The equatorial Atlantic oscillation and its response to ENSO

Abstract An internal equatorial Atlantic oscillation has been identified by analyzing sea surface temperature (SST) observations. The equatorial Atlantic oscillation can be viewed as the Atlantic analogue of the El Niño/Southern Oscillation (ENSO) phenomenon in the equatorial Pacific, but it is much less vigorous. The equatorial Atlantic oscillation is strongly influenced by the Pacific ENSO with the equatorial Atlantic sea surface temperature lagging by about six months. This lag can be explained by the dynamical adjustment time of the equatorial Atlantic to low-frequency wind stress variations and the seasonally varying background state, which favours strongest growth of perturbations in summer. Results of an extended-range simulation with a coupled ocean-atmosphere GCM support this picture.

1 Introduction

Theoretical and modelling studies of tropical air-sea interactions focused mostly on the Pacific Ocean because of the predominance of the El Niño/Southern Oscillation (ENSO) phenomenon, the strongest interannual climate variation (e.g. Philander 1990). Unstable air-sea interactions and the subsurface memory of the ocean are important factors contributing to the ENSO mechanism (e.g. Neelin et al. 1994). The subsurface memory of the system can be expressed in terms of equatorial waves, and one would therefore expect a dependence of the oscillation period on the basin size (Battisti and Hirst 1989). The dominant ENSO period is of the order of about four years. Assuming that the nature of the air-sea interactions in the Atlantic is similar to that in the Pacific, this would imply a considerably shorter period for the Atlantic “ENSO-analogn”, since the basin size of the Atlantic is much smaller than that of the Pacific, and this is indeed the case. In Sect. 2 we show that a weak equatorial Atlantic oscillation exists, while Sect. 3 describes its response to ENSO. We describe the results obtained from a coupled GCM in Sect. 4. The main conclusions are presented in Sect. 5.

2 The equatorial Atlantic oscillation

It has been shown (Servain 1991; Zebiak 1993; Huang et al. 1995; Wright 1987) that the equatorial Atlantic exhibits considerable interannual variability which involves coupled processes similar to those generating ENSO. A four year period was suggested based on model results (Zebiak 1993), but this estimate is inconsistent with the observations which yield a considerably shorter quasi-biennial time scale, as described later. The estimate of a quasi-biennial period is rather stable and obtained by different statistical methods. The primary quantity analyzed is observed SST which was obtained from the GISSST2.2 dataset (Parker et al. 1996). Preliminary results are described in a report by Latif et al. (1996). An equatorial Atlantic SST index (ATL-3) is computed from the observations which is an area average of anomalous SST over the region of strongest equatorial variability (3°N–3°S and 20°W–0°) (Fig. 1a). Standard Fourier and singular spectrum analysis (SSA) were applied, in order to derive the dominant time scale of the SST variability in the equatorial Atlantic. The Fourier spectrum of the ATL-3 time series shows enhanced variability at interannual time scales, with a marginally significant peak at a period of about 30 months (Fig. 1b). Thus, there is considerable variability at the quasi-biennial time scale in equatorial Atlantic SST. In order to test the stability of this result, singular spectrum analysis of the ATL-3 SST index was performed additionally. The SSA confirms the result of the Fourier analysis: the leading mode of the interannual equatorial Atlantic SST variability explaining 20% of the variance is associated with a quasi-biennial time scale. The higher modes explain considerably less variance. The reconstruction using the
leading SSA mode is shown also in Fig. 1a. In summary, the results of the time series analyses show that the quasi-biennial oscillation is the dominant interannual variability mode in the equatorial Atlantic SSTs. Many processes can determine the oscillation period, as discussed by Battisti and Hirst (1989), but the results presented here imply that the role of the basin size is most important in setting the time scale. The quasi-biennial mode undergoes, however, strong interdecadal changes. This is shown by means of wavelet analysis (Torrence and Compo 1998). The time evolution of the wavelet power indicates that the quasi-biennial oscillation was strongest during the period 1950–1980 (Fig. 2). No obvious relationship between the interdecadal ENSO variability in the equatorial Pacific and the interdecadal variability of the equatorial Atlantic oscillation was found.

In order to derive the spatial characteristics of the equatorial Atlantic oscillation, we computed the associated regression pattern of the anomalous SST to the ATL-3 SST index. The equatorial Atlantic oscillation is an inherent Atlantic mode, and strong SST anomalies connected with this mode are found in the equatorial Atlantic only (Fig. 3), where it accounts for up to 90% of the variance in the centre of action. No significant SST anomalies were found outside this region, which demonstrates that the equatorial Atlantic oscillation is not linked to the quasi-biennial variability observed in the Indian and Pacific Oceans described in many papers (e.g. Rasmusson et al. 1990; Barnett 1991; Keppenne and Ghil 1992; Meehl 1993; Barnett et al. 1995).

Fig. 2 Wavelet spectrum of the ATL-3 time series. Time is shown in the y-direction, while the period is shown in the x-direction. The red background estimated by fitting an AR-1 process was subtracted from the wavelet spectrum. The shading indicates regions that exceed the 95% confidence level.

Fig. 3 Spatial distribution of linear regression coefficients (°C) of SST anomalies upon the ATL-3 index. The values are representative of a one-standard-deviation change in the ATL-3 index. The shading shows the variances explained by the regression.