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Some atmospheric and oceanic indices as predictors of seasonal rainfall in the Del Plata Basin of Argentina

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Summary Different oceanic and near-global atmospheric indices are analyzed in connection to the variations of seasonal rainfall over northeastern Argentina in order to determine their potential as predictors. This region is part of the hydrological system of the Del Plata Basin, and is drained by the copious Parana and Uruguay rivers, two of the main courses flowing across the basin. Monthly precipitation, flow rate, Southern Oscillation Index (SOI), sea surface temperature anomaly (SSTa) Index for Niño 3 Region (N3) (1960—2003) and SSTa for different oceanic regions of the Southern Hemisphere (SH) Atlantic and Pacific Oceans (1981—2003) are used. A practical measure of rainfall deviations is obtained by means of the Standardized Precipitation Index (SPI). Significant correlations between SPI and near-global indices (based on SOI and SSTa) determined the months whose indices may be used as predictive variables. Using the Step-wise method, optimum predictors were chosen to generate the linear regression models. From a set of possible models, those with the best fitting statistical measures were considered and the ability of the proposed regression equations tested. The results for the study region showed that during SH spring, summer and early autumn, SPI values are related to SOI and N3, with individual monthly values, at 1- to 5-month lead times used as predictors. Besides, SPI links with SSTa of the Atlantic/Pacific Ocean along the whole year, especially during SH autumn and winter/SH late winter, spring and summer, with different month lags. It is worthwhile noting that almost year-round estimation of rainfall anomalies is possible by using the adequate predictive variable and forecast lead-time.

Introduction

The study region is a vast area in northeastern Argentina, located approximately between 25°—35° South, and 62°—53°

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West, crossed by the copious Parana and Uruguay rivers, whose confluence gives birth to the Rio de la Plata estuary. This region along with broad areas of the republics of Uruguay, Paraguay, Bolivia and Brazil form one of the most important basins in the world: the Del Plata Basin (Fig. 1). With an extension of 3.2 million square kilometers, throughout this basin numerous cities and towns are developed in the riparian zone, more than 60 hydropower dams are built across the main rivers and a waterway is currently undergoing implementation (Hidrovia Parana-Paraguay). More than 80% of the cumulative GNP of the five countries is produced within the basin.

The variability of the hydro-meteorological phenomena in the basin is partially associated with the El Niño-Southern Oscillation phenomenon (ENSO). The warm phase of ENSO is related to an increase of precipitation together with one of discharge of the Parana, Paraguay and Uruguay rivers (Goniadzki, personal communication; Berri et al., 2002). During the warm ENSO episode of 1982–1983, the occurrence of exceptionally heavy rains produced inundations that severely affected the Parana, Paraguay and Uruguay floodplains for more than a year, which implied huge economical losses of more than U$S 1000 M. Conversely, prolonged periods of sustained low waters (as those coinciding with the cold phase of ENSO in 1985, 1988 and 1999) affect numerous productive activities as hydropower generation, river navigation and port operation. Provision of water for treatment plants is also affected: water quality drops seriously (thus increasing treatment costs) and the intake minimum threshold is threatened.

Different studies support the influence of ENSO on the precipitation in the Del Plata Basin, such as Ropelewski and Halpert (1987, 1989), Rao and Hada (1990), Grimm et al. (2000), among others. The ENSO impact on flow rates shows increased discharges during the warm phase on the Uruguay and the Negro rivers (Robertson and Mechoso, 1998), as well as on Parana river at Posadas city (Berri et al., 2002).

Precipitation in Southeastern South America is also modulated by sea surface temperature anomalies (SSTa) of both the Atlantic and Pacific Oceans (Diaz et al., 1998; Genta et al., 1998; Berri and Bertossa, 2004). Other regional forcings are the intensification of the Northwestern Argentine Low over the continent (Lichtenstein, 1981) and summer activity of the South Atlantic Convergence Zone (SACZ) (Nogués-Paegle and Mo, 1997; Barros et al., 2000).

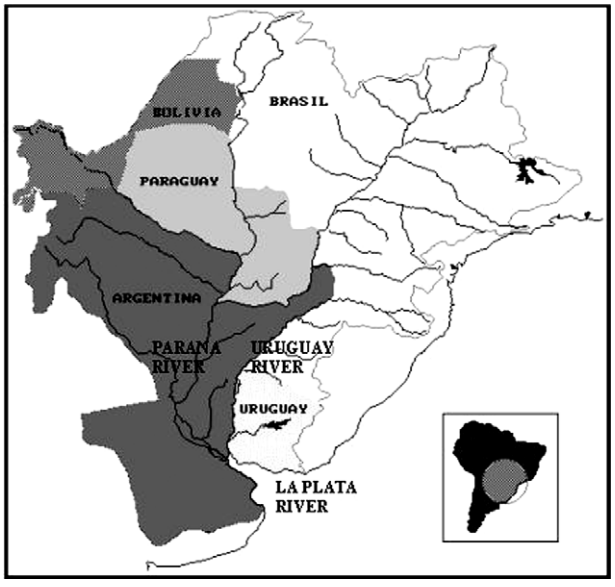

Figure 1 Map of the Del Plata Basin.

Based on the persistence of the Southern Oscillation Index (SOI) and significant correlations with the regional rainfall anomalies, other studies propose predictive schemes based on lagged relationships between rainfall and suitable predictors. McBride and Nicholls (1983) and Stone and Auliciems (1992) found relationships between SOI phases and rainfall in different regions of Australia, proposing rainfall probability information using their ''SOI Phase System''. Shukla and Mooley (1987) showed predictive relationships between monsoon rains in India and two parameters of atmospheric circulation: the SOI and the mid-tropospheric circulation. Matarira and Unganai (1994) and Hyden and Sikoli (2000) proposed rainfall prediction models based on SOI for Southern Africa and the lowlands of Lesotho, respectively. Scian (2000) established the predictive months for rainfall anomalies based on SOI phases in the semi-arid pampean region of Argentina.

Some authors studied the relationship between large-scale patterns of the SSTa and precipitation in different regions of the globe. Ward and Folland (1991) employing SSTa patterns over the Atlantic and Pacific Oceans found adequate relationship with rainfall anomalies in the Sahel and northeast of Brazil. Barnston (1994) used canonical correlation anomalies with near-global SST patterns as well as Northern Hemisphere 700-hPa height fields as predictors of North American and European precipitation and surface temperature. Drosdowsky and Chambers (2001) formulated an operational system for the prediction of Australian seasonal rainfall variations using Indian and Pacific Oceans SSTa patterns. For the southern central South America, Berri and Bertossa (2004) found the diagnostic relationship between regional precipitation anomalies and SSTa over several tropical and sub-tropical oceanic regions.

Therefore, acquiring a deeper knowledge and a longer anticipation of the rainfall variability is of major socio-economic significance for Del Plata basin, thus allowing for a reduction of the negative effects of extreme events. Is it possible to obtain seasonal rainfall predictors in this region?

The purpose of this paper is to recognize the predictability of seasonal rainfall anomalies in northeastern Argentina, using SOI and SSTa of different regions in the Atlantic and Pacific Oceans and to formulate valid predictive schemes.

The data and the methodology used are described in section 'Data and Methodology'. Results are presented in section 'Results', where some empirical seasonal models are proposed. Finally, section 'Discussion of Results and Conclusions' presents a discussion of results and conclusions.

Data and methodology

Data

The monthly precipitation data used for this study were provided by the National Weather Service (Argentina) from available 18 meteorological stations and monthly mean flow