Seasonal climate prediction over South America using the CPTEC/COLA AGCM

Iracema Fonseca de Albuquerque Cavalcanti and José Antonio Marengo;
Center for Weather Forecasting and Climate Prediction/ National Institute for Space Research; Cachoeira Paulista, S.P. Brazil.
Corresponding e-mail: iracema@cptec.inpe.br

Seasonal climate predictability of several regions of South America, using the CPTEC/COLA AGCM, has been assessed through several statistical analyses, studies from model simulations, and through the experience of ten years of applying this model in climate prediction at CPTEC. The AGCM is a spectral model, a version of the Center for Ocean-Land and Atmospheric Studies (COLA) atmospheric model, and has been used with T62L28 resolution in seasonal prediction and climate simulations. The model description can be found in Kinter et al (1997) and Cavalcanti et al (2002).

Results from climate simulations have shown the ability of the AGCM to represent the main global climatological features and the seasonal variability (Cavalcanti et al, 2002). Some typical features of the precipitation field such as the high values of the main convergences zones in the tropics and Southern Hemisphere (ITCZ, SACZ, SPCZ, SICZ), and in the regions of storm tracks of the Northern Hemisphere, and features such as the subtropical jetstreams, subtropical highs, vertical structure of wind and temperature, stationary waves, were well represented by the model.

Regional South American features and statistical analyses from the AGCM results were demonstrated in Marengo et al (2003). The interannual variability of precipitation anomalies for the rainy season of several regions of South America were analysed considering results of 9 integrations with different initial conditions. High convergence among the ensemble members was found for the Northern and Northeast regions and higher dispersion among members in Central and Southeastern Brazil. ROC diagrams which measure the rate of hits and failures showed the highest scores in the Northeast region. This is also the region with high values of reproducibility and anomaly correlations (Cavalcanti et al, 2002; Marengo et al, 2003). Anomaly correlations of precipitation between model results and observations from 1982 to 1991, showed that in all seasons there are high correlation values in the Northern and Northeastern regions and part of the southern region, and low or negative values in large areas of the southeastern region (Marengo et al, 2003). Although the precipitation anomalies are not well simulated over southeastern Brazil, the seasonal cycle and the interannual variability, are very well reproduced by the model, showing a systematic underestimation in the Amazon and southern Brazil regions.

Seasonal prediction has been performed monthly at CPTEC using the CPTEC/COLA AGCM, in an ensemble mode (Cavalcanti et al, 2000). Two ensembles are constructed with 15 different initial conditions each and two fields of boundary forcing conditions. Persisted Sea Surface Temperature (SST) anomaly is applied to one set, and predicted SST in the tropical Pacific and Atlantic Oceans is applied to the other. Predicted Pacific SSTs are obtained from NCEP and the predicted Atlantic Ocean SST is obtained from a statistical model, SIMOC (Repelli and Nobre 2004, Pezzi et al. 1998). Although the model is global, focus is given to South America and specific areas which require climate attention, as Northeast (NE) and Southern Brazil due to droughts and floods. Fortunately, these are the regions which have the highest predictability in South America.

The influence of the two ENSO phases on precipitation over South America is well simulated and predicted by the AGCM, mainly over Northeast and Southern South America. Examples during the period of ten years simulation are shown in Figs.1 and 2 (Page 16). The CMAP precipitation dataset (Xie and Arkin, 1997) was used for comparisons. Negative anomalies in MAM 83 and positive anomalies in MAM 89 over northeastern Brazil were well simulated. During these periods the opposite anomalies over southern Brazil were also well compared with the observations. In 82/83 floods occurred in Southern Brazil, and the model simulated high positive anomalies over the region. In 88/89 the region experienced dry periods which were well represented by the model. Thus, the confidence on the model is very high during these periods of ENSO in these regions. The model responds very well when the SST anomalous forcing is very strong. In other years, the general pattern over Southern Brazil is not well reproduced, however, considering individual members, some of them are able to represent the anomalies.

Features of the South America monsoon, which comprises areas of the southeastern Brazil, are well represented by the model. The climatological precipitation and wind fields at low and high levels of the summer season are typical of this season and differ completely of those in the winter. The Bolivian High and the Upper Atlantic Trough are well represented by the model, as well as the position of the Atlantic Subtropical High which affects the direction of the trade winds over the northeast Brazilian coast. Other features are typical of the summer season, such as the occurrence of SACZ and different ITCZ position compared to that in the winter. In the summer the ITCZ is located between 0 and 5^0 N, and in the winter is between 5^0 and 10^0 N. These are features which compare well to the observations. Large seasonal differences occur also in the wind flow at high levels. There are strong westerlies over South America, in the winter, while in the summer there is anticyclonic circulation associated with strong divergence at high levels.

However, Southeastern Brazil (SE) is the region which has the worst predictability over South America. This is a transition region, between the tropical regime to the north (northeast), which has high predictability, and the extratropical regime to the south, which has medium predictability. The low predictability of the Southeastern Brazil can also be related to the different positions of the frontal systems that affect the region in the daily results, in each integration. When the ensemble mean is taken, the features associated with frontal system disappear. However, when analysis of individual ensemble members are considered, features of the frontal systems are well reproduced (Cavalcanti and Coura Silva, 2003). Another reason for the inability of the model to predict precipitation anomalies over Southeastern Brazil, could be related to the use of an atmospheric model with prescribed SST, which does not allow the interaction between the atmosphere and ocean.

Model development concerning the radiation and convection parameterization schemes, updated vegetation, more realistic soil moisture and variable CO_2 are in progress at CPTEC to improve the seasonal predictions. Studies using the Eta regional model in seasonal prediction are in development at CPTEC to depict, in a higher resolution, the regional features over South America. Another future action is the use of a coupled atmosphere-ocean global circulation model in order to include the interaction between SST and the atmosphere, which has a large importance in the subtropical and extratropical regions. Currently, CPTEC is developing a coupled atmospheric-oceanic model that is the state of the art in coupled modeling. It includes the general coupling (without flux correction) of atmospheric CPTEC/COLA AGCM (T62L28 resolution, with the RAS cumulus parameterization scheme) with the MOM_3 global oceanic circulation model of the NOAA Geophysical Fluid Dynamics Laboratory. The coupled model is being tested for the generation of SST and precipitation forecasts.

A suggestion to overcome the problem of simple ensemble technique, in regions with large dispersion, is to use cluster analysis of the ensemble members. Statistical and other analyses of climate variability are being conducted using another dataset resulting from a climate simulation of 50 years.

Lastly, as part of the modeling and development activities at CPTEC, and in the context of programs such as GEWEX and CLIVAR, we have started studies on the issues of predictability, not just applicable to seasonal precipitation forecasts but also to hydrological predictability. We want to address issues like those proposed in the GEWEX and CLIVAR programs. Studies on the South American Monsoon System are also under development. It is important to consider that Ensemble forecast techniques are beginning to be used for hydrological prediction by operational hydrological services throughout the world. These techniques are attractive because they allow effects of a wide range of sources of uncertainty on hydrological forecasts to be accounted for. The issue of predictability extremes is also very important, and we are focusing on simulations of "climate events" at interannual, intraseasonal and seasonal time scales.

Acknowledgements:
To FAPESP, CNPq and IAI Prosul-CRN055.

References

Cavalcanti, I.F.A., J.A.Marengo, H. Camargo, C.A.C. Castro, M.B.Sanches, G.O.Sampaio, 2000: Climate prediction of precipitation for the Nordeste rainy season of MAM 2000. *Experimental Long-Lead Forecast Bulletin*, 9, No. 1.

Cavalcanti, IFA, J.A.Marengo, P.Satyamurty, C.A Nobre, I. Trosnikov, J.P Bonatti, A O. Manzi, T. Tarasova, L.P. Pezzi, C. D'Almeida, G. Sampaio, C.C. Castro, M. B. Sanches, H.Camargo, 2002: Global climatological features in a simulation using CPTEC/COLA AGCM. *J.Climate*, 15, 2965-2988.

Cavalcanti, IFA, L.H. Coura da Silva, 2003: Seasonal Variability over Southeast Brazil related to frontal systems behaviour in a climate simulation with the AGCM CPTEC/COLA. *14th Symposium on global change and climate variations*. AMS Conference, Long Beach, 2003.

Kinter, III.J.L., D. DeWitt, P.A. Dirmeyer, M.J. Fennessy, B.P. Kirtman, L. Marx, E.K. Schneider, J. Shukla, D. Straus, 1997: The COLA atmosphere-biosphere general circulation model, Vol.1: Formulation. *Report n⁰.51, COLA*, Maryland, 46 pp.

Marengo, J.A., I..FA. Cavalcanti, P.Satyamurty, I. Troniskov, C.A. Nobre, J.P. Bonatti, H.Camargo, G.Sampaio, M.B. Sanches, A.O. Manzi, C.C. Castro, C.DÁlmeida, L.P. Pezzi, L. Candido, 2003: Assessment of regional seasonal rainfall predictability using the CPTEC/COLA atmospheric GCM. *Climate Dynamics*, 21, 459-475.

Pezzi, L.P., C.A.Repelli, P.Nobre, I.F.A. Cavalcanti, G.Sampaio, 1998: Forecasts of Tropical Atlantic SST anomalies using a statistical Ocean Model at CPTEC/INPE Brazil. *Experimental Long-Lead Forecast Bulletin*, 7, n⁰ 1, 28-31.

Repelli, C., P. Nobre, 2004: Statistical Prediction of Sea Surface Temperature over the Tropical Atlantic; *I. J. Climatology*, 24, 34-44

Xie, P., P.A. Arkin, 1997: Global precipitation: A 17-year monthly analysis based on gauge observations, satellite estimates, and numerical model outputs. *Bull. Amer. Meteor. Soc.* 78, 2539-2558.