

TEMPORAL VARIABILITY OF EXTREME DRY EVENTS OVER A REGION OF LA PLATA BASIN

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1. INTRODUCTION

Extreme weather and climate events have received increased attention in the last years. They are the primary uncontrollable weather factor that the environment could be affected. An important aspect of climate extremes is related to excessive dry periods. Dai et al. (1998) shows increases in the overall areas of the world affected by either drought and/or excessive wetness. The Intergovernmental Panel on Climate Change (2007) has reported that more intense and longer droughts have been observed over wider areas since the 1970s, particularly in the tropics and subtropics.

During the last decade, La Plata Basin (LPB) is subject to frequent dry spells, which can sometimes result in more severe and widespread droughts. Frequency droughts of various magnitudes and durations in this region are potentially dangerous, taking into account their impact.

Scientific investigations of drought in LPA have so far been reduced. They characterized the intensity and duration of the periods of drought and hydric excess by means of different indices in specific locations of LPB (Scian and Donnari, 1997; Seiler et al. 2002; Nuñez et al. 2005; among others). Another way to study the severe drought is from the viewpoint of the atmospheric circulation associated (Alessandro and Lichtenstein (1996), Alessandro (2004), others).

Due to rainfall is the primary factor controlling the formation and persistence of drought conditions, in this paper the no occurrence of rainfall is analyzed. Still over, the attention will be focused on extreme dry condition. Understanding the historical frequency, duration, and spatial extent of these extreme dry conditions could also assist planners in determining the likelihood and potential severity of future droughts. The aims of this paper are to determine the spatial patterns of extreme dry conditions in the LPB in order to delineate the degree of continuity of drought in space and analyze the temporal variability, quantifying the changes of these extreme dry conditions.

2. DATA AND METHODOLOGY

2.1 Data Set

Lack of long-term climate data suitable for analysis of extremes is the single biggest obstacle to quantify whether extreme events have changed over the twentieth century, either worldwide or on a more regional basis (Easterling et al. 1999). Specifically, in the study region although there are more rain gauges only 29 rain gauge stations are deemed appropriate for the analysis. High quality daily rainfall data are used from 1961 to 2000 with less than 10% of missing data and continuity of records (Figure 1). All the information used in this study was supplied by the "Servicio Meteorológico Nacional".

2.2. Methodologies

The definition of an extreme condition is intrinsically statistical and a general quantitative determination applicable to any region and for any use is still under discussion. Since the main interest is both in agricultural and hydrological drought, two different periods (summer and winter seasons) are considered. We define an extreme dry event when the length of the sequence of days without rainfall is seven days or more. Then, for each year, the following index is calculated:

NEDE: number of extreme dry events

This index is calculated for the whole year and two austral seasons: summer (ONDE) and winter (MJJA).

Trends in the annual and seasonal indices were analyzed. 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).

Two methods are used in the decadal and interannual analysis in order to facilitate climatic inferences. One is the power spectrum analysis (Mitchell, 1966) and the other a wavelet transform method (Meyers et al., 1993; Torrence and Compo, 1998).

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3. RESULTS

3.1. Mean and interannual variability

Firstly, the mean values of annual and seasonal NEDE indices are analyzed (Figure 2, top). There are no great differences regionally. The region shows values between 11 and 15 for annual NEDE index, whereas during the summer and winter the mean of NEDE index decrease more than the 50%. The spatial variability is greater during the winter. Even though an extreme event is being analyzed the interannual variability is low, showing regions covering great extensions with the same standard deviation (Figure 2, bottom)

3.2 Temporal variability

To determine the most characteristic features of NEDE index, its annual and seasonal evolution for all the stations is analyzed. The annual NEDE index is compiled in Table I. For each station, the three highest values in the analyzed period are indicated with different colors (Table I). There is a tendency to have the biggest extreme events regionally in the beginning of the analyzed period. There are two important extreme events in annual terms, the years 1962 and 1988, where 18 and 14 stations show the highest NEDE index, respectively. The 1962 drought was an important extreme event in Argentina, which affected almost 80% of its territory. Malaka and Núñez (1980) analyzed the fields of different meteorological variables involved.

3.3. Observed trends

To synthesize this temporal variability, the annual and seasonal trends for all the stations are analyzed. Due to the occurrence of the so extreme event at the beginning of the period (year 1962), these trends were calculated with and without this year. The values of the Kendall Tau statistics evaluated in the period (1963-2000) are shown in Figure 3. For the annual NEDE index, the Kendall Tau statistic shows a large region with spatial coherence in the sign of the trend. This region covers the north and northeast and the center-southwest of the region (Figure 3, left). The highest negative values are located in the region of the north. This spatial pattern is resembled during ONDE. However, the highest and significant values are located in the south and southeast of the region (Figure 3, center). During winter the negative trends are concentrated in the

northwest with values close to zero (Figure 3, right).

3.4. Interdecadal and interannual variability

To analyze the interdecadal and interannual variability in the region, the power spectrum and Morlet wavelet transform are applied to the indices. The spatial-temporal variability showed previously can be also seen in this analysis, turning out to be highly non-stationary. The most marked feature is the difference between periods or decades. Figure 4 shows the wavelet transform results of the annual NEDE index for specific stations.

The decadal variability of annual NEDE is observed in few stations of the Argentine northeast, in the period 1975-1995 (see, Posadas in Figure 4). Meanwhile, the 8-yr and 4-yr timescales are observed in stations towards the west (Villa Reynolds in Figure 4) and in the lower La Plata Basin (Paraná in Figure 4).

3.5. Decadal Changes

The previous results indicate that the interdecadal variability is as important as the low frequency variability. To quantify changes in NEDE indices, the percentage of changes related to the period (1961-1970) are calculated. Figure 5 shows the percentage of changes of the annual NEDE index, for three decades: 70, 80 and 90. In the first period (1971-1980), the annual NEDE index decreased in the north of the region, more than 4% (Figure 5, left). This negative region is drained and enlarged in the following decades (Figure 5, center and right). The southern region shows an important change in the 80's decade. This percentage of negative change is only observed during summer, with values up to 30% (Figure 6, left). It is interesting to observe the inverse pattern in practically the entire region during winter (Figure 6, right).

4. CONCLUSIONS

Identifying the interdecadal and interannual variations of a drought index has important applications, mainly when the study region is one of the most important agricultural and hydrologic area of Argentina. Spatial and temporal variability is highly non-stationary. Two significant frequency bands are identified; centered around 8-6 yrs and 4 yrs. Percentage of changes between different periods related to the first decade are calculated. The number of annual dry events decreases in practically the entire region by more than 10 per cent in the

northeastern region, in the last two decades. These negative changes are more intense during summer months, with values greater than 30%. However, during winter the extreme events increase by more of 20 per cent.

Acknowledgements

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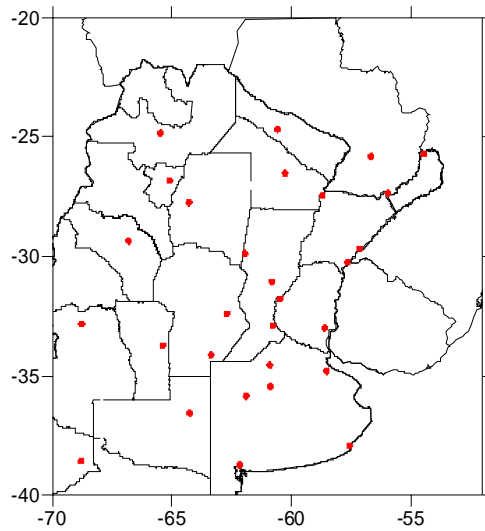


Figure 1. Location of the stations used in the analysis.

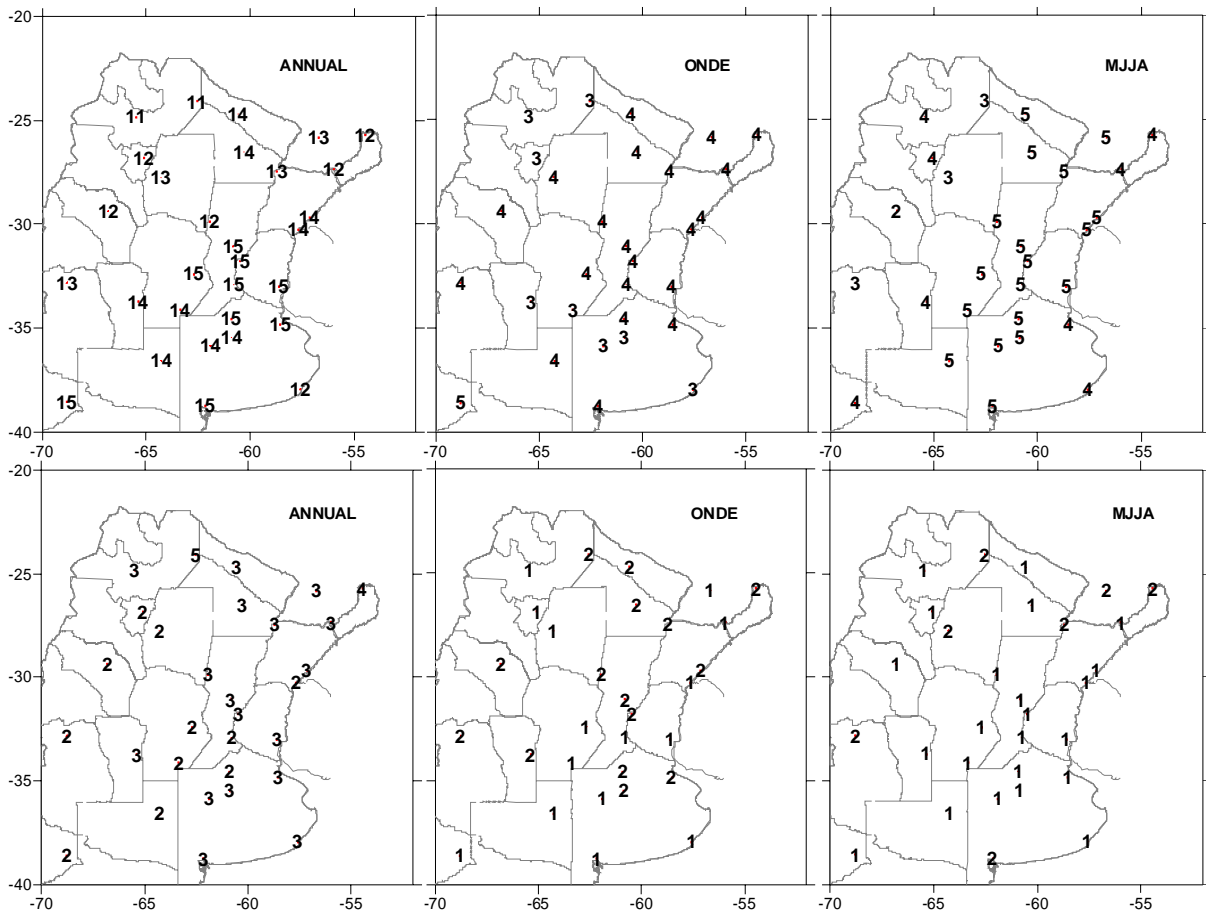


Figure 2. Mean (top) and Standard deviation (bottom) of annual and seasonal NEDE indices (NEDE: number of extreme dry events).

TABLE 1. Annual number of extreme dry events per year and station.

	Ceres	Ezeiza	Gualeguayci	Nuevo Julio	Junin	Laboulaye	M. Juarez	Parana	Pehuajo	Rosario	Sauce Viejo	B. Blanca	V. Reynolds	S. Rosa	Corrientes	Iguazu	Mar Plata	M. Caseros	Posadas	R. S. Peña	S. Estero	Las Lomitas	Mendoza	Neuquen	Paso Libres	Salta	Tucuman	Villarica	La Rioja	
1961	9	19	11	19	15	12	14	13	19	13	15	16	16	18	2	11	8	14	11	17	12	14	15	14	14	13	13	16		
1962	18	16	18	20	16	17	19	21	16	19	22	14	16	15	18	15	18	16	14	18	17	15	13	16	17	11	12	16	14	
1963	11	15	12	11	16	12	15	15	11	9	16	13	13	11	14	13	8	17	14	18	10	17	10	17	16	11	13	14	9	
1964	8	14	16	15	15	12	14	14	15	15	15	13	12	18	13	16	8	14	14	16	14	15	11	13	11	9	11	16	12	
1965	14	15	14	14	17	14	16	16	12	15	15	15	14	18	12	8	12	13	10	13	15	12	10	14	16	14	14	10	11	
1966	11	16	14	18	14	15	14	16	16	16	15	16	13	16	17	3	11	16	12	18	16	15	15	17	9	10	10	13	12	
1967	11	14	12	17	16	13	18	16	20	15	16	18	10	13	15	0	12	14	12	15	14	15	14	12	13	11	14	13	16	
1968	11	15	16	14	11	11	13	16	13	15	13	13	18	15	11	14	9	11	15	10	17	19	12	14	9	14	15	18	12	
1969	14	15	16	12	16	14	18	15	12	14	13	14	15	15	16	15	10	18	12	15	13	15	11	20	14	13	12	14	11	
1970	15	13	15	9	13	13	16	14	11	15	15	17	13	13	16	10	14	15	13	17	16	14	6	18	9	8	11	12	11	
1971	16	14	14	16	15	15	13	15	14	11	18	16	17	19	14	11	15	17	14	10	18	14	19	14	6	11	13	9		
1972	10	13	15	14	14	11	15	16	16	14	17	11	15	11	12	13	9	11	16	13	14	15	17	18	11	14	13	11	15	
1973	8	13	14	17	15	12	12	8	12	14	11	15	14	12	15	12	16	15	14	13	11	17	13	16	12	11	10	14	13	
1974	13	20	18	19	18	13	16	15	16	16	15	15	12	12	16	13	12	15	16	17	10	17	10	17	17	13	14	13	13	
1975	9	18	19	20	15	12	15	14	14	13	15	19	15	16	13	12	15	14	10	15	15	14	12	17	12	13	14	11	12	
1976	12	11	11	13	13	17	14	11	12	12	12	14	16	17	13	14	15	14	16	12	10	16	13	15	14	12	12	16	13	
1977	10	12	12	14	17	18	14	15	15	16	15	17	16	17	14	17	11	14	13	14	17	16	14	18	12	10	14	17	10	
1978	7	14	13	10	10	11	10	11	14	10	14	12	13	15	12	13	8	14	14	12	12	15	11	11	15	6	7	17	8	
1979	13	15	16	12	16	11	15	20	14	14	18	13	15	14	12	16	15	14	14	11	15	12	16	15	12	9	14	11		
1980	14	12	10	19	18	15	13	14	18	14	17	15	12	13	16	17	11	15	14	18	11	16	15	14	16	12	9	13	9	
1981	9	11	15	11	11	13	14	14	15	17	17	13	14	14	15	10	12	17	14	16	12	13	13	11	17	11	9	14	16	
1982	14	16	16	15	16	10	15	15	16	14	18	11	12	13	10	11	11	14	8	13	9	14	13	14	13	12	13	10	10	
1983	13	16	16	15	16	14	16	17	14	19	18	13	16	14	14	11	16	17	11	10	16	13	14	12	16	16	11	10	14	
1984	8	12	13	11	15	13	13	13	15	16	0	11	15	10	12	12	11	7	10	13	10	14	13	15	11	10	12	13		
1985	8	12	16	11	15	14	13	16	9	14	12	17	15	12	15	16	11	15	10	13	14	18	17	14	17	10	10	12	12	
1986	13	15	13	14	14	17	17	13	16	16	15	12	18	12	11	13	11	13	12	11	15	14	17	17	12	15	11	12	12	
1987	14	9	10	12	13	14	10	15	17	13	16	15	10	11	10	15	13	18	14	17	13	16	16	14	17	9	14	14	14	
1988	16	19	21	16	16	13	14	15	15	14	16	11	11	15	16	9	13	17	12	11	12	9	8	15	18	11	12	12	9	
1989	10	17	18	17	18	16	20	21	17	17	20	17	20	17	18	10	15	20	13	17	16	14	12	13	19	10	12	11	12	
1990	9	10	11	11	9	14	13	11	7	10	13	15	15	12	10	8	11	7	9	10	11	14	15	13	7	6	9	10	13	
1991	11	18	14	13	14	17	14	14	13	15	14	19	15	13	13	17	17	10	15	17	13	11	14	13	13	13	9	16	8	
1992	9	14	12	10	11	15	14	10	14	16	12	13	13	14	10	10	11	13	7	15	16	11	12	20	10	14	14	10	9	
1993	14	15	18	13	14	14	15	19	12	18	20	14	9	12	17	18	9	16	12	21	14	16	12	15	13	14	14	16	11	
1994	13	16	16	13	14	13	16	18	13	16	17	14	14	16	12	10	9	14	8	17	12	16	15	17	13	8	9	11	14	
1995	10	19	16	17	20	16	15	19	15	17	13	15	16	16	13	15	13	15	12	13	11	12	13	15	17	14	13	16	11	
1996	12	15	16	15	14	14	17	13	15	18	15	18	14	18	10	9	12	15	9	11	11	6	16	15	13	8	9	9		
1997	12	15	17	12	12	10	15	16	15	18	18	17	10	15	12	11	11	13	13	15	14	17	14	14	14	11	11	16	13	
1998	13	17	16	16	18	17	18	17	16	15	18	17	14	16	14	10	15	15	10	15	14	13	17	15	15	15	8	12	10	15
1999	12	16	13	12	16	16	13	14	15	18	16	15	11	15	13	15	12	14	13	11	9	13	13	15	16	9	13	12	13	
2000	6	13	12	11	15	11	14	13	13	17	10	14	9	11	10	10	9	13	14	9	10	12	17	18	17	8	7	0	15	

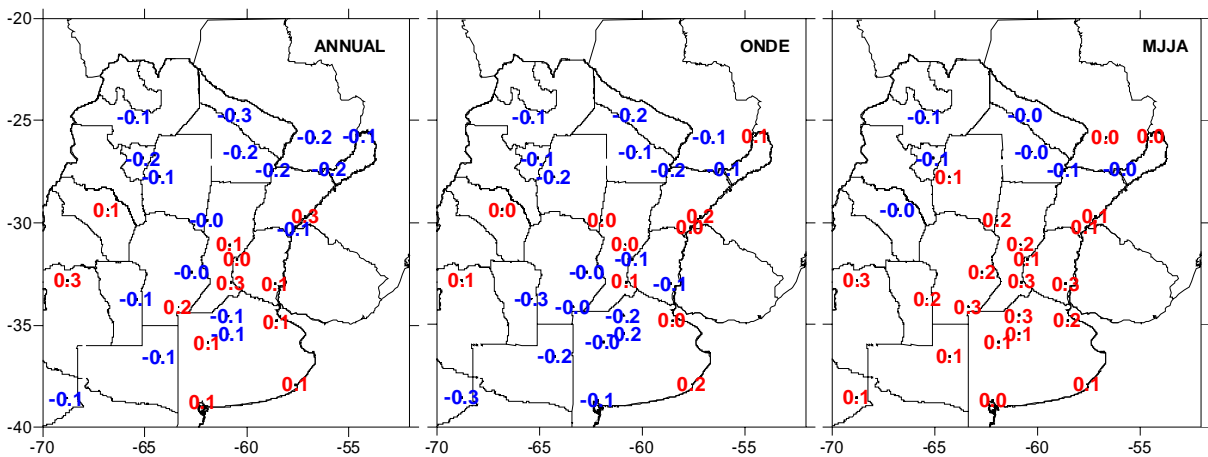
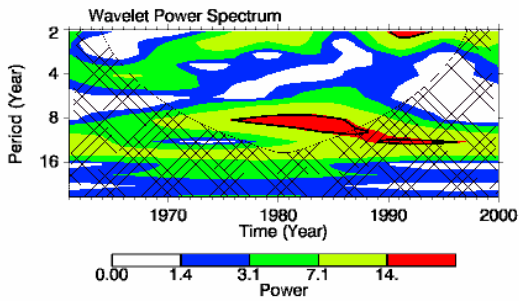
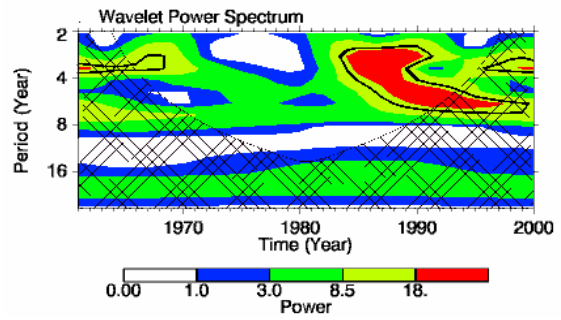


Figure 3. Kendall tau statistics for the annual (left), summer (center) and winter (right) NEDE indices.

POSADAS



VILLA REYNOLDS



PARANÁ

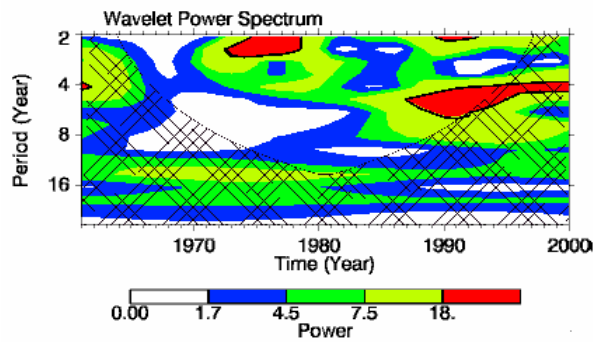


Figure 4. Wavelets transform results of the of the annual NEDE index for specific stations. The thick contour encloses regions of greater than 95% confidence for a red-noise process. Cross-hatched regions on either end indicate the 'cone of influence', where edge effects become important. The shading scale is shown in the label bar.

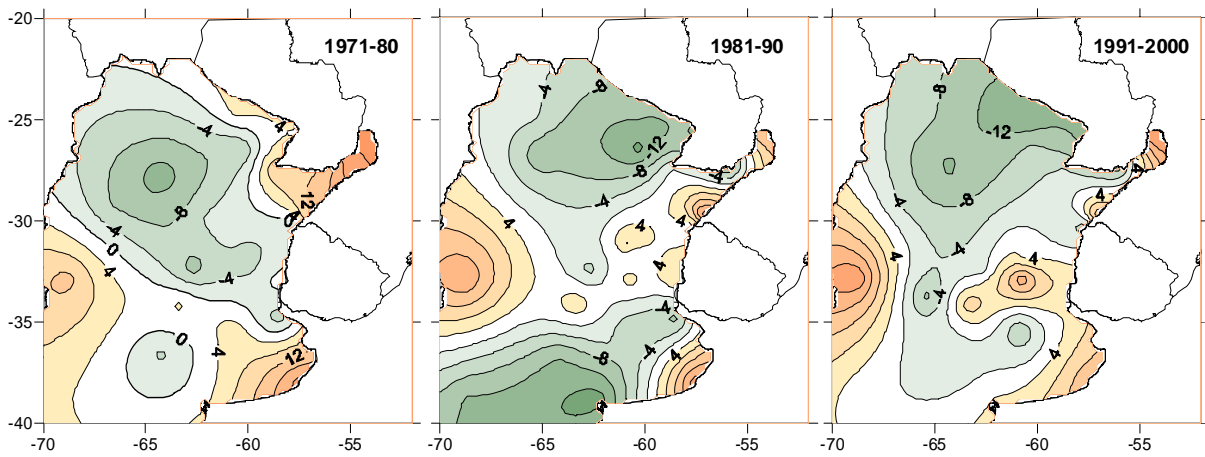


Figure 5. Percentage of change related to the period (1961-1970) for annual NEDE index for three decades.

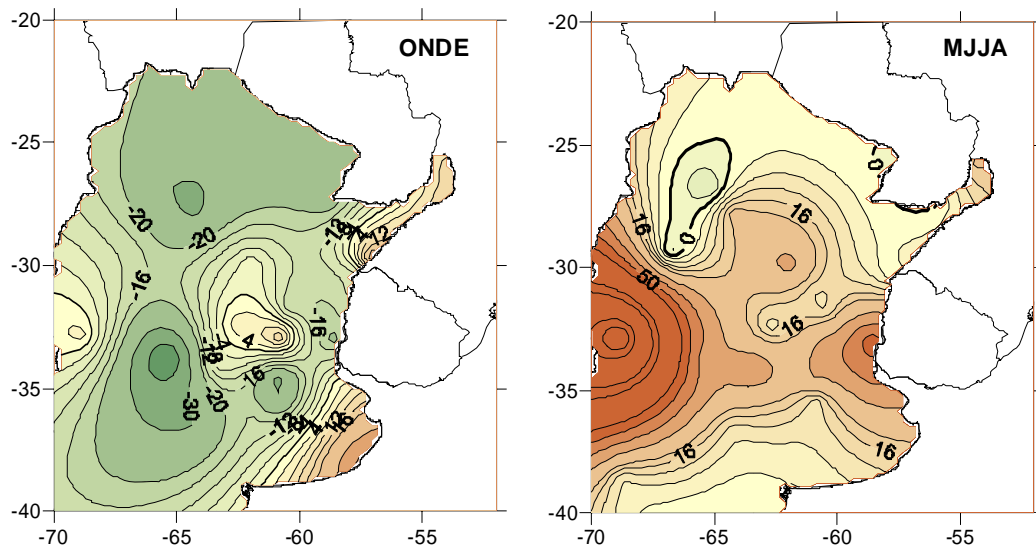


Figure 6. Percentage of change related to the period (1961-1970) for summer and winter NEDE index for the decade 1991-2000.