Sensitivity of convective precipitation development over the Southern Great Plains to patterns of soil moisture

RUTGERS

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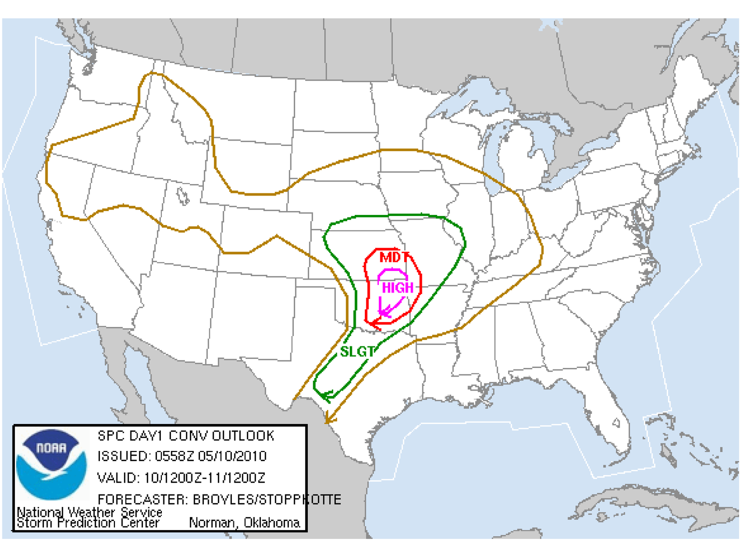
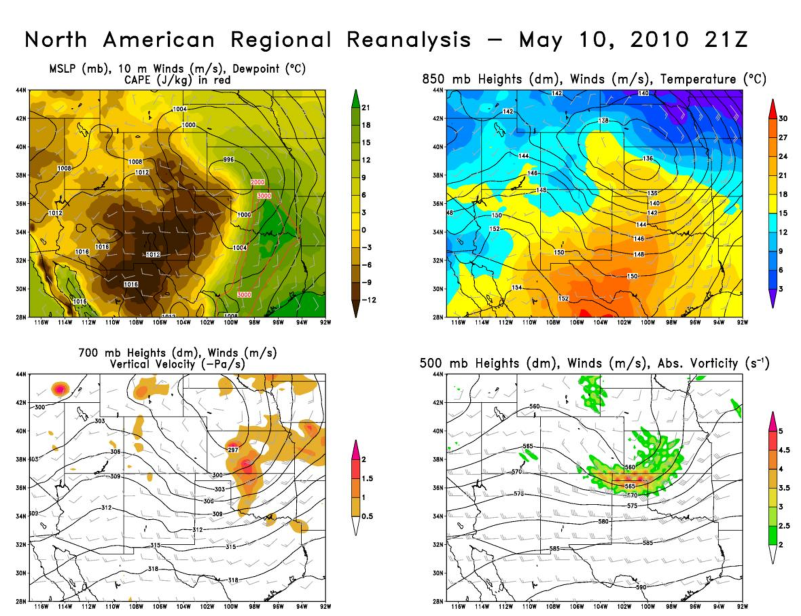
Introduction

This poster will serve as an outline for my proposed Ph.D. dissertation. It will explore the sensitivity of soil moisture observations to convective development over the Southern Great Plains (SGP) of the United States. Several studies have been done on the subject. On a broad scale, the Global Land Atmosphere Coupling Experiment (Koster et al. 2006) determined the SGP region was a hotspot for land atmosphere coupling, meaning there was a positive feedback between soil moisture and precipitation. A study by Pielke and Zeng (1989) determined irrigation systems (which artificially raise soil moisture) can enhance severe weather. They found in their experiment that the lifted index (LI) was much lower (-6.8) over irrigated land than over dry land (+3.0). The boundary between the two had an LI of -7.5 showing that the convergence zone between the two regions is the most unstable. Lanicci et al. (1987) demonstrated that changes in soil moisture distribution will affect the propagation of the dryline through the SGP by running model simulations and adjusting the soil moisture conditions. Holt et al. (2006) conducted a series of experiments over the region during a May 2002 convective case in which strong synoptic forcing was present. They found that an atmospheric model (COAMPS) coupled with the Noah land surface model would correctly approximate the location of convection. However, when a simple slab soil model was used instead of the Noah model, convection was non-existent at the time it was based on observations indicating the importance of an accurate representation of the land surface for the forecasting of convection. All of these studies point to a clear relationship between soil moisture and convection. I plan to investigate the relationship on synoptically active and synoptically benign days .

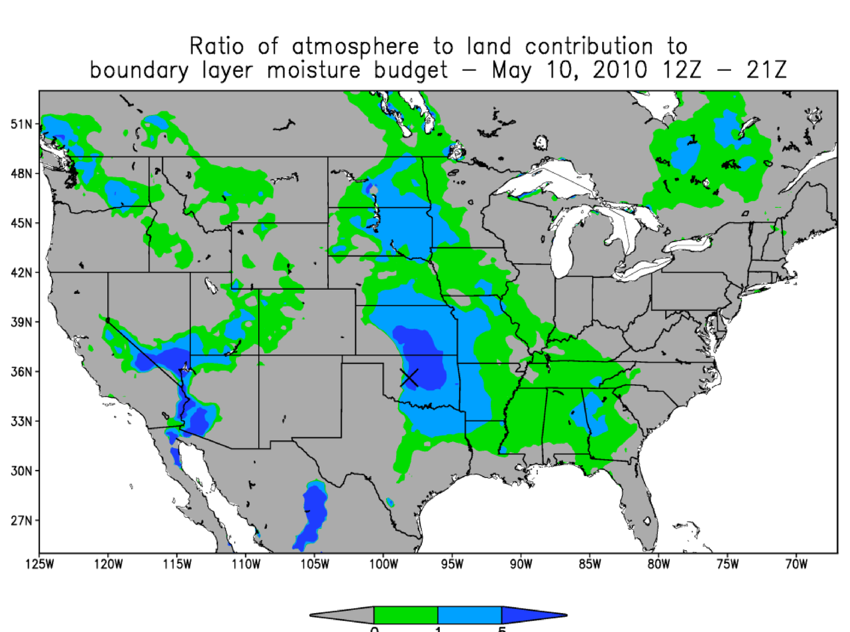
May 10, 2010 Overview

On May 10, 2010 a significant severe weather outbreak occurred over the SGP. This was a day in which strong synoptic forcing played a major role in convective development, with a digging trough at 500 mb, a strong low level jet transporting copious amounts of low level moisture out of the Gulf of Mexico, and a surface low pressure system to the north leading to enhanced wind shear and a propagating dry line. **Below left** is the day 1 convective outlook issued by the Storm Prediction Center at 06Z May 10, and **below right** is a 4 panel synoptic chart generated using North American Regional Reanalysis (NARR) data from 21Z May 10 which is the time convection began to develop. All of the parameters mentioned above are easily seen.



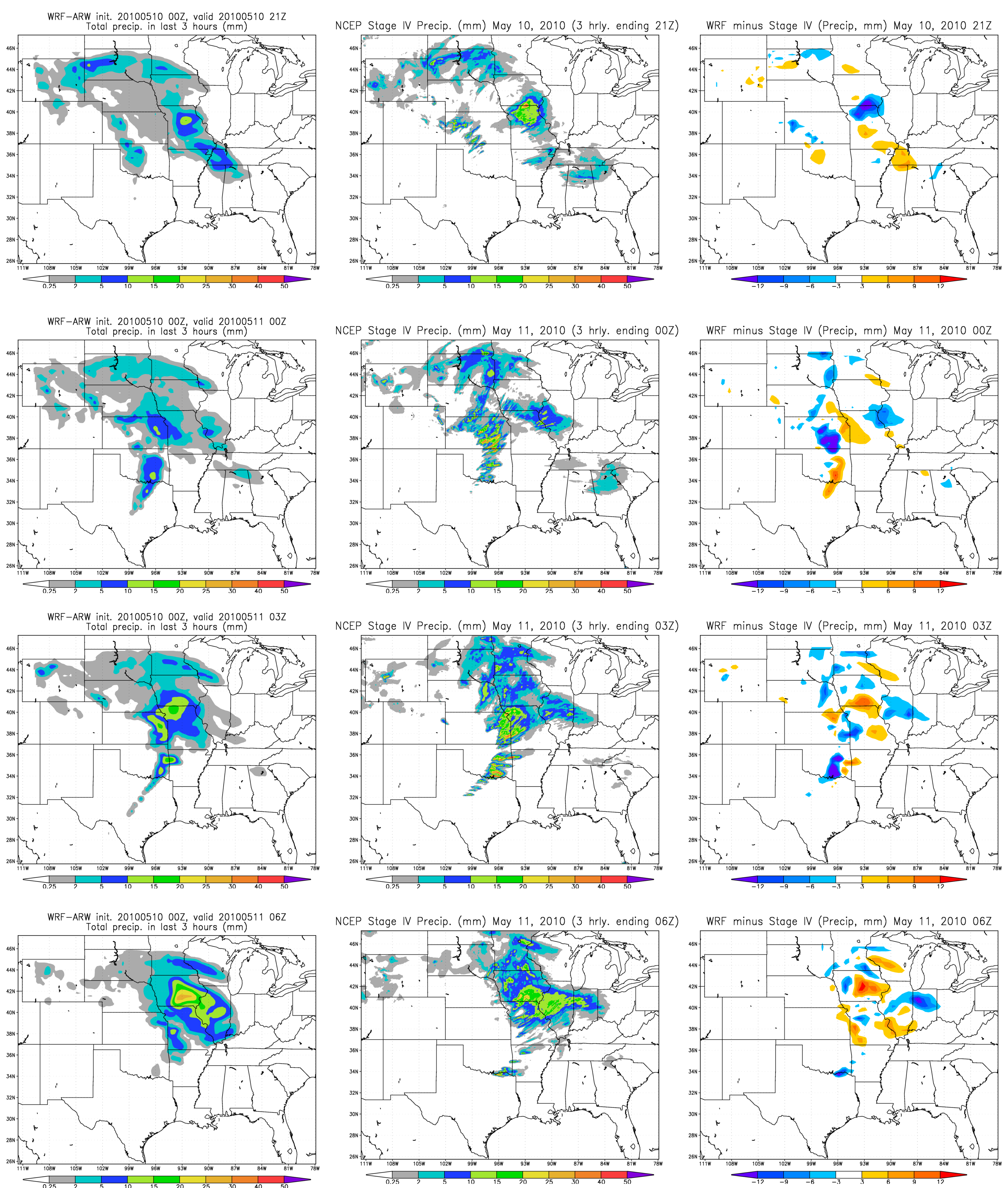


The mixing diagram approach is a good tool to use to visualize the ratio between the flux of moisture form atmospheric transport processes (such as a low level jet) to that from soil moisture. Santanello et al. (2009) give a good background on the subject. Basically, the daytime evolution of low level humidity and the latent heat flux (function of soil moisture) are used to estimate the amount of water vapor that needs to be transported by the atmosphere to create a balanced system. To the **right** is a plot of the previously described ratio. Notice the highest values over the SGP, indicating much stronger atmospheric transport of moisture.



Results from an un-nested WRF run

The Weather Research and Forecasting (WRF-ARW) model is run using NARR data as initial and boundary conditions. For this run, no nesting is done so the horizontal resolution is 32 km. The goal is to see whether or not the overall synoptic pattern is able to be simulated properly by the model. The model was started at 00Z May 10, 2010 and ran 30 hours through 06Z May 11, 2010.

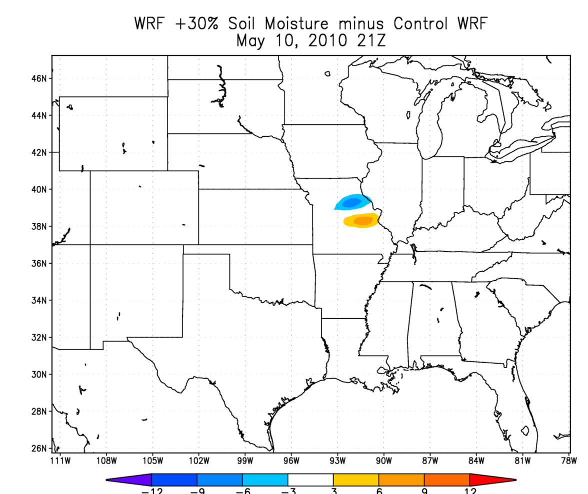


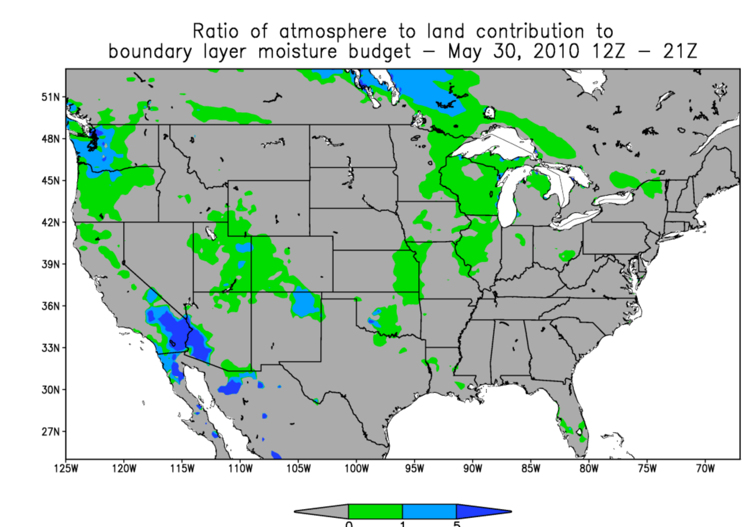
Above are figures representing 3 hour precipitation totals from different sources. Each row represents a different ending time (from top to bottom, 21Z May 10, 00Z, 03Z, and 06Z May 11). The first column represents results from the WRF run while the second column shows the National Centers for Environmental Prediction (NCEP) Stage IV precipitation analysis for the same period, which is at a much higher 4 km resolution. The final column shows the difference between the two. It can be seen that the overall pattern of convection is established in the WRF runs, with differences primarily in location and intensity but this is expected due to the low resolution of the WRF run.

Future Work

The goal of this project is to assess the role of soil moisture on the development of convection. Because of this, the model runs need to be done at a much higher resolution due to the mesoscale nature of convection. I also plan to adjust the soil moisture fields to assess model performance with different initial soil moisture conditions. I will make adjustments both uniformly and based on satellite measurements of soil moisture patterns from the Soil Moisture Ocean Salinity (SMOS) satellite. A good statistical summary of the SMOS data was the subject of Collow et al. (2012). By using the SMOS data to change initial soil moisture, I will also be able to determine the usefulness of data from the satellite as a tool for weather forecasting.

I performed the same simulation in WRF, with the only difference being that initial soil moisture fields were adjusted up by 30%. Results at all times show there was no major differences between the run that used increased soil moisture and the control run (non-adjusted soil moisture). This could be because strong atmospheric transport negated any effects from land surface processes or the resolution of the model was too low. On the **right** is the difference between the two at 21Z May 10.





To the **left**, is a mixing diagram from May 30, 2010, another day with convection, done in the same manner as May 10 case. It is easily seen that on this day moisture transport from the surface is the dominant source of moisture in the lower atmosphere. The next step is to investigate whether or not results from changing the initial soil moisture will be different.

Conclusions so far

1. A synoptic scale WRF run does a fairly good job at simulating the presence of a convective event when compared to the NCEP Stage IV precipitation product.
2. Applying an upward increase in soil moisture for all locations had little effect on the simulated precipitation patterns. This could be due to either the low resolution of the model simulation or the fact that the day was dominated by strong atmospheric transport processes.
3. Much more work still stands to be done, including using different cases, higher resolution models, and adjusted soil moisture patterns to fully determine the sensitivity of soil moisture patterns to convection.

References

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