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ASSESSING FORECAST PERFORMANCE OF THE EMPIRICAL MODEL TO FORECAST PRECIPITATION IN THE SOUTH AND SOUTHEAST REGIONS OF BRAZIL

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1. INTRODUCTION

The majority of the country's population and economical activities (mostly industry and agriculture) are concentrated in the South and Southeastern regions of Brazil. The success of these activities is highly dependent on the accuracy of the weather and seasonal forecasts. Recent climatological studies have indicated that the Sea Surface Temperature (SST) variability in the Atlantic and Pacific oceans exert significant role in the climatic fluctuations in the South and Southeastern regions.

Consistent relationships between precipitation anomalies in Southern Brazil and the extreme phases of ENSO (Barros and Doyle, 1997). In El Niño (La Niña) episodes there is a tendency for positive (negative) precipitation anomalies to occur in the spring of the year of the event and in the autumn and winter of the year following the starting year of the event (Grimm et al., 1998).

Results of Veiga et al. (2002) show that there are four areas in the tropical and equatorial Pacific and two on the South Atlantic with significant influence in the monsoon rainfall in parts of the Southeastern and Central-West Regions of Brazil.

Some studies suggest a precipitation dipole pattern, with centers of action over Southeastern Brazil and the southernmost regions in Southern Brazil, associated with the sea surface temperature anomalies over the Southwestern Atlantic (Barros et. al., 2000; Robertson and Mechoso, 2000; Barreiro et al., 2002; Paegle and Mo, 2002).

An empirical model of monthly precipitation forecast in South (S) and Southeast (SE) Brazil are presented in this paper. The model is based on regression analysis of the time series of the Atlantic and Pacific oceans sea surface temperature (SST) principal component modes.

2. DATA AND METHODOLOGY

The data set basis comprise 35 years (1961-1995) of monthly precipitation observed over S and SE Brazil and the corresponding monthly SST for the Atlantic and Pacific Oceans (denoted by AO and PO, respectively) with spatial resolution of 1ºX1º (Reynolds and Smith, 1994). The original precipitation station data were obtained from ANEEL (*Agência Nacional de Energia Elétrica*) and DAEE (*Departamento de Águas e Energia Elétrica do Estado de São Paulo*). The annual cycle was removed by subtracting from each observation (whether monthly precipitation or SST) the corresponding monthly mean and then scaling this difference by the monthly standard deviation.

The rotated principal components analysis (RPCA) by Varimax method was used to reduce the dimensionality of the SST matrices and identify the SST variability modes.

A hierarchical cluster analysis defined the monthly precipitation regions with homogeneous behavior. This clustering was performed by the analysis of the degree of similarity and the difference between individual thresholds that separate the precipitation regimes.

The empirical model based on linear regression analysis was designed to forecast the average precipitation in homogeneous regions based on the time series of the scores of the principal components of SST as predictors. Lagged forecasts up to 4 months were performed. Given the real time goal of the forecasting technique (i.e., precipitation forecast at time *t* with lag *k*), the statistical model takes into account data collected at previous times (*t*-*k*). However, any forecast model that uses SST data as input may be updated monthly, given that additional SST data as well as monthly precipitation data become available. In this way, forecasts of future precipitation requires that the SST scores be updated every month, even if the model parameters and modal structure are not updated.

The parameters calculated to evaluate the model skill are: i) correlation coefficient (r) between the forecast and observed series; ii) square root of the mean squared error (RMSE); iii) Mean error (Bias).

3. RESULTS

The results of the cluster analysis indicate five regions of homogeneous precipitation over the S and SE of Brazil. The spatial structure of the homogeneous regions, shown in Figure 1, is similar to the spatial distribution of climatological annual precipitation maximums observed in these areas. Throughout almost all S Brazil the precipitation annual mean vary from 1250 to 2000 mm with higher values located over the west of Santa Catarina State (the second state from the south in Figure 1) and over the east of Paraná State (the third state from the south). A region of maximum precipitation is detected in the coast of the S region and an area with minimum precipitation over the northern part of the Minas Gerais State (Quadro, 1996) which is the forth state from the south in Figure 1.

After the identification of the groups of stations with homogeneous precipitation, based in the chosen metrics, the mean precipitation over each homogeneous region in the period of 1961 the 1995 was computed. These new variables reduced the dimension of the forecasting problem. Linear regressions were calculated between the standardized anomaly of the precipitation for each homogeneous region and the times series (scores) from SST modes, obtained by RPCA applied over the Atlantic and Pacific SST data separately. The precipitation forecast was performed up to four lags.

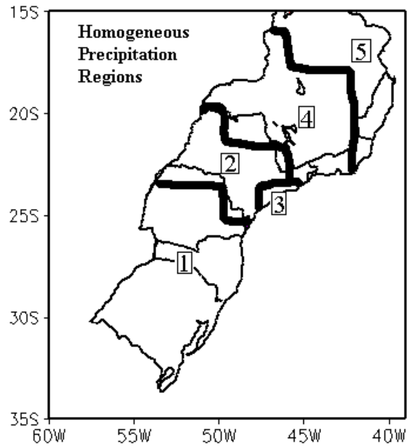

Figure 1: Maps with the homogeneous precipitation regions, identified by cluster analysis, for every month of the year.

Figure 2 shows forecasts obtained with the the above defined regression model, for the five homogeneous regions during the verification period (1986 to 1995). This figure shows the observed precipitation (black solid line) together with their predicted values, from one up to four months lag (dashed lines). The skill parameters for each lagged forecast are presented in the top of each map.

There is little difference in the model skill for each lag. Correlations between the forecast and observed series are significant for all the homogeneous regions at all forecast lags, indicating that a considerable ratio of precipitation variance is explained by the SST.

The better skill of the regression model was reached for homogeneous precipitation regions over the SE of Brazil. The performance of the numerical models for climate predictions especially over the SE of Brazil is low (Marengo et al., 2003). The empirical model is more skillful for the SE than S of Brazil. This characteristic of the empirical model is associated with the fact that the model is not capable to capture the semi-annual cycle variations observed in precipitation series of S Brazil. However, the low frequency tendency is well captured in all regions evaluated.

A small increase in the model skill with increasing lead-time was observed for the region 1 (S of Brazil), region 2 (north of Paraná State and interior of São Paulo State) and region 3 (coastal region of SP). For the region 4 (south of Minas Gerais State) the better skill of the model was reached at lag 3 (i.e three months in advance). In the case of region 5, north of Minas Gerais State and Espirito Santo State, was observed a little difference in skill model at all forecast lags. In general the best empirical model skill was reached for the 4 and 5 homogeneous regions, with under-estimation of the positive extreme values. For the other regions under-estimation of the positive extreme values and super-estimation of the negative extreme were identified.

The stepwise regression defines the order of importance of the predictors utilized in the statistical forecasting model and indicates the adequate number of predictors. For each new forecast the best predictors and the number of predictors for the best skill are defined. Thus, in order to know the main SST modes that contribute for the prognostic model, the result of the latest forecast time for each homogeneous region was analysed. In summary, In summary, for the precipitation forecasts in regions 1 and 2 the results indicate a considerable contribution of the SST anomalies over the tropical PO, in addition to SST information over the subtropical bands of the south PO and AO. Region 3 is mainly characterized by the contribution of the subtropical band of the South PO, followed by contribution of the SST anomalies in the central area of the subtropical South AO. In the case of region 4 it is clearly identified the influence of the tropical AO meridional SST gradient, at lags 1 and 2. The best predictors for region 5 indicate the control exerted by the SST over the subtropical band of the South AO and PO at all lags.

The empirical model skill based on the evaluation metric (correlation coefficients, square root of the mean squared error and bias) is satisfactory. mainly for the Southeastern region of Brazil. This type of model is shown to be useful for precipitation seasonal forecasts in S and SE Brazil and for the the identification of new predictors.

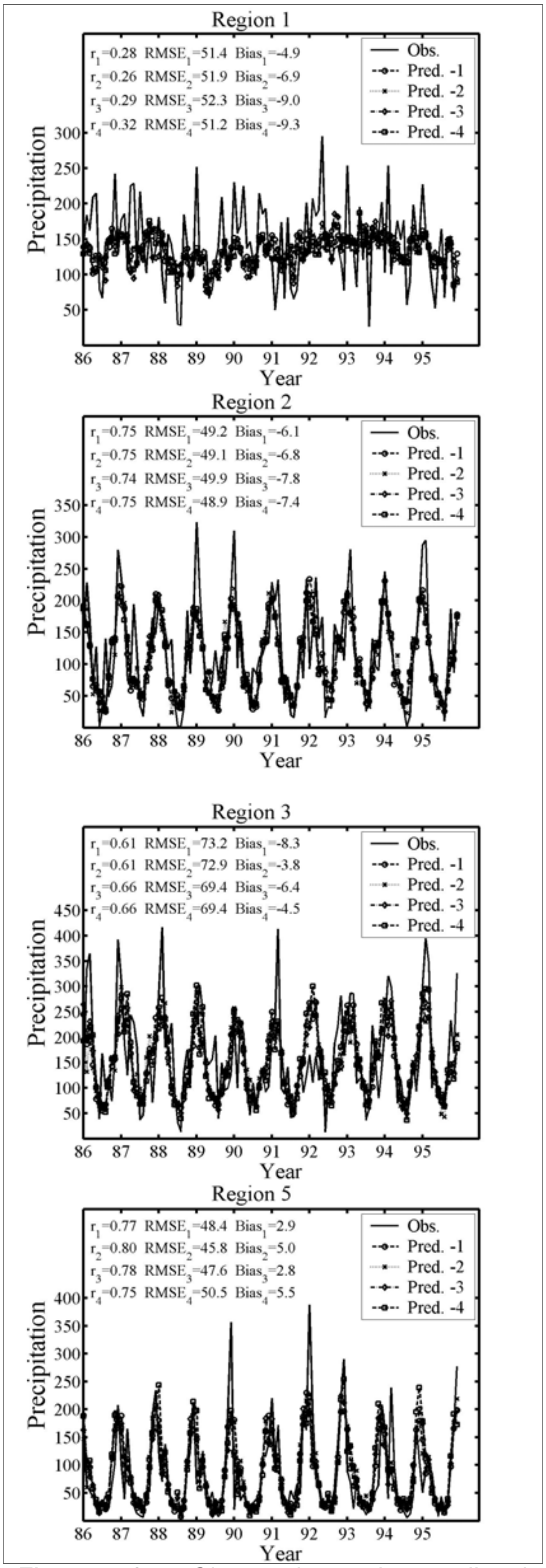

Figure 2: Observed and predicted precipitation over homogeneous regions, to prediction at one to four months lag.

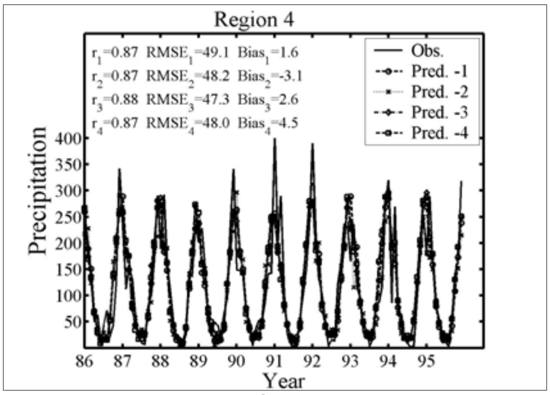

Figure 2: Continuation.

Acknowledgements

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