Forecast of the May-June-July Atmospheric Circulation Using the UCLA-AGCM and the NCEP-forecasted global SST, combined with a statistical downscaling to estimate May-June-July 2010 precipitation in the northern part of Southeastern South America

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In this work we use hindcasts and forecasts of global sea surface temperature (SST) ields obtained with the NCEP CFS (Saha et al. 2006), which are publicly available on line. The NCEP CFS SST hindcasts and forecasts considered here are initialized with oceanic and atmospheric conditions assimilated during February. The SST fields from the hindcasts or forecasts are bias corrected and used to simulate an ensemble mean of the global atmospheric circulation for each season May-June-July (MJJ) from 1981 to 2003. Atmospheric circulation is simulated with the UCLA AGCM, which is a finite difference model with state of the art parameterization of the physical processes. Its description and recent developments can be found at Konor et al. (2008). In this work we use a medium resolution AGCM, that has an horizontal resolution of 2º of latitude by 2.5º of longitude, and 29 layers in the vertical direction, which extends from the earth surface to the level of 1 hPa. Then a downscaling technique allow us to "project" the simulated anomalous circulations for each year on statistical regional patterns, and estimate the regional rainfall in part of SESA based on statistical relationships between these projections and the observed rainfall. In these way we by-pass the use of model-calculated seasonal rainfall which we know have deficiencies derived from the low resolution of the version of the model used, and from other causes, such as deficiencies in the tropical South America processes, etc. According to this, we will proceed as follows:

First, we show results for the hindcasts of MJJ atmospheric circulation. We focus on anomalous vector wind at 200 hPa since this variable is well correlated with surface climate anomalies at SESA both in observations (Cazes Boezio et al. 2003) and in our hindcasts. We compute empirical orthogonal functions (EOFs) in a region around South America, and the corresponding PCs (time series). Since PC2 results to be significantly correlated with observed precipitation in northern SESA (NSESA), we can propose a “downscaling” technique based on this correlation.

Second, we use NCEP CFS global SST forecast (bias corrected) initialized with conditions of February 2010 to compute with the UCLA AGCM a forecast of the expected MJJ 2010 atmospheric circulation, and then we project the correspondent regional 200 hPa zonal wind anomaly onto the second EOF referred above. This can be considered a forecast of PC2 for MJJ 2010. The forecasted PC2 is used to infer the regional rainfall for this season by using the downscaling technique.

Hindcasts computations and results.

Short term bias of the NCEP CFS SST hindcasts or forecasts is in principle removed with the following procedure: we subtract to each monthly SST from a hindcast or a forecast the mean of all the hindcasts for the respective month, obtaining a hindcast of the monthly SST anomalies. These SST anomalies are over imposed to climatological SSTs obtained from the GISST dataset (Rayner et. al. 1994).

Then we simulate the atmospheric circulation with the UCLA AGCM, prescribing the bias corrected global SST monthly fields. (The UCLA AGCM infers daily SST fields by linear interpolation of the monthly fields.) We perform six AGCM simulations per year. Each individual AGCM simulation extends from early April to the following July 31th. For a particular year, the only difference among the atmospheric simulations is found in the initialization. We start each of the six simulations from 0:00 GMT of April 7th, 8th, 9th, 10th , 11th and 12th respectively, but using for all of them the same set of prognostic variables, that corresponds to 0:00 GMT of April 10th

from a previous simulation. For simulated atmospheric variables of interest we compute for each year the MJJ ensemble mean (averaging the six AGCM simulations for that year), and we subtract from it the average of all the analogous means from 1981 to 2003. In this way we obtain a hindcasts of the anomalous circulation for each MJJ.

We compute EOFs to the anomalous wind at 200 hPa over a domain around South America, which lies between 50ºS and 10ºN, and 90ºW and 30ºW. Figure 1 a and b show the first and second EOFs in terms of linear regression of the zonal wind anomaly with the standardized time series of the respective PC, as in Robertson and Mechoso 2000. This regression is computed globally. At each point of the model horizontal grid, regression coefficient can be interpreted as the anomalous wind that corresponds to one standard deviation of the PC in a linear adjustment. At each grid point, the statistical significance of the regression is computed in terms of the statistical significance of the correspondent correlation coefficient, considering a two tails t-Student test of 23 degrees of freedom. (Fig. 1 shows areas with significance above 95% color shaded.) PC 1 and 2 account respectively for 49% and 23% of the sum of all PCs variances. At the domain used for the EOFs computation, EOF1 is associated with positive anomalies (in the positive phase of the pattern) over northern South America and over western central South America, and negative anomalies over southern South America. Over tropical and subtropical Pacific, we find zonal wind anomalies consistent with ENSO (in the positive phase of the PC, enhanced subtropical westerlies and weakened Walker cell circulation over the Equator). EOF2 shows, over the domain considered for its computation, strengthened subtropical westerlies (for the positive phase) at the east of central South America, and opposite anomalies at the north of the continent. Statistically significant anomalies are more concentrated around South America in comparison with EOF1.

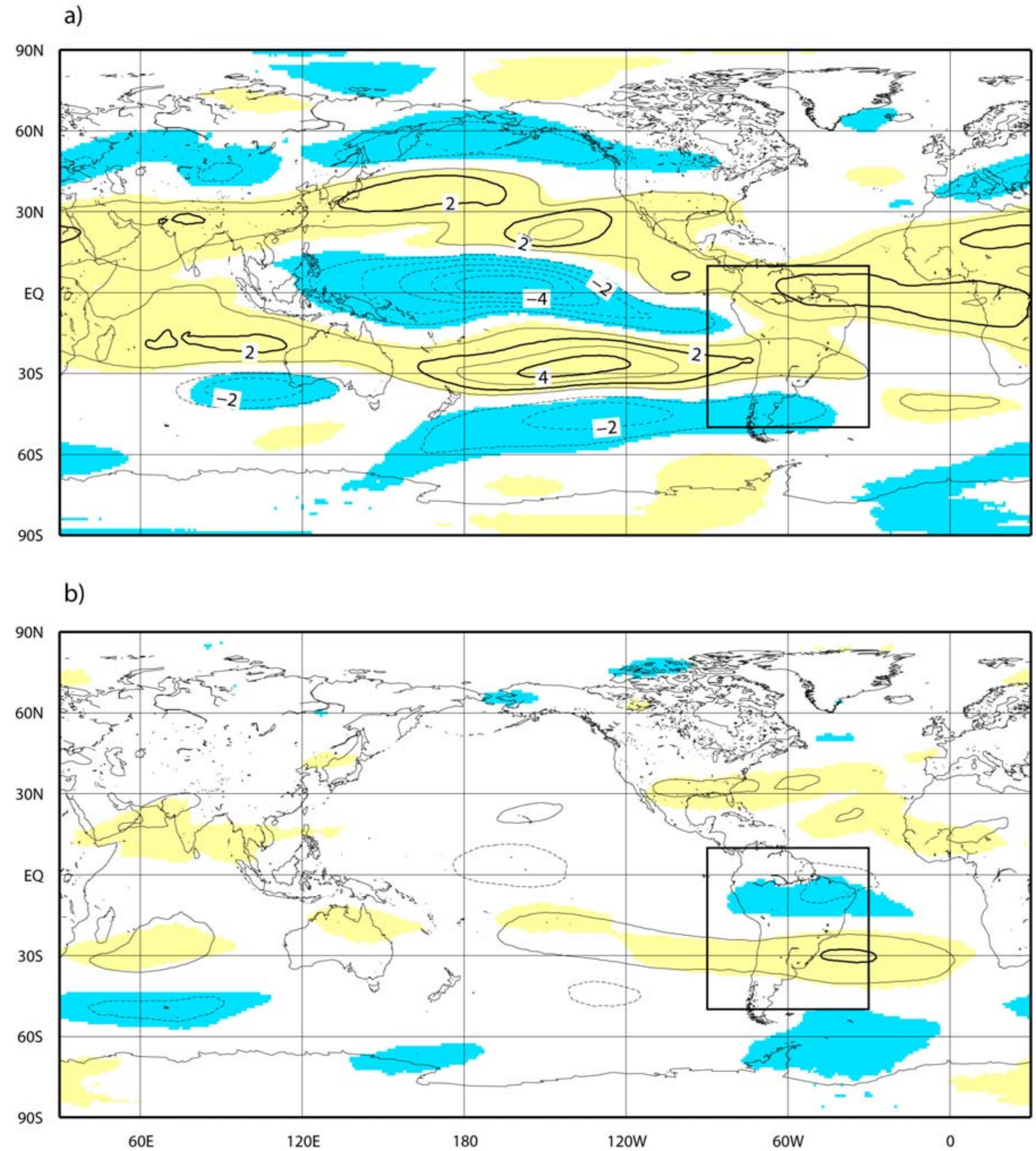

Figure 1 a) First EOF for MJJ anomalous zonal wind at 200 hPa for the hindcasts from 1981 to 2003. EOFs are computed in the domain 50ºS-10º, 90ºW-30ºW (indicated with a box). Contour interval is 1 m/s, color shading indicates statistical significance of the regression (in terms of the correspondent correlation coefficient) above 95%, according to a two tail Student test considering 23 degrees of freedom. b: idem a, for the second EOF.

Figure 2 shows the correlation of PC1 and PC2 with the simultaneous MJJ precipitation from CMAP analysis (Xie Arkin 1997). We find that the PC1 is significantly correlated (positively) with precipitations in the topical Pacific, mostly in its north western and north central parts, and in the south tropical Atlantic (negatively). It is also significantly correlated with precipitation anomalies in northern Brazil (negatively) and in Central Eastern Brazil (positively). PC2 is also positively correlated with precipitations in the tropical Pacific, but mostly in the central and eastern parts of this regions, and is positively correlated with precipitation in the northern part of Southeastern South America. In this contribution we are going to focus on a part of this region, which lies between 32ºS and 24ºS and between 62.5ºW and the Atlantic coast (Figure 3). This figure comprises most of the state of Rio Grande do Sul in Brazil and the northern part of Uruguay, and we call it hereafter RGS-NU. Figure 4 shows the statistical relationship between PC2 and the regional MJJ precipitation over RGS-NU. Correlation of these variables is 0.61, which is statistically significant at a level greater than 95% according to a t-student test for 23 degrees of freedom. The diagram of Fig. 4 is the key piece in the downscaling procedure that we use to estimate the MJJ regional precipitation. This plot works as a statistical predictor using the PC2 (from a hindcast or a forecast) as input, as we describe bellow.

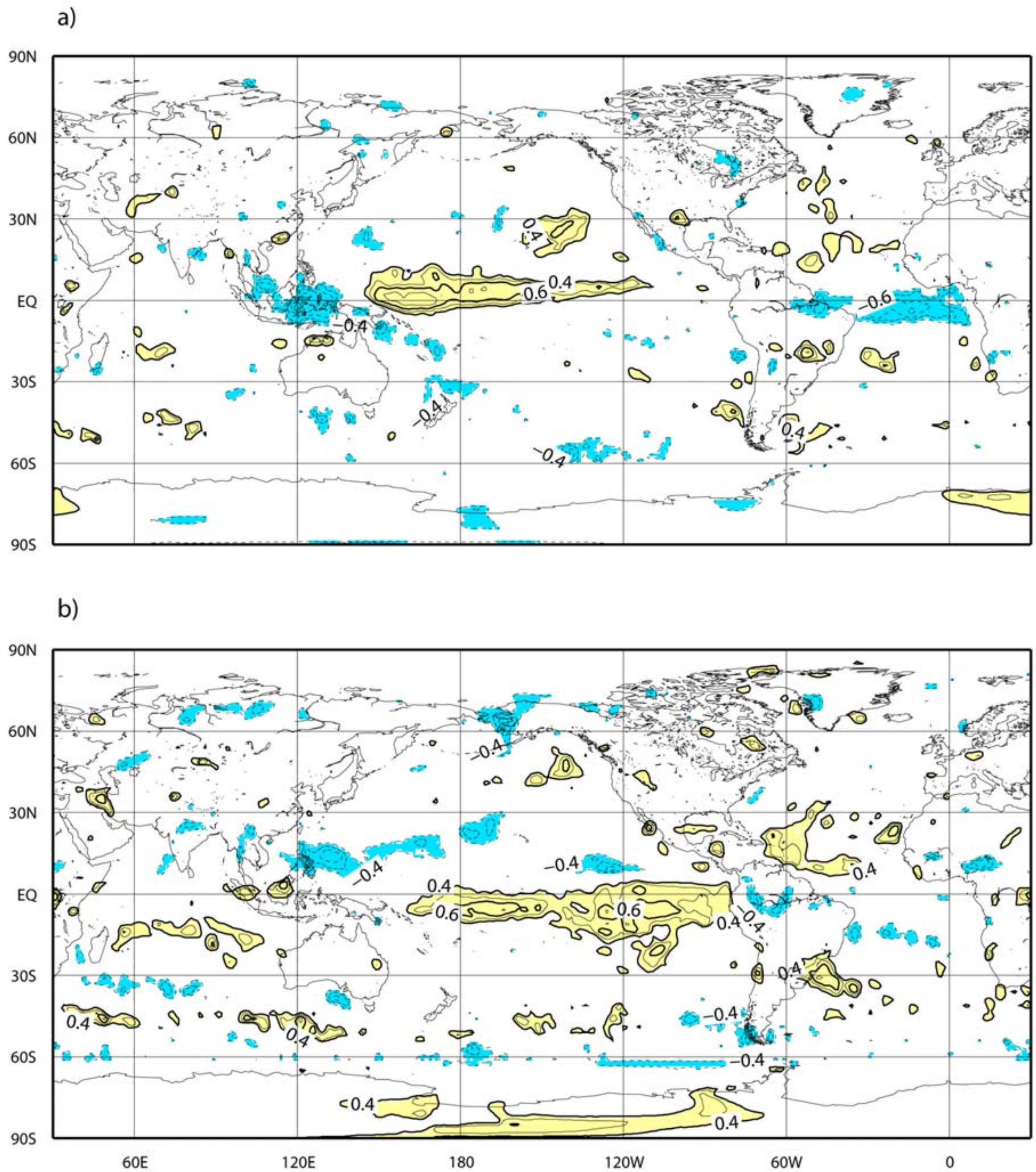

Figure 2. a: Correlation of PC1 of MJJ hindcasts from 1981 to 2003 with simultaneous precipitation

from CMAP analysis. Contour interval is 0.1 (only values above 0.4 or below -0.4 are shown). Color shading indicates statistical significance of the correlation, computed as in Fig. 1. b: same as a, for PC2.

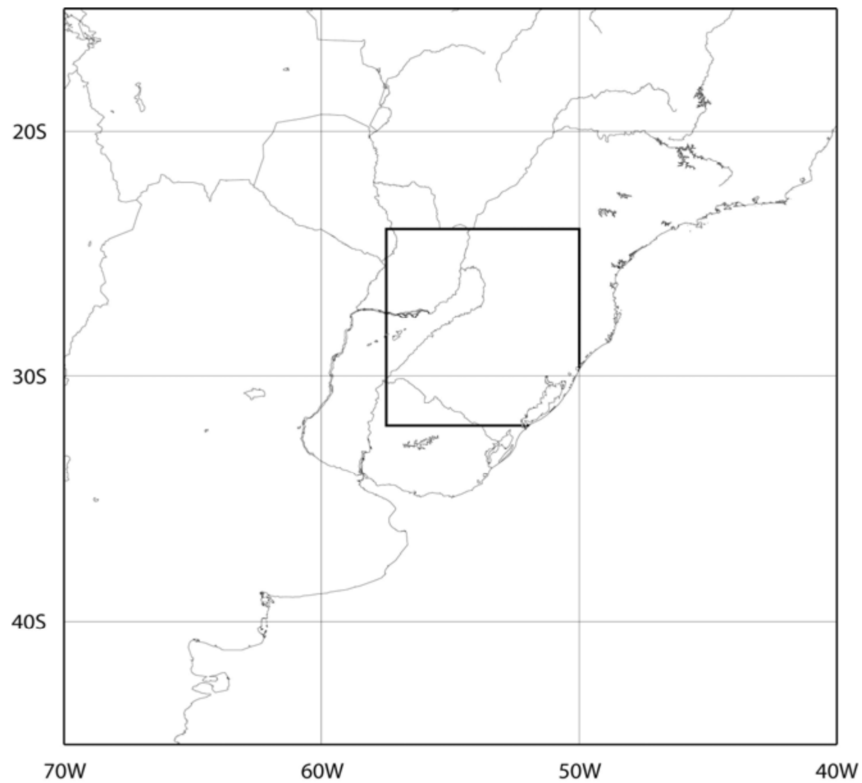

Figure 3: NSESA region

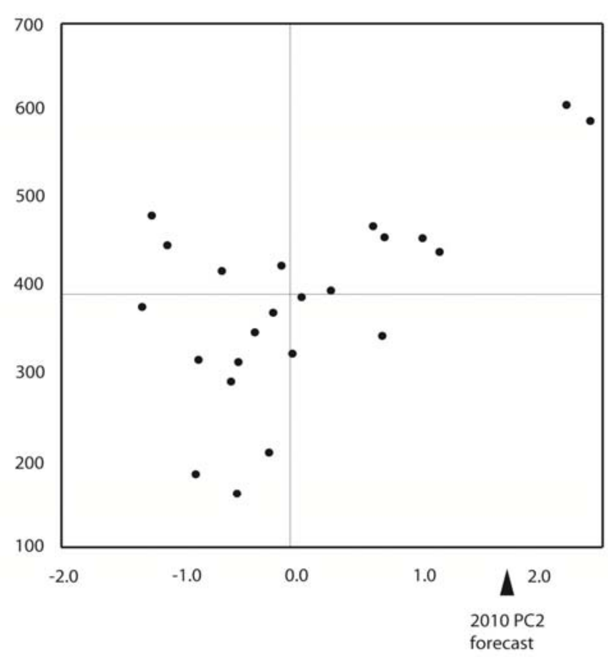

Figure 4: PC2 vs. CMAP rainfall in RGS-NU (for MJJ). The horizontal line shows the median of the precipitation for the whole population. Vertical dashed line shows the valus of PC2 -0.1 (there

are ten cases with PC2 above it). Value of 2010 PC2 forecasts is also indicated.

The MJJ 2010 forecast.

The projection of the MJJ 200 hPa anomaly of the zonal wind simulated with the SST forecast initialized from February 2010 onto EOF2 gives the forecast of PC2 (2010), which, after standardization, is 1.73. The anomaly is computed considering the hindcasts climatology, and the simulations are analogous to those of the hindcasts (six simulations from early April). SST forecast is bias corrected as before, using the hindcasts SST climatology. Fig 4 shows only two cases with PC2 values larger than the forecasted value for 2010. We consider the 10 most negative cases of PC2 values in the 1981-2003 record as the most reasonable subpopulation analogous to the to MJJ 2010 in terms of expected 200 hPa anomalous circulation around South America. The precipitation median of this subpopulation is 446 mm, and it has 7 cases out of 10 with lower precipitation than the median of the total population of hindcasts, which is 390 mm. Considering this, we propose an expected median of 446 mm for the expected precipitation over RGS-NU during MJJ of 2010, and a chance of 0.7 of precipitation below the median of the total population.

In summary, in RGS-NU, we expect a positive shift of the expected MJJ precipitation.

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