Influences of Mesoscale Land-PBL Interactions on a 12-Day Episode of Precipitation during IHOP_2002

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1. Background and Motivation

The Southern Great Plains (SGP) of the United States is a region of strong subseasonal variability of warm season precipitation. The precipitation variability is likely governed by a variety of factors including large-scale variations in moisture flux convergence and local variations in evaporation. Studies using General Circulation Models (GCMs) coupled with Land-Surface Models (LSMs) have indicated a particularly strong sensitivity of subseason precipitation to soil moisture conditions over the SGP (Koster et al. 2004a,b; Ruiz-Barradas and Nigam 2005). The goal of the current study is to use a high resolution coupled LSM/convection-resolving atmospheric model to explicitly examine how the land-surface conditions can influence SGP subseasonal precipitation through their interaction with the overlying daytime planetary boundary layer (PBL).

2. Experimental Design

• Coupled WRF/LSM 12-Day Simulation of the Convectively Active IHOP 9-21 June 2002 Period over a Regional Domain

• Fine-Scale Land Surface (e.g., Soil Moisture) Initial Condition Supplied by HRLDAS (Chen et al. 2006) run offline

WRF Model:

- 4-km horizontal grid spacing over 2128 x 1540 km domain
- Lateral boundary conditions from 3-h Eta model analyses
- Coupled with Noah land surface model
- Mellor-Yamada Janjic (Eta model scheme) PBL
- RRTM (longwave) and Dudhia (shortwave) radiation schemes
- Lin et al. bulk microphysics
- No cumulus parameterization (i.e, explicit deep convection)

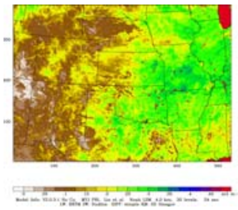
HRLDAS:

• Input:
  - 4-km hourly NCEP Stage II rainfall
  - 1-km land use type and soil texture maps
  - 0.5 degree hourly GOES downward solar radiation
  - 0.15 degree AVHRR vegetation fraction
  - T, q, u, v from model based analysis

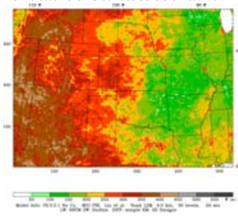
• Output:
  Long-term evolution of multilayer soil moisture and temperature, surface fluxes, and runoff.

3. Mean 12-Day Surface and Atmospheric Conditions

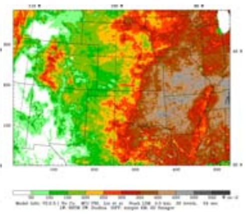
Simulated 18 UTC Soil Moisture



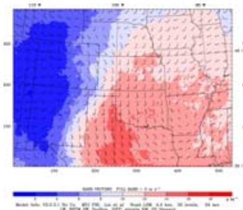
Simulated 18 UTC Surface Sensible Heat Flux



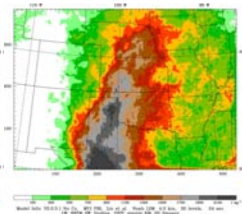
Simulated 18 UTC Surface Latent Heat Flux



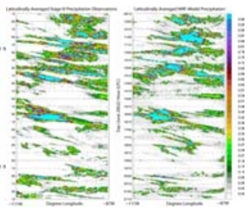
Simulated 00 UTC PBL Winds and Moisture



Simulated 00 UTC CAPE for Lowest 500-m Air



Observed (left) and Simulated (right) Precipitation



• Simulated surface fluxes [sensible (latent) flux dominant west (east) of 100 deg] consistent with regional soil moisture gradients

• Large late P.M. CAPE occurs in zone of regional soil moisture contrasts, and is maximized where midday sensible heat flux exceeds latent heat flux

• The zone of maximum CAPE coincides with time-averaged moist, southerly flow and is likely also influenced by advection

• Coherent latitudinally-averaged precipitation features (lower right) are well-simulated including:
  - Long-track zonally propagating rain streaks originating near region of large time-average 00 UTC CAPE (~ 100 W)
  - Short-track zonally propagating rain streaks originating near the continental divide (~ 110 W)
  - Quasi-stationary afternoon convection east of ~ 92 W

References

Chen et al., 2006: Evaluation of the characteristics of the NCAR high-resolution land data assimilation system. *Journal of Applied Meteorology*, Conditionally Accepted.

Koster et al., 2004a: Regions of strong coupling between soil moisture and precipitation, *Science*. Vol. 305, 1138-1140.

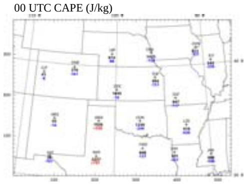
Koster et al., 2004b: Realistic initializtion of land surface states: Impacts on subseasonal forecast skill. *Journal of Hydrometeorology*, Vol. 5, 1049-1063.

Ruiz-Barradas and Nigam, 2005: Warm season rainfall variability over the U.S. Great Plains in Observations, NCEP and ERA-40 reanalyses, and NCAR and NASA atmospheric model simulations, *Journal of Climate*, Vol. 18, 1808-1830.

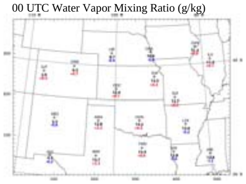
4. Model Comparison with Observations

Mean 12-Day Simulated PBL Quantities (top numbers) with Departures from National Weather Service Sounding Observations (bottom numbers)

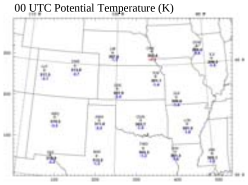
00 UTC CAPE (J/kg)



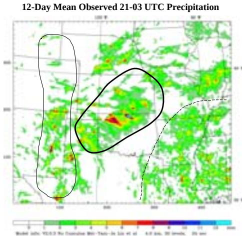
00 UTC Water Vapor Mixing Ratio (g/kg)



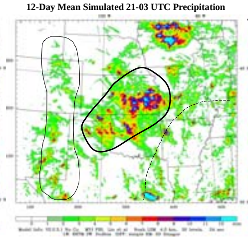
00 UTC Potential Temperature (K)



12-Day Mean Observed 21-03 UTC Precipitation



12-Day Mean Simulated 21-03 UTC Precipitation



• **Three zones of late PM precip highlighted on left**

- Front range precip (thin solid) well simulated

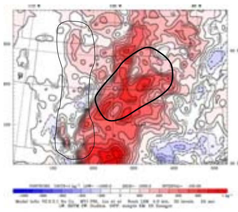
- SGP precip (bold solid) well simulated, but QPF somewhat too large, which could be influenced by local ~ 0-2 g/kg positive WRF PBL moisture bias (top center)

- Lower Mississippi Valley precip (thin dashed) is under forecasted by WRF, consistent with the local 400-600 J/kg negative WRF CAPE bias (top left)

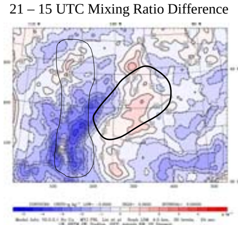
- WRF daily-averaged 00 UTC CAPE is close to that observed over much of the domain with the two exceptions being over TX panhandle (resulting from PBL moisture excess) and lower Mississippi Valley (resulting from PBL moisture and potential temperature deficits)

5. 12-Day Mean Daytime (15-21 UTC) PBL Evolution

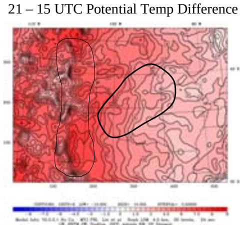
21 – 15 UTC CAPE Difference



21 – 15 UTC Mixing Ratio Difference



21 – 15 UTC Potential Temp Difference



• The three zones of simulated precipitation (section 4, lower center) follow distinct daytime evolution of CAPE, which are in turn related to differences in evolution of mixing ratio (center) and potential temperature (right)

- Large daytime CAPE increases in SGP precipitation zone are related to increases in both PBL temperature and moisture. These changes result from local fluxes but likely have a strong component due to horizontal advection.

- Small increases to neutral daytime CAPE changes in the front range precipitation zone result from moisture decreases (associated with deep PBL growth and vertical mixing) approximately compensating (in terms of moist static energy) the strong potential temperature increases

6. Summary and Future Work

• A coupled convection-resolving atmospheric/LSM initialized with high resolution land-surface conditions has been used to simulated an extended (12-day) period of active convection over the Southern Great Plains

• Atmospheric boundary layer properties (e.g., potential temperature, moisture, CAPE) and precipitation are generally well simulated over much of the region in a time-averaged sense

• Preliminary results indicate both advection and local evaporation contribute strongly to daytime increases in CAPE and subsequent evening precipitation over the Southern Great Plains

• Future work will analyze simulations with different land-surface initializations to determine influences of soil moisture on the PBL and precipitation during this 12-day period