TEMPORAL VARIABILITY IN THE LENGTH OF NO-RAIN SPELLS IN ARGENTINA

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1. INTRODUCTION

The analysis of daily rainfall in Argentina is a subject of great interest owing to the hydrological problems. This interest is not merely climatological; it must be considered when we are designing hydrologic systems, managing agricultural and natural resources. Central-northeastern Argentina belongs to the La Plata Basin. Extreme events can cause enormous losses in the agricultural and cattle raising sector. In particular, any change in the probability of no rain spell would cause significant damage to agriculture and hydrology.

Precipitation in Argentina has strong geographical variations. These range from a very well defined annual cycle (peak rainfall during the warm season) in the North and Northwest to an almost uniform distribution with small peaks during spring and autumn in the eastern-central area, northeastern Argentina and to the scarce rainfall in the South (Rusticucci and Penalba, 2000; Penalba and Vargas, 2005). Daily rainfall regime and geographic distribution over the Argentina region has been studied by Penalba and Robledo (2005). Daily precipitation percentiles and the frequency of rainday show the same spatial variation, having the greatest values in the northeast region.

The study of wet or dry spells for a significant number of stations is rather limited. Ruiz (2005) analyzed daily dry condition in one station of Argentina, focus the attention in the dry spell of 5 to 7 days. In the Argentine humid and semihumid region, Vargas and Alessandro (1985, 1990) estimated theoretically the sequences of the anomaly of the temperature and monthly rainfall applying the geometrical distribution. Penalba and Vargas (2005) analyzed the spatial and temporal changes in the frequency of months per year of low rainfall and sequences of consecutive month with below normal rainfall and fitted two theoretical models, binomial and geometric in the Río de la Plata Basin.

Amongst the most frequently used stochastic procedures for the treatment of wet and dry spells are the Markov chains of different orders. Markov chains and their properties are used in many scientific fields, among others Haan et. al. (1976), Moon et. al. (1994), Gregory et. al. (1993), Martin-Vide and Gomez (1999), Tolika and Maheras (2005) and Lana and Burgueño (1998).

For the present study, our attention is to analyze the length of the no-rain spells, the number of days that comprising them and their temporal variability, specially evaluate changes before and after the 1970's.

2. DATA AND METHODOLOGY

High quality daily station datasets are used in this analysis. Although there are more raingauges in the Argentina territory only 35 raingauge stations and 1 Paraguayan station are deemed appropriate for the analysis with long records (more than 40 years); less than 10% of missing data and continuity of records. All the information used in this study were supplied by the "Servicio Meteorológico Nacional" and the "Instituto Nacional de Tecnología Agropecuaria" (local organization). The data used were processed to included the best available datasets: statistical tests, comparison with neighbouring stations and local knowledge (Sneyers, 1990). This database represents the different types of climate existing in Argentina, even thought the number of raingauges with reliable daily data to the south of 40ºS (Patagonia region) and middle and high mountain areas (central-western region) is low (see Figure 1 for their locations).

Precipitation events occurring on 29 February (leap year) were omitted from the analysis. The shorter period analyzed was 1961-2003 and the longest one was 1911-2003.

The definition of no-rain spells is based on the length of the sequences of days without precipitation. The probability of having dry spells of certain duration is estimated theoretically by employing the first-order Markov chain time series model. The probability that a dry spell will last exactly n days is given by the following analytical expression:

$$Q_n = p_{00}^{n-1}(1 - p_{00})$$

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where p_{00} is the probably of a dry day following a dry day.

For further details on the theoretical distributions used, the reader is referred to Feller (1968), Katz (1974) and Wilks (1995). In order to verify the goodness-of-fit, statistics X were computed and the spatial fit variations were inspected (Buishand, 1982; Sneyers 1990). Statistics X has a χ^2 distribution with γ degrees of freedom. The agreement between the fit and observations is satisfactory at the 95% level.

3. RESULTS

3.1 Geographical distribution of dry spells

Figure 2 shows the regional distribution of the longest dry spells (in days) in Argentina. The longest dry spells are recorded in western Argentina and also in the South, while the shortest ones occur in the Mesopotamia. The analysis of the longest dry spells is relevant in the analysis of the drought and also its impact in the society. This is the case of the maximum dry spell occurred in Pergamino (192 days) in the summer 1996/97, which caused enormous losses in the agricultural production.

In this analysis we are interested in climatic results. So, the number of dry spells of length equal to or more to 60 is compiled in Figure 3. This result shows up the rainfall regime, the greatest number of dry spells in the western region decreasing towards the East and South.
Finally, the mean length of dry spells in days is calculated. Figure 4 completes the great rainfall variation existent in Argentina. As a general feature, we can observe that the expected length becomes larger from east to west, with remarkably low values, in relative terms, of less than or equal to 6 days, assigned to the stations located to the east of meridian 65ºW. Conversely, the rest of the country is linked to expected lengths of 10, 11 and 12 days, with a noticeably strong positive gradient, which is evident in the central-west Argentina. The isohyet of 6 days divides the Argentina in two: towards the east is located a region with wetter condition very important agricultural production and westwards lies a region of deserts which is the extension of the coastal deserts of Peru and northern Chile.

These results show the different rainfall regime in the arid zones of Argentina. One in the East of the Andes, where the number of long dry spells has to be very high because of the summer is very dry, in contrast with the arid condition show in Patagonia, where the rainfall is low through the year.

3.2. Climatic frequency distributions.

Once the empirical distribution of frequencies of dry spells according to their length is found, the same frequencies have been estimated for each station using the Markov chain distribution models. The concurrence between the fit and the series of observations is satisfactory only in the east of Argentina north to 37ºS, with a significance level of 95% (Figure 5). The biggest differences between the theoretical and empirical distribution are located in a transitions zone from wet to dry episodes and in a region of dry condition.

In the case of the first–order Markov chain only takes into account the probability of a dry day following a dry day (P00). The spatial behavior of this parameter is shown in Figure 6. All the stations show high values of P00, observing the smallest values (0.78) in the northeastern. So, as the probability of a dry day after a dry day is high in a great part of Argentina, it will be difficult for a first-order Markov chain to adjust the empirical distribution.

3.3. Temporal changes in dry condition

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). In order to analyze if there is a change in the length of the dry spells two periods are analyzed 1961–70 and 1981–90.

Figure 7 shows the spatial distribution of the average dry length (in days) for all the studied area in the two periods. As a general feature, we can observed that the expected length becomes smaller in the last period. The remarkably differences are observed in the western region where the mean dry length is 11 days. It is interested to observe that there is not evidence of change in the northeastern and eastern region and in the province of Buenos Aires.

Analogous results are obtained for the adjustment between theoretical and empirical frequencies and for the persistence P00, even though the differences between the two periods are smaller. Figure 8 shows the estimation of P00. The greater differences are again observed in the central-western Argentina.

4. CONCLUSIONS

Extreme weather events in Argentina affect the agro-socio-economic environment. From the viewpoint of water resources management policy, a detailed study of drought periods is absolutely necessary as well as the forecasting extreme episodes of consecutive dry days. The Markov chains model give us a more complete description of the dry behavior related to a rain gauge.

The length of dry spells in Argentina is very high. The mean length of the dry spells increases from east to west, from around to 5 days to more than 11 days. The longest dry spells (more than 150 days) occurred in the western region. The adjustment of the empirical distribution of frequencies of dry spells using first-order Markov chain is statistically satisfactory in northeaster Argentina. In accordance with the adjustment of the distribution of dry spells, the "drought" can be considered a Markovian process in northeaster Argentina.

The behavior of the dry spells before and after the atmospheric circulation change around 1970´s was analyzed. The region where the changes are more evidence is in the western region. In general, the longest and mean length becomes smaller and the persistence of no rainday is less, in the last period.

Acknowledgements
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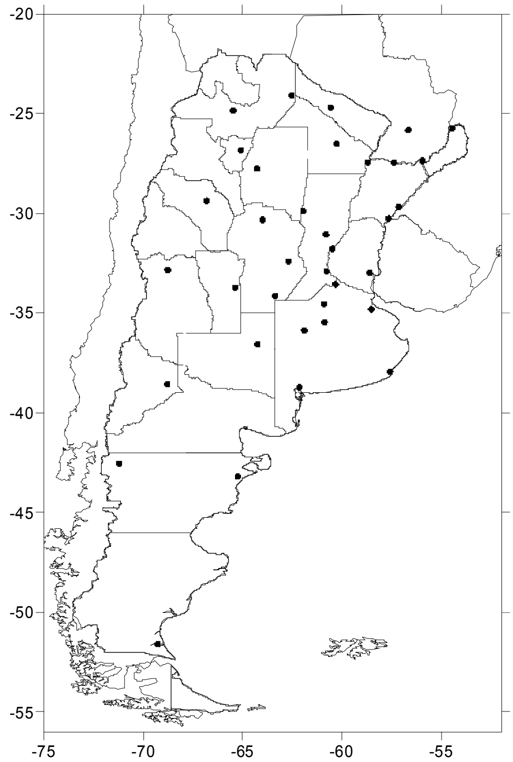

Figure 1: The distribution of the stations under in the study.

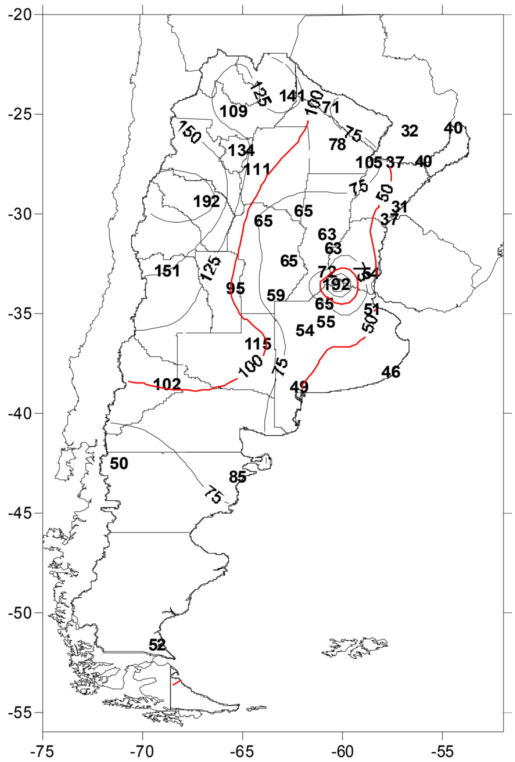

Figure 2: Maximum length in days of the dry spells.

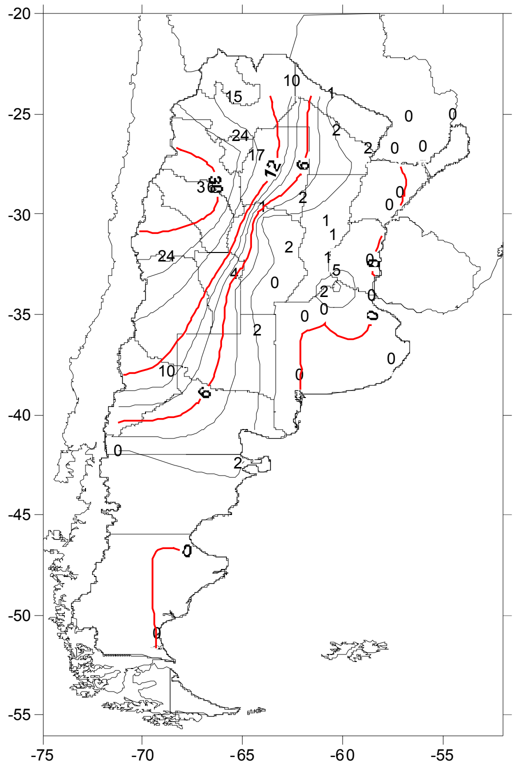

Figure 3: Number of dry spells of length equal to or more than 60 days.

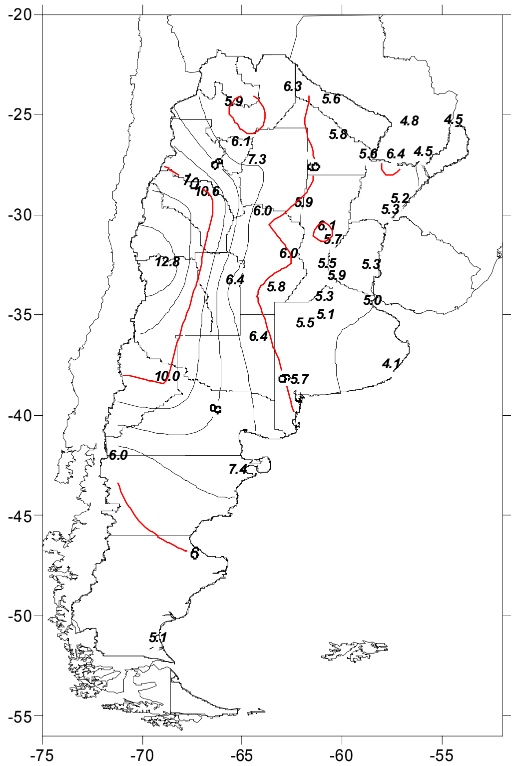

Figure 4: Mean length in days of the dry spells.

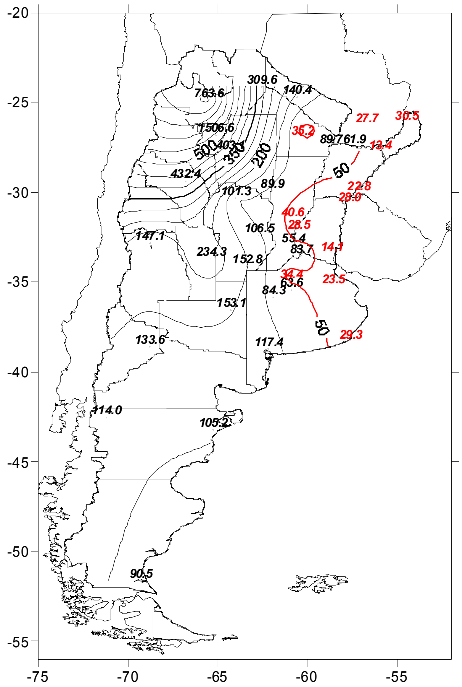

Figure 5: Empirical values of Chi-squared, for each station, comparing the empirical distribution of frequencies of dry spells and theoretical estimation using first-order Markov chain distribution models. Red numbers are significant at 95%.

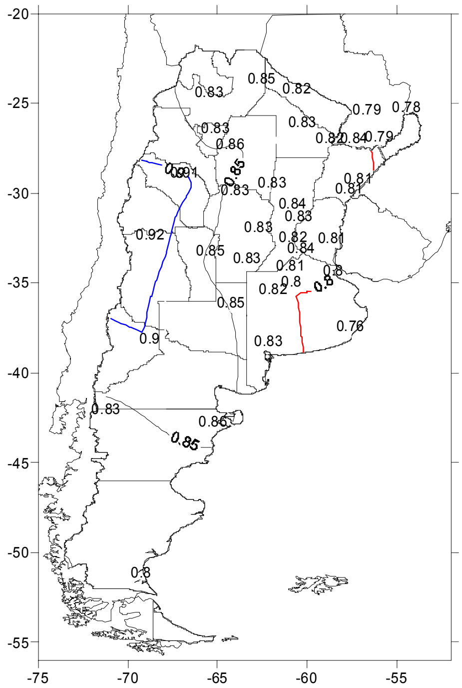

Figure 6: Persistence of no rainday.

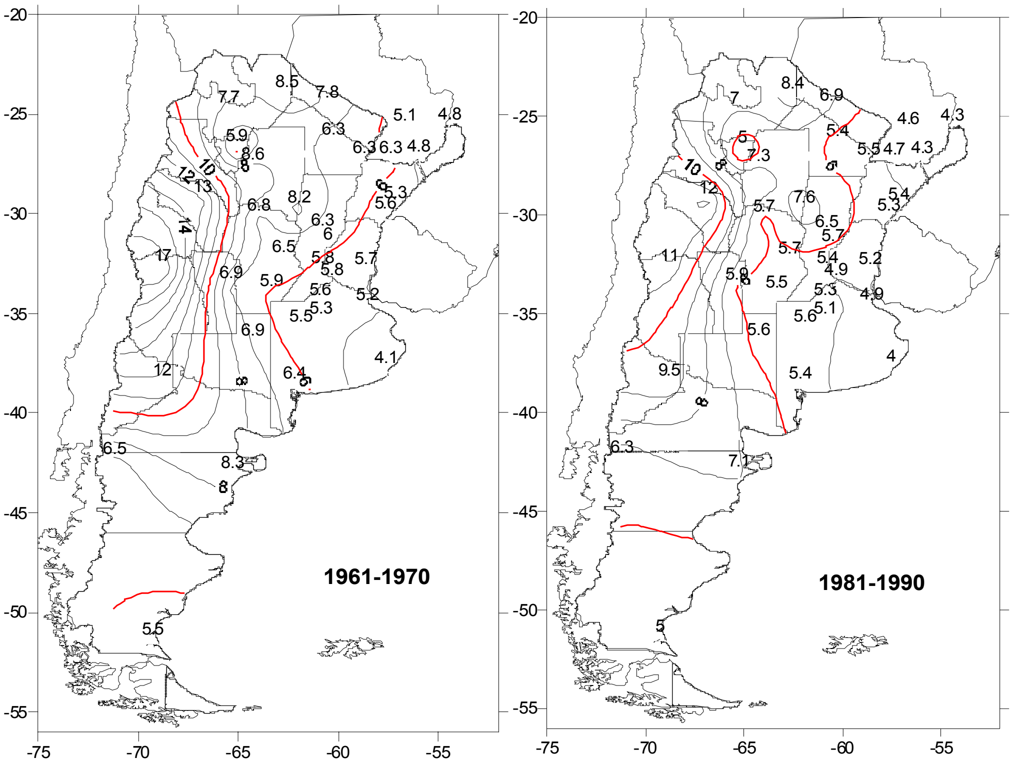

Figure 7: Mean length in days of the dry spells in two periods 1961–70 and 1981–90.

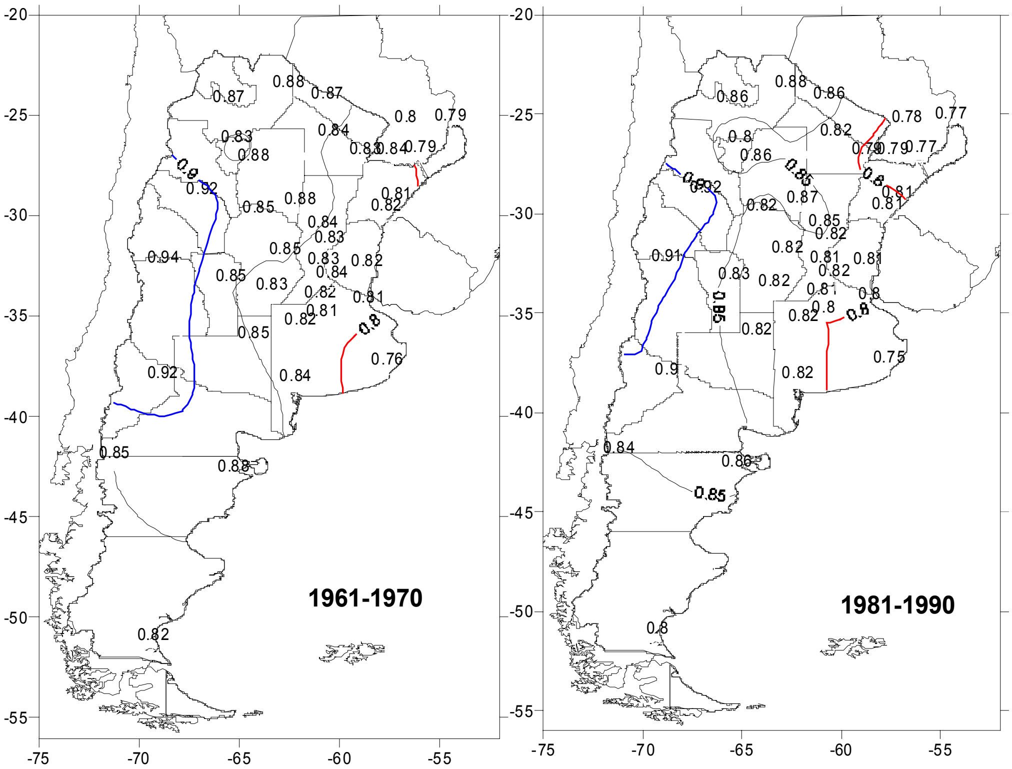

Figure 8: Persistence of no rainday in two periods 1961–70 and 1981–90.