# MODEL EVALUATION AND OUTPUT VERIFICATION AT CPTEC

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## 1. Introduction

Numerical model evaluation and model output verification are two essential activities at the Numerical Weather Prediction centres. Model evaluation is necessary for the improvement of the models and the algorithms therein. Output verification is a routine activity through which the meteorologist associates the model weather with the real or observed weather. He or she seeks a one-to-one correspondence between the model forecast situation and the real world situation, that is necessary for issuing bulletins for the end users such as agriculture sector, civil defence organisations and the transport companies that rely heavily on weather information. The distinction between verification and evaluation is somewhat similar to the difference between weather and climate.

Verification of model products and evaluation of the model performance in terms of the synoptic systems is an important exercise at the Centro de Previsão de Tempo e Estudos Climáticos (CPTEC). The meteorologist examines the position, intensity and evolution of the synoptic systems such as frontal boundaries, centres of pressure, troughs and ridges, and convergence zones in the forecasts, and compare them with those in the observations.

CPTEC has been operating two numerical models, a global CPTEC/COLA spectral model (Bonatti 1998) and a limited area regional Eta model (Chou and Justi da Silva 1999), for the numerical guidance in Brazil. The resolution of the global model is T62L28 (since Nov 1994) and that of the regional model is 40kmL36 (since 1997). The centre's NWP operational suite consists of four global runs with 00, 06, 12 and 18 UTC analyses and two regional runs with 00 and 12 UTC analyses. The 00 and 12 UTC global runs go as far as 7 days and the intermediate runs go as far as 12 hours. The regional model runs integrate up to 72 hours at both the 00 and 12 UTC. The initial analysis for the global model is taken from the National Centres for Environmental Prediction (NCEP), and the initial analysis and the boundary conditions for the Eta model runs are obtained from the CPTEC/COLA global model outputs. The initial conditions for the global model are specified from NCEP's T126 analysis truncated to T62. Another operational global model run is performed using the CPTEC OI/JMA analysis. Very recently, since the beginning of Nov 1999, the model resolution is increased to T126L28 for which the NCEP global analysis provides the initial values.

The future plans for the first semester of 2000 are to introduce global and regional Physical-Statistical Analysis System (PSAS/DAO-NASA) in the models, include Relaxed Arakawa-Schubert scheme for the cumulus parameterisation and possibly increase the domain of the regional model. An ensemble medium-range weather forecast package using perturbations based on the principal components is already tested (Coutinho 1999) and is ready to go into operation as soon as computing and storage capacities become adequate.

The evolution of the CPTEC model performance statistics since 1995, and the systematic errors in the global and regional model outputs over South American region in Sep 1999 runs are presented in this paper.

## 2. CPTEC/COLA Model Evaluation

The annual mean 500 hPa anomaly correlation (AC, skill) for South American region (SA) (101-011W, 60S-15N), the Southern Hemisphere (SH) (20-80S, 180W-180E) and the Northern Hemisphere (NH) (20-80N, 180W-180E) for the years 1995 through 1999 are shown in Fig. 1. There is perceptible improvement of the skills in 1999 for SA and SH. The Range of Useful Forecast (RUF, with threshold at 60% AC) is 6 days in 1999 as compared to 5.5 days in 1995 for SA region. For NH, however, the model presented its best performance in 1988. It has to be borne in mind that the 1999 statistics are based on only 9 months data (Jan–Sep).

The improvement of model performance over SA in 1999 is mainly due to the observational data coverage and some minor changes in the physics of the model. The reasons for the deterioration of AC in the NH in 1999 are not clear yet. The differences between the two Hemispheres in terms of RUF are small. But the differences in the skill at 2, 3 and 4 days forecast range are significant in which the NH skills are higher than the SH or SA skills. This, once again, could be attributed to better data coverage in the NH.

The summer skills in general suffered a slight deterioration in 1998-99 for days 1, 2 and 3. There is a slight improvement for SA winter for days 1, 2 and 3, which may be attributed to recent improvement of radiosonde network in Brazil (about 16 stations in 1999 against fewer than 8 stations in 1998). The skills for SA region are lowest for the spring season (Sep-Nov), falling below 90% by 36h of integration and are the best for autumn in 1999. There was perceptible improvement of the skill in 1999 at 48h range for autumn whereas there was equally perceptible deterioration in summer.

The model forecast mean monthly sea level pressure (MSLP) over the SA region for September 1999 showed that the subtropical high pressure cell in the South Atlantic drifted westward into southern Brazil and Uruguay region gradually with the forecast range (up to 168h). The 850 hPa temperature (T850) over central Brazil gradually became cooler with the forecast range, but the relative humidity (RH850) showed good consistency.

Up to 96h range the biases in the fields of MSLP, T850 and RH850 were small over the continent and increased somewhat for 120h and longer range forecasts to –1.5 hPa. The model showed a slight dry bias over the south-central and south-eastern regions of Brazil where the temperatures were slightly (~0.5C) overestimated. There were no big changes in the root-mean-square errors (RMSE) with forecast range. RMSE in the temperature fields were of the order of 3 to 4C but the relative humidity errors were as large as 35%.

In the synoptic evaluation of the model the positions of (1) frontal boundaries, (2) low pressure centres associated with fronts, (3) high pressure centres in the wake of fronts, (4) subtropical high centre in the South Atlantic, (5) subtropical high centre in the Pacific, and (6) subtropical jet-stream over South America are considered. If the position of the synoptic system over the South American continent is within one grid distance (1.87°, ~ 200 km) of the observed position it is considered a "near" forecast. If the forecast position is to the east or to the north of the observed position it is considered to be advanced and if the forecast position is to the west or to the south it is considered to be lagging "behind". If the pressure centre is within 2 hPa of the observed value the intensity is considered "right". Otherwise it is either stronger than or weaker than observed intensity depending on the sign of the difference.

Figure 2 depicts the synoptic evaluation of Sep 1999 frontal positions and low centre positions and intensities over SA in the forecasts from 00 UTC global runs. The percentage of

fronts forecast in the right position in the 24h forecasts was 85% which fell to 50% in the 96h forecasts and to 30% in the 120h forecasts. Percentage of fronts lagging behind the observed position increased with the forecast range. 80% of the low centres were forecast in their right position in the 24h forecasts, and at 120h fewer than 15% were forecast in the right position. In general beyond 72h range there were more lows lagging behind the corresponding observed positions than there were lows advancing forward.

## 3. Eta Model Verification and Evaluation

The Eta model is not evaluated by calculating the "skill" because there is no Eta model climatology for the South American region. The MSLP bias in Sep 1999 grew from 1 hPa in the 24h forecasts to more than 3 hPa in the 60h forecasts in the South Atlantic. This indicates that the cyclogenesis in the South Atlantic is underestimated in the model. There was a dry bias over the northern and eastern coastal belts of Brazil and a wet bias over central tropical South America, especially in the forecasts valid for 00 UTC. There was also a cold bias over central Brazil at 48 and 60h forecast ranges. These biases were either absent or were very weak in the global model outputs. The RMSE in the MSLP and RH850 grew with forecast range in the south-eastern sector of the domain of the model. The humidity errors in the Eta model forecasts were of the same order of magnitude as in the global model. The T850 showed large errors in the region west of Northeast Brazil.

The wind was more easterly in the lower levels and more westerly in the higher levels over Northeast Brazil, thus increasing the vertical shear in the mid troposphere. The biases of the order of 2 $ms^{-1}$ in the upper troposphere were in reasonable limits. The model atmosphere was wetter at the surface and became drier around 900 hPa level. Humidity biases of the order of 1.5 g/kg are significant and there is an indication that the mixed layer processes and the convection scheme are responsible for this behavior.

## 4. Precipitation Forecast Verification and Evaluation

The precipitation forecasts are verified on the pentad and monthly basis. The accumulated precipitation in September 1999 in the global model 00 UTC runs showed gradual increase of rainfall from 24h forecast to 96h forecast and a gradual decrease later in western and southern Amazonia. However it is interesting to note that the fields at different ranges were similar. The monthly-accumulated precipitation forecast by the Eta model ranges for the month of September 1999 showed that the precipitation increased with forecast range over the Amazon basin. A high precipitation region appeared over south-eastern parts of the state of Pará in the 36h forecast and intensified and moved westward into eastern Amazonas state at 60h. The Eta model forecasts showed an area of large precipitation in the state of Rio Grande do Sul (southernmost Brazil) that was not given in the global model. The observations confirm the forecasts of the Eta model with a displacement of the precipitation area to the north by a few hundreds of km.

The model forecasts of precipitation are totalled over 5-day periods (pentads) and are compared with the mean IR brightness measured by the GOES-8 satellite. Irrespective of the low values of the daily skills of precipitation forecast, this information is useful for many purposes, especially in the artificial reservoir management. We observed in our operations at CPTEC that this type of verification is much more revealing than the daily verification of the 24-hour accumulated precipitation.

Figure 3 shows the verification of 24-hour accumulated precipitation forecast, with 60h lead time valid for 12 UTC on 07 Nov 1999, obtained with five different models. The CPTEC T126 and NCEP models were closer to the observations over the continent.

## 5. Summary

Both model verification and model evaluation are very important exercises at the CPTEC. Monthly, seasonal and annual mean model errors of the meteorological variable forecasts (biases) reveal the spatial distribution of systematic overestimation and underestimation of the variables. The superposition of observations and the forecasts reveal the displacement and intensification of the maxima and minima. The spatial anomaly correlation or "skill" gives us the degree of similarity between the forecast and observed fields. The CPTEC global model has improved from 1995 to 1999 in terms of AC over the South American region. The model showed dry and cold biases over Southeast Brazil.

Synoptic verifications of the models are presented for the month of Sep 1999. The frontal boundary positions were well forecast up to 84h range. The positions of the low centres were well predicted up to 48h range. Their intensities were either well forecast or were underestimated more often than overestimated. The precipitation forecasts for different ranges showed a good consistency among them.

The Eta model developed a positive bias in MSLP fields at 48 and 60h forecast range in the Atlantic near Argentina and Uruguay indicating that the cyclogeneses in this sea were underestimated. The model showed a dry bias along the coasts of Northeast Brazil and a wet bias in central Brazil and Peru. Warm bias in the eastern parts of Brazil increased with forecast range. The regional model could capture the monthly-accumulated maximum precipitation region over southern Brazil.

The objective of the verification and evaluation of the models through the identification of synoptic systems is to make the operational meteorologist aware of the virtues, limitations and systematic errors of the available numerical guidance, and thereby to provide increasingly skilful forecasts to the users.

### References

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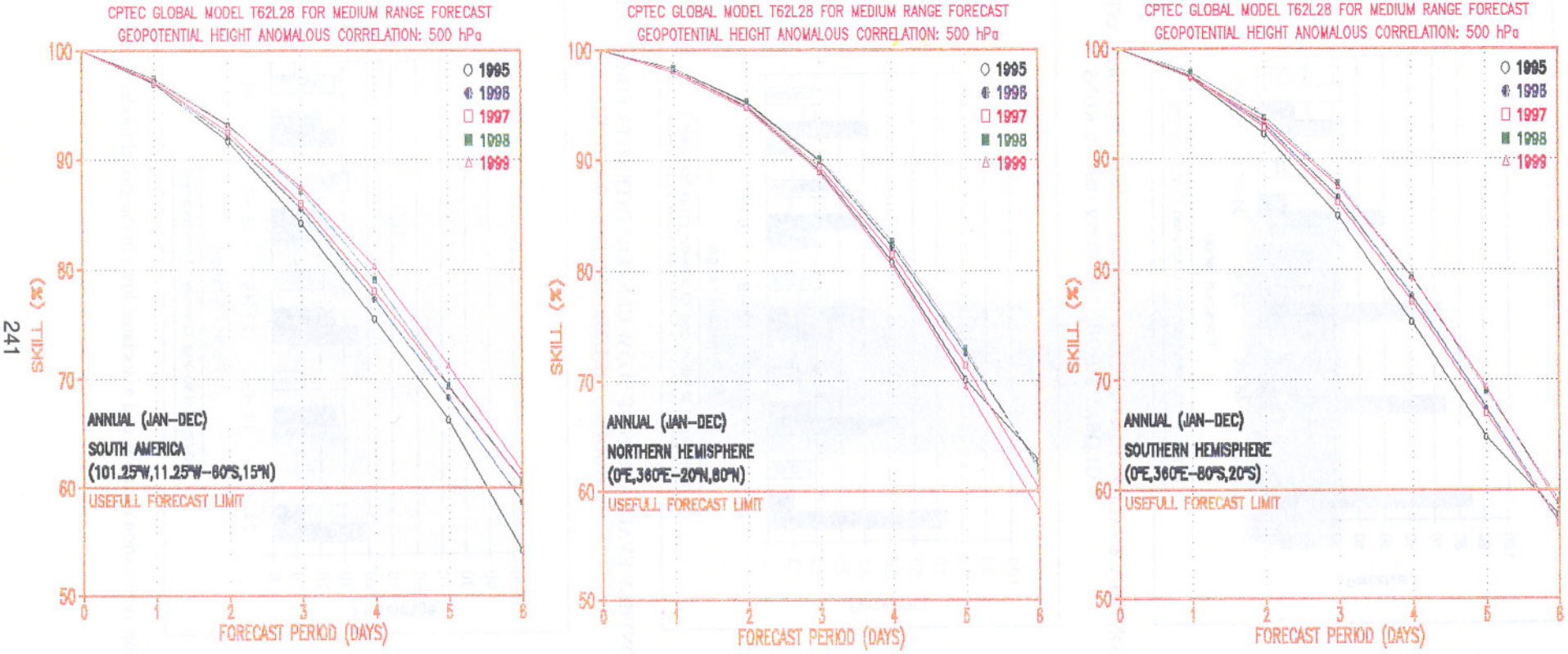
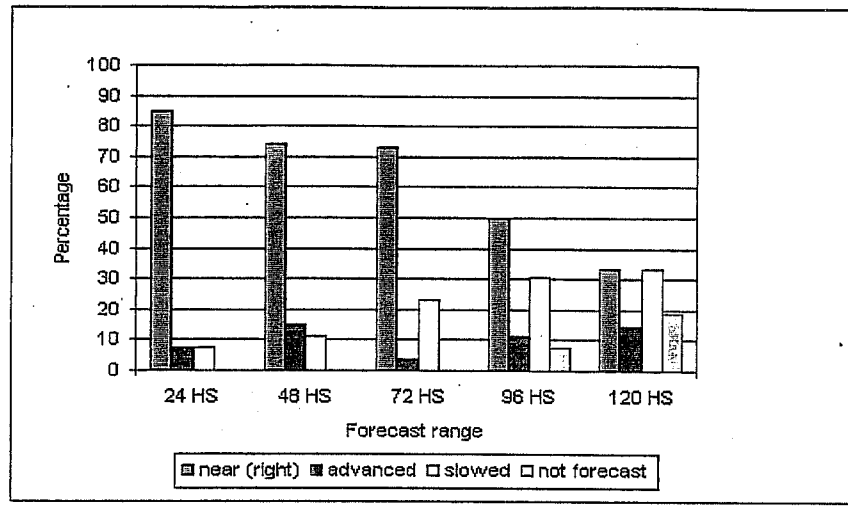
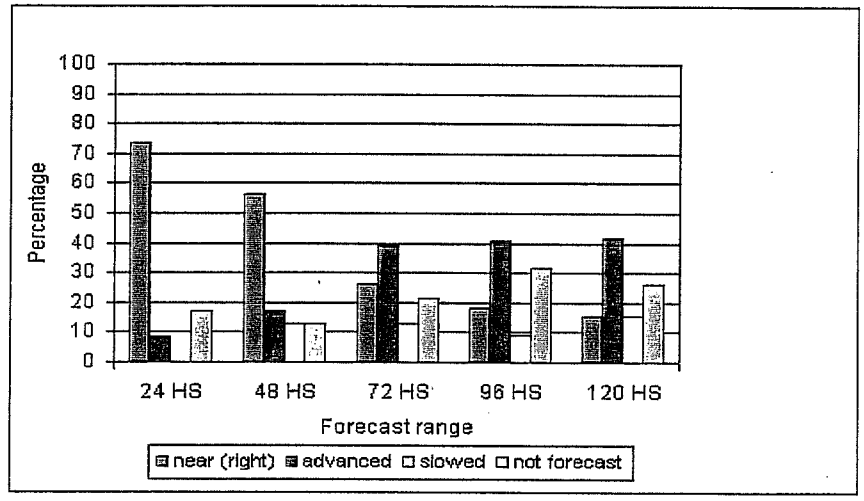



Fig. 1 – Annual mean skill (500 hPa anomaly correlation) of the CPTEC/COLA T62L28 NWP model: (a) South America, (b) Northern Hemisphere, (c) Southern Hemisphere.

MONTHLY EVALUATION OF FRONTAL POSITION FORECASTS BY CPTEC GLOBAL MODEL - SEP/1999 - 00UTC RUNS




MONTHLY EVALUATION OF "LOW CENTER" POSITION FORECASTS BY CPTEC GLOBAL MODEL - SEP/1999 - 00UTC RUNS




MONTHLY EVALUATION OF "LOW CENTER" INTENSITY FORECASTS BY CPTEC GLOBAL MODEL - SEP/1999 - 00UTC RUNS

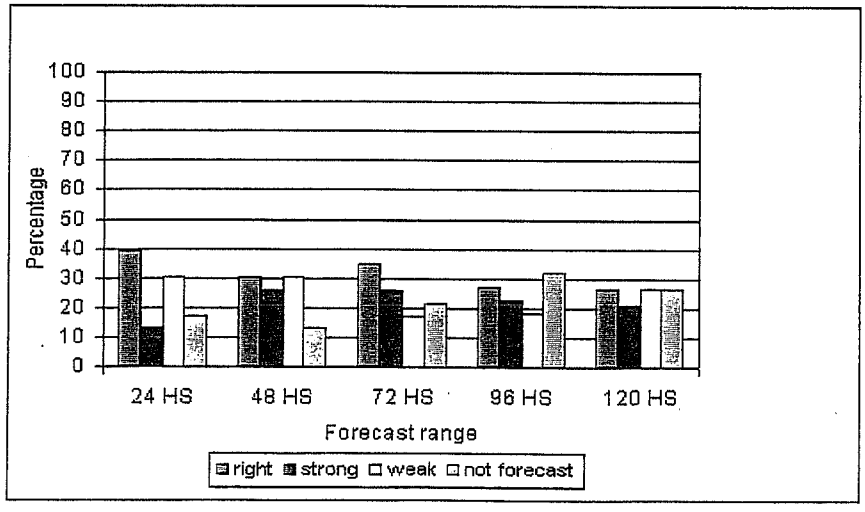



Fig. 2 – Position verification of fronts and associated lows in the global model forecasts in September 1999.

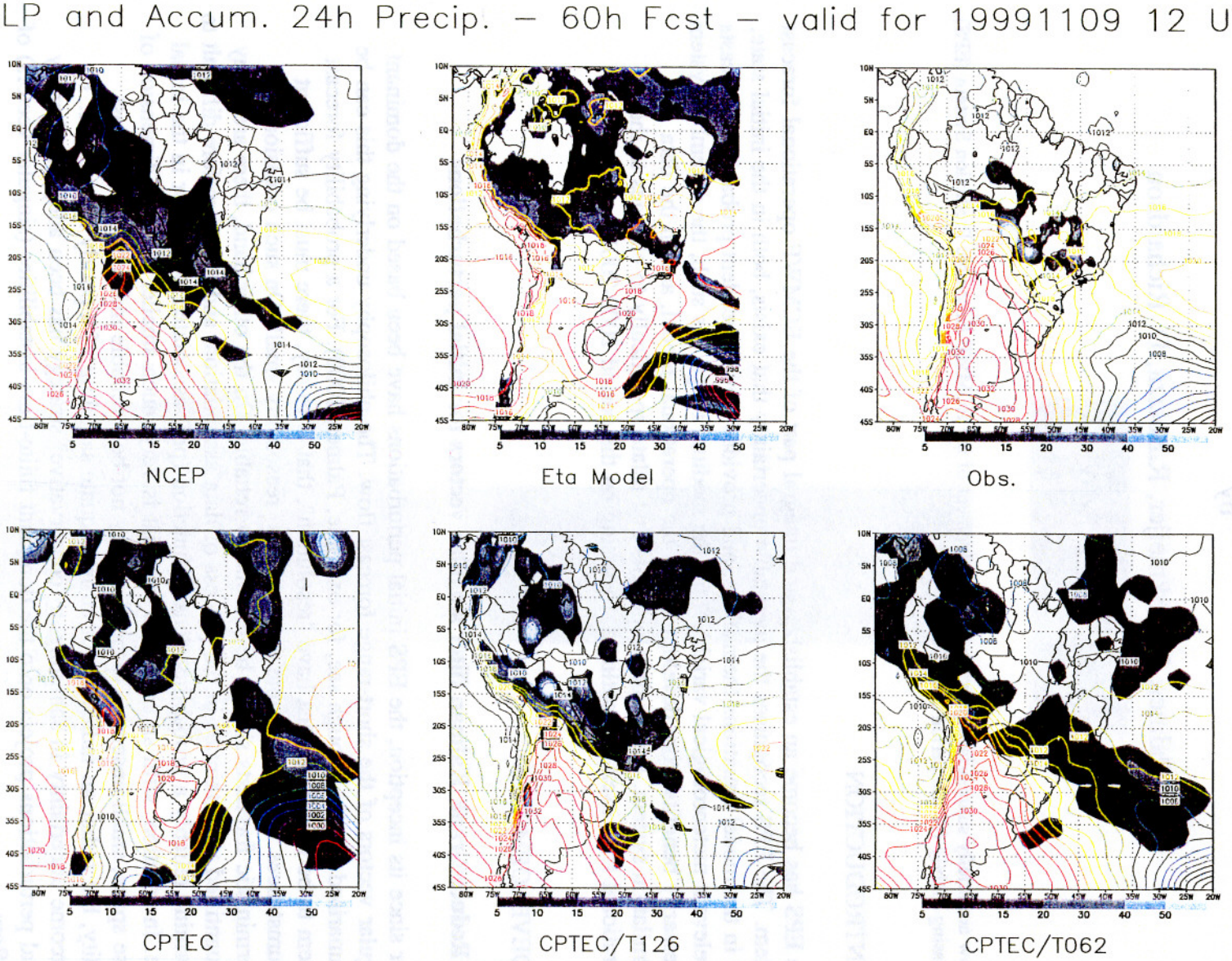



Fig. 3 – Comparison of the 60h model forecasts and the verifying observations for 07 Nov 1999. Mean sea level pressure at intervals 4 hPa and rainfall in color scale shown in figure.