland over the past century, Nat. Hazards Earth Syst. Sci., 20, 2535-2546, https://doi.org/10.5194/nhess-20-2535-2020, 2020
Pelt, S., Kraftige storme med oprindelse i Nordatlanten, Vejret, 137, 44-47, 2013
Penna NT, WE Featherstone, J Gazeaux, RJ Bingham, The apparent British sea slope is caused by systematic errors in the levelling-based vertical datum, Geophys. J. Int., 194, 772-786, 2013
Petroleum Safety Authority Norway: Annual Report 2005, Stavanger, 2005 [pdf timestamp 28 April 2006]
Petroleum Safety Authority Norway: Annual Report 2006. Supervision and facts, Stavanger, 26 April 2007.
Petroliagis TI and P Pinson, Early warnings of extreme winds using the ECMWF Extreme Forecast Index, Meteorological Applications, 21, 171-185, 2014.
Piontkowitz, Thorsten & Carlo Soerensen, Consequences of Climate Change along the Danish Coasts, Safecoast Action 5A, Danish Coastal Authority, Hojbovej 1, 7600 Lemvig, Denmark, kdi@kyst.dk, December 2008
Post, P. and T. Kõuts, "Characteristics of cyclones causing extreme sea levels in the northern Baltic Sea,"Oceanologia 56 (2), 241–258, https://doi.org/10.5697/oc.56-2.24, 2014.
Rantanen, H., Chapter IV. Coping with Power Disturbances, in C. Pursiainen (ed), Early Warning and Civil Protection. When does it work and why does it fail? Nordregio report 2008:1, p.95-119.
Rantanen M, D van den Broek, J Corner, VA Sinclair, MM Johansson, J Sarkka, TK Laurila, and K Jylha, The impact of serial cyclone clustering on extremelyhigh sea levels in the Baltic Sea, Geophysical Research Letters, 51, e2023GL107203, https://doi.org/10.1029/2023GL107203, 2024.
Roberts JF, AJ Champion, LC Dawkins, KI Hodes, LC Shaffrey, DB Stephenson, MA Stringer, HE Thornton, DB Youngman, The XWS open access catalogue of extreme European windstorms from 1979 to 2012, Nat. Hazards Earth Syst. Sci, 14, 2487-2501, 2014
Rosenorn, Stig, Vintervejret 2004-2005, Vejret, 103, 23-25, 2005
RWS, Stormvloedflits 2005-02. Zeer zware zuidwesterstorm veroorzaakt vrij hoge waterstanden langs de kust (contributor Jan Kroos). https://open.rijkswaterstaat.nl/open-overheid/onderzoeksrapporten/%40257045/stormvloedflitsen-wmcn-kust/, 2005a
RWS, Stormvloedflits 2005-03. Stormtij en storm met orkankracht veroorzaken hoge waterstanden langs de kust (contributor Jan Kroos). https://open.rijkswaterstaat.nl/open-overheid/onderzoeksrapporten/%40257045/stormvloedflitsen-wmcn-kust/, 2005b

Seewetter - Kiel: Orkantief Erwin, http://www.seewetter-kiel.de/seewetter/orkan_erwin.htm, last access: 10Dec2024
Sieber, Jeanette, Impacts of extreme hydro-meteorological events on electricity generation and possible adaptation measures. A GIS-based approach for corporate risk management and enhanced climate mitigation concepts in Germany. Ph.D. thesis, Julius-Maximilians-Universitaet Wuerzburg - Institut fuer Geographie, Karlsruhe, November 2012
Schold S, S Hellstrom, C-L Ivarsson, P Kallberg, H Lindow, S. Nerheim, S Schimanke, J Sodling, L Wern, Vattenstandsdynamik langs Sveriges kust, SMHI, Oceanografi, Nr. 123, 82 pp, 2017
SMHI, Per - Januaristormen 2007, 6Aug2009, https://www.smhi.se/kunskapsbanken/meteorologi/per-januaristormen-2007-1.5287
SMHI, Gudrun - Januaristormen 2005,, https://www.smhi.se/kunskapsbanken/meteorologi/stormar-i-sverige/enskilda-stormar-och-ovader/gudrun-januaristormen-2005-1.5300, 13 oktober 2011
SMHI, Rekord: Vattenstand, https://www.smhi.se/data/oceanografi/havsvattenstand/rekord-havsvattenstand-1.2269, updated 26 November 2024a, last access: 06 January 2025.
SMHI, Stationslista vattenstand, https://www.smhi.se/kunskapsbanken/stationslista-havsvattenstand-1.13981, 27Nov2024b, (last access: 8Jan2025)
SMHI, Högvattenhändelser idag och i framtiden, https://www.smhi.se/klimat/stigande-havsnivaer/hogvattenhandelser-idag-och-i-framtiden, last access: 10Jan2025
Soomere, T., A. Behrens, L. Toumi, J.W. Nielsen: Wave conditions in the Baltic proper and in the Gulf of Finland during windstorm Gudrun, Nat Hazards Earth Syst. Sci., 8, 37-46, 2008.
Sorensen C, SM Ingvardsen, I Andersen, BB Kloster, KDI, Hojvandsstatistikker 2007, Extreme sea level statistics for Denmark, 2007, Kystdirektoratet, Dec, 2007.
Spencer T, SM Brooks, BR Evans, JA Tempest, I Moeller, Southern North Sea storm surge event of Dec.5, 2013: Water levels, waves, and coastal impacts, Earth Science Reviews, 146, 120-145, 2015.
Statistica, The costliest winter storms ever to hit Europe. Fatalities and financial losses of Europe's 10 costliest winter storms (source Munich Re), 08Dec2015
SurgeWatch, Storm Event 11th January 2005, in Haigh, I.D., O. Ozsoy, M.P. Wadey, R.J. Nicholls, S.L. Gallup, T. Wahl, J.M. Brown,Data descriptor: An improved database of coastal flooding in the United Kingdom from 1915 to 2016, Scientific Data, 4: 170100, DOI: 10.1038/sdata.2017.100, 2017
Suursaar, U. and J. Sooaar, Storm surge induced by extratropical cyclone Gudrun: hydrodynamic reconstruction of the event, assessment of mitigation actions and analysis of future flood risks in Parnu, Estonia, WIT Transactions on Ecology and the Environment, vol.91, pp241-250, WIT Press, 2006.
Suursaar, U., T. Kullas, M. Otsmann, I. Saarmae, J. Kuik, M. Merilain, Cyclone Gudrun in January 2005 and modelling its hydrodyanamic consequences in the Estonian coastal waters, Boreal Environmental Research, 11, 143-159, 2006.
Tatge, Yoern, Looking back, looking forward: Anatol, Lothar and Martin ten years later, 09Dec2009. https://www.air-worldwide.com/publications/air-currents/looking-back-looking-forward-anatol-lothar-and-martin-ten-years-later/
Tetzlaff, G., Extreme rain and wind storms in teh mid-latitudes I, Singapore, 21-22.04.2009. https://imsarchives.nus/edu.sg/oldwww/Programs/09fluidss/files/Gerd Tetzlaff.pdf (Spring School on Fluid Mechanics and Geophysics of Environmental Hazards, Singapore, April 19-May 2, 2009) [pdf datestamp: 14/05/2009]
thejournal.ie, The deadliest storms to ever hit Europe, 14Dec2015 0610AM, https://www.thejournal.ie/europe-storms-2497164-Dec2015/, accessed 10Dec2020
Thompson, K.R., An analysis of British monthly sea level, Geophys. J. R. astr. Soc., 63, 57-73, 1980.
Tonisson H, K Orviku, J Jaagus, U Suursaar, A Kont, R Rivis, Coastal damages on Saaremaa Island, Estonia, caused by the extreme storm and flooding on January 9, 2005, Journal of Coastal Research, 24, 602-614, 2008.
Verlaan M, A Zijderveld, H de Vries, J Kroos, Operational storm surge forecasting in the Netherlands: developments in the last decade, Phil. Trans. R. Soc. A, 363, 1441-1453, doi: 10.1098/rsta.2005.1578, 2005.
Walser, M. and F. Wagner (ed.): The 50 year success story - Evolution of a European Interconnected Grid, Secretariat of UCTE, Boulevard Saint-Michel 15, B-1040 Brussels, Belgium, https://eepublicdownloads.entsoe.eu/clean-documents/pre2015/publications/ce/110422_UCPTE-UCTE_The50yearSuccessStory.pdf, 2009 last access: 6 October 2025
Wikipedia, Floods in Saint Petersburg, https://en.wikipedia.org/wiki/Floods_in_Saint_Petersburg, 24Jan2025
Wikipedia, Ekstremveret Gudrun, https://nn.wikipedia.org/wiki/Ekstremv%C3%AAret_Gudrun, last access: 29Apr2025
Wolf, J.: Modelling of waves and setup for the storm of 11-12 January 2005, Proudman Oceanographic Institute, report no. 181, March 2007.
Wolski, T., B. Wisniewski, A. Giza, H. Kowalewska-Kalkowska, H. Boman, S. Grabbi-Kaiv, T. Hammarklint, J. Holfort, Z. Lydeikaite, Extreme sea levels at selected stations on the Baltic coast, Oceanologia, 56, 259-290, 2014
Woodworth, PL: Sea level change in Great Britain between 1859 and the present, Geophys. J. Int., 213, 222-236, 2018.