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MECHANISMS OF THE INFLUENCE OF EL NIÑO AND LA NIÑA EPISODES ON THE FREQUENCY OF EXTREME PRECIPITATION EVENTS IN BRAZIL.

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1. INTRODUCTION

[1]The sea surface temperature (SST) anomalies associated with El Niño (EN) and La Niña (LN) episodes produce anomalous heat and water vapor fluxes from the Pacific Ocean to the atmosphere. The associated convection anomalies cause upper level divergence anomalies that perturb the global circulation. Rossby waves are triggered and the Walker and Hadley circulations are disturbed. There are significant impacts on several regions of South America (SA) during the different phases of the El Niño – Southern Oscillation (ENSO) (e. g., Ropelewski and Halpert, 1987; Aceituno, 1988; Grimm et al., 2000; Grimm, 2003, 2004).

Gershunov (1998) shows that there is significant difference between probability associated with extreme precipitation events in USA during EN and LN episodes. This difference represents greater potential predictability of increase or reduction of those extreme events during these episodes.

In view of the significant impact of ENSO episodes on the monthly and seasonal amounts of rainfall in several regions of SA, this study is focused on the impact of EN and LN episodes on the frequency of extreme precipitation events in the continent. This information is useful to refine climate prediction during these episodes and enhances preparedness for natural disasters.

Besides the quantitative assessment of the frequency modifications, we compare the mean anomalous atmospheric state during EN and LN episodes with the atmospheric conditions during extreme precipitation events in the most affected regions to get some insight into the reasons for these modifications.

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2. DATA AND METHODS

Daily station rainfall data in the period 1956-2002 are gridded to 1.0º to achieve more homogeneous distribution of data.

Running means over three days are computed and the values attributed to the central days. Gamma distributions are fitted to these means, one for each day of the year. Precipitation data are then replaced by their respective percentiles. Extreme events are those with a three-day mean percentile above 85. The number of extreme events is computed for each month of each year. Years are classified as EN, LN (Table 1), and normal years, considering, according to the EN/LN cycle, that the year starts in August (year 0) and ends in July (year +1). The mean frequency of extreme events for each month, within each category of year, and the difference between these mean frequencies for EN and normal years, and for LN and normal years are computed, as well as their statistical significance.

Table 1. El Niño and La Niña years

El Niño (0)	1957, 1963, 1965, 1969, 1972, 1976, 1982, 1986, 1987, 1991, 1997
La Niña (0)	1964, 1967, 1970, 1971, 1973, 1975, 1985, 1988, 1999

The relationships between large-scale atmospheric perturbations during ENSO episodes and variations in the frequency of extreme precipitation events are sought through composites of anomalous atmospheric fields during EN and LN episodes, and for extreme events in regions in which there is significant change in the frequency of these events. This analysis, carried out with NCEP/NCAR reanalysis data, comprises winds at 850 hPa and 200 hPa, and vertically integrated moisture flux and its divergence. The anomalies of atmospheric fields are calculated, as was done for precipitation data, for three-day running means, with respect to climatological values for each of these means, smoothed by a 30-day running mean. Here we present the results of this analysis only for extreme precipitation events in November within a region near Foz do Iguaçu, in the southwestern part of the state of Paraná, Brazil.

3. RESULTS AND DISCUSSION

EN and LN episodes influence significantly the frequency of extreme events in several regions in Brazil during certain periods of the ENSO cycle. Only the results for November and January are shown in Figure 1. In November, there is outstanding impact on the frequency in southern Brazil, with opposite effects in EN and LN episodes. In EN years there are more extreme events, whereas they are reduced during LN years. In northern South America there are also opposite changes in the number of extreme events. This is completely consistent with the impact on monthly and seasonal rainfall (Grimm et al. 2000; Grimm 2003; 2004).

The frequency of extreme precipitation events undergoes a reversal in Central-East Brazil, from November (0) to January (+), both in EN and LN years. The same happens, with reverse signs, in the northern part of southern Brazil. The same reversal occurs for monthly rainfall, as shown in Grimm (2003, 2004).

The significant increase of extreme events usually affects a less extensive area than its significant reduction, both in EN and LN years. This is especially visible when comparing the impact on South Brazil in November (0), and on Central-East Brazil in January (+)

Figures 2 and 3 display the mean anomalous fields during November (0) of EN and LN years. Ciclonic anomalies predominate over southwestern SA and anticiclonic ones prevail over the subtropics to the east. Opposite anomalies are characteristic of LN years, though somewhat shifted southwestward. At low-levels, anomalies associated with EN strengthen the low-level jet east of Andes, while those associate with LN tend to weaken this jet. These anomalies enhance moisture inflow (outflow) into southern Brazil and moisture flux convergence (divergence) in this region during EN (LN) episodes.

The anomaly fields during extreme events near Foz do Iguaçú, in the southwestern region of the Paraná State, South Brazil, are not significantly different in the vicinity of this region in EN and LN years (Figs. 4 and 5). The general features of those anomaly fields are similar, no matter if the extreme events happen during EN or LN episodes or in normal years. They show the essential ingredients for enhanced precipitation: moisture convergence and mechanisms for lifting the air to the condensation level. At low-level there is cyclonic circulation and inflow into the region, while at upper-levels the subtropical jet is strengthened over the region and there is a cyclonic anomaly to the west.

The comparison of the extreme events composites in Figs. 4 and 5 with the monthly anomalies in Figs. 2 and 3 shows why the frequency of extreme events varies significantly between EN and LN episodes near Foz do Iguaçu. The anomalous features in the vicinity of this region during extreme events are very similar to the monthly anomalies for EN episodes, but opposite to the anomalies observed during LN years. The large increase in the frequency of extreme events is, therefore, due to very favorable large scale conditions, while the reduction is caused by large scale conditions that do not favor high and persistent precipitation.

A correlation analysis is carried out to verify whether there is another mechanism responsible for extreme events in November in the region of Foz do Iguaçu that does not work during other rainfall events in this month (Fig. 6). In general, the relationship between sea sueface temperature (SST) and monthly rainfall is similar to the relationship between SST and the frequency of extreme events. There are, however, some differences. For instance, the frequency of extreme events is more correlated with SST anomalies in the subtropics of the Pacific Ocean than is monthly rainfall, as the region with higher positive correlation is enlarged around the equator and westward (Fig. 6, bottom). Therefore, there is a stronger latitudinal SST gradient in the subtropics of central South Pacific, which seem to be more favorable to extreme events. There are also some differences in the North Atlantic and North Pacific, which might indicate influence of interdecadal modes on the frequency of extreme precipitation events

4. CONCLUSIONS

The mean frequency of extreme events for each month, within each category of year, and the difference between these mean frequencies for EN and normal years, and for LN and normal years show that EN and LN episodes influence significantly the frequency of extreme events in several regions in Brazil during certain periods.

In the regions where the frequency of extreme events increases (decreases) during an ENSO episode (EN or LN) the anomaly composites during extreme events show similarity (difference) with respect to the mean monthly anomalies during this episode. This indicates that the frequency of extreme events increases (decreases) when the large-scale perturbations favor (hamper) the circulation anomalies associated with extreme events in those regions. This also means that the behavior of the frequency of extreme events is consistent with that of the monthly or seasonal total precipitation.

The same conclusion can be reached through the correlation analysis of SST with the monthly precipitation series or the frequency of extreme events in regions in which these events have their frequency changed during EN and LN episodes. In general, the relationship between SST and monthly rainfall is similar to the relationship between SST and the frequency of extreme events. There are, however, some differences. For example, in the analyzed region the increase of extreme events is more associated with the SST gradient in subtropical South Pacific that is the monthly rainfall. Also some differences in the correlation patterns in North Atlantic and the broadening of significant correlation patterns towards the subtropics of eastern Pacific when considering the frequency of extreme events suggests a possible role of interdecadal variability in modulating this frequency, for in these regions SST is affected by interdecadal global modes of variability.

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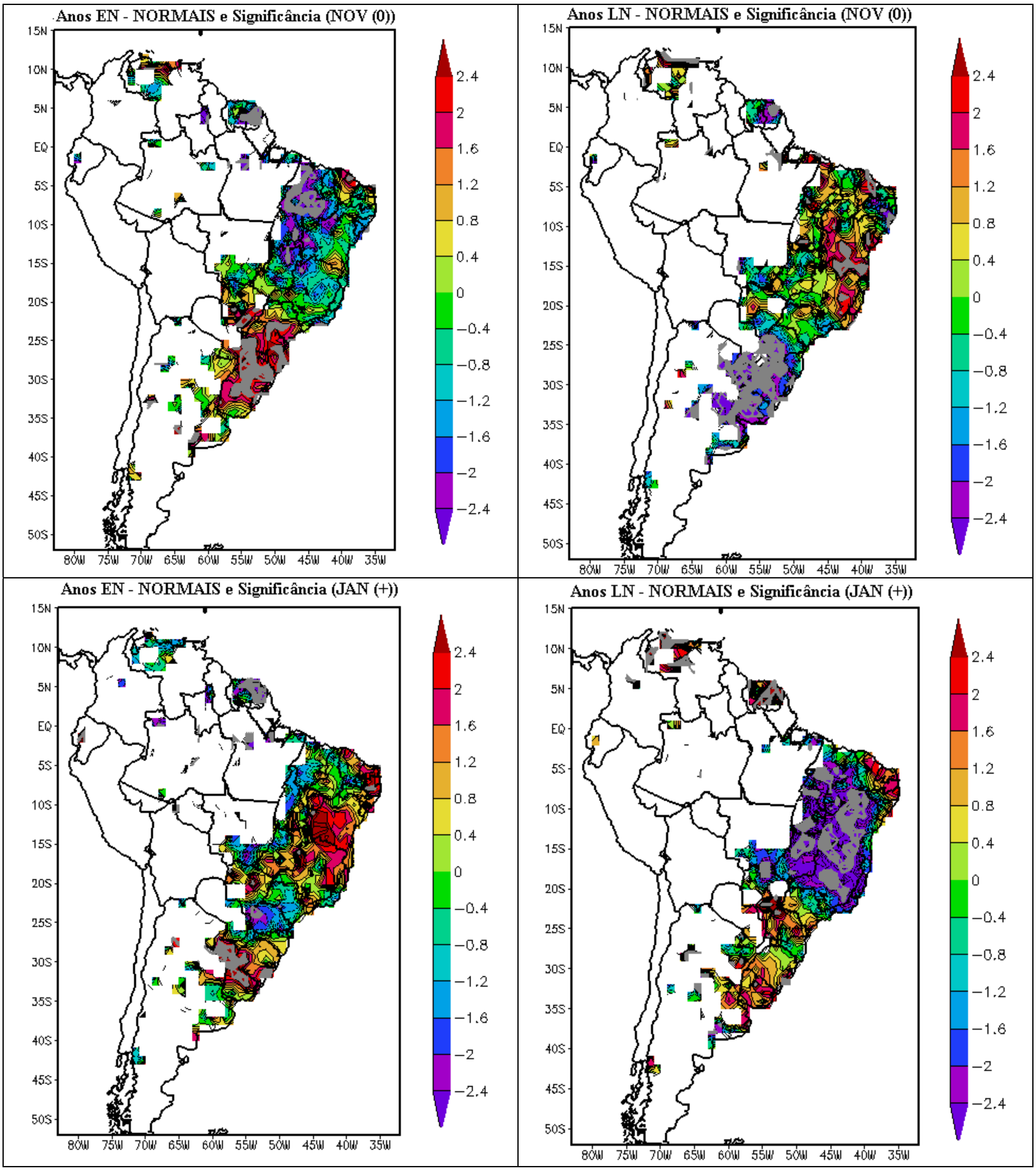

Figure 1. Difference between number of extreme events in El Niño years and neutral years (left) and in La Niña years and neutral years (right), for November (0) (top) and January (+) (bottom). Differences significant to a level better than 0.10 are shaded in gray.

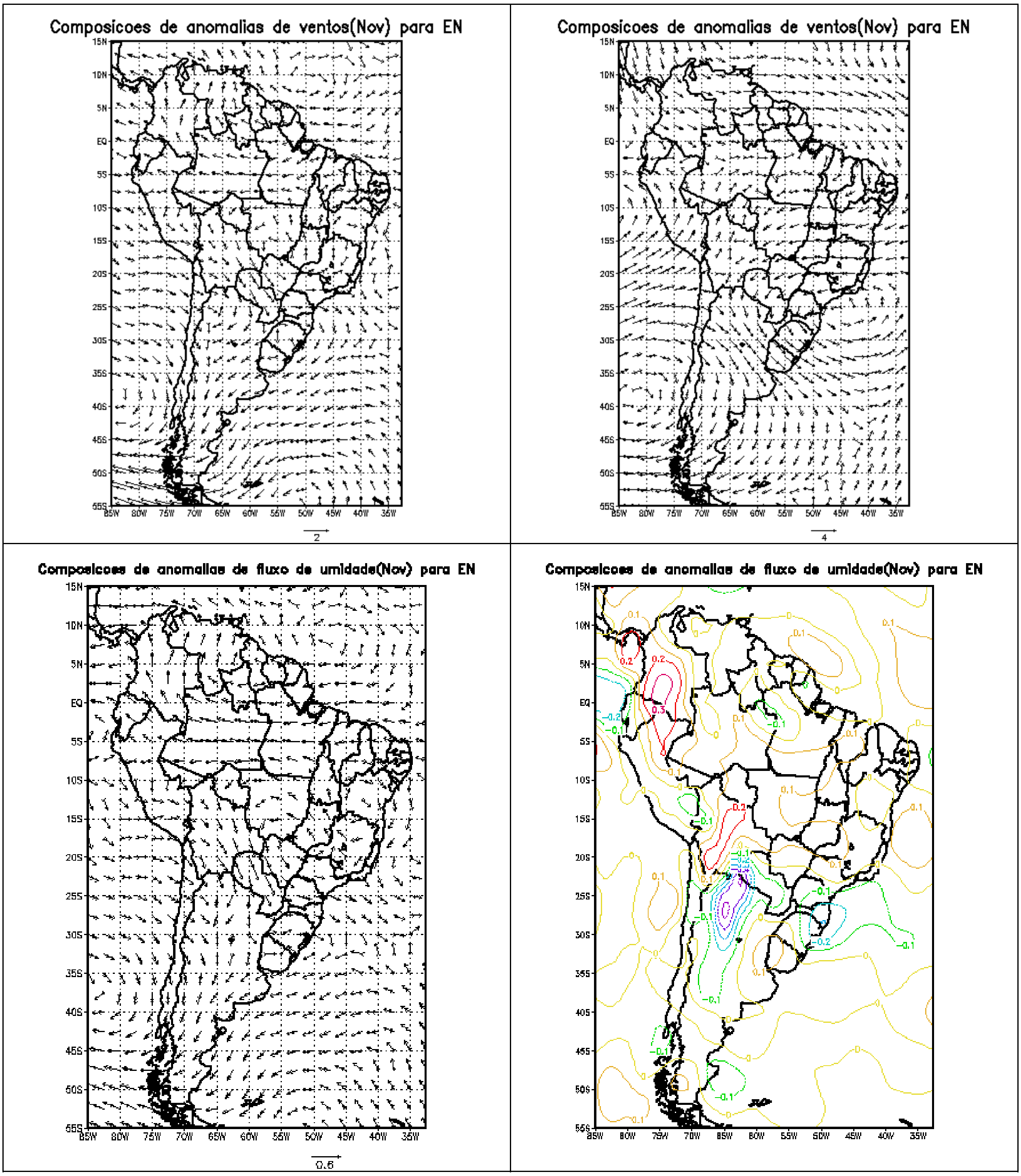

Figure 2. Composites of monthly wind anomalies (top) at 850 hPa (left) and 200 hPa (right), and vertically integrated moisture flux (bottom, left) and its divergence (bottom right), for November (0) of El Niño years.

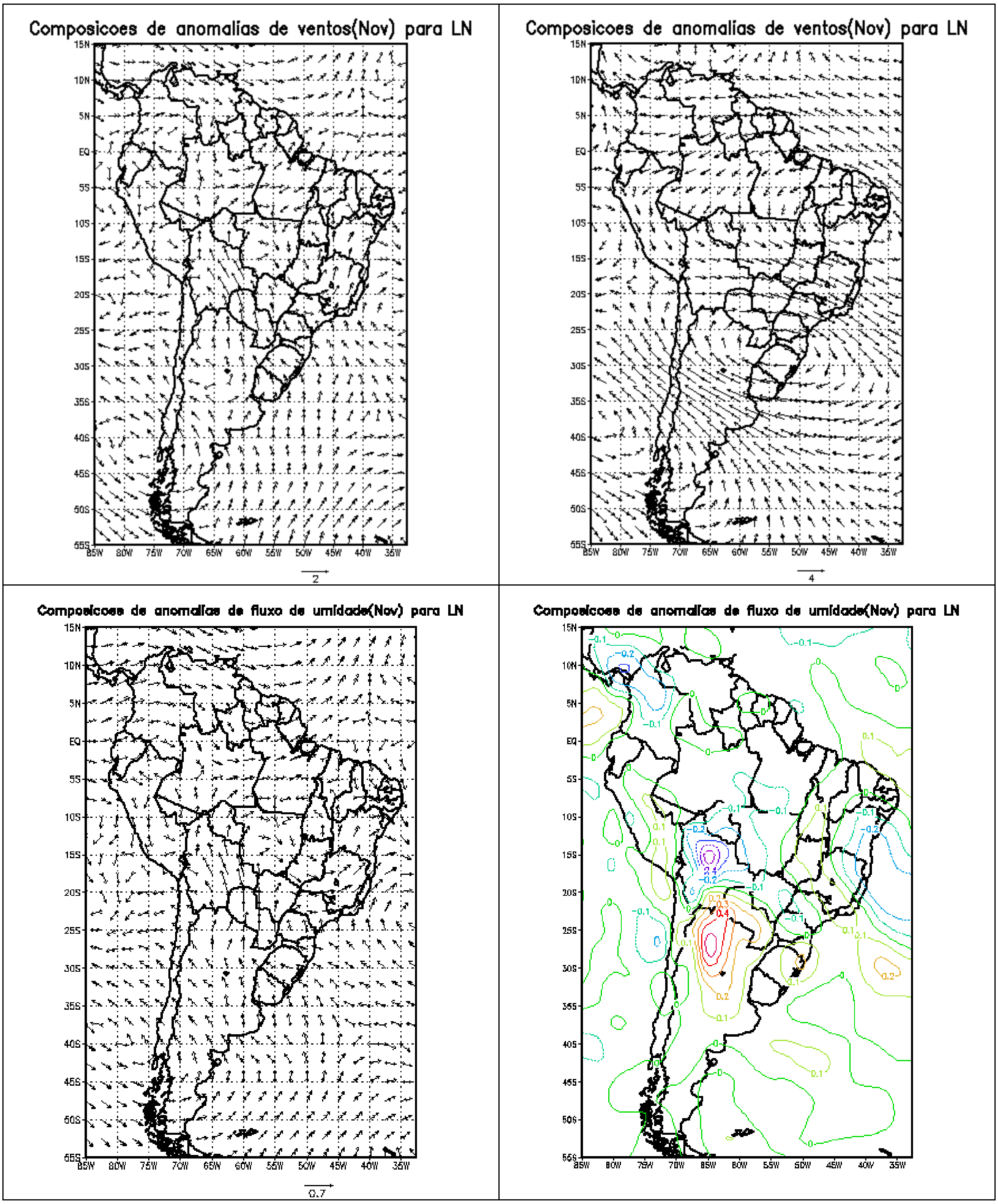

Figure 3. Composites of monthly wind anomalies (top) at 850 hPa (left) and 200 hPa (right), and vertically integrated moisture flux (bottom, left) and its divergence (bottom right), for November (0) of La Niña years.

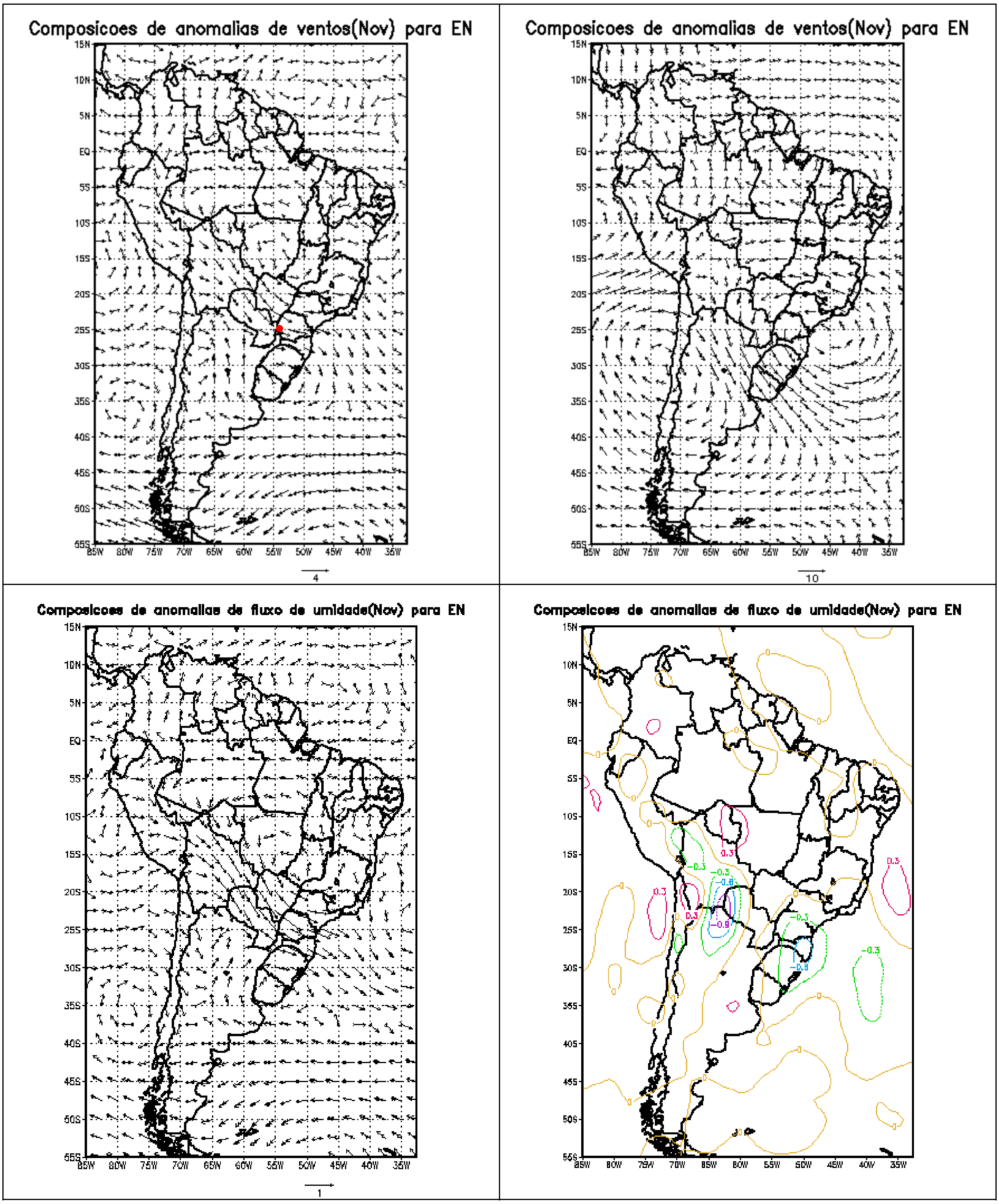

Figure 4. Composites of wind anomalies (top) at 850 hPa (left) and 200 hPa (right), and vertically integrated moisture flux (bottom, left) and its divergence (bottom right), for extreme events in a region near Foz do Iguaçu, Paraná (indicated by a red circle in the first panel), in November (0) of El Niño years.

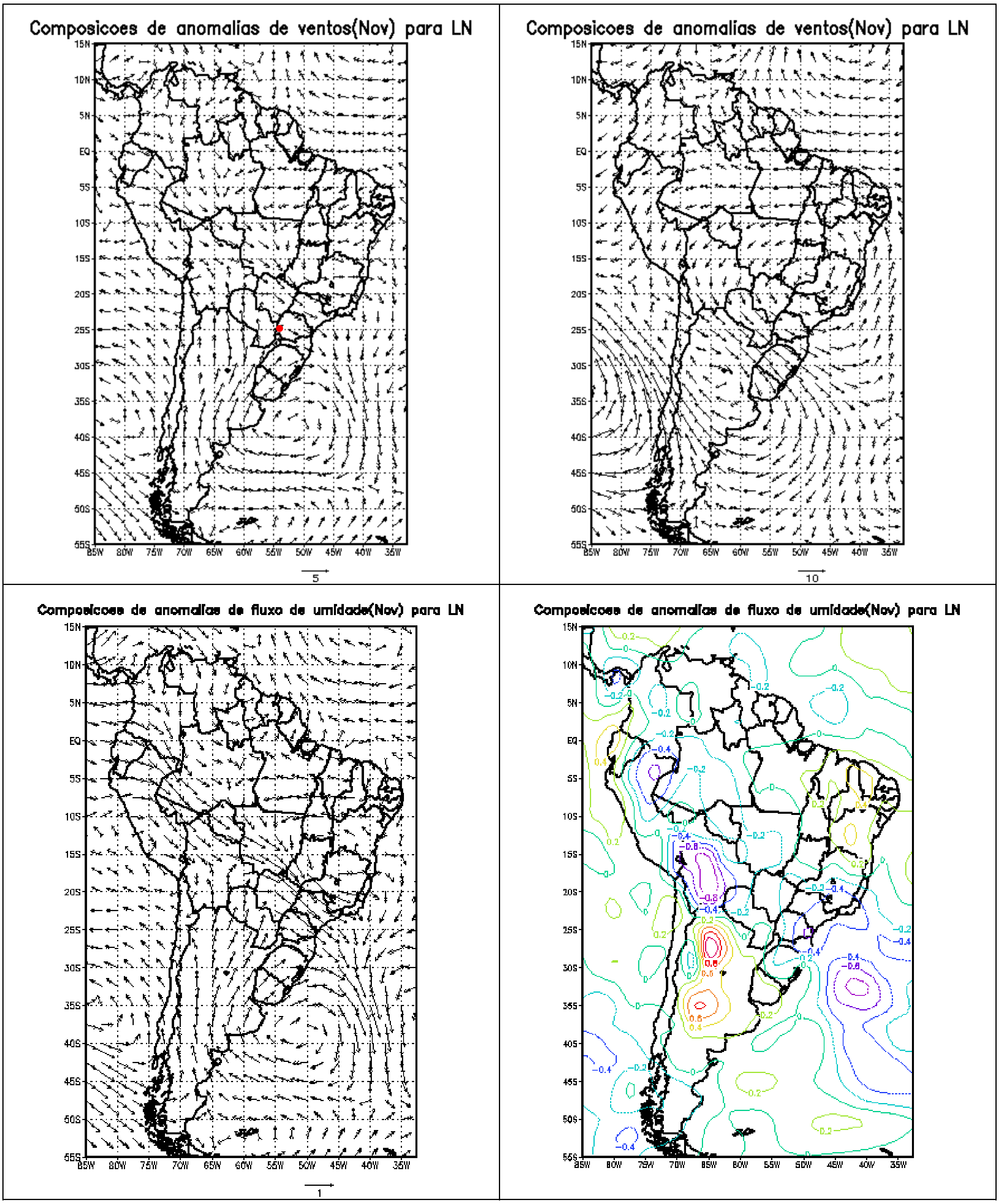

Figure 5. Composites of wind anomalies (top) at 850 hPa (left) and 200 hPa (right), and vertically integrated moisture flux (bottom, left) and its divergence (bottom right), for extreme events in a region near Foz do Iguaçu, Paraná (indicated by a red circle in the first panel), in November (0) of La Niña years.

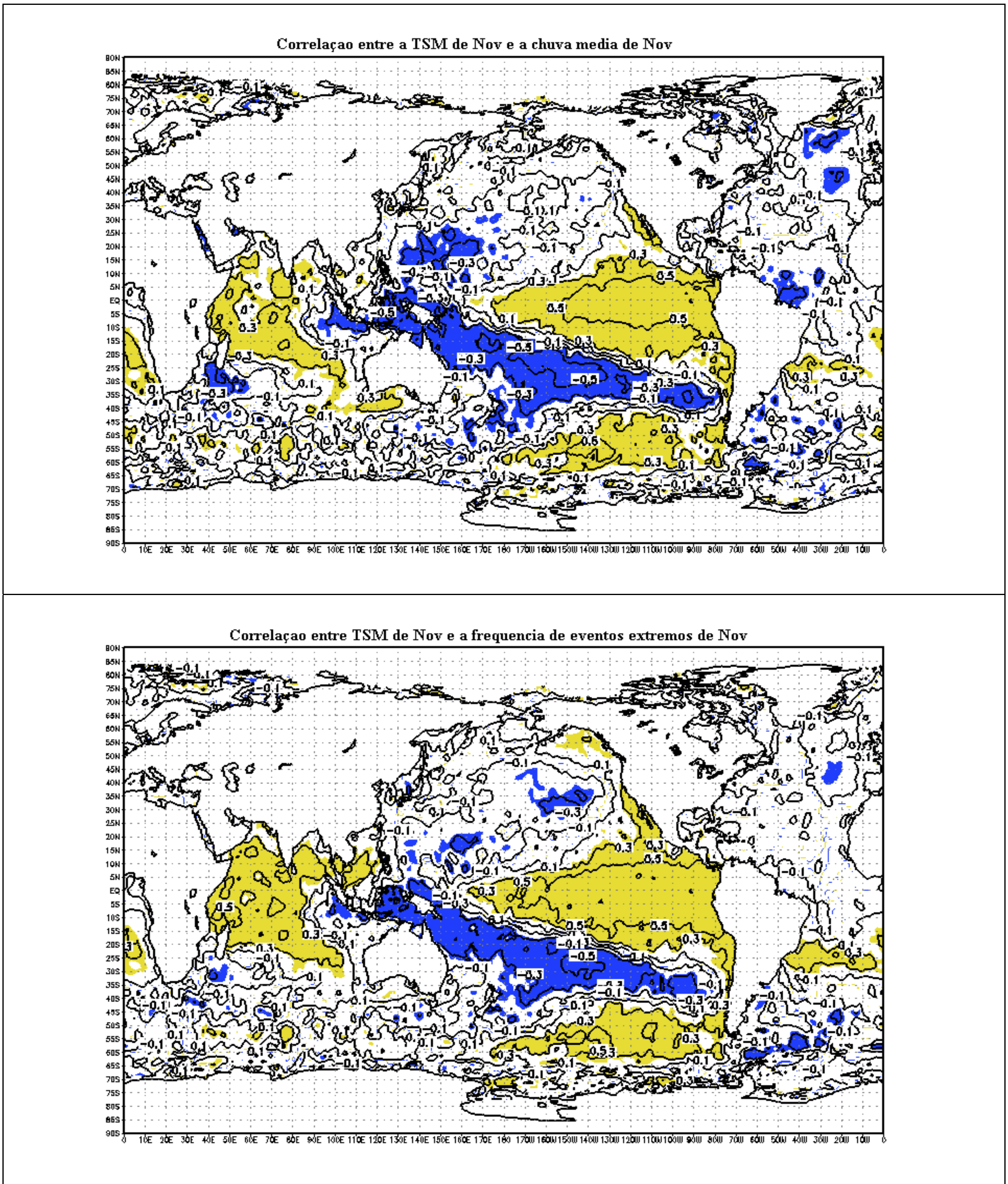

Figure 6. Correlation coefficients between SST and (top) monthly precipitation in a region near Foz do Iguaçu, Paraná, and (bottom) frequency of extreme precipitation events in the same region. Regions in yellow (blue) indicate correlation significant to a level better than 0.05.