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THE ROLE OF THE SOUTH INDIAN AND SOUTH PACIFIC OCEANS ON THE SOUTH AMERICAN MONSOON VARIABILITY

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1. INTRODUCTION

Many studies have discussed the interannual variability of a meridional seesaw of dry and wet conditions over tropical and subtropical South America (SA) associated to the modulation of the South Atlantic Convergence Zone (SACZ) (e.g. Robertson and Mechoso, 2000).

The modulation of SACZ events or the South American climate in general can be influenced by the sea surface temperature (SST) (e.g. Diaz et al., 1998). For example, several works verified the influence of El Niño-Southern Oscillation (ENSO) events over the South American precipitation (Grimm et al, 1998 and others). Barros and Silvestri (2002) showed that the subtropical south-central Pacific and the central-east equatorial Pacific have a similar effect on the interannual variability of the precipitation over southeastern South America in the Austral Spring. Saji et al. (2005) verified a relationship between the Indian Dipole and the air temperature over the subtropical South America in the Austral Spring.

This work investigates the impact of three different low-frequency SST variability modes located in the Indian and the Pacific oceans over the interannual variability of the South American Monsoon System (SAMS) using observational analysis. A more detailed discussion can be found in Drumond (2005).

2. DATA AND METHODS

The 2ºx2º Reynolds and Smith (2004) SST data, the 2.5ºx2.5º monthly Chen et al. (2002) precipitation anomalies and the 2.5ºx2.5º National Center for Atmospheric Research (NCAR) Reanalysis data set (Kalnay et al., 1996) were used to elaborate this study.

Rotated Empirical Orthogonal Function (REOF) analysis was applied over the normalized Summer (December, January and February, DJF) SST anomalies observed during the period 1950-2001 in the South Pacific+Equatorial Pacific (SEP) (40ºS-18ºN; 120º-286º) and in the Indian (IN) (40ºS-32ºN; 20º-116º) oceans. For each experiment, the modes obtained via EOF were rotated using Normalized Varimax. Extremes events were selected by applying the one standard deviation threshold over their normalized Principal Component time series and they were studied through composites.

3. PRELIMINARY RESULTS

Figure 1 presents the three low-frequency SST variability modes selected for this study. The second mode obtained in the IN region explains 12% of the total variance and it is located around 25ºS;80ºE (figure 1a). Figure 1b shows the second SEP mode (explaining 12,4% of the total variance), which consists in a region extending from the subtropical southwestern Pacific towards the Indonesia, where the maximum loading is located. Finally, The sixth SEP mode explains 6% of the total variance and it consists in a region located over the Southwestern Pacific reaching the maximum value near to the New Zealand (figure 1c).

According to the composites, warmer waters observed in the region of the second IN mode (figure 1a) are associated with enhanced austral summer precipitation over the subtropics (figure 2a). REOF analysis also indicates that warmer waters over the region of the second SEP mode (figure 1b) are associated with drought conditions over the SACZ and enhanced precipitation over the subtropics (figure 2b). On the other hand, warmer waters observed over the region of the sixth SEP mode (figure 1c) are associated with enhanced precipitation over the SACZ and drought conditions over the subtropics (figure 2c).

At high levels, one can see in the composite for the warm events of the second IN mode an anomalous wave train propagating over the Indian Ocean (figure 3a). This train bifurcates on Western Australia, where part of it crosses the continent towards Indonesia and another one propagates in an arch-trajectory towards the Eastern Pacific. In this region, wave propagation can be observed towards the tropics, while another train keeps its propagation over the extratropics. A cyclonic anomaly observed over eastern Brazil is probably associated with the drought in the region. This wave propagation seems to follow the Subpolar Jet, which may act as a wave guide as proposed by Hoskins and Ambrizzi (1993) for the Austral Summer.

The composite for the warm events of the second SEP mode shows an anomalous wave train emanating from the Western Pacific towards South America via subtropics at high levels (figure 3b). An anomalous anticyclonic circulation extending from western South America to southern Brazil is probably associated with the enhanced precipitation over the subtropics.

Finally, one can identify two anomalous wave trains in the composite for the warm events of the sixth SEP mode: one emanating from Indonesia and another one from the Central Pacific (figure 3c). There

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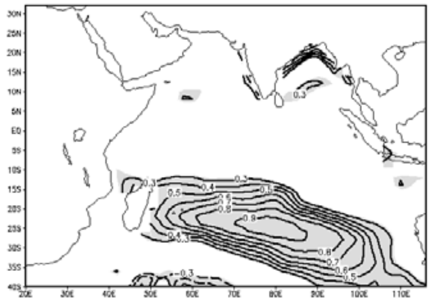
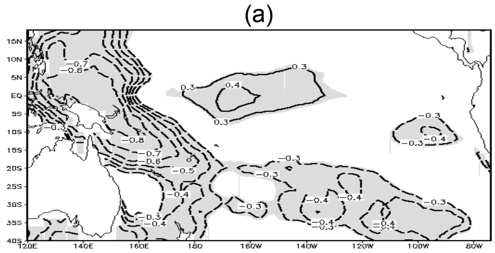
is an anomalous wave train surrounding the southern hemisphere via the extratropics. An anomalous anticyclonic circulation is observed over the tropical South America and it could be associated with the enhanced precipitation over this region. On the other hand, an anomalous cyclonic circulation occurs over the subtropical South America.



(a)



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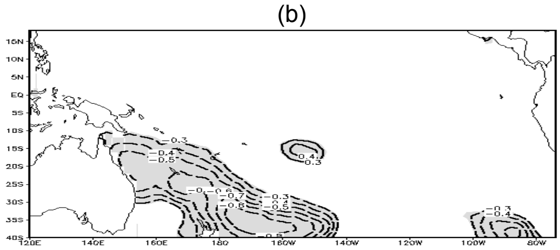
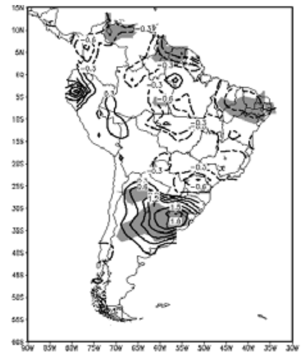


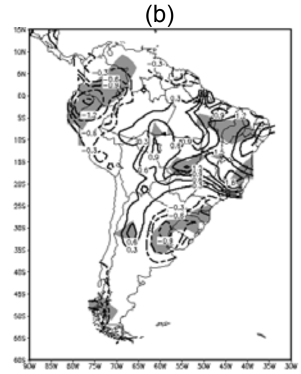
(c)

Figure 1a: Pattern of the second REOF of SST anomalies observed in the IN region during the austral summer; b: the same as a, but for the second REOF observed in the SEP region; c: the same as a, but for the sixth REOF observed in the SEP region. Gray areas indicate regions where the correlation is statistically significant at the 95% level according to the T test. Only correlation coefficients with absolute values higher than 0.3 are indicated, and the interval between the isolines is 0.1. The solid (dashed) isolines represent positive (negative) values.



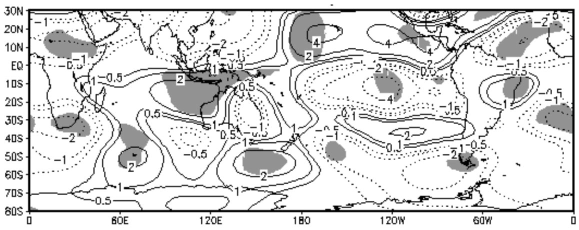
(a)

(b)

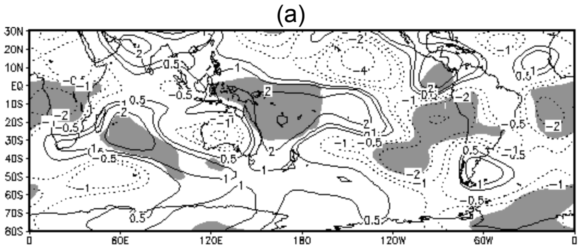


(c)

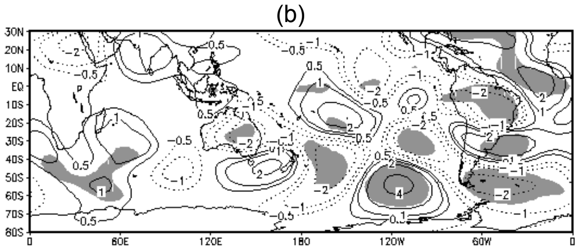
Figure 2a: Composite of DJF precipitation anomalies (mm/day) for the warm extreme events of the rotated 2nd IN mode; b: the same as a, but for the rotated 2nd SEP mode; c: the same as a, but for the rotated 6th SEP mode. The interval of the isolines is 0.3 mm/day. The solid (dashed) isolines represent positive (negative) values. Shaded areas indicate statistically significant anomalies at the 90% level according to the T test.



(a)



(b)



(c)

Figure 3a: Composite of DJF 200hPa anomalous zonally asymetric component of stream function ($x10^6 m^2 s^{-1}$) for the warm extreme events of the rotated 2nd IN mode; b: the same as a, but for the rotated 2nd SEP mode; c: the same as a, but for the rotated 6th SEP mode. The absolute values of the isolines are 0,5; 1; 2; 4: 6 $x10^6 m^2 s^{-1}$. The solid (dashed) isolines are positive (negative) values. Shaded areas indicate statistically significant anomalies at the 90% level according to the T test.

3 DISCUSSION

The aim of this work is to investigate the impact of three different low-frequency SST variability modes located in the Indian and the Pacific oceans over the interannual variability of the SAMS through an observational study. REOF analysis was applied over the Summer SST anomalies observed in the South Pacific + Equatorial Pacific and in the Indian oceans in order to obtain the variability modes. The associated extremes events were studied through composites.

The statistical results suggest that the warmer waters observed in the southern Indian and in the western Pacific oceans could be related to dry conditions over the SACZ and enhanced precipitation over the subtropical South America. On the other hand, warmer waters over southwestern South Pacific could be associated with enhanced precipitation over the SACZ and dryness over the subtropics.

According to the composites for the Indian mode, the wave propagation seems to follow the Subpolar Jet, which may act as a wave guide as proposed by Hoskins and Ambrizzi (1993) for the Austral Summer. The composite for the western Pacific mode shows an anomalous wave train emanating from the Western Pacific towards South America via subtropics in high levels. Finally, the composite for the southwestern south Pacific mode shows two anomalous wave trains: one emanating from Indonesia and another one from the Central Pacific.

We must recall that all these results are obtained through a statistical analysis. In order to evaluate the dynamical hypothesis, numerical experiments forced by the SST modes are being elaborated with the Community Climate Model and their results will be presented elsewhere.

4 ACKNOWLEDGEMENTS

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