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Toward a South America Land Data Assimilation System: Aspects of land surface model spin-up using the Simplified Simple Biosphere

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[1] This paper describes a spin-up experiment conducted over South America using the Simplified Simple Biosphere (SSiB) land surface model to study the process of model adjustment to atmospheric forcing data. The experiment was carried out as a precursor to the use of SSiB in a South American Land Data Assimilation System (SALDAS). The results from an 11 year long recursive simulation using three different initial conditions of soil wetness (control, wet and dry) are examined. The control run was initiated by interpolation of the NCEP/DOE Global Reanalysis-2 (NCEP/DOE R-2) soil moisture data set. In each case the time required for the model to reach equilibrium was calculated. The wet initialization leads to a faster adjustment of the soil moisture field, followed by the control and then the dry initialization. Overall, the final spin-up states using the SSiB-based SALDAS are generally wetter than both the NCEP/DOE R-2 and the Centro de Previsao do Tempo e Estudos Climaticos (CPTEC−Brazilian Center for Weather Forecast and Climate Studies) operational initial soil moisture states, consequently modeled latent heat is higher and sensible heat lower in the final year of simulation when compared with the first year. Selected regions, i.e., in semiarid northeastern Brazil, the transition zone to the south of the Amazon tropical forest, and the central Andes were studied in more detail because they took longer to spin up (up to 56 months) when compared with other areas (less than 24 months). It is shown that there is a rapid change in the soil moisture in all layers in the first 2 months of simulation followed by a subsequent slow and steady adjustment: This could imply there are increasing errors in medium range simulations. Spin-up is longest where frozen soil is present for long periods such as in the central Andes.

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1. Introduction

[2] The large variations in regional climate and surface characteristics (i.e., topography, vegetation, and soil) in South America make climate and weather forecasting a challenging task [*De Goncalves et al.*, 2004; *Liebmann et al.*, 1999; *Marengo et al.*, 2002]. The exchange of heat, moisture, and momentum between the land surface and the atmosphere are all highly dependent on land surface processes and an accurate initialization of the surface stores of energy and water in fully coupled forecast models is critical. To better understand and determine the land surface energy and moisture stores for initiating prediction systems and to address land surface management issues in South America, a South American Land Data Assimilation System (SALDAS) has been created. This system is based on the concepts used in the Land Data Assimilation System (LDAS [*Rodell et al.*, 2004]) used at the NASA's Hydrology Sciences Branch at Goddard Space Flight Center (GSFC). In this study, the LDAS has been adapted to interface with the regional Eta atmospheric model [*Janjic*, 1979, 1984] that is used for weather forecasting at CPTEC (Centro de Previsão de Tempo e Estudos Climaticos), the Brazilian Center for Weather Forecasts and Climate Studies. It is therefore based on the Simplified Simple Biosphere (SSiB [*Xue et al.*, 1991, 2001]) Land Surface Model (LSM) which is used in the coupled Eta system. The results presented here are the first from a series of studies to explore the value of the SALDAS in forecasts systems. Future research will assess the impact of using

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SALDAS-generated initial fields of soil moisture and soil temperature in weather and climate forecasts. This study evaluates the spin-up characteristics of SSiB when operating in the climate of South America and is similar to the evaluation of spin-up characteristics for North America, *Cosgrove et al.* [2003], who compared the behavior of several LSMs and found spin-up times showed a large spatial variation and were correlated most strongly with precipitation and temperature. Further research has been conducted by *Rodell et al.* [2005] who compared 10 methods for initializing a land surface model. They concluded that when multiple years of forcing data are not available, one of the best approaches is to use climatological average states derived from the same model for the time of year of initialization.

[3] The process of a model adjustment to forcing fields (i.e., model spin-up) can severely bias land surface simulations and, if not properly recognized and understood, could potentially degrade the value of LDAS-calculated initiation fields, therefore compromising associated weather and climate simulations. *Xue et al.* [2004] showed that with improved initial soil moisture and vegetation maps, the intensity and location of the summer precipitation over East Africa and West Asia in a coupled Global Circulation Model that included SSiB were also improved. To better understand how the spatial and temporal climate and land surface complexities over South America affect SSiB spin-up, the results of three 11 year long simulations where analyzed. Forcing data for the same 365-day period in 2001–2002 was recursively applied for 11 years in experiments initialized with different soil water contents: completely dry (DRY), fully saturated (WET), and a control run (CTR) which was initiated from the NCEP/DOE Global Reanalysis 2 (NCEP/DOE R-2 [*Kanamitsu et al.*, 2002]).

6. Summary and Conclusions

[24] The present study investigated aspects of the spin-up for the SSiB model applied over South America. Specifically, it explored the time it takes for this model to adjust soil moisture in response to atmospheric forcing, and the differences in modeled moisture states (and related surface fluxes) between values defined from the NCEP/DOE Global Reanalysis 2 (NCEP/DOE R-2 [*Kanamitsu et al.*, 2002]) data set and the equivalent states calculated by SSiB as equilibrium states with recursive application of meteorological forcing data for South America. The preferred SSiB soil moisture states are also compared with those used at CPTEC for climate and weather forecast models.

[25] A spatial analysis was made of the time required for modeled states to approach within specified percentages of their long-term equilibrium values. This revealed a marked dependency of spin-up time on precipitation regime. Over some regions with low precipitation but relatively large evapotranspiration, such as the semiarid northeastern Brazil (NE), or with little precipitation and long periods with frozen soil and low near surface air temperatures, such as the Central Andes (AN–north of Chile, northwest Argentina and southwest Bolivia), or in transition zones, such as the southern limits of the Amazon tropical forest in the Brazilian state of Mato Grosso (CE), the model can take many months (even several years) to reach equilibrium. However, over regions where precipitation is abundant (e.g., the tropical Amazon forest) or well distributed through the year (southern and central South America and coastal areas), the model reached equilibrium for 0.01% PC in less than 18 months. In this present study, spin-up times are, in general, noticeably less than those found by *Cosgrove et al.* [2003] for the Mosaic model applied in North America. Arguably this is related to the more abundant precipitation and the more prevalent presence of denser associated vegetation cover.

[26] The final soil moisture states calculated by recursive application of forcing data with SSiB are, in general, moister than those derived from the NCEP/DOE R-2 reanalysis fields except in southeastern Argentina and central Andes (AN). The impact of using different specifications of initial states was also investigated for three regions (NE, CE and AN) in more detail. In the NE and CE regions, the preferred SSiB soil moisture states are moister than the NCEP/DOE-R2 and moister still than the climatological soil moisture states used at CPTEC for routine whether and climate simulations for South America. Consequently, there is an average increase in the latent heat flux and decrease in sensible heat flux, suggesting a potential impact on precipitation and perhaps atmospheric circulation. In the AN region, where the soil temperature is below freezing most of the year, the preferred SSiB states are drier than the NCEP/DOE-R2 soil moisture states, resulting in a decrease in the latent heat flux and an increase in the sensible heat flux. Note that, unlike NCEP/DOE-R2, the CPTEC soil moisture states in this region (AN) are drier than the preferred SSiB states. Although one of the main motivations for this study was to provide a better understanding of the spatial characteristics of spin-up of SSiB over South America, and insight has certainly resulted from this, a more broadly based study similar to that of *Rodell et al.* [2005] is needed, using other methodologies which, for example, take interannual variability into account.