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 2009 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 April. 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 1982 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 (Robertson and Mechoso 2000) and in our hindcasts. We compute empirical orthogonal functions (EOFs) in a region around South America, and the corresponding PCs (time series). Since PC1 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 April 2009 to compute with the UCLA AGCM a forecast of the expected MJJ 2009 atmospheric circulation, and then we project the correspondent regional 200 hPa wind anomaly onto the first EOF referred above. This can be considered a forecast of PC1 for MJJ 2009. The forecasted PC1 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 May 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 May 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 60ºS and the Equator and 110ºW and 10ºW. Figure 1 shows the first EOF in terms of linear regression of the 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. Vectors are shown only in those grid points where at least one component of the wind has statistically significant correlation (at 95% level) with the corresponding PC. This significance is computed through a t-student test considering 23 degrees of freedom. At the domain used for the EOFs computation, EOF1 shows a anticyclonic vortex (in its positive phase) eastward South America, centered around 15ºS. Southward and eastward this vortex we find a wave like pattern of anomalous circulations. The variance of PC1 is 32% of the total variance of the PCs.

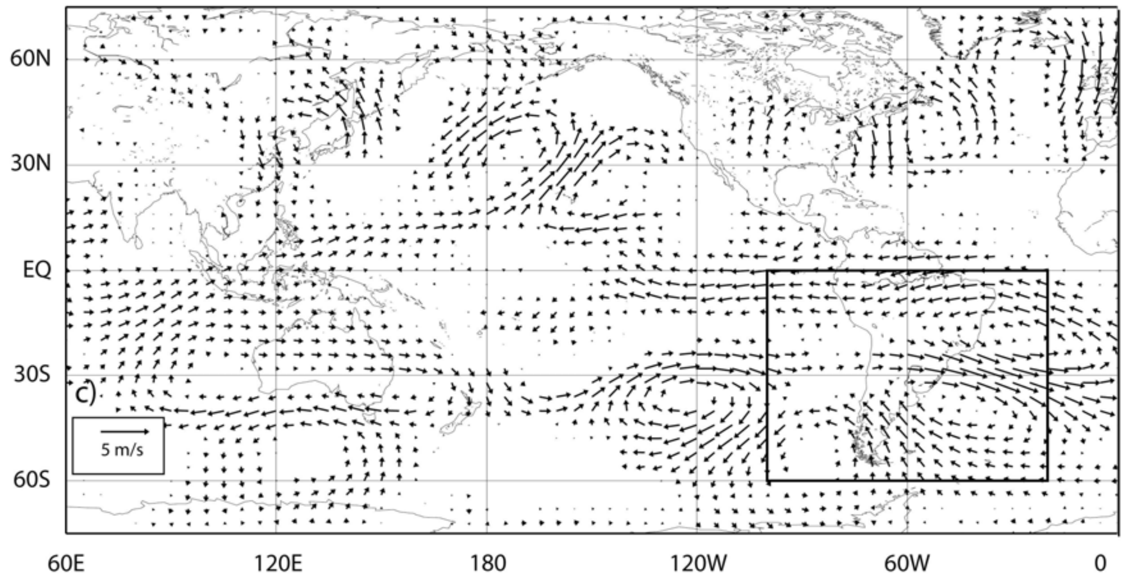

Figure 1 First EOF for MJJ anomalous vector wind at 200 hPa for the hindcasts from 1981 to 2003. EOFs are computed in the domain 60ºS-0º, 110ºW-10ºW (indicated with a box). Each component of the vectors shown is the linear regression coefficient of the local anomaly of u or v with the standardized PC1 time series. Vectors are shown only at points were at least one of the two components has statistically significant correlations with PC1.

Figure 2 shows the correlation of PC1 and with the simultaneous MJJ precipitation from CMAP analysis (Xie Arkin 1997). We find that the PC is associated with anomalies in the tropical Pacific. The PC is also associated with anomalies over north of Southeastern South America. (NSESA). Considering this result, we are going to focus on NSESA, which we define as the region that lies between 32ºS and 24ºS and between 62.5ºW and the Atlantic coast (Figure 3). Figure 4 shows the statistical relationship between PC1 and the regional precipitation over NSESA. Correlation of these variables is 0.45, 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 PC1 (from a hindcast or a forecast) as input, as we describe bellow. We wish to comment that it is found in observational studies that an anticyclonic vortex placed eastward NSESA is associated with positive anomalies of precipitation over this region during several seasons of the year (Robertson and Mechoso 2000, Cazes-Boezio et al. 2003). The anticyclonic vortex at the east of South America found in Fig. 1 is also associated with positive anomalies over NSESA, but it is shifted to the north about 15º respect to the vortex found in the referred works, which is centered around 30ºS. This may indicate a systematic error of the UCLA AGCM forced with CFS hindcasts, and requires further studies. The significant correlation of observed precipitation over NSESA with the PC derived from simulation suggests that this statistical analysis of the model output may correct to some extent such systematic error.

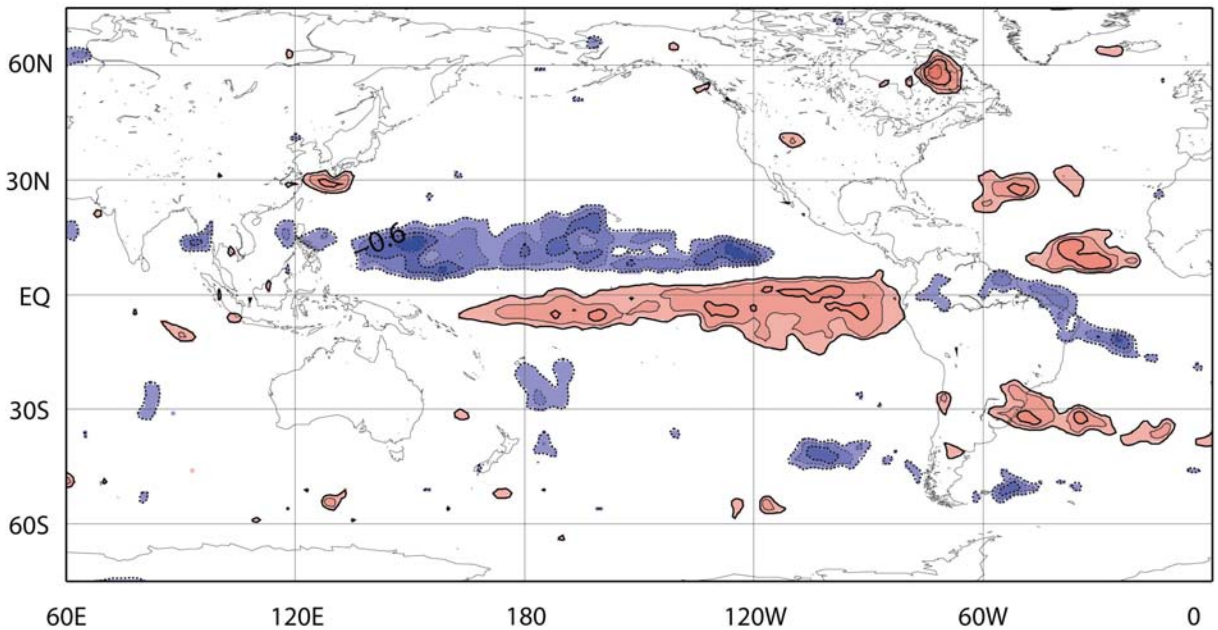

Figure 2. Correlation of PC1 of AMJJ hindcasts from 1981 to 2003 with simultaneous precipitation from CMAP analysis. Contour interval is 0.1. Only values above 0.4 or below -0.4 are shown.

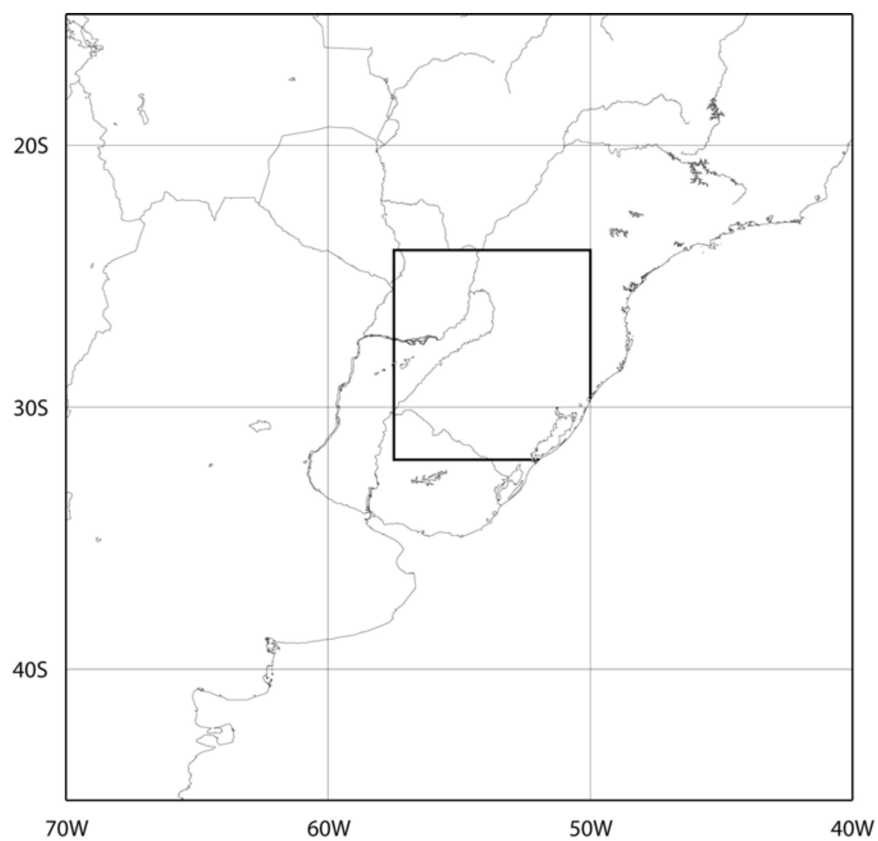

Figure 3: NSESA region

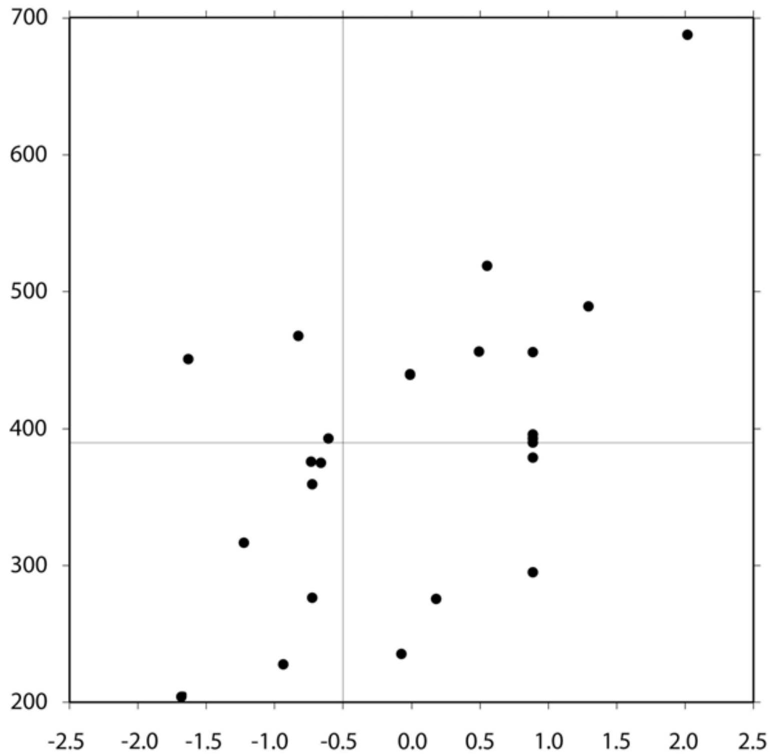

Figure 4: PC1 vs. CMAP rainfall in NSESA. The horizontal line shows the median of the precipitation for the whole population. Vertical dashed shows the PC1 value of -0.5.

The MJJ 2009 forecast.

The projection of the anomaly onto EOF1 gives the forecast of PC1 (2009), which, after standardization, is -2.8. There are not such negatives PC1 values in our 1981-2003 hindcasts (Figure 4). We consider the 10 most negative cases of PC1 values in the 1981-2003 record as the most reasonable subpopulation analogous to the to MJJ 2009 in terms of expected 200 hPa anomalous circulation around South America. The precipitation median of this subpopulation is 367 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 367 mm for the expected precipitation over NSESA during MJJ of 2009, and a chance of 0.7 of precipitation below the median of the total population.

In summary, in NSESA, we expect a moderate negative shift of the expected MJJ precipitation.

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