Impact of the scheme of deep convection in the global data assimilation system LETKF of the CPTEC/INPE

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Abstract

Data assimilation experiments with two different deep convection schemes were conducted at Center for Weather Forecasting and Climate Studies of the National Institute for Space Research (CPTEC/INPE). The objective of this work is to verify wether or not the deep convection parametrization scheme impact on data assimilation system of the Global Local Ensemble Transform Kalman Filter (GLETKF). The GLETKF is the Kalman Filter combined with Spectral Atmospheric Global Circulation Model (AGCM). The global model with T126L28 resolution and the convective schemes Kuo and Grell were used. The results are evaluated comparing with the analysis proceeding from the National Center for Environmental Prediction - NCEP. The results have shown that the choice of the scheme of deep convection in the CPTEC AGCM affects the analysis. The Grell scheme in comparison of Kuo scheme reduced significatively the quadratic average error in the geopotencial height fields over South America at medium and high levels (500 hPa and 250 hPa).

Introduction

A Data Assimilation System seeks to improve weather forecast through statistical corrections applied to short-term forecasts generated by numerical atmospheric models. Such corrections are also fundamental for the observations. The goal of a data assimilation process is to generate initial conditions to be used in numerical weather forecast in order to better represent reality at the initial model integration time. Historically, the GDAD (Group on Data Assimilation Development from CPTEC/INPE) performed studies to optimize the use of the available observational datasets (e.g. Holzschuh et al., 2009; Sapucci et al., 2009; Andreoli, et al., 2008, 2007; Aravéquia et al., 2007; Herdies et al., 2007; Sapucci et al., 2007, 2006).

From the modeling point of view, an efficient data assimilation system also needs a numerical model with good predictability in order to keep the forecast errors at a minimum. Thus, this work presents a new prospective towards this aspect of the numerical modeling in the data assimilation process aiming to verify the impact of a deep convection scheme in the global model assimilation using the Local Ensemble Transform Kalman Filter (LETKF) over South America.

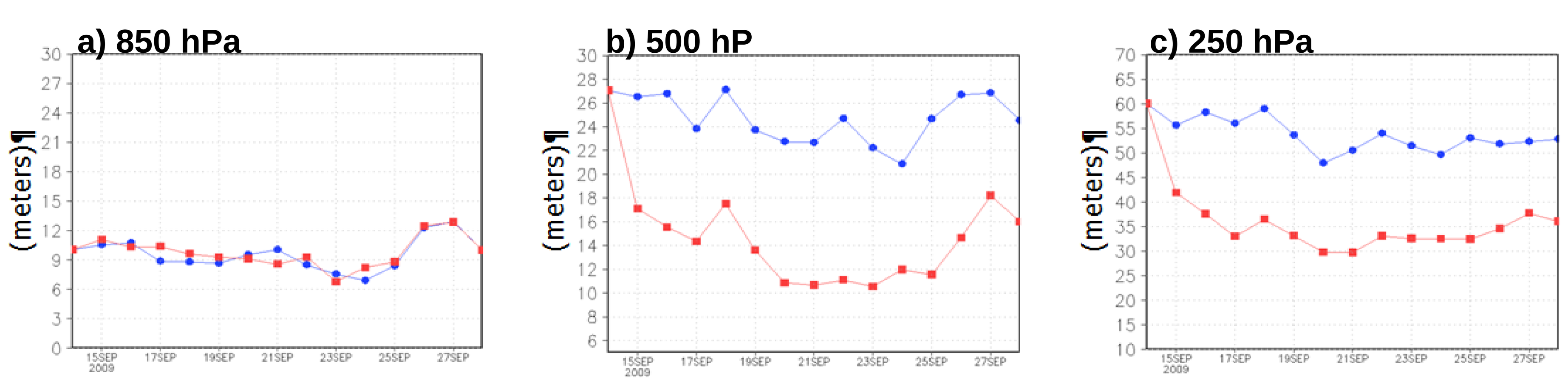

FIG.2 – RMS error for analysis of the geopotential height average on the domain of South America: a) the 850 hPa; b) 500 hPa; c) 250 hPa. Experiment KUO (blue line) and experiment GRELL (red line).

Results and Discussions

The mean temporal distribution of the RMSE for the geopotential height over South America (SA) for the 850, 5000 and 250 hPa during the experiments (KUO and GRELL) is shown in Figure 2. In both cases, the magnitude of the error increases with height, in agreement with the vertical distribution of geopotential height. At 850 hP level the errors have similar magnitude however, in 500 and 250 hPa analyses using GRELL show improvement over KUO. Furthermore, GRELL experiments show a decrease in the error at 500 hPa closing to values seen at 850 hPa and at 250 hPa the error reduction is up to 50%.

GRELL showed improved performance over most of the domain as shown in Figure 3 nevertheless, it showed worst results over the subtropical high over the Pacific Ocean and regions where transient system dominate (see day 21).

In general, the analyses generated by the GLETKF using both GRELL and KUO schemes are satisfactory on low and high levels. Those analyses were able to reproduce the main sinoptic events during the studied period (Figs 4 and 5). Errors are found also in the Andes mountains where NCEP analysis show a upper air warm high pressure system. For the Bolivian High, the KOU scheme showed the least values of pressure when compared to GRELL scheme and the NCEP analysis itself.

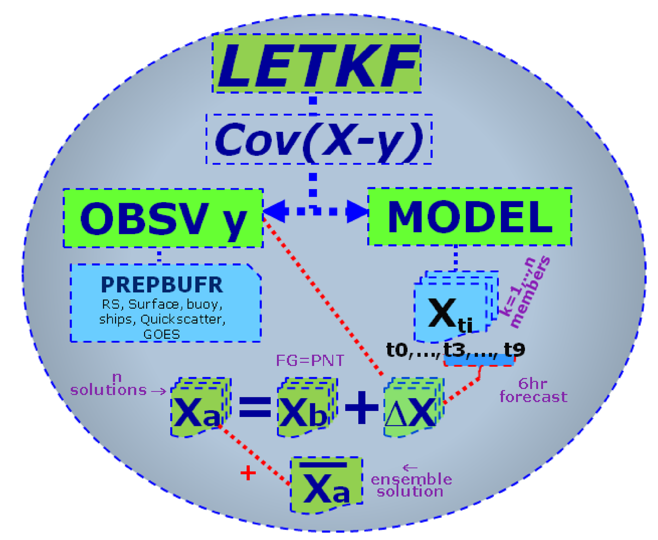

FIG.1– System LETKF: model and observed data.

The LETKF

LETKF (Ott et al, 2004, Halim and Hunt, 2007, Szunyogh et al, 2005, 2007) is a modern statistical technique that incorporates ensemble forecast and data assimilation through a Kalman Filter. This statistical system was originally conceived in a combination of a global model from NCEP and was adapted for the global model from CPTEC/INPE (GLETKF).

This tool provides some advantages over other traditional methods such as (i) reduction of computational time since the error covariance matrices for the model and observations are solved locally; (ii) a design for the historical space-time (trajectory) of the analysis within a observations window of approximately 6 hours (or another customized range); (iii) parameterization of the forecast error covariance matrix using a set of model states and update of the covariance at each assimilation step (Fig. 1)

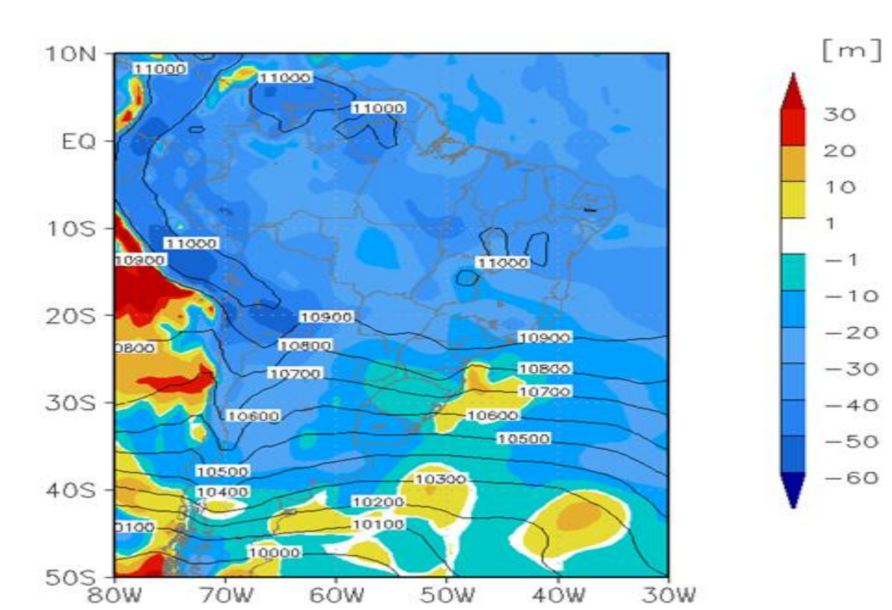

FIG.3 –Difference between the GRELL and KUO RMS errors of the analysis of the geopotential height in 250 hPa for 21 / Sep / 2009 00Z. Negative differences show improvements with the use of the convective scheme Grell. Contours maps show the geopotential height (m) from the NCEP.

Concluding Remarks

The simple change of deep parameterization schemes in the CPTEC AGCM modify significantly the errors at middle troposphere on the CPTEC Data Assimilation System, which indicates the importance of the different processes involved in each cumulus parameterizations scheme, such as the choice of the trigger function and closures. Additional simulations will be done, for instance, the impact of soil moisture and surface processes in order to verify the better physical configurations for GLETK system.

The AGCM

The numerical experiments were performed using the Atmospheric Global Circulation Model (AGCM) from CPTEC/INPE INPE (Panetta et al., 2007) in a T126L28 resolution. It is a spectral model and its physics involves a topography defined using a vertical sigma coordinate. The deep convection scheme, in particular, had two options applied: KUO (Kuo, 1965; modified by Anthes, 1977); and GRELL (Grell, 1993).

The Observational Datasets

The system assimilated observations from various sources. The observational system includes pressure, temperature, humidity and wind from surface and upper air. The conventional observations include surface stations, buoys, ships and oceanic platforms in addition to radiossounds, airplanes and pilot balloons. Wind information was obtained from satellite using the Cloud Track Wind (CTW) method and Quickscat over the oceans and vertical profiles obtained from radars from the NPN network and vertical azimuth (Vertical Azimuth Display - VAD) from NEXRAD. This information can be obtained through the NOAA's prepbufr (htpp://www.nco.ncep.noaa.gov/slib/decoders/BUFRLIB/) and preprocessed before ingestion in the system.

The Experiments

The GLETKF uses 40 ensemble member. In the first time-step the first-guess was obtained from the first 10 days of September, 2009 (every 6 hours). The data assimilation cycle was performed at every 6 hours totalizing 4 analyses per day. The domain comprises the continental South America and the period studied was from 14 to 28 of September, 2009 with analysis of 00Z.

Two experiments were performed with the GLETKF: (i) with a deep convection scheme KUO (ii) deep convection scheme of GRELL. All the settings were the same for both experiments, except the convection schemes. For evaluation purposes, the high resolution NCEP analysis was used and RMSE was calculated in this study.

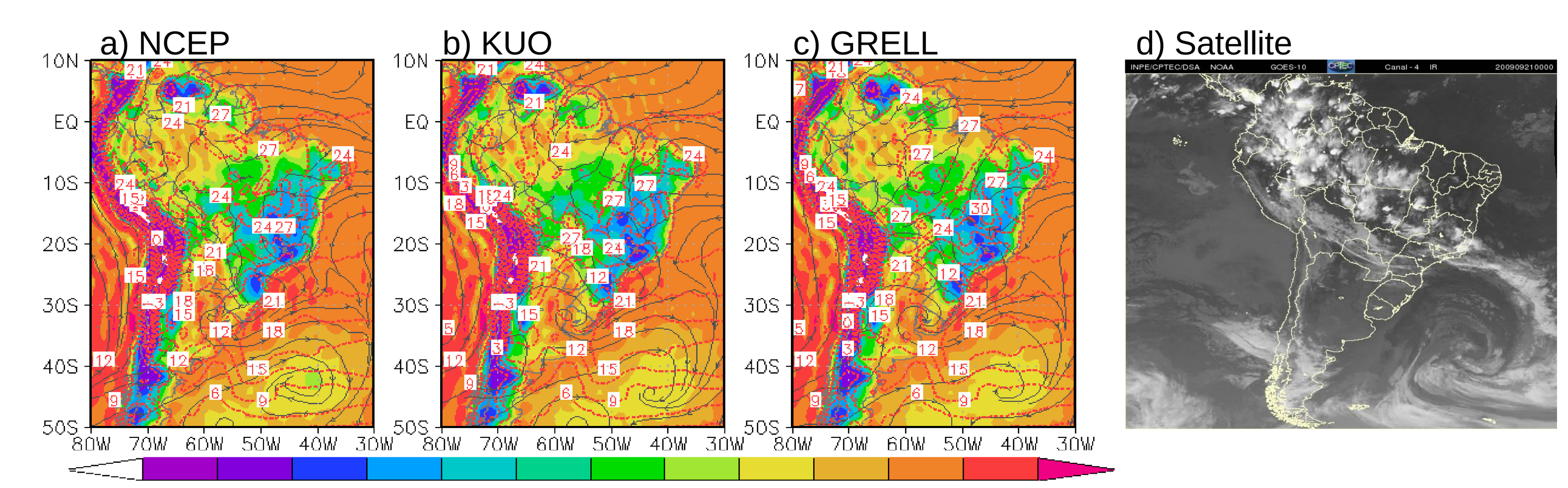

FIG 4– Surface analysis to 21/Sep/2009 00Z:) NCEP, b) KUO, c) GRELL. Shaded areas indicate atmospheric pressure (hPa). Dotted bold red contours indicate Temperature (ºC) , with interval each 3ºC. Fine gray contour indicate wind flow. In (d) Infrared Satellite Image obtain GOES-10 to 21/Sep/2009 00Z.

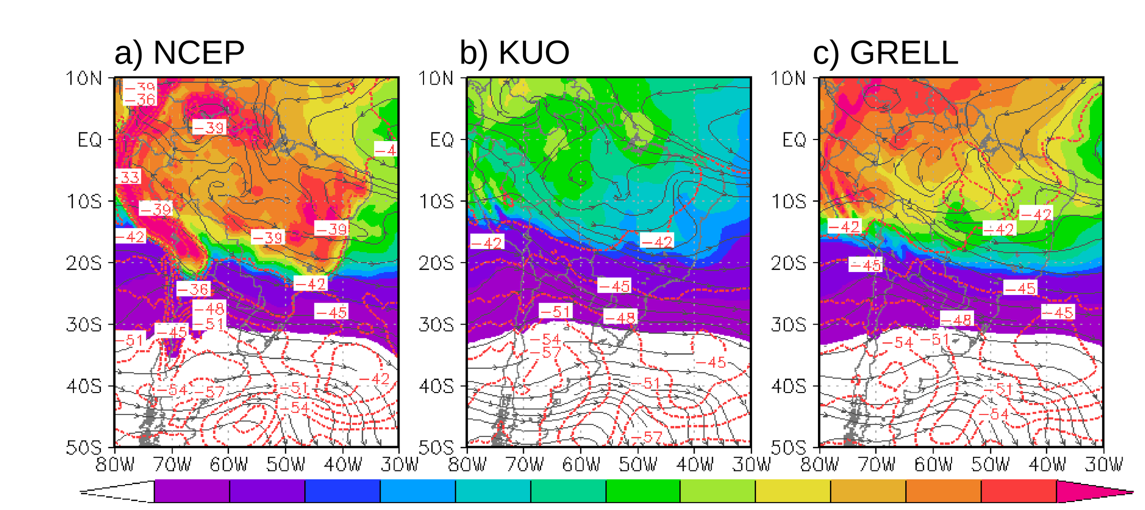

FIG 5 – Analysis to 250 hPa to 21/Sep/2009 00Z : a) NCEP, b) KUO, c) GRELL. Shaded areas indicate geopotential height (m). Dotted bold red contours indicate Temperature (ºC) , with interval each 3ºC. Fine gray contour indicate wind flow.

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