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EXPERIMENTS WITH EOF-BASED PERTURBATION METHOD TO ENSEMBLE WEATHER FORECASTING IN MIDDLE LATITUDES

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1. INTRODUCTION

The atmosphere is an example of system that presents sensitivity to the initial conditions. The importance of the initial conditions for the numerical simulation errors is explained by the theory known as chaos. Briefly, the chaos is related to the sensitivity that some non-linear dynamic systems present to the initial conditions as they evolve in the time, i.e. slightly different initial conditions may produce remarkable distinct solutions. Thus, still that model was perfect, as the real initial state of the atmosphere is not completely known, there are inevitably errors in the model analysis that will grow up with the integration time, leading to reduction of forecast quality and maintaining the impossibility of evaluate the future atmospheric conditions indefinitely. The ensemble weather forecasting approach represents a way to consider these aspects in the atmosphere prediction.

The ensemble weather forecasting started operationally at the Center for Weather Forecasting and Climate Studies (CPTEC) in October 2001. The EOF-based perturbations method (Zhang, 1997; Zhang and Krishnamurti, 1999; Coutinho, 1999) was used to generate the perturbed initial conditions. Since the implementation the initial perturbations has been calculated for a tropical atmosphere belt (0° - 360°W; 45°S – 30°N). In this study, the EOF-method is applied to perturb the middle latitudes in order to evaluate the performance of the CPTEC ensemble prediction system (EPS) with three different configurations of the perturbed initial conditions.

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2. THE EOF-BASED PERTURBATION METHOD

Essentially, the method is based on: a) random perturbations are added to control initial condition to generate random perturbed initial condition; b) the full model is integrated for 36 hours starting from the control and from the perturbed initial conditions saving results each 3 hours; c) a time series is constructed for the successive differences between control and perturbed forecasts; d) an empirical orthogonal functions analysis (EOF) is performed for the time series of difference fields in order to obtain the fastest growing perturbation; e) the eigenmode associated to the largest eigenvalue is considered as the fastest growing mode; f) the fastest growing mode is normalized to pre-fixed amplitudes; g) the “optimum” ensemble of initial conditions is generated by adding (subtracting) this fastest eigenmode to (from) the control analysis.

3. CONTROL INITIAL CONDITIONS AND CLIMATOLOGY

The control initial conditions used to produce the ensemble prediction were obtained from National Center for Environmental Prediction (NCEP). In this work, these analyses are considered the best estimate of real state of atmosphere and are used to compare with the forecasting and to calculate some statistical indexes. The period used in this study is the first fifteen days of January 2005 at 1200 UTC.

The forecast and analysis anomalies and the standard deviation of 500 hPa geopotential height are calculated with respect the NCEP Reanalysis 2 climatology (Kanamitsu, 2002).

4. EXPERIMENTS DESIGN

The CPTEC EPS generates for each run 15 members (14 perturbed and 1 control) out to 15 days lead time. To produce the predictions is

Table 1. Perturbation regions for each experiment.

Experiment	***PTR***	***PET***	PGL
Perturbation Regions	(0-360E; 45S-30N)	(0-360E; 90S-30S) + (0-360E; 30N-90N)	(0-360E; 90S-30S) + (0-360E; 30S-30N) + (0-360E; 30N-90N)

used the CPTEC general circulation model with gaussian grid and T126L28 resolution, however forecast and analysis fields are interpolated onto a regular 2.5 x 2.5 grid in order to calculate the statistical indexes.

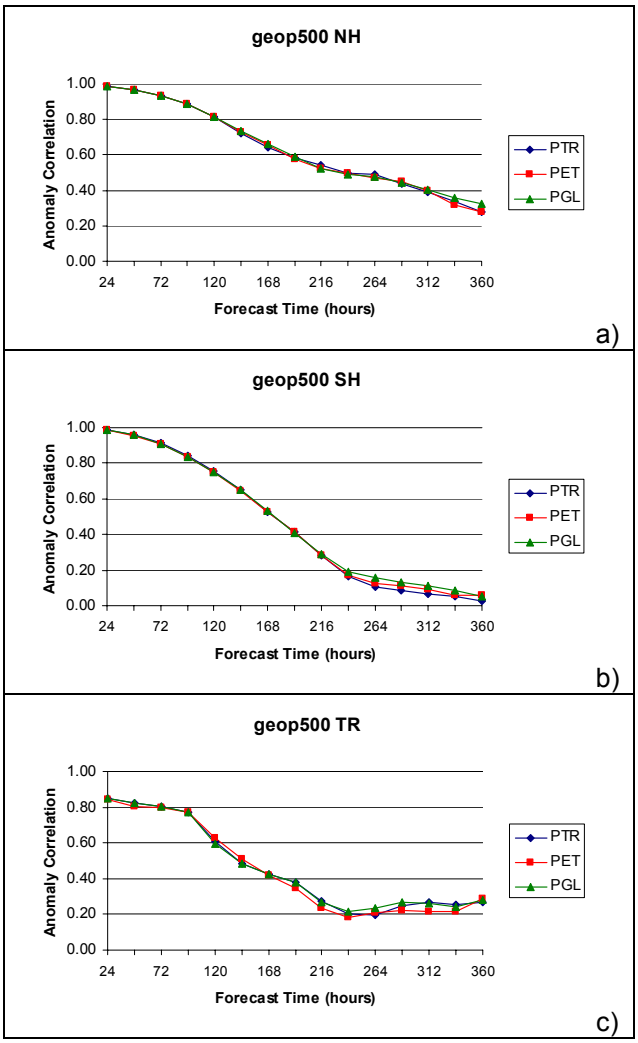

Figure 1. Average anomaly correlation of 500-hPa geopotential height ensemble mean forecasts. a) Northern Hemisphere; b) Southern Hemisphere; c) Tropics.

It was performed three experiments in this study, as described to follow and summarized in Table 1:

i. Experiment PTR: this experiment represents the configuration of operational initial condition perturbations used currently to generate the ensemble forecasting at CPTEC. The perturbations are evaluated and applied only to tropical region;
ii. Experiment PET: the EOF-method is used to evaluate perturbations in middle latitudes. It is not applied perturbations in the tropics;
iii. Experiment PGL: the perturbations are evaluated to tropics and middle latitudes separately and applied simultaneously to the initial conditions.

To assess the performance of the three experiments is calculated the daily Anomaly correlations (AC), root mean square error (RMSE), ensemble spread (ES), Brier Skill Score (BSS) and the components of Brier Score: reliability (Rel), resolution (Res) and uncertainty. The BSS is evaluated using the uncertainty component as reference, accordingly Wilks (1995) and Buizza et al. (2005). It is presented the mean indexes on the period.

The 500-hPa geopotential height forecasts over Southern Hemisphere (SH, 90°-20°S), Tropics (TR, 20°S-20°N) and Northern Hemisphere (NH, 20°-90°N) is considered to evaluation. The components of Brier Score are calculated for the probabilistic forecasts of 500-hPa geopotential height to be greater than 1 standard deviation with respect to climatology and the probability intervals is determined according the ensemble members (WMO, 1992).

5. RESULTS

The Fig. 1a-c shows the AC for ensemble mean to experiments and considered regions. It is noticed that for the first 10-days of integration the performance of the ensemble mean is similar to all experiments. From 10 up to 15-days, the experiment PGL presents slightly better performance than the other experiments. Similar

performances of the ensemble mean it was expected since the performance of the forecasts it is strongly related to skill of the model. As in these experiments no modification was carried through in the configuration of the model it was not waited great variations in the performance of the forecasts.

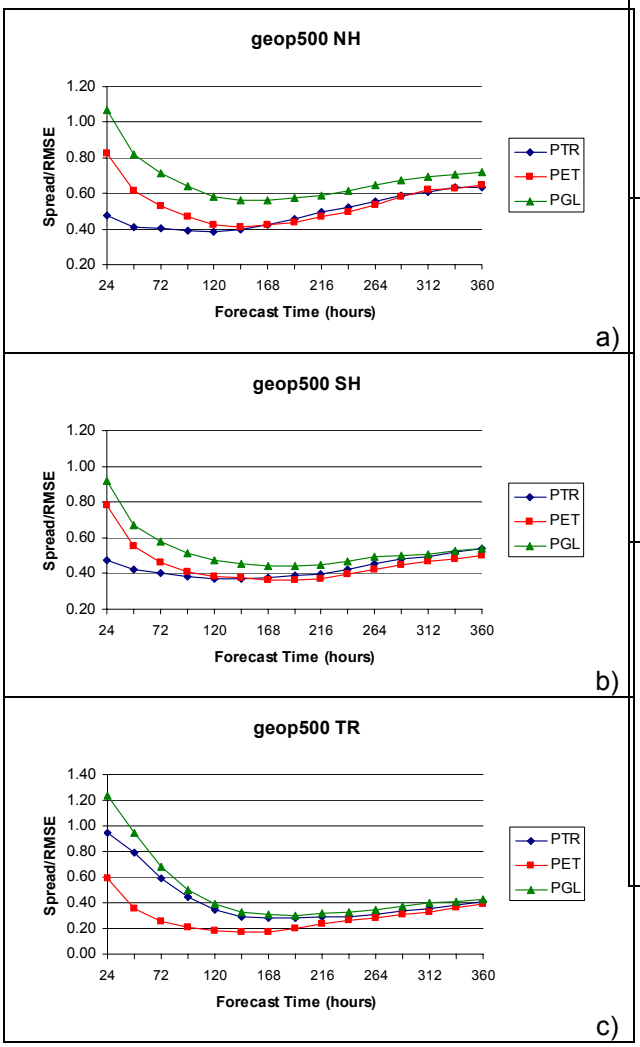

Figure 2. Average ratio of ensemble spread over RMSE of ensemble mean for 500-hPa geopotential height forecasts. a) Northern Hemisphere; b) Southern Hemisphere; c) Tropics.

Greater modifications were obtained in the ensemble spread (Fig. 2a-c) in the NH to all lead forecasts and to SH and TR to short range forecasts. The ratio of ensemble spread over RMSE to experiment PGL it is about the double of the operational run. It is verified that perturbations in the extra-tropics only does not produce so significant results as in the experiment PGL in which was applied concomitantly perturbations in the tropics. Despite the increase in the ensemble spread the system keeps under dispersive, in part because the model error is not considered in the CPTEC EPS.

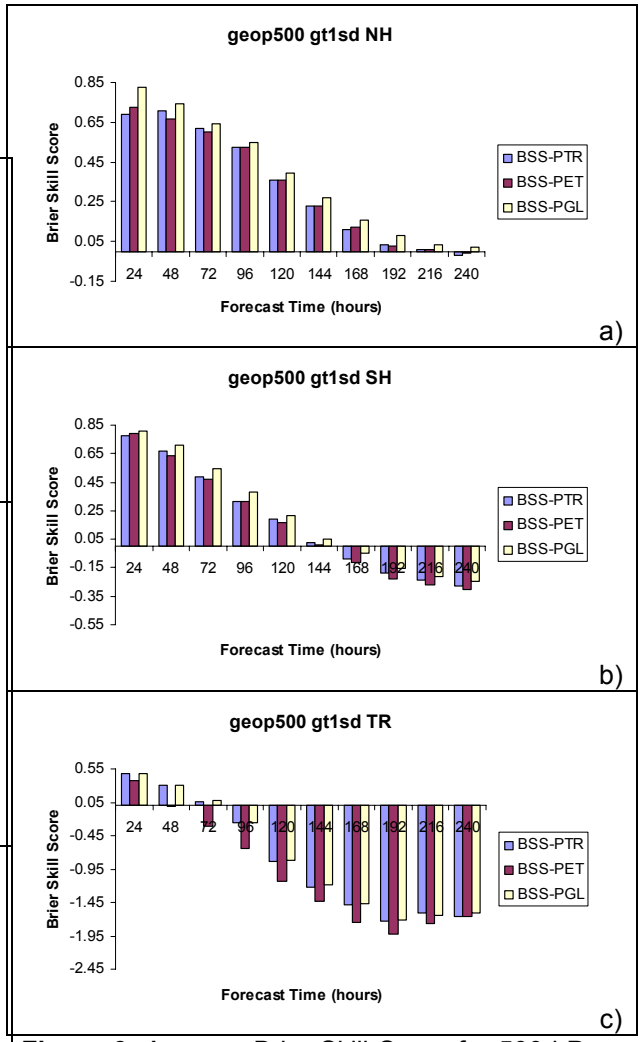

Figure 3. Average Brier Skill Score for 500-hPa geopotential height forecasts. a) Northern Hemisphere; b) Southern Hemisphere; c) Tropics. Probability intervals is determined according the number of ensemble members.

The application of EOF-method, as designed in the experiment PGL, produces positive results for probability forecasts what cab be seen through the BSS and the BS components. It is evident that the experiment PGL shows the best performance for the three regions and all forecast lead time (Fig. 3a-c). It can also be verified significant differences in the performances for each region. The resolution dominates the BSS up to about 10 days in the NH, 6 days in the SH and 3 days in the TR (Fig. 4a-c). It is noticed in the experiment PGL a reduction in the reliability and an increase in the resolution in comparison with the other experiments. It confirms that the application of EOF-perturbations in the extratropics produces positive influence in the forecast performance.

This modification may help to improve the performance of the CPTEC EPS forecasts.

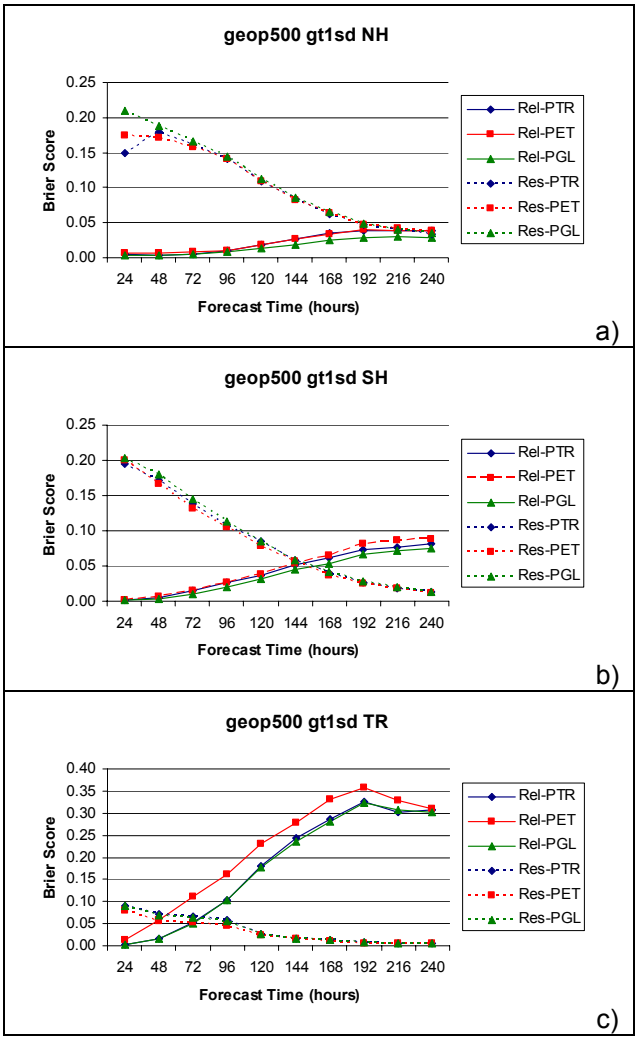

Figure 4. Average reliability and resolution components of the Brier Score for 500-hPa geopotential height forecasts. a) Northern Hemisphere; b) Southern Hemisphere; c) Tropics. Probability intervals is determined according the number of ensemble members.

6. CONCLUSIONS

Improvements in the quality of numerical weather forecasting performed at the CPTEC it is a continuous goal of the CPTEC researchers. This study has this motivation, improve the CPTEC ensemble forecasting through modifications in the region where the initial condition perturbations are evaluated. It is verified that the experiment in which is applied perturbations in the extratropics simultaneously with perturbations in the tropics is the configuration that present better results. This result is not a complete surprise, since perturbations in middle latitudes tend to increase more quickly than perturbations in the tropical region, contributing to increase the spread of the forecasts and improving the statistical indexes that assess the probability forecast quality. However these results suggest that EOF-method, although originally had been developed to produce perturbations in the tropical region, it can also be used with relative success to produce perturbations in middle latitudes.

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