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FREQUENCY OF PRECIPITATION IN THE HUMID PAMPA OF ARGENTINA

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1. INTRODUCTION

Climate is one of the most important limiting factors for agricultural production, in particular the precipitation. Agriculture is quite sensitive to the ordinary rhythm of the climate, being adjusted to make use of the seasonal changes. Failure of the expected seasonal rainfall or any other kind of disturbance of the rhythm leads to economic losses.

Climate variability is the major source of risk for agricultural production in Argentina, a major farming country. Crop productivity in Argentina is highly dependent on rainfall during particular windows of time (Hall *et al.*, 1992; Podestá *et al.*, 1999) and varies from east to west according to a precipitation gradient. Regional precipitation over the Argentine Pampas in particular is marked by the peculiarities associated with prevailing topographical and atmospheric conditions. The complexity of precipitation regimes and the understanding of these characteristics are of economic and agricultural value.

Annual and monthly precipitation variability in different regions of Argentina were studied by different authors. For example, Boulanger (2005), Castañeda and Barros (1994), Minetti and Vargas (1997), Penalba and Vargas (1996), Rusticucci and Penalba (2000), Krepper y otros (1989), Vargas (1987), Krepper y Sequeira (1998). The authors showed a general increase in annual precipitation particularly in the region of interest in this work and in the western stations the long-term annual precipitation change was represented by a positive "jump" or discontinuity. Penalba (2004) found the same behavior in summer months. Liebmann et al. (2004) identified seasonal (January-March) linear trends of precipitation during 1976-99. Moreover the isohyets were displaced 200 km westward in this century, with a positive increase in several parts of the country 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. 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.

Crop diversification and production depend not only on total precipitation, but also on the distribution of precipitation during the growing season. Frequencies of daily precipitation events have important implications for agriculture as well as for management of natural resources.

The objectives of this work are to analyze the annual cycle of percentiles are the frequency of daily precipitation events throughout the year, with special interest in extreme and very heavy rainfall.

2. DATA AND METHODOLOGY

Historical daily rainfall records were obtained from the National Weather Service for 26 pluviometric stations located in the humid Pampa, located north of 40°S and east of 65°W. Precipitation events occurring on 29 February (leap year) were omitted from the analysis. The shorter period analyzed was 1962-2003 and the longest one was 1908-2003. Figure 1 shows the stations used and Table I gives the names, provinces, latitudes, longitudes and the lengths of records.

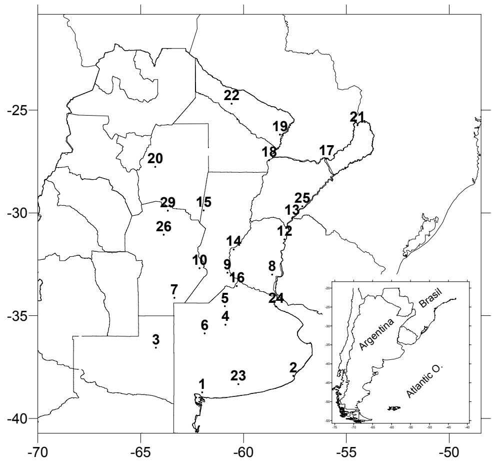

Figure 1: *Distribution of the stations used in the study*

The data used were processed to obtain consistent homogeneous databases. All stations selected have less than 10% of months missing for their period of record. Stations were subjected to statistical tests to check for artificial jumps, outliers and trends in the series (Buishand, 1982).

The analysis of spatial and temporal patterns of 50th, 75th, 90th, and 95th percentiles of daily precipitation are analyzed over the whole period of each station. The frequency of precipitation events for each day of the year is assessed. This frequency is determined for daily precipitation

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events of at least 0.1, 2, 5, 10, 30, 50, 80, 100 mm and also for the 75th, 90th, 95th percentiles. These percentiles are clarified by smoothing the data using a 7-day running average. The persistence of rainday and no rainday is also analyzed by assessing the probability of rainday when the day before was a rain day and the probability of no rainday when the day before was a no rainday. The annual cycles of these statistics are smoothing using 7-day running average. To analyze together spatial behavior and temporal evolution through the year the average of these statistics are performed by selected months.

Table I. Names, numbers (#), provinces, locations and record periods at the stations shown in Figure 1.

Stations	#	Provinces	Latitude (ºS)	Longitude (ºW)	Period
Bahía Blanca	1	Buenos Aires	-38,44	-62,10	1956-2003
Mar del Plata	2	Buenos Aires	-37,56	-57,35	1962-2003
Santa Rosa	3	La Pampa	-36,34	-64,16	1937-1996
9 deJulio	4	Buenos Aires	-35,27	-60,53	1950-1996
Junín	5	Buenos Aires	-34,33	-60,55	1950-1996
Pehuajo	6	Buenos Aires	-35,52	-61,54	1959-2003
Labolulaye	7	Cordoba	-34,08	-63,22	1950-2003
Gualeguaychú	8	Entre Rios	-33,00	-58,37	1961-2003
Rosario	9	Santa Fe	-32,55	-60,47	1949-1996
Marcos Juarez	10	Cordoba	-32,42	-62,09	1956-2003
Villa María	29	Cordoba	-29,54	-63,41	1959-2003
Concordia	12	Entre Rios	-31,18	-58,01	1963-2003
Monte Caseros	13	Corrientes	-30,16	-57,39	1961-2003
Paraná	14	Entre Rios	-31,47	-60,29	1956-2003
Ceres	15	Santa Fe	-29,53	-61,57	1956-2003
Pergamino	16	Buenos Aires	-33,56	-60,33	1931-1996
Posadas	17	Misiones	-27,22	-55,58	1962-2003
Corrientes	18	Corrientes	-27,27	-58,46	1903-2003
Formosa	19	Formosa	-26,12	-58,14	1963-2003
Santiago Estero	20	Santiago Estero	-27,46	-64,18	1956-2003
Iguazu	21	Misiones	-25,44	-54,28	1961-2003
Las Lomitas	22	Formosa	-24,42	-60,35	1959-2003
Tres Arroyos	23	Buenos Aires	-38,2	-60,15	1959-1996
OCBA	24	Buenos Aires	-34,34	-58,25	1908-1998
Paso de los Libres	25	Corrientes	-29,41	-57,90	1959-2003
Pilar	26	Cordoba	-31,40	-63,53	1930-2003

3. RESULTS

The annual rainfall in the region under study ranges from 500 to 1800 mm, decreasing towards the southwest. The annual rainfall distribution in the Argentine northeast shows two equinoctial maxima with a monthly precipitation of more than 50 mm all the year round. The distribution continues, with rainfall gradually decreasing southwards while to the west-southwest rainfall is predominantly during the summer (Hoffman, 1975; Prohaska, 1976; Krepper *et al*., 1989; Penalba and Vargas, 1996; Rusticucci and Penalba, 2000; Penalba and Vargas, 2004).

The annual cycle of the 50thpercentile of daily precipitation amount shows the lest annual range among the percentiles. Even though the interdiurnal variability is greater in the highest percentile; the annual cycle of the interdiurnal variability for each percentile is less in the northeastern stations, increasing toward the south and southwest (Figure 2). The mean 50th and 95th percentiles rainfall were calculated for selected months (Figure 3 and 4). January 50th percentile rainfall shows values around 10 mm/day in the Argentine northeast and stations in the north of the province of Buenos Aires.

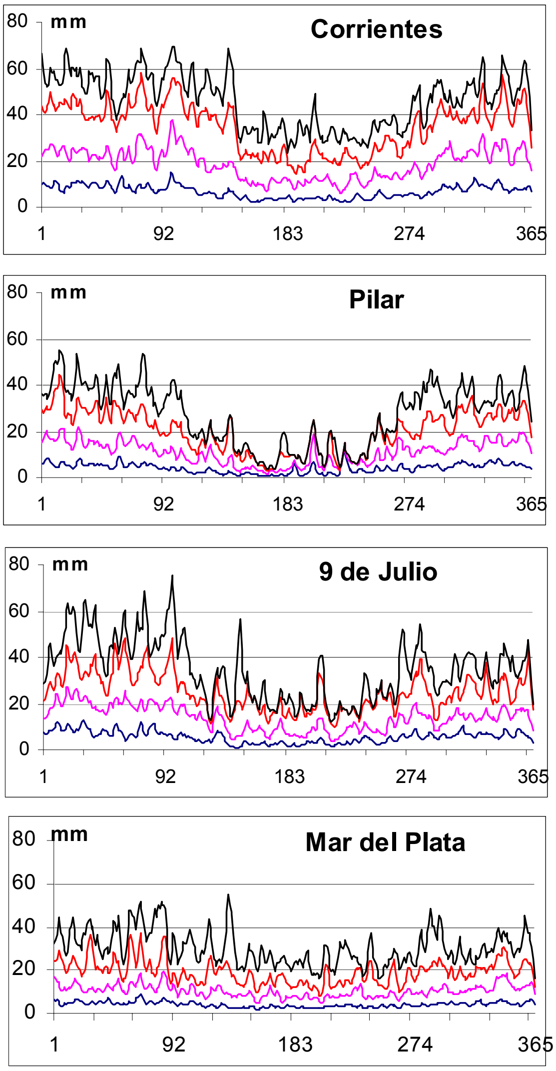

Figure 2: *Annual cycle of (---)50th, (---) 75th , (---) 90th, (---) 95th percentiles of daily precipitation amount.*

Towards the west there is an extensive zone with values around 7 mm/day. During April the 50th percentile decreases in the whole region except for the northeastern stations, increasing the gradient in the west-east direction. During winter the value of this percentile is very low in almost all the region, beginning to increase during the spring. The gradient in the northeast-southwest and west-east direction is restored in October.
As the value of the percentile increases a greater spatial variability is observed (Figure 4). The maximum values of the 95th percentile of daily precipitation occurs in the eastern area, being of 55 and 65 mm/day in January and April respectively. In the rest of the area, the maximum values occur during summer, varying from 55 mm/day in northeast area to 25 mm/day in southwest area. The minimum values of 95th percentiles are observed during winter in the whole region, varying from 35 mm/day (northeast) to 10 mm/day (southwest).

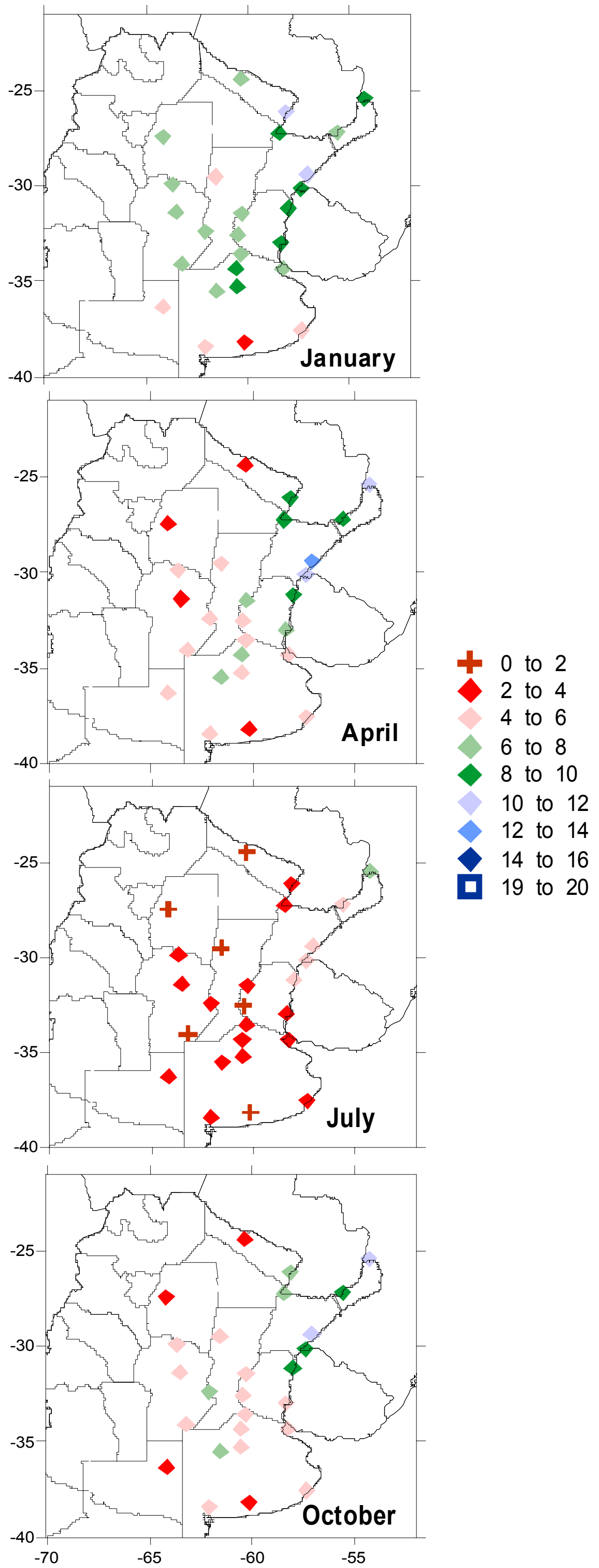

Figure 3: *Mean 50th percentile of daily precipitation (mm/day) per month.*

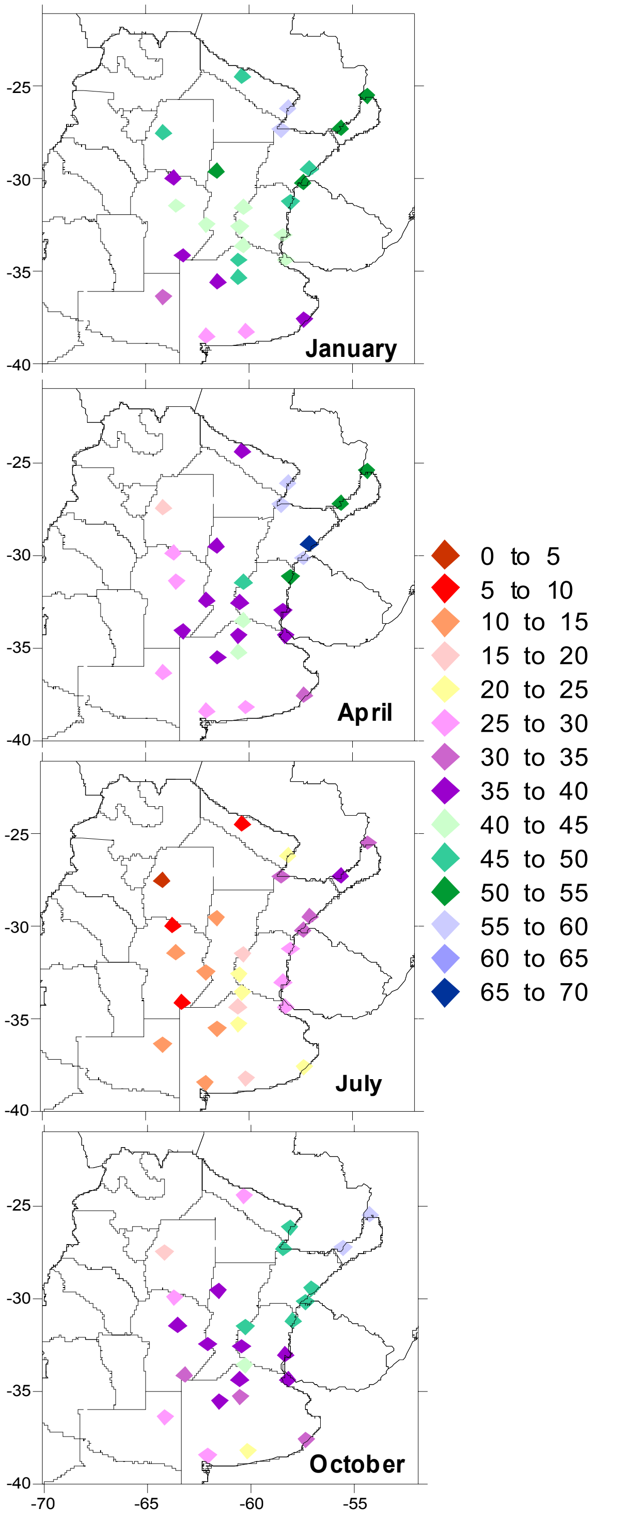

Figure 4: *Mean 95th percentile of daily precipitation (mm/day) per month.*

The number of rainy days, greater than 0.1 mm, per year shows a similar pattern to that of the amount of rainfall. In the northeastern region and the coastal stations such as Mar del Plata have the highest values with more than 80 days of precipitation per year. Towards the west this values decreases to 60 days of rainfall in Pilar, 70 days in the north of the Buenos Aires and in the transition region to the arid areas the values are generally around 50 days. The annual variation of the days with precipitation is much more uniform than that of the amounts of precipitation. The greatest annual variability is observed in the western stations, with the maximum in December and the minimum in August instead of July (Figure 5).

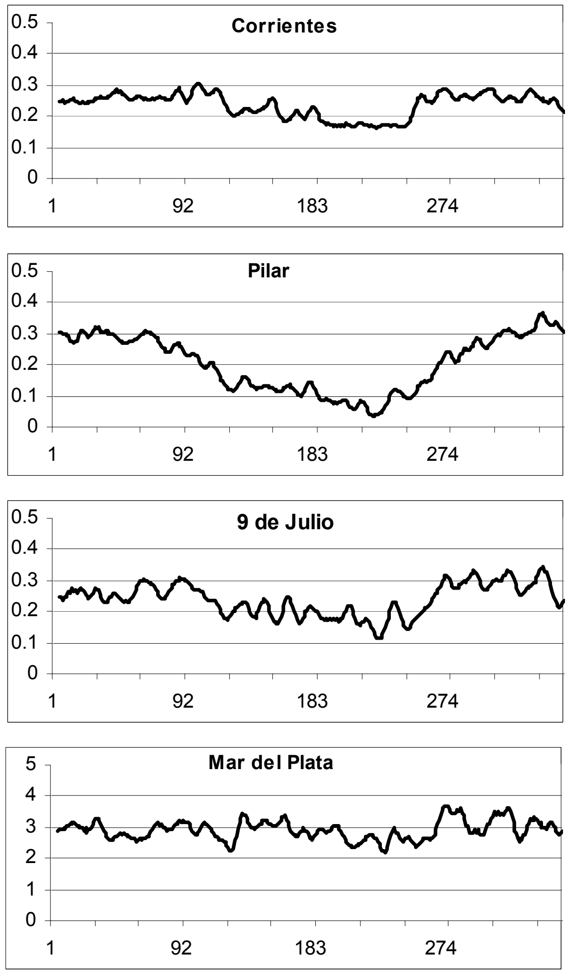

Figure 5: *Annual cycle of daily precipitation that exceeds 0.1 mm.*

The study region is wetter in part because of a greater frequency of precipitation events. This is exemplified by the spatial characteristic in the value of the frequency of daily precipitation greater than 0.1 mm/day. Similar spatial behavior are found for greater amount of precipitation. The mean frequency of daily precipitation distribution exceeding 10 mm/day is illustrated in Figure 6. The frequency of daily precipitation events exceeding during January varied among locations with the lowest frequencies occurring at the southwestern stations and the highest frequencies occurring at the northeastern one. Three of four mayor crops in the humid pampa are summer crops. During these months the crop needs different bioclimatic requirements, one of them is the humidity. The area with greatest values of daily rainfall exceeding 10 mm/day represents the core zone of these crops. However precipitation greater than 10 mm/day is often needed to exceed daily evaporative losses during the summer.

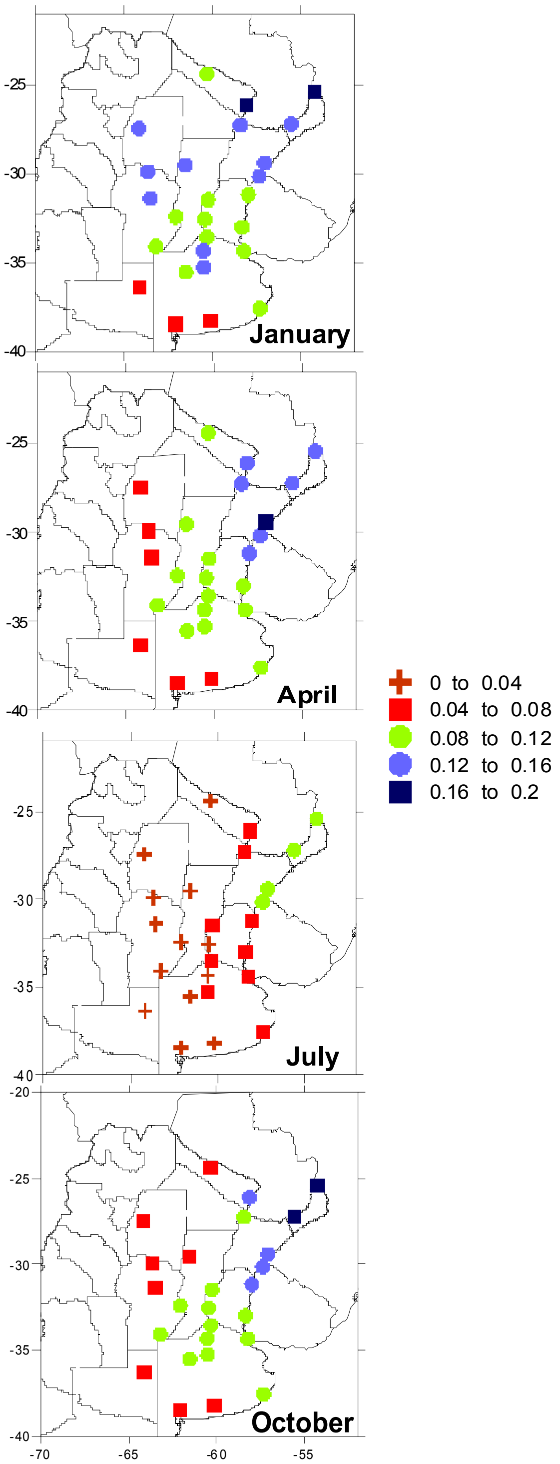

Figure 6: *Mean frequency of daily precipitation events during four months.*

Finally the daily persistence of rainday and no rainday is analyzed. The spatial pattern of the persistence of rainday follows the spatial behavior of the frequency of precipitation events.

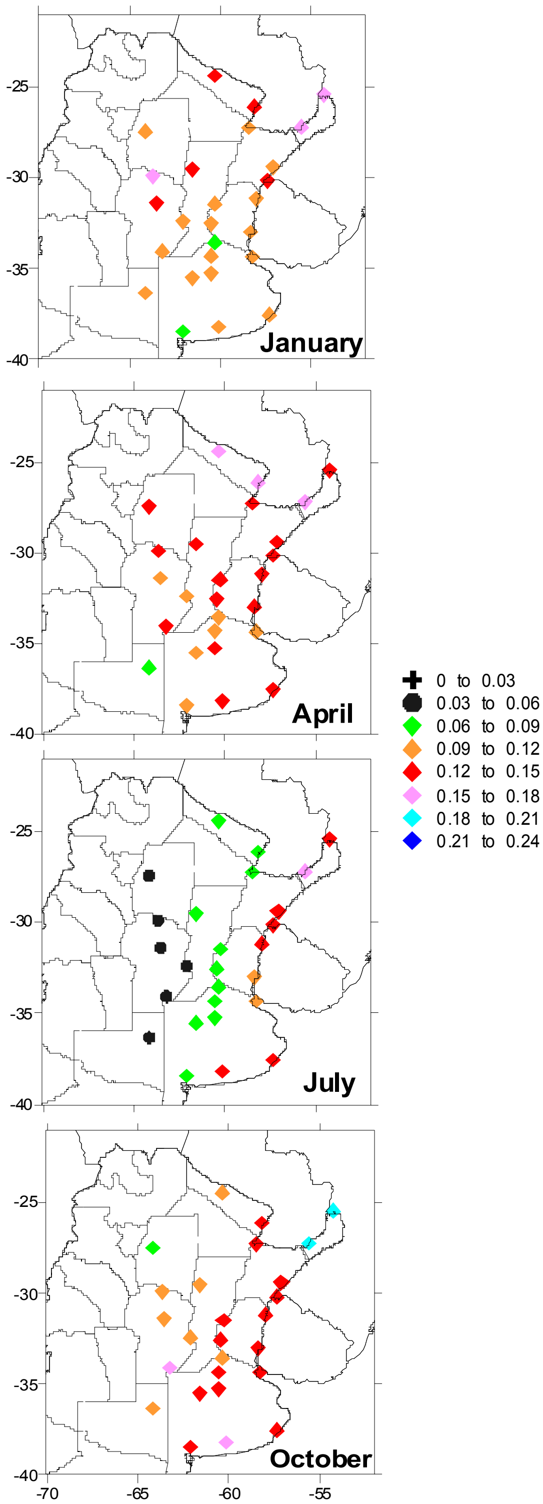

Figure 7: *Monthly mean of persistence of rainday during four months.*

The persistence of rainday throughout the year shows high values during the wet season and low values during the drier season. The monthly mean of persistence of rainday is shown in Figure 7. The greater seasonal variability is observed in the western stations, with values around 15% in January and the lowest of 9% in July. The lowest seasonal variability was observed in the northeastern and coastal stations with a persistence of 10 to 15%.

Intense precipitation events, in excess of 50 and 80 mm/day were uncommon throughout the year. In particular rainfall events in excess of 100 mm are very rare. Total events in excess this value ranged from 4 in the southwest to 74 in the northeast, in the whole period analyzed for the station involved. Precipitation events of this magnitude are a potential cause of flooding or loosing of crop. The occurrence of these extreme events in the central study zone (core zone of the principal crops) ranged from 10 at Rosario station to 16 at Nueve de Julio station; with more likely to occur on days in the autumn than in the spring.

4.CONCLUSIONS

In a view to document one of the principal factors affecting different crops in the humid pampa of Argentina, the spatial and temporal rainfall variability has been examined. The study zone plays a crucial role in the local economies. In particular, it is one of the largest food producers in the world. Cropping systems include maize, soybean and wheat-soybean doublecrop.

The objectives of this work are to analyze the annual cycle of percentiles and the frequency of daily precipitation events throughout the year, with special interest in extreme and very heavy rainfall.

Spatial and temporal variability in the frequency of daily precipitation is observed across the humid pampa. Precipitation occurred more frequently at northeastern than at southwestern climate stations. The annual cycles of the daily precipitation amount and the frequency of rainday show the same temporal variability, showing that the rainfall variation is not caused by variations in the intensity. The occurrence of extreme events are very uncommon, specially in the core zone of the crops.

This seasonal distribution of rainfall in conjunction with the temperature regime of these latitudes provides almost optimum conditions for agriculture and livestock breeding.

This regional and seasonal variability in precipitation must be considered when designing hydrologic systems and managing agricultural and natural resources.

Acknowledgements

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