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TRENDS IN EXTREME DAILY RAINFALL EVENTS IN LA PLATA BASIN

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1. INTRODUCTION

The analysis of daily precipitation in Argentina and mainly La Plata Basin, is a subject of great interest due to the impact in the agronomical and hydrological issues. This interest is not merely climatological; it also affects other areas of the environment and society, specially when the extreme in the rainfall are taking into account.
While rainfall statistics at hemisphere scale have merited attention of climatologists, regional scale rainfall still deserves interest in order to obtain new views to describe its particular characteristics. Reasons for this include a lack of adequate data, since no climate factors (e.g. changes in station location) often bias extremes more than climatic means, and problems related to choosing appropriate thresholds to define extremes.

There are fewer studies of regional variability in climatic extremes in the study region. Haylock et al (2005) examine daily rainfall observations over the period 1960-2000, determining changes in both total and extreme rainfall for South America; Penalba and Vargas (2001) observed that extreme negative (positive) annual anomalies are concentrated in the first (last) half of the century in the agricultural areas of Argentina. Penalba and Robledo (2005) analyze the annual cycle of daily percentiles and the frequency of daily rainfall events throughout the year.

Several authors have reported jumps and/or tendencies in time series of annual and seasonal rainfall in LPB, as well as in particular months or seasons of the year (Boulanger et al. 2005, Penalba and Vargas 2004 and 1996; Castañeda and Barros 1994; Rusticucci and Penalba 2000; Penalba 2004, Liebmann et al. 2004, Minetti and Vargas 1997). Moreover the isohyets in Argentina were displaced 200 km westward in the last century, with a positive increase specially in the humid pampas privileged the farming production (Hoffmann et al., 1987). Such discontinuities and/or trends in precipitation can affect mean as well as extreme values.

The relationship between the patterns of annual and seasonal rainfall and circulation indexes have been analyzed by Pittock (1980) for Argentina and Chile; Barros et al. (2000) for Southern South America and Agosta and Compagnucci (2002) for the central-eastern Argentina, among other. Focus the attention in extreme indices and sea surface temperatures we can mentioned to Haylock et al (2005). The above mentioned evidence shows that during the last decades significant rainfall changes occurred in some regions of the country.

In this paper, we are interested to quantify these changes and the spatial domain. The objectives of this study are to provide a study of the variations in the climate indices, giving by the frequency of daily precipitation and the persistence; how much of the yearly index comes from each season index and a quantification of these changes and their spatial domain. Special attention is given to interdecadal and interannual variations of the climate indices, used for monitoring climate variability.

2. DATA AND METHOD

2.1 Geographic location

La Plata Basin is formed by the confluence of the Paraná and Uruguay rivers and flowing to the Atlantic Ocean, which covers territories of Argentina, Brazil, Bolivia, Paraguay and Uruguay (Figure 1).

The mean total annual rainfall rate in the study area is around 1200 mm. This rainfall annual quantity shows a space variation with direction NE-SW. The areas with lower annual rainfalls, approximately 300 mm, are located at the Argentinean northwest; while in south of Brazil presents annual precipitations higher than 1600 mm. The rainfall mean annual cycle in the basin has a strong geographical component; varying from a very defined annual cycle (rainfall maximum during the summer) in the northern and northwestern area to a uniform seasonal distribution with maxima during spring and autumn in the eastern-central area, northeast Argentina and south of Brazil (for more detailed see Penalba and Vargas, 2005). The annual cycles of the daily precipitation amount and the frequency of rainday show the same temporal variability. The persistence of rainday throughout the year shows high (low) values during the wet (drier) season. The greater (lowest) seasonal variability is observed in the western stations (northeastern and coastal stations) (Penalba and Robledo, 2005).

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2.2. Data

Long-term daily data of rainfall from 34 raingauges in Argentina, located north of 37ºS and east of 67ºW, 4 raingauges in Uruguay, 10 raingauges in Brazil and 3 raingauges in Paraguay (Figure 2). All the information used in this study were supplied by the "Servicio Meteorológico Nacional" of Argentina and Paraguay; argentine local organizations (INTA Santa Rosa and Pergamino); "Instituto Nacional de Investigación Agropecuaria" of Uruguay and from the databases built in the European Community Project " Assessing the impact of future climatic change on the water resources and the hydrology of the River of the Silver basin, Argentina: ARG/B7-3011/94/25".

The analysis of climate change indices focus on extremes requires high quality daily data in long record. Homogeneity testing was performed at all the information in order to check the quality of the data (Sneyers, 1990). Only series presenting no inhomogeneity have been retained with less than 10% of missing data for their period of record. The shorter period analyzed is 1972-2004 and he longest one 1908-2004.

2.3. Methods

Extreme weather is defined by events which lie outside the normal range of intensity and can be identified by different thresholds in different places.

Extremes of a climate variable are events that are observed rarely and statistically they correspond to the far ends of the frequency distribution of the variable. Changes in extremes are, therefore, caused by changes in the frequency distribution of the variable.

The indices used in this study are defined using thresholds, based on statistical quantities such as the 75th, 90th and 95th percentiles. These percentiles are clarified by smoothing the data using a 7-day running average.

The aim of employing different thresholds is to detect their likely impact on the variations in the number of wet spells and their distribution. Apart from these thresholds, the selection of 0.1mm and 10 mm thresholds also have a practical consequences. The former amount (0.1mm) is chosen to analyze the temporal variability of the rain day and the latter one (10 mm) is the rainfall amount often needed to exceed daily evaporative losses during summer months (Vargas, 1982) .

Rainfall indices were defined as:

♦ Persistence of rainday (no rainday): probability of rainday (no rainday) when the day before was a rain day (no rainday). Hereafter P11 and P00 respectively.

♦ Percentage of events: number of days with precipitation greater than or equal to 0.1, 10 mm and also their own the 75th, 90th and 95th percentiles of rain days (hereafter: PE > 0.1, PE > 10; PE > 75th; and so on).

♦ Seasonal proportion index: proportion of yearly PE index that comes from seasonal PE index. Hereafter PI.

Seasonal (DJF, MAM, JJA, SON) and annual values (December to November of the next year) of these indices were calculated on a yearly basis for each station for its whole period.

Trends in the annual and seasonal indices were analyzed in a common period (1961-2000). A non-parametric Kendall-tau test was used in order to determine the possible existence of statistically significant trends assuming a 95% probability level (Sneyers, 1990). In this analysis the Uruguayan stations were included even though only La Estanzuela station (34° 29' S and 57° 44' W) has the completed period.

3. RESULTS

3.1. Observed trends

To determine the most characteristic features of the rainday and no rainday the temporal evolution of P11 and P00 is analyzed. Figure 3 shows the sign of the annual trends for all the stations in the common period 1961–2000. It is interested to observe the spatial coherence in the sign and the significance of the annual trends of P11, showing that the probability of rainday when the day before was a rain day increase in the whole region. The probability of no rainday when the day before was a no rainday shows a greater spatial variability (Figure 3, down). Two coherence regions in the sign and significance of the annual trends with opposite characteristics are observed; one in southern Brazil (negative trends) and the other over Mesopotamia region (positive trends). The sign of the trend in the rest of the region will depend on the location of the station.

The maps shown in Figure 4 (left) summarize the spatial distribution of the sign for the annual and seasonal PE > 0.1 trends. Almost all the stations present positive annual trend. Two large regions with spatial coherence in the significant trend are observed: one in the southern Brazil and northeast Argentina and the other in the southwest region. A small coherence region with negative annual trend is observed in the central eastern region where only one station shows significant trend. This result is mainly due to the behavior during the winter months where the negative trend is significant in some stations of this region. During these months the positive and significant trends are placed in southern Brazil and northeast Argentina The number of stations with positive and significant trends shows seasonal variability (Figure 4, left). The seasons with the greatest values are MAM and DJF (22 and 13, respectively) and the least number of stations with significant positive trends is observed during spring months (Table I).

An important aspect of climate extremes relates to extreme droughts and moisture surpluses. In this study we are interested in the last extreme, characterized or represented by PE> 75th percentile or greater one. The spatial pattern of the PR > 75th trends resemble the results show before, diminishing the number of significant stations (Figure 4, right and Table I). In the annual index, three regions of spatial coherence in the significant of the trend are observed a) southern Brazil and Northeast Argentina; b) southwest of the study region and c) two stations in the Norwest. This spatial pattern is resembled during summer and autumn months. During these months this index shows the greatest number of stations with significant trends (Table I).

A further examination of these indexes show different temporal behavior, depending on the season and the station. Figure 5 and Figure 6 show the time series of the these seasonal values, after the 11 yr running mean was applied. The selected stations have the longest period of analysis and are located in northeast Argentina and southern Brazil, region with important hydrological consequences. Some interannual and interdecadal variations are observed in both indexes (PE>0.1 and PE>75). See for example the "maximum" values around 1975 and 1985 and the minimum around 1964 in Encarnación during JJA. The length of these periods and the central year of these maximum values will depend on the station (see JJA for B292). The longest time series analyzed are Tucumán and OCBA, located in the northwest and in the end of the Basin, respectively. It is interested to observed how the temporal variability of the extreme index (PE>75th) is similar to the temporal variability of PE>0.1. See for example the two jumps in summer index around 1950 and 1970; and during Spring months the minimum values around 1937 and the maximum around 1960.

The temporal variability observed in these studied indexes could be due to different atmospheric and oceanographic conditions. Atmospheric circulation in Southern South America showed a significant change around 1970´s (Agosta and Compagnucci, 2002; Barros, et al. 2000) as well as in other regions of South Hemisphere (Gisbson 1992, van Loon y otros 1993, Hurrel y van Loon 1994, Trenberth 1995).
The percentage change after 1970´s is analyzed, comparing two periods before and after this change. In order to analyze the greater number of stations the selected periods are 1961-75 and 1980-96. Figure 7 shows the spatial pattern for the annual, summer and winter percentage change for PE>0.1 (left) and PE>75th (right). The greatest positive change is concentrated for both indices in a nuclei on the northeast Argentina and southern Brazil. An area of relatively large values is also presented in the northwest Argentina with seasonal variability. The Mesopotamia region shows negative change, more intense and covering a bigger area during JJA. This negative changes enhance and enlarge when the extreme index is analyzed. During spring and autumn months the negative changes only are observed in small spots (not shown).

3.2. Seasonal proportion index

Due to changes in extreme annual indices can occur from changes in specific seasons, seasonal proportion index is calculated.
Firstly, the climatic behavior is analyzed. The shape of the explained percentage field for each season resembles the annual cycle of the rainfall regime. Figure 8 shows the seasonal proportion index for PE>75th. During DJF months the greatest contribution is located over northwestern Argentina and the group of Brazilian stations located in the northeastern study region, decreasing towards the eastern coast of Argentina, Uruguay and south Brazil. The northwestern maximum moves towards the north of Argentina with values greater than 30% in MAM. In the rest of the region the spatial variability is low. During JJA the shape of the explained percentage field is similar to summer months, changing the gradient, minimum in the northwestern Argentina and northeast Brazil, increasing towards the eastern coast of Argentina, Uruguay and south Brazil. During SON months the greatest contribution is observed in the south, decreasing towards the northwest. This season shows the less spatial variability and winter shows the greatest one. The spatial pattern of PI for PE>0.1 index shows similar results (not shown).

Finally, the percentage change of PI after 1970´s is analyzed, comparing two periods 1961-75 and 1980-96. The shape of the explained percentage field of each season resembles the long-term behavior shown in Figure 9. In the 1980-96, during DJF months the gradient increases due to the maximum in the northwestern enlarge and deeply the minimum of Uruguay and south

Brazil. Meanwhile during JJA months the gradient decreases due to mainly the explained percentage is less over Uruguay and southern Brazil. For the transition seasons the explained percentage increases in the last period, being the mainly different located in the southern, close to the Río de la Plata river.

4. CONCLUSIONS

A climatologic knowledge of the daily rainfall regime of La Plata Basin is analyzed by means of indices given by annual and seasonal series of persistence of rainday and no rainday, number of days with rainfall greater than or equal to different thresholds; and proportion of yearly indices that comes from seasonal indices.

The main objective of this paper was analyzed the trend and the temporal variability of these indices, quantifying the changes before and after the 1970's. Fifty one stations with high quality data set are analyzed in the longest (shorter) period 1908-2004 (1972-2004).

The hydrological consequence of accumulated precipitation falling on a number of consecutive days may be more severe than just an intense precipitation falling on a single day. The trend of PE>0.1 and PE>75th were investigated and for each season the results showed similarities and the same regions with the spatial coherence, even though the number of stations with significance trend decreases in PE>75th. There is a large region of spatial coherence in the sign of the trend, located in southern Brazil, Paraguay and northeast Argentina, showing significant increases in annual and seasonal values. Only during Spring months this region conserves the sign of the trend but the number of stations showing significant decreases. On the other hand, the winter trend was found to be the opposite for the majority of stations in central-eastern Argentina, Uruguay and few stations in the province of Buenos Aires. This result has important implications for agriculture as well as for management of natural resources. Specially, in the stations in the province of Buenos Aires where the wheat production is very important. Consequently after the 1970´s, a noticeable negative change in this region was observed. Related to the positive change, located in southern Brazil and northeastern Argentina, it is interested to note that the percentage change increases in PE>75th.

The annual and seasonal trends of persistence of rainday and no rainday were also studied. The results showed significant positive trend in P11 in the whole region. It is worthy of mention the spatial pattern observed in the P00. The regions with positive and negative significant trends are mainly in agreement with the results showed below.

Acknowledgements

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Figure 1: Main orographic features of La Plata Basin.

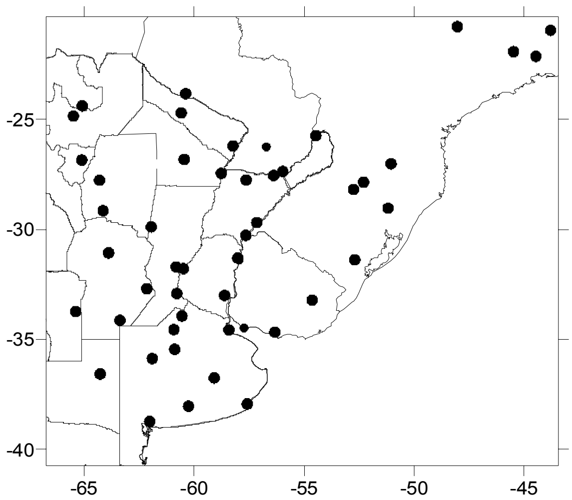

Figure 2: *Distribution of the stations used in the study.*

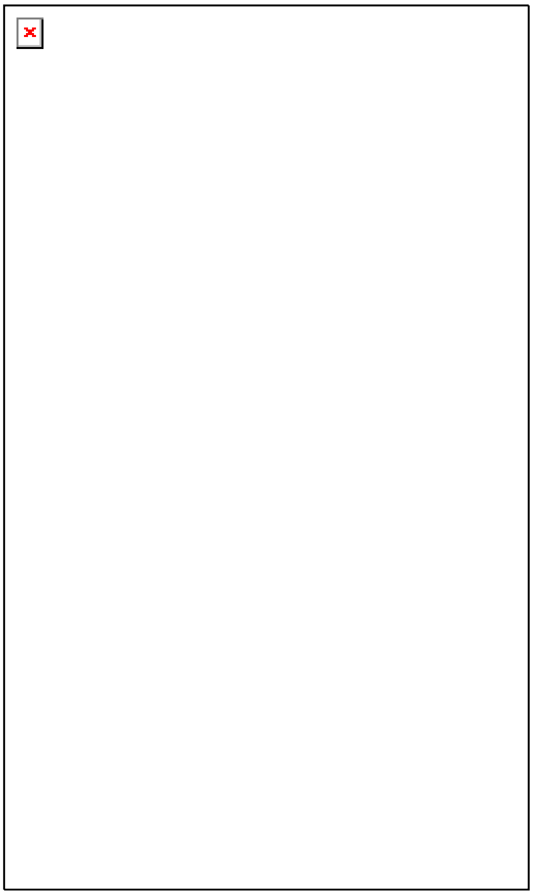

Figure 3: *Sign of the trend in persistences as measured by Kendall’s tau. An increase is showed by a ‘+’, a decrease by a ‘∇’. Values greater than (–0.22; + 0.22) indicate significant at p<0.05.*

Table I
Number of stations with significant annual and seasonal trends

PE>0.1	DEF	MAM	JJA	SON	Annual
Negative	0	0	5	0	2
Positive	13	22	10	4	24
PE>75th	**DEF**	**MAM**	**JJA**	**SON**	**Annual**
Negative	0	0	1	1	0
Positive	7	15	1	4	19

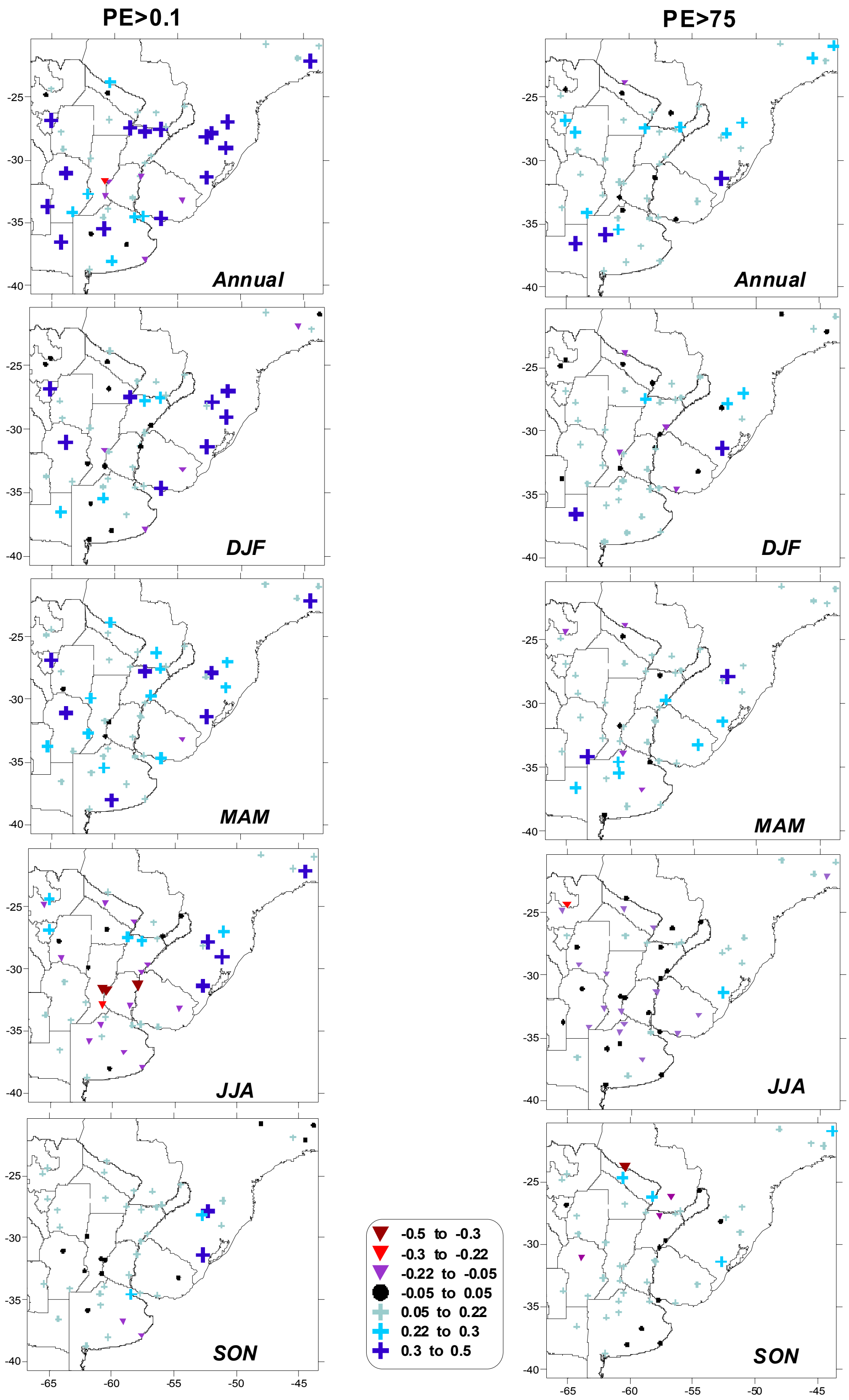

Figure 4: *Idem Figure 3*

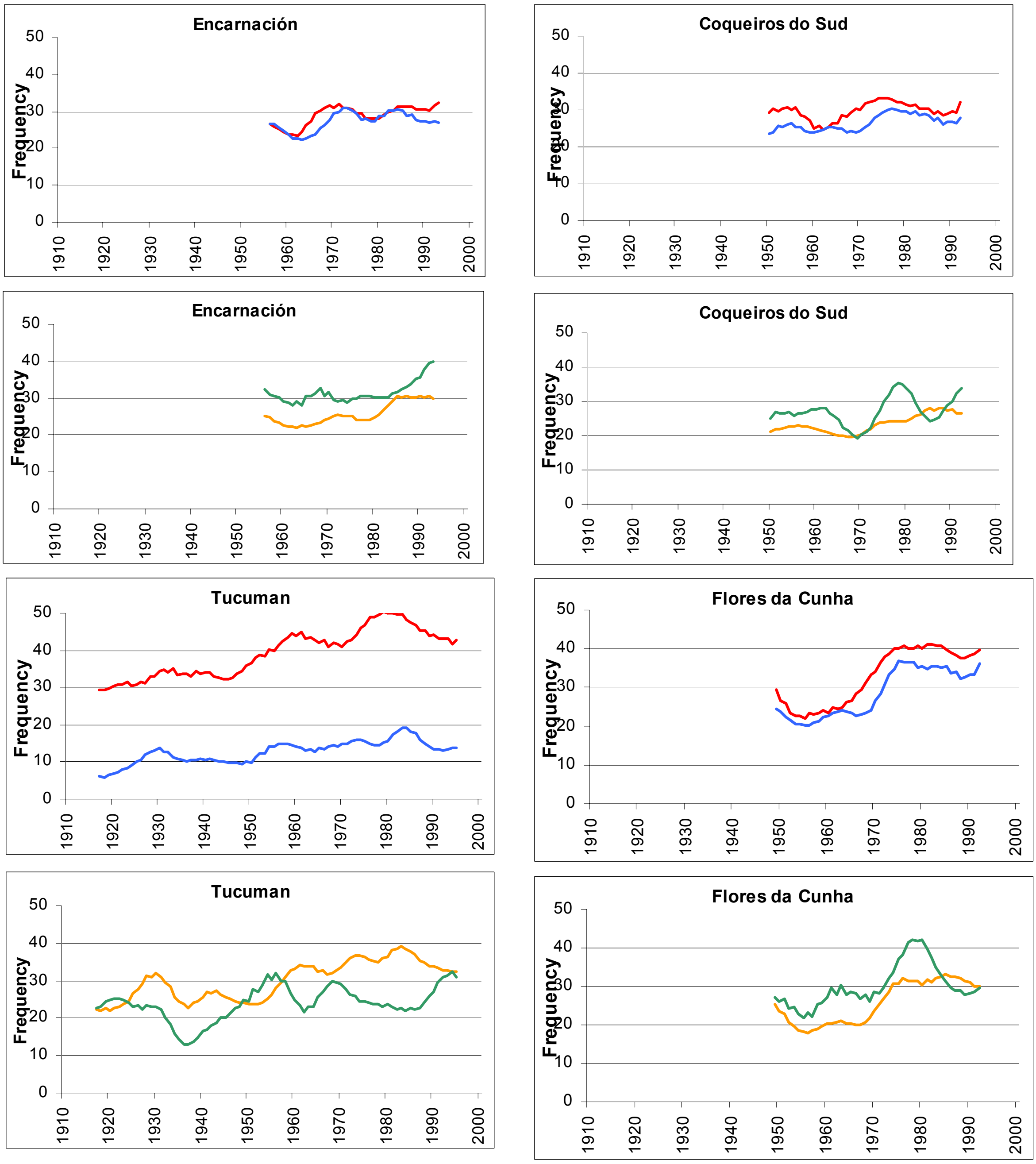

Figure 5: *Time series of PE> 0.1 index for selected stations (Encarnación: -27.55, -56.38; Tucumán: -26.51, -65.12; B292: -29.03, -51.18; B287: -28.18, -52.75).*

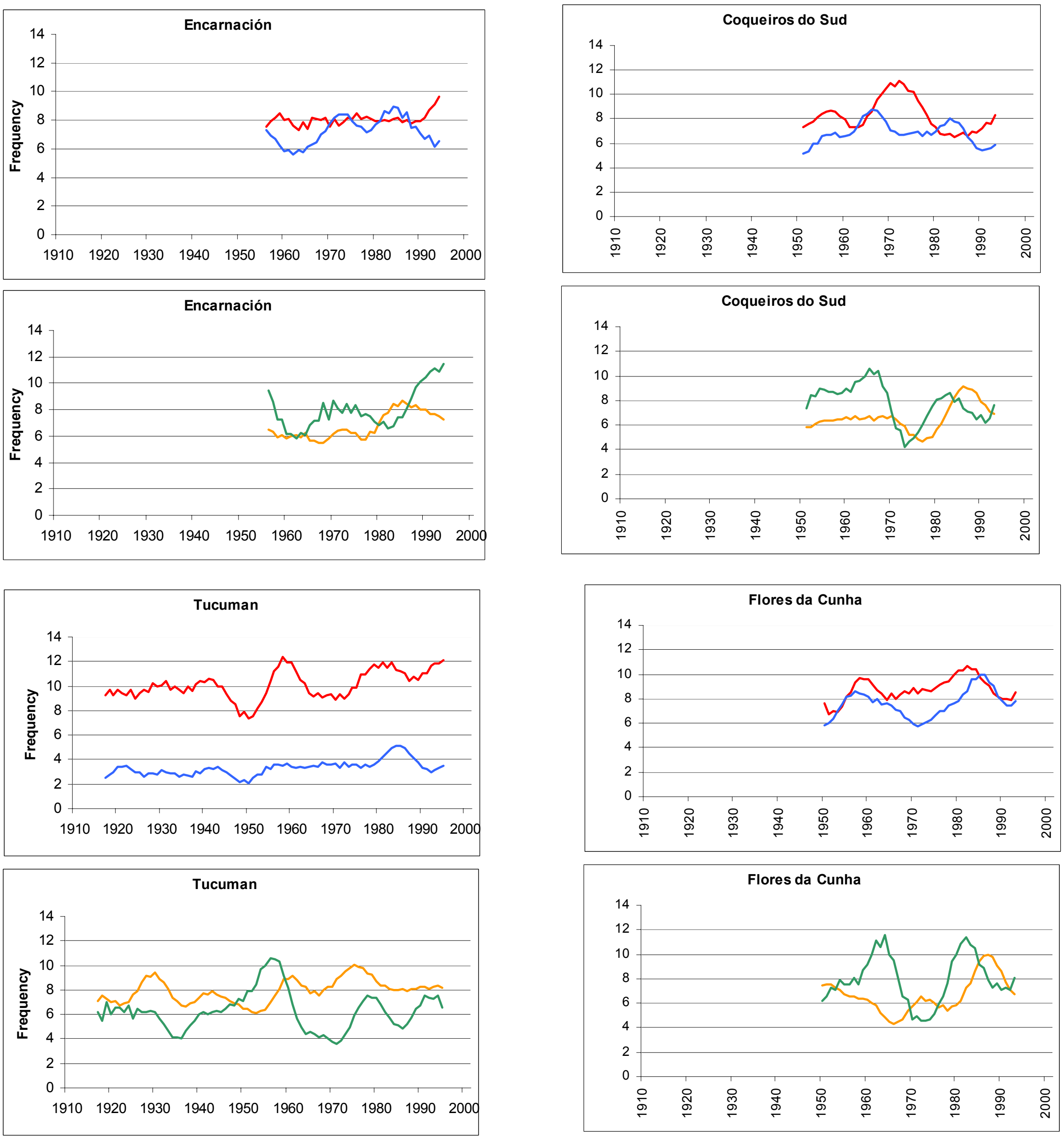

Figure 6: *Idem Figure 5 for PE > 75^th^ index.*

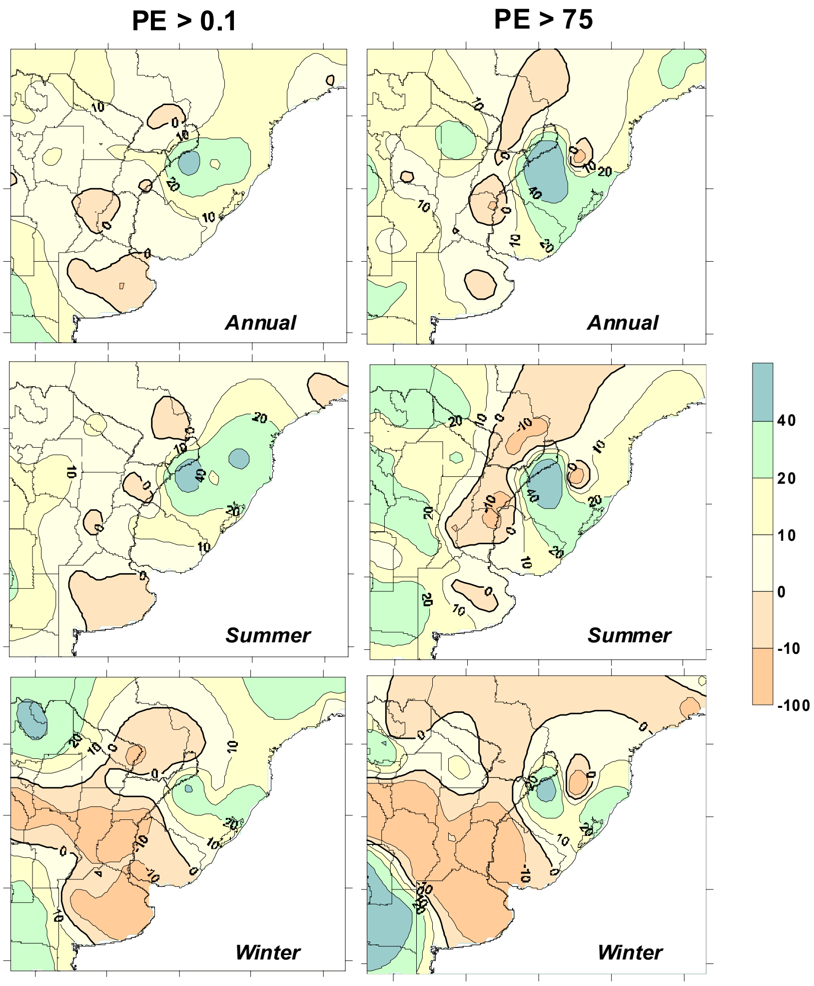

Figure 7: *Percentage change for PE>0.1(left) and PE>75th (right) for annual, summer and winter values.*

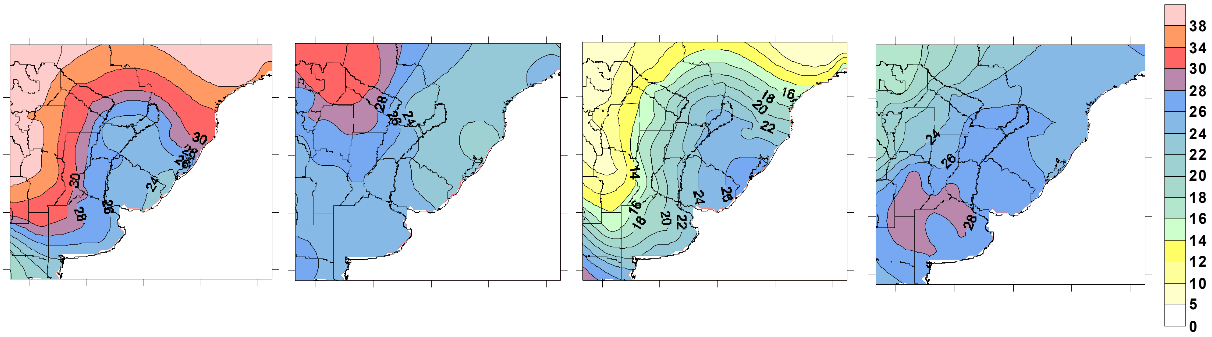

Figure 8: *Seasona*l proportion index *for PE>75th calculated for the climatic period.*

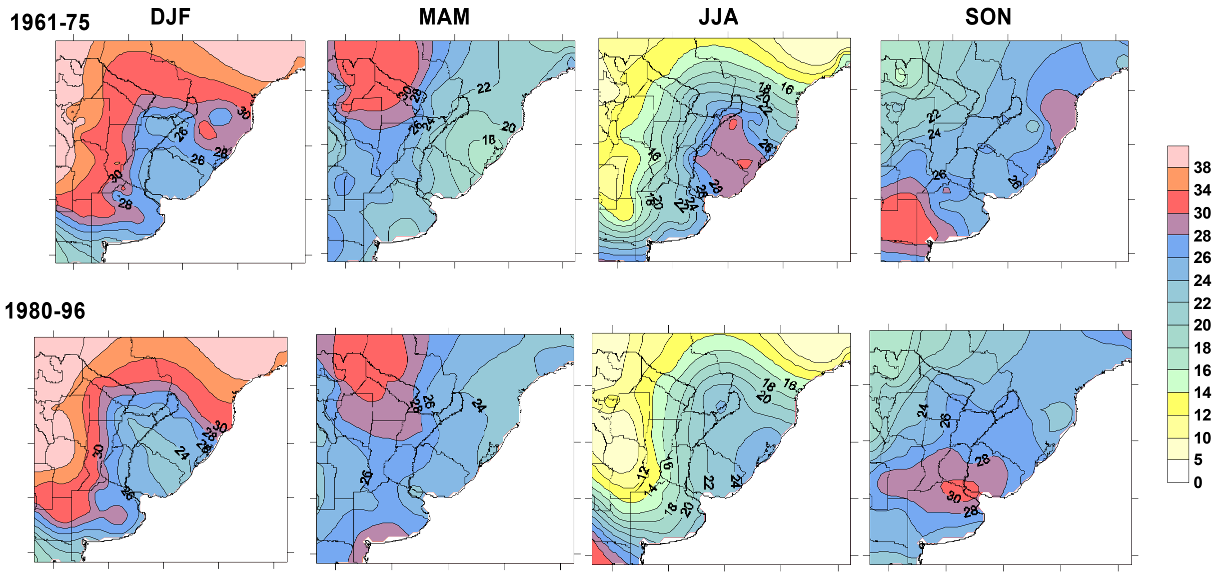

Figure 9: *Seasona*l proportion index *for PE>75th calculated for two periods.*