P2.4 SENSITIVITY OF LOCAL SURFACE WEATHER FORECASTS TO INITIAL SOIL MOISTURE: CASE STUDIES OVER THE MISSISSIPPI DELTA REGION

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1. INTRODUCTION

Refinement of lands surface processes description in atmospheric numerical models is considered to have an apparent potential for improvement of numerical weather prediction skills. This improvement could be achieved by implementation of advanced Land Surface Models (LSM) into numerical weather forecasting models (e.g. Marshall et al., 2003; Tewari et al., 2005; Taylor et al., 2005) and by accurate specification of lower boundary initial conditions for soil moisture and temperature fields (Godfrey et al., 2005).

Despite recent progress of numerical modeling in understanding interactions between soil moisture and atmosphere (e.g. Schär et al., 1998) covering various temporal (days, weeks, and months) and spatial (from local/regional to continental) scales there is still lack of the knowledge about physical mechanisms involving in these interactions. Most of the previous analyses were limited to case studies (e.g. Ashby and Cotton, 2001). Due to the nonlinear nature of the atmospheric response, it depends strongly on a choice of the particular atmospheric situation and on the atmospheric model (including various parameterization choices) used for numerical simulation.

This paper describes preliminary results of comparison between performances of two Numerical Weather Forecasts (NWF) having different initial conditions for the soil moisture. The forecasts were performed to investigate sensitivity of NWF quality (especially the prediction skill of the surface layer parameters) to different types of soil moisture initialization. Typical patterns of surface layer parameters response covering 72-hr forecast period and involving transition from the rainy/cloudy to cloud-free weather will be described. An integration domain used for NWF covers the Lower Mississippi Delta region shown in Fig. 1. The initial and boundary condition data were taken from NCEP 40-km operational reanalysis fields (NCAR/DSS, 2006).

2. DESCRIPTION OF EXPERIMENTS

Two main simulations were performed: one with initial soil moisture fields from NCEP 40-km operational reanalysis dataset (control run), and the other with initial soil moisture produced by the long-term integration (spanning the period from October 1996 to December 2005) of the NOAH model (Ek et al., 2003), which was available within the Land Information System (LIS) framework developed at NASA's GSFC (Peters-Lidard et al., 2004, Kumar et al., 2006).

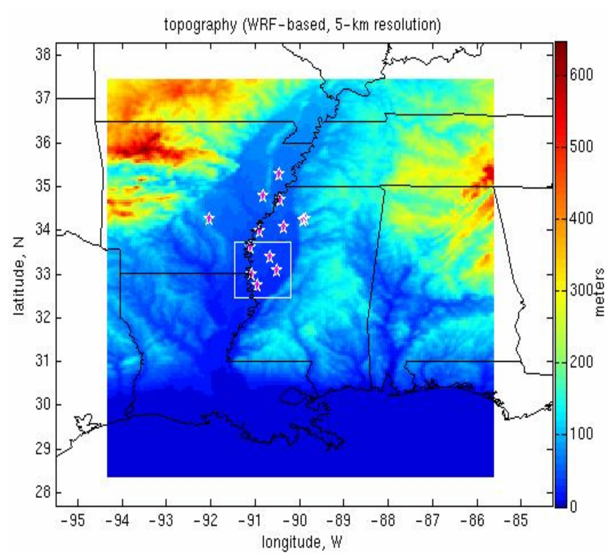

Figure 1. Topography of the WRF 5-km domain. Stars stand for SCAN points locations. Small rectangle in the center indicates 1-km NOAH/LIS domain (see Mostovoy et al., /2007/ for details).

2.1 *WRF configuration*

An advanced version 2 of the Weather Research and Forecasting (WRF) model (Skamarock et al., 2006) was used to study sensitivity of atmospheric

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surface layer forecasts to soil moisture initialization. The WRF integration domain used in this study (having the grid with horizontal spacing of 5 km and with 31 vertical levels) is shown in Fig. 1. Following physics options of the model were used: the Ferrier microphysics scheme, rapid radiative transfer model scheme for the longwave radiation, Dudhia (1989) scheme for the shortwave radiation, Monin-Obukhov parameterization of the surface boundary layer, NOAH LSM, and the Yonsei University PBL scheme. This PBL scheme accounts for a counter-gradient turbulent transport and describes explicitly entrainment processes at the top of the PBL.

The WRF model was run for 72 hr starting from 06/01/2005 at 00 UTC. Two runs were performed with the same initial conditions except for the initial soil moisture fields.

2.2 *Soil moisture initial fields*

The NOAH/LIS LSM was configured to simulate soil moisture fields at 0.05°x0.05° latitude-longitude resolution (approximately 5x5 km²) over a domain covering the lower part of the Mississippi Delta and adjacent territories. The domain is shown in Fig. 1. The NOAH LSM used for soil moisture retrospective simulations had 4 standard layers in the soil. Soil texture properties were represented by CONUS-SOIL (Miller and White, 2006) data based on USDA STATSGO database having 19 soil types. The vegetation/land use description was based on 13 land cover classification types developed at the University of Maryland.

The North American Land Data Assimilation System (NLDAS) fields were used to force the NOAH LSM model. The NLDAS forcing project was described in detail by Cosgrove et al. (2003). NLDAS fields cover CONUS region and are available online from the end of 1996 until present with $1/8^{th}$ latitude-longitude resolution (fields are available every hour).

The NOAH/LIS simulations of soil moisture at the 5-km grid were compared with point measurements. Thirteen Soil Climate Analysis Network (SCAN, 2006) points supported by the USDA Natural Resources Conservation Service were selected over the NOAH/LIS domain. These sites with available measurements of the volumetric soil moisture at different levels are shown in Fig. 1 by stars. Locations of these sites are also indicated by numbers in Fig. 2 (right frame).

3. RESULTS

Figure 2 shows two initial soil moisture content (volumetric fraction averaged for 0-10 cm layer) distribution: one for the control WRF run with moisture fields extracted from the 40-km NCEP Eta reanalysis data and other simulated by NOAH/LIS with 5-km resolution (the NOAH/LIS run). The NOAH/LIS soil moisture distribution exhibits small scale variability patterns, which are closely associated with that of soil type's distribution (a plot not shown). Clearly, this fine scale variability of soil moisture was not reproduced by the 40-km NCEP reanalysis fields (left frame in Fig. 2). Despite this difference, good spatial consistency is observed between 40-km and 5-km soil moisture fields.

Small-scale variations in initial soil moisture fields cause corresponding changes in surface meteorological fields. Figure 3 shows a typical distribution of the difference in 2-m air temperature between the control and the NOAH/LIS WRF run for the 24 hr and 48 hr forecast periods. These variations are clearly seen in Fig. 3 (left frames). A spatial distribution of a soil moisture content difference between these WRF runs is also shown in Fig. 3 (right frames).

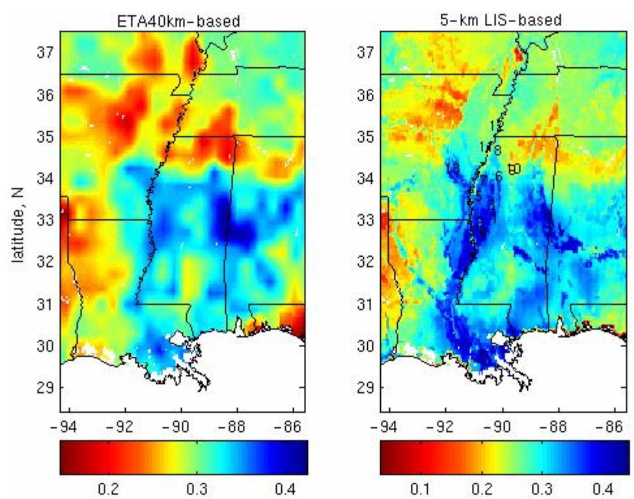

Figure 2. Initial fields (valid for 06/01/2005 00 UTC) of volumetric soil moisture content (average fraction for 0-10 cm layer) from NCEP ETA 40-km reanalysis data (left frame) and from NOAH/LIS 5-km retrospective simulation (right frame).

Figures 4 and 5 show selected time series of the 2-m air temperature and the soil moisture content (volumetric fraction averaged for 0-10 cm layer) produced by the control and the NOAH/LIS WRF simulation at two SCAN sites (Silver City and N. Issaquena). SCAN measurements are also plotted in these Figures. An overall agreement is observed (except for the first 22 hours of integration) between SCAN data and predicted values. Though values of the air temperature produced by two forecasts are very close, at some periods (see for example the forecast range of 24-30 hours in Fig. 4) the NOAH/LIS values have shown a closer agreement with SCAN measurements than those of the control run.

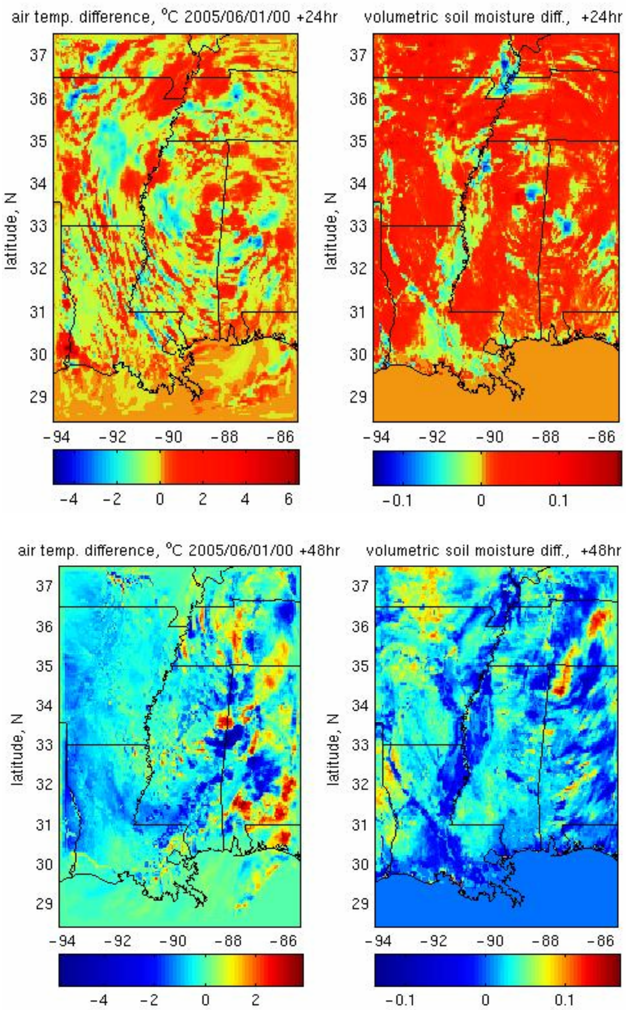

Figure 3. Geographical distribution of difference between the control run and the WRF forecasts (upper row: 2005/06/01 +24 hr; lower low: 2005/06/01 +48 hr) performed with initial soil moisture fields generated by the NOAH/LIS long-term integration. 2-m air temperature (left panels) and volumetric fraction (average for 0-10 cm layer) of the soil moisture content (right panels).

Note that both runs indicate a rather low temporal variability of the moisture content even in the most upper (0-10 cm) soil layer (as illustrated by lower frames in Figs. 4 and 5). Figures 4 and 5 show that initial deviations of the soil moisture from the control run are highly persistent during the entire forecast period of 72 hours. This fact suggests an importance of an adequate specification of initial soil moisture fields in order to get better prediction accuracy of atmospheric surface layer variables.

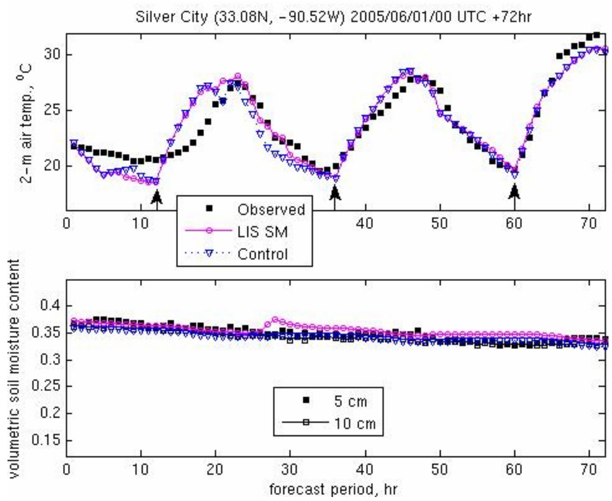

Figure 4. Time series of 2-m air temperature (upper frame) and volumetric fraction of the soil moisture content (lower frame) for the Silver City SCAN site (shown by number 1 in Fig. 2 /right frame/). Arrows stand for 6 AM of Standard Local Time. Note rather low variability of the soil moisture during the entire forecast period.

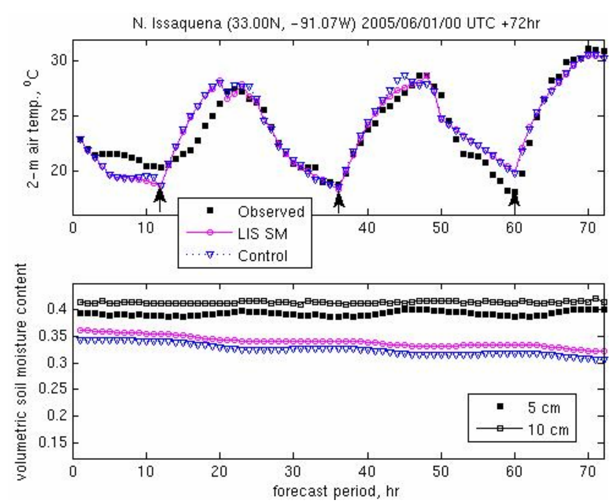

Figure 5. The same as in Fig. 4, but for the N. Issaquena SCAN site (shown by number 2 in Fig. 2 /right frame/).

The presented case study shows clearly that relatively small differences (within ±0.1 of the volumetric fraction content) in initial soil moisture fields can result in changes by several degrees (°C) of the 2-m air temperature forecasted by the WRF model.

4. ACKNOWLEDGMENTS

The authors of this paper would like to acknowledge NASA for its funding of this research through NAS1303032 via the Mississippi Research Consortium. We appreciate timely consultations provided by the LIS Helpdesk (Drs. Sujay Kumar and Yudong Tian). We acknowledge the services of the USDA Natural Resources Conservation Service for maintaining the SCAN data webpage.

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