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Impact of different initial soil moisture fields on Eta model weather forecasts for South America

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[1] Two 7-day weather simulations were made for South America in July 2003 and January 2004 (in the Southern Hemisphere summer and winter) to investigate the impacts of using different soil moisture initialization fields in the Eta model coupled to the Simplified Simple Biosphere (SSiB) land surface model. The alternative initial soil moisture fields were (1) the soil moisture climatology used operationally by the Centro de Previsão do Tempo e Estudos Climáticos in Brazil and (2) the soil moisture fields generated by a South American Land Data Assimilation System (SALDAS) based on SSiB. When the SALDAS soil moisture fields were used, there was an increase in the model performance relative to climatology in the equitable threat score calculated with respect to observed surface precipitation fields and a decrease (up to 53%) in the root-mean-square error relative to the NCEP analysis of the modeled geopotential height at 500 hPa and mean sea level pressure. However, there was small change in the model skill in positioning the primary South American weather systems because of a change in the upper troposphere circulation caused by SALDAS initialization, most noticeably in the South Atlantic Convergence Zone.

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1. Introduction

[2] Soil moisture significantly impacts climate and weather simulations in numerical models by affecting the partitioning of energy between latent and sensible heat due to differences in the availability of heat and water at the surface. In this way, the initial soil moisture prescribed in a model can affect not only the near-surface air temperature and humidity, but also local atmospheric circulations and precipitation.

[3] Several studies have investigated the sensitivity of atmospheric models to soil moisture changes at different timescales in both seasonal and short-term simulations. *Shukla and Mintz* [1982] showed that simulated precipitation increases when using a wet initialization rather than dry initiation of land surfaces. By running a general circulation model (GCM) for several thousands of years, *Koster et al.* [2000] concluded that predictions of precipitation are most influenced by soil moisture in the transition zones between humid and dry climates. *Fennessy and Shukla* [2000] and, more recently, *Zhang and Frederiksen* [2003] suggested that including observed soil moisture data in the initial conditions used in a model improves seasonal forecasts. At reduced temporal and spatial scales, it has been shown that the initiation of moist convection can be influenced by the spatial distribution of soil moisture [*Pielke*, 2001; *Weaver and Avissar*, 2001; *Findell and Eltahir*, 2003a, 2003b]. *Kanamitsu et al.* [2000] investigated the predictability of soil moisture and temperature in the NCEP seasonal forecast system using climatological and NCEP-DOE reanalysis 2 and found improved model skill over arid and semiarid regions where initial soil moisture conditions are critical.

[4] There has been considerable progress in the methodology of soil moisture data assimilation [*Houser et al.*, 1998; *Walker and Houser*, 2001; *Margulis et al.*, 2002; *Reichle et al.*, 2002; *Reichle and Koster*, 2003; *Crow and Wood*, 2003; *Seuffert et al.*, 2003], although the lack of observations in regions such as South America still compromises numerical simulations. Consequently, in South America the use of a Land Data Assimilation System [*Rodell et al.*, 2004] represents a promising alternative for ingesting ground-based and satellite observational data products by using land surface modeling and data assimilation techniques to generate optimal fields of land surface states and fluxes and initial fields of soil moisture.

[5] Over the past few years, there has been an increasing effort to use regional models to better represent mesoscale processes, topography, coastal geometry, and land surface characteristics in South America, although several aspects of regional climate modeling such as resolution, lateral

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boundary conditions, initialization, spin-up time, and model variability remain poorly assessed [*Giorgi and Mearns*, 1999; *Weisse et al.*, 2000; *Tanajura*, 1996]. *Tanajura and Shukla* [2000] investigated the influence of the Andes on South American summer climate using the Eta model reinitialized every 48 hours. *Chou et al.* [2000] also used the Eta model over South America to make a detailed investigation of forecasts made with the Centro de Previsão de Tempo e Estudos Climáticos/Center for Ocean-Land-Atmosphere Studies (CPTEC/COLA) GCM [*Bonatti*, 1996] during opposite phases of the annual precipitation cycle. *Seluchi et al.* [2003] used the Eta model to study the extremely dry warm wind that occurs east of the Andes Cordillera (called the Zonda) that has an orographic origin similar to that of the Foehn that blows in Germany and Austria and the Chinook that occurs east of the Rocky Mountains. *Chou et al.* [2002] made a validation study of the Eta model coupled with a simplified version of *Sellers et al.*'s [1986] Simplified Simple Biosphere model (SSiB) [*Xue et al.*, 1991] over South America by performing 1 month simulations in the dry and wet seasons. This model is hereafter referred to as the "Eta-SSiB model."

[6] The present work investigates the impacts of soil moisture initialization in the Eta-SSiB model operating over South America with 40 km spatial resolution. The model is initialized using two different soil conditions. One is the soil moisture climatology used operationally at CPTEC, the resulting runs being here referred to as the control runs (CTR runs). The second used a product derived from a 3 year South American LDAS run made with an offline version of SSiB forced by the Global Data Assimilation System (GDAS) atmospheric fields for South America, the resulting being here referred to as SALDAS runs. Two 7 day runs were performed during the austral winter (in the dry season, in July 2003) and summer (in the wet season, in January 2004) using these different initial soil moisture conditions. The resulting 72 hours forecasts were then compared with each other and with observations. The models used are described in sections 2 and 3 and the soil moisture initialization procedures in section 4. Methods and analysis are explained in section 5 and results presented in section 6. Section 7 gives a summary and the conclusions.

7. Summary and Conclusions

[40] In this study, the Eta model coupled to SSiB was run over South America with a grid resolution of 40 km and with boundary and initial conditions taken from NCEP analysis. The model was initialized using two different soil conditions; one, the soil moisture climatology used operationally at CPTEC; the other, the product of a 3 year LDAS run using SSiB forced by the GLDAS atmospheric fields. Two 7 day runs were performed during the austral winter (the dry season, in July 2003) and summer (the wet season, in January 2004) with these alternative initial soil moisture conditions. The resulting forecasts of up to 72 hours were compared against each other and against observations.

[41] The CTR soil moisture fields were, on average, drier than the SALDAS soil moisture fields in both January and July in northeastern Brazil, the inner continent, southern portions of Amazonia, and in a region that extends from southern Argentina to northern of Peru, with increasingly greater differences at greater depth. In January, the SALDAS soil moisture fields are drier than the CTR fields in the inner continent and southeastern Brazil, especially in the surface layer. Regardless of which initial soil moisture fields were used, the Eta model was able to predict the general location of precipitation in both seasons reasonably well. In particular, the model correctly predicted the convective band from Peru to southeast Brazil and correctly located the ITCZ in January. In July, the Eta-SSiB misplaced the precipitation associated with the ITCZ to some extent compared to OLR fields, but this may be due to the influence of the model's lateral boundary conditions. The increase in the latent heat flux over north of Argentina, Paraguay and Bolivia in the SALDAS initialization caused an increase in the lower troposphere temperature and as consequence the Eta-SSiB model predicted the BH (a warm core upper tropospheric cyclonic vortex) west of the CTR predictions, shifting the SACZ southward. Nonetheless, the Eta-SSiB model generally did predict the position of the precipitation correctly over the continent quite well in July although, when compared to the measured OLR, it appeared to displace the convection associated with the frontal systems southward.

[42] In January 2004, a quantitative analysis of model precipitation against station observations shows that the SALDAS initialization yields a better ETS than the CTR initiation for the 24 hour forecast for all regions, with up to 23% improvement for light precipitation and up to 10% improvement for all others thresholds. There is degradation of the BIAS for light precipitation in the N region, but improvement in all other regions. With the SALDAS initialization, the 72 hour forecasts also show an overall increase in ETS performance of 20% in all regions and for all thresholds. For the same forecast period, there is an average increase in performance for BIAS of 10% for thresholds lower than 19 mm but degradation in performance above this threshold. Because precipitation is low in July, only the precipitation events below the 19 mm threshold are significant. For the 24 hour forecasts, there was an improvement of 3% in the ETS and a degradation of around 5% in BIAS for all regions when the SALDAS initiation fields were used. For the 72 hours forecasts, there was an improvement of up to 30% in the ETS in the N region, but a degradation of around 5% in the BIAS.

[43] The differences between modeled surface temperatures and observations are similar for both initiation fields and, on average, about 2°C colder in January and 4°C colder in July. The SALDAS runs have larger areas with temperatures colder than the CTR runs in January, particularly near the east coast in southern Brazil and Argentina. In July, the CTR run is colder than the SALDAS run in semiarid and desert areas where the initial soil moisture is drier and there is greater nighttime radiative cooling. When comparing the surface temperature predictions between the two runs, the areas where SALDAS initial soil moisture fields are moister than CTR show lower temperatures due to an increase in the latent heat flux in the energy partitioning.

[44] The 500 hPa geopotential height and mean sea level pressure analysis show a general improvement in the performance of the model of up to 53% (in the N area) when initialized by SALDAS soil moisture fields. Whenever there is degradation of performance in predicting the geopotential height or mean sea level pressure, the percentage change is less than 10%.