Influence of variations in low-level moisture and soil moisture on the organization of summer convective systems in the US Midwest

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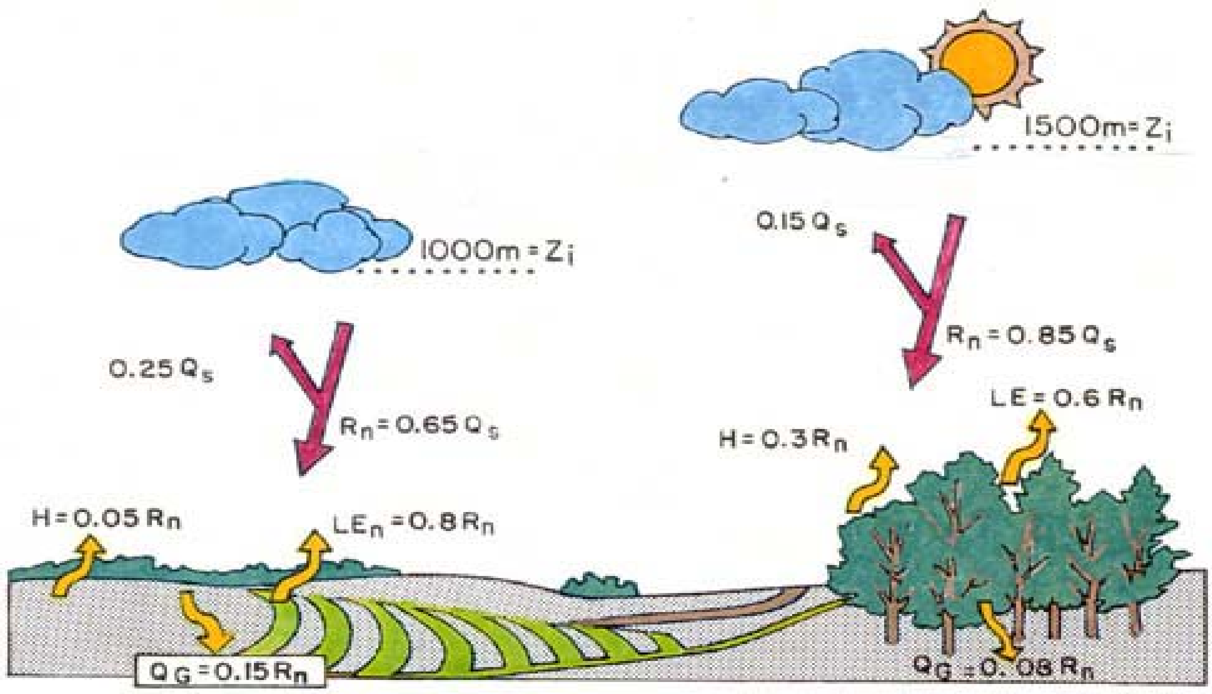
Land Surface Impact on PBL Processes



Schematic of the differences in surface heat energy budget and planetary boundary layer over a forest and cropland.

LCAM Land Surface-Climate Research

Integrating multiple sensor, multi-scale satellite data with conventional Climate data for observational and regional climate modeling studies

Development of land surface-related variables for use in coupled land-atmosphere models (with Dr. Kevin Gallo – NOAA/NESDIS)

Improving the representation of surface heterogeneity in the land-surface component of the Colorado State University Regional Atmospheric Modeling System-RAMS (with Dr. Roger Pielke Sr. & CSU RAMS Modeling Group)

Introduction and Motivation

An important aspect in operational forecasting, particularly in the warm season, is the timing of convective initiation and subsequent evolution of convective systems.

Prior observational and modeling studies have demonstrated that soil moisture strongly contributes to the variability of surface temperature and continental precipitation via the exchange of water and energy between the land surface and atmosphere (e.g. Koster et al. 2000; Adegoke et al. 2003; Anderson et al. 2004)

Because vegetation also affects the surface energy budget, it is probably just as important. A growing number of recent studies have investigated the impact of satellite-derived leaf area index in the land surface schemes of mesoscale models (e.g. Lu and Shuttleworth 2002)

We postulate both of these effects are maximized during 'weak' synoptic flow regimes, where there is little large-scale advection of moisture. Here we investigate this hypothesis in a case study of August 2000 in the Midwest U.S. with a regional model.

August 2000 Case

Prior observational analysis (Carleton 2005) using point-source data established that this period was a weak synoptic flow regime in the Midwest compared to the rest of the summer.

A more detailed analysis of the month using atmospheric reanalysis and U.S. daily precipitation data (Higgins et al. 1996) show that a series of mesoscale convective systems (MCSs) occurred across Missouri, Illinois, Indiana, and Ohio during Aug. 5-6.

After that time as a high pressure ridge developed in the area, the synoptic scale environment was unfavorable for convection, yet convective precipitation occurred in southern parts of Missouri, Illinois, and Indiana.

Did the soil moisture and vegetation provide a mechanism to force this convective precipitation and how it organized in the later part of the month?

Regional Model Set Up

Regional Atmospheric Modeling System (RAMS), Version 4.3

Relevant information for this experiment:

Chen and Cotton (1983) radiation scheme

Lateral boundary forcing by the North American Regional Reanalysis (NARR; Mesinger et al. 2005) with weak internal nudging to maintain the large-scale variability in the simulation (Castro et al. 2005)

NARR downscaled directly to a 5 Km grid

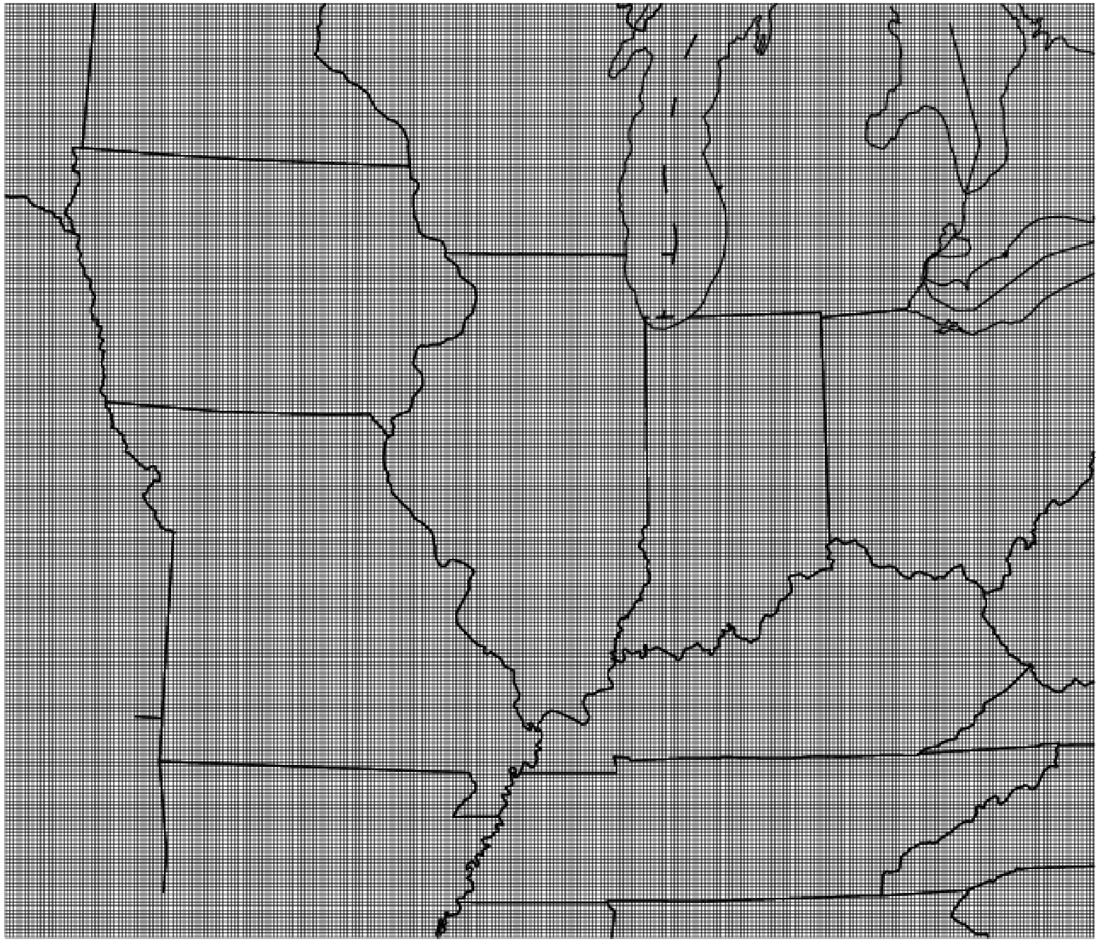
Explicit microphysical representation of precipitation with no convective parameterization

LEAF-2 Land Surface scheme (Walko et al. 2000)

Simulation length: 1-31 August 2000

Simulations performed on a 24-node linux cluster at LCAM, UMKC

RAMS Model Domain



5 km grid spacing; 280 x 240 grids; 30 levels

Offline Soil Moisture and Vegetation Datasets for RAMS Sensitivity Experiments

Soil Moisture

Retrospective North American Land Data Assimilation (NLDAS) soil moisture from the MOSAIC model (Cosgove et al. 2003) at approximately 12 km resolution (0.125 degree). Used as initial condition only.

Replaces default homogeneous soil moisture specified by model-user.

Vegetation

NASA Global Inventory Modeling and Mapping Studies (GIMMS) satellite-derived normalized difference vegetation index (NDVI) at 8 km resolution. Converted to leaf area index (LAI) using the algorithm by Sellers et al. (1996). Updated throughout the simulation.

Replaces default climatological LAI evolution prescribed per vegetation type in LEAF-2 (Implemented by Adriana Albetran as part of her dissertation work)

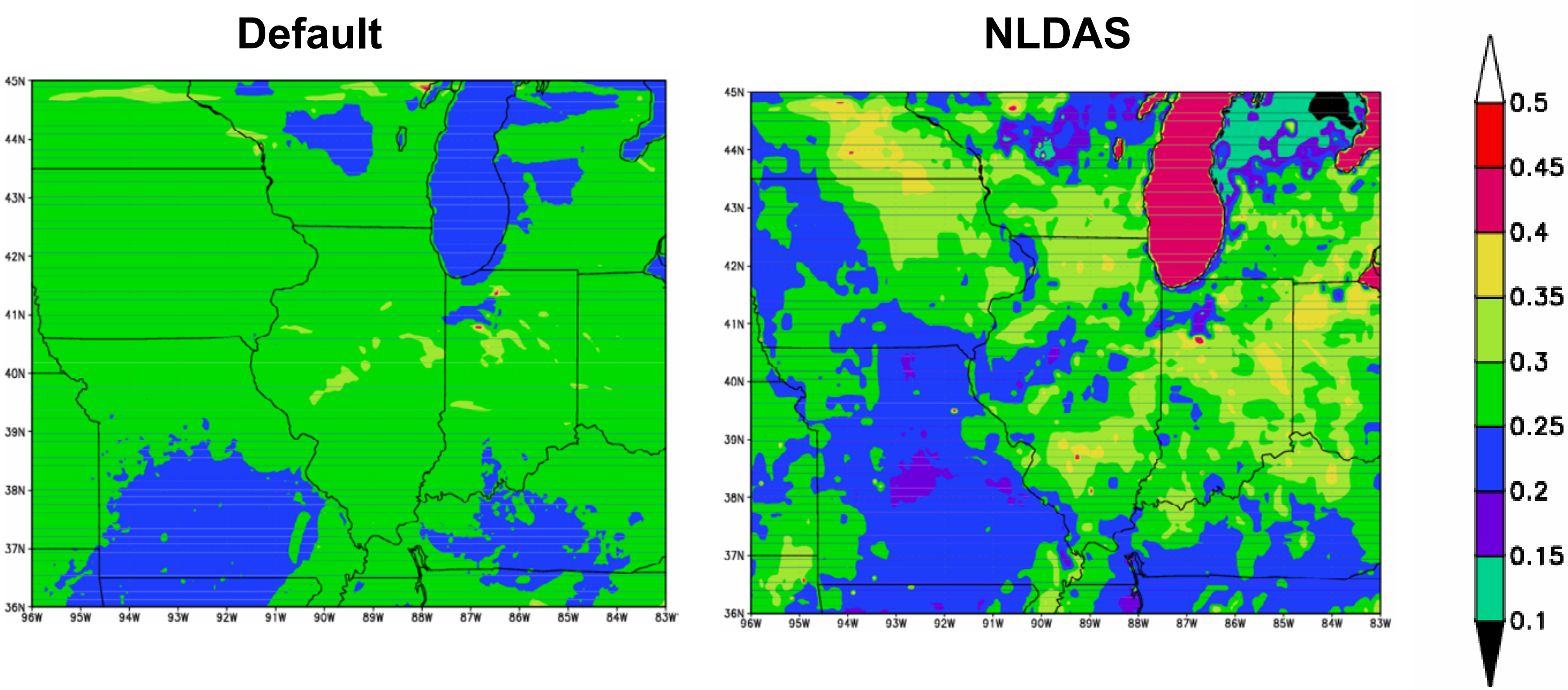
RAMS Sensitivity Experiments

Experiment Number

1) Default	2) NLDAS	3) LAI	4) NLDAS+LAI
Homogeneous soil moisture Climatological LAI	NLDAS heterogeneous soil moisture Climatological LAI	Homogeneous soil moisture GIMMS satellite-derived LAI	NLDAS heterogeneous soil moisture GIMMS satellite-derived LAI

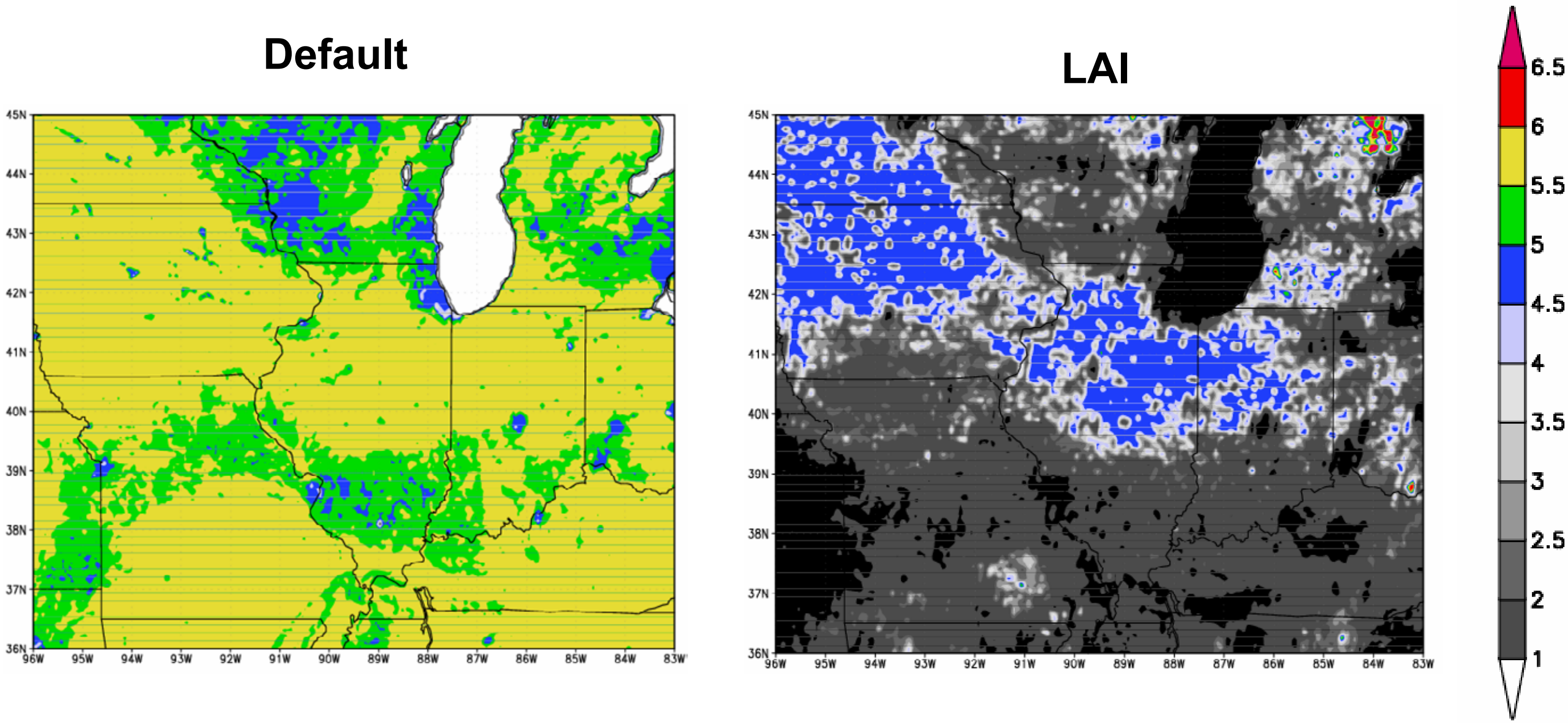
NOTE: The homogeneous soil moisture value determined by the average NLDAS value for the model domain.

Volumetric Soil Moisture ($m^3\ m^{-3}$)
After 15 Simulation Days



Larger gradients in soil moisture in NLDAS experiment, particularly in the southern part of the domain where soil moisture is generally lower.

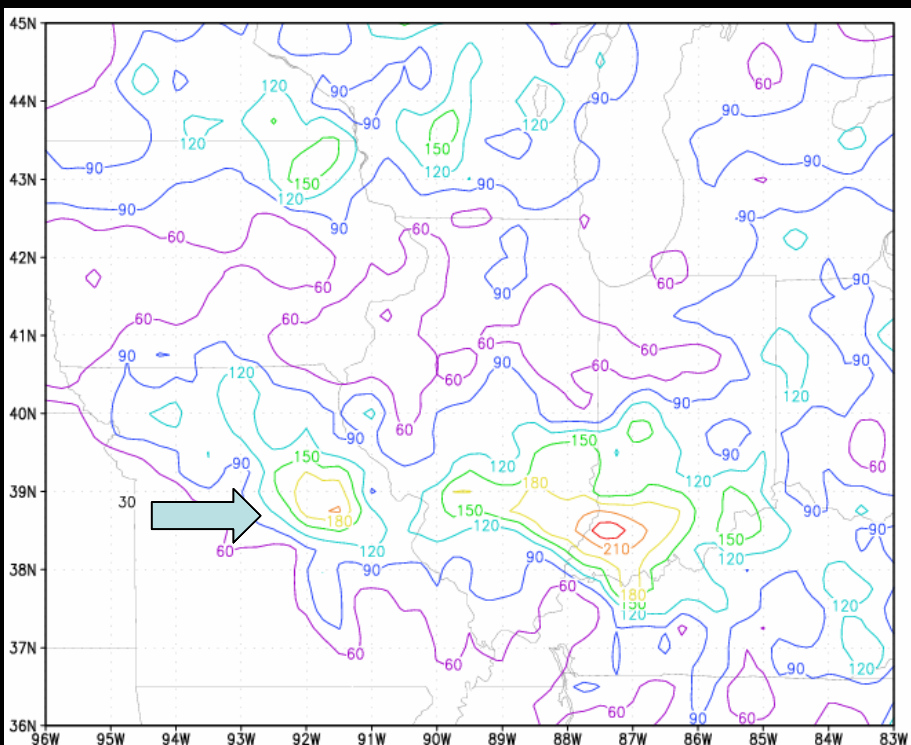
Leaf Area Index ($m^2 \, m^{-2}$)
After 15 Simulation Days



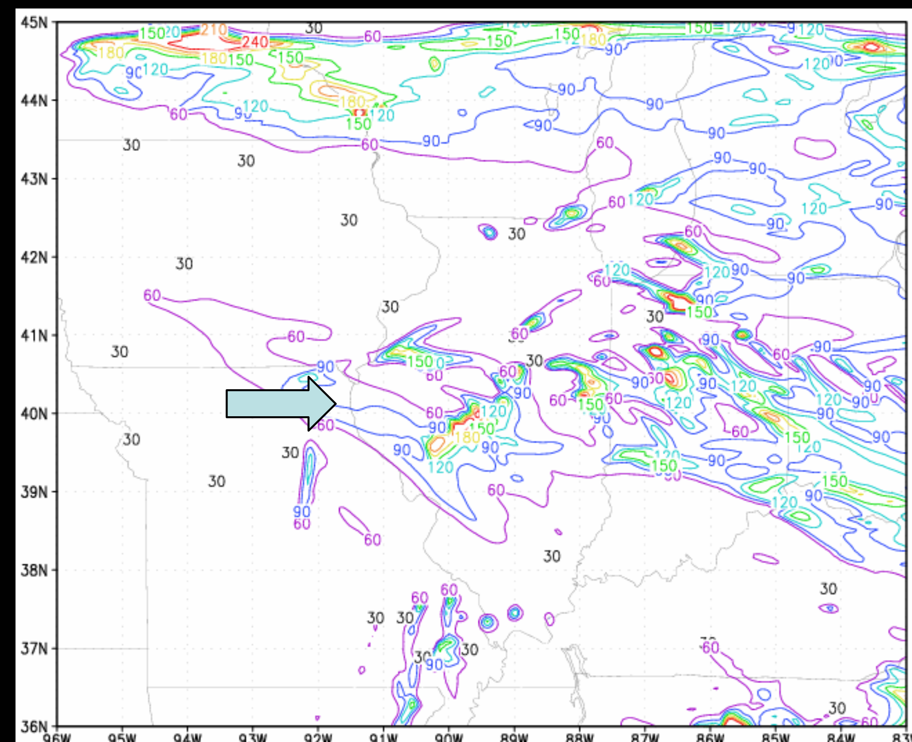
A domain-wide decrease in LAI using GIMMS data. Largest decrease in the southern part of the domain.

Total August Precipitation (mm)
Observed vs. RAMS Default

NCEP Observed



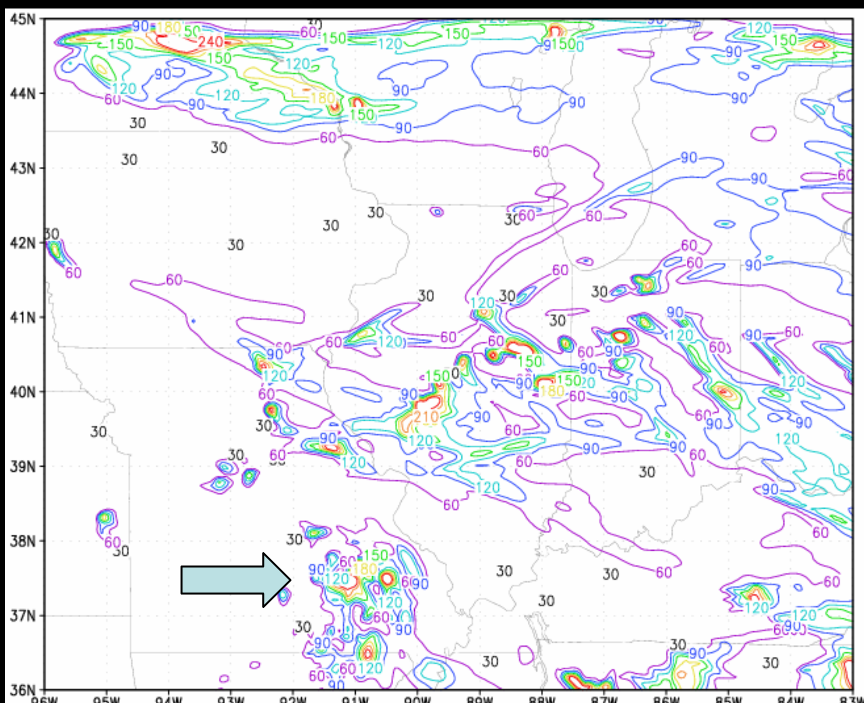
Default



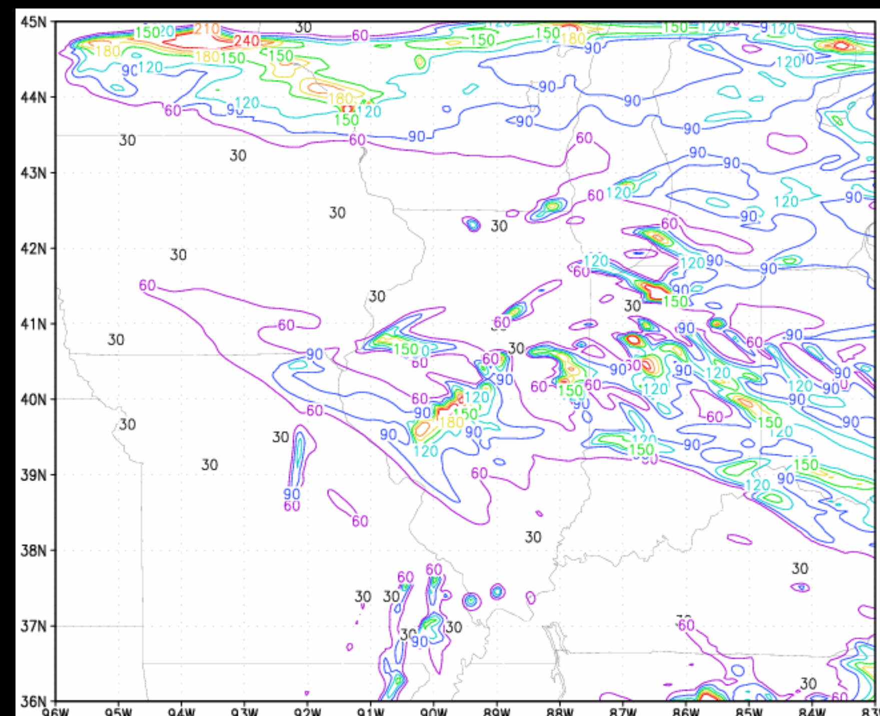
Precipitation band in the default case is farther north than observed. Very little precipitation in the southern part of the domain.

Total August Precipitation (mm)
NLDAS vs. Default

NLDAS



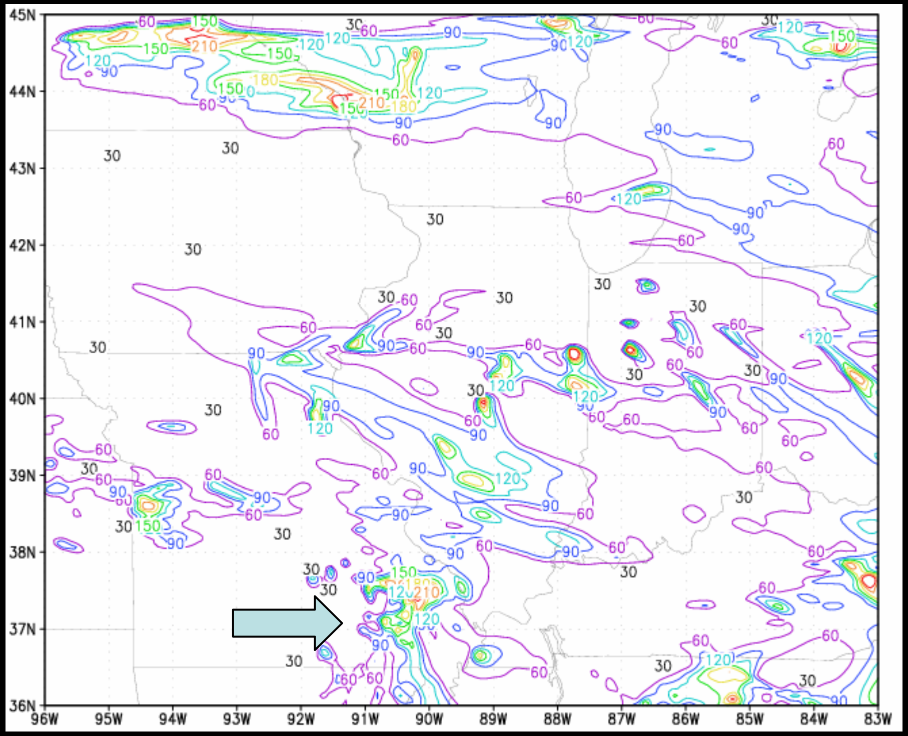
Default



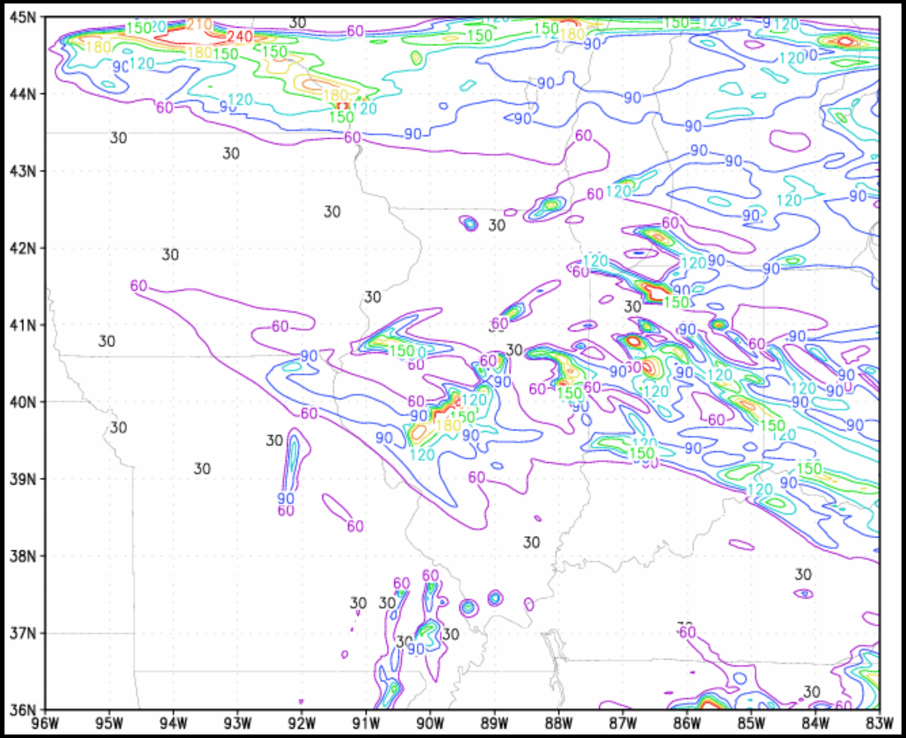
Note increase in precipitation in the southern part of the domain, particularly southeast MO.

Total August Precipitation (mm)
LAI vs. Default

LAI



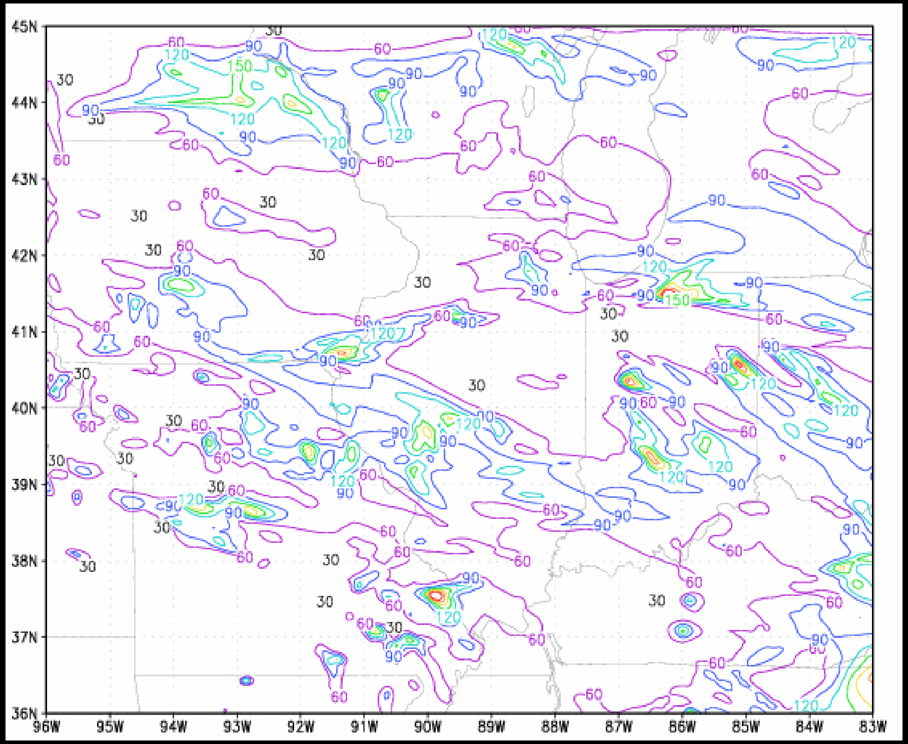
Default



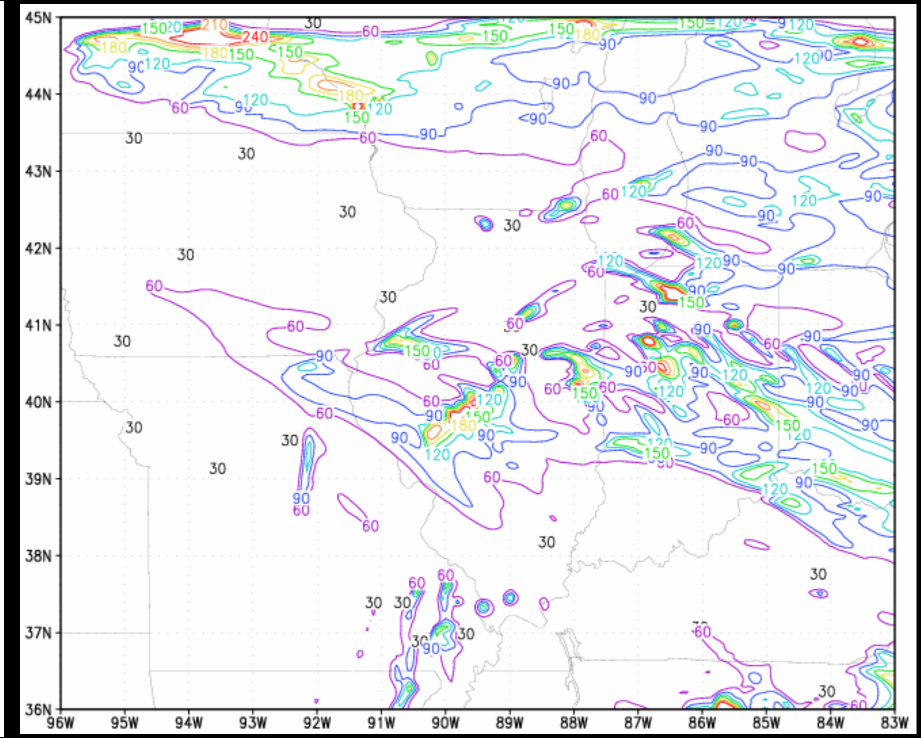
Similar effect as variable soil moisture.

Total August Precipitation (mm)
NLDAS+LAI vs. Default

NLDAS+LAI

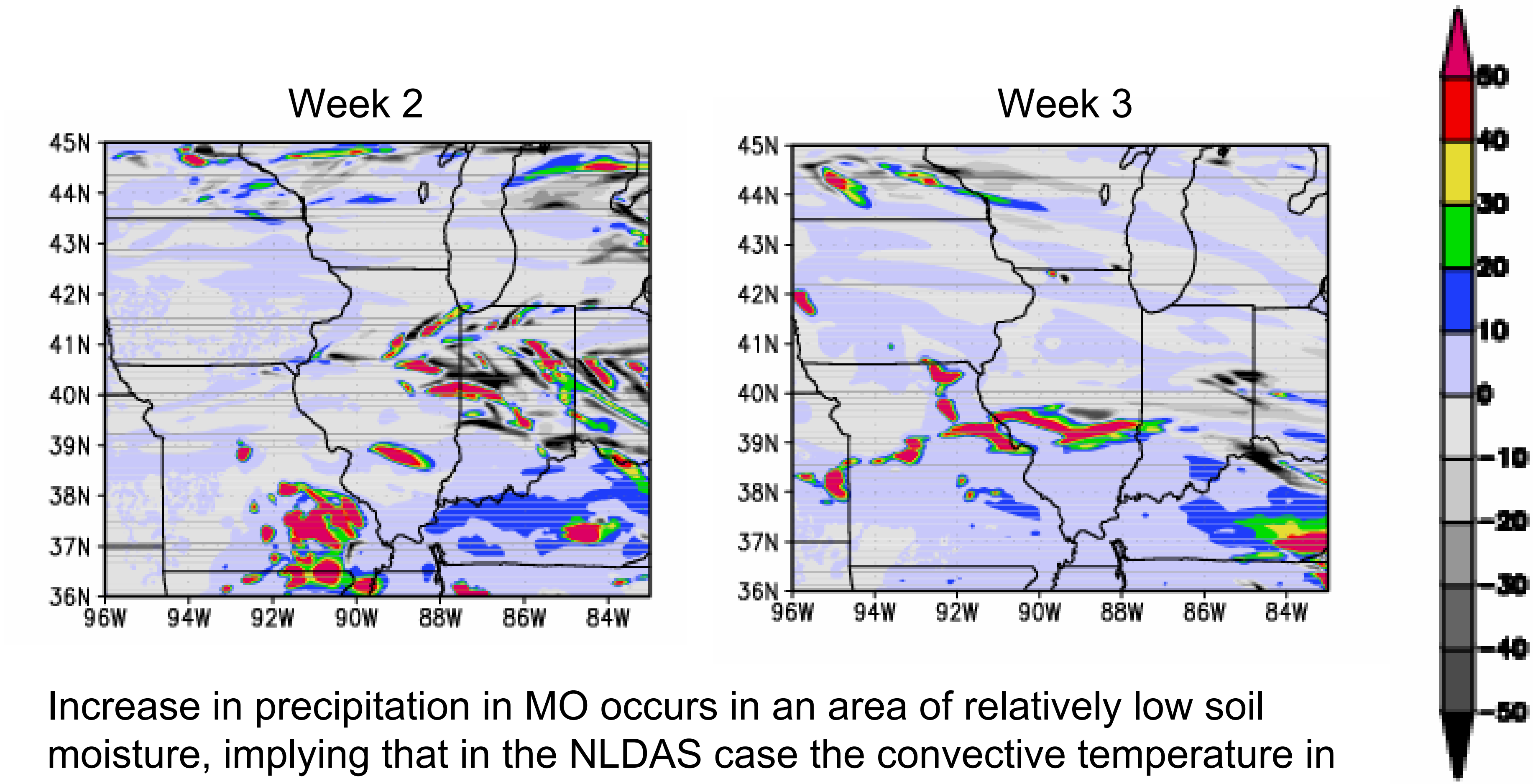


Default



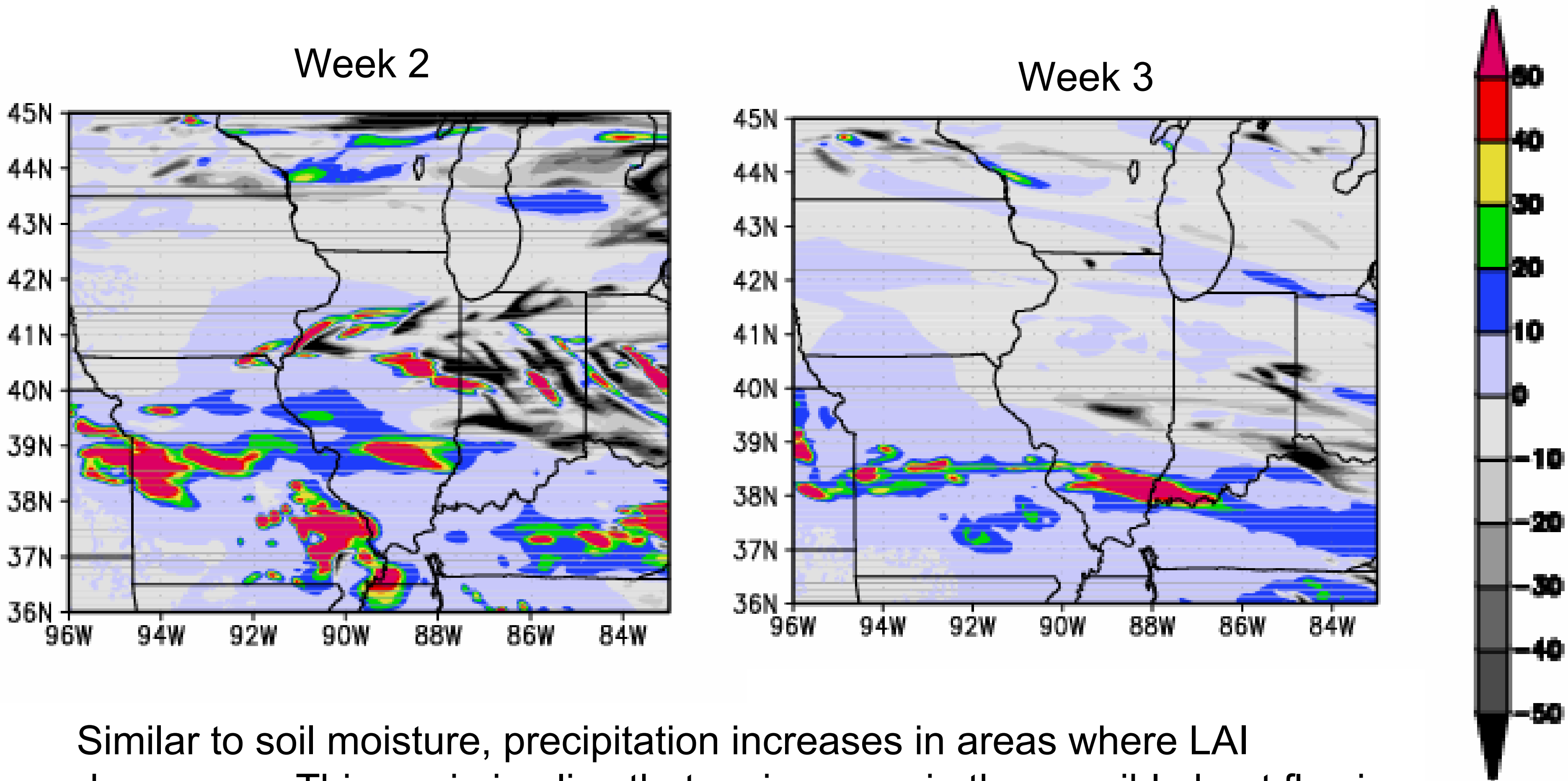
Qualitatively, the precipitation from the NLDAS-LAI experiment appears to validate best with observations. Precipitation increases occur in the southern part of the domain and appear to be due to local convective forcing.

Precipitation Differences (mm): Simulation Weeks 2 and 3
NLDAS – Default



Increase in precipitation in MO occurs in an area of relatively low soil moisture, implying that in the NLDAS case the convective temperature in this area is reached sooner and/or increased local moisture transport from more soil moist areas to the east.

Precipitation Differences (mm): Simulation Weeks 2 and 3
LAI – Default



Similar to soil moisture, precipitation increases in areas where LAI decreases. This again implies that an increase in the sensible heat flux is decreasing the time to reach the convective temperature.

Conclusions and Future Work

A more realistic representation of the surface boundary affects the amount and spatial distribution of precipitation and improves the model-generated precipitation as compared to NCEP observations. The NLDAS+LAI experiment appears to give the best result.

The NLDAS, LAI, and NLDAS+LAI experiments showed an increase in precipitation in the southern part of the domain, coincident with the areas of locally forced convection.

Increases in precipitation in both the NLDAS and LAI experiments appear to be linked to an increase in sensible heat flux, decreasing the the time to reach convective temperature.

Upcoming analysis of the data will quantitatively assess the scale dependence of convective organization between the simulations, using the factor analysis technique of Stein and Alpert (1993) on the2-D spectrum of integrated moisture flux convergence.