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Review of: El Niño influence over South America during the mid-holocene

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Abstract. This work reports on the relationship between the Pacific Ocean sea surface temperature variability and precipitation over South America in the IPSL coupled model simulations of the present and the 6kyr Before Present (Mid-Holocene) climate. The model results suggests that the control exerted by ENSO on precipitation in South America was less frequent in the Mid-Holocene compared to the present climate and that the spatial distribution of the ENSO influence is considerably different in the two periods.

1 Introduction

This work analyzes the ENSO impact on precipitation in South America for model simulations of the present climate and the Mid-Holocene (6000 years BP) performed by the Institut Pierre et Simon Laplace. These simulations were performed in order to check the feedback of the climatic system to changes due to seasonal contrasts of incident solar radiation at the top of the atmosphere. The Mid-Holocene period shows an increase of the seasonal cycle in the Northern Hemisphere and a decrease in the Southern Hemisphere due to changes in the Earth orbital parameters, especially the precession of the equinoxes (Braconnot et al., 2000).

Experiments with coupled ocean-atmosphere climate models (Clement et al., 2000; Liu et al., 2000) suggest that ENSO (El Niño/Southern Oscillation) events were smaller in amplitude and occurred less frequently in the Mid-Holocene. The onset of ENSO-like variability appears to have occurred in the Mid-Holocene and it is verified in records of past ENSO events (McGlone et al., 1992; Sandweiss et al., 1996; Rodbell et al., 1999; Gagan et al., 2004).

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2 Model and simulations

The model in this study is the coupled ocean/atmosphere climate model of the Institut Pierre et Simon Laplace (IPSL) which is composed by an atmospheric component based on the Laboratoire de Météorologie Dynamique (LMD), version 5.3, while the oceanic component is the "Océan Parallélisé" without flux correction. A complete description of the model and of the experimental design is provided by Braconnot et al. (1997) and Braconnot et al. (2000). Coupling between the atmosphere and ocean occurs once a day. River and coastal runoff dynamics are included, but restricted to the 46 major rivers around the world. The atmospheric model includes a land surface scheme to compute the water and energy exchanges between land and atmosphere, which depends on the vegetation type and soil moisture.

The following simulations are used in this work:

- TB1 experiment – Present Day climate (only the last 70-years of a 150-year simulation were taken). Ocean and atmosphere interact each other, and vegetation is taken from observed modern climatology;

- TH1 experiment – Mid-Holocene climate (the last 70-years of a 150-year simulation was taken). Biome distribution was prescribed as present conditions but the Earth's Orbital parameters were prescribed as in the Paleoclimate Modelling Intercomparison Project.

First of all, a Principal Component Analysis was carried out in order to explore the structure of the spatial and temporal variability of the Pacific Ocean modes and to identify possible changes between the present and the Mid-Holocene patterns. This technique was applied to the Pacific Ocean surface temperature data, for the 70-year monthly series sets of both TB1 and TH1 simulations, and the selected area extends from 40° S to 20° N and from 140° E to 70° W, with resolution of $5° \times 5°$. Afterwards, the relationship between the derived modes and the precipitation over South America through heterogeneous correlation maps was evaluated.

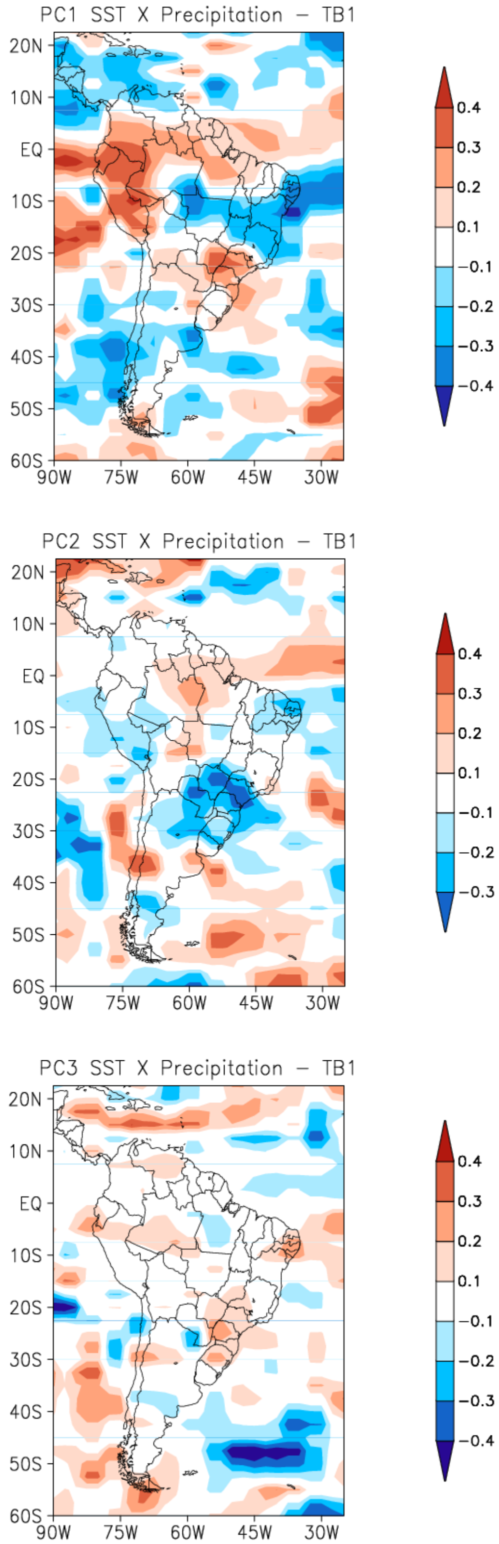

Fig. 1. Heterogeneous correlations maps between the three first modes of Pacific Ocean SST and precipitation for TB1 simulations. The colored regions emphasize the significant correlations at the 95% level.

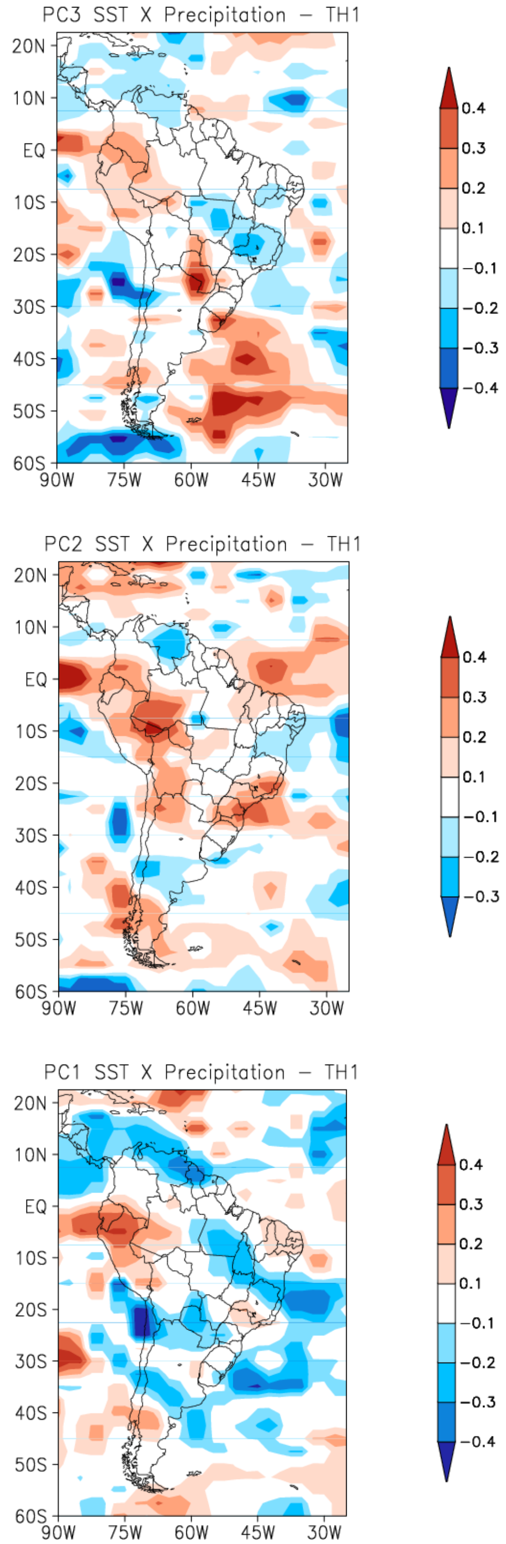

Fig. 2. Heterogeneous correlations maps between the three first modes of Pacific Ocean SST and precipitation for TH1 simulations. The colored regions emphasize the significant correlations at the 95% level.

3 Results

Accordingly to North's rule of thumb (North et al., 1982) three modes for TB1 and four for TH1 were kept. Therefore, only the first three modes are considered and its patterns are associated to the ENSO variability in tropical Pacific Ocean. These modes accounts for 31.7% and 34.4% of the total variance for TB1 and TH1, respectively.

The first mode derived in this work resembles the first variability mode of the Pacific obtained by Weare and Nasstron (1982). The first mode represents the anomalous heating in the Eastern tropical Pacific, which extends over the central Pacific (El Niño). During the Mid-Holocene, a total variance increase for the first mode was verified, indicating that this mode was more important in the past, despite the fact that the frequency of occurrence was lower. The second principal component shows a dipole pattern, with the inversion of the coefficients at approximately 5° S, and it is similar for both periods.

A relationship between the third derived principal component in this study and the mode obtained by Weare and Nasstron (1982) was observed and it represents a particular phase of ENSO episodes (marked for anomalies with contrary signal at both Eastern and Western Tropical Pacific). This mode, which represents most of the total variance in TB1, together with the first one, suggests the displacement of the maximum variability of the coastal region of the South America along the Equator during several months. Significant differences have also been observed in the spatial distribution of the two periods and both time series are characterized by interannual oscillations. However, in TH1 the interdecadal variability is more prominent.

The heterogeneous correlation maps of precipitation for TB1 and TH1 are shown in Figs. 1 and 2, respectively. The relationship between precipitation and the first mode of the Pacific Ocean surface temperatures is defined in the two periods and relevant differences can be observed. In Northwestern South America, in both cases, there is a positive relationship between the time series of the amplitude of this mode and precipitation, indicating an increase of precipitation associated with El Niño events. However, this relationship spreads over a significantly larger region in TB1. In Northeastern Brazil, where it is known that precipitation is inhibited during events of El Niño (Ropelewski and Halpert, 1987), this behaviour is evident only in TB1. Moreover, a positive correlation on part of the south and southeast of Brazil was verified, while this relationship is barely detected in TH1.

For the second sea surface temperature mode, differences in the heterogeneous correlation for precipitation appears on Southestern and Southern Brazil in both TB1 and TH1. However, TB1 and TH1 have inverted patterns of the correlation maps. A significant positive relationship is observed only in the TH1 experiment over Northwestern Sotuh America.

Finally, the relationship between the third sea surface temperature mode and the precipitation field is not highly significant over the continent in TB1 (Fig. 1c). However, there are regions in the TH1 (Fig. 2c) case where the heterogeneous correlations are more significant (positive in Northwestern South America and Paraguay and negative in Southeastern and Central Brazil).

4 Conclusions

The principal mode of sea surface temperature variability in the Pacific Ocean, the ENSO mode, accounts for most of the total variance during the Mid-Holocene, although its dominant frequency was lower. El Niño phenomenon remote influence in the South American precipitation is different in both periods and the areas with particularly relevant changes are the Northeastern and Northwestern South America, as well as Southern and Southeastern Brazil. These regions have well established relationships between precipitation and El Niño in the present (Kousky and Ropelewski, 1989; Rao and Rada, 1990; Grimm et al., 2000), but they were significantly different in the Mid-Holocene. These differences can be associated to changes in some global patterns of the atmospheric circulation, such as the Hadley and Walker cells and the Subtropical Jet Stream (stronger in the Southern Hemisphere during the Mid Holocene spring) due to the changes in the solar forcing. The changes in the large scale circulation features have a direct impact on the structure of the rain producing systems in South America, such as the the Intertropical Convergence Zone which was displaced to the south during the mid-Holocene (Braconnot et al., 1999) and the South Atlantic Convergence Zone.

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