Operational medium-range and long-range forecast at CPTEC/INPE

Iracema Fonseca de Albuquerque Cavalcanti, Centro de Previsão de Tempo e Estudos Climáticos (CPTEC), Instituto Nacional de Pesquisas Espaciais (INPE)

1 Medium-range forecast

The current numerical weather forecast at CPTEC is performed using an Atmospheric Global Circulation Model and a Regional Model. The CPTEC/COLA AGCM is run operationally with resolution of T126 L28 (forecast up to 12 days), twice a day (00 and 12 GMT). A version with resolution of T170 L42 is being run experimentally and higher resolution is being tested. Probabilistic forecast up to 7 days is also provided operationally, running the model in an ensemble mode of 15 members (once a day), using the T126 L28 version. The Eta regional model with resolution of 40 km is run twice a day for 7 days and has as lateral boundary conditions, the outputs of the AGCM. A version with 20 and 10 km resolution is run in an experimental way to specific areas of Brazil. The initial conditions for the integrations are provided by NCEP, but the Japan Meteorological Agency (JMA) assimilation system is used in one of the AGCM integrations. The Global Physical-space Statistical Assimilation System (GPSAS) and Regional PSAS are applied in experimental mode to be used in a near future. The Satellite Division at CPTEC extracts wind fields and other variables from satellite images, and the incorporation of these dataset in the assimilation systems is very important to improve the forecast over South America, due to few radiosondes in the continent.

The ensemble prediction technique for weather forecast was implemented at CPTEC following the development of *Coutinho* (1999). The generation of perturbations is based on the method of Zhang (*Zhang and Krishnamurti*, 1997) for hurricane prediction, with some modifications. This method is adequate to South America, which has a large area in the tropical region. Other methods are based on linear dynamic instability, which are not appropriated to generate perturbations in tropical regions. The perturbations are obtained from the first eigenvector of an Empirical Orthogonal Function Analyses applied on the difference fields between results of nine random perturbation fields and a non-perturbed field. The perturbed fields are wind and temperature. The precipitation probability for South America, from an ensemble of 15 integrations using this perturbation method, is shown in Fig. 1a. These are probabilities of precipitation to the 5th day forecast, above 1 mm, 5 mm, 10 mm and 20 mm. In a study of model results (*Mendonça*, 1999) it was observed that the model has a tendency to super-estimate the number of grid points where the precipitation occur. Thus, regions with probabilities over 65% can be considered as regions with high probability of precipitation occurrence, and below 65% as regions with low probability. In regions where the probability is below 35% there is high probability of non-occurrence of rain. The map of probabilities of rain above 20 mm represents the forecast of intense precipitation. It was also observed in a study of model results that the model sub-estimates the number of grid points with intense rainfall, thus we can consider that regions with probabilities over 5% have high probability of rain above 20 mm. A recent development in the ensemble weather forecast is the cluster analysis, following Wards minimum variance method (*Wilks*, 1995), to obtain distinct groups of forecasts (Fig. 1b). Products of the ensemble weather forecasts also include 'spaghetti' diagrams of geopotential and temperature and probability plumes of several variables, as shown in Fig. 2.

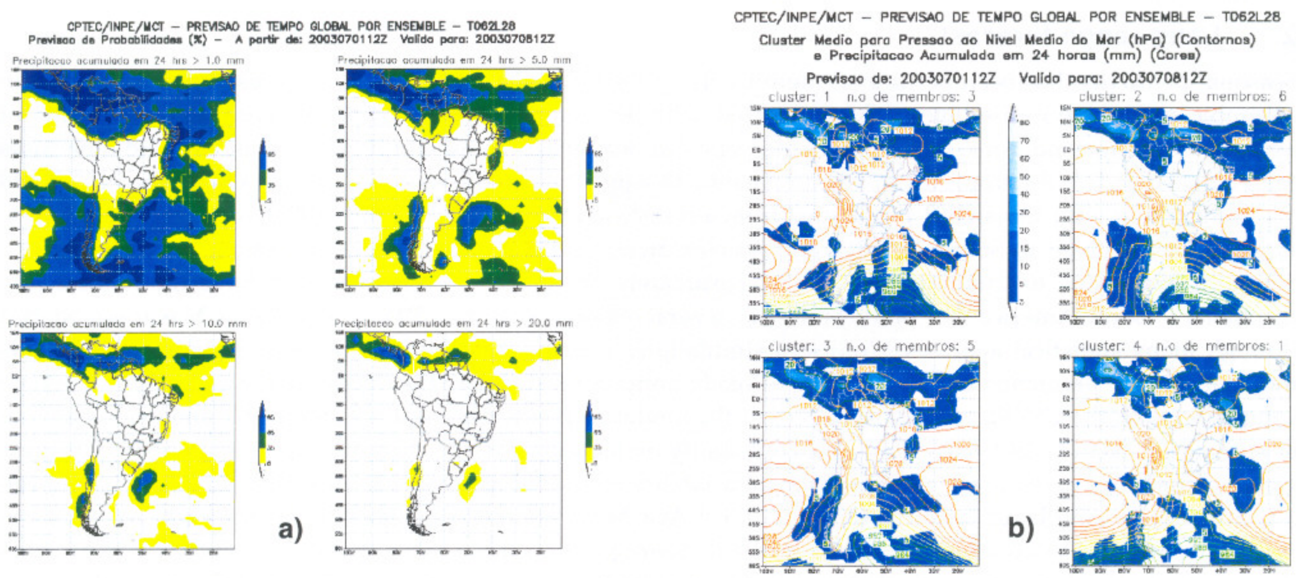

Fig. 1 (a) 7-day forecast of precipitation probability from the 15-member ensemble; (b) clusters of precipitation and sea level pressure.

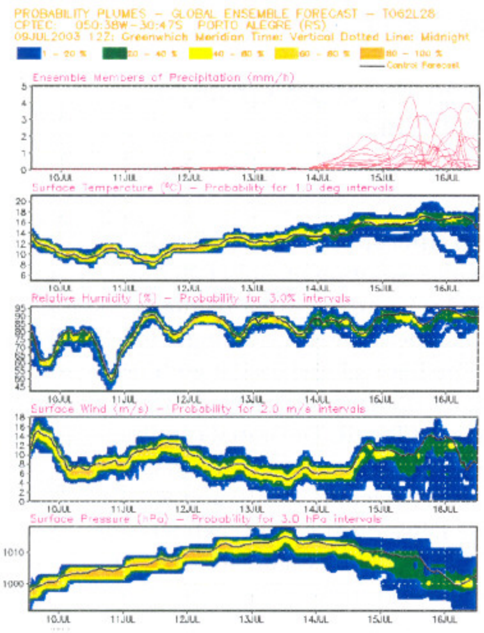

Fig. 2 Dispersion plume of precipitation and probability plumes of temperature, relative humidity surface wind and surface pressure.

The evaluation of weather forecasts in the model results (AGCM T126, AGCM T170 and Eta) is verified through several analyses available also at the CPTEC homepage. They consist in monthly analyses of systematic errors, RMS, hit score, equitable threat score, bias and superposition of satellite image and pressure/wind field.

Outputs of the AGCM are also used to run sea wave models, and a transport model. The global prediction of sea waves is performed with the WAM model and the atmospheric forcing is the surface winds produced by CPTEC/COLA AGCM, T126L28. The regional version of the WAM model has resolution of 30 km. Model wave products are maps of the wave height, direction and period of maximum wave height. These are used by the Brazilian Navy to do the monitoring of the large coast of Brazil and to alert fishers and small boats. The transport model is coupled to RAMS, a regional model, which uses outputs of the CPTEC/COLA AGCM as lateral boundary conditions. This model is used to trace gases from biomass burning in Amazonia and Central Brazil, and other anthropogenic gases. Outputs of the AGCM are also applied to a model to forecast risk of fires. The products are used by IBAMA, institution that does the environmental monitoring. Products of soil humidity from the hydrological model are used in Nordeste monitoring.

The AGCM, Eta and WAM models, which run on the NEC SX4 up to 2002, were implemented on NEC SX6 supercomputer in 2003. The AGCM was parallelized to improve the performance in the new machine. At present, the supercomputer has 32 processors (4 nodes of 8 processors), performs 256 GFLOPs and the T126 L28 AGCM takes 11 minutes and 32 seconds to integrate 7 days using 8 processors. The final configuration of NEC SX6 is 96 processors (12 nodes of 8 processors).

2 Long range forecast

Seasonal prediction has been performed monthly using the CPTEC/COLA AGCM with resolution T62L28 in an ensemble mode. Two ensembles are constructed with 15 different initial conditions each and two fields of boundary forcing conditions. One set uses the persisted Sea Surface Temperature (SST) anomaly, and other uses the predicted SST in the tropical Pacific and Atlantic Oceans. Predicted Pacific SST are obtained from NCEP and the predicted Atlantic Ocean SST is obtained from a statistical model, SIMOC (*Pezzi*, 1998). Although the model is global, focus is given to South America and specific areas, which requires climate attention, as Northeast and Southern Brazil due to droughts and floods. Fortunately, these are the regions which have the highest predictability in South America. The predictability of several regions using the CPTEC/COLA AGCM was established through many statistical analyses, studies of simulations, and through the experience of 8 years applying this model in climate prediction at CPTEC. It was already noticed, in studies of the interannual variability in a climate simulation with the CPTEC/COLA AGCM, that the model responds very well when the SST anomalous forcing is very strong, as in ENSO years. Thus, the confiability on the model is very high during these periods. The main global climatological features and the seasonal variability of several atmospheric variables were reasonably well represented in a simulation with the CPTEC/COLA AGCM (*Cavalcanti et al.*, 2002). Regional South America features and statistical analyses were demonstrated in *Marengo et al.* (2003). Interannual variability of precipitation anomalies in several regions of South America showed high convergence among members of the ensemble for the Northeast region and higher dispersion among members in Amazonia and in the South America monsoon region.

There was also good comparison of the ensemble mean with the observed precipitation anomaly for Northeast. ROC diagrams which measures the rate of hits and failures showed also the highest scores in the Northeast region.

The numerical prediction results are presented in maps of precipitation anomalies and precipitation probabilities. A mask is applied to the anomaly field, to remove values in places where there is not statistical significance. The probability map and the mask are constructed based on nine integrations of ten years simulation results. A longer integration of 50 years is being conducted to improve the statistical analysis of results. Examples with results of a seasonal prediction are shown in Figs. 3 and 4. In monthly meetings at CPTEC, the global atmospheric and ocean conditions as well as the regional conditions are discussed. In these meetings, based on numerical model predictions, predictability of several regions of South America, intensity of the SST forcing, and verifying the consistence with other GCMs, a consensus map of probabilities is constructed (Fig. 5).

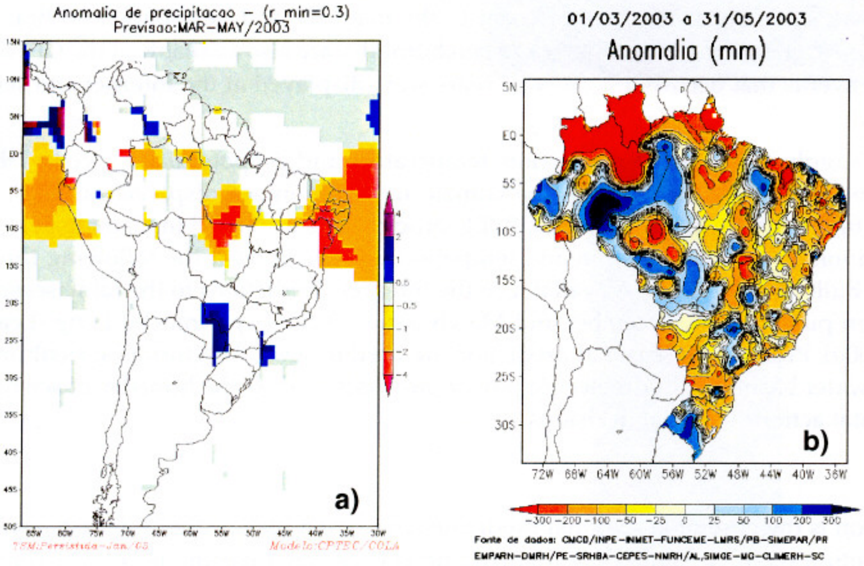

Fig. 3 (a) MAM 2003 precipitation anomaly predicted by CPTEC/COLA AGCM (mm/day); (b) MAM 2003 observed precipitation anomaly (mm).

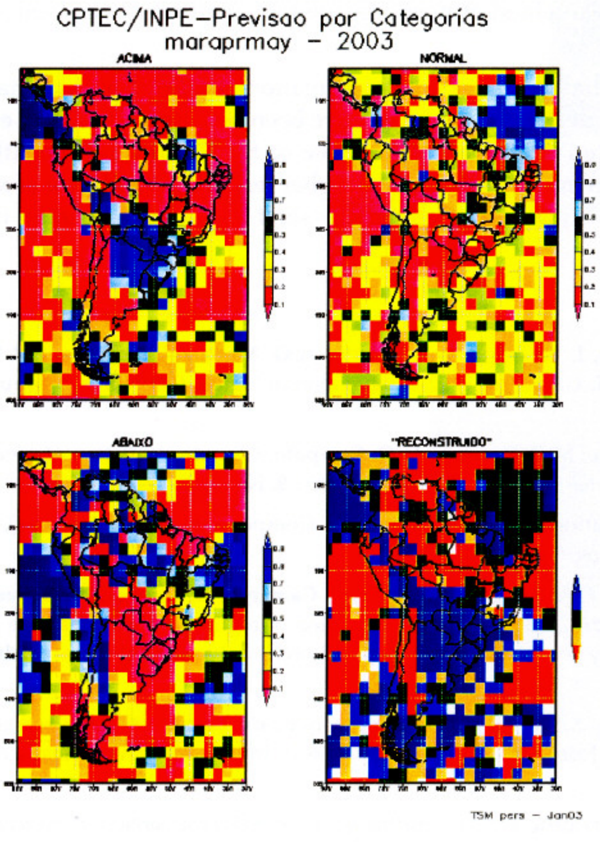

Fig. 4 Precipitation probability in categories. MAM 2003.

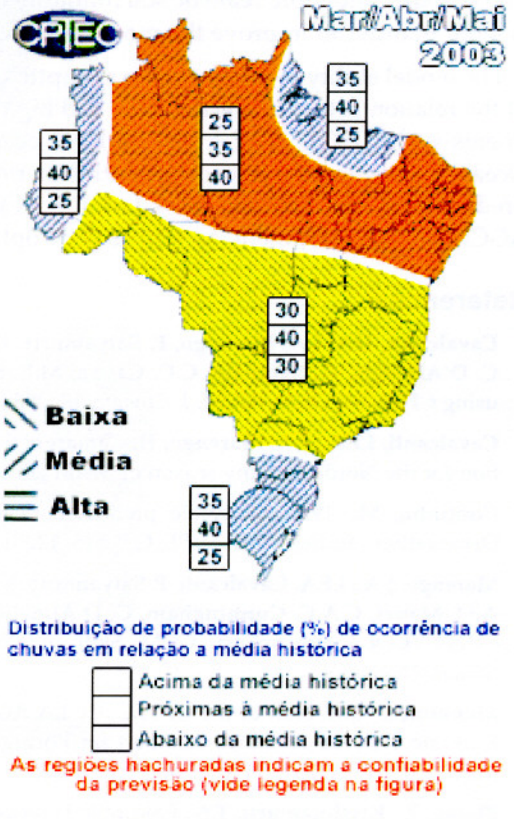

Fig. 5 Consensus seasonal prediction. MAM 2003.