CLIMATE VARIABILITY OVER SOUTH AMERICA IN THE NCEP CLIMATE FORECAST SYSTEM

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1. INTRODUCTION

Seasonal predictions at regional levels are vital to plan national and regional strategies to minimize the socio-economic losses caused by climate variability. In addition there is no doubt about the high relevance that such prediction have for different human activities like the hydrological resources management, agricultural activities, among others.

Ensembles of seasonal predictions are made routinely at a number of operational meteorological centers around the world, using comprehensive coupled models of the atmosphere, oceans, and land surface. Probabilistic seasonal forecasts based on such multi-member and even on multi-model ensembles provide the most currently reliable results as well as they are an excellent strategy to reduce model uncertainties (e.g., Palmer et al. 2004, and references therein). In addition, due to the relative coarse spatial resolution that current coupled models have as well their limitation to reproduce key local processes, the use of those seasonal predictions at regional levels require also of some “recalibration” usually based on statistical or dynamical downscaling techniques (e.g. Landman and Goddard, 2002). In any case, a detailed assessment of the model performance in representing the climate mean and variability over the region of interest is indispensable.

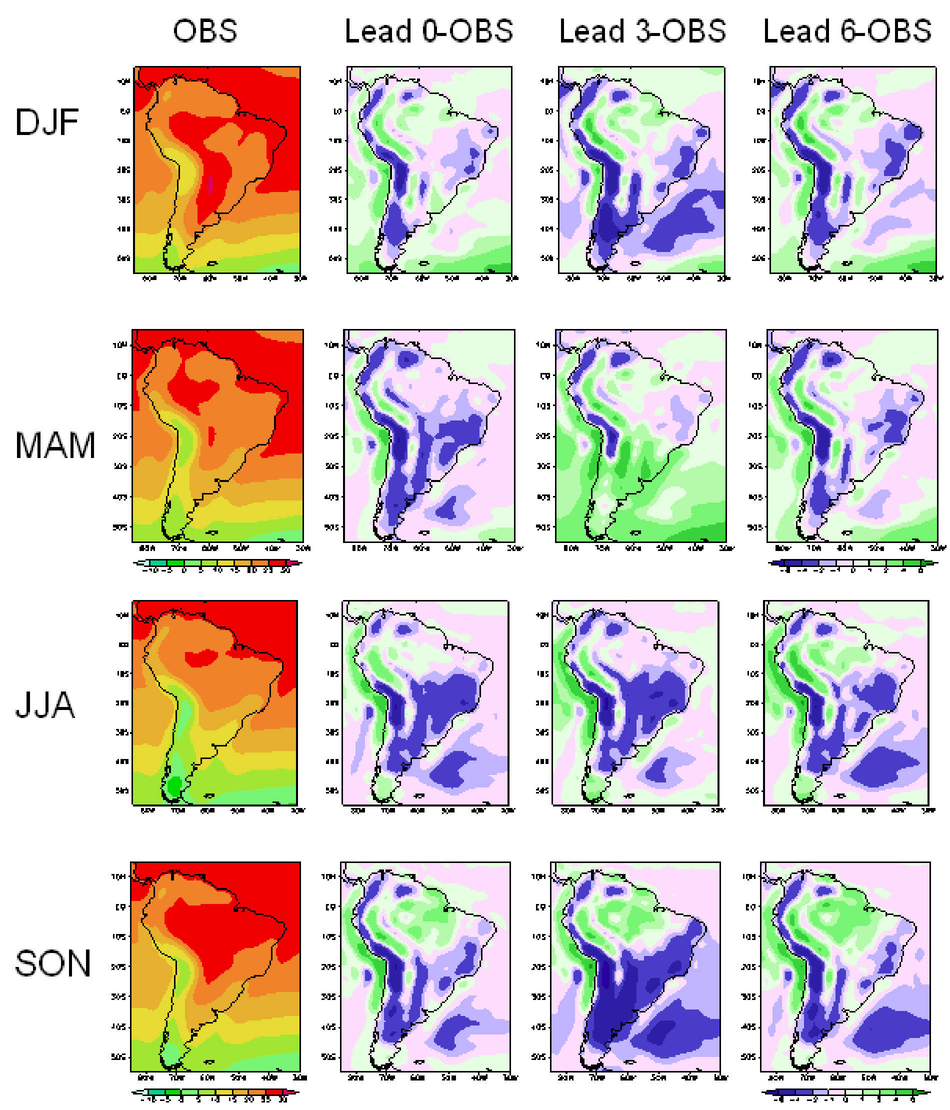

Figure 1: Observed climatology and the CFS model climate bias for surface temperature. Climate bias is obtained by subtracting the observed climatology from the model forecast climatology. The model climate biases for the 0-, 3-, and 6-month lead forecast are included. Unit is °C.

The South American geography is dominated by the Andes Mountains, a very narrow orographic system spreading along the western continent with heights that reach 6,000 m in subtropical latitudes. In addition, the Brazilian plateau, covering most of eastern Brazil but with heights lower than the Andes is another important topographic structure in the continent. Both mountainous systems as well as the fact that the largest continental portion is in the tropical regions, produce distinctive features in the South American climate which result a challenge for the general circulation model (GCM). Vera et al. (2006, and references therein) provides a description of the main climate features in the continent that are characterized during austral summer, by the main convective activity centered over central Brazil and linked with a southeastward band of cloudiness and precipitation extending from southern Amazonia toward southeastern Brazil and the surrounding Atlantic Ocean, known as the South Atlantic convergence zone (SACZ). On the other hand during austral winter, begins, regions of heavy precipitation over the southern Amazon and central Brazil migrate northwestward toward the equator, while a center of maximum precipitation is discernible over the subtropical southeastern South America. A continental-scale gyre transports moisture westward from the tropical Atlantic Ocean to the Amazon basin, and then southward toward the extratropics of South America. A regional intensification of this gyre circulation to the east of the Andes Mountains is due to the South American low-level jet (SALLJ), with strongest winds in Bolivia. The SALLJ transports considerable moisture between the Amazon and the La Plata basins and is present throughout the year. At the subtropics, the la Plata Basin is of particular interest as it encompasses the most important regions of five countries (Argentina, Brazil, Uruguay, Paraguay, and Bolivia), in terms of the socio-economic activities that develop over there. In particular, both hydrological resources management and agricultural activities are very important in the region and particularly sensitive to climate variability.

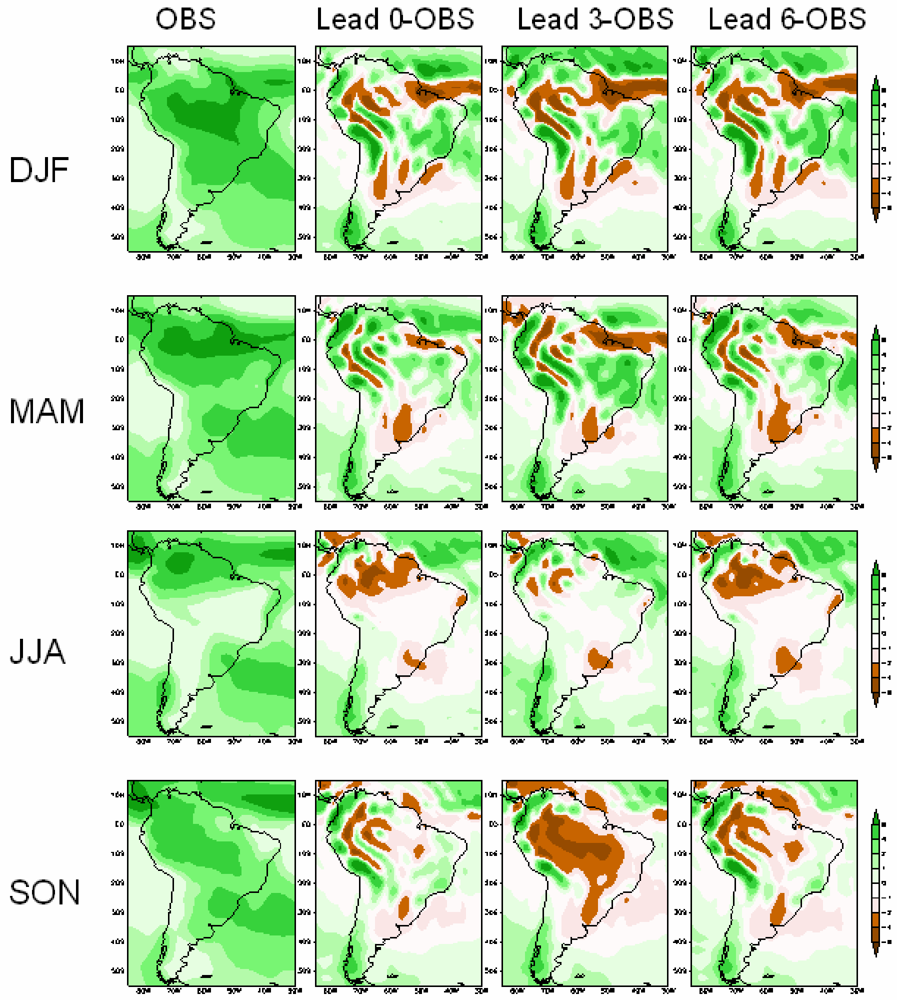

Figure 2: As in Fig. 1, but for precipitation rate. Unit is mm day^{-1}.

Regional assessments of seasonal predictions over South America are limited. Marengo et al. (2003), performed an assessment of the regional seasonal rainfall predictability over South America from an ensemble of nine simulations of the CPTEC/COLA atmospheric general circulation model

(GCM). Their results show that the model exhibits reasonable ability to simulate the precipitation annual cycle although it also shows large systematic errors like the underestimation of the rainfall in the Amazon Region. Marengo et al. (2003), also found high level of predictability in the northern portion of South America, and moderate levels at the La Plata Basin and the subtropical sector. On the other hand, low levels of predictability are observed over central Brazil and the SACZ. The fact that the GCM used by Marengo et al. (2003) was not coupled either to the ocean or to the land might be affecting the model performance over those particular regions.

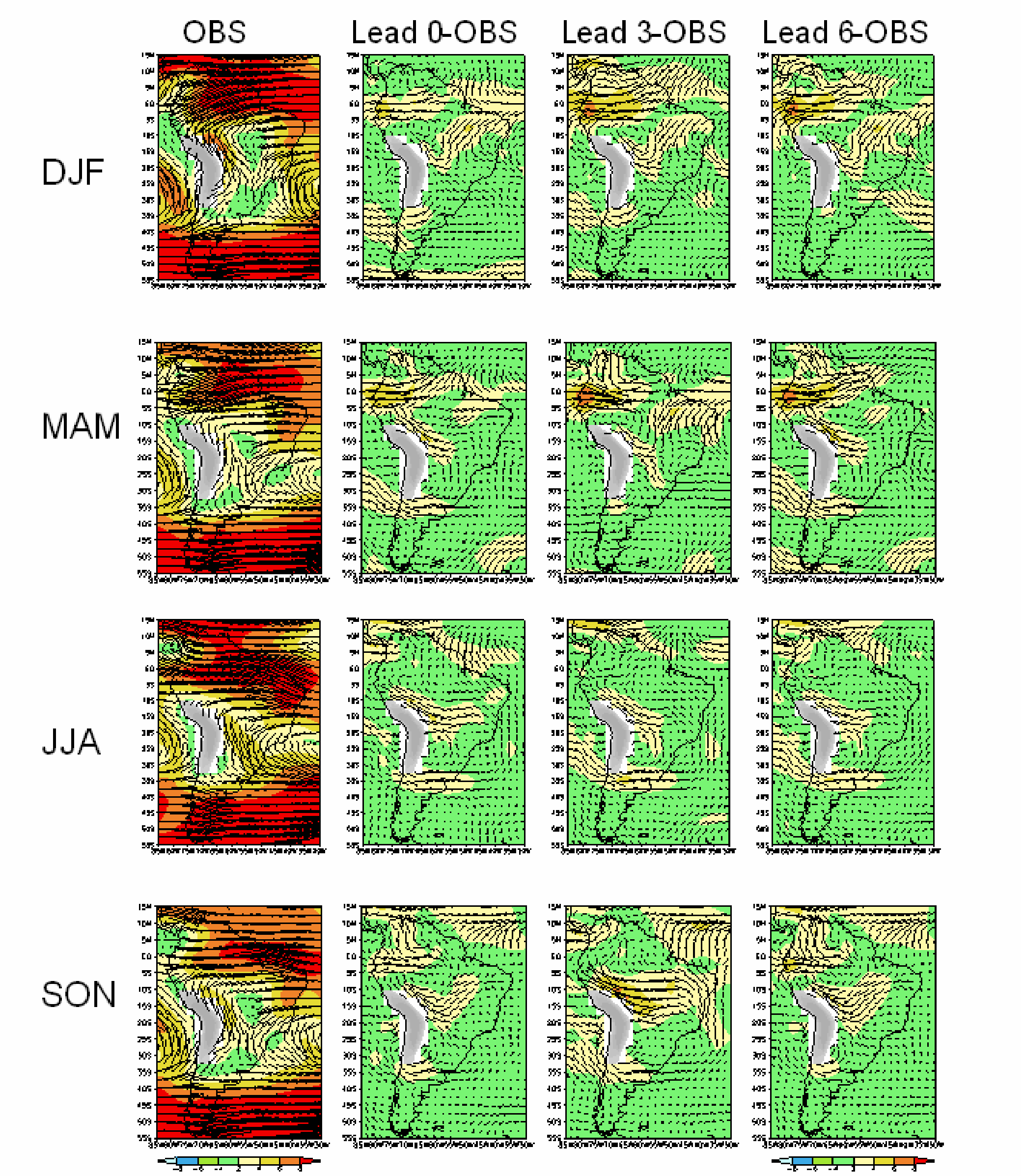

Figure 3: As in Fig. 1, but for 850-hPa wind vectors and associated magnitudes. Unit is m s^{-1}.

In 2004, The Climate Forecast System (CFS), the fully coupled ocean–land–atmosphere dynamical seasonal prediction system (Saha et al. 2006), became operational at the National Center for Environmental Prediction (NCEP). In particular, 24 years of fully coupled retrospective forecasts became available, which are very important for model assessment, which is critical in determining the utility of the real-time dynamical forecast. Therefore, the purpose of this paper is to present a preliminary evaluation of CFS hindcast skill in representing climate mean and variability over South America.

2. THE CFS

The 24-year retrospective forecast data set from the NCEP Climate Forecast System (CFS) is analyzed in order to explore the model behavior over South America. CFS is fully described and evaluated in global scales by Saha et al. (2006). The atmospheric component of the CFS is a lower-resolution version of the Global Forecast System (GFS) that was the operational global weather prediction model at NCEP during 2003. The ocean component is the GFDL

Modular Ocean Model version 3 (MOM3). CFS is a fully coupled modeling system with no flux correction.

The set of fully coupled retrospective forecasts available cover a 24-yr period (1981–2004), with 15 forecasts per calendar month out to 9 months into the future.

NCEP-NCAR reanalysis (Kalnay et al. 1996) and the CPC Merged Analysis of Precipitation (CMAP, Xie and Arkin, 1997) datasets are used for the forecast assessment.

3. RESULTS AND DISCUSSION

The analysis first concentrated on studying the multi-forecast ensemble mean biases in surface temperature, precipitation, and circulation during the warm season. Figure 1 exhibits the model climate bias in surface temperature for DJF, MAM, JJA, and, SON seasons and for 0-month, 3-month, and 6-month lead retrospective forecasts, respectively. The Andes Mountains induces bands of systematic errors parallel to the topography that extend well into the continent. In addition, warm biases are observed over the Amazon basin, while cold biases are observed over eastern tropical South America and the subtropical plains. The warm bias at the tropical region is strong particularly during austral spring. Moreover the 6-month lead retrospective forecast gets slightly stronger over that region during JJA and SON. On the other hand cold biases at the subtropical and eastern sector are stronger during JJA and for 0-month and 3-month lead forecasts than for 6-month lead forecast. On the other hand, warm biases are noticeable over the subtropics for 3-month lead forecast during MAM.

Figure 2 shows the model climate bias for precipitation rate that also exhibits bands of systematic errors induced by the presence of the Andes. Dry biases are over the Amazon basin and the subtropical plains while over eastern tropical region and particularly along the South Atlantic Convergence Zone the bias are characterized by wetness. In general, bias patterns for precipitation are very similar among all forecast leads. The exception are the 3-month lead forecast biases that get wetter over eastern tropical South America during MAM and significantly drier from the Amazons to the subtropical regions during SON.

Figure 3 shows the model climate biases for the 850-hPa wind vectors and the associated magnitude. Systematic error vectors exhibits an anticyclonic-like circulation over the central Andes, which in turn induces and overestimation of the westerlies over the extratropics and an underestimation of the SALLJ. The latter can explain the negative precipitation biases observed at the SALLJ exit over the subtropical plains (Fig. 2) as it weakens the moisture convergence over there. Underestimation of the easterlies is also discernible over the equatorial region, particularly during DJF and MAM. In addition, summer low-level wind biases are larger in the same direction that the observed winds over the tropical eastern region towards the SACZ. Model biases slightly increase with forecast lead, particularly during DJF and MAM, and over the tropical regions.

An analysis of the CFS ability in representing the climate variability over the La Plata Basin was also made using the Lead 0 multi-run ensemble mean. The La Plata Basin (LPB) extends along a wide region over southeastern South America between 15 and 40 °S to the east of the Andes Mountains. The LPB covers about 3.2 million km^2 over Argentina, Bolivia, Brazil, Paraguay and Uruguay having a fundamental role in the economy of these countries. The LPB region encompasses around 136 million people representing 57% of the combined population of the five countries and 41% of South America. Also, 60% of the combined GNP of the five countries that represents 41% of South America is generated in the LPB (e.g. Silvestri and Vera, 2008). A detailed analysis of the hydrological cycle in the LPB can be found for example in Berbery and Barros (2002). In particular, it is well known that LPB climate variability is significantly influenced by the surface ocean conditions particularly at the tropical Pacific Oceans, and during austral spring. Figures 4 and 5 shows the correlation values between OND precipitation anomalies averages over the region 63ºW-50ºW and 33ºS-21°S, considered as representative of precipitation variability in LPB (hereafter LPB index), and both SST anomalies and 200-hPa geopotential height anomalies respectively, for both observations and 0-month lead forecasts. The model captures very well the relationship between the precipitation variability in the basin with that associated with the sea surface temperature variability over the tropical Pacific and Indian Ocean, although the relationship between LPB index and SST anomalies is in general slightly stronger than observed (Fig. 4). Moreover, the model is able to represent very well the location and intensity of the correlation centers between LPB index and the 200-hPa geopotential height anomalies, mainly characterized by Rossby-like wave trains emanating from tropical sector of central Pacific and Indian Oceans. Similar maps for 3-month lead forecasts (not shown) also show good resemble with the observed patterns. The fact that these preliminary model skill assessments provide very reasonable results is promising in determining the utility of the real-time CFS forecast over the LPB region.

4. REFERENCES

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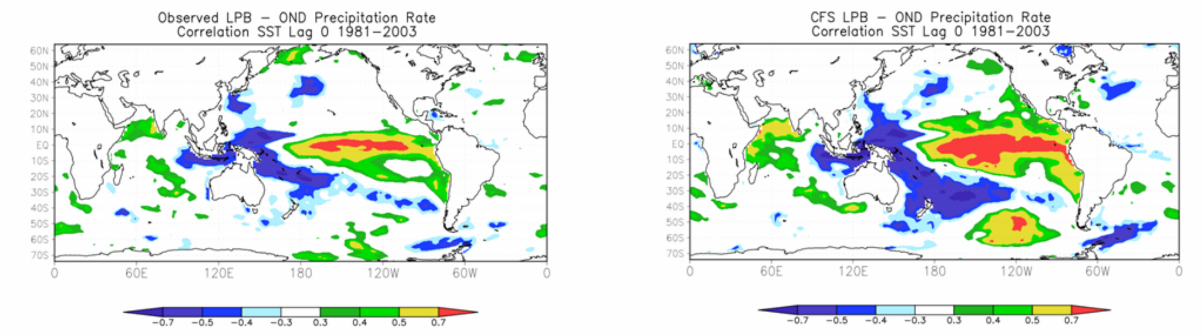

Figure 4: Correlation maps between LPB index (see text) and SST anomalies from the 0-lead multi-member mean forecast.

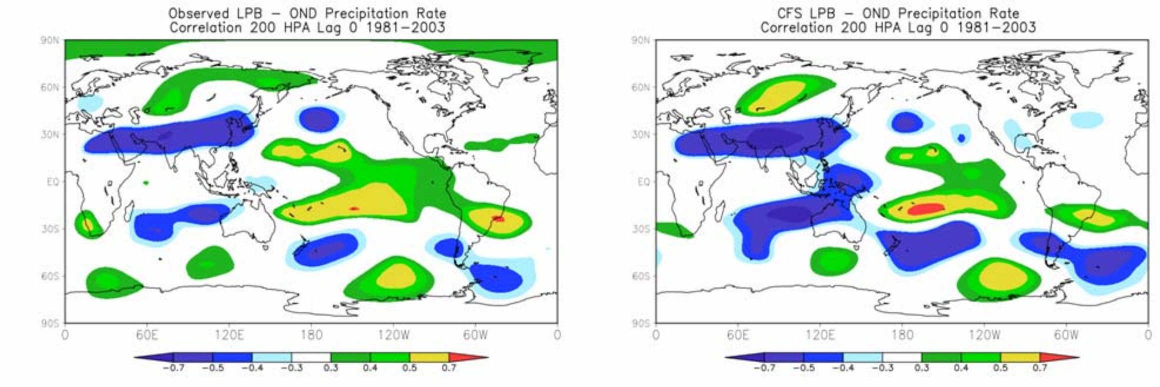

Figure 5: Correlation maps between LPB index (see text) and 200-hPa geopotential height anomalies from the 0-lead multi-member mean forecast.