Forecast of the October-November-December Atmospheric Circulation Using the UCLA-AGCM and the NCEP-forecasted global SST, combined with a statistical downscaling to estimate October-November-December 2010 precipitation in Southeastern South America

Gabriel Cazes Boezio and Gabriel J. Pisciottano.
Facultad de Ingeniería, Universidad de la República, Uruguay.

In this work we use hindcasts and forecasts of global sea surface temperature (SST) fields 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 June. 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 October-November-December (OND) 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 OND atmospheric circulation. We focus on anomalous zonal wind at 200 hPa since this variable is well correlated with surface climate anomalies at SESA both in observations (Cazes Boezio et al. 2003, 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 Southeastern South America (SESA), we can propose a "downscaling" technique based on this correlation.

Second, we use NCEP CFS global SST forecast (bias corrected) initialized with conditions of June 2010 to compute with the UCLA AGCM a forecast of the expected OND 2010 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 OND 2010. 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. 1996).

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 seven AGCM simulations per year. Each individual AGCM simulation extends from late June to the following December 31th. For a particular year, the only difference among the atmospheric simulations is found in the initialization. We start each of the seven from June 25th, the initial conditions correspond to this date in previous simulations. For simulated atmospheric variables of interest we compute for each year the OND ensemble mean (averaging the seven 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 OND.

We compute EOFs to the anomalous zonal wind at 200 hPa over a domain around South America, which lies between 60ºS and 10ºN and between 110ºW and 10ºW. Figure 1a shows the first EOF 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 the domain used for the EOFs computation, EOF1 shows westerly anomalies at northern and subtropical South America. There is a local maximum of this anomaly located approximately at 32ºS-50ºW. The variance of PC1 is 55% of the total variance of the PCs.

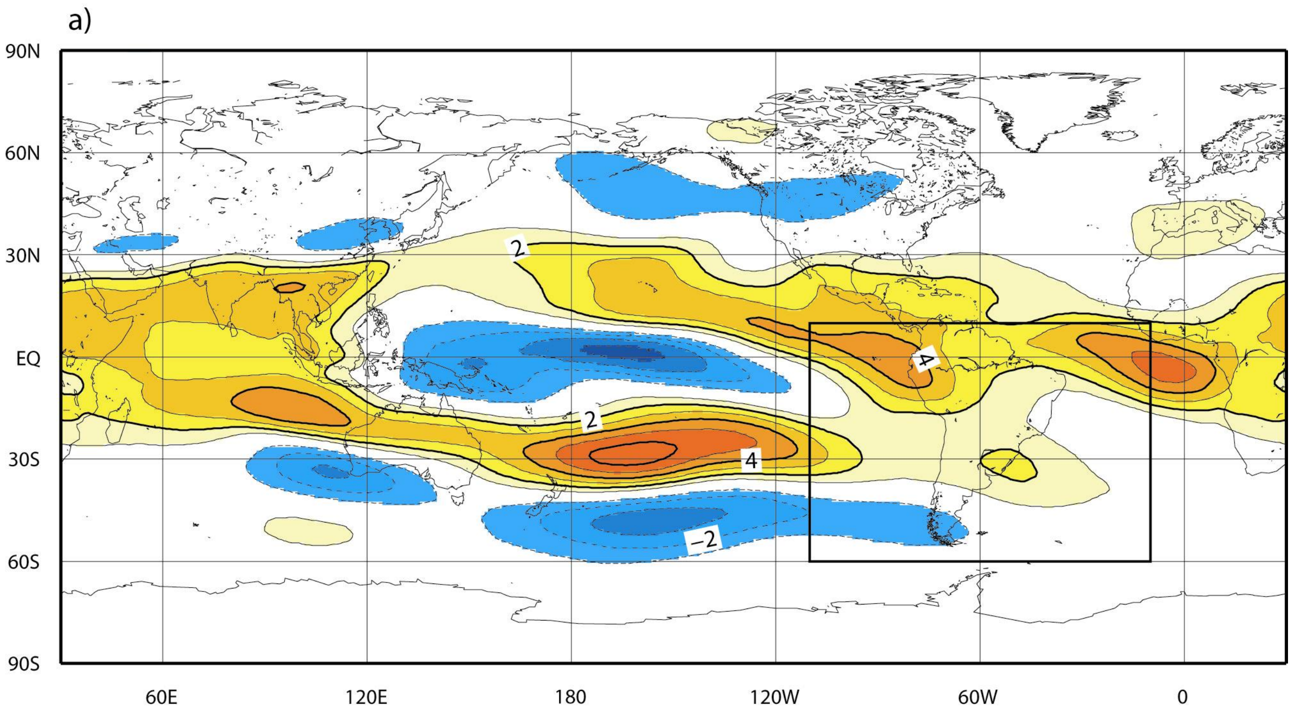

Figure 1 First EOF for OND anomalous zonal wind at 200 hPa for the hindcasts from 1981 to 2003. EOFs are computed in the domain 60ºS-10ºN, 110ºW-10ºW (indicated with a box). The values shown are computed at each model grid pint as the linear regression coefficient of the local anomaly of u with the standardized PC1 time series.

It is found that PC1 is well correlated with the simultaneous OND total seasonal precipitation, spatially averaged through the grid points of the CMAP data set (Xie Arkin 1997) that are inside Uruguay (this region is indicated in Fig. 2). Figure 3 shows the statistical relationship between PC1 and the regional precipitation over Uruguay, defined in this way. Correlation of these variables is 0.54, 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. 3 is the key piece in the downscaling procedure that we use to estimate the OND regional precipitation. This plot works as a statistical predictor using the PC1 (from a hindcast or a forecast) as input, as we describe bellow.

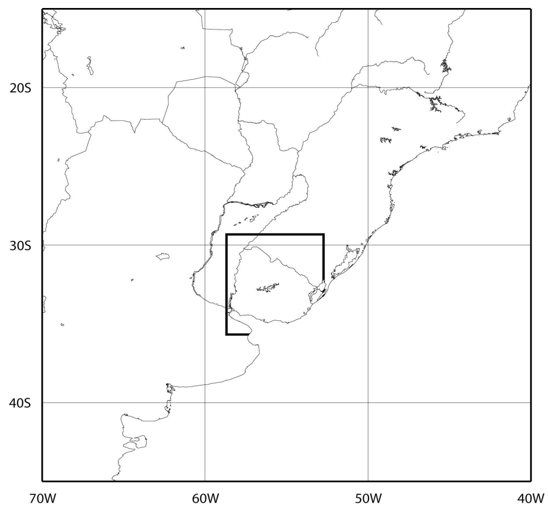

Figure 2: Region around Uruguay considered for the precipitation forecast.

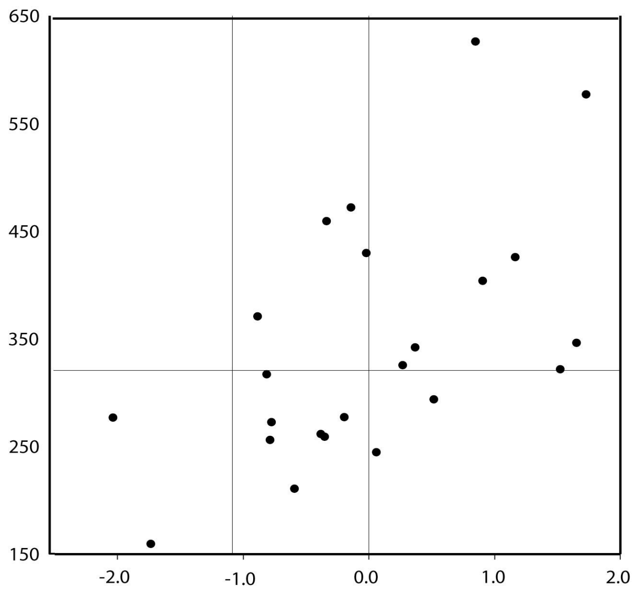

Figure 3: PC1 vs. CMAP OND total precipitation (mm) in Uruguay. The horizontal line shows the median of the precipitation for the whole population. Vertical line shows the PC1 value of -1.05, (forecasted for OND 2010) and 0.0. The 13 hindcasts with PC1 value less tan zero are considered the closer to the OND 2010 forecast.

The OND 2010 forecast.

The forecasted OND 2010 200 hPa wind anomaly is shown in Fig.4. It has typical features related with ENSO cold phase, and its projection onto EOF1, which gives the forecast of PC1 (2010), is **-1.05** (after standardization). We consider the 13 most negative cases of PC1 values in the 1981-2003 record as the most reasonable subpopulation analogous to the OND 2010 in terms of expected 200 hPa anomalous circulation around South America (see Fig. 3). The respective precipitation median is 280mm, and the subpopulation has 9 cases out of 13 with smaller precipitation than the median of the total population of hindcasts, which is 323 mm. Considering this, we propose an expected median of 280 mm for the precipitation over SESA during OND of 2010, and a chance of 9/13; (aproximately 0.7) of precipitation below the median of the total population.

In summary, in SESA, we expect a moderate negative shift of the expected OND 2010 total precipitation in Uruguay.

We regard this rather early prediction of OND 2010 precipitation in our country as useful, however, an update of this forecast around early austral spring is very advisable.

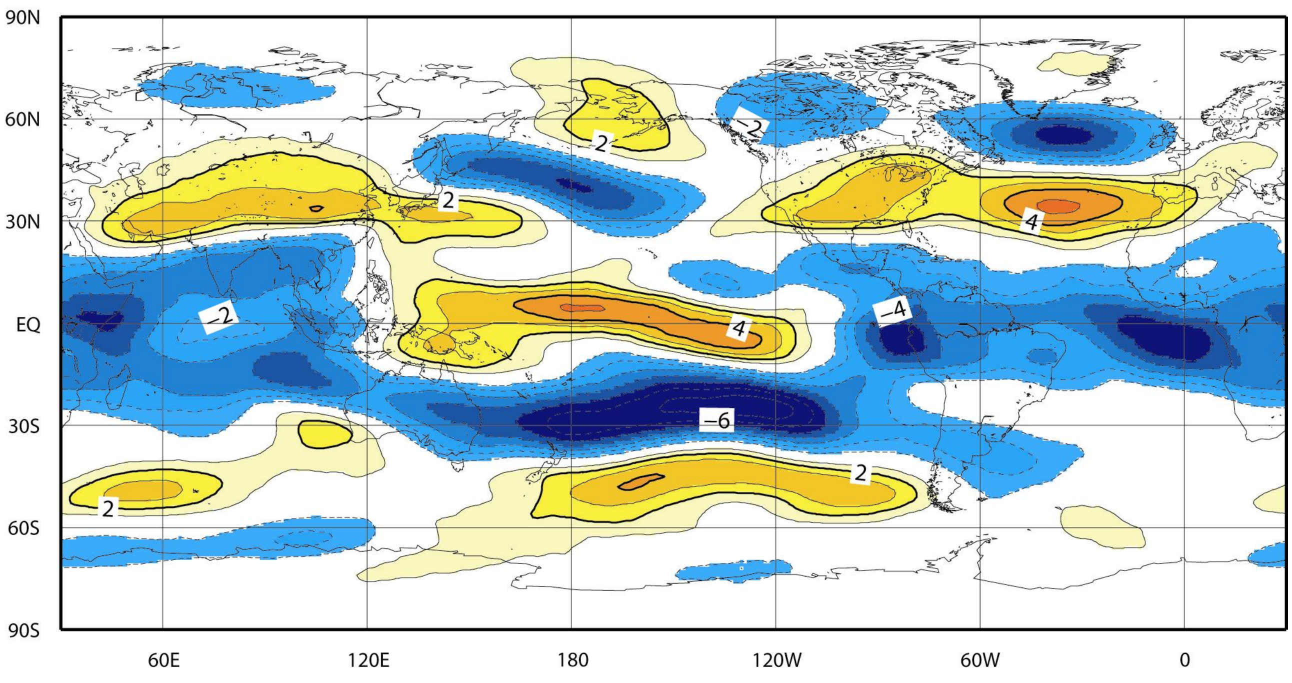

Figure 4. Forecasted 200 hPa zonal wind anomaly for OND 2010.

Acknowledgments: ANCAP (Administración Nacional de Combustibles, Alcohol y Portland) and CONICYT (project PDT 63-281) of Uruguay supported the work that made possible this contribution. NOAA NCEP makes available numerical data of retrospective and actual forecasts from the CFS, as well as the CMAP precipitation analysis. Computations were done at the computer cluster of the School of Engineering, Universidad de la República, Uruguay. Dr. Gabriel Usera and the staff of cluster of the School of Engineering took part of their valuable time providing technical assistance that made the use of the computer cluster possible.

References

- Cazes-Boezio G., A. W. Robertson A. and C. R. Mechoso 2003. Seasonal dependence of teleconnections over South America and relationships with precipitation in Uruguay, *J. Clim.,* **16***,* 1159-1176.

- Konor C., G, Cazes Boezio, C. R. Mechoso, and A. Arakawa, 2008: Parameterization of PBL processes in an Atmospheric General Circulation Model: Description and Preliminary Assessment. *Mon. Wea. Rev,* **137**, 1061-1082

- Rayner N. A., E. B. Horton, D. E. Parker, C. K. Folland and R. B. Hackett, 1996: Version 2.2 of the global sea-ice and sea surface temperature data set, 1903-1994, Climate Research Technical Note 74, 43pp. (Unpublished manuscript available from The Met Office, London Road, Bracknell, RG12 2SY, U. K.)

- Robertson A. and C. R. Mechoso 2000: Interannual and Interdecadal variability of the South Atlantic Convergence Zone. *Mon. Wea. Rev*., **128**, 2947-2957.

- Saha, S., S. Nadiga, C. Thiaw, and others, 2006: The NCEP Climate Forecast System. *J. Climate*, **19** (15), 3483-3517.

- Xie and Arkin, 1997: Global Precipitation: A 17-year monthly analysis based on gauge observations, satellite estimates, and numerical model outputs, *Bulletin of the American*

Meteorological Society, **78**, 2539-2558