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COUPLING BETWEEN SACZ AND SST OF THE ATLANTIC AND PACIFIC OCEANS

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1) INTRODUCTION

Several recent studies have analyzed the influence of the ocean surface temperature anomalies in the South Atlantic Convergence Zone (SACZ) variability. Barros et al. (2000) indicated that warm (cold) sea surface temperature (SST) in the region between 20ºS-40ºS and west of 30ºW is followed by a southerly (northerly) displacement of the SACZ. According to Robertson and Mechoso (2000), the SACZ interannual variability is accompanied by SST anomalies with atmospheric forcing in the southwest Atlantic, with a dipole structure at about 40ºS. This variability is highly independent of the El Niño Southern Oscillation (ENSO). Doyle and Barros (2002) suggested a positive feedback in the interannual scale between positive (negative) SST anomalies in the western part of the Subtropical Atlantic and weak (intense) intensity of the SACZ that intensifies the SACZ low level circulation.

Related to the numerical studies, Barreiro et al. (2002) obtained two responses to the SST anomalous forcing: a local response to the SST anomalies of the South Atlantic, with interannual and decadal time scales, almost without signal over the continent, consisting of a dipole structure in the precipitation near the coast of South America, accompanied by an anomalous clockwise circulation of the surface winds; and a response of SST Pacific anomalies in the interannual time scales, mainly in the high level circulation, consisting of the northward displacement of the SACZ, associated with the precipitation anomalies during warm events of ENSO. Using a regional model, Teixeira et al. (2002) observed that the positioning and the intensity of the SACZ simulated precipitation is influenced by the SST anomalies in the southwestern Atlantic (SACZ position displaced in the direction of the warm water). The regional model produced more (less) precipitation on the regions with positive (negative) SST anomalies. To understand the coupling between the SACZ and the South Atlantic, Chaves and Nobre (2004) carried out a series of experiments with atmospheric and ocean models. These results suggest that negative SST anomalies, generally observed in the SACZ region, represent a response of the ocean to the atmospheric forcing.

With the objective of better understanding the ocean-atmosphere interaction and the SACZ, the relation between SST anomalies and precipitation in South America for the austral summer was evaluated through the Singular Value Decomposition (SVD) technique.

2) DATA AND METODOLOGY

Monthly precipitation data of the Global Precipitation Climatology Project (GPCP; Adler et al., 2003) are used. The data is available from 1979 to l the present in a 2,5º $\times$ 2,5º resolution. The Reynolds and Smith SST dataset (Reynolds et al. 2002) has been used from December of 1981 to the present in a 1º $\times$ 1º resolution.

To evaluate the relationship between SST anomalies and precipitation, the SVD (Bretherton et al., 1992; Wallace et al., 1992) technique was used to identify the variability modes in which the variations of SST and precipitation are strongly coupled. The SVD was applied to monthly precipitation data in South America (40°S the 0 and 65°W 30°W) and SST of the Atlantic (40°S 20°N and 60°W 15°E) and Pacific Ocean (40°S 20°N and 140°E 90°W), separately. This technique was applied to the December-January-February period from 1981 to 2004, and for three monthly lags (1 to 3 months) between precipitation and SST, with the SST lagged with respect to precipitation.

3) RESULTS

For all lagged SVD analysis and for both oceans, the first two modes represent more than 60% of the covariance. As an indicator of the coupling intensity, the correlation between the expansion coefficients of the variables was calculated. The results are presented in Table 1 and all coefficients are statistically significant from the point of view of the t-Student test at the 5% significance level. For the Atlantic Ocean, with exception of the lag 1 case, the second mode presents more intense coupling between the South America precipitation and the SST anomalies. For the Pacific Ocean, in all cases, the coupling is more intense for the first mode and the relationship between the SST and the

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precipitation on the South America is stronger in comparison with the Atlantic Ocean case.

Table 1- Square covariance fraction (SCF) and correlation (R) between the expansion coefficients of the two variables for two first SVD modes.

		SCF		R	
Lag	Mode	Atlantic	Pacific	Atlantic	Pacific
0	1	43,7%	82,7%	0,56	0,82
0	2	18,5%	6,0%	0,64	0,72
1	1	47,2%	82,0%	0,62	0,79
1	2	17,0%	5,6%	0,59	0,72
2	1	40,8%	82,6%	0,52	0,78
2	2	20,7%	5,7%	0,62	0,72
3	1	50,2%	80,7%	0,50	0,76
3	2	15,2%	6,5%	0,57	0,74

Initial analysis of the SVD modes obtained in the Atlantic Ocean indicated that the spatial and time patterns of the precipitation for the first mode are the same for all lags (the dipole pattern representing the SACZ north-south variation). A dipole pattern precipitation was also obtained by other authors (Barros et al., 2000 and Doyle and Barros, 2002).

The time and spatial patterns of the SVD for the zero-lag SST of the Atlantic Ocean is shown in Figure 1. For the first mode, a spatial pattern with negative coefficients in the South Atlantic (up to approximately 30°S), surrounded by two areas of positive coefficients to the north and the south is identified. For the Southern Hemisphere, this variability mode is coherent with the Venegas et al. (1997) and Sterl and Hazeleger (2003) modes, presenting a dipole pattern to the south of the Equator. It has been suggested that there is a linkage with the atmosphere described by the strengthening and weakening of the subtropical anticyclone that seems to force fluctuations in a north-south dipole structure in SST anomalies induced by the wind. The first mode of the tropical region pattern represents the dipole of the Tropical Atlantic and is similar to the oceanic variability mode obtained by Nobre and Shukla (1996). This pattern is anti-symmetrical with respect to the equator, associating a weakening of the trade winds to the warmest SST and a strengthening of the trade winds to the coldest SST anomalies.

In agreement with the first mode described above, the SACZ position displaced to the south (north) would be related to the warm (cold) SST in the south tropical Atlantic and cold (warm) to the south of the analyzed domain (from 30°S), coherent with Doyle and Barros (2002) and Barros (2000). As the Doyle and Barros paper, a feedback between positive (negative) SST anomalies in the subtropical western Atlantic and weak (intense) activity of the SACZ can enhance the circulation at low levels associated to the SACZ "see-saw".

The homogeneous field of precipitation in the second mode is representative of the SACZ (Figure 1d), presenting the Amazonian precipitation and its extension in direction to the Atlantic with NW-SE orientation. Thus, it is possible to associate this mode to the SACZ intensity, and the largest region of SST influence is observed in the tropical South Atlantic. The coupling with the ocean indicates an increase of precipitation associated with warm SST anomalies in the tropical South Atlantic. A possible physical explanation for this coupling is the relationship of this particular oceanic mode with the east-west displacement of the South Atlantic Subtropical High (Venegas et al., 1997). Thus, a displacement to the west of the subtropical high increases the moisture flow towards the continent, thus intensifying the SACZ.

The precipitation pattern for the first mode is approximately the same at all lags. However changes in the SST pattern are observed. For the SST negatively lagged by one month the influence region of the tropical South Atlantic is smaller and intensifies in the tropical north Atlantic. For the second mode, the spatial and time patterns are similar to the pattern displayed in Figure 1 and the main difference is observed in the SST with larger area of negative coefficients.

In the first SST mode negatively lagged by two months, the SST tripole pattern is completely misplaced, with large magnitude in the equatorial Atlantic. In this case, the SACZ is southerly displaced and associated to cold SST anomalies in the equatorial region that intensifies the trade winds and increases the moisture transport towards the continent. The second mode is characterized by the displacement of the precipitation associated to the SACZ, which is to the south with respect to the patterns associated with the previous lags. The second model Atlantic Ocean pattern is similar to the pattern obtained for with one month lag.

Finally, for the first mode SST 3-month lag mode an extension of the region with negative coefficients of the tropical region it is evident. Significant positive coefficients to south of the domain are also observed. The precipitation pattern in the second mode is similar to the pattern obtained with 2-months lag. However, the region of significant coefficients is extended to the south. In this mode, the SST pattern presents a larger area of negative coefficients in the southwest of domain, indicating that cold SST along the southern Brazil coast precedes a position of the SACZ to the south during the summer.

The SVD for the Pacific Ocean indicated the same variability modes at all lags. Therefore, only one of the cases is discussed (lag 0 shown in Figure 2). The same precipitation pattern is obtained in the first mode of the Atlantic Ocean and for the SST the pattern presents variability of the tropical region in the interannual scale. This mode represents the anomalous heating in the Tropical East Pacific that extends to the central Pacific, associated to the ENSO phenomenon (Weare and Nasstron, 1982; Enfield and Mayer, 1997). In this case a SACZ position to the south (north) is associated with the El Niño phase (La Niña). This result is coherent with the Ropelewiski and Halpert (1987) and Grimm et al. (2000) studies, where it is shown that there is an increase (reduction) of the precipitation in southeast South America (Uruguay, Paraguay and the subtropical part of Argentina and Brazil) during the warm phase (cold) of ENSO.

The second mode presents a precipitation pattern with negative coefficients on a large part of the domain. For SST pattern indicates a dipole structure of the anomalies in the tropical region, with interannual variability. Thus, an increase of the SACZ precipitation should be associated with warm SST anomalies in eastern Pacific and with cold anomalies in western Pacific.

4) CONCLUSIONS

The evaluation of the relationship between SST and precipitation, through the SVD analysis, lead to the identification of coupled SST anomalies modes and precipitation during the austral summer and SST lagged negatively in relation to the precipitation. The first mode for the Atlantic Ocean indicates that when the SACZ is displaced to the south (north), the warm (cold) SST is observed in the south tropical Atlantic and cold (warm) SST anomalies to the south of the domain (south of 30°S). For the lagged SST anomalies, the north-south displacement of the SACZ is mainly related to the tropical SST. For the second mode, the precipitation field is associated to the SACZ intensity, and the region with stronger SST influence is in the tropical South Atlantic. This coupling indicates that the increase of precipitation is associated with warm SST anomalies in the tropical South Atlantic and a similar pattern is verified at all lags. For the Pacific Ocean, the same spatial structure is observed at all lags and modes. The precipitation pattern in the first mode is similar to the first mode of the Atlantic Ocean (dipole) and it indicates that a southerly (northerly) displaced SACZ is associated with the El Niño (La Niña) event. The second mode is associated to an increase of the SACZ precipitation and warm SST anomalies in the East Pacific and to cold anomalies in the West Pacific.

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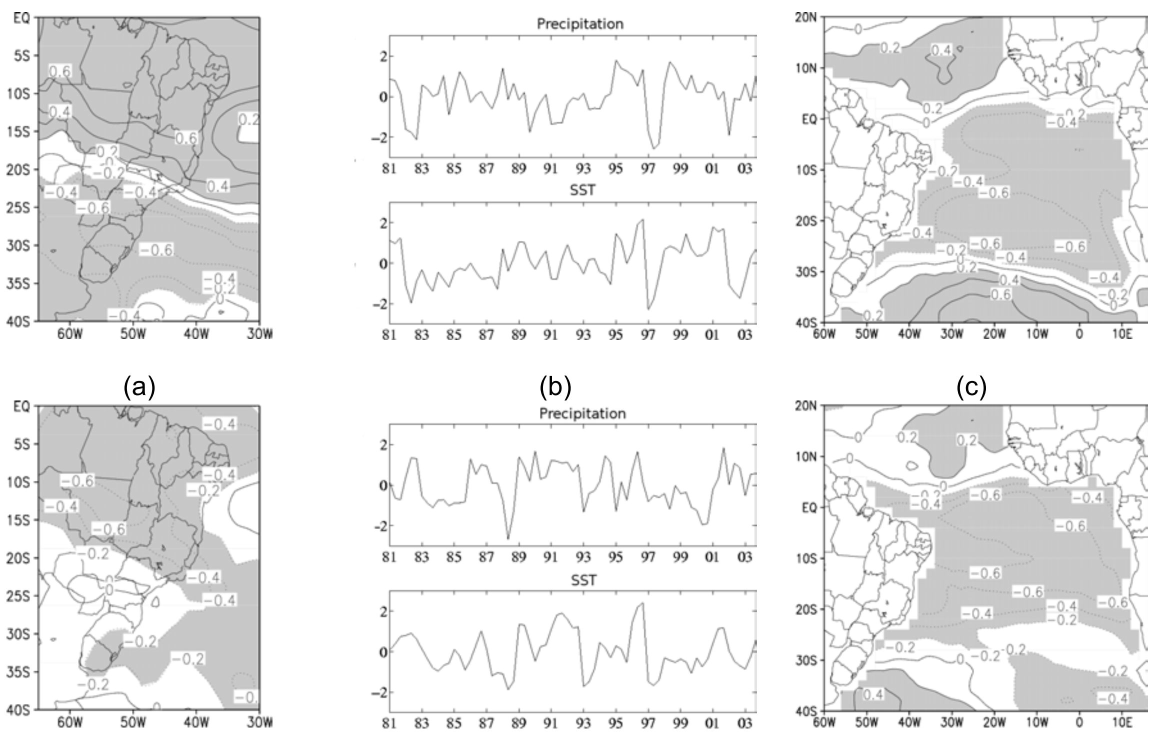
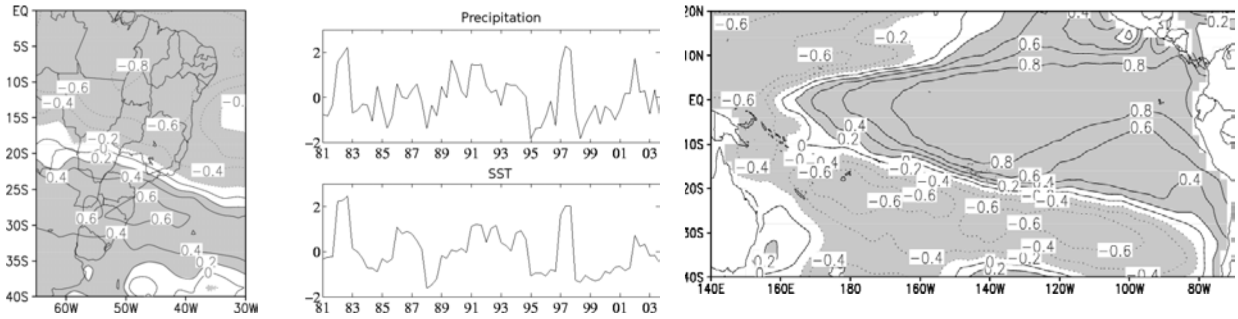


(d) (e) (f)

Figure 1- Spatial patterns and expansion coefficients of first (a, b and c) and second (d, e and f) coupled modes of the normalized precipitation anomalies and SST of the Atlantic Ocean. The spatial patterns are the homogeneous maps of correlation. The shading emphasizes the statistically significant regions, for the test t-Student, to the 5% level of significance.



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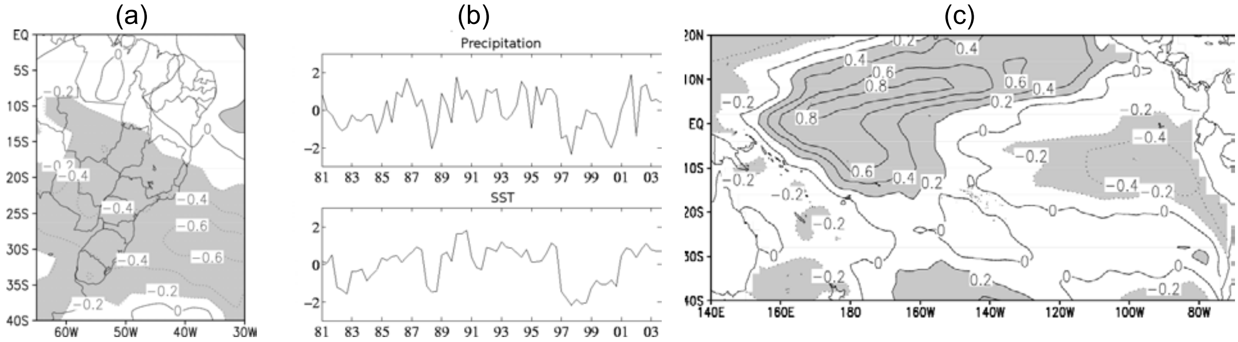

(d) (e) (f)

Figure 2 - Spatial patterns and expansion coefficients of first (a, b and c) and second (d, e and f) coupled modes of the normalized precipitation anomalies and SST of the Pacific Ocean. The spatial patterns are the homogeneous maps of correlation. The shading emphasizes the statistically significant regions, for the test t-Student, to the 5% level of significance.