Supplement of Adv. Geosci., 49, 187–196, 2019
https://doi.org/10.5194/adgeo-49-187-2019-supplement

Advances in Geosciences
Open Access
EGU

Supplement of

Storm Tilo over Europe in November 2007: storm surge and impacts on societal and energy infrastructure

Anthony James Kettle

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

S1 Tide gauge information

Table S1. Tide gauge information for 76 sites in the United Kingdom, France, the Netherlands, Germany, Denmark, and Norway. The sites have been ordered counter-clockwise around the North Sea with distances from Lerwick, UK.

N [1]	Abb [2]	Name [3]	Co [4]	Distance (km) [5]	Long-Itude [6]	Lat-itude [7]	Time Interval Original (min) [8]	Time Interval Analysis (min) [9]	Reference Sea Level (m) [10]	Calculated Average Sea Level (m) [11]
1	LW	Lerwick	UK	0	-1.14	60.15	15	15	1.329	1.340
2	WK	Wick	UK	238	-3.09	58.44	15	15	2.058	2.065
3	LE	Leith	UK	518	-3.18	55.99	15	15	3.216	3.219
4	NS	North Shields	UK	670	-1.44	55.01	15	15	3.014	3.047
5	WH	Whitby	UK	747	-0.61	54.49	15	15	3.531	3.608
6	IM	Immingham	UK	842	-0.19	53.63	15	15	4.285	4.349
7	CR	Cromer	UK	955	1.30	52.93	15	15	3.001	3.312
8	LT	Lowestoft	UK	1008	1.75	52.47	15	15	1.329	1.905
9	FE	Felixstowe	UK	1057	1.35	51.96	15	15	2.196	2.306
10	SH	Sheerness	UK	1123	0.74	51.44	15	15	3.125	3.313
11	DV	Dover	UK	1148	1.32	51.12	15	15	3.839	3.913
12	CA	Calais	FR	1202	1.87	50.97	60	60	?	4.125
13	DK	Dunkerque	FR	1235	2.37	51.05	60	60	?	3.476
14	CZ	Cadzand	NE	1310	3.38	51.38	10	10	0.0	0.208
15	WL	Westkapelle	NE	1322	3.43	51.52	10	10	0.0	0.214
16	VL	Vlissingen	NE	1325	3.60	51.44	10	10	0.0	0.259
17	TE	Terneuzen	NE	1330	3.83	51.33	10	10	0.0	0.342
18	RM	Roomport buiten	NE	1340	3.68	51.62	10	10	0.0	0.242
19	EU	Euro platform	NE	1344	3.28	51.99	10	10	0.0	0.193
20	HW	Hansweert	NE	1347	4.00	51.45	10	10	0.0	0.384
21	BA	Bath	NE	1354	4.22	51.40	10	10	0.0	0.434
22	BH	Brouwershavensche Gat 08	NE	1357	3.82	51.75	10	10	0.0	0.316
23	LG	Lichteiland Goeree	NE	1360	3.67	51.93	10	10	0.0	0.284
24	HH	Hoek van Holland	NE	1388	4.12	51.98	10	10	0.0	0.340
25	SC	Scheveningen	NE	1404	4.26	52.10	10	10	0.0	0.288
26	IJ	Ijmuiden buitenhaven	NE	1445	4.55	52.46	10	10	0.0	0.304
27	DH	Den Helder	NE	1492	4.74	52.96	10	10	0.0	0.273
28	OS	Oudeschild	NE	1503	4.85	53.03	10	10	0.0	0.305
29	KW	Kornwerderzand buiten	NE	1530	5.33	53.07	10	10	0.0	0.425
30	VH	Vlieland haven	NE	1537	5.09	53.30	10	10	0.0	0.283
31	HL	Harlingen	NE	1542	5.41	53.18	10	10	0.0	0.408
32	TL	West-Terschelling	NE	1549	5.22	53.36	10	10	0.0	0.307
33	TN	Terschelling Nordzee	NE	1562	5.33	53.44	10	10	0.0	0.237
34	NE	Nes	NE	1582	5.77	53.43	10	10	0.0	0.425
35	WG	Wierumergronden	NE	1598	5.96	53.52	10	10	0.0	0.278
36	LR	Lauwersoog	NE	1599	6.20	53.41	10	10	0.0	0.444
37	SM	Schiermonnikoog	NE	1604	6.20	53.47	10	10	0.0	0.439
38	DF	Delfzijl	NE	1622	6.93	53.33	10	10	0.0	0.514

39	HG	Huibertgat	NE	1622	6.40	53.57	10	10	0.0	0.244
40	NZ	Nieuwe Statenzijl	NE	1626	7.21	53.23	10	10	0.0	0.753
41	EE	Eemshaven	NE	1629	6.83	53.45	10	10	0.0	0.421
42	EH	Emshörn	DE	1634	6.84	53.49	1	10	5.02	5.519
43	BK	Borkum-Südstrand	DE	1634	6.66	53.58	1	10	5.00	5.369
44	BF	Borkum-Fischerbalje	DE	1635	6.75	53.56	1	10	5.03	5.454
45	ND	Norderney-Riffgat	DE	1664	7.16	53.70	1	10	4.99	5.438
46	SP	Spiekeroog	DE	1688	7.68	53.75	1	10	5.06	5.536
47	WW	Wangerooge-West	DE	1697	7.87	53.78	1	10	5.03	5.465
48	WN	Wangerooge-Nord	DE	1701	7.93	53.81	1	10	5.03	5.440
49	MP	Mellumplate	DE	1704	8.09	53.77	1	10	5.02	5.428
50	AW	Leuchtturm Alte Weser	DE	1713	8.13	53.86	1	10	4.96	5.361
51	BZ	Bake Z	DE	1732	8.31	54.01	1	10	5.00	5.420
52	SN	Scharhörn	DE	1733	8.47	53.97	1	10	4.99	5.377
53	HE	Helgoland-Binnenhafen	DE	1734	7.89	54.18	1	10	5.00	5.397
54	MG	Mittelgrund	DE	1735	8.64	53.94	1	10	5.00	5.463
55	ZE	Zehnerloch	DE	1736	8.66	53.96	1	10	5.00	5.481
56	HB	Hamburg-St. Pauli	DE	1740	9.97	53.55	1	10	5.00	5.868
57	BU	Büsum	DE	1757	8.86	54.12	1	10	?	5.478
58	WI	Wittdün	DE	1791	8.39	54.63	1	10	?	5.371
59	HU	Husum	DE	1792	9.03	54.47	1	10	5.00	5.489
60	HR	Hörnum	DE	1802	8.30	54.76	1	10	5.00	5.373
61	HO	Højer	DK	1831	8.66	54.96	10	10	0.0	0.582
62	LS	List	DE	1831	8.44	55.02	1	10	5.00	5.360
63	HY	Havneby	DK	1842	8.57	55.09	10	10	0.0	0.391
64	BM	Ballum	DK	1848	8.69	55.13	10	10	0.0	0.657
65	RI	Ribe (Havet på forlandet)	DK	1870	8.67	55.34	10	10	0.0	0.438
66	EJ	Esbjerg	DK	1879	8.42	55.47	10	10	0.0	0.309
67	HV	Hvide Sande (Havet)	DK	1936	8.11	56.00	10	10	0.0	0.251
68	TS	Thorsminde (Havn)	DK	1980	8.12	56.37	10	10	0.0	0.274
69	TH	Thyborøn (Havet hofde 58)	DK	2021	8.21	56.71	10	10	0.0	0.312
70	HA	Hanstholm (Havn)	DK	2067	8.60	57.13	10	10	0.0	0.224
71	HI	Hirtshals	DK	2100	9.97	57.60	10	10	0.0	0.151
72	SK	Skagen	DK	2104	10.60	57.72	10	10	0.0	0.380
73	TG	Tregde	NO	2183	7.50	58.00	10	10	?	0.578
74	SV	Stavanger	NO	2346	5.73	58.97	10	10	?	0.698
75	BG	Bergen	NO	2501	5.30	60.40	10	10	?	0.973
76	MY	Maløy	NO	2637	5.10	61.90	10	10	?	1.209

Notes:

[1] Running index.

[2] Two letter station abbreviation used in manuscript.

[3] Station name.

[4] Country operating the tide gauge.

[5] Distance counter-clockwise around North Sea starting from Lerwick in the UK.

[6] Decimal longitude.

[7] Decimal latitude.

[8] Time interval of data in original data set.

[9] Time interval used in the spectral analysis; the one minute data for Germany have been averaged onto a 10 minute grid.

[10] Reported mean sea level on the scale of the tide gauge. For the UK, this is taken as the average water level for November, 2007 as presented in Bradshaw (2007). For Germany, the reference points for the water level gauges are taken from Pegel Online (https://www.pegelonline.wsv.de) where available. For the Netherlands and Denmark, null values are assumed. For France and Norway, no information is given about the mean sea level of the stations used here.

[11] Calculated average of the water level data for the 14 day interval 1 November 2007 00:00 GMT to 15 November 2007 00:00 GMT for the original time series data.

References for Table

Bradshaw, E. (ed): Annual Report for 2007 for the UK National Tide Gauge Network and Related Sea Level Science, National Tide and Sea Level Facility, NERC 100017897 2007.

S2 Tabulated information for weather-related incidents

Table S2. Large wave report and shipping/platform accidents in the North Sea during Storm Tilo 8–9 November 2007 (to support the Fig. 1 and Fig. 5 of the manuscript).

N [1]	Abb [2]	Name [3]	Long-itude [4]	Lat-itude [5]	Date (GMT) dd/mm/yyyy [6]	Time (GMT) hh:mm [7]	Uncer time (h) [8]	Flag wea [9]	Flag type [10]	Nr. rep [11]	Source [12]
1	AUR	Aurelia	4.61	52.46	09/11/2007	00:45	0	Y	i	1	KW09
2	BZZ	Buzzard Platform	0.89	57.84	09/11/2007	12:00	24	Y	p	4	LCW23, UPS09, UPS12
3	DNA	Daina	10.08	54.36	09/11/2007	12:00	24	Y	c	3	LCW23, CL07
4	BLU	DS Blue Wave	9.52	54.21	08/11/2007	17:00	0	N	e	6	LCW23, CL07
5	EKO	Ekofisk	3.20	56.50	09/11/2007	00:54	0	Y	p	2	MD13, DM17
6	EVA	Eva Danielsen	2.43	51.83	09/11/2007	06:00	12	Y	e	4	LCW23, CL07
7	FNO	FINO1	6.59	54.01	09/11/2007	12:00	6	Y	p	1	OEA08
8	FLN	Flinterbaltica	1.84	55.28	09/11/2007	10:00	0	Y	t	2	LCW23
9	HMX	Hamburg Max	4.61	52.46	09/11/2007	01:45	0	Y	i	1	KW09
10	LND	Linda	9.13	53.90	08/11/2007	12:00	24	N	c	2	LCW16, CL07
11	MKR	Menkar	3.56	51.40	08/11/2007	23:00	0	Y	i	1	KW09
12	NRD	Nordana Andrea	10.08	54.36	09/11/2007	12:00	24	Y	c	9	LCW23, CL07
13	NYK	NYK Antares	5.84	53.75	09/11/2007	03:12	0	Y	d	11	LCW23, CL07, KW09, KW22, KW23
14	SCH	Schelde Highway	9.13	53.90	08/11/2007	12:00	24	N	c	2	LCW16, CL07
15	ULR	Ulrika G	9.66	54.31	09/11/2007	12:00	24	N	g	1	CL07
16	VLD	Vlieland	5.42	53.17	09/11/2007	16:54	0	Y	e	1	LCW23

Notes:

[1] Incident index

[2] Incident abbreviation used in figures of manuscript

[3] Name of ship or platform in incident

[4] Decimal longitude

[5] Decimal Latitude

[6] Date of incident (GMT)

[7] Time of incident (GMT)

[8] Range of uncertainty in time of report in hours; 24h indicates that an incident took place at some time on the reported day but more precise information is not available in the literature.

[9] Flag indicating that bad weather or sea state was mentioned in the incident description, or where a single large wave event is indicated.

[10] Flag indicating the type of incident: c is collision between two ships, d is containers lost overboard in a single wave incident, e is engine problems or power blackout, g is grounding, i is injury or man overboard, p is platform incident, t is deck cargo logs lost overboard.

[11] Number different report or updates of the incident among all the sources. Most of the sources have just one report of the incident, but Lloyd's Casualty Week typically carries a series of update reports in its week's summary with additional update reports in the following reports.

[12] Source list: CL07 is Cargo Law (2007); DM17 is Donelan and Magnusson (2017); KW09 is Kustwachtcentrum (2007a); KW22 is Kustwachtcentrum (2007b), KW23 is Kustwachtcentrum (2007c); LCW16 is Lloyds Casualty Week (2007a); LCW23 is Lloyds Casualty Week (2007b); MD13 is Magnusson and Donelan (2013); OEA08 is Outzen et al. (2008); UPS09 is Upstream (2007a); UPS12 is Upstream (2007b)

References for Table

Cargo Law: International Vessel Casualties & Pirates Database for year 2007 - Jan Through Dec. 2007, http://www.cargolaw.com/presentation_casualties.07.html

Donelan, M.A. and Magnusson, A.-K.: The making of the Andrea wave and other rogues, Scientific Reports, 7, 44124, doi: 10.1038/srep44124, 2017.

Kristandt, J., Brecht, B., Frank, H., and Knack, H.: Optimization of empirical storm surge forecast-modeling of high resolution wind fields, Die Küste, 81, 301–348, 2014

Kustwachtcentrum: Press Report, Noordwester storm Info nr 1, time stamp: 09/11/2007 0930, 2007a.

Kustwachtcentrum: Press Report, Zoektocht naar verloren containers, info nr. 1, time stamp: 22/11/2007 1330, 2007b

Kustwachtcentrum: Press Report, Zoektocht naar verloren containers, info nr. 2, time stamp: 23/11/2007 1600, 2007c

Lloyd's Casualty Week: 16 Nov 2007a.

Lloyd's Casualty Week: 23 Nov 2007b.

Loewe, P.: Atmosphaerenphysik, System Nordsee. 2006 & 2007: Zustand und Entwicklungen, ed. by P. Loewe, H. Klein, S. Welgelt-Krenz, Berichte des Bundesamtes fuer Seeschifffahrt und Hydrographie, pp. 37–114, Nr.49/2013

Magnusson, A.K. and Donelan, M.A.: The Andrea wave characteristics of a measured North Sea rogue wave, Journal of Offshore Mechanics and Arctic Engineering, 135, 2013.

Outzen, O., Herklotz, K., Heinrich, H., and Lefebvre, C.: Extreme waves at FINO 1 research platform caused by Storm 'Tilo' on 9 November 2007, DEWI Magazin No.33, 10pp, August 2008.

Upstream: Storm downs Nexen's Buzzard, contributor: Jonathan Davis, date stamp: 09 Nov 2007a.

Upstream: Storm clips Buzzard's wings, contributor: Anthea Pitt, date stamp: 12 Nov 2007b.

S3 Tabulated information on literature reports of skew surge during the storm

Table S3. Literature reports of skew surges for stations around the North Sea during Storm Tilo. A given station has at least one and up to three skew surge reports from different sources. Note that the different national sea level agencies have slightly different methods of reporting the skew surge concept. For example in the UK, it is calculated as the measured water level minus the expected high tide level based on a model of the different spectral tide components over a long period. In Germany, the skew surge concept is reported as the measured water level minus the average of the high tide levels over a long period of time.

Station name [1]	CO [2]	Longi-tude [3]	Lati-tude [4]	Nr [5]	Skew Surge1 (m) [6]	T1 [7]	Ref1 [8]	Skew Surge2 (m) [9]	T2 [10]	Ref2 [11]	Skew surge3 (m) [12]	T3 [13]	Ref3 [14]
Felixstowe	UK	1.35	51.96	2	1.180	0	NTLSF13a	0.971	2	B07			
Lowestoft	UK	1.75	52.47	2	1.642	0	NTLSF13a	1.555	2	B07			
Whitby	UK	-0.61	54.49	1	1.027	0	NTLSF13a						
Dover	UK	1.32	51.11	1	1.263	0	NTLSF13b						
Sheerness (Kent)	UK	1.75	52.47	1	1.338	2	EA12						
Whitby (Yorkshire)	UK	-0.61	54.49	1	1.009	2	B07						
Cromer	UK	1.30	52.93	1	1.009	2	B07						
Nieuwpoort	BE	2.73	51.15	1	1.342	2	VH16						
Oostende	BE	2.93	51.23	1	1.534	2	VH16						
Zeebrugge	BE	3.20	51.35	1	1.504	2	VH16						
Vlissingen	NE	3.60	51.45	1	1.400	0	RWS07c						
Roompot buiten	NE	3.67	51.62	1	1.700	0	RWS07c						
Hoek van Holland	NE	4.12	51.98	1	1.850	0	RWS07c						
Den Helder	NE	4.75	52.97	1	1.900	0	RWS07c						
Harlingen	NE	5.42	53.17	1	2.340	0	RWS07c						
Delfzijl	NE	6.93	53.33	1	2.680	0	RWS07c						
Station Wattenmeer	DE	7.67	53.75	2	2.130	0	REA09	2.150	0	BEA09			
Norderney	DE	7.15	53.70	3	2.550	0	KEA14	2.550	0	H07	2.550	0	H08
Langeoog	DE	7.50	53.72	1	2.530	0	H07						
Spiekeroog	DE	7.68	53.75	1	2.580	0	H07						
Wangerooge	DE	7.87	53.78	1	2.630	0	H07						
Knock	DE	7.03	53.33	1	3.110	0	H07						
Emden	DE	7.18	53.33	2	3.290	0	H07	3.150	7	HEA10a			
Emssperrwerk	DE	7.31	53.32	2	3.440	0	WIKI18a	3.280	0	L08			
Leyhoern	DE	7.03	53.55	1	2.780	0	H07						
Bensersiel	DE	7.58	53.67	1	2.760	0	H07						
Leuchtturm Alte Weser	DE	8.13	53.87	1	2.460	0	H07						
Wilhelmshaven	DE	8.12	53.53	1	3.080	0							
Cuxhaven	DE	8.72	53.87	3	2.910	0	H07	2.900	0	L13	2.740	6	GB09
Helgoland	DE	7.88	54.18	1	2.500	0	L08						
Hamburg St Pauli	DE	9.79	53.55	3	3.300	0	L08	3.330	0	KIT07	3.330	0	AB13
FINO1	DE	6.59	54.01	1	2.800	0	OEA08						
Bremerhaven Alte Lauchtturm	DE	8.57	53.55	1	3.000	7	HEA10a						
Langeoog Back Barrier	DE	7.47	53.70	1	3.010	7	HW14						
Thisted Havn	DK	8.70	57.00	1	1.065	2	KDI17						

Notes:

[1] Water level station name

[2] Country: UK, United Kingdom; BE, Belgium; NE, The Netherlands; DE, Germany; DK, Denmark

[3] Decimal longitude

[4] Decimal latitude

[5] Number of skew surge reports from different sources

[6] Value of skew surge from report 1

[7] Processing key for skew surge report 1: 0, skew surge number given in report and used without alteration; 2, skew surge calculated as the difference between the reported water level and the average high tide; 7, skew surge calculated from digitized low and high tide water levels for a short data time series across the period of the storm.

[8] Reference key for skew surge report 1: AB13, AON Benfield (2013); B07, Bradshaw (2007); BEA09, Badewien et al. (2009); EA12, Environment Agency (2012); GB09, Gönnert and Buss (2009); H07, Heyken (2007); H08, Heyken (2008); HEA10a, Herrling et al. (2010); HW14, Herrling and Winter (2014); KDI17, Ditlevsen et al. (2018); KEA14, Kristandt et al. (2014); KIT07, Karlsruhe Institute of Technology (2007); L08, Lefebvre (2008); L13, Loewe (2013); NTLSF13a, National Tide and Sea Level Facility (2013a); NTLSF13b, National Tide and Sea Level Facility (2013); OEA08, Outzen et al. (2008); REA09, Reuter et al. (2009); RWS07c, Rijkswaterstaat (2007); VH16, Vlaamse Hydrografie (2016); WIKI18a, WIKI.

[9] as for [6] but for report 2

[10] as for [7] but for report 2

[11] as for [8] but for report 2

[12] as for [6] but for report 3

[13] as for [7] but for report 3

[14] as for [8] but for report 3

References for Table

AON Benfield: Historie von 1703 bis 2012: Winterstuerme in Europe, Stand: Januar 2013.

Bradshaw, E. (ed): Annual Report for 2007 for the UK National Tide Gauge Network and Related Sea Level Science, National Tide and Sea Level Facility, NERC 100017897 2007.

Badewien, T.H., Zimmer, E., Bartholoma, A., and Reuter R.: Towards continuous long-term measurements of suspended particulate matter (SPM) in turbid coastal waters, Ocean Dynamics, 59, 227–238, 2009.

Ditlevsen C., Merino Ramos, M., Sørensen, C., Ciocan, U.R., and Piotkowitz, T.: Højvandsstatistikker 2017, Kystdirektoratet, Februar 2018.

Environment Agency, Thames Barrier Project Pack, 2012.

Gönnert, G., and Buss, T.: Sturmfluten zur Bemessung von Hochwasserschutzanlagen, Berichte des Landesbetriebes Strassen, Bruecken und Gewaesser Nr.2/2009

Herrling, G. and C Winter, C.: Morphological and sedimentological response of a mixed-energy barrier island tidal inlet to storm and fair-weather conditions, Earth Surf. Dynam., 2, 363–382, 2014.

Herrling, G., Knaack, H., Kaiser, R., and Niemayer, H.D.: Evaluation of design water levels at the Ems-Dollard estuary considering the effect of a storm surge barrier, Coastal Engineering, 2010.

Heyken, H.: Schwere Sturmflut an niedersachsischer Nordseekuste - Dunnenabbruche auf den Inseln, NLWKN Niedersachsischer Landesbetrieb fuer Waserwirtschaft, Kuesten- und Naturschutz, 09/11/2007.

Heyken, H.: 15 Sturmfluten sind keine Boten des Klimawandels, in Herma Heyken (ed), Jahresbericht 2007, NLWKN Niedersaechsicher Landesbetrieb fuer Wasserwirtschaft, Kuesten- und Naturschutz, pp14–15, Norden, April, 2008

Karlsruhe Institute of Technology: Sturm, Schnee, Regen. Mitteleuropa/Schwarzes Meer 09.-13.11.2007 (text CE), Wettergefahren-Fruehwarnung, Institut fuer Meteorologie und Klimaforschung, (document time stamp: Samstag, 17.November 2007, 18:00MEZ) 2007.

Lefebvre, C.: Orkan TILO am 8. und 9. November 2007, DWD report 01Jan2008

National Tide and Sea Level Facility, website summary: http://www.ntslf.org/storm-surges/storm-surge-climatology/england-east, last access 2013a.

National Tide and Sea Level Facility, website summary: http://www.ntslf.org/storm-surges/storm-surge-climatology/england-south, last access 2013b.

Outzen, O., Herklotz, K., Heinrich, H., and Lefebvre, C.: Extreme waves at FINO1 research platform caused by storm 'Tilo' on 9 November 2007, DEWI Magazin No. 33, August 2008.

Reuter R., TH Badewien, T.H., Bartholoma, A., Braun, A., Luebben, A., and Rullkoetter, J.: A hydrographic time series station in the Wadden Sea (southern North Sea), Ocean Dynamics, DOI 10.1007/s10236-009-0196-3, 2009.

Rijkswaterstaat: Verslag van de Stormvloed van 9 november 2007 (SR88), Ministerie van Verkeer en Waterstaat, Direktoraat-Generaal Rijkswaterstaat, Waterdienst, Stormvloedwaarschuwingsdienst/SVSD, Postbus 17, 8200 AA Lelystad, www.svsd.nl, Lelystad, 45 pp., november 2007.

Vlaamse Hydrografie, Overzicht van de Tijwaarnemingen Langs de Belgische Kust. Periode 2001-2010 voor Nieuwpoort, Oostende en Zeebrugge, Ministerie van de Vlaamse Gemeenschap, Agentschap Maritieme Dienstverlening en Kust, Afdeling Kust, Vlaamse Hydrografie, Oostende (document time stamp=24 Feb 2016, document author=beirenro), 2016.

WIKI, Liste der Sturmfluten an der Nordsee, https://de.wikipedia.org/wiki/Liste_der_Sturmfluten_an_der_Nordsee (accessed 24 March 2018).

S4 Tabulated skew surge based on an analysis the tide gauge records in this study

Table S4. Skew surge for stations around the North Sea during Storm Britta from Kettle (2018)

Index	Name of Station	Distance around North Sea from Lerwick (km)	Longitude	Latitude	Skew Surge (m)
1	Aberdeen	386	-2.07	57.14	0.220
2	Leith	518	-3.18	55.99	0.109
3	North Shields	670	-1.44	55.01	0.430
4	Whitby	747	-0.61	54.49	0.716
5	Immingham	842	-0.19	53.63	0.621
6	Cromer	955	1.30	52.93	1.121
7	Lowestoft	1008	1.75	52.47	1.362
8	Harwich	1057	1.29	51.95	0.999
9	Sheerness	1123	0.74	51.45	0.904
10	Dover	1148	1.32	51.11	0.678
11	Vlissingen	1325	3.60	51.44	1.265
12	Roompot buiten	1340	3.68	51.62	1.372
13	Europlatform	1344	3.28	51.99	1.472
14	Lichteiland Goeree	1360	3.67	51.93	1.479
15	Hoek van Holland	1388	4.12	51.98	1.532
16	Scheveningen	1404	4.26	52.10	1.645
17	Ijmuiden buitenhaven	1445	4.55	52.46	1.834
18	Den Helder	1492	4.74	52.96	1.843
19	Texel Nordzee	1531	4.73	53.12	1.639
20	Vlieland Haven	1537	5.09	53.30	1.950
21	Harlingen	1542	5.41	53.18	2.425
22	West Terschelling	1549	5.22	53.36	2.017
23	Terschelling Nordzee	1562	5.33	53.44	1.864
24	Wierumergronden	1598	5.96	53.52	1.930
25	Lauwersoog	1599	6.20	53.41	2.888
26	Schiermonnikoog	1604	6.20	53.47	2.692
27	Huibertgat	1622	6.40	53.57	2.298
28	Delfzijl	1622	6.93	53.33	3.681
29	Nieuwe Statenzijl	1626	7.21	53.23	4.195
30	Eemshaven	1629	6.83	53.45	3.099
31	Borkum-Sudstrand	1634	6.66	53.58	2.659
32	Borkum-Fischerbalje	1635	6.75	53.56	2.835
33	Norderney Riffgat	1664	7.16	53.70	2.761
34	Langeoog	1675	7.52	53.72	2.960
35	Spiekeroog	1688	7.68	53.75	2.905
36	Wangerooge-West	1697	7.87	53.78	2.836
37	Wangerooge-Nord	1701	7.93	53.81	2.329
38	Leuchtturm Alte Weser	1713	8.13	53.86	2.318
39	Bake Z	1732	8.31	54.01	2.062
40	Scharhorn	1733	8.47	53.97	2.258
41	Helgoland Binnenhafen	1734	7.89	54.18	1.886
42	Zehnerloch	1736	8.66	53.96	2.299
43	Busum	1757	8.86	54.12	2.112
44	Wittdün	1791	8.39	54.63	1.601
45	Husum	1792	9.03	54.47	1.961
46	Hörnum	1802	8.30	54.76	1.489

47	List	1831	8.44	55.02	1.561
48	Hojer	1831	8.46	54.96	1.751
49	Havneby Havn	1842	8.57	55.09	1.472
50	Ballum Sluse	1848	8.69	55.13	1.781
51	Ribe Kammersluse	1870	8.68	55.34	1.531
52	Esbjerg Havn	1879	8.42	55.47	1.196
53	Hvide Sand Havet	1936	8.11	56.00	1.177
54	Hvide Sand Havn	1936	8.13	56.00	1.309
55	Thorsminde Havet	1980	8.11	56.37	1.251
56	Thorsminde Havn	1980	8.12	56.37	1.353
57	Ferring Havet	1999	8.12	56.52	1.129
58	Thyboren Havn	2021	8.22	56.71	0.998
59	Hirtshals Havn	2100	9.96	57.60	0.609
60	Skagen Havn	2104	10.60	57.72	0.818

S5 Tabulated diagnostics related to Fig. 5 of the main manuscript

Table S5. Information of the e-folding decay times of the highest oscillation during Storm Tilo 8–9 November 2007

N [1]	Abb [2]	Name [3]	N [4]	Start of fist oscillation (days) [5]	End of last oscillation (days) [6]	Time span (hours) [7]	e-fold decay time (hours) [8]	Height of highest oscillation (cm) [9]	Period of highest oscillation (hours) [10]
1	LW	Lerwick	3	8.448	8.542	1.375	4.729	13.5	0.502
2	WK	Wick	2	8.667	8.719	0.624	1.810	9.6	0.749
3	LE	Leith	2	7.333	7.688	4.248	9.624	25.5	3.751
4	NS	North Shields	2	7.896	8.031	1.625	3.961	10.7	2.251
5	WH	Whitby	5	7.385	7.802	8.002	8.208	12.4	3.250
6	IM	Immingham	3	7.969	8.229	4.500	7.894	16.8	1.750
7	CR	Cromer	4	7.938	8.177	3.876	4.187	33.2	3.250
8	LT	Lowestoft	4	7.594	8.021	8.124	7.314	36.6	3.499
9	FE	Felixstowe	4	7.656	8.010	6.499	5.775	28.0	3.250
10	SH	Sheerness	3	7.719	8.083	6.374	3.549	25.3	3.749
11	DV	Dover	3	8.292	8.635	6.250	3.596	37.5	3.499
12	CA	Calais	3	8.333	8.833	8.002	14.484	34.8	3.000
13	DK	Dunkerque	3	8.208	8.708	7.500	9.910	32.8	4.000
14	CZ	Cadzand	4	7.868	8.243	6.835	5.162	57.6	3.166
15	WL	Westkapelle	2	7.368	7.688	3.833	8.174	54.5	3.499
16	VL	Vlissingen	3	7.875	8.194	5.669	2.196	49.8	3.334
17	TE	Terneuzen	3	7.896	8.243	6.499	2.724	58.7	3.168
18	RM	Roomport buiten	3	8.236	8.340	1.750	0.793	63.1	1.166
19	EU	Euro platform	2	8.021	8.194	2.083	1.994	32.4	3.502
20	HW	Hansweert	3	7.750	8.090	5.666	4.903	54.1	3.833
21	BA	Bath	2	7.938	8.278	4.085	6.701	63.1	3.334
22	BH	Brouwershavensche Gat 08	4	8.326	8.583	4.915	9.287	57.9	1.834
23	LG	Lichteiland Goeree	5	7.389	7.924	10.750	15.232	26.1	3.499
24	HH	Hoek van Holland	3	8.056	8.208	2.083	1.570	43.0	2.832
25	SC	Scheveningen	3	8.021	8.118	1.416	2.156	57.0	1.000
26	IJ	Ijmuiden buitenhaven	2	7.986	8.097	1.334	4.190	51.7	1.668
27	DH	Den Helder	3	8.000	8243	3.751	1.807	48.1	3.334
28	OS	Oudeschild	3	7.500	7.764	4.250	1.620	23.5	3.667
29	KW	Kornwerderzand buiten	2	8.611	8.868	3.082	3.257	34.0	3.334
30	VH	Vlieland haven	3	7.521	7.743	3.330	1.550	19.4	3.502
31	HL	Harlingen	3	8.632	8.868	3.418	2.453	40.6	3.334
32	TL	West-Terschelling	2	8.257	8.319	0.750	0.954	24.4	0.667
33	TN	Terschelling Nordzee	4	7.986	8.111	2.500	2.684	60.9	0.667
34	NE	Nes	3	7.569	7.813	3.749	2.127	19.5	3.334
35	WG	Wierumergronden	2	7.750	7.917	2.000	1.338	29.0	3.499
36	LR	Lauwersoog	2	8.667	8.840	2.083	1.503	21.6	3.499
37	SM	Schiermonnikoog	3	8.153	8.438	4.334	5.699	25.7	3.833
38	DF	Delfzijl	8	8.458	8.736	5.834	5.147	60.2	0.835
39	HG	Huibertgat	3	7.604	7.924	5.582	3.340	37.2	3.665
40	NZ	Nieuwe Statenzijl	5	7.701	8.056	6.833	3.075	93.2	2.501

41	EE	Eemshaven	3	8.201	8.264	1.001	0.880	42.1	0.499
42	EH	Emshörn	2	8.194	8.354	1.918	1.707	24.3	3.334
43	BK	Borkum-Südstrand	4	7.625	7.938	5.501	2.776	33.1	3.499
44	BF	Borkum-Fischerbalje	2	7.632	7.875	2.916	3.646	17.8	3.835
45	ND	Norderney-Riffgat	2	7.653	7.840	2.251	1.562	37.2	.334
46	SP	Spiekeroog	3	7.667	7.819	2.002	0.925	30.5	2.666
47	WW	Wangerooge-West	3	8.479	8.604	1.831	1.572	26.7	0.665
48	WN	Wangerooge-Nord	3	7.674	7.944	4.166	4.214	32.0	3.833
49	MP	Mellumplate	6	7.688	8.229	10.999	8.314	27.5	3.667
50	AW	Leuchtturm Alte Weser	2	7.174	7.514	4.082	15.663	23.1	3.833
51	BZ	Bake Z	3	7.701	8.021	5.498	2.677	29.6	3.667
52	SN	Scharhörn	4	7.708	8.042	6.082	3.078	31.5	3.502
53	HE	Helgoland-Binnenhafen	2	7.681	7.840	1.915	1.051	23.5	3.499
54	MG	Mittelgrund	4	7.715	8.097	6.833	4.681	28.6	3.667
55	ZE	Zehnerloch	2	7.722	7.958	2.832	2.043	30.0	3.334
56	HB	Hamburg-St. Pauli	3	7.382	7.875	8.002	10.287	61.1	3.168
57	BU	Büsum	2	8.306	8.431	1.500	0.800	24.8	2.498
58	WI	Wittdün	2	8.250	8.382	1.584	0.971	23.5	2.834
59	HU	Husum	3	7.042	7.549	8.167	15.761	42.4	3.833
60	HR	Hörnum	2	8.160	8.243	1.001	1.130	21.1	1.334
61	HO	Højer	2	8.125	8.201	0.917	0.775	25.8	1.334
62	LS	List	2	8.104	8.236	1.584	3.614	12.4	1.332
63	HY	Havneby	3	7.243	7.604	6.415	5.383	10.2	3.499
64	BM	Ballum	2	8.215	8.292	0.917	1.305	21.8	0.667
65	RI	Ribe (Havet på forlandet)	4	7.285	7.646	6.583	3.819	20.3	3.000
66	EJ	Esbjerg	2	7.958	8.083	1.500	2.988	11.4	1.500
67	HV	Hvide Sande (Havet)	2	8.021	8.069	0.583	0.724	28.2	0.667
68	TS	Thorsminde (Havn)	2	8.507	8.576	0.833	5.879	21.2	1.001
69	TH	Thyborøn (Havet hofde 58)	2	8.174	8.292	1.418	1.405	26.9	2.333
70	HA	Hanstholm (Havn)	2	8.333	8.431	1.166	1.188	39.5	1.834
71	HI	Hirtshals	1	8.924	8.958	?	?	26.8	0.833
72	SK	Skagen	1	8.903	8.958	?	?	44.0	1.332
73	TG	Tregde	3	8.264	8.354	1.250	3.595	6.6	1.500
74	SV	Stavanger	5	7.931	8.757	16.166	45.148	11.8	3.331
75	BG	Bergen	5	7.785	8.236	8.918	3.401	10.9	3.502
76	MY	Maløy	2	8.667	8.715	0.583	0.368	8.3	0.665

Notes:

[1] Running index.

[2] Station abbreviation used in manuscript.

[3] Station name.

[4] Number of sequentially decreasing zero-crossing oscillations after and including the highest down-crossing oscillation during the two day period of Storm Tilo 8–9 November 2007.

[5] Starting time of oscillation sequence in days after 1 November 2007 00:00 GMT (i.e., the approximate middle of the storm period on 9 November 2007 00:00 GMT would appear as day 8.000 in this column)

[6] Ending time of oscillation sequence in days after 1 November 2007 00:00 GMT.

[7] Time span of the complete sequence of decreasing oscillations in hours.

[8] e-folding decay time of the decreasing oscillations in hours. There were two cases where the e-folding decay time could not be calculated because the highest oscillation during the 48 hour period occurred at the end of the time series on 8–9 November 2007.

[9] Trough-to-peak height of the highest down-crossing oscillation in centimetres.

[10] Zero-crossing period of the highest down-crossing oscillation in hours.

S6 Diagrams of diagnostics based on Fig. 5 of the main manuscript

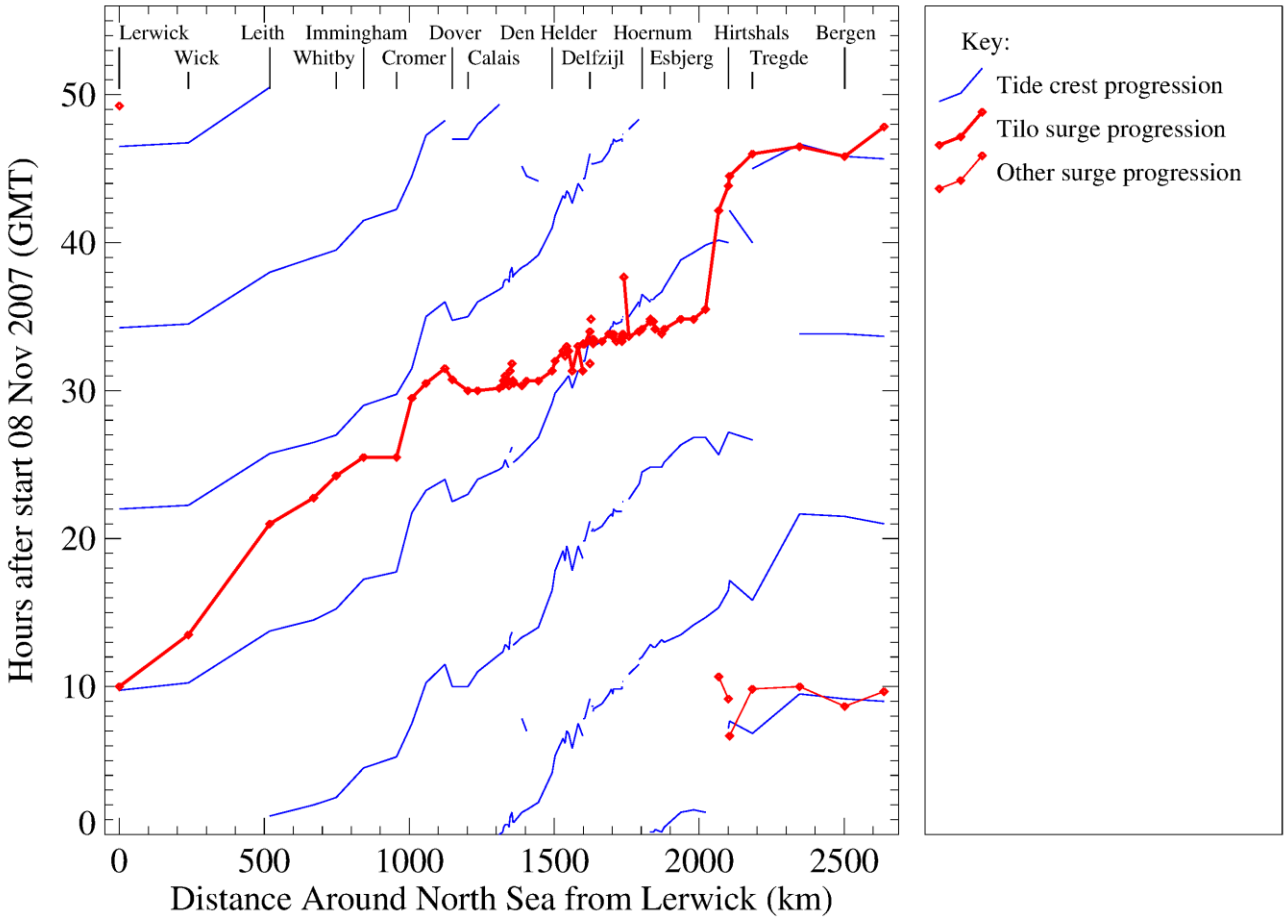

Figure S1: Relation between time and coastline distance around the North Sea during Storm Tilo on 8–9 November 2007 for the semi-diurnal tides and storm surge peak.

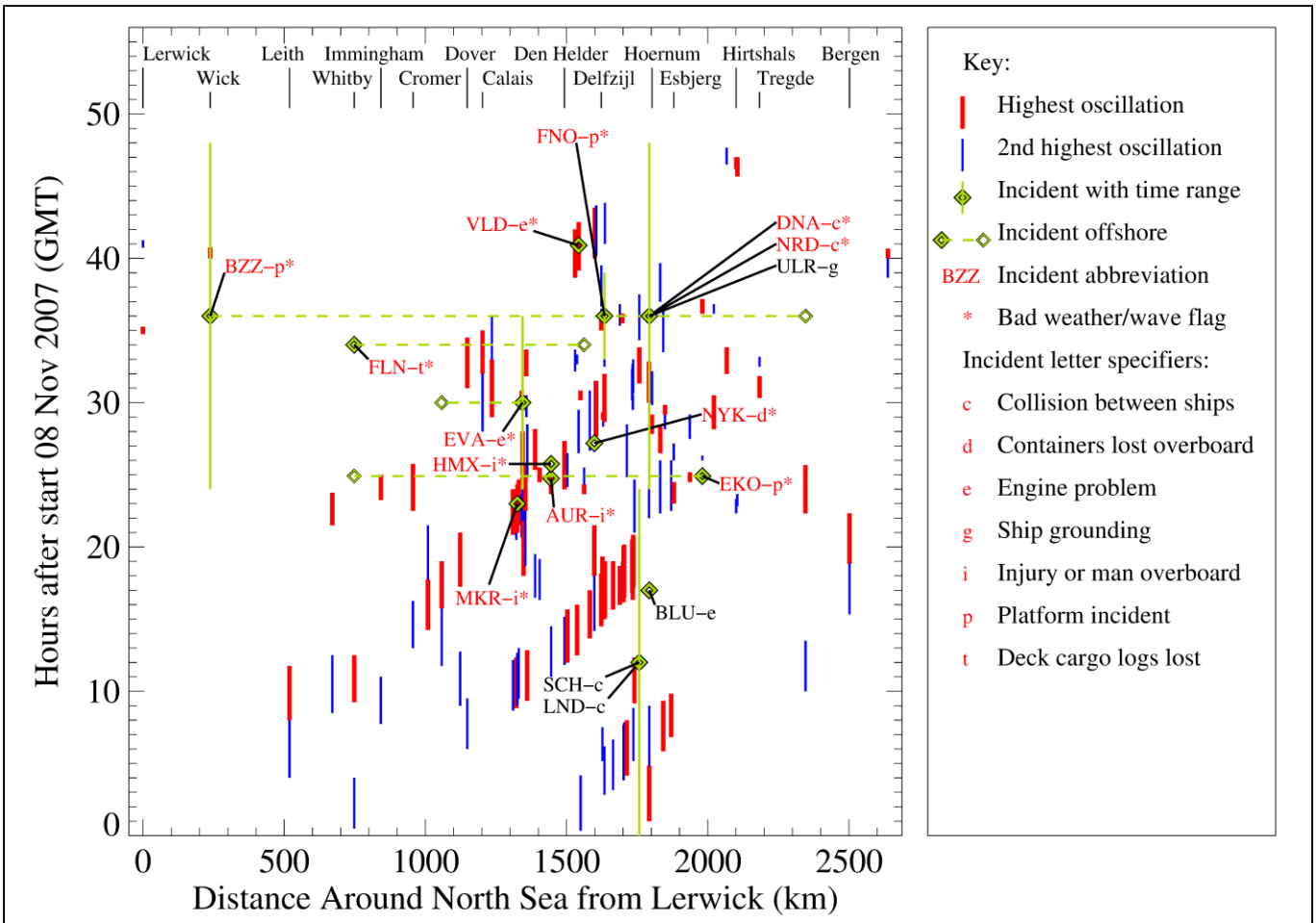

Figure S2: Relation between time and coastline distance around the North Sea during Storm Tilo on 8–9 November 2007 for the highest two trough-to-peak heights of the down-crossing short period oscillations and the shipping/platform incidents.

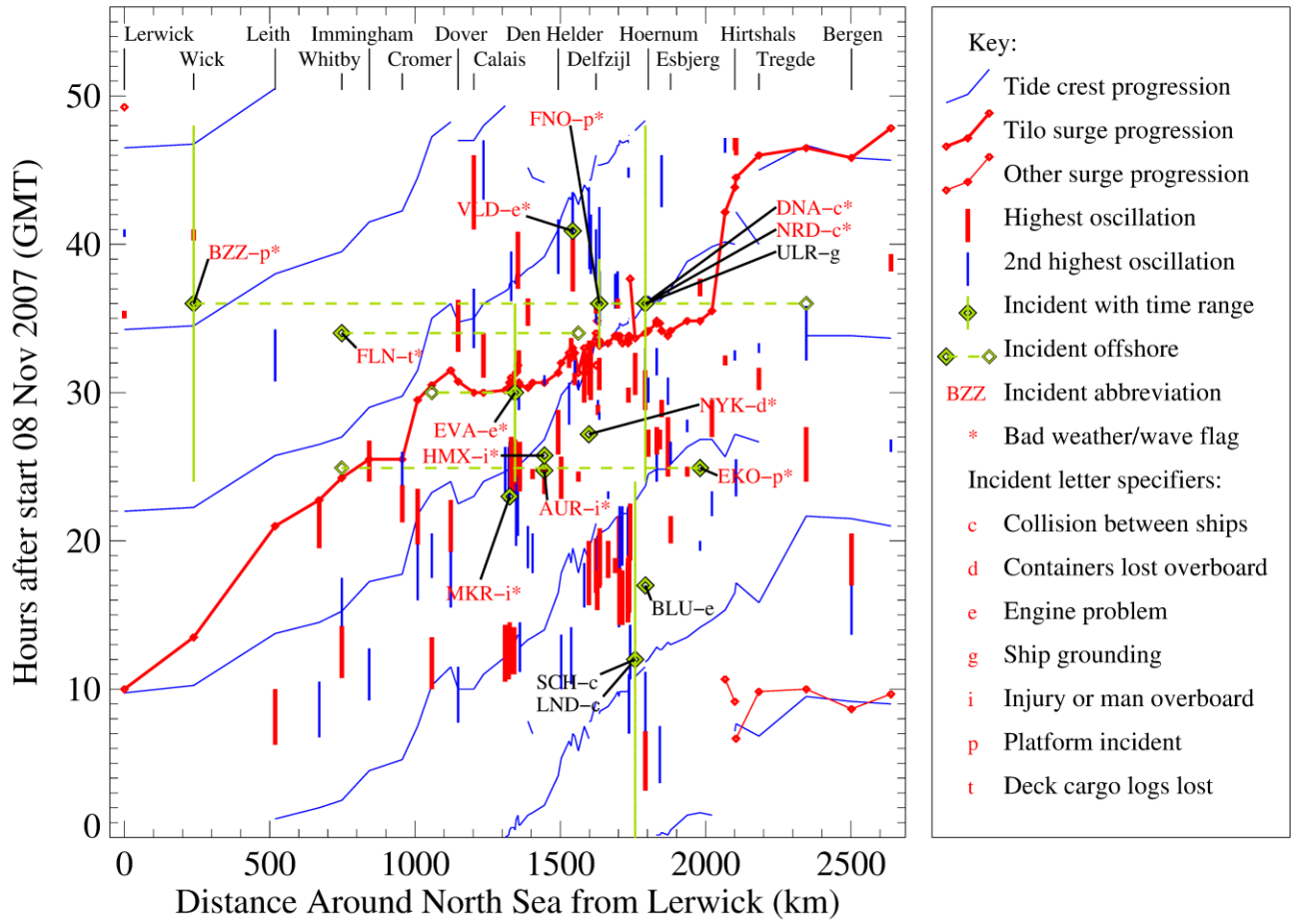

Figure S3: Relation between time and coastline distance around the North Sea during Storm Tilo on 8–9 November 2007 for the semi-diurnal tides, storm surge peak, two highest trough-to-peak heights of the up-crossing oscillations from the reconstructed short period water level time series, and shipping/platform incidents. (i.e., same as Figure 5 of the manuscript except using the up-crossing oscillations of the short period reconstructed time series).

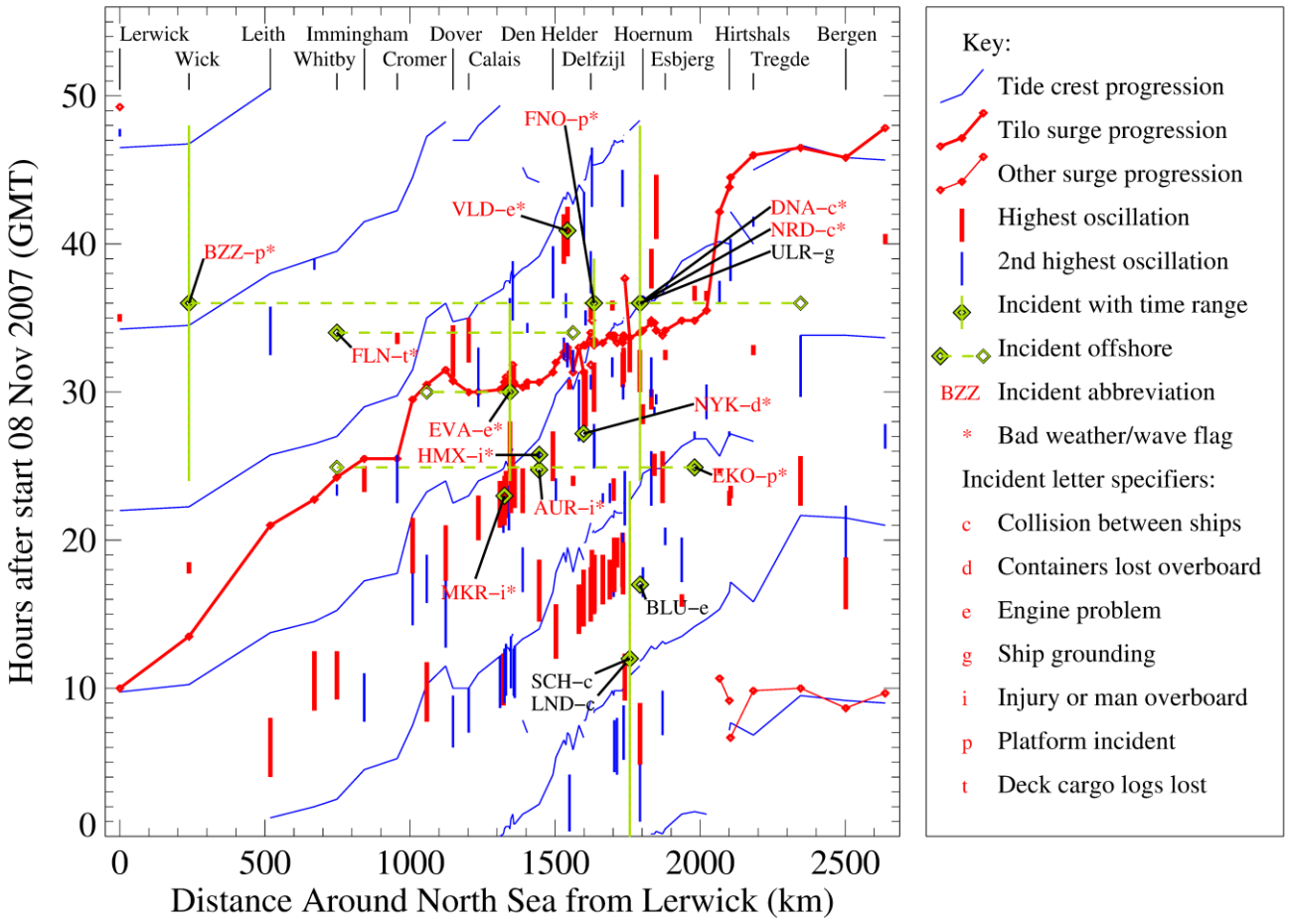

Figure S4: Relation between time and coastline distance around the North Sea during Storm Tilo on 8–9 November 2007 for the semi-diurnal tides, storm surge peak, two highest crest heights (maximum amplitudes) of the down-crossing oscillations from the reconstructed short period water level time series, and shipping/platform incidents. (i.e., same as Figure 5 of the manuscript except selecting the oscillations with the highest crest heights instead of the highest trough-to-peak height ranges).

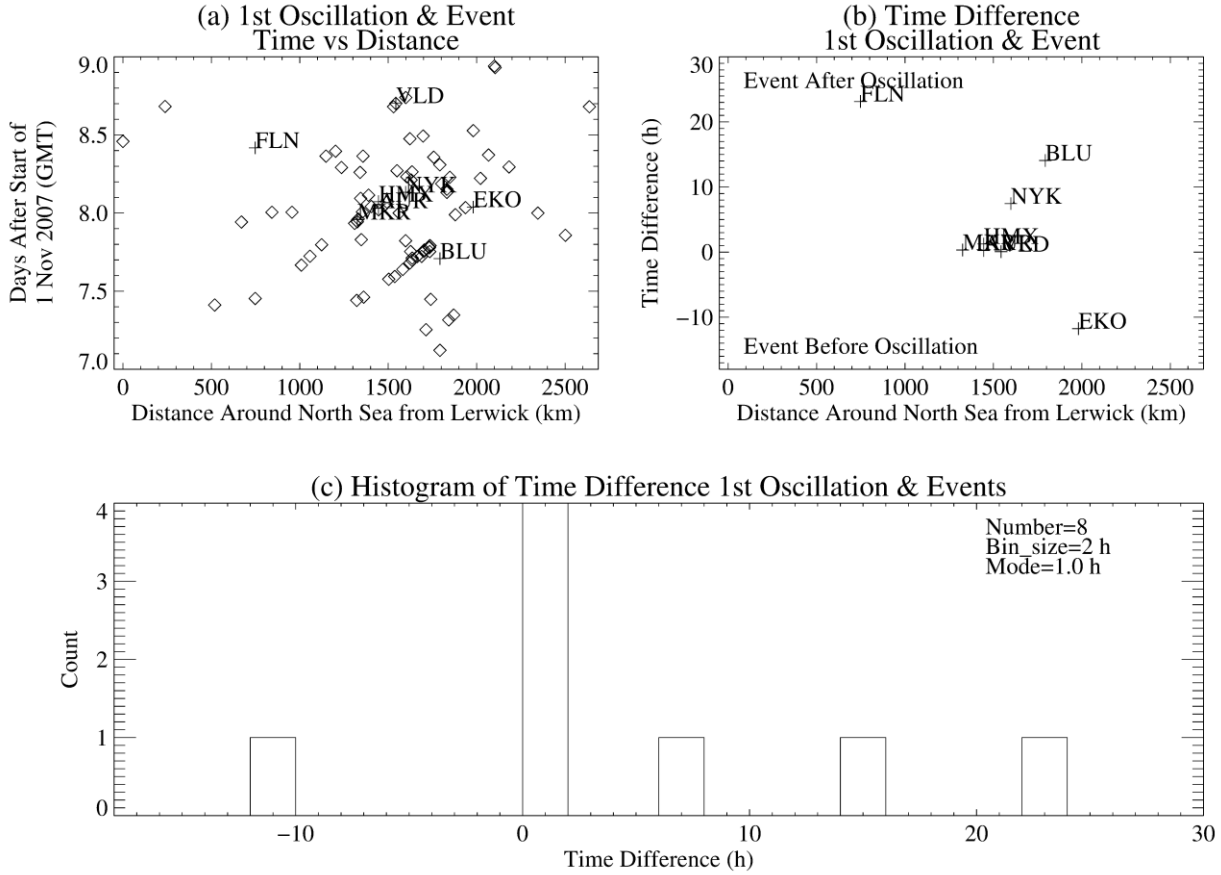

Figure. S5: Diagnostics of the time difference between the offshore events and the highest trough-to-peak heights of the down-crossing oscillations in the short period water level reconstruction during Storm Tilo 8–9 November 2007 (based on the Fig. 5 of the manuscript). Only a subset of the offshore events whose time was precisely reported was included in this figure. (a) Highest oscillation (diamonds) and offshore events (crosses) plotted on axes of time versus distance around the North Sea from Lerwick. (b) Time of offshore event minus highest oscillation versus distance around the North Sea from Lerwick. (c) Histogram of the time difference in (b). The histogram suggests that approximately half of the offshore events occurred within two hours after the highest down-crossing oscillation of the two day period.

S7 Diagrams to support the calculation of the e-folding decay time of the highest oscillation during Storm Tilo 8–9 November 2007.

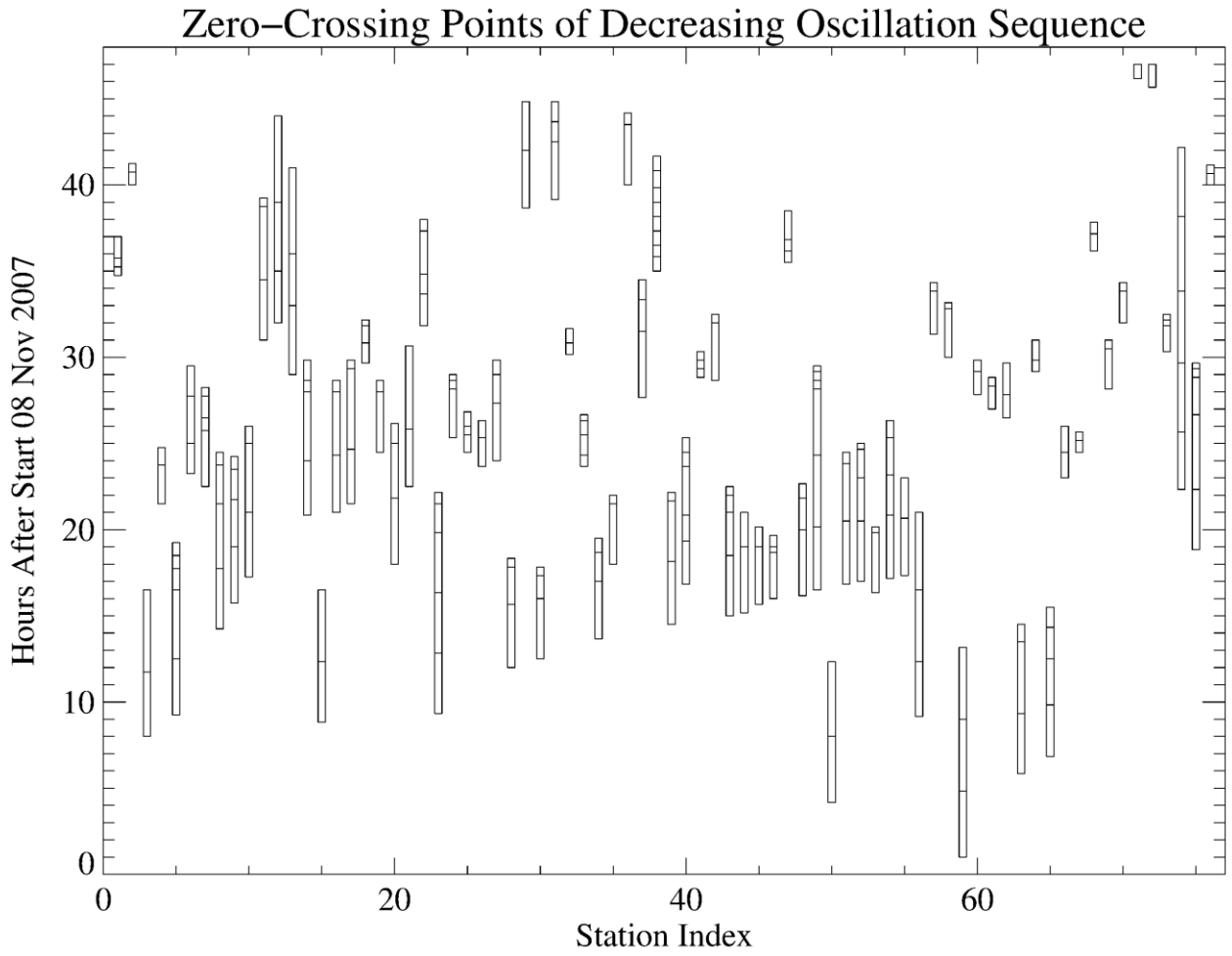

Figure S6: Index series showing the time span of the series of down-crossing oscillations with monotonically decreasing trough-to-peak heights. The zero-crossing starting and ending times of the individual oscillations within the full time span are indicated.

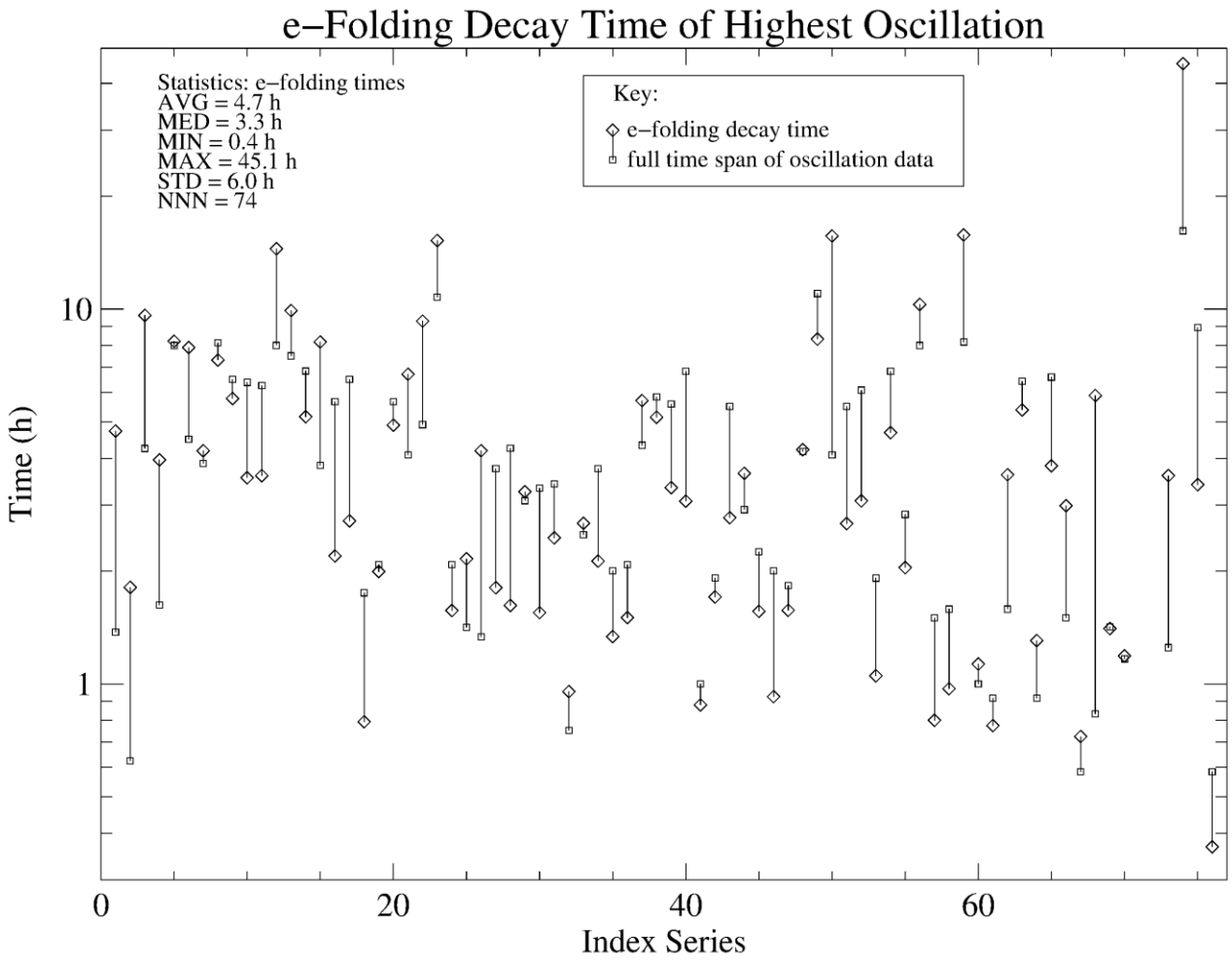

Figure S7: Station index series of the e-folding decay times of the highest down-crossing short period oscillation in the data set of North Sea tide gauge stations during Storm Tilo on 8–9 November 2007. The calculated e-folding decay times is shown by diamonds. The full time span of the decreasing oscillations that is used in the calculation is indicated by a small square. The statistics of the calculated e-folding decay times for the subset of 74 stations with valid data is given in the top left hand corner (two stations were excluded because the highest oscillation occurred at the very end of the two day storm period).

S8 Diagrams giving an overview of meteorological conditions during Storm Tilo 8–9 November 2019 (reproduced from the EGU 2019 ERE poster presentation)

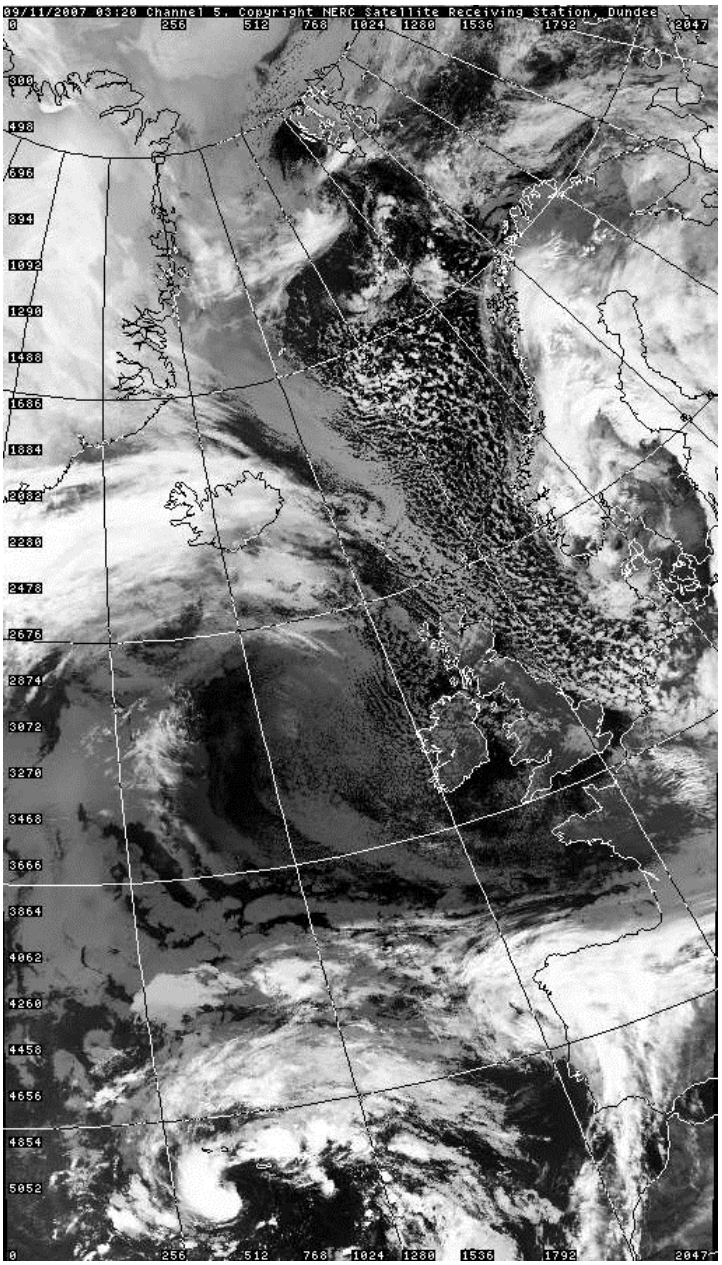

Figure S8: AVHRR thermal infrared satellite image for 9 November 2007 03:20 GMT (http://www.sat.dundee.ac.uk). The picture highlights the open cell convective cloud structure over the North Sea that is associated with a cold air outbreak and strong north winds behind the eastward moving low pressure centre.

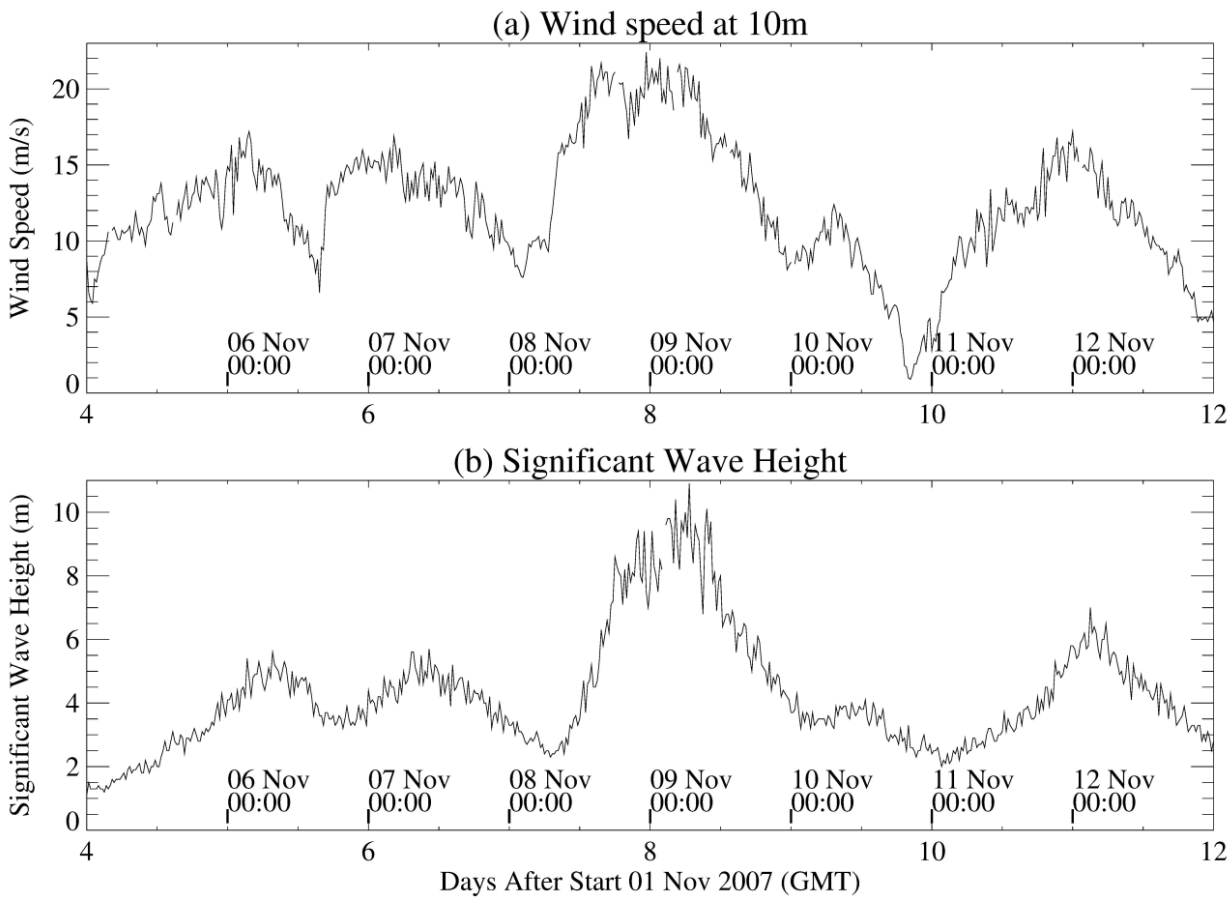

Figure S9: Wind speed and significant wave height from the Norwegian Ekofisk platform in the central North Sea during Storm Tilo. The data sets for the plot come from the Eklima website of the Norwegian meteorological authority, met.no

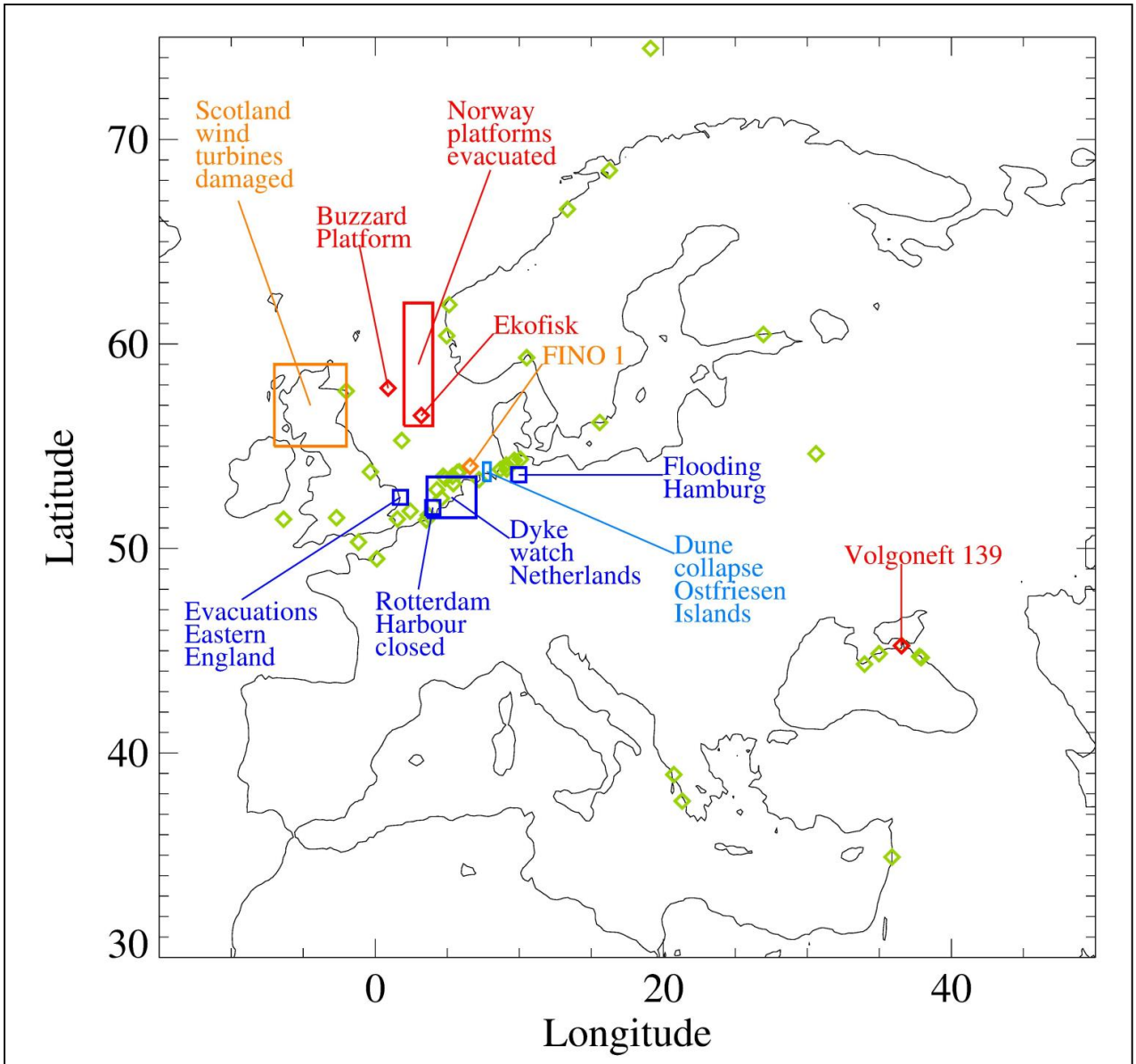

Figure S10: Schematic map of events and infrastructure impacts for Storm Tilo 8–9 November 2007. Note that Storm Tilo produced a secondary storm in the eastern Mediterrean Sea and Black Sea that caused a number of ship sinkings and emergencies on 11 November 2007 (green diamonds).

S9 Time series of the original water level data and different frequency band components

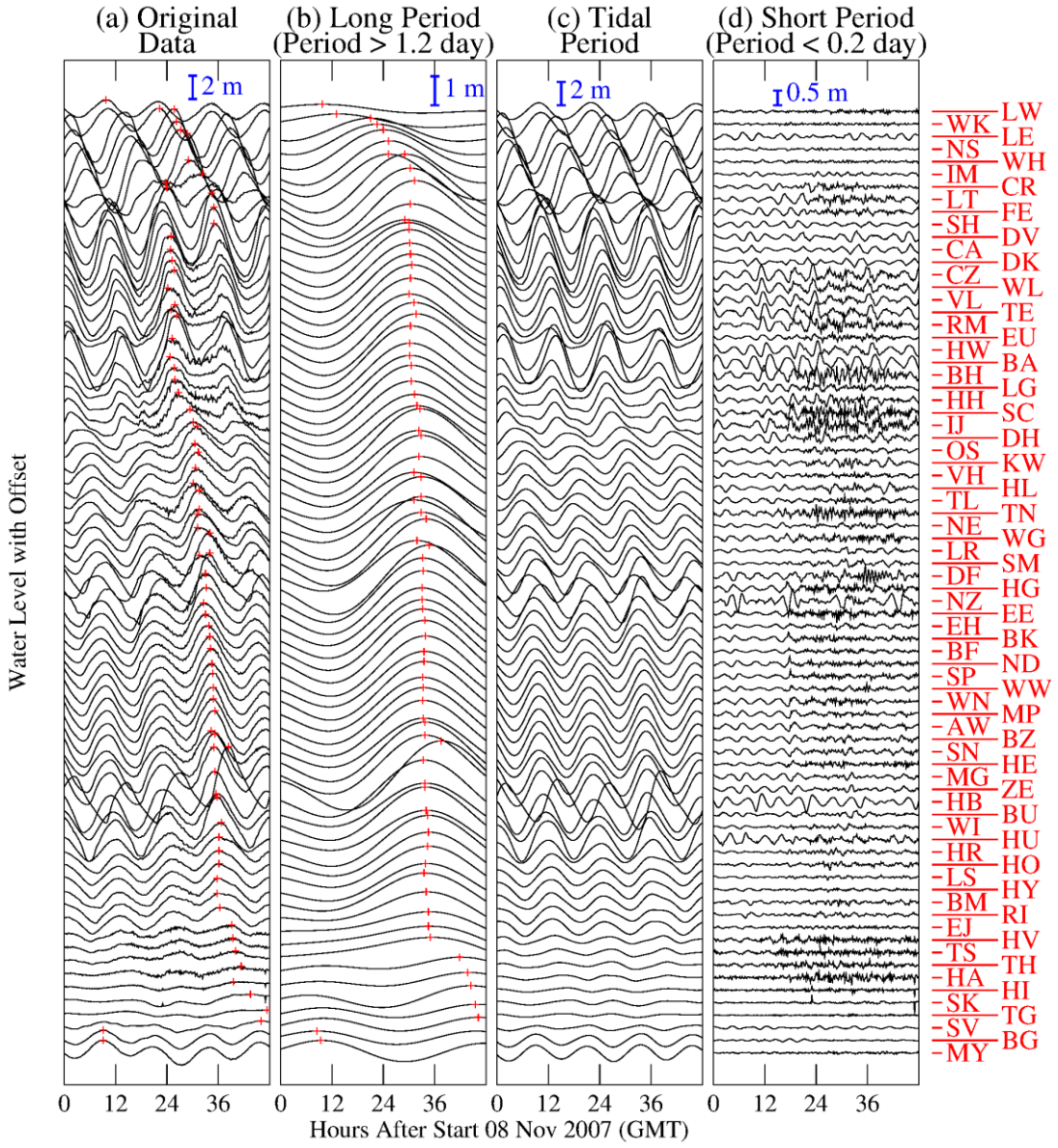

Figure S11: (a) Original tide gauge time series for the 2 day interval of Storm Tilo 8–9 November 2007 and reconstructions for the (b) long period component (periods >1.2 days; storm surge), (c) intermediate period component (periods in the range 0.2–1.2 day; tide), and (d) short period component (periods <0.2 days; harbour seiche). The figure shows the data for 76 stations.

S10 Diagrams of the tide gauge station and event locations

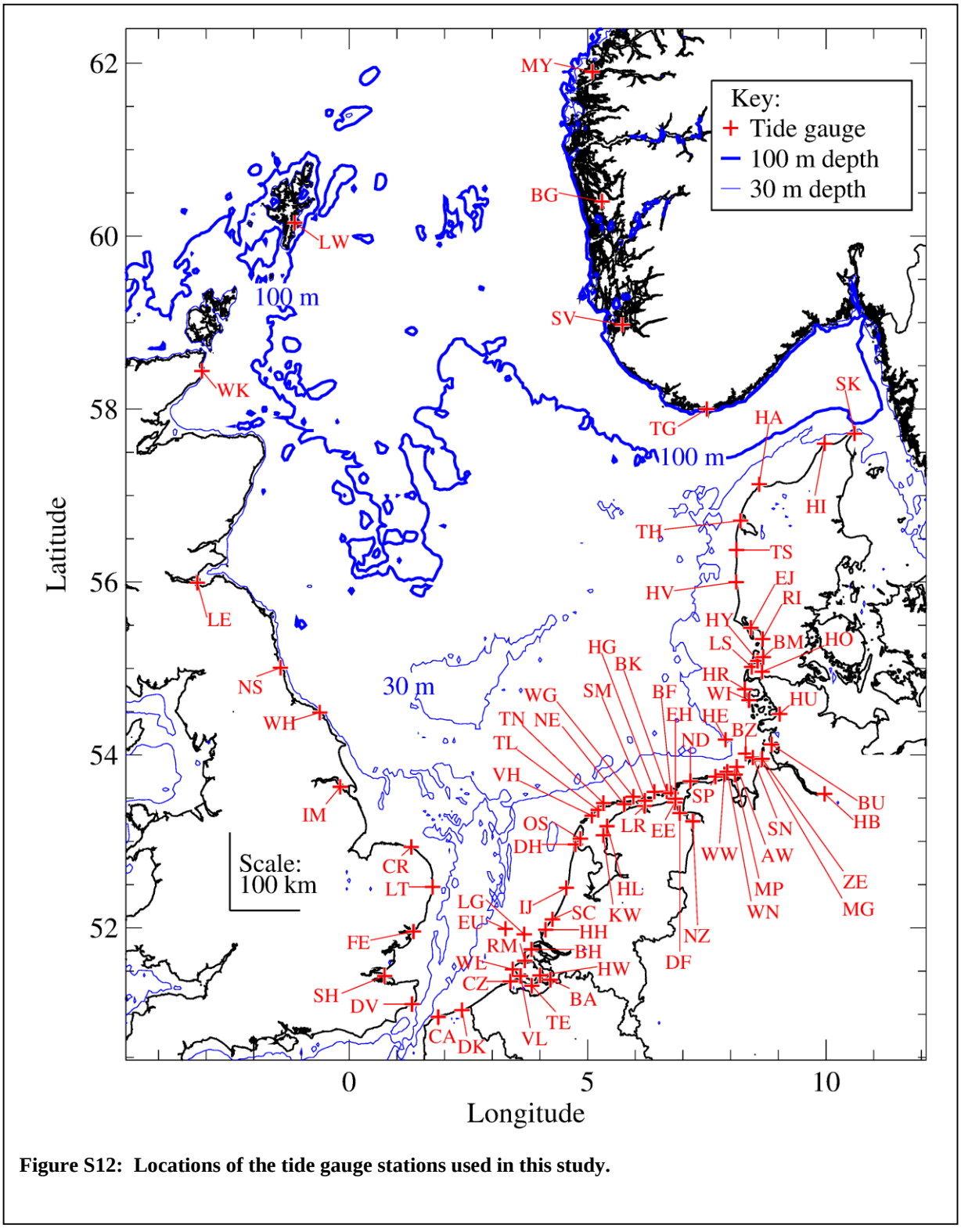

Figure S12: Locations of the tide gauge stations used in this study.

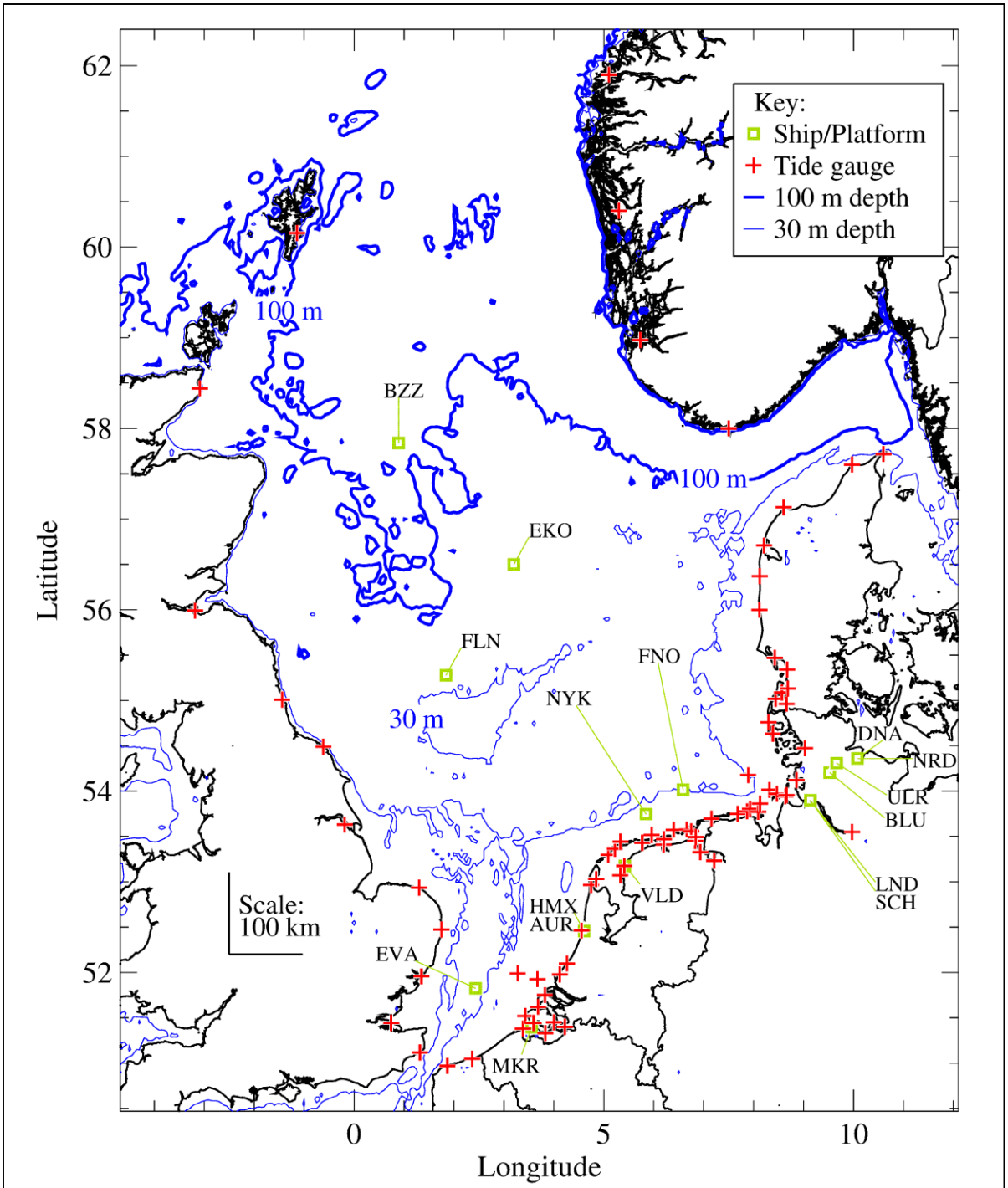

Figure S13: Location of offshore events (accidents and large wave reports) and tide gauge stations around the North Sea during Storm Tilo 8–9 November 2007.

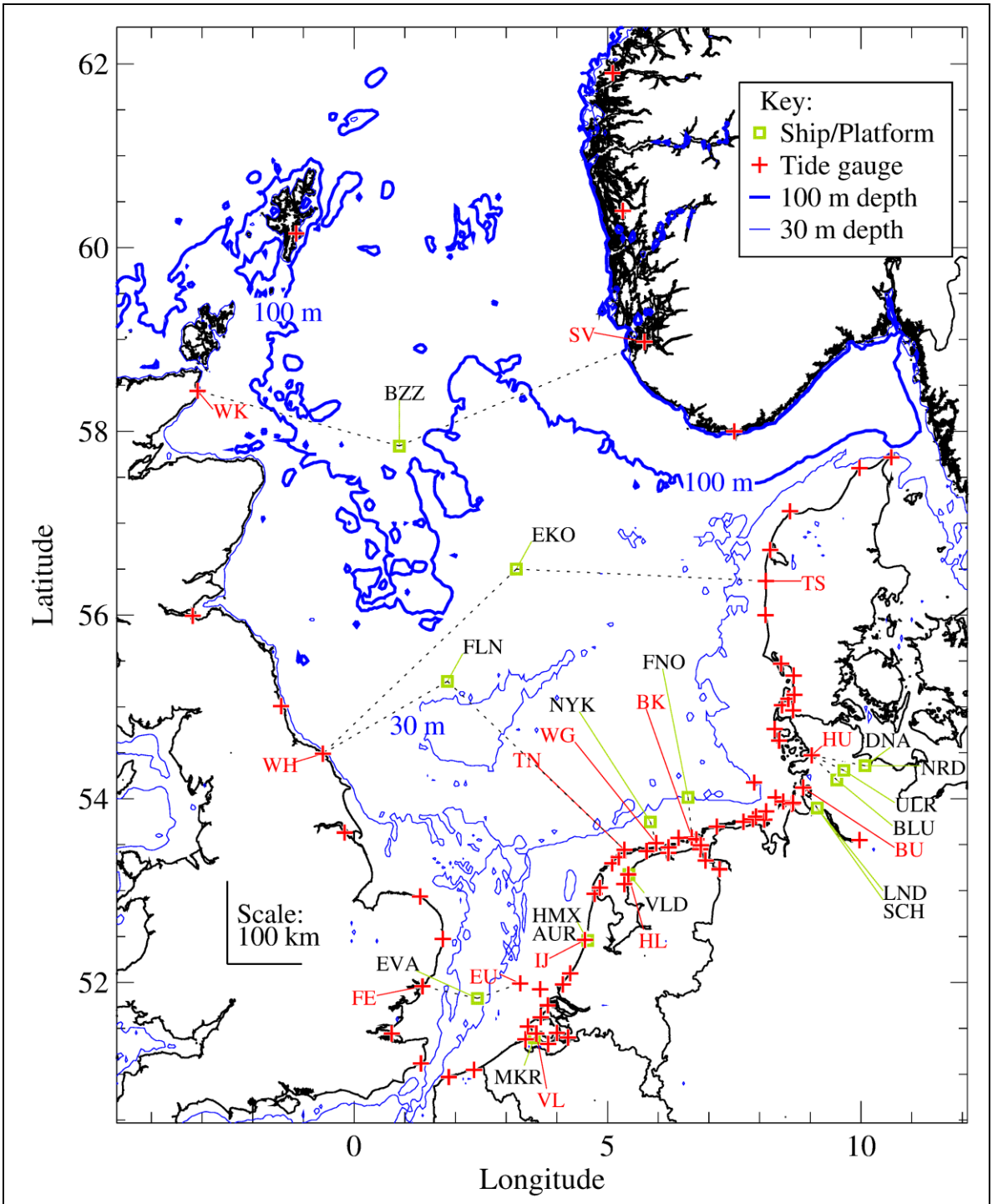

Figure S14: Location of offshore events (accidents and large wave reports) and the nearest tide gauge stations for Storm Tilo on 8–9 November 2007. For four offshore events far offshore (BZZ, EKO, FLN, and AUR) the closest tide gauge stations on eastern and western sides of the North Sea are indicated with dotted black lines.

S11 Tabulated working notes for literature survey

Table S6. Master list of tables in working notes

Table	Content
S1	Master list of tables in working notes
S2	List of sources reviewed for project
S3	List of normal photos of Tilo/Andrea event
S4	Ranking of Tilo/Andrea among recent storms; assessing importance of storm
S5	Storm Tilo/Andrea: severe forecast
S6	Storm Tilo/Andrea: not as bad as expected
S7	Storm Tilo/Andrea: extended period bad weather
S8	Names of the storm
S9	Storm Tilo/Andrea: satellite pictures and weather maps
S10	Storm Tilo/Andrea: list meteorological data
S11	Storm Tilo/Andrea: significant wave height and sea state
S12	Storm Tilo/Andrea: storm trajectory map
S13	Storm Tilo/Andrea: coastal flooding and evacuations
S14	Storm Tilo/Andrea: surge reports and quantitative water levels
S15	Storm Tilo/Andrea: surge barrier closures
S16	Storm Tilo/Andrea: beach damage
S17	Storm Tilo/Andrea: list bridge closures, cancelled ferry crossings, port closures, airport cancel, rail interruptions
S18	Storm Tilo/Andrea: structural damage to wind farms & buildings
S19	Storm Tilo/Andrea: general ship/rig emergency reports/offshore incidents/platform evacuations
S20	Storm Tilo/Andrea: instrument failures during storm
S21	Storm Tilo/Andrea: model results and fields
S22	Storm Tilo/Andrea: climatological background of storm

Table S7. List of sources reviewed for project (arranged by year and then alphabetically)

Source	Type[1]	Full Reference and Notes
Environment Agency (2006)	4	Environment Agency, Somerset and the sea, The 1981 storm - 25 years on, Environment Agency, Manley House, Kestrel Way, Exeter, Devon, EX2 7LQ, 2006
Aftenposten 20071106	1	Aftenposten, Ekofisk og Valhall evakueres for stormen.1500 ansatte pa oljefeltene kofisk og Valhall i Nordsjoen kan bli evakuerte for den forventede storm Andrea natt til fredag. 06Nov2007 13:35
Aftenposten 20071109	1	Aftenposten 20071109, Stormen kan vaere rester av orkanen Noel. Noel forsterket seg igjen over Atlantikhavet og besokte Norge. Nina Loedemel, 09Nov2007, 1432local
BBC (20071109a)	1	BBC, North Sea flood tide fears recede, Fri 09 November 2007, 1033GMT
BBC (20071109b)	1	BBC, Thousands go hame after tide fear, Friday 9 November, 16:50GMT
Bergens Tidende (20071109)	1	Bergens Tidende, Bolgehoyder opp mot 18 meter. Stormen som kommer inn til kysten i kveld kan bli en av arets toffeste, 08 Nov 2007 15:51 (contributor Leif Gullstein)
Bradshaw (2007)	3	Bradshaw, Elizabeth (ed), Annual Report for 2007 for the UK National Tide Gauge Network and Related Sea Level Science, National Tide and Sea Level Facility, NERC 100017897 2007
Cargolaw (2007)	3	Cargolaw, International vessel casualties & pirates database for year 2007 – Jan. through Dec. 2007, http://www.cargolaw.com/presentation_casualties.07.html, downloaded from the Internet 14Sep2018

Guardian (2007)	1	The Guardian, Environmental disaster as Russian tanker sinks, Mon, 2007/11/12, 09:18 GMT (reporter: Luke Harding, Moscow)
Heyken (2007)	1	Heyken, Herma, Schwere Sturmflut an niedersachsischer Nordseekuste - Dunnenabbruche auf den Inseln, 09/11/2007, NLWKN Niedersachsischer Landesbetrieb fuer Waserwirtschaft, Kuesten- und Naturschutz.
Horsburgh (2007)	3	Horsburgh, Kevin, Foreword, in Bradshaw, Elizabeth (ed), Annual Report for 2007 for the UK National Tide Gauge Network and Related Sea Level Science, National Tide and Sea Level Facility, NERC 100017897 2007, p.2
KIT20071117	1	KIT20071117, Sturm, Schnee, Regen. Mitteleuropa/Schwarzes Meer 09.-13.11.2007 (text CE), Karlsruhe Institute of Technology, Wettergefahren-Fruehwarnung, Institut fuer Meteorologie und Klimaforschung, Samstag, 17.November 2007, 18:00MEZ
Kustwachtcentrum (2007/11/06)	1	Kustwachtcentrum Den Helder, Containers verloren, Persberich 06Nov2007, emailed from Edwin Granneman 08Oct2008
Kustwachtcentrum (2007/11/09)	1	Kustwachtcentrum, Persbericht, Noordwester storm, Info nr.1, 09Nov/2007
Kustwachcentrum (2007/11/09)	1	Kustwachtcentrum, Persbericht, Zoektocht naar verloren containers, info nr.1, 22Nov2007 1330
LCW(20071123)	3	Lloyd's Casualty Week, Weather and Navigation, pp17-20, Nov23/2007
Met Eireann (2007)	3	Met Eireann, Monthly Weather Bulletin, No.259, November 2007 -half page report with 2 weather maps, 2 satellite images; separate page for buoys
Met Office (2007)	3	Met Office, 2007. Daily Weather Summary, November 2007
MIROS-Ekofisk (2007)	3	MIROS, Ekofisk Monthly Report, November 2007. Doc No. ND/1024/07/11, Project: 1024-800 Ekofisk Met-Ocean Data Recording, Classification Open. Date 19December2007, prepared by AKS
North Norfolk News (2007)	1	North Norfolk News, Surge floods prompt new erosion fears, 14 November 2007, 01:00, Happisburgh Village Website, http://www.happisburgh.org.uk/press/nnn141107.html
PON (2007)	3	PON_1_2007_data (MS Excel spreadsheet, 'published on 12/03/2013'), hyperlink access from: https://www.gov.uk/guidance/oil-and-gas-environmental-alerts-and-incident-reporting, Oil and gas: environmental alerts and incident reporting including anonymous reporting. (spreadsheet downloaded 14Sep2018, document timestamp 15Jun2012) -spreadsheet with 7 cases offshore leakages from 06–11 Nov 2007; 2 cases ascribed to severe weather)
RWS (2007)	1	RWS, Verslag van de Stormvloed van 9 november 2007 (SR88), Ministerie van Verkeer en Waterstaat, Direktoraat-Generaal Rijkswaterstaat Waterdienst, Stormvloedwaarschuwingsdienst/SVSD, Postbus 17, 8200 AA Lelystad www.svsd.nl, Lelystad, november 2007, 45pp
Tagesspiegel (2007)	1	Der Tagesspiegel, Orkan 'Tilo'. Duenenabbruch kostet Helgoland Millionen, 09/11/2007, 16:55 (mit AFP/ddp)
Telegraph (20071111)	1	The Telegraph, Ecological disaster feared after tanker sinks, (contributor: Paul Eccleston) (11Nov2007)
Unwetterzentrale (2007)	1	Unwetterzentrale, Randtif TILO, undated website, http://www.unwetterzentrale.de/uwz/299.html (accessed 01Sep2007)
Upstream20071107_pitt	1	Upstream, Anthea Pitt, 07Nov2007, Evacuations under way as storm roars in
Upstream20071109_davis	1	Upstream, Jonathan Davis, 2007/11/09, Storm Downs Nexen's Buzzard
Upstream20071109_oneill	1	Upstream, Michael O'Neill, 2007/11/09, Storms force Ekofisk closures
Upstream20071109_wells	1	Upstream, Rob Wells, 09Nov2007, Passing storm keeps platforms shut
Upstream20071112_pitt	1	Upstream, Anthea Pitt, 12Nov2007, Storm clips Buzzard's wings
Wiese (2007)	1	Wiese, Heiko, Lebensgeschichte. Tiefdruckgebiet Tilo (getauft am 06.11.2007), written on 03Dec2007

		http://www.met.fu-berlin.de/wetterpate/Lebensgeschichten/Tief_TILO_06_11_07.htm
Bancroft (2008)	3	Bancroft, George P, Marine Weather Review - North Atlantic Area. September through December 2007, Mariners Weather Log, Vol 52, No 1, April 2008. -half page report of Storm Tilo with three buoy & 2 ship reports
Eden (2008)	3	Eden, Philip, Weather Log, November 2007, Weather, 63(1), i-iv, 2008.
Eecen (2008)	3	Eecen PJ, Meteorological Measurements OWEZ. Half year report - 01-07-2007 - 31-12-2007, ECN-E--08-061, OWEZ_R_121_20070701-20071231_wind_resource_2007_2, Oct 2008 (47pp) (met-ocean data across storm period)
Heyken (2008)	3	Heyken, Herma, 15 Sturmfluten sind keine Boten des Klimawandels, in Herma Heyken (ed), Jahresbericht 2007, NLWKN Niedersaechsicher Landesbetrieb fuer Wasserwirtschaft, Kuesten- und Naturschutz, pp14-15, Norden, April, 2008
Lefebvre (2008)	1	Lefebvre, Christiana, Orkan TILO am 8. und 9. November 2007, DWD report 01Jan2008
Magnusson et al (2008)	2	Magnusson, A.K., J. Johannessen, K.-F. Dagestad, O. Breivik, O.J. Aarnes, B. Furevik, Bolge-strom interaksjon til nytte for oljeindustri, WACUSAR_sluttrapport.doc, 19/12/2008
Outzen et al (2008)	1	Outzen, O., K. Herklotz, H. Heinrich, C. Lefebvre, Extreme waves at FINO1 research platform caused by storm 'Tilo' on 9 November 2007, DEWI Magazin No. 33, August 2008.
Piotkowitz and Soerensen (2008)	3	Piotkowitz, 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
Badewien et al (2009)	3	Badewien TH, E Zimmer, A Bartheloma, R Reuter, Towards continuous long-term measurements of suspended particulate matter (SPM) in turbid coastal waters, Ocean Dynamics (2009) 59: 227-238, DOI 10.1007/s10236-009-0183-8
Behrens & Guenther (2009)	3	Behrens, A. and H. Gunther, 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
Goennert and Buss (2009)	3	Goennert, Gabriele & Thomas Buss, Sturmfluten zur Bemessung von Hochwasserschutzanlagen, Berichte des Landesbetriebes Strassen, Bruecken und Gewaesser Nr.2/2009, Freie und Hansestadt Hamburg, Landesbetrieb Strassen, Bruecken und Gewaesser, Hamburg, ISSN 1867-7959
Magnusson (2009a)	1	Magnusson, A.K., Forecasting extreme waves in practice, Proceedings Rogue waves 2008, ed. by Michel Olagnon and Marc Previsto, Brest, France, 13-15 Oct., 2008. http://www.ifremer.fr/web-com/stw2008/rw (pdf date stamp May 19,2009).
Magnusson (2009b)	1	Magnusson AK, 2009, 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.
POL (2009)	3	POL, Annual Report 2007-2008, Proudman Oceanographic Laboratory, 40pp, 13May2009
Reuter et al (2009)	3	Reuter R, TH Badewien, A Bartholoma, A Braun, A Luebben, J Rullkoetter, A hydrographic time series station in the Wadden Sea (southern North Sea), Ocean Dynamics, DOI 10.1007/s10236-009-0196-3, 2009
Rosenthal and Lehner (2009)	2	Rosenthal W. and S Lehner, North Sea cases of extreme individual waves, 11.International Workshop on Wave Hindcasting and Forecasting &

		2.Coastal Hazards Symposium, 2009?
Herrling et al (2010)	2	Herrling, Gerald, Heiko Knaack, Ralf Kaiser, Hanz D. Niemayer, Evaluation of design water levels at the Ems-Dollard estuary considering the effect of a storm surge barrier, Coastal Engineering 2010.
Gray et al (2011)	2	Gray AL, O Martinez-Avarado, LH Baker, PA Clark, Conditional symmetric instability in sting-jet storms, QJRMS, 137, 1482-1500, 2011
Groen and Caires (2011a)	3	Groen, Geert and Caires, Sofia, Storm Catalog The Netherlands, nov 2011a, KNMI/Deltares. http://projects.knmi.nl/hydra/stormcatalogus/index.htm (accessed 15June2019 after being placed back online by Josine Camps)
Groen and Caires (2011b)	1	Groen Geert & Caires Sofia, Summary 09-11-2007, nov 2011b, KNMI/Deltares. http://projects.knmi.nl/hydra/stormcatalogus/Cases/05_09-11-2007/Samenvatting/samenvatting.html
Hessner (2011)	1	Hessner, K., Extreme wave analysis at FINO1 during TILO storm event Nov. 8-9, 2007, Ocean WaveS GmbH data report for DONG Energy Power A/S, OceanWaveS GmbH, Hansekontor, Vor dem Bardowicker Tore 6b, 21339 Luneburg, Germany, July 2011
Magnusson (2011)	1	Magnusson, Ann Karin, True sea state ...? Comparing different sensors and analyzing techniques, 12th Wave Workshop, Hawaii's Big Island, Oct.30-Nov4, 2011 (32 slides)
Met Office (2011)	1	MetOffice, Storm surge - November 2007, Met office website last updated 11May2011.https://www.metoffice.gov.uk/about-us/who/how/case-studies/floods-2007.
Rosenthal et al (2011)	2	Rosenthal W, AL Pleskachevsky, S Lehner, S Brusch, Observation and modeling of high individual ocean waves and wave groups caused by a variable wind field, 12th International Workshop on Wave Hindcasting and Forecasting, Kohala Coast, Hawai'i, HI, 2011.
Environment Agency (2012)	3	Environment Agency, Thames Barrier Project Pack 2012, Environment Agency
Esurge_2007_tilo (2012)	1	Esurge_2007_tilo (2012), North Sea surge (2007) by Phillip Harwood 2012/11/01 18:00
Zorndt et al (2012)	2	Zorndt AC, T Schlurmann, I Grabemann The influence of extreme events on hydrodynamics and salinities in the Weser estuary in the context of climate impact research, Coastal Engineering 2012.[document date stamp 11Oct2012]
AON Benfield (2013)	3	AON Benfield, Historie von 1703 bis 2012: Winterstuerme in Europea, Stand: Januar 2013
Loewe (2013)	3	Loewe,P, Atmosphaerenphysik, pp37-114, System Nordsee. 2006 & 2007: Zustand und Entwicklungen, ed. by P. Loewe, H. Klein, S. Weigelt-Krenz, Berichte des Bundesamtes fuer Seeschifffahrt und Hydrographie, Nr.49/2013
Magnusson and Donelan (2013)	1	Magnusson, AK and MA Donelan, The Andrea wave. Characteristics of a measured North Sea rogue wave, Journal of Offshore Mechanics and Arctic Engineering, 135, 1-10, 2013
Brecht and Frank (2014)	1	Brecht, B and H Frank, High resolution modelling of wind fields for optimization of empirical storm flood predictions, Adv/ Sci. Res., 11, 1-6, 2014
Kristandt et al. (2014)	3	Kristandt, J., B. Brecht, H. Frank, H. Knack, Optimization of empirical storm surge forecast-modeling of high resolution wind fields, Die Kuste, 81, 301-348, 2014
Stoffelen (2014)	2	Stoffelen, Ad, Modelling Surges, Cork eSurge Training 20-21 Feb 2014.
Weissenberger & Chouinard (2015)	3	Weissenberger S and O Chouinard, Adaptation to Climate Change and Sea Level Rise, Springer Briefs in Environmental Science, 2015.
VH (2016)	3	Vlaamse Hydrografie, Overzicht van de tijwaarnemingen langs de Belgische

		kust. Periode 2001-2010 voor Nieuwpoort, Oostende en Zeebrugge, Ministerie van de Vlaamse Gemeenschap, Agentschap Maritieme Dienstverlening en Kust, Afdeling Kust, Vlaamse Hyrografie, Oostende, 38pp, document time stamp 24Feb2016, author='beirenro'
Doneland and Magnusson (2017)	1	Donelan MA & A-K Magnusson, The making of the Andrea Wave and other rogues, Scientific Reports, 7:44124, DOI: 10.1038/srep44124 (2017)
Hart et al (2017)	3	Hart NCG, SL Gray, PA Clark, Sting-jet windstorms over the North Atlantic: climatology and contribution to extreme wind risk, Journal of Climate, 30, pp 545-5471, 2017
Herrling et al (2017)	1	Herrling G, Benninghoff, Zorndt A, Winter C, Drivers of channel-shoal morphodynamics at the outer Weser estuary, Coastal Dynamics 2017, Paper No. 261, pp.333-345
Jensen et al (2017)	3	Jensen J, S Niehuser, A Arns, S Dangendorf, Sensor- und risikobasiertes Fruhwarn-system fuer Seedeiche (EarlyDike), AP1 - Sturmflutmonitoring und Sturmflutssimulator - Fachbericht 2016, Siegen, April 2017
Larsen et al (2017a)	3	Larsen XG, J Du, R Bolanos, S Larsen, On the impact of wind on the development of wave field during storm Britta, Ocean Dynamics, 67, 1407-1427, 2017a.
Larsen et al (2017b)	3	Larsen, XG etal, Extreme winds and waves for offshore turbines: Coupling atmosphere and wave modeling for design and operation in coastal zones, DTU Wind Energy, (DTU Wind Energy E, vol.154) (Final report for ForskEL project PSO-12020 X-WiWa), 2017b
Caithness Windfarm (2018/08/05)	3	Caithness Windfarm, Wind Turbine Accident and Incident Compilation, 2018/08/05
Capellen email 25Sep2018	3	Capellen, John, email of 25Sept2018 with 2 reports, wind speed summary of Skagen during TILO and North Atlantic wind map during TILO
WIKI20180324	3	WIKI, Liste der Sturmfluten an der Nordsee, copied 2018/03/24, https://de.wikipedia.org/wiki/Liste_der_Sturmfluten_an_der_Nordsee

Notes:

[1] Type: 1=Tilo focus (or used as key example in general discussion); 2=1-4 case studies with Storm Tilo; 3=Storm Tilo is one of many case studies or mentioned only; 4=Tilo not mentioned

Table S8. List of normal photos of Tilo/Andrea event (arranged by year and then alphabetically)

Source	Full Reference and Notes
BBC (20071109a)	BBC, North Sea flood tide fears recede, Fri 09 November 2007, 1033GMT -PHOTO. Surfer on coast
BBC (20071109b)	BBC, Thousands go hame after tide fear, Friday 9 November, 16:50GMT FIG: [PHOTO] waves battered beach huts at Southwold (Rachel Temple) FIG: [MAP] areas most at risk: Immingham, Kings Lynn, Great Yarmouth, Lowestoft, Felixstowe, Deal FIG: [PHOTO] water breached sea defenses in Great Yarmouth
Heyken (2007)	Heyken, Herma, Schwere Sturmflut an niedersachsischer Nordseekuste - Dunnenabbruche auf den Inseln, 09/11/2007, NLWKN Niedersachsischer Landesbetrieb fuer Waserwirtschaft, Kuesten- und Naturschutz. PHOTO1. Norddeich mole 09Nov near ferry dock PHOTO2.ferry car gangway Norddeich 09Nov PHOTO3. Storm surge on the dike at Linteler Marsch PHOTO4. Storm surge in the Linteler Marsch by Norden PHOTO5. Storm surge 09 Nov, Norderney, Georgshohe

Aftenposten 20071109	Aftenposten 20071109, Stormen kan vaere rester av orkanen Noel. Noel forsterket seg igjen over Atlantikhavet og besokte Norge. Nina Loedemel, 09Nov2007, 1432local -PHOTO. Hurricane Noel in Carribbean
Tagesspiegel (2007)	Der Tagesspiegel, Orkan 'Tilo'. Duenenabbruch kostet Helgoland Millionen, 09/11/2007, 16:55 (mit AFP/ddp) FIG [photo] A flooded access road at the harbour in Domumer Siel (Kreis Aurich)
Outzen et al (2008)	Outzen, O., K. Herklotz, H. Heinrich, C. Lefebvre, Extreme waves at FINO1 research platform caused by storm 'Tilo' on 9 November 2007, DEWI Magazin No. 33, August 2008. -PHOTO1: photo: damage on working deck of FINO1; FINO1 tower seen from below
Stoffelen (2014)	Stoffelen, Ad, Modelling Surges, Cork eSurge Training 20-21 Feb 2014. -PHOTO. Delfzijl harbor flooded

Table S9. Ranking of Tilo/Andrea among recent storms; assessing importance of storm (arranged by year and then alphabetically)

Source	Full Reference and Notes
BBC (20071109b)	BBC, Thousands go home after tide fear, Friday 9 November, 16:50GMT -Benn: TILO most significant storm since 1953 -Phil Rothwell EA flood policy: Tilo on same level as 1953 but sea defenses improved
Bergens Tidende (20071108)	Bergens Tidende, Bolgehoyder opp mot 18 meter. Stormen som kommer inn til kysten i kveld kan bli en av arets toffeste, 08 Nov 2007 15:51 (contributor Leif Gullstein) -TILO expected to be toughest of years -expected Hs 10-11m less than all time high of 12m recorded during Borgny 2006Nov01
Met Office (2007)	Met Office, 2007. Daily Weather Summary, November 2007 -east coast storm surge at 2-2.5m is worst since 1953
North Norfolk News (2007)	North Norfolk News, Surge floods prompt new erosion fears, 14 November 2007, 01:00, Happisburgh Village Website, http://www.happisburgh.org.uk/press/nnn141107.html -storm surge was worst since 1953 for north Norfolk
Piotkowitz and Soerensen (2007)	Piotkowitz, 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. -Tilo storm surge in souther Skagerakk was 1 of 20 Danish storm surges in period 1991-2008 acknowledged by Danish Storm Council (DSC) for damage compensation.
Tagesspiegel (2007)	Der Tagesspiegel, Orkan 'Tilo'. Duenenabbruch kostet Helgoland Millionen, 09/11/2007, 16:55 (mit AFP/ddp) -storm surge comparisons with 1976 Capella storm
Magnusson et al (2008)	Magnusson, A.K., J. Johannessen, K.-F. Dagestad, O. Breivik, O.J. Aarnes, B. Furevik, Bolge-strom interaksjon til nytte for oljeindustri, WACUSAR_sluttrapport.doc, 19/12/2008 -no severe hits recorded during TILO; during BRITTA Ekofisk & Valhall evacuated to shore & Valhall had lifeboats damaged on northern side
Outzen et al (2008)	Outzen, O., K. Herklotz, H. Heinrich, C. Lefebvre, Extreme waves at FINO1 research platform caused by storm 'Tilo' on 9 November 2007, DEWI Magazin No. 33, August 2008. -TILO & BRITTA of comparable rank in causing damage to FINO1
Behrens & Guenther (2009)	Behrens, A. and H. Gunther, Operational wave prediction of extreme storms in Northern Europe, Nat. Hazards, 49, 387-399, 2009 -Anatol 03/12/1999, Lothar 26/12/1999, Jeanette 27/12/2002, Gudrun 08/01/2005, Britta 01/11/2006, Karla 30/12/2006, Kyrill 18/01/2007, Tilo 09/11/2007, Paula26/01/2008, Emma 29/02/2008
Emeis and Turk (2009)	Emeis, S. and M. Turk, Wind-driven wave heights in the German Bight, Ocean Dynamics, 59, 463-475, 2009 -Storm Tilo similar to Storm Britta; more severe than storm Erwin 01Jan2005 -Erwin & Britta were the worst storms at FINO1 in its first years of operation
Gonnert and Buss (2009)	Goennert, Gabriele & Thomas Buss, Sturmfluten zur Bemessung von Hochwasserschutzanlagen, Berichte des Landesbetriebes Strassen, Bruecken und

	Gewaesser Nr.2/2009, Freie und Hansestadt Hamburg, Landesbetrieb Strassen, Bruecken und Gewaesser, Hamburg, ISSN 1867-7959. -rank 7 water level 1901-2008: 03/01/76 10/01/76 03/12/99 16/02/62 28/01/94 10/01/95 09/11/07
Magnusson (2009)	Magnusson AK, 2009, 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. (powerpoint presentation) -Britta most severe Ekofisk storm in period 1997-2009; Tilo probably rank2; 2 serious storms in period 1997-2006
POL (2009)	POL, Annual Report 2007-2008, Proudman Oceanographic Laboratory, 40pp, 13May2009 -50y surge in eastern England; fear that it would be as bad as Jan 1953 surge
Reuter etal (2009)	Reuter R, TH Badewien, A Bartholoma, A Braun, A Luebben, J Rullkoetter, A hydrographic time series station in the Wadden Sea (southern North Sea), Ocean Dynamics, DOI 10.1007/s10236-009-0196-3, 2009 -dataset 2007-2008: Kyril, Orkun 18Mar2007; Tilo 09Nov2007; Emma 01Mar2008 (TILO highest surge)
Rosenthal and Lehner (2009)	Rosenthal W. and S Lehner, North Sea cases of extreme individual waves, 11.International Workshop on Wave Hindcasting and Forecasting & 2.Coastal Hazards Symposium, 2009? -TILO one of three focus storms; others being Britta 01Nov2006 & New Year's Day storm 01Jan1995
Herrling et al. (2010)	Herrling, Gerald, Heiko Knaack, Ralf Kaiser, Hanz D. Niemayer, Evaluation of design water levels at the Ems-Dollard estuary considering the effect of a storm surge barrier, Coastal Engineering 2010. -Britta water level in Emden 1cm below all time maximum at Emden. -intercomparison of 3 storm surges along Ems-Dollard estuary: Britta>Tilo>Anatol
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 -Comparison TILO 2008 with Great Storm 1987, Anna 2002, Gudrun 2005
Groen and Caires (2011a)	Groen, Geert and Caires, Sofia, Storm Catalog The Netherlands, nov 2011, KNMI/Deltares. http://projects.knmi.nl/hydra/stormcatalogus/index.htm (accessed 15June2019 after being placed back online by Josine Camps) -part of top 3 hydraulic events (in list of 17 storm surges; with 01Feb1983 & 1953 storm?) -first time since construction that Nieuwe Waterweg & Maeslantkering were operationally closed -water level at Hoek van Holland highest since 1954 but still 90cm lower than 1953 storm
Groen and Caires (2011b)	Groen Geert & Caires Sofia, Summary 09-11-2007, nov 2011b, KNMI/Deltares. http://projects.knmi.nl/hydra/stormcatalogus/Cases/05_09-11-2007/Samenvatting/samenvatting.html -part of top 3 hydraulic events (in list of 17 storm surges; with 01Feb1983 & 1953 storm?) -first time since construction that Nieuwe Waterweg & Maeslantkering were operationally closed
Hessner (2011)	Hessner, K., Extreme wave analysis at FINO1 during TILO storm event Nov. 8-9, 2007, Ocean WaveS GmbH data report for DONG Energy Power A/S, OceanWaveS GmbH, Hansekontor, Vor dem Bardowicker Tore 6b, 21339 Luneburg, Germany, July 2011 -TILO & BRITTA both caused damage to working deck of FINO1
Magnusson (2011)	Magnusson, Ann Karin, True sea state ...? Comparing different sensors and analyzing techniques, 12th Wave Workshop, Hawaii's Big Island, Oct.30-Nov4, 2011 (32 slides) -list of 21 storm cases at Ekofisk 2007–2009; Ekofisk is rank 1 followed by storm 18Mar2007
Rosenthal et al (2011)	Rosenthal W, AL Pleskachevsky, S Lehner, S Brusch, Observation and modeling of high individual ocean waves and wave groups caused by a variable wind field, 12th International Workshop on Wave Hindcasting and Forecasting, Kohala Coast, Hawai'i, HI, 2011. -storm TILO one of top three (01Jan1995 and storm BRITTA 01Nov2006) to calculate return period of extreme storms with wave events that can damage FINO1 research platform

Esurge_2007_tilo (2012)	Esurge_2007_tilo (2012), North Sea surge (2007) by Phillip Harwood 2012/11/01 18:00 -highest surge in the North Sea for 20 years; at one stage feared it would be as bad as 1953
Zorndt et al. (2012)	Zorndt AC, T Schlurmann, I Grabemann The influence of extreme events on hydrodynamics and salinities in the Weser estuary in the context of climate impact research, Coastal Engineering 2012.[document date stamp 11Oct2012] -water levels in Weser estuary higher for TILO 2007 than BRITTA 2006 -BRITTA & TILO worst storm surges of recent times
AON Benfield (2013)	AON Benfield, Historie von 1703 bis 2012: Winterstuerme in Europe, Stand: Januar 2013 -TILO & BRITTA not among top insurance losses
Loewe (2013)	Loewe,P, Atmosphaerenphysik, pp37-114, System Nordsee. 2006 & 2007: Zustand und Entwicklungen, ed. by P. Loewe, H. Klein, S. Weigelt -most serious storms 2006-7 & 2007-8 winters: Britta 01Nov2006, Franz 12Jan2007, Orkun 18Mar2007, Tilo 09Nov2007 with Cuxhaven high water levels: 239, 223, 227, 290; Tilo at rank 1 -Britta & Tilo storm surges assessed to be worst of last 100 years on Niedersachsen coast; Kyrill has higher wind speeds but there was mismatch in wind intensity & tidal cycle.
Brecht and Frank (2014)	Brecht, B and H Frank, High resolution modelling of wind fields for optimization of empirical storm flood predictions, Adv/ Sci. Res., 11, 1-6, 2014 -3 biggest surges of 20th century 1962, 1976, 1999; 1962 with 315 fatalities -3 very severe surges of 20th century 2006, 2007, 2013
Kristandt et al (2014)	Kristandt, J., B. Brecht, H. Frank, H. Knack, Optimization of empirical storm surge forecast-modeling of high resolution wind fields, Die Kuste, 81, 301-348, 2014 -COSMO focus studies for TILO 2007, KYRILL 2007, BRITTA 2006 -data table listing TILO among 39 most serious storm surges 1962-2011; TILO 6th in list (3rd if equal levels removed)
Weissenberger & Chouinard (2015)	Weissenberger S and O Chouinard, Adaptation to Climate Change and Sea Level Rise, Springer Briefs in Environmental Science, 2015. -storm TILO 2007 was the only time Delta works dams activated in interval between completion 1990s & 2012
VH (2016)	Vlaamse Hydrografie, Overzicht van de tijwaarnemingen langs de Belgische kust. Periode 2001-2010 voor Nieuwpoort, Oostende en Zeebrugge, Ministerie van de Vlaamse Gemeenschap, Agentschap Maritieme Dienstverlening en Kust, Afdeling Kust, Vlaamse Hyrografie, Oostende, 38pp, document time stamp 24Feb2016, author='beirenro' -storm surge above thresholds for Nieuwpoort, Oostende, Zeebrugge -09Nov2007 previous exceedances: 02Jan1995 for Nieuwpoort & 01Feb1953 for Oostende & Zeebrugge -BRITTA not included at any Belgian station
Jensen et al (2017)	Jensen J, S Niehuser, A Arns, S Dangendorf, Sensor- und risikobasiertes Fruhwarn-system fuer Seedeiche (EarlyDike), AP1 - Sturmflutmonitoring und Sturmflutssimulator - Fachbericht 2016, Siegen, April 2017 -Tilo surge residual time series included in top 10 list in Fig.4-4
Larsen et al (2017)	Larsen XG, J Du, R Bolanos, S Larsen, On the impact of wind on the development of wave field during storm Britta, Ocean Dynamics, 67, 1407-1427, 2017. -table comparing storms of highest Hs in the North Sea from 2005/01/08 (Erwin) to 2013/01/30 (unnamed) -Tilo>Britta>>all other storms -highest Hs at FINO1 measured during Tilo; assessed as 20y return value

Table S10. Storm Tilo/Andrea: severe forecast (arranged by year and then alphabetically)

Source	Full Reference and Notes
Aftenposten 20071106	Aftenposten, Ekofisk og Valhall evakueres for stormen.1500 ansatte pa oljefeltene kofisk og Valhall i Nordsjoen kan bli evakuerte for den forventede storm Andrea natt til fredag. 06Nov2007 13:35 -advance forecast for Andrea storm on 06Nov2007 enables evacuation of Ekofisk & Valhall

BBC (20070911b)	BBC, Thousands go home after tide fear, Friday 9 November, 16:50GMT -Gordon Brown chairs COBRA meeting morning 09Nov2007
Bergens Tidende (20071108)	Bergens Tidende, Bolgehoyder opp mot 18 meter. Stormen som kommer inn til kysten i kveld kan bli en av arets toffeste, 08 Nov 2007 15:51 (contributor Leif Gullstein) -Tilo expected to be year's toughest storm with Hs 10-11m
Guardian (20071112)	The Guardian, Environmental disaster as Russian tanker sinks, Mon, 2007/11/12, 09:18 GMT (reporter: Luke Harding, Moscow) -severe weather forecast issue 1 day before Black Sea ship disaster
Telegraph (20071111)	The Telegraph, Ecological disaster feared after tanker sinks, (contributor: Paul Eccleston) (11Nov2007) -advanced forecast of severe storm in Black Sea from 10Nov2007; ships still left port
MetOffice (2011)	MetOffice, Storm surge - November 2007, Met office website last updated 11May2011.https://www.metoffice.gov.uk/about-us/who/how/case-studies/floods-2007 -forecast of biggest surge for 50 years on East coast -water levels 10cm below top of sea defenses in Great Yarmouth; hairs breadth of breaching them -4 BOBR briefings -forecast water levels 50-90cm above alert levels
Esurge_2007_tilo (2012)	Esurge_2007_tilo (2012), North Sea surge (2007) by Phillip Harwood 2012/11/01 18:00 -feared it would be similar to the 1953 catastrophe -deep area of low pressure – Cyclone Tilo -in UK storm surge forescasts starting 05Nov; 63 mph winds & storm surges up to 3m

Table S11. Storm Tilo/Andrea: not as bad as expected (arranged by year and then alphabetically)

Source	Full Reference and Notes
BBC (20071109b)	BBC, Thousands go home after tide fear, Friday 9 November, 16:50GMT -water levels 20cm lower than originally feared -widespread fears flooding diminished as tides peaked without dyke breaches
North Norfolk News (2007)	North Norfolk News, Surge floods prompt new erosion fears, 14 November 2007, 01:00, Happisburgh Village Website, http://www.happisburgh.org.uk/press/nnn141107.html -storm surge was not as high as expected because wind direction was off
Capellen email 25Sep2019	Email from John Capellen DMI on 25Sep1999 -Tilo not mentioned in Denmark storm list, annual climate summary or Vejret magazine
Tagesspiegel (2007)	Der Tagesspiegel, Orkan 'Tilo'. Duenenabbruch kostet Helgoland Millionen, 09/11/2007, 16:55 (mit AFP/ddp) -storm flooding damage Tilo 500,000 EUR compared with 330,000,000EUR for Jan 2007 storm
Metoffice (2011)	MetOffice, Storm surge - November 2007, Met office website last updated 11May2011.https://www.metoffice.gov.uk/about-us/who/how/case-studies/floods-2007 -winds were largely offshore; waves not as high as could have been -storm surge had lessened 20-30cm from precious forecast while travelling down coast
Esurge_2007_tilo (2012)	Esurge_2007_tilo (2012), North Sea surge (2007) by Phillip Harwood 2012/11/01 18:00 -'… this worst case scenario failed to materialize' -dissipation of the storm & the fact that winds were largely offshore -on average the storm surge was 20–30 cm les than predictions

Table S12. Storm Tilo/Andrea: Extended period bad weather (arranged by year and then alphabetically)

Source	Full Reference and Notes
Aftenposten 20071106	Aftenposten, Ekofisk og Valhall evakueres for stormen.1500 ansatte pa oljefeltene kofisk og Valhall i Nordsjoen kan bli evakuerte for den forventede storm Andrea natt til fredag. 06Nov2007 13:35 -evacuation of Valhall & Ekofisk for Andrea storm from Thursday 08Nov2007
BBC (20071109a)	BBC, North Sea flood tide fears recede, Fri 09 November 2007, 1033GMT

	-2 days of UK storm surge only: Nov8-9 2007
Cargolaw (2007)	Cargolaw, International vessel casualties &pirates database for year 2007 – Jan. through Dec. 2007, http://www.cargolaw.com/presentation _casualties.07.html, downloaded from the Internet 14Sep2018 -bad weather ship accidents Nov6-12, 2007
PON (2007)	PON_1_2007_data (MS Excel spreadsheet, 'published on 12/03/2013'), hyperlink access from: https://www.gov.uk/guidance/oil-and-gas-environmental-alerts-and-incident-reporting, Oil and gas: environmental alerts and incident reporting including anonymous reporting. (spreadsheet downloaded 14Sep2018, document timestamp 15Jun2012) -7 cases of offshore leakages in period 06-11Nov2007; 2 weather incidents explicitly specified 08Nov & 09 Nov 2007
KIT20071117	KIT20071117, Sturm, Schnee, Regen. Mitteleuropa/Schwarzes Meer 09.-13.11.2007 (text CE), Karlsruhe Institute of Technology, Wettergefahren-Fruehwarnung, Institut fuer Meteorologie und Klimaforschung, Samstag, 17.November 2007, 18:00MEZ -title has 09-13Nov2007 -analysis maps 06-13Nov2007 -Stefan-Noel-Tilo-Valter-Urs-Wolf -North Sea coastal stations still registering peak gusts Nov10
Met Eireann (2007)	Met Eireann, Monthly Weather Bulletin, No.259, November 2007. -extended period bad weather Europe Nov8-11
MIROS-Ekofisk (2007)	MIROS, Ekofisk Monthly Report, November 2007. Doc No. ND/1024/07/11, Project: 1024-800 Ekofisk Met-Ocean Data Recording, Classification Open. Date 19December2007, prepared by AKS -sea state crosses 4m threshold 06-13 Nov 2007
Unwetterzentrale (2007)	Unwetterzentrale, Randtif TILO, undated website, http://www.unwetterzentrale.de/uwz/299.html (accessed 01Sep2007) -duration of influence in middle Europe 08-12Nov2007
Upstream20071107_pitt	Upstream, Anthea Pitt, 07Nov2007, Evacuations under way as storm roars in -Valhall platform closed starting at end 07Nov 2007
Upstream20071109_wells	Upstream, Rob Wells, 09Nov2007, Passing storm keeps platforms shut -StatoilHydro platforms Visund & Oseberg South closed from Thursday
Aftenposten 20071109	Aftenposten 20071109, Stormen kan vaere rester av orkanen Noel. Noel forsterket seg igjen over Atlantikhavet og besokte Norge. Nina Loedemel, 09Nov2007, 1432local -Andrea storm Norway was continuation of Hurricane Noel from Carribbean
Eecen (2008)	Eecen PJ, Meteorological Measurements OWEZ. Half year report - 01-07-2007 - 31-12-2007, ECN-E--08-061, OWEZ_R_121_20070701-20071231_wind_resource_2007_2, Oct 2008 (47pp) -high wind speed period 05-13 Nov 2007 -lowest pressure 09 & 14 Nov 2007
Magnusson et al (2008)	Magnusson, A.K., J. Johannessen, K.-F. Dagestad, O. Breivik, O.J. Aarnes, B. Furevik, Bolge-strom interaksjon til nytte for oljeindustri, WACUSAR_sluttrapport.doc, 19/12/2008 -FOBOX waverider near Karmoy shows first Hs exceedance over 4m 06-11 Nov 2007
Outzen et al (2008)	Outzen, O., K. Herklotz, H. Heinrich, C. Lefebvre, Extreme waves at FINO1 research platform caused by storm 'Tilo' on 9 November 2007, DEWI Magazin No. 33, August 2008. -period of intense storm 08-09Nov2007 -time series of Hs indicates Hs>4m between 06-13 Nov 2007
Badewien et al (2009)	Badewien TH, E Zimmer, A Bartheloma, R Reuter, Towards continuous long-term measurements of suspended particulate matter (SPM) in turbid coastal waters, Ocean Dynamics (2009) 59: 227-238, DOI 10.1007/s10236-009-0183-8

	-wind speed time series showing 3 wind speed peaks Nov6,9,13, 2007
Magnusson (2009b)	Magnusson AK, 2009, 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. -Ekofisk storm from 1500 08Nov – 1800 09Nov 2007
Rosenthal and Lehner (2009)	Rosenthal W. and S Lehner, North Sea cases of extreme individual waves, 11.International Workshop on Wave Hindcasting and Forecasting & 2.Coastal Hazards Symposium, 2009? -high sea state FINO1 on 06-13Nov2007
Hessner (2011)	Hessner, K., Extreme wave analysis at FINO1 during TILO storm event Nov. 8-9, 2007, Ocean WaveS GmbH data report for DONG Energy Power A/S, OceanWaveS GmbH, Hansekontor, Vor dem Bardowicker Tore 6b, 21339 Luneburg, Germany, July 2011 -FIG7 of report shows SWH, peak period & peak wave direction start 05Nov to end 10Nov 2007
Environment Agency (2012)	Environment Agency, Thames Barrier Project Pack 2012, Environment Agency -Thames Barrier closure only Nov 8-9
Esurge_2007_tilo (2012)	Esurge_2007_tilo (2012), North Sea surge (2007) by Phillip Harwood 2012/11/01 18:00 -'from 5th November onwards alerts of possible flooding were raised for East Anglia and SE England'
Zorndt et al (2012)	Zorndt AC, T Schlurmann, I Grabemann The influence of extreme events on hydrodynamics and salinities in the Weser estuary in the context of climate impact research, Coastal Engineering 2012.[document date stamp 11Oct2012] -surge lasted 1.4d for TILO vs 1.5d for BRITTA
Magnusson and Donelan (2013)	Magnusson, AK and MA Donelan, The Andrea wave. Characteristics of a measured North Sea rogue wave, Journal of Offshore Mechanics and Arctic Engineering, 135, 1-10, 2013 -shows storm period just over 1 day 08Nov2018 1500 to 09Nov2018 1800
Brecht and Frank (2014)	Brecht, B and H Frank, High resolution modelling of wind fields for optimization of empirical storm flood predictions, Adv/ Sci. Res., 11, 1-6, 2014 -storm TILO assumed to have the 4 day duration like most of 39 North Sea storm surge cases 1962-2011

Table S13. Names of the storm (arranged by year and then alphabetically)

Source	Full Reference and Notes
Andrea	Aftenposten, Ekofisk og Valhall evakueres for stormen.1500 ansatte pa oljefeltene kofisk og Valhall i Nordsjoen kan bli evakuerte for den forventede storm Andrea natt til fredag. 06Nov2007 13:35 Aftenposten 20071109, Stormen kan vaere rester av orkanen Noel. Noel forsterket seg igjen over Atlantikhavet og besokte Norge. Nina Loedemel, 09Nov2007, 1432local Magnusson, A.K., Forecasting extreme waves in practice, May 19,2009, Rogue waves 2008, Brest, France, 13-15 Oct., 2008. http://www.ifremer.fr/web-com/stw2008/rw Magnusson, A.K., J. Johannessen, K.-F. Dagestad, O. Breivik, O.J. Aarnes, B. Furevik, Bolge-strom interaksjon til nytte for oljeindustri, WACUSAR_sluttrapport.doc, 19/12/2008 Magnusson, Ann Karin, True sea state ...? Comparing different sensors and analyzing techniques, 12th Wave Workshop, Hawaii's Big Island, Oct.30-Nov4, 2011 (32 slides) Magnusson, AK and MA Donelan, The Andrea wave. Characteristics of a measured North Sea rogue wave, Journal of Offshore Mechanics and Arctic Engineering, 135, 1-10, 2013
Storm surge – November 2007	MetOffice, Storm surge - November 2007, Met office website last updated 11May2011. https://www.metoffice.gov.uk/about-us/who/how/case-studies/floods-2007. Esurge_2007_tilo (2012), North Sea surge (2007) by Phillip Harwood 2012/11/01 18:00
Stormvloed 09 Nov 2007 (SR88)	RWS, Verslag van de Stormvloed van 9 november 2007 (SR88), Ministerie van Verkeer en Waterstaat, Direktoraat-Generaal Rijkswaterstaat Waterdienst, Stormvloedwaarschuwingsdienst/SVSD, Postbus 17, 8200 AA Lelystad www.svsd.nl, Lelystad, november 2007, 45pp
Noordwester	Kustwachtcentrum, Persbericht, Noordwester storm, Info nr.1, 09Nov/2007

storm	
Tilo	KIT20071117, Sturm, Schnee, Regen. Mitteleuropa/Schwarzes Meer 09.-13.11.2007 (text CE), Karlsruhe Institute of Technology, Wettergefahren-Fruehwarnung, Institut fuer Meteorologie und Klimaforschung, Samstag, 17.November 2007, 18:00MEZ Der Tagesspiegel, Orkan 'Tilo'. Duenenabbruch kostet Helgoland Millionen, 09/11/2007, 16:55 (mit AFP/ddp) Unwetterzentrale, Randtif TILO, undated website, http://www.unwetterzentrale.de/uwz/299.html (accessed 01Sep2007) Wiese, Heiko, Lebensgeschichte. Tiefdruckgebiet Tilo (getauft am 06.11.2007), written on 03Dec2007 http://www.met.fu-berlin.de/wetterpate/Lebensgeschichten/Tief_TILO_06_11_07.htm Outzen, O., K. Herklotz, H. Heinrich, C. Lefebvre, Extreme waves at FINO1 research platform caused by storm 'Tilo' on 9 November 2007, DEWI Magazin No. 33, August 2008. Badewien TH, E Zimmer, A Bartheloma, R Reuter, Towards continuous long-term measurements of suspended particulate matter (SPM) in turbid coastal waters, Ocean Dynamics (2009) 59: 227-238, DOI 10.1007/s10236-009-0183-8 Emeis, S. and M. Turk, Wind-driven wave heights in the German Bight, Ocean Dynamics, 59, 463-475, 2009 Reuter R, TH Badewien, A Bartholoma, A Braun, A Luebben, J Rullkoetter, A hydrographic time series station in the Wadden Sea (southern North Sea), Ocean Dynamics, DOI 10.1007/s10236-009-0196-3, 2009 Rosenthal W. and S Lehner, North Sea cases of extreme individual waves, 11.International Workshop on Wave Hindcasting and Forecasting & 2.Coastal Hazards Symposium, 2009? Herrling, Gerald, Heiko Knaack, Ralf Kaiser, Hanz D. Niemayer, Evaluation of design water levels at the Ems-Dollard estuary considering the effect of a storm surge barrier, Coastal Engineering 2010. Gray AL, O Martinez-Avarado, LH Baker, PA Clark, Conditional symmetric instability in sting-jet storms, QJRMS, 137, 1482-1500, 2011. Hessner, K., Extreme wave analysis at FINO1 during TILO storm event Nov. 8-9, 2007, Ocean WaveS GmbH data report for DONG Energy Power A/S, OceanWaveS GmbH, Hansekontor, Vor dem Bardowicker Tore 6b, 21339 Luneburg, Germany, July 2011 Rosenthal W, AL Pleskachevsky, S Lehner, S Brusch, Observation and modeling of high individual ocean waves and wave groups caused by a variable wind field, 12th International Workshop on Wave Hindcasting and Forecasting, Kohala Coast, Hawai'i, HI, 2011. Esurge_2007_tilo (2012), North Sea surge (2007) by Phillip Harwood 2012/11/01 18:00 Zorndt AC, T Schlurmann, I Grabemann The influence of extreme events on hydrodynamics and salinities in the Weser estuary in the context of climate impact research, Coastal Engineering 2012.[document date stamp 11Oct2012] AON Benfield, Historie von 1703 bis 2012: Winterstuerme in Europe, Stand: Januar 2013 Loewe,P, Atmosphaerenphysik, pp37-114, System Nordsee. 2006 & 2007: Zustand und Entwicklungen, ed. by P. Loewe, H. Klein, S. Welgelt-Krenz, Berichte des Bundesamtes fuer Seeschifffahrt und Hydrographie, Nr.49/2013 Brecht, B and H Frank, High resolution modelling of wind fields for optimization of empirical storm flood predictions, Adv/ Sci. Res., 11, 1-6, 2014 Kristandt, J, B Brecht, H Frank, H Knaack, Optimization of empirical storm surge forecast – modelling of high resolution wind fields, Die Kuste, 18, 301-308, 2014 Weissenberger S and O Chouinard, Adaptation to Climate Change and Sea Level Rise, Springer Briefs in Environmental Science, 2015. Hart NCG, SL Gray, PA Clark, Sting-jet windstorms over the North Atlantic: climatology and contribution to extreme wind risk, Journal of Climate, 30, pp 545-5471, 2017 Herrling G, Benninghoff, Zorndt A, Winter C, Drivers of channel-shoal morphodynamics at the outer Weser estuary, Coastal Dynamics 2017, Paper No. 261, pp.333-345 Larsen XG, J Du, R Bolanos, S Larsen, On the impact of wind on the development of wave field during storm Britta, Ocean Dynamics, 67, 1407-1427, 2017.

Table S14. Storm Tilo/Andrea: satellite pictures and weather maps (arranged by year and then alphabetically)

Source	Full Reference and Notes
KIT20071117	KIT20071117, Sturm, Schnee, Regen. Mitteleuropa/Schwarzes Meer 09.-13.11.2007 (text CE), Karlsruhe Institute of Technology, Wettergefahren-Fruehwarnung, Institut fuer Meteorologie und Klimaforschung, Samstag, 17.November 2007, 18:00MEZ FIG. 8XDWD weather maps covering 06-13Nov FIG. Satellite picture 06/11/2007 12:07UTC, NOAA-18 VIS/IR. Source: BJ Bruton FIG. Satellite picture 07/11/2007 11:00UTC, TERRA VIS. Source NASA Earth Lab FIG. Satellite picture 08/11/2007 15:41UTC, NOAA-15 IR. Source: Geog. Inst., Uni Bern FIG. Satellite picture 09/11/2007 11:45UTC, Meteosat VIS. Source: EUMETSAT FIG. Satellite picture 10/11/2007 13:05UTC, NOAA-18 VIS/IR. Source: BJ Burton FIG. Satellite picture 11/11/2007 12:45UTC, Meteosat VIS. Source: EUMETSAT FIG. Satellite picture 12/11/2007 15:45UTC, NOAA-15 IR. Source: Geog Inst Uni Bern FIG. Satellite picture 13/11/2007 11:45UTC, Meteosat VIS. Source: EUMETSAT
Met Eireanne (2007)	Met Eireann, Monthly Weather Bulletin, No.259, November 2007 -FIG1. Synoptic chart Nov8/2007 0000UTC -FIG2. Synoptic chart Nov9/2007 0000UTC -FIG3. Satellite image (IR?) Nov8/2007 1115UTC Northwest Europe -FIG4. Satellite image (IR?) Nov11/2007 1111UTC Black Sea & Ukraine
Met Office (2007)	Met Office, 2007. Daily Weather Summary, November 2007 -FIG. [map] surface pressure analysis 0000UTC 08Nov2007 showing TILO low P 986 hPa N of Scotland -FIG. [map] surface pressure analysis 1200UTC 08Nov2007 showing TILO low P 977 hPa over Bergen -FIG. [map] Europe sfc reports P, airt, cloud cover, wspd/wdir 0000GMT 08Nov2007 -FIG. [map] UK only sfc reports P, airt, cloud cover, wspd/wdir 0600GMT 08Nov2007 -FIG. [map] Europe sfc reports P, airt, cloud cover, wspd/wdir 1200GMT 08Nov2007 -FIG. [map] UK only sfc reports P, airt, cloud cover, wspd/wdir 1800GMT 08Nov2007 -FIG. [map] UK only significant weather with thunderstorm & convection -FIG. [map] UK only min & max temperature showing up to 5C decr with cold front -FIG. [map] AM & PM rainfall; max 7 mm Scotland, 6mm England -FIG. [map] surface pressure analysis 0000UTC 09Nov2007 showing TILO low P ??? hPa over Bergen -FIG. [map] surface pressure analysis 1200UTC 09Nov2007 showing TILO low P 984 hPa N Baltic -FIG. [map] Europe sfc reports P, airt, cloud cover, wspd/wdir 0000GMT 09Nov2007 -FIG. [map] UK only sfc reports P, airt, cloud cover, wspd/wdir 0600GMT 09Nov2007 -FIG. [map] Europe sfc reports P, airt, cloud cover, wspd/wdir 1200GMT 09Nov2007 -FIG. [map] UK only sfc reports P, airt, cloud cover, wspd/wdir 1800GMT 09Nov2007 -FIG. [map] UK only significant weather with thunderstorm & convection -FIG. [map] UK only min & max temperature showing up to 9C decr with cold front -FIG. [map] AM & PM rainfall; low ppt levels
RWS (2007)	RWS, Verslag van de Stormvloed van 9 november 2007 (SR88), Ministerie van Verkeer en Waterstaat, Direktoraat-Generaal Rijkswaterstaat Waterdienst, Stormvloedwaarschuwingsdienst/SVSD, Postbus 17, 8200 AA Lelystad www.svsd.nl, Lelystad, november 2007, 45pp -FIG0. Satellite pic (vis) of storm 08Nov2007 2000U? with cloud band at Dutch coast
Aftenposten 20071109	Aftenposten 20071109, Stormen kan vaere rester av orkanen Noel. Noel forsterket seg igjen over Atlantikhavet og besokte Norge. Nina Loedemel, 09Nov2007, 1432local FIG1. Andrea at 19:00 Thursday night, when the wind increased to storm strength over Rogaland. The low pressure center was over Rogaland & on way southeast. FOTO Meteorologisk Institut. MSG VISIR_Europea_Meteosat 3-9-10 1007 2007-11-08 18:00 Thursday 2007-11-08 18UTC FIG2. Satellite image NOAA-17 S-Norge-(SAF_SE) 1+2+4 2007-11-09 10:23.

	Friday 2007-11-09 12UTC
Bancroft (2008)	Bancroft, George P, Marine Weather Review - North Atlantic Area. September through December 2007, Mariners Weather Log, Vol 52, No 1, April 2008. -NE Atlantic weather map 12UTC Nov 7 & 12UTC Nov 8/2007
Eden (2008)	-daily surface pressure maps Europe
Lefebvre (2008)	Lefebvre, Christiana, Orkan TILO am 8. und 9. November 2007, DWD report 01Jan2008 FIG1. Path of hurricane centre of TILO with 6h position of low centre FIG2. Surface analysis of sea level pressure from 08/11/2007 12UTC, 18UTC; 09/11/2007 00, 06, 12, 18UTC FIG6. MAP: Wind direction & speed as 10min averages at midday on 09/11/2007 in knot FIG7. MAP: The highest wind gust in knot between 1015-1315 MEZ on 09/11/2007 (1 km/h is 1kt * 1.85)
Magnusson et al (2008)	Magnusson, A.K., J. Johannessen, K.-F. Dagestad, O. Breivik, O.J. Aarnes, B. Furevik, Bolge-strom interaksjon til nytte for oljeindustri, WACUSAR_sluttrapport.doc, 19/12/2008 -FIG13. ENVISAT ASAR for 09Nov2013 10:00UTC with derived info for significant wave height & peak wavelength
Outzen et al (2008)	Outzen, O., K. Herklotz, H. Heinrich, C. Lefebvre, Extreme waves at FINO1 research platform caused by storm 'Tilo' on 9 November 2007, DEWI Magazin No. 33, August 2008. -FIG2: 6 DWD weather maps Nov8 (12,18UTC) & NOV9 (00,06,12,18)
Rosenthal and Lehner (2009)	Rosenthal W. and S Lehner, North Sea cases of extreme individual waves, 11.International Workshop on Wave Hindcasting and Forecasting & 2.Coastal Hazards Symposium, 2009? -weather map for 09Nov2007, 0000UTC
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 -0100 UTC 08Nov2007
Groen and Caires (2011b)	Groen Geert & Caires Sofia, Summary 09-11-2007, nov 2011b, KNMI/Deltares. http://projects.knmi.nl/hydra/stormcatalogus/Cases/05_09-11-2007/Samenvatting/samenvatting.html -FIG1. [map] map North Atlantic with 500hPa geopotential & surface pressure 08Nov2007 00:00UTC; from Wetterzentrale using NCEP reanalysis -FIG2. [map] map North Atlantic with 500hPa geopotential & surface pressure 09Nov2007 00:00UTC; from Wetterzentrale using NCEP reanalysis -FIG3. [map] map North Atlantic with 500hPa geopotential & surface pressure 10Nov2007 00:00UTC; from Wetterzentrale using NCEP reanalysis -FIG4. [map] map North Atlantic with 850hPa temperature 08Nov2007 00:00UTC; from Wetterzentrale using NCEP reanalysis -FIG5. [map] map North Atlantic with 850hPa temperature 09Nov2007 00:00UTC; from Wetterzentrale using NCEP reanalysis -FIG6. [map] map North Atlantic with 850hPa temperature 10Nov2007 00:00UTC; from Wetterzentrale using NCEP reanalysis
Rosenthal et al (2011)	Rosenthal W, AL Pleskachevsky, S Lehner, S Brusch, Observation and modeling of high individual ocean waves and wave groups caused by a variable wind field, 12th International Workshop on Wave Hindcasting and Forecasting, Kohala Coast, Hawai'i, HI, 2011. -FIG3. NOAA AVHRR thermal infrared image on 9.11.2007, 03.20 UTC
Brecht and Frank (2014)	Brecht, B and H Frank, High resolution modelling of wind fields for optimization of empirical storm flood predictions, Adv/ Sci. Res., 11, 1-6, 2014 -FIG2. map of locations of available data for 9 Nov 2018 -FIG3. Map of North Sea surface pressure field and 10m wind speed and direction the 09Nov2007 0600UTC -FIG5. Map of northwest Europe showing model wind speed bias with respect to nuding run
Stoffelen (2014)	Stoffelen, Ad, Modelling Surges, Cork eSurge Training 20-21 Feb 2014.
Capellen (20180925)	Capellen, John, email of 25Sept2018 with 2 reports, wind speed summary of Skagen during TILO and North Atlantic wind map during TILO

	-gridded field of 10m wind speed over Europe and North Atlantic for Friday 09Nov2007 0600UTC

Table S15. Storm Tilo/Andrea: list meteorological data (arranged by year and then alphabetically)

Source	Full Reference and Notes
Aftenposten 20071109	Aftenposten 20071109, Stormen kan vaere rester av orkanen Noel. Noel forsterket seg igjen over Atlantikhavet og besokte Norge. Nina Loedemel, 09Nov2007, 1432local -night 08-09Nov wspd up to hurricane strength on Utsira
Heyken (2007)	Heyken, Herma, Schwere Sturmflut an niedersachsischer Nordseekuste - Dunnenabbruche auf den Inseln, 09/11/2007, NLWKN Niedersachsischer Landesbetrieb fuer Waserwirtschaft, Kuesten- und Naturschutz. -wind speed 80-110km/s 160km north of Emsmundung
KIT20071117	KIT20071117, Sturm, Schnee, Regen. Mitteleuropa/Schwarzes Meer 09.-13.11.2007 (text CE), Karlsruhe Institute of Technology, Wettergefahren-Fruehwarnung, Institut fuer Meteorologie und Klimaforschung, Samstag, 17.November 2007, 18:00MEZ -list of top 10 peak gusts 09-11Nov2007 -list of top 10 24h ppt accumulations 08-09Nov2007 to 11-12Nov2007 -list of snow heights Germany
LCW (20071123)	Lloyd's Casualty Week, Weather and Navigation, pp17-20, Nov23/2007 -strongest gusts at Fair Isle between Orkney & Shetland Islands: 93mph
Met Eireanne (2007)	Met Eireann, Monthly Weather Bulletin, No.259, November 2007 -Simperopol, Crimean Peninsula Nov11: sustained wind speed=87km/h; gusts to 116km/h -TAB page 4. Maximum wind speed & gust of the month with date/time - FIG page 5. Time series data buoy M1; max wind speed Nov8 1800UTC 25 knot; max Hs Nov09 0200UTC 4m
Met Office (2007)	Met Office, 2007. Daily Weather Summary, November 2007 -station reports of air temperature, pressure, wind speed & direction every 12h as symbols on map
MIROS-Ekofisk (2007)	MIROS, Ekofisk Monthly Report, November 2007. Doc No. ND/1024/07/11, Project: 1024-800 Ekofisk Met-Ocean Data Recording, Classification Open. Date 19December2007, prepared by AKS -figure of time series wind speed, gust & wind direction (10min averages) -figure of time series of 3h maximum wind speed, 3h maximum gust & air temperature -figure of time series of dew point temperature, humity, air pressure -figure of time series of sea temperature & cloud level -simple statistics: max wspd 23.0m/s 08Nov2007 14:00; max gust 29.0m/s 08Nov2007 15:40
RWS (2007)	RWS, Verslag van de Stormvloed van 9 november 2007 (SR88), Ministerie van Verkeer en Waterstaat, Direktoraat-Generaal Rijkswaterstaat Waterdienst, Stormvloedwaarschuwingsdienst/SVSD, Postbus 17, 8200 AA Lelystad www.svsd.nl, Lelystad, november 2007, 45pp -FIG1. Time series of wspd & wdir at platform K13 with dominant wdir at 330deg -FIG1.1: TS wind speed & direction: Lichteiland Goeree: 19.5m/s 09Nov2007 05:00M? -FIG1.2: TS wind speed & direction: Europlatform: 22m/s 09Nov2007 03:00M? (data gap) -FIG1.3: TS wind speed & direction: Hoek van Holland: 22m/s 09Nov2007 01:00M? (data gap) -FIG1.4: TS wind speed & direction: IJmuiden semafoor: 22m/s 09Nov2007 02:30M?, 2nd=11:00M? (data gap) -FIG1.5: TS wind speed & direction: Platform K13A: 21.5m/s 09Nov2007 01:00M?, 2nd=06:00M?, 3rd=09:00M? (data gap) -FIG1.6: TS wind speed & direction: Huibertgat: 23m/s 09Nov2007 06:30M? (major data gap)

Unwetterzentrale (2007)	Unwetterzentrale, Randtif TILO, undated website, http://www.unwetterzentrale.de/uwz/299.html (accessed 01Sep2007) Lowest central pressure in European area: 971hPa, 08Nov2007, 12UTC, northern North Sea Chosen wind gusts over 75km/h (Mountain, Islands, or Coast) -152km/h Nebelhorn -141km/h Hiddensee-Dornbusch -137km/h Wendelstein -91km/h Nossen, Leck, Itzenhow (MM) -87km/h Nuenchen-Giesling, Hohn -85km/h Ansbach
Wiese (2007)	Wiese, Heiko, Lebensgeschichte. Tiefdruckgebiet Tilo (getauft am 06.11.2007), written on 03Dec2007 http://www.met.fu-berlin.de/wetterpate/Lebensgeschichten/Tief_TILO_06_11_07.htm -wspd 57km/h Stornaway -high pressure gradient across Germany 40hPa between Rugen 990hPa & Saarland 1030hPa -Berlin-Dahlem gusts up to 20.6m/s; avg wind speed 9.1m/s -Brocken gusts up to 33m/s -temperature decrease 3-5C
Bancroft (2008)	Bancroft, George P, Marine Weather Review - North Atlantic Area. September through December 2007, Mariners Weather Log, Vol 52, No 1, April 2008. -listing wind speed for 3 buoys & 2 ships on Nov8/2007 12UTC
Eden (2008)	Eden, Philip, Weather Log, November 2007, Weather, 63(1), i-iv, 2008. -peak gust of 81kt at Fair Isle
Eecen (2008)	Eecen PJ, Meteorological Measurements OWEZ. Half year report - 01-07-2007 - 31-12-2007, ECN-E--08-061, OWEZ_R_121_20070701-20071231_wind_resource_2007_2, Oct 2008 (47pp) -OWEZ mast: max wspd 25-30 m/s; air temperature drop 12C to 4C; pressure drop 1040 to 1008 hPa
Lefebvre (2008)	Lefebvre, Christiana, Orkan TILO am 8. und 9. November 2007, DWD report 01Jan2008 -FIG5. Time series wind speed of maximum gusts from 08Nov to the 09Nov2007: UFS DT Bucht, St Peter Ording, Norderney, Westermarkelsdorf, Boltenhagen, Arkona. -FIG6. MAP: Wind direction & speed as 10min averages at midday on 09/11/2007 in knot -FIG7. MAP: The highest wind gust in knot between 1015-1315 MEZ on 09/11/2007 (1 km/h is 1kt * 1.85) -FIG8a.Hourly time series of 10min wspd & gusts in Nsea: UFS Dt Bucht, St. Peter Ording, Norderney -FIG8b.Hourly time series of 10min wspd & gusts in Baltic: Westermarkelsdorf, Boltenhagen, Arkona -TAB1. Maximum gusts for different stations on 09/11/2007 for North Sea, Baltic Sea & high areas
Outzen et al (2008)	Outzen, O., K. Herklotz, H. Heinrich, C. Lefebvre, Extreme waves at FINO1 research platform caused by storm 'Tilo' on 9 November 2007, DEWI Magazin No. 33, August 2008. -FIG4. Time series graphs of wind speed & wind direction for UFS Deutsche Bucht, St. Peter Ording, Norderney -TABLE1: maximum gust values at 15 North Sea coastal stations
Badewien et al (2009)	Badewien TH, E Zimmer, A Bartheloma, R Reuter, Towards continuous long-term measurements of suspended particulate matter (SPM) in turbid coastal waters, Ocean Dynamics (2009) 59: 227-238, DOI 10.1007/s10236-009-0183-8 -wind speed during TILO at Bf 8 -FIG13c: time series wind speed at Station Watt for Nov 2007.
Rosenthal and Lehner (2009)	Rosenthal W. and S Lehner, North Sea cases of extreme individual waves, 11.International Workshop on Wave Hindcasting and Forecasting & 2.Coastal Hazards Symposium, 2009? -tabulated gust speeds for series of stations in the German Bight, North Sea area
Magnusson (2011)	Magnusson, Ann Karin, True sea state ...? Comparing different sensors and analyzing techniques, 12th Wave Workshop, Hawaii's Big Island, Oct.30-Nov4, 2011 (32 slides)

	-time series wind speed & wind direction at Ekofisk
Rosenthal et al (2011)	Rosenthal W, AL Pleskachevsky, S Lehner, S Brusch, Observation and modeling of high individual ocean waves and wave groups caused by a variable wind field, 12th International Workshop on Wave Hindcasting and Forecasting, Kohala Coast, Hawai'i, HI, 2011. -'… with maximum wind speeds of 120 km/h…'
Magnusson and Donelan (2013)	Magnusson, AK and MA Donelan, The Andrea wave. Characteristics of a measured North Sea rogue wave, Journal of Offshore Mechanics and Arctic Engineering, 135, 1-10, 2013 -time series U10 & wind direction Ekofisk platform 08Nov2007 1200GMT to 10Nov2007 0000GMT -max 10m wspd 23m/s
Donelan and Magnusson (2017)	Donelan MA & A-K Magnusson, The making of the Andrea Wave and other rogues, Scientific Reports, 7:44124, DOI: 10.1038/srep44124 (2017) -wind quite steady at 22m/s for 7h at Ekofisk
Larsen et al. (2017b)	Larsen, XG et al, Extreme winds and waves for offshore turbines: Coupling atmosphere and wave modeling for design and operation in coastal zones, DTU Wind Energy, (DTU Wind Energy E, vol.154) (Final report for ForskEL project PSO-12020 X-WiWa), 2017b. -Tilo max wspd at 100m at FINO1 is ~28.5 m/s (model); meas value covered by model (Fig 37)
Capellen email 25Sep1999	Email from John Capellen DMI on 25Sep1999 -Skagen station 6041; 10-min avg wind speed 21m/s; just up to 32m/s around mid-day 09-10UTC -map of analyzed wind speeds

Table S16. Storm Tilo/Andrea: significant wave height and sea state (arranged by year and then alphabetically)

Source	Full Reference and Notes
Guardian (20071112)	The Guardian, Environmental disaster as Russian tanker sinks, Mon, 2007/11/12, 09:18 GMT (reporter: Luke Harding, Moscow) -SWH 6m at time of Black Sea ship disaster
Kustwachtcentrum (2007/11/06)	Kustwachtcentrum Den Helder, Containers verloren, Persberich 06Nov2007, emailed from Edwin Granneman 08Oct2008 -Hs 3-4m at 1330 06Nov2007, 14km N of Terschelling at time of lost containers
Met Eireann (2007)	Met Eireann, Monthly Weather Bulletin, No.259, November 2007 - FIG page 5. Time series data buoy M1; max wind speed Nov8 1800UTC 25 knot; max Hs Nov09 0200UTC 4m
MIROS-Ekofisk (2007)	MIROS, Ekofisk Monthly Report, November 2007. Doc No. ND/1024/07/11, Project: 1024-800 Ekofisk Met-Ocean Data Recording, Classification Open. Date 19December2007, prepared by AKS -time series of significant wave height H1/3; average wave period Tz; maximum wave height Hmax -simple statistics: significant wave height [9.6,9.3,8.6]; maximum wave height [16.1,12.8,13.9]
Lefebvre (2008)	Lefebvre, Christiana, Orkan TILO am 8. und 9. November 2007, DWD report 01Jan2008 -mention that Britta wave that damaged FINO1 >10m FIG9. Time series Hs for Helgoland & Nordseeboje 01.01.2007 to 28.12.2007
RWS (2007)	RWS, Verslag van de Stormvloed van 9 november 2007 (SR88), Ministerie van Verkeer en Waterstaat, Direktoraat-Generaal Rijkswaterstaat Waterdienst, Stormvloedwaarschuwingsdienst/SVSD, Postbus 17, 8200 AA Lelystad www.svsd.nl, Lelystad, november 2007, 45pp -FIG8.1. TS wave height & direction Europlatform: maxhgt=6m, datetime=09Nov 0800, P=9.4s -FIG8.2. TS wave height & direction IJmuiden: maxhgt=8m, datetime=09Nov 1330, P=12.2s (data gap) -FIG8.3. TS wave height & direction Eierlandse Gat: maxhgt=7.4m,datetime=09Nov 1000, P=12.1s -FIG8.4. TS wave height & direction Schiermonnikoog Noord: maxhgt=8.2m,datetime=09Nov

	1230, P=14.6s (data gap)
Magnusson et al (2008)	Magnusson, A.K., J. Johannessen, K.-F. Dagestad, O. Breivik, O.J. Aarnes, B. Furevik, Bolge-strom interaksjon til nytte for oljeindustri, WACUSAR_sluttrapport.doc, 19/12/2008 -Hs up to 11m at Ekofisk during TILO -Hs7m at FOBOX waverider near Karmoy
Outzen et al (2008)	Outzen, O., K. Herklotz, H. Heinrich, C. Lefebvre, Extreme waves at FINO1 research platform caused by storm 'Tilo' on 9 November 2007, DEWI Magazin No. 33, August 2008. -max Hs 10.5m for WAMOS radar & ADCP systems about 12:00 MEZ -time series graphs of WAMOS radar & ADCP 01-17Nov 2007 -maximum period WAMOS 15.9s, ADCP 14.3s; for 32m water depth wavelengths 257m & 228m
Magnusson (2009)	Magnusson, A.K., Forecasting extreme waves in practice, Proceedings Rogue waves 2008, ed. by Michel Olagnon and Marc Previsto, Brest, France, 13-15 Oct., 2008. http://www.ifremer.fr/web-com/stw2008/rw (pdf date stamp May 19,2009). -Ekofisk maximum Hs=10.95m during Tilo -time series Hs at Ekofisk
Magnusson (2009b)	Magnusson AK, 2009, 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. -time series Hs Ekofisk
Rosenthal and Lehner (2009)	Rosenthal W. and S Lehner, North Sea cases of extreme individual waves, 11.International Workshop on Wave Hindcasting and Forecasting & 2.Coastal Hazards Symposium, 2009? -maximum Hs FINO1 ~11m measured by WAMOS & AWAC
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 -mention of extreme waves in North Sea
Hessner (2011)	Hessner, K., Extreme wave analysis at FINO1 during TILO storm event Nov. 8-9, 2007, Ocean WaveS GmbH data report for DONG Energy Power A/S, OceanWaveS GmbH, Hansekontor, Vor dem Bardowicker Tore 6b, 21339 Luneburg, Germany, July 2011 -FIG7: time series WAMOSII & AWAC data: Hs, peak period, & peak wave direction -peak AWAC Hs=10.81 09Nov 08:02UTC; peak WAMOS II Hs=10.7m 09Nov 11:27UTC
Magnusson (2011)	Magnusson, Ann Karin, True sea state ...? Comparing different sensors and analyzing techniques, 12th Wave Workshop, Hawaii's Big Island, Oct.30-Nov4, 2011 (32 slides) -maximum Hs from LASAR at 11.5m; minimum Hs from MRF at 9.7m -time series of Hs & Tp -wave spectrum snapshots and polar diagrams at 08 Nov (1200, 1500, 1800 UTC) and 09 Nov (0000UTC) -time series of Andrea wave
Rosenthal et al (2011)	Rosenthal W, AL Pleskachevsky, S Lehner, S Brusch, Observation and modeling of high individual ocean waves and wave groups caused by a variable wind field, 12th International Workshop on Wave Hindcasting and Forecasting, Kohala Coast, Hawai'i, HI, 2011. -'… significant wave heights in excess of 10m, wave periods of about 15s and wave lengths of more than 220m.'
Magnusson and Donelan (2013)	Magnusson, AK and MA Donelan, The Andrea wave. Characteristics of a measured North Sea rogue wave, Journal of Offshore Mechanics and Arctic Engineering, 135, 1-10, 2013 -time series Hs & Tp platform 08Nov2007 1200GMT to 10Nov2007 0000GMT; max Hs=11m at 0630 GMT
Donelan and Magnusson (2017)	Donelan MA & A-K Magnusson, The making of the Andrea Wave and other rogues, Scientific Reports, 7:44124, DOI: 10.1038/srep44124 (2017) -'Hs increased from 9m to 10.5m'
Larsen et al. (2017a)	Larsen XG, J Du, R Bolanos, S Larsen, On the impact of wind on the development of wave field during storm Britta, Ocean Dynamics, 67, 1407-1427, 2017a. -Hs=10.1m at FINO1 (AWAC); greater then 9.8m during Britta; highest on record; 20y return

	value
Larsen et al (2017b)	Larsen, XG etal, Extreme winds and waves for offshore turbines: Coupling atmosphere and wave modeling for design and operation in coastal zones, DTU Wind Energy, (DTU Wind Energy E, vol.154) (Final report for ForskEL project PSO-12020 X-WiWa), 2017b -FIG.54: Horns Rev Buoy N maximum Hs during Tilo is 5.4m (meas) & 6.1m (modelled)

Table S17. Storm Tilo/Andrea: storm trajectory map (arranged by year and then alphabetically)

Source	Full Reference and Notes
RWS (2007)	RWS, Verslag van de Stormvloed van 9 november 2007 (SR88), Ministerie van Verkeer en Waterstaat, Direktoraat-Generaal Rijkswaterstaat Waterdienst, Stormvloedwaarschuwingsdienst/SVSD, Postbus 17, 8200 AA Lelystad www.svsd.nl, Lelystad, november 2007, 45pp
Lefebvre (2008)	Lefebvre, Christiana, Orkan TILO am 8. und 9. November 2007, DWD report 01Jan2008
Kristandt et al (2014)	Kristandt, J, B Brecht, H Frank, H Knaack, Optimization of empirical storm surge forecast – modelling of high resolution wind fields, Die Kuste, 18, 301-308, 2014 -trajectories of 6 most serious storms in terms of Norderney storm surge levels.
Hart et al (2017)	Hart NCG, SL Gray, PA Clark, Sting-jet windstorms over the North Atlantic: climatology and contribution to extreme wind risk, Journal of Climate, 30, pp 545-5471, 2017

Table S18. Storm Tilo/Andrea: coastal flooding and evacuations (arranged by year and then alphabetically)

Source	Full Reference and Notes
BBC (20071109a)	BBC, North Sea flood tide fears recede, Fri 09 November 2007, 1033GMT -night of Nov8-9 1000s evacuated in England in preparation of 3m skew surge -500 people spent night at refuge centres in local schools -tides peaked 0700-0800GMT; no major breaches of flood defenses -Great Yarmouth not flooded substantially; surge peak 20cm lower than expected -surveillance operations to continue along northern Dutch coast; 1/3 country under sea level -Germany flood warnings for Elbe & Elm(sp?) rivers
BBC (20071109b)	BBC, Thousands go home after tide fear, Friday 9 November, 16:50GMT -map flood risk from Immingham to Felixstowe -flood defenses Great Yarmouth breached -rail line Norwich-Lowestoft flooded -1000's return home
Horsburgh (2007)	Horsburgh, Kevin, Foreword, in Bradshaw, Elizabeth (ed), Annual Report for 2007 for the UK National Tide Gauge Network and Related Sea Level Science, National Tide and Sea Level Facility, NERC 100017897 2007, p.2 -worst storm surge in 50y -local minor flooding Lowestoft -storm surge forecast in real time
LCW (20071123)	Lloyd's Casualty Week, Weather and Navigation, pp17-20, Nov23/2007 -100s people evacuated from low areas of eastern England -Great Yarmouth closed to traffic as Yare River rose nearly to bridge surface; defences breached in town centre
North Norfolk News (2007)	North Norfolk News, Surge floods prompt new erosion fears, 14 November 2007, 01:00, Happisburgh Village Website, http://www.happisburgh.org.uk/press/nnn141107.html -20 houses flooded Walcott; waves over sea wall -families sought shelter other places
RWS (2007)	RWS, Verslag van de Stormvloed van 9 november 2007 (SR88), Ministerie van Verkeer en Waterstaat, Direktoraat-Generaal Rijkswaterstaat Waterdienst, Stormvloedwaarschuwingsdienst/SVSD, Postbus 17, 8200 AA Lelystad www.svsd.nl, Lelystad, november 2007, 45pp -dike watch on entire coast for first time since 1976
Tagesspiegel	Der Tagesspiegel, Orkan 'Tilo'. Duenenabbruch kostet Helgoland Millionen, 09/11/2007,

(2007)	16:55 (mit AFP/ddp) -500 people evacuated overnight from eastern England; Great Yarmouth streets under water -Hamburg flooding: Fischmarkt, Speicherstadt, Hafen-City
Upstream20071109_wells	Upstream, Rob Wells, 09Nov2007, Passing storm keeps platforms shut -England east coast storm surge 20cm lower than expected
Eden (2008)	Eden, Philip, Weather Log, November 2007, Weather, 63(1), i-iv, 2008. -coastal flooding was very limited in eastern England
Lefebvre (2008)	Lefebvre, Christiana, Orkan TILO am 8. und 9. November 2007, DWD report 01Jan2008 -bank areas flooded in Emden, Bremerhaven, Hamburg
Piotkowitz and Soerensen (2008)	Piotkowitz, 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 -Tilo was one of 20 Danish storm surges 1991-2008 acknowledged for compensation by the Danish Storm Council (DSC)
POL (2009)	POL, Annual Report 2007-2008, Proudman Oceanographic Laboratory, 40pp, 13May2009 -minor flooding Lowestoft
MetOffice (2011/05/11)	MetOffice, Storm surge - November 2007, Met office website last updated 11May2011.https://www.metoffice.gov.uk/about-us/who/how/case-studies/floods-2007. -water level 10cm below sea wall Great Yarmouth -number of minor floods in Norfolk & Suffolk -breach of sea defenses in Suffolk -no loss of life; some damage to property. -offshore winds meant that waves were not an issue
Environment Agency (2012)	Environment Agency, Thames Barrier Project Pack 2012, Environment Agency -no damage to people or property behind the Thames Barrier; flood contained in estuary
Esurge_2007_tilo (2012)	Esurge_2007_tilo (2012), North Sea surge (2007) by Phillip Harwood 2012/11/01 18:00 -maximum storm surge in UK at Lowestoft -'number of minor breaches in Norfolk & Suffolk with some damage to property' -Netherlands; 'first ever operational closure of the Maeslantkering, but no significant flooding resulted' -Germany: flooding recorded
AON Benfield (2013)	AON Benfield, Historie von 1703 bis 2012: Winterstuerme in Europe, Stand: Januar 2013 -500 people evacuated eastern England -several streets in Great Yarmouth under water
WIKI20180324	WIKI, Liste der Sturmfluten an der Nordsee, copied 2018/03/24, https://de.wikipedia.org/wiki/Liste_der_Sturmfluten_an_der_Nordsee -worst flooding in Hamburg since 1900

Table S19. Storm Tilo/Andrea: surge reports and quantitative water levels (arranged by year and then alphabetically)

Source	Full Reference and Notes
Bradshaw (2007)	Bradshaw, Elizabeth (ed), Annual Report for 2007 for the UK National Tide Gauge Network and Related Sea Level Science, National Tide and Sea Level Facility, NERC 100017897 2007 -monthly min/max for absolute water levels & skew surges -reference points for UK tide gauges
Heyken (2007)	Heyken, Herma, Schwere Sturmflut an niedersachsischer Nordseekuste - Dunnenabbruche auf den Inseln, 09/11/2007, NLWKN Niedersachsischer Landesbetrieb fuer Waserwirtschaft, Kuesten- und Naturschutz. -max skew surge: Norderney (2.55m), Langeoog (2.53m), Spiekeroog (2.58m), Wangerooge (2.63m), Knock (3.11m), Emden (3.29m), Emssperrwerk (3.44m), Leyhoern (2.78m), Benserziel (2.76m), Leuchtturm Alte Weser (2.46m), Wilhelmshaven (3.08m), Cuxhaven (2.91m)

	-Dike watch on Ostfriesen islands
KIT20071117	KIT20071117, Sturm, Schnee, Regen. Mitteleuropa/Schwarzes Meer 09.-13.11.2007 (text CE), Karlsruhe Institute of Technology, Wettergefahren-Fruehwarnung, Institut fuer Meteorologie und Klimaforschung, Samstag, 17.November 2007, 18:00MEZ -skew surge Hamburg 3.33m uMThw
Met Office (2007)	Met Office, 2007. Daily Weather Summary, November 2007 -east coast skew surge reported at 2-2.5m
RWS (2007)	RWS, Verslag van de Stormvloed van 9 november 2007 (SR88), Ministerie van Verkeer en Waterstaat, Direktoraat-Generaal Rijkswaterstaat Waterdienst, Stormvloedwaarschuwingsdienst/SVSD, Postbus 17, 8200 AA Lelystad www.svsd.nl, Lelystad, november 2007, 45pp FIG7.1. Time series water level, tide, surge for Vlissingen 08Nov 1200-09Nov 1200; surge=2.5m, meas=3.65m, tide=2.25m FIG7.2. Time series water level, tide, surge for Roompot buiten 08Nov 1200-09Nov 1200; surge=2.5m, meas=2.6 m, tide=1.7m FIG7.3. Time series water level, tide, surge for Hoek van Holland 08Nov 1200-09Nov 1200; surge=2.0m, meas=3.15m, tide=2.0m FIG7.4. Time series water level, tide, surge for Den Helder 08Nov 1200-09Nov 1200; surge=2.0m, meas=2.7m, tide=0.8m FIG7.5. Time series water level, tide, surge for Hoek van Holland 08Nov 1200-09Nov 1200; surge=2.6m, meas=2.6m, tide=1.2m FIG7.6. Time series water level, tide, surge for Den Helder 08Nov 1200-09Nov 1200; surge=2.7m, meas=4.2m, tide=1.5m
Tagesspiegel (2007)	Der Tagesspiegel, Orkan 'Tilo'. Duenenabbruch kostet Helgoland Millionen, 09/11/2007, 16:55 (mit AFP/ddp) -Hamburg skew surge 3.30m; absolute water level 5.42m uNN -Helgoland skew surge 2.50m; absolute level 3.70m uNN -Gandersum skew surge 3.44m -Emden skew surge 3.29m -Wilhelmshaven skew surge 3.08m
Heyken (2008)	Heyken, Herma, 15 Sturmfluten sind keine Boten des Klimawandels, in Herma Heyken (ed), Jahresbericht 2007, NLWKN Niedersaechsicher Landesbetrieb fuer Wasserwirtschaft, Kuesten- und Naturschutz, pp14-15, Norden, April, 2008 -Norderney skew surge level: 09Nov2007: 2.55m; 01Nov2006: 2.55m; 12Jan2007: 2.16m; 18Mar2007: 2.16m
Lefebvre (2008)	Lefebvre, Christiana, Orkan TILO am 8. und 9. November 2007, DWD report 01Jan2008 -skew surge Helgoland 2.50 MThw -skew surge Emssperrwerke 3.28m MThw -skew surge Hamburg ~3.30m MThw; absolute level 5.42m over Normalnull
Outzen et al (2008)	Outzen, O., K. Herklotz, H. Heinrich, C. Lefebvre, Extreme waves at FINO1 research platform caused by storm 'Tilo' on 9 November 2007, DEWI Magazin No. 33, August 2008. -max water level=32.7m -skew surge 2.8m above mean high tide (29.9m) -4.7m above chart datum (28.0m at FINO1)
Badewien et al (2009)	Badewien TH, E Zimmer, A Bartheloma, R Reuter, Towards continuous long-term measurements of suspended particulate matter (SPM) in turbid coastal waters, Ocean Dynamics (2009) 59: 227-238, DOI 10.1007/s10236-009-0183-8 -FIG13b: time series water level at Station Watt
POL (2009)	POL, Annual Report 2007-2008, Proudman Oceanographic Laboratory, 40pp, 13May2009 -Sheerness: max surge=2.3m; surge at hightide1=0.9m; surge at hightide2=1.0m -Lowestoft: max surge 2.1m; surge at hightide1=0.7m; surge at hightide2=1.7m
Reuter et al (2009)	Reuter R, TH Badewien, A Bartholoma, A Braun, A Luebben, J Rullkoetter, A hydrographic time series station in the Wadden Sea (southern North Sea), Ocean Dynamics, DOI 10.1007/s10236-009-0196-3, 2009 -absolute water level & derived skew surge

Gonnert and Buss (2009)	Goennert, Gabriele & Thomas Buss, Sturmfluten zur Bemessung von Hochwasserschutzanlagen, Berichte des Landesbetriebes Strassen, Bruecken und Gewaesser Nr.2/2009, Freie und Hansestadt Hamburg, Landesbetrieb Strassen, Bruecken und Gewaesser, Hamburg, ISSN 1867-7959 -Cuxhaven max water level 944cm (NN=500cm); maximum surge 279cm; high tide 676cm (NN=500cm) -Time series graph of the water levels & surge levels at Cuxhaven
Herrling et al (2010)	Herrling, Gerald, Heiko Knaack, Ralf Kaiser, Hanz D. Niemayer, Evaluation of design water levels at the Ems-Dollard estuary considering the effect of a storm surge barrier, Coastal Engineering 2010. -time series water level at Emden -maximum water levels along Ems-Dollard estuary
Environment Agency (2012)	Environment Agency, Thames Barrier Project Pack 2012, Environment Agency -Sheerness true surge +2.39m -Sheerness resultant tide (total water level NN=0m?) 3.73m & 3.58m (successive semi-diurnal tides)
Zorndt et al (2012)	Zorndt AC, T Schlurmann, I Grabemann The influence of extreme events on hydrodynamics and salinities in the Weser estuary in the context of climate impact research, Coastal Engineering 2012.[document date stamp 11Oct2012] -figure of water levels for 20days for Leuchtturm Alte Weser and Bremerhaven Alte Leuchtturm
AON Benfield (2013)	AON Benfield, Historie von 1703 bis 2012: Winterstuerme in Europe, Stand: Januar 2013 -Hamburg storm surge 3.33m -storm surge German coast 2.3-3.3m
Loewe (2013)	Loewe,P, Atmosphaerenphysik, pp37-114, System Nordsee. 2006 & 2007: Zustand und Entwicklungen, ed. by P. Loewe, H. Klein, S. Welgelt-Krenz, Berichte des Bundesamtes fuer Seeschifffahrt und Hydrographie, Nr.49/2013 -Cuxhaven skew surge during TILO: 290cm
Kristandt et al (2014)	Kristandt, J., B. Brecht, H. Frank, H. Knack, Optimization of empirical storm surge forecast-modeling of high resolution wind fields, Die Kuste, 81, 301-348, 2014 -Norderney skew surge 255cm -comparison with other storms at Norderney
VH (2016)	Vlaamse Hydrografie, Overzicht van de tijwaarnemingen langs de Belgische kust. Periode 2001-2010 voor Nieuwpoort, Oostende en Zeebrugge, Ministerie van de Vlaamse Gemeenschap, Agentschap Maritieme Dienstverlening en Kust, Afdeling Kust, Vlaamse Hyrografie, Oostende, 38pp, document time stamp 24Feb2016, author='beirenro' -quantitative wave levels & high tide levels for Nieuwpoort, Oostende & Zeebrugge -skew surge can be calculated
Herrling et al (2017)	Herrling G, Benninghoff, Zorndt A, Winter C, Drivers of channel-shoal morphodynamics at the outer Weser estuary, Coastal Dynamics 2017, Paper No. 261, pp.333-345 -time series graph of water level at Bremerhaven Alter Leuchtturm -statement that water levels at Bremerhaven Alter Leuchtturm reached 4.75m
Jensen et al (2017)	Jensen J, S Niehuser, A Arns, S Dangendorf, Sensor- und risikobasiertes Fruhwarn-system fuer Seedeiche (EarlyDike), AP1 - Sturmflutmonitoring und Sturmflutssimulator - Fachbericht 2016, Siegen, April 2017 -Tilo storm residual time series for Cuxhaven shown in FIG4-4 with maximum value ~2.7m
WIKI20180324	WIKI, Liste der Sturmfluten an der Nordsee, copied 2018/03/24, https://de.wikipedia.org/wiki/Liste_der_Sturmfluten_an_der_Nordsee -water levels: St Pauli NN+5.42m; CuxhavenNN+4.44m (Windstau 2.79m)

Table S20. Storm Tilo/Andrea: surge barrier closures (arranged by year and then alphabetically)

Source	Full Reference and Notes
BBC (20091109a)	BBC, North Sea flood tide fears recede, Fri 09 November 2007, 1033GMT

	-Thames Barrier already being rain 1000GMT 09Nov2007 -Maeslant barrier closed at Rotterdam (Europe's largest port) for first time since construction 1990s -1/2h for barrier doors to close -barrier to remain closed until 1700
BBC (20091109b)	BBC, Thousands go home after tide fear, Friday 9 November, 16:50GMT -Thames barrier closed for main storm tide & next one -Rotterdam giant storm surge barrier closed for first time
Heyken (2007)	Heyken, Herma, Schwere Sturmflut an niedersachsischer Nordseekuste - Dunnenabbruche auf den Inseln, 09/11/2007, NLWKN Niedersachsischer Landesbetrieb fuer Waserwirtschaft, Kuesten- und Naturschutz. -Emssperrwerk bei Gandersum in Landkreis Leer closed Friday morning
Horsburgh (2007)	Horsburgh, Kevin, Foreword, in Bradshaw, Elizabeth (ed), Annual Report for 2007 for the UK National Tide Gauge Network and Related Sea Level Science, National Tide and Sea Level Facility, NERC 100017897 2007, p.2 -accurate water level forecasts to within 8cm for Sheerness -Sheerness predictions important for Thames barrier
LCW (20071123)	Lloyd's Casualty Week, Weather and Navigation, pp17-20, Nov23/2007 -Maeslantkering closed for first time since opening 2007 -Thames barrier closed as precaution
RWS (2007)	RWS, Verslag van de Stormvloed van 9 november 2007 (SR88), Ministerie van Verkeer en Waterstaat, Direktoraat-Generaal Rijkswaterstaat Waterdienst, Stormvloedwaarschuwingsdienst/SVSD, Postbus 17, 8200 AA Lelystad www.svsd.nl, Lelystad, november 2007, 45pp -barriers closed: Oosterscheldekering, Maeslantkering, Hartelkering -barrier remaining open: Stormvloedkering in de Hollandsche Ijssel
Tagesspiegel (2007)	Der Tagesspiegel, Orkan 'Tilo'. Duenenabbruch kostet Helgoland Millionen, 09/11/2007, 16:55 (mit AFP/ddp) -Maeslant barrier closed for first time since construction 1997 -all storm barriers in Netherlands closed -dyke gates & protection closed in Germany
Lefebvre (2008)	Lefebvre, Christiana, Orkan TILO am 8. und 9. November 2007, DWD report 01Jan2008 -12 surge defences in Niedersachsen closed, including Emssperrwerke -Netherlands closed Rotterdam surge defence, opened in 1997.
Herrling et al (2010)	Herrling, Gerald, Heiko Knaack, Ralf Kaiser, Hanz D. Niemayer, Evaluation of design water levels at the Ems-Dollard estuary considering the effect of a storm surge barrier, Coastal Engineering 2010. -Gandersum surge barrier closed during Tilo
Groen and Caires (2011a)	Groen, Geert and Caires, Sofia, Storm Catalog The Netherlands, nov 2011, KNMI/Deltares. http://projects.knmi.nl/hydra/stormcatalogus/index.htm (accessed 15June2019 after being placed back online by Josine Camps) -first operational closure of Nieuwe Waterweg & Maeslantkering
Groen and Caires (2011b)	Groen Geert & Caires Sofia, Summary 09-11-2007, nov 2011b, KNMI/Deltares. http://projects.knmi.nl/hydra/stormcatalogus/Cases/05_09-11-2007/Samenvatting/samenvatting.html -first operational closure of Nieuwe Waterweg & Maeslantkering
Environment Agency (2012)	Environment Agency, Thames Barrier Project Pack 2012, Environment Agency -Thames Barrier activated; construction completed 1983, opened May 1984
Esurge_2007_tilo (2012)	Esurge_2007_tilo (2012), North Sea surge (2007) by Phillip Harwood 2012/11/01 18:00 -first operational closure of Maeslantkering in the Netherlands
Zorndt et al (2012)	Zorndt AC, T Schlurmann, I Grabemann The influence of extreme events on hydrodynamics and salinities in the Weser estuary in the context of climate impact research, Coastal Engineering 2012.[document date stamp 11Oct2012] -Britta 2006 & Tilo 2007 storm surges did not cause any losses because of high level of

	protection on German coastline by dikes & flood barriers.
AON Benfield (2013)	AON Benfield, Historie von 1703 bis 2012: Winterstuerme in Europe, Stand: Januar 2013 -Rotterdam port closed -all surge barriers Netherlands closed
Stoffelen (2014)	Stoffelen, Ad, Modelling Surges, Cork eSurge Training 20-21 Feb 2014. -closure of Maeslantkering 09Nov2007 for first time since construction -surge info for design from 1988 -anticipated closure rate ½ per 5 years -mention of other Netherlands barriers: Oosterschelde, Krimpen a/d Ijssel, Maeslantkering, Hartelkering
Weissenberger and Chouinard (2015)	Weissenberger S and O Chouinard, Adaptation to Climate Change and Sea Level Rise, Springer Briefs in Environmental Science, 2015. -closure of Delta Works dams during TILO
WIKI20180324	WIKI, Liste der Sturmfluten an der Nordsee, copied 2018/03/24, https://de.wikipedia.org/wiki/Liste_der_Sturmfluten_an_der_Nordsee -first closing of Maeslantkering surge barrier Rotterdam

Table S21. Storm Tilo/Andrea: beach damage (arranged by year and then alphabetically)

Source	Full Reference and Notes
Heyken (2007)	Heyken, Herma, Schwere Sturmflut an niedersachsischer Nordseekuste - Dunnenabbruche auf den Inseln, 09/11/2007, NLWKN Niedersachsischer Landesbetrieb fuer Waserwirtschaft, Kuesten- und Naturschutz. -dune breaches: Hammersee, Langeoog, Spiekeroog, Wangerooge -8 million euros spent on extra dune protection previous summer
Tagesspiegel (2007)	Der Tagesspiegel, Orkan 'Tilo'. Duenenabbruch kostet Helgoland Millionen, 09/11/2007, 16:55 (mit AFP/ddp) -massive damage on Helgoland dunes -severe dune collapse Juist, Langeoog, Spiekeroog, Wangeroog - report NLWKN
Heyken (2008)	Heyken, Herma, 15 Sturmfluten sind keine Boten des Klimawandels, in Herma Heyken (ed), Jahresbericht 2007, NLWKN Niedersaechsicher Landesbetrieb fuer Wasserwirtschaft, Kuesten- und Naturschutz, pp14-15, Norden, April, 2008 -dune collapse: Juist (at Hammersee), Langeoog (Pirolatal), Spiekeroog (Suderdunen), Wangeoog (Harlehorn) -dune chain massively strengthened summer 2007 -winter 2006/7 threatened complete breakthrough of dune chain; further breaks on 09Nov2007
Lefebvre (2008)	Lefebvre, Christiana, Orkan TILO am 8. und 9. November 2007, DWD report 01Jan2008 -significant dune collapse in Helgoland where surge water levels 2.50m over MThw -some reports of dune collapse on islands & coast of North Sea
AON Benfield (2013)	AON Benfield, Historie von 1703 bis 2012: Winterstuerme in Europe, Stand: Januar 2013 -dune collapses on Langeoog & Juist
Loewe (2013)	Loewe,P, Atmosphaerenphysik, pp37-114, System Nordsee. 2006 & 2007: Zustand und Entwicklungen, ed. by P. Loewe, H. Klein, S. Welgelt-Krenz, Berichte des Bundesamtes fuer Seeschifffahrt und Hydrographie, Nr.49/2013 -significant dune collapses on Ostfrisian Islands during BRITTA & TILO
WIKI20180324	WIKI, Liste der Sturmfluten an der Nordsee, copied 2018/03/24, https://de.wikipedia.org/wiki/Liste_der_Sturmfluten_an_der_Nordsee -massive dune collapses on Helgoland

Table S22. Storm Tilo/Andrea: list bridge closures, cancelled ferry crossings, port closures, airport cancel, rail interruptions (arranged by year and then alphabetically)

Source	Full Reference and Notes
BBC (20071109b)	BBC, Thousands go home after tide fear, Friday 9 November, 16:50GMT -Felixstowe port closed -rail line flooded Norwich-Lowestoft
KIT20071117	KIT20071117, Sturm, Schnee, Regen. Mitteleuropa/Schwarzes Meer 09.-13.11.2007 (text CE), Karlsruhe Institute of Technology, Wettergefahren-Fruehwarnung, Institut fuer Meteorologie und Klimaforschung, Samstag, 17.November 2007, 18:00MEZ -earliest opening wintersport towns of Lech & Zurs since 1974 -high level of avalanche threat in Alps
LCW (20071123)	Lloyd's Casualty Week, Weather and Navigation, pp17-20, Nov23/2007 -bridges closed to high-sided vehicles: Skye, Kessock, Tay, Forth; Erskine central Scotland completely closed -ferry operator Caledonian MacBrayne cancelled 6 crossings with a dozen more disrupted by weather (interruped services: Ullapool to Stornaway; Mallaig to Canna) -Rotterdam & Hamburg ports closed -some ferries to East Frisian islands cancelled -storm closed Vagar airport in Faroe Islands; ferry & bus companies suspended services (Nov8?) -a few ferry crossings between Sweden, Norway & Denmark have been cancelled (Denmark Road Directorate)
Tagesspiegel (2007)	Der Tagesspiegel, Orkan 'Tilo'. Duenenabbruch kostet Helgoland Millionen, 09/11/2007, 16:55 (mit AFP/ddp) -ferries to Germany Ostfriesen islands stopped -ship traffic jam in front of Antwerp -Kiel Canal closed because of high water; ship traffic jam
AONbenfield (2013)	AON Benfield, Historie von 1703 bis 2012: Winterstuerme in Europe, Stand: Januar 2013 -Rotterdam port closed

Table S23. Storm Tilo/Andrea: structural damage to wind farms & buildings (arranged by year and then alphabetically)

Source	Full Reference and Notes
North Norfolk News (2007)	North Norfolk News, Surge floods prompt new erosion fears, 14 November 2007, 01:00, Happisburgh Village Website, http://www.happisburgh.org.uk/press/nnn141107.html -decking on Cromer pier splintered
Outzen et al (2008)	Outzen, O., K. Herklotz, H. Heinrich, C. Lefebvre, Extreme waves at FINO1 research platform caused by storm 'Tilo' on 9 November 2007, DEWI Magazin No. 33, August 2008. -damage to FINO1 platform 15m working deck from wave strike.
Hessner (2011)	Hessner, K., Extreme wave analysis at FINO1 during TILO storm event Nov. 8-9, 2007, Ocean WaveS GmbH data report for DONG Energy Power A/S, OceanWaveS GmbH, Hansekontor, Vor dem Bardowicker Tore 6b, 21339 Luneburg, Germany, July 2011 -FINO1 working platform damage
Caithness Windfarm (2018/08/05)	Caithness Windfarm, Wind Turbine Accident and Incident Compilation, 2018/08/05 -3 wind energy accident reports from Scotland 07-08Nov2007

Table S24. Storm Tilo/Andrea: general ship/rig emergency reports/offshore incidents/platform evacuations (arranged by year and then alphabetically)

Source	Full Reference and Notes
Aftenposten	Aftenposten, Ekofisk og Valhall evakueres for stormen.1500 ansatte pa oljefeltene kofisk og

20071106	Valhall i Nordsjoen kan bli evakuerte for den forventede storm Andrea natt til fredag. 06Nov2007 13:35 -Evacuation of Valhall & Ekofisk from Thursday 08Nov2007 -1400 people from Ekofisk moved to other platforms or land
BBC (20071107a)	BBC, North Sea flood tide fears recede, Fri 09 November 2007, 1033GMT -Norway forced to close several oil platforms off coast; Norway 5th largest exporter crude oil -Norway production 220000bpd expected to be slashed by 10%; expected increase in crude world prices
BBC (20071107b)	BBC, Thousands go home after tide fear, Friday 9 November, 16:50GMT -platforms off Norway closed
Guardian (20071112)	The Guardian, Environmental disaster as Russian tanker sinks, Mon, 2007/11/12, 09:18 GMT (reporter: Luke Harding, Moscow) -ship disaster in Black Sea; Volganeft-139 oil spill described
KIT20071117	KIT20071117, Sturm, Schnee, Regen. Mitteleuropa/Schwarzes Meer 09.-13.11.2007 (text CE), Karlsruhe Institute of Technology, Wettergefahren-Fruehwarnung, Institut fuer Meteorologie und Klimaforschung, Samstag, 17.November 2007, 18:00MEZ -outline of Black Sea storm events; tanker sinking with 2000t oil
Kustwachtcentrum (2007/11/09)	Kustwachtcentrum, Persbericht, Noordwester storm, Info nr.1, 09Nov/2007 -4 ship events associated with sea state off Netherlands coast
LCW(20071123)	Lloyd's Casualty Week, Weather and Navigation, pp17-20, Nov23/2007 -Norwegian oil production to be cut by 10% or 220000 barrels/day after BP closes Valhall & ConocoPhillips planned to shut 5 Ekofisk field platforms -BP spokesman said Valhall expected to be down for a few days; total suspended 80000 Bpd production -press report Nov10: oil production on Norwegian shelf back to normal after 7 platforms closed down before before storm hit North Sea Thursday Nov8 -700 oil workers evacuated from most exposed platforms as precaution on Wed & Thu (Nov 7 & 8) -NRK: no reports of serious damage or injuries -loss of 6.5 million NOK in income for company StatoilHydro
Met Eireann (200711)	Met Eireann, Monthly Weather Bulletin, No.259, November 2007. -outline of ship sinkings/groundings during Black Sea storm
PON (2007)	PON_1_2007_data (MS Excel spreadsheet, 'published on 12/03/2013'), hyperlink access from: https://www.gov.uk/guidance/oil-and-gas-environmental-alerts-and-incident-reporting, Oil and gas: environmental alerts and incident reporting including anonymous reporting. (spreadsheet downloaded 14Sep2018, document timestamp 15Jun2012) -UK.GOV spreadsheet with 2 cases of offshore platform leakages from severe weather
Telegraph (20071111)	The Telegraph, Ecological disaster feared after tanker sinks, (contributor: Paul Eccleston) (11Nov2007) -ecological disaster with oil spill from Volganeft-139 -6 other ships ran aground
Upstream20071107_pitt	Upstream, Anthea Pitt, 07Nov2007, Evacuations under way as storm roars in -evacuation from Ekofisk (ConocoPhillips) & Valhall (BP) -Valhall shutting end of 07Nov2007 -subsidence at Ekofisk (6-7m) & Valhall -StatoilHydro has no plans to shut production -no platform evacuations UK sector
Upstream20071109_davis	Upstream, Jonathan Davis, 2007/11/09, Storm Downs Nexen's Buzzard -Buzzard platform production shut down; 1 of 3 power generation turbine exhaust stacks damaged -StatoilHydro resumed production at Visund & Oseberg South -Statoil closed 9 platforms in Nsea sector; worried about lifeboat capacity at Heimdal & Gran fields -ConocoPhillips had shut down 7 platforms; previously indicated 5
Upstream2007110	Upstream, Michael O'Neill, 2007/11/09, Storms force Ekofisk closures

9_oneill	-ConocoPhillips closed 7/16 platforms in Ekofisk field; originally planned 5/16 -StatoilHydro planned 320000 boed lost production; ended up with 110000 boed lost production -Visund platform restarted night Nov8-9; Oseberg south restarted later Nov 9
Upstream20071109_wells	Upstream, Rob Wells, 09Nov2007, Passing storm keeps platforms shut -same info O'Neill report -England east coast surge 20cm lower than expected
Upstream20071112_pitt	Upstream, Anthea Pitt, 12Nov2007, Storm clips Buzzard's wings -Buzzard platform remained closed on Monday after storm because of damage to 1 of 3 turbine exhaust stacks
Lefebvre (2008)	Lefebvre, Christiana, Orkan TILO am 8. und 9. November 2007, DWD report 01Jan2008 -significant damage to Forschungsplattform Nordsee (FINO1) -Norway suspended operations on Nsea oil/gas & some shipping suspended
Outzen et al (2008)	Outzen, O., K. Herklotz, H. Heinrich, C. Lefebvre, Extreme waves at FINO1 research platform caused by storm 'Tilo' on 9 November 2007, DEWI Magazin No. 33, August 2008. -wave damage to FINO1 research platform
Magnusson (2009)	Magnusson, A.K., Forecasting extreme waves in practice, May 19, 2009, Rogue waves 2008, Brest, France, 13-15 Oct., 2008. http://www.ifremer.fr/web-com/stw2008/rw -first years EXWW 3h forecast sufficient -Ekofisk demobilization procedures started 2005-2006; needs 3d forecast Hs -Hs=9m considered threshold for action -measuring systems have peak clipping -TILO evacuations not explicitly mentioned
AONbenfield (2013)	AON Benfield, Historie von 1703 bis 2012: Winterstuerme in Europe, Stand: Januar 2013 -Norway oil production interrupted

Table S25. Storm Tilo/Andrea: instrument failures during storm (arranged by year and then alphabetically)

Source	Full Reference and Notes
RWS (2007)	RWS, Verslag van de Stormvloed van 9 november 2007 (SR88), Ministerie van Verkeer en Waterstaat, Direktoraat-Generaal Rijkswaterstaat Waterdienst, Stormvloedwaarschuwingsdienst/SVSD, Postbus 17, 8200 AA Lelystad www.svsd.nl, Lelystad, november 2007, 45pp -wave & meteorological instruments with data gaps
Outzen et al (2008)	Outzen, O., K. Herklotz, H. Heinrich, C. Lefebvre, Extreme waves at FINO1 research platform caused by storm 'Tilo' on 9 November 2007, DEWI Magazin No. 33, August 2008. -FINO1 waverider buoy reported to be nonfunctional during TILO storm.
Goennert and Buss (2009)	Goennert, Gabriele & Thomas Buss, Sturmfluten zur Bemessung von Hochwasserschutzanlagen, Berichte des Landesbetriebes Strassen, Bruecken und Gewaesser Nr.2/2009, Freie und Hansestadt Hamburg, Landesbetrieb Strassen, Bruecken und Gewaesser, Hamburg, ISSN 1867-7959. -36h failure of Scharhorn met station during storm TILO evening 08Nov2007 to morning 10Nov2007 -partial failure of Cuxhaven tide gauge 20:00-23:00 09/11/2007
Magnusson (2009)	Magnusson, A.K., Forecasting extreme waves in practice, May 19,2009, Rogue waves 2008, Brest, France, 13-15 Oct., 2008. http://www.ifremer.fr/web-com/stw2008/rw -data gap in waverider record 03:00 Nov9/2007 before maximum Hs 06:30
Magnusson (2009b)	Magnusson AK, 2009, 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. -radio transmission interruption from Waverider 1.5km from receiver at Ekofisk during high sea state
Herrling et al (2010)	Herrling, Gerald, Heiko Knaack, Ralf Kaiser, Hanz D. Niemayer, Evaluation of design water levels at the Ems-Dollard estuary considering the effect of a storm surge barrier, Coastal

	Engineering 2010. -data gaps in time series water level at Emden.
Hessner (2011)	Hessner, K., Extreme wave analysis at FINO1 during TILO storm event Nov. 8-9, 2007, Ocean WaveS GmbH data report for DONG Energy Power A/S, OceanWaveS GmbH, Hansekontor, Vor dem Bardowicker Tore 6b, 21339 Luneburg, Germany, July 2011 -data gaps in AWAC & WAMOSII wave instrumentation
Magnusson (2011)	Magnusson, Ann Karin, True sea state ...? Comparing different sensors and analyzing techniques, 12th Wave Workshop, Hawaii's Big Island, Oct.30-Nov4, 2011 (32 slides) -bias in Waverider and MRF at sea states >8m probably due to MIROS quality control procedures. -LASAR system seems okay but with some spikes and data gaps
Magnusson and Donelan (2013)	Magnusson, AK and MA Donelan, The Andrea wave. Characteristics of a measured North Sea rogue wave, Journal of Offshore Mechanics and Arctic Engineering, 135, 1-10, 2013 -short data gaps in LASAR record -AIGR parameter & sea spray plume after crest of Andrea wave

Table S26. Storm Tilo/Andrea: model results and fields (arranged by year and then alphabetically)

Source	Full Reference and Notes
KIT20071117	KIT20071117, Sturm, Schnee, Regen. Mitteleuropa/Schwarzes Meer 09.-13.11.2007 (text CE), Karlsruhe Institute of Technology, Wettergefahren-Fruehwarnung, Institut fuer Meteorologie und Klimaforschung, Samstag, 17.November 2007, 18:00MEZ -maps of 500hPa geopotential & ground pressure 06-13Nov2007 -maps of 850hPa geopotential & temperature 06-13Nov2007
RWS (2007)	RWS, Verslag van de Stormvloed van 9 november 2007 (SR88), Ministerie van Verkeer en Waterstaat, Direktoraat-Generaal Rijkswaterstaat Waterdienst, Stormvloedwaarschuwingsdienst/SVSD, Postbus 17, 8200 AA Lelystad www.svsd.nl, Lelystad, november 2007, 45pp -FIG3.1: Map 08Nov 1900M: wind speed, wind direction, surface air pressure; max wspd near coast SW Norway -FIG3.2: Map 08Nov 2200M: wind speed, wind direction, surface air pressure; max wspd near coast SW Norway -FIG3.3: Map 09Nov 0400M: wind speed, wind direction, surface air pressure; max wspd near coast SW Norway -FIG3.4: Map 09Nov 1000M: wind speed, wind direction, surface air pressure; max wspd near coast SW Norway -FIG3.5: Map 09Nov 1600M: wind speed, wind direction, surface air pressure -FIG3.6: Map 09Nov 2200M: wind speed, wind direction, surface air pressure
Magnusson et al (2008)	Magnusson, A.K., J. Johannessen, K.-F. Dagestad, O. Breivik, O.J. Aarnes, B. Furevik, Bolge-strom interaksjon til nytte for oljeindustri, WACUSAR_sluttrapport.doc, 19/12/2008 -wave model map results for North Sea & special Karmoy case study
Magnusson (2009)	Magnusson, A.K., Forecasting extreme waves in practice, Proceedings Rogue waves 2008, ed. by Michel Olagnon and Marc Previsto, Brest, France, 13-15 Oct., 2008. http://www.ifremer.fr/web-com/stw2008/rw (pdf date stamp May 19,2009). -FIG12: ECMWF prediction on 6-240h time scales; U10, Hs, Tp at Ekofisk -FIG13: Map of forecast wave field by ECMWF model +84h & +96h. Oldest forecast closest to Ekofisk waverider -FIG14: Map of forecast Hs 08Nov2007 18UTC at +54h for WAM10 & +66h from ECMWF. Storm maxima in W Nsea -FIG15: Map of forecast Hs +33h at 08Nov2007 with ECMWF, WAM fine/course resolution
Herrling et al (2010)	Herrling, Gerald, Heiko Knaack, Ralf Kaiser, Hanz D. Niemayer, Evaluation of design water levels at the Ems-Dollard estuary considering the effect of a storm surge barrier, Coastal Engineering 2010. -FIG4. Wind speed & direction map over northwest Europe during storm TILO, 09Nov2007 0900UTC.

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 -model field analysis of TILO with trajectory diagnostic
Magnusson (2011)	Magnusson, Ann Karin, True sea state ...? Comparing different sensors and analyzing techniques, 12th Wave Workshop, Hawaii's Big Island, Oct.30-Nov4, 2011 (32 slides) -gridded fields of wind speed, wind direction, sea level pressure at 09Nov2007 at 00:00UTC -modelled Hs field in North Sea & south Norwegian Sea with Ekofisk indicated; highest Hs field near Norwegian coast
Esurge_2007_tilo (2012)	Esurge_2007_tilo (2012), North Sea surge (2007) by Phillip Harwood 2012/11/01 18:00 -NOC storm surge model of North Sea
Magnusson and Donelan (2013)	Magnusson, AK and MA Donelan, The Andrea wave. Characteristics of a measured North Sea rogue wave, Journal of Offshore Mechanics and Arctic Engineering, 135, 1-10, 2013 -FIG4. Hindcast fields of winds, surface pressure, and waves from NORA10 database. Left: mean sea level pressure with wind arrows. Right: Hs with arrows for mean wave direction
Brecht and Frank (2014)	Brecht, B and H Frank, High resolution modelling of wind fields for optimization of empirical storm flood predictions, Adv/ Sci. Res., 11, 1-6, 2014. -FIG3. Wind field over Nsea for storm TILO 09Nov2007 06:00UTC, 3h before maximum water level at Norderney. 10m wspd in knots. 2hPa pressure intervals. Blue dots location verification stations.
Stoffelen (2014)	Stoffelen, Ad, Modelling Surges, Cork eSurge Training 20-21 Feb 2014. -TILO convection cells resolved with high resolution 1.7km Harmonie with assimilated Quikscat -TILO map of model predictions of surface wind speed southern North Sea with Qscat
Capellen email 25Sep1999	Email from John Capellen DMI on 25Sep1999 -Natl/Europe wind speed field 0600UTC 09Nov2007

Table S27. Storm Tilo/Andrea: climatological background of storm (arranged by year and then alphabetically)

Source	Full Reference and Notes
Met Eireann (2007)	Met Eireann, Monthly Weather Bulletin, No.259, November 2007. -driest autumn in more than 20years; driest in Birr since 1933 -autumn mean air temperature 1-2C above normal -County Mayo stations had warmest autumn on record; most other stations lower than autumn 2006 -torrential rain and floods/landslides in Tabasco, Mexico starting Oct 28; worst flooding in 5 decades -heavy rain in Algeria between Nov24-28 -heavy rain in Vietnam starting on Oct 26 and continues until mid-November -severe to extreme drought in China across much of south of country -heavy snowfall in Europe cause ski resorts to open early; 500mm snow near Vienna on Nov. 15; Zurich had heaviest snowfall since 1955.
Eden (2008)	Eden, Philip, Weather Log, November 2007, Weather, 63(1), i-iv, 2008. -mean max temperature Nov2007 1C higher than 1971-2000 mean in all regions -mean min temperature 2.5C above normal in Scotland & N Ireland by at normal in England
Heyken (2008)	Heyken, Herma, 15 Sturmfluten sind keine Boten des Klimawandels, in Herma Heyken (ed), Jahresbericht 2007, NLWKN Niedersaechsicher Landesbetrieb fuer Wasserwirtschaft, Kuesten- und Naturschutz, pp14-15, Norden, April, 2008 -15 storm surges in 1 year not indication of climate change -interannual variability ofsurge frequency; 1950-1960s low; 1970s-1990s high; 2006-2008 high -highest hurricane floods Norderney in 1963 & 1976 -Britta & Tilo were worst storm surges; 2 other severe surges 12Jan2007 & 18Mar2018 with

	Norderney level 2.16m -record June skew surge of 1.32m (2.88m uNN) on 26Jun2007; prev record 2.75m uNN 29June 1960 -unusual inland flooding in southern Niedersachsen. -FIG. Time series 1936-2007 Norderney storm surge numbers
Bancroft (2008)	Bancroft, George P, Marine Weather Review - North Atlantic Area. September through December 2007, Mariners Weather Log, Vol 52, No 1, April 2008. -in terms of winds, TILO strongest storm in this part of Atlantic basin in 3 month period
Reuter etal (2009)	Reuter R, TH Badewien, A Bartholoma, A Braun, A Luebben, J Rullkoetter, A hydrographic time series station in the Wadden Sea (southern North Sea), Ocean Dynamics, DOI 10.1007/s10236-009-0196-3, 2009 -winters 2006-7 & 2007-8 significantly warmer than usual -very high warming trend at station Wattenmeer 2002-2009
Metoffice (20110511)	MetOffice, Storm surge - November 2007, Met office website last updated 11May2011. https://www.metoffice.gov.uk/about-us/who/how/case-studies/floods-2007. -storm surges are likely to be higher & more frequent under climate change, as early as this century
Loewe (2017)	Loewe,P, Atmosphaerenphysik, pp37-114, System Nordsee. 2006 & 2007: Zustand und Entwicklungen, ed. by P. Loewe, H. Klein, S. Welgelt-Krenz, Berichte des Bundesamtes fuer Seeschifffahrt und Hydrographie, Nr.49/2013 -2006/2007 warmest in 130 year weather record -temperatures 3K above normal in all months & seasons -Omega blocking high phenomenon -Britta & Tilo assessed as worst storm surges of 100y; significant dune collapse Ost-Frisian islands

S12 Record of manuscript reviews and corrections

Manuscript modifications following referee reports

Referee 1:

The figure 5 is important and as such displays its information clearly. But I have a problem being sure if the various wiggly lines and short bars depicting the progression of the tide and the position of the events actually agree in position well or not? Could a numerical estimate of the match between various of the graphical elements be designed, and then a quantitative piece of information be presented? Such a measure could then be exposed to Monte Carlo testing and the significance of its value be understood.

Author's Response:

Figure 5 is a summary diagram of all the data sets plotted on axes of time versus distance around the North Sea. It shows the progression of the surge peak, semi-diurnal tidal peaks, short period oscillations, and infrastructure incidents. The figure indicates that there may be relationships in time and location among the geophysical parameters and the infrastructure events.

The reviewer has suggested if there is a way to compare the different graphical elements in the figure. The easiest way to do this is a pair-wise comparison of the individual datasets and a statistical analysis of their time offsets. An example of this is shown in Figure S5 of the Supplementary Material for a comparison of the offshore events and the short period oscillations. Of the full set of offshore events, a subset of eight was selected on the basis of precise time reports. The histogram of the time difference between these events and the highest down-crossing oscillation at the nearest the tide gauge station indicates that half of the events occurred within two hours of the highest oscillation.

The reviewer has suggested a sophisticated Monte Carlo approach to assess significance of this kind of result. This was not done because of the sparse nature of the data set and possible reporting biases for the infrastructure events. The conference presentation was intended as general overview of the events of one storm, and journal page limitations prevent the expansion of the manuscript is this direction. The reviewer's suggestion of a sophisticated statistical analysis may be useful if the phase relationships among the different data sets that were observed for Storm Tilo are also seen for other storms.

Author's Changes in Manuscript

The following sentence was added to the manuscript:

> Figures S5 of the Supplementary Material focuses on the pairwise comparison of the offshore events and the highest short period oscillations of the closest tide gauge station, and it suggests that there may be a close relationship between these data sets.

Referee 1:

1) I don't know what a 'skew surge' is. It is probably straightforward to explain, and may well be a common phrase in some research areas, but it does not immediately explain itself to me. I'd suggest it can be explained, as this would increase the accessibility to a wider audience.

Author's Response:

The definition of the skew surge is included in the updated manuscript and a reference is made to Williams et al (2016). 'Skew surge' is the difference between the maximum measured sea level during a storm event and the expected high tide level based on a model.

Author's Changes in Manuscript:

Two sentences in the manuscript have been changed:

> The height of the measured of the measured water level above the expected high tide prediction (i.e., skew surge; William et al., 2016) is an important parameter to assess the impact of storm surge coastal flooding. For this study, the height of the maximum measured water level (Fig. 3a) minus the median of the high tide peaks for period of the analysis of 1–14 November 2007 is shown for different locations around the North Sea in Fig. 4.

Additional sentences have been added to the header for Table S3 in the Supplementary Material for clarification of the literature reports of skew surge:

> Note that the different national sea level agencies have slightly different methods of reporting the skew surge concept. For example, in the UK it is calculated as the measured water level minus the expected high tide level based on a model of the different spectral tide components over a long period. In Germany, the skew surge concept is reported as the measured water level minus the average of the high tide levels over a long period of time.

Referee 1:

2) On Page 7 near lines 11 and 12 I would like to see a few more details on this 'e folding decay time' - what is it and what is the physics behind it? A good reference is enough for the interested reader.

Author's response:

The referee is correct, and the passage has been changed to give more information on the e-folding decay time.

Author's Change in Manuscript:

The following passage has been added to manuscript:

> The technical literature recognizes that the extreme water level fluctuations associated with tsunamis and harbour seiches last for periods of hours to days, oscillating at particular frequencies before decaying out through frictional energy losses (Pugh, 1987; Murty, 1977; Pattiaratchi and Wijeratne, 2015). Many published time series recordings of the phenomena show approximately exponentially decreasing trends. Murty (1977, p.243) quantifies the trend in terms of a 'decay constant', which would correspond to the inverse of the e-folding time in his mathematical treatment, and Dean and Dalrymple (1991) give more information on the mathematical description of exponentially decaying long waves.

Referee 1:

3) Also on page 7 near line 27 we are told that sea-levels have exceeded numerical model predictions - I am fine with the idea, but some references are needed. Elaborating this part of the evaluation of the project outcome could strengthen future uses of the method employed in the work.

Author's Response:

The referee is correct, and the passage has been clarified with references.

Author's Change in the Manuscript:

The revised sentence now appears as:

> On the other hand, storm flood levels during Storm Britta exceeded the numerical model predictions that encapsulate the understanding of storm surge dynamics (RWS, 2006a,b; RWS, 2007a), and certain reports indicate there may have been a high risk of coastal dyke breaches and flooding (Ulm et al., 2018).

Referee 2:

(1) you should add an atmospheric Figure showing storm Tilo dynamics - perhaps show a series of MSLP/surface wind maps (each hour or something) or plot a center of cyclone minimum on one map (so map, cross to mark position of cyclone minimum and hour of cyclone minimum at one location, then at the next location, and so on...).

Author's Response:

For background meteorological information, the original EGU 2019 poster presentation had an infrared satellite cloud image, time series graph of wind speed at the North Sea Ekofisk platform, and a schematic map showing energy infrastructure impacts. Journal page constraints prevent the inclusion of extra meteorology graphs in the main manuscript, so additional information has been included in the Supplementary Material.

Author's Change in Manuscript

In the Supplementary Material, a section has been added near the end with tabulated working notes for the project. One of the thematic tables lists meteorological information that has been located in different published reports. As well, three figures from the EGU 2019 poster have been added to the Supplementary Material: an AVHRR cloud satellite image from the storm (Figure S8), time series wind speed and wave height data from the central North Sea (Figure S9), and a schematic map showing the main energy infrastructure impacts (Figure S10).

Referee 2.

(2) You seem to confuse spectral analysis with filtering throughout the paper. I would say that you first did spectral analysis, from this you have determined appropriate cut-off periods, and then did filtering to obtain time series shown in Figure 3 and used for subsequent analysis. Is this so or you did something else? If yes, please give characteristics of the filter which you have used.

Author's Response:

The referee is correct that the spectral analysis was conducted first and then two cut-off periods were chosen to define three bands with characteristic short periods, intermediate periods (tide), and long periods (surge). The procedure is based on Stull (1988) and described in the Methods section of the manuscript. The cut-off periods are given in the Methods section and shown graphically in Figure 2. The procedure might also be described in terms of spectral filters, and the cut-off periods described in terms of square or top-hat filters. However, this filter terminology was not used by Stull (1988), who described the process in terms of a time series reconstruction from different frequency bands. The submitted manuscript retains this terminology as it makes clear that the original time series can be simply reconstructed by adding up the three different frequency components given in the report. For some readers, 'filtering' terminology might give the impression that some characteristics of the data were lost or masked.

Author's Change in Manuscript:

No alterations were made for this comment.

Referee 2:

(3) Please add references throughout the manuscript wherever you give some claims above something (below I list some examples, but there are more instances you do not provide references for your claims!)

Author's Response:

The referee is correct that extra references are required in certain sections.

Author's Change in Manuscript:

Extra references have been added in the manuscript at the points indicated by the two referees. The Supplementary Material has an extra section with tables of references used in this work, divided according to the different storm impacts.

Minor comments:

Referee 2:

Page 2. Line 15. " and possibly other dynamic features that are poorly understood" - which other dynamic features? List them, and provide a reference.

Author response:

The referee is correct that there should be more information in this paragraph on the hypotheses for large wave events.

Author's Change in Manuscript:

This paragraph was split in two, and the following passage was placed in the new second paragraph:

> The underlying physical mechanisms that give rise to these types of wave events are unclear. The presentation of Rosenthal et al. (2008) shows the model results of a ship-type wake pattern in the context of the Storm Britta but with much larger proportions that might result from a travelling low pressure centre. In an investigation of the New Year's Day storm of 1995, Rosenthal et al. (2011) highlights that two notable ship accidents in the northern and southern parts of the North Sea occurred under the same convective cloud band, and there is a possibility of a concentration of wave energy along atmospheric convergence lines in the flow direction of certain offshore storms. Another hypothesis relates to a resonant amplification of travelling wave groups from atmospheric gust structures moving at nearly the same speed during certain winter storms with open cloud cell convective structures (Rosenthal et al., 2011; Pleskachevsky et al., 2012).

Referee 2:

Page 2. Line 19. Add reference for Hurricane Katrina.

Author's Response:

The referee is correct that there should have been a reference here.

Author's Change in Manuscript:

The sentence has been changed to:

> During hurricanes and cyclones at low latitudes, maximum surge levels can reach 9 m (Pugh 1987), and for Hurricane Katrina in the northern Gulf of Mexico water levels of 7.5 m were recorded (Muir-Wood and Grossi, 2008).

Referee:

Page 4. Regarding spectral analysis. I suggest creating an additional wavelet plot for this station - it would show more clearly during which time interval energy increased, and at which periods.

Author's response:

The Fourier spectral analysis in the manuscript was conducted as part of a procedure to separate the measured water level data into three components corresponding to sea surge, tides, and harbour seiches. A separate wavelet analysis

would be interesting as a follow-on project, but it was not the part of original EGU 2019 conference poster presentation. Journal page constraints prevent the extension of the analysis in this direction.

Author's Change in Manuscript:

No change in the manuscript has been made.

Referee:

Page 4. Lines 19-21. Add references for mentioned meteotsunami cut-off periods.

Author's response:

The referee is correct, and references to two overview papers have been included here.

Author's change in manuscript:

The sentence in the manuscript now appears as:

> Other investigations of meteotsunamis have used similar filtering techniques to isolate the meteotsunami signal from the tide, and different frequency cutoff thresholds have been used corresponding to periods that vary between 2 and 6 hours (Monserrat et al, 2006; Pattiaratchi and Wijeratne, 2015).

Referee:

Page 5. You say that "Most of the reports give fairly precise information on the location and time of the accidents, and it is possible to compare them with the short period oscillation features observed in the water level data." - but I believe most of these off-shore accidents should be related to infragravity waves - and your tide gauges have a too long sampling period (10 min) to catch these waves. Please clarify.

Author's response

The referee is correct. The manuscript already contained a passage in the results section explaining the link between the wave accidents and the tide gauge signal:

> Because the short period oscillations have amplitudes of tens of centimetres and periods on the order of tens of minutes to hours, they do not directly record the wave field that was identified as a contributing factor in several offshore incidents. On the other hand, they indicate where an analysis of wave data recordings might be targeted for insight into the offshore incidents.

Author's change in manuscript

The additional passage has been added to the manuscript at the point indicated by the referee:

> Although some of the infrastructure events may have been caused by large infragravity waves whose time duration would be too short to register on tide gauges (e.g., KNRM, 2007), the impact of these waves on nearby coasts and harbours may have excited transient harbour seiches with periods on the order of 10's of minutes, which is within the measurement capability of water level recorders.

Referee 2:

Page 5. Line 20. "Eeceed" -> "exceeding"

Author's response:

The referee is correct.

Author's change in manuscript:

The typo has been corrected

Referee 2:

Page 5. Line 25. "to the tide" -> "to the tide propagation speed". Also is this statement that speeds are comparable made just visually, or were the speed estimated/calculated from data? If you are to make this claim, please estimate/calculate speeds from data.

Author's response:

The referee is correct that this passage needed to be changed or better supported.

Author's change in manuscript:

The passage has been changed to highlight the feature and suggest possible different geophysical hypotheses that might be tested in other work:

> Among some of the stations showing longer period oscillations, there are instances of temporal offsets that may be due to shallow water wave propagation or be linked with the field of moving atmospheric convection cells over the North Sea.

Referee 2:

Figure 2. Please add confidence intervals.

Author's response:

The referee is correct. An error analysis of the spectral graph has been carried out.

Author's change in manuscript:

A new spectral graph has been produced for the manuscript with the average and standard deviation uncertainty shown. An estimate of the noise level has been made. The figure caption has been changed and now reads:

> **Figure 2. Spectrum of the 14 day water level time series from Lerwick, UK. The original 15 minute time series was subsampled to give three data sets of 45 minute resolution from which the spectral mean and standard deviation uncertainty could be calculated, as shown. The noise level was estimated based on the standard deviation of the first difference of the original time series.**

Referee 2:

Figure 3. Graphs are very hard to read. As you have a really huge number of stations, I suggest that you to only every third station. No information will be lost - and it will be much easier to read the figures.

Author's Response:

I agree with the referee that there are too many lines on this plot.

Author's change in manuscript

Figure 3 in the main manuscript has now been changed to show every second station. The original figure with all the stations has been moved to the Supplementary Material. The caption of Fig. 3 has an extra sentence:

The plot shows a subset of time series data from 38 stations, and the full data set of 76 stations used in this project is shown in the Supplementary Material.

Addition Changes in the Manuscript and Supplementary Material

-The acknowledgements section has an extra sentence for the referee contributions in improving the manuscript.

-In the Supplementary Material three extra maps of the offshore events and tide gauge stations have been added, showing subsets of the information from Figure 1 of the manuscript.