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DIFFERENT EL NIÑO INTENSITIES AND THEIR IMPACT ON THE SOUTH AMERICAN LOW-LEVEL JET EAST OF THE ANDES DURING THE AUSTRAL SPRING

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1.INTRODUCTION

The relationship between the warm episodes of the El Niño/Southern Oscillation (ENSO) and its remote influence over the South America atmospheric circulation and precipitation has been investigated by many authors (Kiladis and Diaz, 1989; Drumond and Ambrizzi, 2003; and others). Grimm et al. (1998) described that in spring of the El Niño (EN) years there is a tendency to higher than median precipitation in the northeastern Argentina, southern Brazil and Uruguay; on the other hand, in summer this pattern is weakened. Precipitation anomalies on these regions is part produced by the South American Low-Level Jet east of the Andes (SALLJ) that seems to be responsible for transporting large quantities of moisture from the Amazon region and Tropical Atlantic to the subtropics, producing enhanced rainfall in its exit region (Marengo et al., 2004). However, there are not many studies showing how the inter ENSO variability influence the position and intensity of the SALLJ and therefore its preferential region of activity during different seasons of the year.

In a recent study, Silva et al. (2006) verified that during the austral summer (DJF) the location of the flux convergence varies depending on the intensity of the ENSO event. The daily composites indicate that the maximum of the SALLJ winds and convection seems strong and more concentrated over the La Plata basin during strong EN and more dispersive and displaced to the north in the weak ones. It was also noticed that there was not any indication of convection over the SACZ region in this period being in agreement with a recent work from Liebmann et al. (2004) who suggested that on a daily time scale, a preference for rain in the SACZ should coincide with a weak jet and dry conditions downstream of it, and vice versa. On the other hand, the convection during the weak EN occurred in a larger region showing OLR anomalies in the central and southeast of Brazil. These results suggest that depending on the intensity of a warm ENSO event, the interaction with the transient systems can be different being one of the possible mechanisms of the precipitation variability over the La Plata basin region during inter-El Niño episodes as indicated by Magaña and Ambrizzi (2005 and references therein). This study aims to analyze the differences in the SALLJ features between the austral spring and summer. This preliminary study is divided as follows. Section 2 presents the data and methodology. Some indication of the SALLJ frequency, atmospheric circulations composites associated and the SALLJ composites during strong and weak EN events are discussed in the Section 3. The final discussion of the results is giving in Section 4.

2. DATA AND METHODOLOGY

The reanalysis from NCEP/NCAR (Kalnay et al., 1996) have been used for Sep-Oct-Nov (SON) between 1950 to 2003 period: four times daily - zonal

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and meridional winds from 1000 hPa to 200 hPa level and Sea Level Pressure (SLP) in a 2.5º x 2.5º longitude-latitude grid. The monthly mean – streamfunction in the 0.21 and 0.85 sigma levels (about 200 hPa and 850 hPa levels, respectively), specific humidity from 1000 hPa up to 300 hPa level on 2.5º grid and monthly mean Sea Surface Temperature (SST) from NOAA Extended Reconstructed SST (Wooddruf et al., 1987) in a 2.0º x 2.0º longitude-latitude grid were also used.

The years of EN episodes included in this study were chosen following the same criteria as in Silva et al. (2006) and only the strong and weak intensities will be analyzed. The methodology of Silva et al. (2006) was applied in this study. The Bonner criterion 1 (Bonner, 1968) was applied to define the occurrence of SALLJ in the Santa Cruz-Bolivia (17.75ºS; 63.06ºW) region. The influence of the large-scale atmospheric circulation was investigated through composites of SST anomalies over the Equatorial Pacific, streamfunction anomalies, vertically integrated moisture flux and divergent anomalies. On the other hand, the impact of the synoptic circulations in the maintenance of the SALLJ was examined through the composites of SLP and wind anomalies at 850 hPa. The composites were constructed in accordance with the intensity of EN events, and considering the daily mean of the fields two days before (Day -2), during (Day 0) and two days after (Day +2) the maximum SALLJ activity, respectively. A preliminary comparison between the composites in spring and summer has been made. A Student's T test (Harrison and Larkin, 1998) was applied to all composites presented in this paper. The anomaly of the composite was accepted with the confidence level of 95%.

3. RESULTS

According Silva et al. (2006), the warm ENSO phase seems to favor the enhanced SALLJ cases during austral summer. The austral spring cases showed a lesser frequency when compared to the summer and indicated that November is the preferential month for the SALLJ occurrence (Table not shown). Based in these results the inter-seasonal differences of the atmospheric circulations are presented below.

Figures 1 and 2 show the composites of the perturbed streamfunction anomaly (i.e., with zonal mean removed) at 200 hPa of strong and weak EN events. In general, one can see quasi-stationary Rossby waves spanning poleward from the central-eastern Pacific in the upper troposphere as a result of anomalously intense convective activity. In the spring of strong events the anomalous anticyclone observed over the Equatorial Pacific is weak and displaced westward when compared to the summer (Figs. 1a and 2a). The subtropical westerly winds tend to be stronger than normal. There is the presence of an anomalous cyclonic circulation southwest of South America (SA) and an anticyclonic anomaly around the southern and southeastern Brazil. These features can favor the stationary cold fronts on the northern Argentina. For the weak events (Figs. 1b and 2b) the amplitude of the Rossby wave pattern is weak when compared to the strong events, being probably related to the intensities of the SST anomalies (Figs. not shown). In the spring (Fig. 1b) it is observed a higher amplitude of the waves when compared to the Fig. 2b, however there is not a clearly phase shifting as observed during the strong events.

The atmospheric configuration of the flow at lower levels and its vertical moisture distribution can be represented by a vertically integrated moisture flux (Figs. 3 and 4). In both seasons, for strong events, the moisture transport occurs from the tropics to the extratropics showing anomalous moisture divergence in the Tropical North Atlantic and Amazon region and anomalous convergence over the northern Argentina and southern Brazil (Fig. 3a and 4a). However, during SON the mainly source of anomalous moisture divergence over the Amazon Basin moves westward. The easterly trade winds and the northerly flux were enhanced and there is a very significant increase of the moisture convergence over the northern Argentina and southern Brazil when compared to DJF. During weak EN at both seasons the amplitude of the Tropical North Atlantic and Amazon moisture divergence is much weaker and the easterly trade winds were less intense when compared to the strong EN events (Figs. 3b and 4b). However, during the spring (Fig. 3b) the northerly flux transports moisture to the Centre and Southeast Brazil, i.e., there is a strong convergence where the South Atlantic Convergence Zone (SACZ) is usually located. In the summer (Fig. 4b) the moisture originated from the Amazon region is weaker and the convergence region moves to the north of the northern Argentina, Paraguay and southern Brazil.

At 850 hPa (Figure not shown), the rotational wind anomalies for the strong EN events exhibits a consistent anticyclonic anomaly over northern central SA, that strength the easterlies in the western equatorial Atlantic. However, the anticyclonic circulation is more intense during the spring than in the summer, mainly over central Brazil. The anomalous pattern seems to direct the moisture toward La Plata basin as shown by Fig. 3a. For the weak EN events the anticyclonic anomaly is weakened and a cyclonic anomaly is established over central Brazil. The low-level cyclonic anomaly increases the moisture flux into central-east Brazil, where strong and consistent moisture convergence anomalies take place as observed in Fig. 3b.

It must be recalled that an important percentage of the moisture variability over the La Plata basin and southeast SA comes from the passage of cold fronts in the region. Thus, we are quite aware of their importance as moisture source and this matter is currently being investigated.

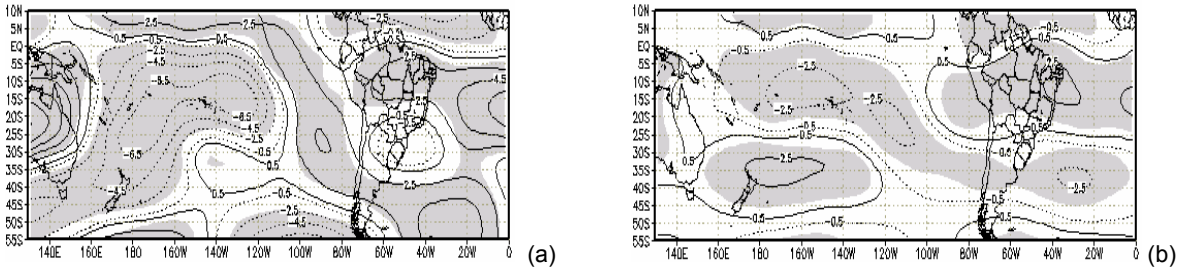

Fig. 1: Composites of streamfunction anomaly ($m^2.s^{-1}$) at 200 hPa observed during austral spring for strong and weak EN years (a, b). Contour interval is $2x10^{-6}$ $m^2.s^{-1}$ and the negative contours are dotted. Anomalies statistically significant at the confidence level of 95% are shaded.

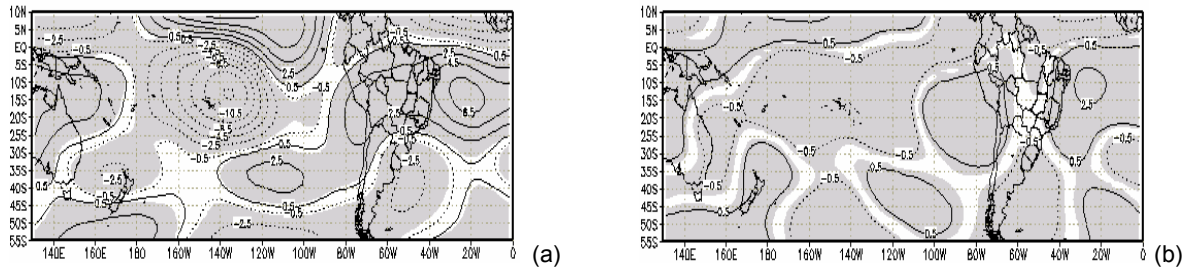

Fig. 2: The same as Figure 1, but for austral summer (from Silva et al. 2006).

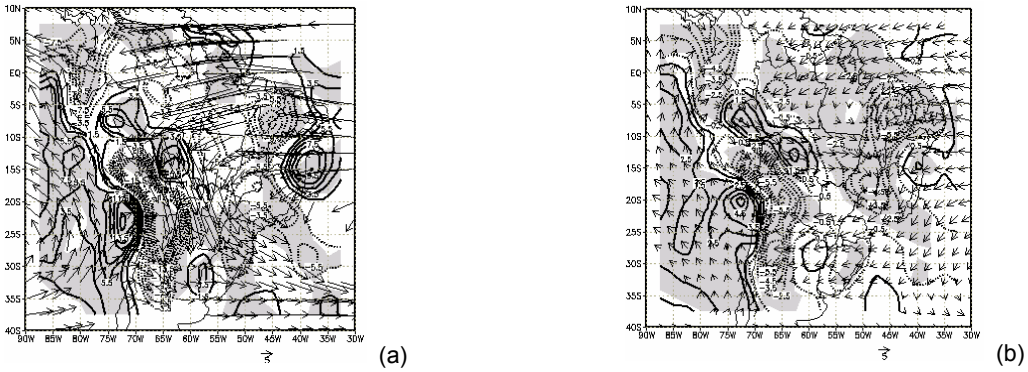

Fig. 3: Vertically integrated moisture flux ($g.m^{-1}.s^{-1}$) and divergent anomaly ($mm.dia^{-1}$) composites during austral spring for strong and weak EN years (a, b). Contour interval is 2 $mm.dia^{-1}$ and the negative contours are dotted. The flux plotted and the shaded areas indicate statistically significant anomalies at the confidence level of 95%.

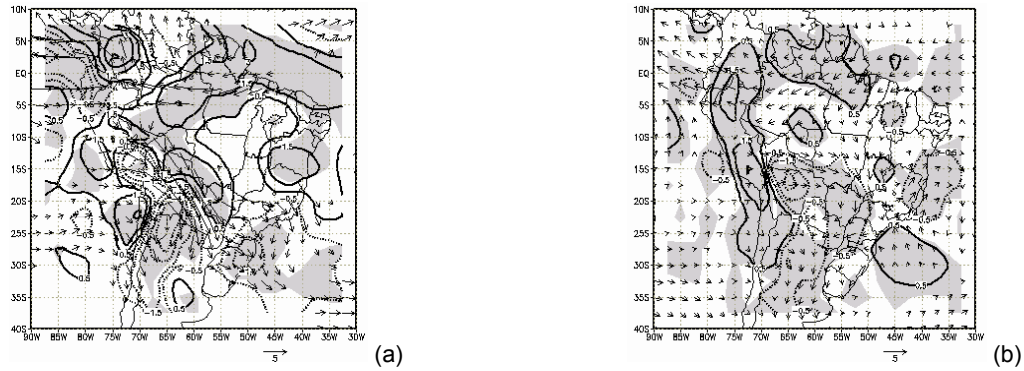

Fig. 4: The same as Figure 3, but for austral summer (from Silva et al. 2006).

The composites of SLP and wind vector anomalies at 850 hPa for strong and weak EN at Day -2, Day 0 and Day +2 of the maximum activity of the SALLJ is shown in Fig. 5. At Day -2, in both cases (Figs. 5a and 5d), one can see the passage of a low pressure system through the south cone of SA. For the strong EN the wind is orientated towards the La Plata basin (northern Argentina, Paraguay and southern Brazil) while that for the weak EN it is around the climatological position of the SACZ (e.g. Liebmann et al., 1999). During the progression of the low pressure system over SA the wind field is re-organized and at Day 0 (Figs. 5b and 5e) we can observe that the maximum SALLJ activity is different in both cases.

It seems strong and more concentrated over the La Plata basin during the strong event and more dispersive and displaced to the north in the weak one. The displacement of the low pressure systems from the south cone of SA towards the Atlantic Ocean coincides with the weakening of the SALLJ two days after its maximum intensity (Figs. 5c and 5f). These results suggest that depending on the intensity of a warm EN event, the interaction with the transient systems can be different somewhat explaining the precipitation variability over the La Plata basin region during inter-El Niño episodes, as indicated by Magaña and Ambrizzi (2005 and references therein). In both EN events the austral spring composites seems that the size and amplitude of the cyclone systems entering through the south cone of SA is bigger than in the summer season (see Fig. 5 from Silva et al. 2006). It is also interesting to notice that the low pressure dominates the whole South American continent in this case while this is not observed during the summer, where there is a clear pressure gradient in its central part. This is probably due to the variability of the Walker and Hadley circulation cells over South America during warm ENSO events (Ambrizzi et al., 2004).

4. FINAL DISCUSSION

The analyses during the austral spring revealed a smaller frequency of SALLJ occurrence when compared to the summer where the number of events is higher in November. The composites of the atmospheric circulation shows an inter-seasonal variability in the Rossby wave activity that seems to be related to the changes in the large-scale circulation induced by SST anomalies over the Equatorial Pacific. For example, during SON of strong EN years the enhancement of the 200 hPa subtropical westerly winds over the southwest SA is accompanied to the increased of meridional moisture transport coming from the SA tropics to the La Plata basin. The easterly trade winds and the northerly flux were enhanced when compared to the summer. In the both seasons for weak EN the amplitude of the Tropical North Atlantic and Amazon moisture divergence is much weaker and the easterly trade winds were less intense when compared to the strong EN events. In spring the low-level cyclonic anomaly over central Brazil increases the moisture flux into central-east Brazil, where strong and consistent moisture convergence anomalies take place. During the summer the moisture is transported to the north of the La Plata Basin.

The influence of the midlatitude transients crossing the south cone of SA over the SALLJ was analyzed through daily composites of different EN intensity events. The daily composites indicate that the maximum of the SALLJ winds and convection seems strong and more concentrated over the La Plata basin during the strong EN and more dispersive and displaced to the north in the weak ones. This displacement has an impact on the precipitation over the region, particularly over the La Plata basin. One interesting aspect also observed in the daily composites for the spring was that the size and amplitude of the cyclone systems entering the south cone of SA are clearly bigger than during the summer. It seems that the transient wavelength differences may play an important role in the modulation of the SALLJ position and intensity. It is worthy mentioning that the transients can contribute to the seasonal moisture anomalies over the subtropics and La Plata basin. Studies considering the other seasons and ENSO events together with the numerical experiments with complex models such as General Circulation Model (GCM) are still necessary in order to better understand the low and high frequency wave interaction discussed here. Such studies are currently being done.

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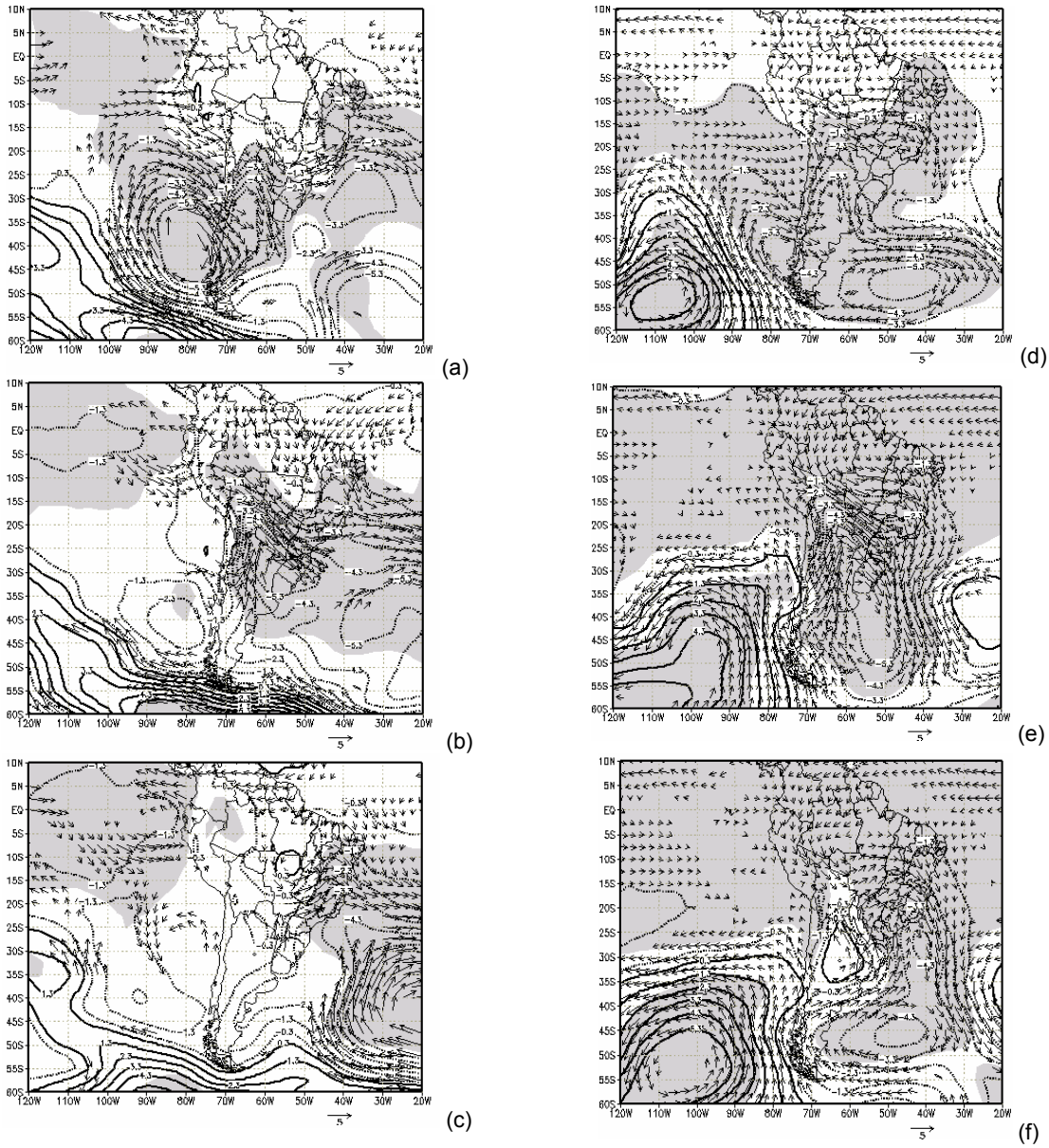

Fig. 5: Daily composites of SLP (hPa) and wind vector anomaly ($m.s^{-1}$) at 850 hPa during strong (a-c) and weak (d-f) EN years, for episodes of SALLJ detected in Santa Cruz during SON. Sequence of panels shows the circulation for the Days -2, 0, +2 of the maximum activity of the SALLJ. Contour interval is 1 hPa and the negative contours are dotted. The wind plotted and the shaded areas indicate statistically significant anomalies at the confidence level of 95%.

REFERENCES

Ambrizzi, T., Souza, E. B., Pulwarty, R.S., 2004: The Hadley and Walker regional circulation and associated ENSO impacts on South American seasonal rainfall. *The Hadley Circulation: Present, Past and Future*. H.F. Diaz and R. S. Bradley Eds., Kluwer Academic Publishers, Dordrecht, 203-235.

Bonner, W.D., 1968: Climatology of the Low Level Jet. *Monthly Weather Review,* 96, 833-850.

Drumond, A.R.M., Ambrizzi, T., 2003: Observational and numerical study of the atmospheric circulation over the Americas during extreme episodes of the Southern Oscillation. *Brazilian Journal of Meteorology*, 18(1), 1-12 [*Available in Portugues*].

Grimm, A.M., Ferraz, S.E.T., Gomes. J., 1998: Precipitation anomalies in southern Brazil associated

with El Niño and La Niña events. *J.Climate,* 11, 2863-2880.

Liebmann, B., Kiladis, G.N., Vera, C.S., Saulo, A.C., Carvalho, L.M.V., 2004: Subseasonal variations of rainfall in South America in the vicinity of the low-level jet east of the Andes and comparison to those in the South Atlantic convergence zone. *J.Climate,* 17(19), 3829-3842.

Liebmann, B., Kiladis, G.N., Marengo, J.A., Ambrizzi, T., Glick, J.D., 1999: Submonthly convective variability over South America and the south Atlantic convergence zone. *Journal of Climate,* 12, 1877-1891.

Harrison, D.E., Larkin, N.K., 1998: El Niño-Southern Oscillation sea surface temperature and wind anomalies1946-1993. *Rev. Geophysics,* 36(3), 353-399.

Kalnay, E., Kanamitsu, M., Kistler, R., Collins W., Deaven, D., Gandin, L., Iredell, M., Saha, S., White G., Woollen, J., Zhu, Y., Chelliah, M., Ebisuzaki, W., Higgins, W., Janoviak, J., Mo, K.C., Ropelewski, C., Wang, J., Leetmaa, A., Reynolds, R., Roy, J., Joseph, D., 1996: The NCEP/NCAR 40-year Reanalysis *Project. Bull. Amer. Meteor. Soc.,* 77(3), 437-471.

Kiladis, G.N., Diaz, H.F., 1989: Global climatic anomalies associated with extremes in the Southern Oscillation. *J.Climate,* 2, 1069-1090.

Magaña, V., Ambrizzi, T., 2005: Dynamics of subtropical vertical motions over the Americas during El Niño boreal winters. *Atmósfera*, 18(4), 211-233.

Marengo, J.A., Soares, W.R., Saulo, C., Nicolini, M., 2004: Climatology of the Low-Level Jet east of the Andes as derived from the NCEP reanalyses. *J. Climate*, 17, 2261-2280.

Silva G.A.M., Ambrizzi, T., Marengo, J., 2006: Inter ENSO variability and its impact on the South American Low-Level Jet east of the Andes during the austral summer. *Inter.Journal of Climatology*, Submitted.

Wooddruff, S.D., Slutz, R.J., Jenne, R.L., Steurer, P.M., 1987: A comprehensive ocean-atmosphere data set. *Bull. Amer. Meteor. Soc,* 68, 1239-1250.