Rainfall anomalies in the Uruguay-Southern Brazil region related to SST in Pacific and Atlantic oceans using canonical correlation analysis

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Abstract

The relationship between rainfall anomalies in Uruguay and Southern Brazil (UY-RS) and sea surface temperature (SST) anomalies in Pacific and Atlantic Ocean is investigated by means of Canonical Correlation Analysis (CCA). It was found in previous studies that rainfall anomalies in this region are likely to be influenced by SST anomalies in the Pacific (ENSO phenomenon). In this study was confirmed that rainfall anomalies in the Uruguay-Southern Brazil region are influenced by Pacific SST, but also by other regions as SCPZ and the region which is covered by the high pressures in southern-eastern Pacific. it was found that Atlantic SST variability also has a nonnegligible impact on the precipitation anomalies in them region.

1. Introduction

Some previous studies have pointed out the influence of the El Niño/Southern Oscillation (ENSO) phenomenon in the Pacific Ocean on the precipitation anomalies in the Southern Brazil - Uruguay Region (hereafter UY-RS) in some seasons of the year (Aceituno,1988; Kousky and Ropelewski, 1989; Lau and Sheu, 1988, Ropelewski and Halpert, 1987 and 1989, Rao and Hada, 1990, Pisciottano et al., 1993). On the other hand, in spite of there not being any studies on the influence of the Atlantic ocean, the role played by the South Atlantic Convergence Zone (SACZ) and frontal systems over the region should not be underestimated. Also, it has to be taken into account that the water vapor sources for this region are the South Atlantic Ocean and the moisture from tropical South America and that the region is directly affected by the South Atlantic cyclonic circulation. The sea surface temperature is a forcing factor of these atmospheric features.

In this study the influence of Atlantic and Pacific Ocean SST on precipitations of the UY-RS region is studied by means of Canonical Correlation Analysis (CCA).

2. Methodology and data

CCA is used here to study the relationship between SST anomalies (predictor) and rainfall anomalies (predictand), both as a diagnostic tool. CCA is a generalization of multiple regression analysis. It is a least-squares statistical method for analyzing the cross-covariance structure between two fields, looking for the patterns that tend to occur together in time (either contemporaneously or with a lag) and the degreeof connection between both.

The SST data wère obtained from GOGA dataset which has a grid of 7.5 degrees in longitude and 4.5 in latitude. The 25 N - 42,30' S band for Pacific and Atlantic were selected as predictor areas, comprising 132 grids points for the Atlantic and 314 for the Pacific. Monthly rainrfall data from 40 stations in UY-RS (19 in Uruguay and 21 in Brazil) were considered as predictand. The data were kindly given by Direccion Nacional de Meteorologia (Uruguay) and Instituto Nacional de Pesquisas Agronomicas do Rio Grande do Sul (IPAGRO) and Instituto Nacional de Meteorologia (INMET).

The simultaneous relationship between bothe fields were considered for each season (November-February, October-December and April-July (Studzinski and Diaz,1994)), taking in each case as a predictor either Atlantic ocean, or the Pacific ocean or the combination of both. A description of the method and calculations is given in Barnett and Presendorfer (1987) and an alternative and similar one in Graham (1990).

For each field an EOF prefiltering is performed. The analysis continues with the principal component time series (PC) of the EOF retained modes. Each PC in each field is normalized. It is intended to find a pair of time series, u on the side of predictor side and v on the predictand, which are linear combinations of their respective normalized PC such that their correlation is maximum in absolute value, that is

$$|\mathrm{Cor}\ (u,v)| = \max$$

The g-maps and h-maps (one for each mode) are called canonical patterns or canonical maps and they are of paramount importance because the correlations, if significant, show the most relevant patterns of variabiliy 'together' in time i.e., either with or withou time-lag) for both fields.

3. Discussion

3.a. November-February

The canonical patterns for Pacific alone and Atlantic alone as predictors are very similar to both oceans together as predictors. They show in the Pacific ocean (Figure 1) the ENSO region and the SPCZ as significant regions and in the Atlantic the South Atlantic Convergence Zone (SACZ). The pattern directly linked to the rainfall anomalies seems to be the SACZ. Grimm and Silva Dias (1993) suggest that teleconnection between this zone and ENSO during austral summer, is actually indirect, through the ENSO impact on the position of SPCZ. During warm events the anomalous enhancement of convection in the Central Equatorial Pacific in the Northern Hemisphere and the subsidence in the subtropical Central/Eastern Pacific are the causes for the eastward migration of the SPCZ and consequently enhanced convection at the SACZ and North Atlantic (Lau and Chan,1983). The sensitivity of the SACZ to the position and shape of the anomalous divergence in the SPCZ is shown in Grimm and Silva Dias (1993). When the SPCZ is closer to its climatological position the convection in the SACZ is weaker. Casarin and Kousky (1986) in a composite analysis of atmospheric circulation during events of rainfall anomalies in Southern Brazil suggest that the anomalous eastward position of the SPCZ during ENSO is a cause of the convection over SACZ. The others significant spots found in the Atlantic case (Figure 2) need to be subject of further investigation.

3.b. April-July

The analysis of the canonical patterns of Pacific and Atlantic together as predictors are not easily interpretated because there are very small and scattered significant spots in the Atlantic. For Pacific the pattern indicates that with warmer SST in the Tropical Pacific the Walker Cell is weaker, as a consequence more uniform SSTs would appear in the Equatorial Pacific and a stronger Hadley Cell is established. This circulation creates stronger jet stream in both hemispheres with the strongest in the winter season. Ropelewski and Kousky (1989) found that during warm events the subtropical jet stream shows a extension to the east through the Atlantic (western sector), especially during autumn, winter and the beginning of spring. Surrounding the jet the frontal activity and cyclones are stronger.

Looking at the relationship found in the canonical map for Pacific alone as a predictor and UY-RS it is shown that for warmer SST in the ENSO region and Northern Pacific and colder in the Eastern Pacific high pressure region it would be expected a negative rainfall anomaly in UY-RS. The explanation for this feature could be that with the high pressure localized near the west coast of South America (indicated by the colder SSTs) doing a blocking the frontal systems do not reach the UY-RS region. The significant region in the UY-RS indicates that to analize the impact of Pacific SST anomalies in the rainfall anomalies during April -Julyl it is necessary to look at regions northward of UY-RS.

In the case of Atlantic canonical maps the relationship of warmer SSTs in the significant region related to positive rainfall anomalies is coherent. The region in the ocean seems to be associated to the cyclonic circulation mentioned above.

3.c. October -December

The canonical maps for both oceans as predictors have showed a weak signal in the Atlantic and a dipole type in the Equatorial Pacific. For Pacific alone the ENSO region, the SPCZ and the Pacific high region appear as the most significant regions. During positive phase of SOI (with stronger Walker circulation) the SPCZ moves westward from its climatological position. As mentioned above as the convection in the SACZ is related to the position of the SPCZ, this tends to be inhibited.

4. Conclusions

It is confirmed that rainfall anomalies in the region are influenced by Pacific SST, in particular by ENSO, but also by other regions as SPCZ and the region which is covered by the high pressures in south-eastern Pacific.

It is found that Atlantic SST variability also has a nonnegligible impact on the precipitation anomalies in the region. Taking into account the proximity of the Atlantic Ocean to UY_RS it is not yet clear whether some (or all) of the shown Atlantic SST patterns correspond to a global or a regional feature.

Another questions which also have to be answered are: 'How much of the rainfall variability in UY-RS is a response to Pacific SST variability and how much is due to Atlantic?' and linked to this, 'How independent are the Atlantic and Pacific SST variabilities ?'

5. - References

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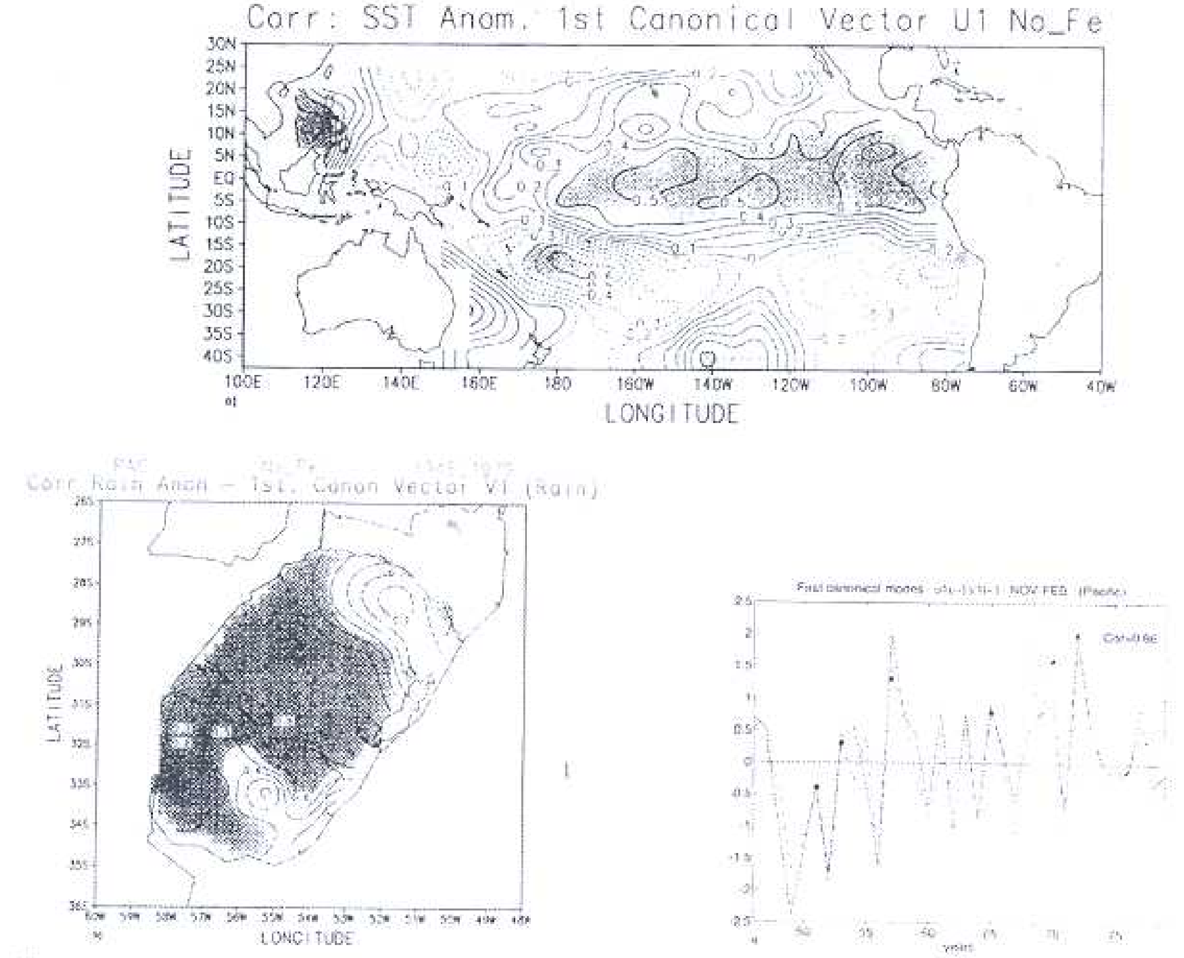

Fig. 1 - Canonical maps and time series for Nov-Feb season with Pacific as predictor. First canonical modes: a) canonical pattern (g1) for Pacifi; b) Canonical pattern (h1) for predictand side (RS-UY); c) First canonical mode u1, v1. Shaded areas reprsent regions at 5% significant

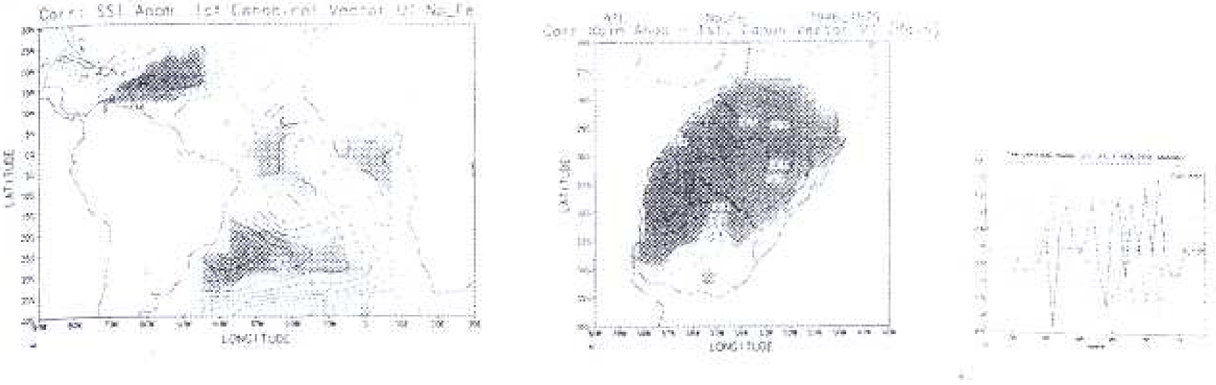

Fig. 2 - Canonical maps and time series for Nov-Feb with Atlantic as predictor. a) First canonical pattern (g1) for Atlantic; b) First canonical pattern (h1) for the predictand side (UY-RS) c) First canonical mode u1,v1. Shaded areas represent regions at 5 % significant