Low-frequency precipitation and river flow variability in Cuenca del Plata

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Introduction

Cuenca del Plata is the second largest hydrological basin in South America (around $3.6x10^6 km^2$). This region is of significant social and economical importance by the density population, the agriculture activity (this region, including the argentinian "pampa humeda", is one of the richest agricultural regions in South America) and the hydroelectricty production which provides a large part of the needs of the MERCOSUR countries (Argentina, Bolivia, Brazil, Paraguay and Uruguay).

A major feature of the seasonal variability in Cuenca del Plata is the South American Monsoon which extends from the tropical continental region southwestward from December to March (austral summer) connecting the tropical Atlantic Inter Tropical Convergence Zone (ITCZ) with the South American Convergence Zone (SACZ) via the large scale atmospheric circulation mainly characterized by a low-level jet (Virji, 1981; Lenters and Cook, 1995; Zhou and Lau, 1998). The South American low-level jet takes birth in the northern part of South America at the foothills of the Andes and transports moisture from the equatorial region southward along theAndes mountains and southeastward into the Atlantic around 20°S-35°S (Labraga et al., 2000).

The interannual-to-decadal climate variability of South America has already been a subject of numerous studies which mainly highlighted the ENSO teleconnections (e.g. Aceituno, 1989; Pisciottano et al., 1994; Grimm et al., 2000; Zhou and Lau, 2001; Paegle and Mo, 2002). Teleconnections with the Atlantic have also been identified on decadal time scales (Venegas et al., 1997; Robertson and Mechoso, 2000). Both Pacific and Atlantic teleconnections on interannual-to-interdacadal time scales have been shown to influence the discharges of the main rivers of Cuenca del Plata (Camilloni and Barros, 2000; Robertson and Mechoso, 2000; Berri et al., 2002).

The present study has two main objectives. The first one is to describe the main modes of precipitation variability in Cuenca del Plata on interannual-to-decadal time scales during both the rainy and dry seasons associating such modes of variability to atmospheric patterns and potential sea surface temperature anomaly predictors in the Pacific and Atlantic basins. The second objective is to adress the relationship with observed river floods in Cuenca del

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Plata to evaluate the predictability of such events when related to persistent climate modes. Only results of the first objective are presented herefater.

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Major modes of variability

Precipitation data were either derived from CMAP (Xie and Arkin, 1997) or in-situ stations from the Climate Research Unit. The CMAP and CRU datasets potentially give access to different informations. On one hand, the CRU data cover a long period of time (potentially from 1901 to 1998) which allows to study the interannual-to-decadal modes of variability in Cuenca del Plata. However, the data may not be fully reliable in regions poorly or not at all covered by *in-situ* stations. On the other hand, the CMAP data merges satellite measurements with *in-situ* stations and should offer a more reliable spatial coverage over continents. Moreover, data are also available over the oceans allowing to study the coherent patterns between the continental and oceanic regions. Unfortunately, the data only cover the 1979-2001 period which does not allow to study to a full extent the decadal-to-interdecadal variability. We therefore performed statistical tests to evaluate whether the data have significantly different means, seasonal and interannual variability over Cuenca del Plata. Although some differences occur on the western side of the basin on interannual time scale, the EOF analysis of both data sets show similar patterns and principal components (Figs. 1 and 2). Based on these results, in the following, we either combine the two data sets considering the CRU data from 1959 to 1978 and CMAP data from 1979 to 2002 or their principal components.

First, the data are filtered with an 11-month Hanning filter in order to get rid of potential aliasing when studying the low-frequency component of a specific season. Then we defined the rainy and dry seasons respectively covering the November-to-March and May-to-September periods. An EOF analysis was performed over each season. During the rainy season, three modes of variability are clearly separated according to the North et al. (1982) rule of thumb. They explain more than 60% of the low-frequency variance in austral summer. During the dry season, only two modes are well separated. They also explain more than 60% of the low-frequency variance in austral winter.

During both seasons, the first mode of variability is associated to ENSO variability (~35% of the variance in austral summer and ~45% in winter, see Figs. 1 and 2). A comparison between the Niño3 index and the first PCs show that the two time series are in phase in summer while the precipitation PC lags Niño3 by two months in winter. Overall, the statistical comparison shows that the correlation with ENSO is strongly influenced by the extreme events of the time series. This result suggests that the relationship between ENSO and precipitation over Cuenca del Plata is not as linear as advocated in the litterature.

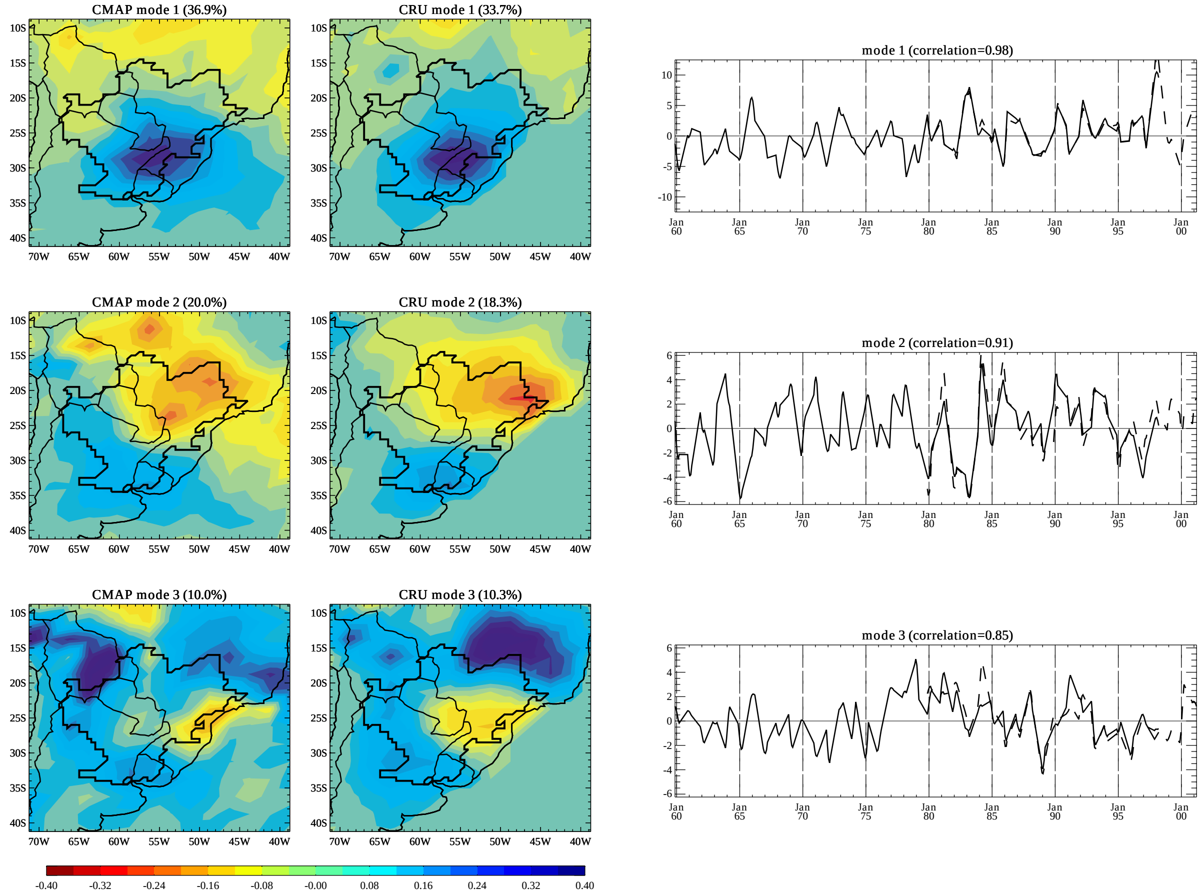


Figure 1: Austral summer EOF analysis of CMAP (1979-2001) and CRU (1959-1998) data sets. From left to right: normalized spatial stuctures of CMAP, of CRU (the limits of the hydrological basin are superimposed) and time series of CMAP (dashed line) and CRU. From up to bottom are plotted results for the first to third modes.

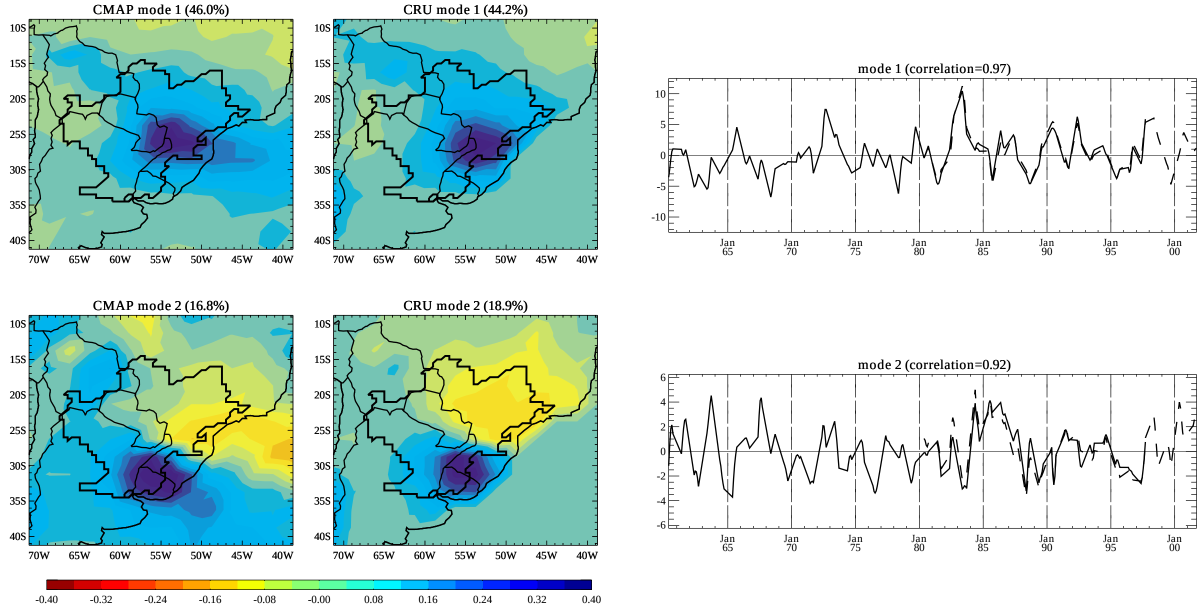
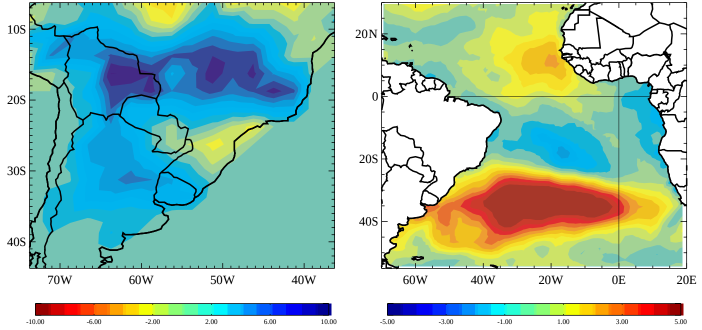


Figure 2: Austral winter EOF analysis of CMAP (1979-2001) and CRU (1959-1998) data sets. From left to right : normalized spatial stuctures of CMAP, of CRU (the limits of the hydrological basin are superimposed) and time series of CMAP (dashed line) and CRU. From up to bottom are plotted results fro the first to second modes.

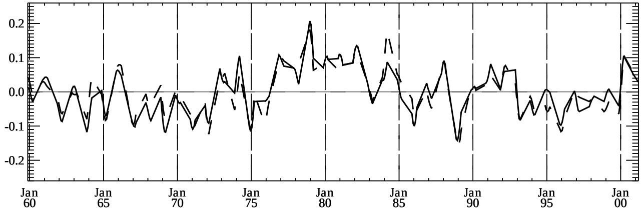
During both seasons, the second mode of variability (see Figs. 1 and 2) is associated to low-frequency variability of the South Atlantic Convergence Zone which in summer is associated to the South American Monsoon System (around 15%-20% of the variance during the two seasons). We found that on near-decadal time scale, the SACZ experienced meridional displacements in its mean position together with changes in its strength. The most coherent sea surface temperature pattern associated with that variability is a large SST anomaly off-shore Southern Brazil and Uruguay coasts.

Finally, during the rainy season, the third mode of variability (about 10% of the variance; see Fig. 1) displays an horseshoe pattern around Southern Brazil. The associated time series interestingly displays a clear shift in variability in 1976. It appears to be highly correlated with the low-frequency variability of sea surface temperature anomalies identified by Venegas et al. (1997) to respond to changes in the South Atlantic Anticyclone intensity (see Fig. 3).


(a) SVD2(P)

(b) SVD2(SST)

(c) SVD2(P) and EOF3(P)



(d) SVD2(SST) and SVD2(P)

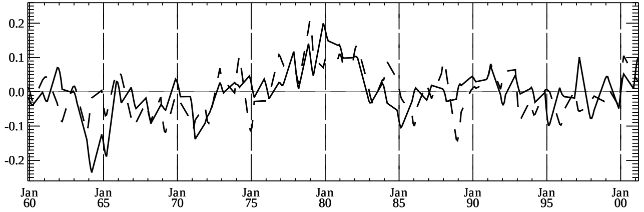


Figure 3: (a) Spatial pattern of the second SVD mode (~20% of the total variance) between precipitation over Cuenca de la Plata and sea surface temperature anomalies in the subtropical South Atlantic Ocean; (b) Time series of the second SVD mode in precipitation and of the third precipitation principal component: (c) Time series of the second SVD mode in sea surface temperature anomalies and in precipitation.

Conclusions and perspectives

Investigating the modes of low-frequency precipitation variability in Cuenca del Plata over the ultimate 50 years has allowed to separate three modes in austral summer and two modes in winter. During each season, the computed modes explain more than 60% of the total variance. We identified each mode to be associated either to ENSO in the Pacific, SACZ variability or intensity of the South Atlantic Subtropical Anticyclone.

We are currently evaluating the relationship between these modes and certain river floods in Cuenca del Plata in order to build a predictive model of river floods associated to low-frequency climate variability.

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