7.10 LOW-LEVEL CIRCULATION PATTERNS AND PRECIPITATION IN THE ARGENTINE PAMPAS. ASSOCIATION WITH SOYBEAN YIELD.

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1. INTRODUCTION

The study of atmospheric circulation patterns and the analysis of their frequency, distribution and temporal variability result a useful tool for climate diagnostics. Revisions of the analysis methodologies and applications to synoptic-climatology can be found in Barry and Perry (1973), Yarnal (1993) and more recently in Yarnal et al. (2001). For southern South America, Compagnucci et al. (1998) discussed different methodologies for classification of synoptic situations and Compagnucci and Salles (1997) characterised the main synoptic patterns by means of principal component analysis (PCA) of observed daily sea-level pressure for the period 1972-1983. Solman and Menéndez (2003) classified winter daily fields of 500 hPa geopotential heights for the period 1966-1999 by means of K-means clustering technique and studied their relationship with precipitation and temperature in Argentina. Bischoff and Vargas (2003) studied the 500 and 1000 hPa weather type circulations and their relationship with some extreme climatic conditions using reanalyses developed by the ECWMF for the period 1980-1988. This kind of synthesis are very important to develop objective forecast methods and meteorological-climatic diagnostics to interact with others systems like agriculture or hydrology.

Subsequently, in regions with an important world agricultural production it is necessary to study the climate events and related meteorological conditions that have a strong impact on the economy. Argentine Pampas (central-eastern Argentina) is one of these regions being the third-largest producer region of soybean crop in the world (Podesta et al. 1999). Therefore, this work aims to identify characteristics of the atmospheric circulation at low levels over southern South America in order to relate these types to precipitation amounts and soybean yields in the Pampas region.

2. METHODS AND DATA

In order to perform this study anomalies of daily averages of 1000 hPa geopotential heights for the period 1979-2001 in a 2.5° x 2.5° latitude-longitude grid were used. The series of daily maps was obtained from the NCEP/NCAR reanalysis II. The domain chosen extends from 60° S to 15°S and 90°W to 30°W and it was defined to study circulation patterns that affect Southern South America (Figure 1). It includes 475 grid points. The period of months chosen was from October to May of the next year: 243 days x 22 years = 5346 maps. These months were selected since major precipitations in central-eastern Argentina occur in this period (Prohaska 1976) and due to the importance of agriculture within the study area (Figure 1).

Principal component analysis (Green 1978; Jolliffe 1986) was carried out on daily maps to determine the main synoptic types and their frequency. The PCA results using the T-mode approach and the correlation matrix showed that the first six principal components (PC) explained more than 80 per cent of the total variance. Unrotated solutions were used in this work since Varimax orthogonal rotated solutions (Richman 1986) did not redistribute satisfactorily the variance explained by the PC. The direct and inverse modes of the first six PC scores patterns determined 12 different spatial patterns for geopotencial fields (Figure 2). A 0.7 factor loading value was used as a threshold to retain the daily maps that are represented fairly well by these 12 synoptic patterns and the series of seasonal frequencies (total frequency from October to May) were calculated for each pattern.

In order to link low-level circulations patterns to regional rainfall in the Pampas, series of monthly rainfall for the period 1979-2001 were used. The dataset was provided by the National Meteorological Service of Argentina. Five stations were used in the analysis since series with more than 10% missing data were eliminated. An “out of range” consistency checks on the series were performed and they were

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consisted from a statistical analysis. However, the five stations used are located in the soybean's production core region and in the centre of the Argentine Pampas (Figure 1). The areal average of 'seasonal precipitation' (total precipitation from October to May) in the Pampas region was calculated from the monthly dataset.

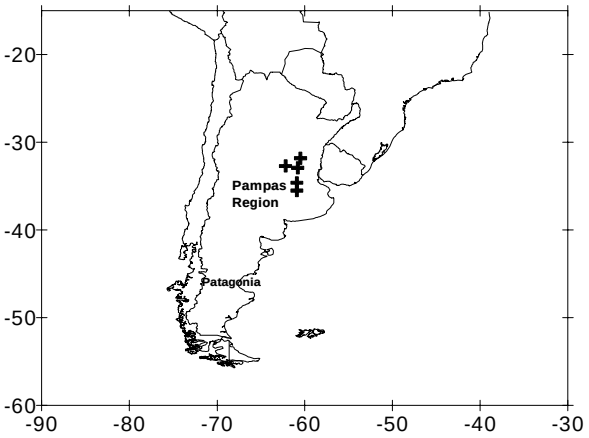

Figure 1. The study area. Black cruces indicate location of rainfall stations.

This work focuses on yield (estimated as the ratio of total production to area harvested) as an indicator of a crop's vulnerability to climate variability. The 58 series of yield used in this analysis were obtained from Argentina's Secretaría de Agricultura, Ganadería, Pesca y Alimentación de la Nación (SAGPyA 2000) and they correspond to provincial departments located in the Pampas region. The series of annual frequency of provincial departments where the soybean yield was classified as a minimum or maximum were used in the study.

3. RESULTS

3.1 Weather Patterns

The PC spatial patterns and their associated 1000 hPa geopotential fields are presented in Figure 2 and their characteristics are summarised in Table 1. Geopotential fields are shown instead of anomalies in order to make better synoptic interpretations. The 12 patterns obtained (direct and inverse modes of the first six PC scores patterns) fit very well with the main synoptic types recognized by forecasters.

Table 1. Characteristics of the direct (D) and inverse (I) modes of the first six PC scores patterns. *SP: South Pacific; SA: South Atlantic*

PC Pattern	***Description***
PC1 D	Trough over southern part of the continent and SP Ocean-Deep SA High
PC1 I	Post-frontal anticyclone entering via the SW of Patagonia generating cold air advection
PC2 D	Intensified zonal flow in mid- and high latitudes – Trough over Patagonia and center of Argentina.
PC2 I	Two systems with NNW-SSE direction: High over SP Ocean to Patagonia and higher latitudes, Low over North of the country to SA Ocean.
PC3 D	High-pressure system centered at the eastern part of humid Pampas.
PC3 I	Low-pressure system centered at southeast of the continent
PC4 D	High-pressure system over Argentina. SA and SP Highs limited to lower latitudes.
PC4 I	Intensified SA and SP Highs, relative low over Argentina, westerly flow restricted south of 50°S
PC5 D	Low-pressure system centered at south of Patagonia affecting the entire country.
PC5 I	High-pressure system entering via the North of Patagonia, intensified westerlies south of 47°S over the SP Ocean
PC6 D	Low-pressure system over center and north of Argentina extending to SA Ocean. Ridge entering south of the continent.
PC6 I	High-pressure system centered at Uruguay, trough over Patagonia

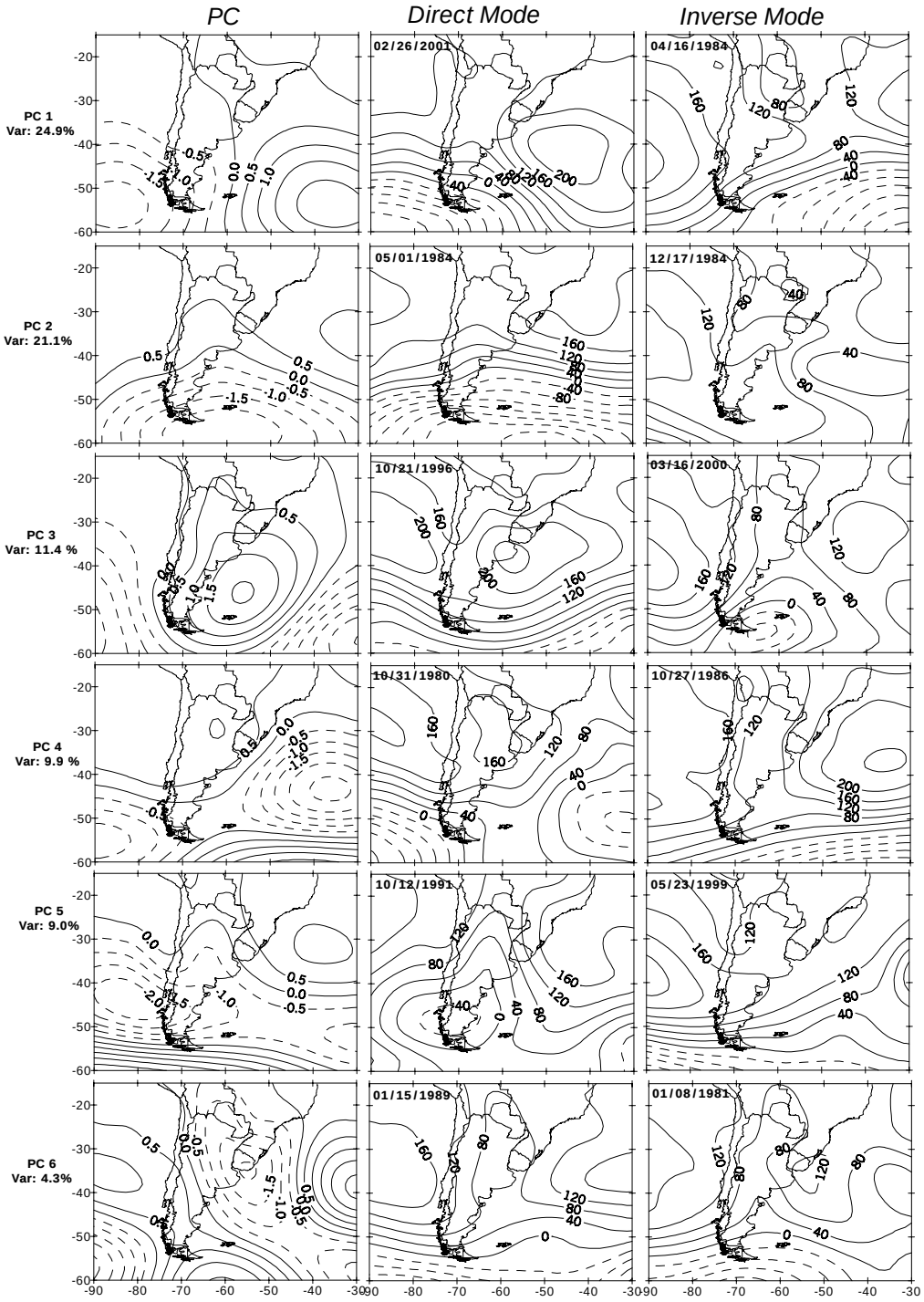

Figure 2. Spatial patterns of PC scores for the first six PCs (left column) and associated geopotential fields of 1000 hPa for the direct (central column) and inverse (right column) mode. *Dashed line: negative values. Var: Percentage of explained variance.*

Even though the analyzed period in this work is relatively short to infer temporal variabilities, the temporal series of seasonal frequencies of the 12 synoptic patterns were studied in order to find main characteristics. The seasonal frequencies of fields associated with the PC1's inverse mode present a progressive decrease with time. Meanwhile those associated with the inverse modes of PC4 and PC5 as well as frequencies associated with PC3's direct mode show a weak progressive increase with time (Figure 3). These results indicate a weak positive 'trend' in the seasonal frequency of N-NE flow (warm and humid) situations over central Argentina and a negative one in the

seasonal frequencies of situations with cold air advection over this area. The most important interannual variability of seasonal frequencies was found for the synoptic situations with an intense/weak zonal flow in mid- and high latitudes (maps associated with direct and inverse modes of the second PC pattern) mostly in the second half of the record. This result may be related to the variability of baroclinic situations which are associated with the intensity of the zonal flow. The opposite behavior (major standard deviation in the first half of the record) is observed in the interannual variability of situations with intense S-SW flow over the southern part of the continent (inverse mode of the third PC pattern) (not shown).

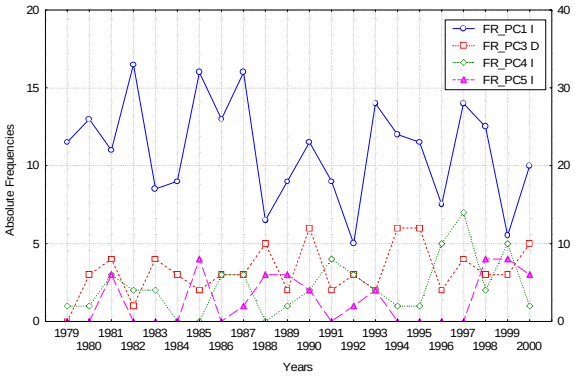

Figure 3. Time series of seasonal frequencies of daily fields associated with the inverse mode of the PC1, PC4 and PC5 and with the direct mode of the PC3.

3.2 Seasonal rainfall

The seasonal frequency of daily maps for the 12 synoptic patterns associated with the areal average of the total precipitation in Argentine Pampas was also analyzed. It was found that the maximum total precipitation in central-eastern Argentina is mainly associated with the occurrence of inverse modes of the second and fourth PCs (Figure 4). These patterns favor N-NE flow (warm and humid air advection in the lower troposphere) over the Pampas and weaker zonal flow situations. Total minimum precipitation is linked to high frequencies of circulation patterns associated with the direct mode of the first PC. Even tough these synoptic types cause a warm and humid N-NE advection over the whole region, the South Atlantic High is strengthened inhibiting ascending air motions and obstructing disturbances migration toward lower latitudes.

These results show that areal precipitation variability in the Argentine Pampas can be linked to temporal variations of specific synoptic situations. This is also observed in the increase of situations with favorable conditions for generating rain (warm and moist advection) and the gradually increase in annual precipitation in recent decades over this area (Hoffmann et al. 1987; Castañeda and Barros 1994, 2001;. Penalba and Vargas 1996, 2004).

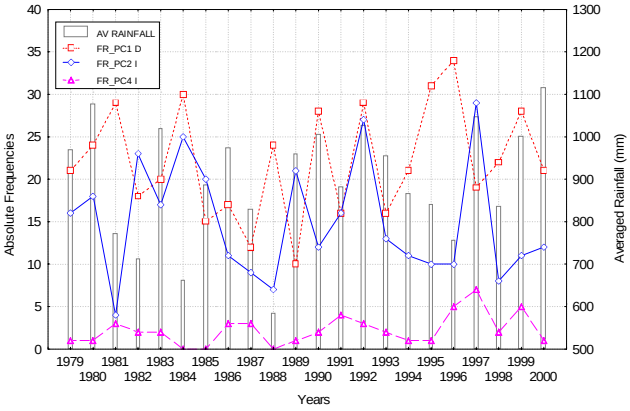

Figure 4. Time series of the areal average of seasonal precipitation in the Pampas (bars) and time series of seasonal frequencies of daily fields associated with the inverse mode of the PC2 and PC4 and with the direct mode of the PC1.

3.3 Soybean Yield

Finally, the annual frequency of provincial departments in the Pampas region where the soybean yield was classified as a minimum was related to the averaged total precipitation series and the circulation patterns. It was found that higher frequencies of minimum soybean yield are well associated with minimum averaged seasonal precipitation (significant correlation with α=5%). Moreover, higher (lower) frequencies of circulation types associated with the direct (inverse) mode of the first (third) PC can be linked to higher frequencies of minimum (maximum) soybean yield condition (Figure 5). These synoptic types induce, on one hand, warm and humid anomalous advection without ascending air motions resulting in high air temperature and no rainfall and on the other hand, cold southwestesterly flow anomalies in the Pampas region resulting in below normal air temperature or probably in late frosts. Both effects impact negatively on soybean yield.

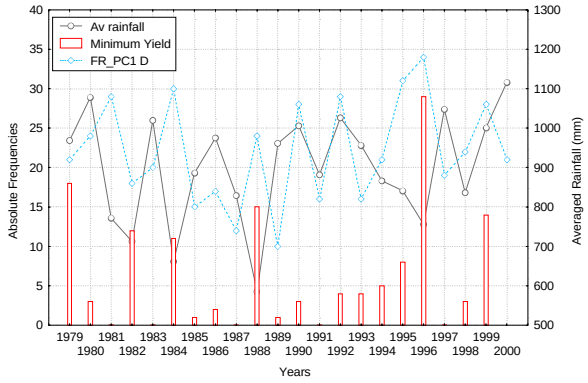

Figure 5. Time series of frequencies of provincial departments with minimum soybean yield condition (bars), of areal average of total precipitation in the Pampas and of seasonal frequencies of daily fields associated with the direct mode of the PC1.

4. CONCLUSIONS

This paper dealt with synoptic situations represented by daily 1000 hPa geopotential fields in order to find synoptic patterns in southern South America. Using an unrotated PCA with T-mode approach, the outline spatial structures of the PCs obtained fit very well with the main synoptic fields recognized by forecasters. However, it could be possible to find other synoptic fields resulting from the combination of two or more PCs.

Even though the analyzed period in this work (1979-2001) is relatively short to infer temporal variabilities it was found a progressive increase in the seasonal frequency of N-NE flow (warm and humid) situations over central Argentina and a decrease in the seasonal frequencies of situations with cold air advection over this area. Further studies are needed but it can be suggested that an increase of favorable situations for generating rain (warm and moist advection) is coincident with the gradual rise in annual precipitation observed in recent decades over this area. On the other hand, a progressive diminution of cold air advection situations is coincident with the increase of temperature values over this area (Easterling et al. 1997; Rusticucci and Barrucand 2004).

Areal precipitation variability in the Argentine Pampas can be linked to temporal variations of specific synoptic situations. Maximum total precipitation in central-eastern Argentina is mainly associated with patterns that favor N-NE flow generating warm and humid air advection in the lower troposphere over the Pampas and weaker zonal flow situations. Total minimum precipitation is linked to high frequencies synoptic situations where the South Atlantic High is strengthened inhibiting ascending air motions and obstructing disturbances migration toward lower latitudes.

The interactions of climatic system with agriculture was studied by means of soybean yield as an indicator of a crop's vulnerability to climate variability. Higher frequencies of minimum soybean yield are well associated with minimum averaged seasonal precipitation and with synoptic types that induce, on one hand, warm and humid anomalous advection without ascending air motions resulting in high air temperature and no rainfall and on the other hand, cold southwestesterly flow anomalies in the Pampas region resulting in below normal air temperature or probably in late frosts. Both effects impact negatively on soybean yield.

This work was intended as a first approach to identify characteristics of the atmospheric circulation over southern South America that can be related to precipitation amounts and soybean yields in the Pampas region. The study of the distribution and temporal series of the circulations patterns in temporal scales lower than seasonal as well as others geopotential levels are recommended in further studies.

Acknowledgments

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