Land Data Assimilation at CPTEC/INPE Atmospheric Global Circulation Model

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1. Introduction

During the last decade, an ever growing number of numerical sensibility studies suggested that atmospheric variability is strongly influenced by the land-atmosphere coupling, in particular due to soil moisture anomalies. Indeed, soil moisture impacts the atmosphere by controlling the evaporation component in the surface water and energy balance equations. Through variations in the evaporation, soil moisture also affects the sensible (H) and latent heat fluxes (E). Therefore, soil moisture is capable of producing changes in the atmospheric temperature and humidity and can also impact precipitation (Seneviratne et al. 2010). On the one hand, there is a control in the amount of evaporation and consequently, water availability in the atmosphere for precipitation.

Soil moisture also impacts the Planetary Boundary Layer (PBL) through H and E, changing temperature and humidity and affecting its vertical development. This is crucial for convective triggering (Gentine et al. 2013), especially over Amazon Basin, where precipitation has a diurnal cycle marked by the occurrence of precipitation peaks hours after the maximum solar radiation. Bechtold et al. (2004) and Santos e Silva et al. (2012) using numerical simulations showed that the improvement in the representation of the diurnal cycle of precipitation over tropical region of South America is related with better representation of convective trigger when the convective parameterization is coupled to H and E.

By the importance of soil moisture for numerical weather and climate prediction, especially for the precipitation forecasts, we have applied a soil moisture data assimilation technique developed by (Mahfouf 1991) to better represent the soil moisture states in the initial conditions of the Brazilian global Atmospheric circulation Model (BAM) of the Center for Weather Forecasting and Climate Studies of the Brazilian National Institute for Space Research (CPTEC/INPE). In the next section we present a short description of the data assimilation technique and a general description of the numerical experiment performed.

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2. Methodology and experimental design

a. Surface analyses

In the method proposed by Mahfouf (1991), near surface meteorological observations measured routinely and transmitted throughout the Global Telecommunication System (GTS) can be used to estimate soil moisture. In this method, an independent two–dimensional statistical interpolation is performed to analyze 2–m temperature and relative humidity. The analysis increment for these two variables are used to analyze the water content of all soil layers of BAM land surface model. Each soil layer is analyzed separately; however, in the following equations subscripts indicating the soil layer are omitted:

$$\delta\theta = \alpha \times (T_a - T_b) + \beta \times (rH_a - rH_b), \tag{1}$$

where T_a and T_b are the analyzed and background 2–m temperature and rH_a and rH_b are the analyzed and background 2–m relative humidity. The analysis relies essentially on the coefficients and, also known as optimum coefficients, which are computed following Douville et al. (2000).

b. Numerical experiment

Two long–range runs of 17 years were performed to verify if better representation of the soil moisture states in the initial conditions of the BAM can improve the precipitation simulations. Both simulations were initialized from the same atmospheric initial conditions and forced by the same Sea Surface Temperature (SST). The first experiment is a Open Loop (OL) in which the soil moisture evolves freely. Another experiment considers the method proposed by Mahfouf (1991) (Land Data Assimilation [LDAS]), with a data assimilation cycle of 6 hours with soil moisture correction by increments of atmospheric 2–m temperature and humidity.

3. Results

Differences between the simulations with and without soil moisture data assimilation indicate that in general, occurs a constant addition of water in the soil, suggesting the presence of systematic errors in the model, especially in North and South American continents (figure not shown). These errors can be associated with simplifications and deficiencies in the land surface model instead random errors from the atmospheric forcing. Nevertheless, consecutive changes in the soil water content (positive or negative increment of soil moisture) impact horizontal distribution of soil moisture and consequently E and H fluxes.

The cumulative effect of the changes improves the amount of soil moisture in some regions leading to an improvement in the forecast of the variables in lower troposphere, mainly the relative humidity (not shown). These modifications contributed to a better representation of the mean annual precipitation cycle over different regions of the world. In the Figure 1 it is presented the global mean annual cycle of precipitation. The correlation between each experiment and Climate Prediction Center – Merged Analysis of Precipitation (Xie and Arkin 1997, CMAP) data is 0.4 in OL and 0.8 in LDAS experiment. Major improvement has occurred from July to October.

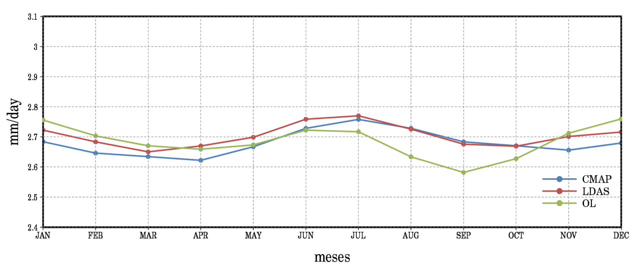

Fig. 1. Global mean annual cycle of precipitation (mm/day). Green line represents the OL experiment, red line the soil moisture data assimilation run and blue line represents CMAP observational data.

Figure 2 shows the annual mean difference between monthly total precipitation from LDAS and OL experiments. Improvements are noticed over North and South American continents, in particular over Amazon Basin and Southern South America.

The regions of higher improvements are similar to spatial patterns showed by Global Land–Atmosphere Coupling Experiment (Koster et al. 2006, GLACE) reinforcing the coupling strength over these regions.

4. Concluding remarks

The use of soil moisture data assimilation contributed to a better representation of the mean annual cycle of precipitation over different regions of the world, like North and South American continents, Africa and Northern Europe. Differences between total precipitation showed some improvement of precipitation over regions similar to the spatial patterns showed by GLACE, reinforcing the coupling strength of soil moisture and precipitation over some regions of world.

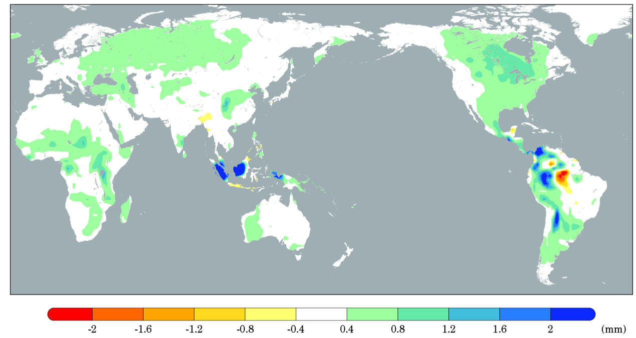

Fig. 2. Annual mean of the difference between monthly total precipitation produced by the LDAS and OL experiments.

Due to improvement in the annual cycle of precipitation in this long–range run, the present study shows a potential benefits in the use of a soil moisture data assimilation to improve BAM for seasonal forecasting applications. Such investigation will be explored in future studies.

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