Evaluation of convection-allowing ensemble forecasts of extreme rainfall associated with a mesoscale vortex

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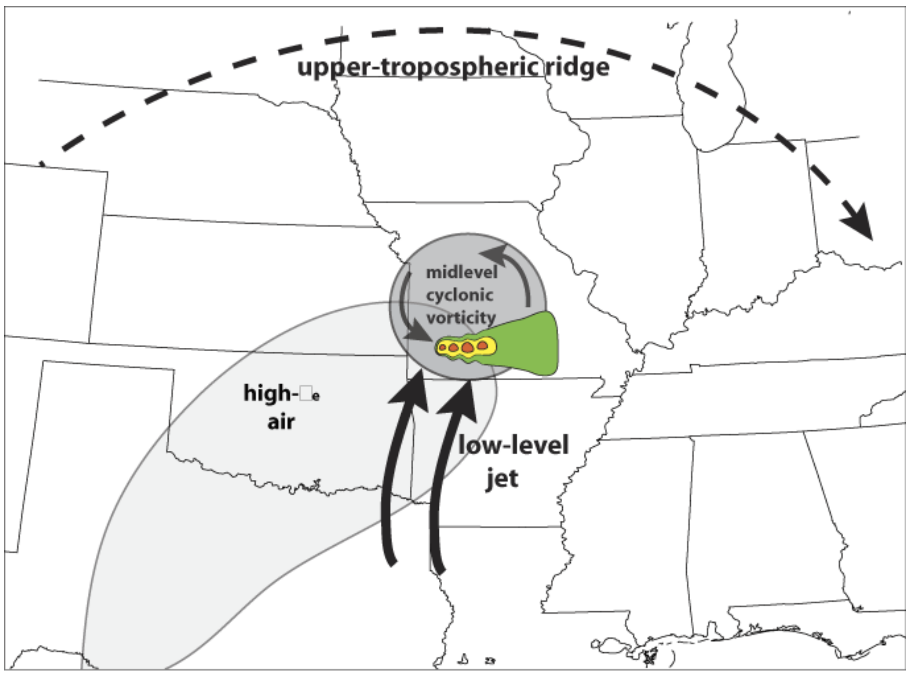
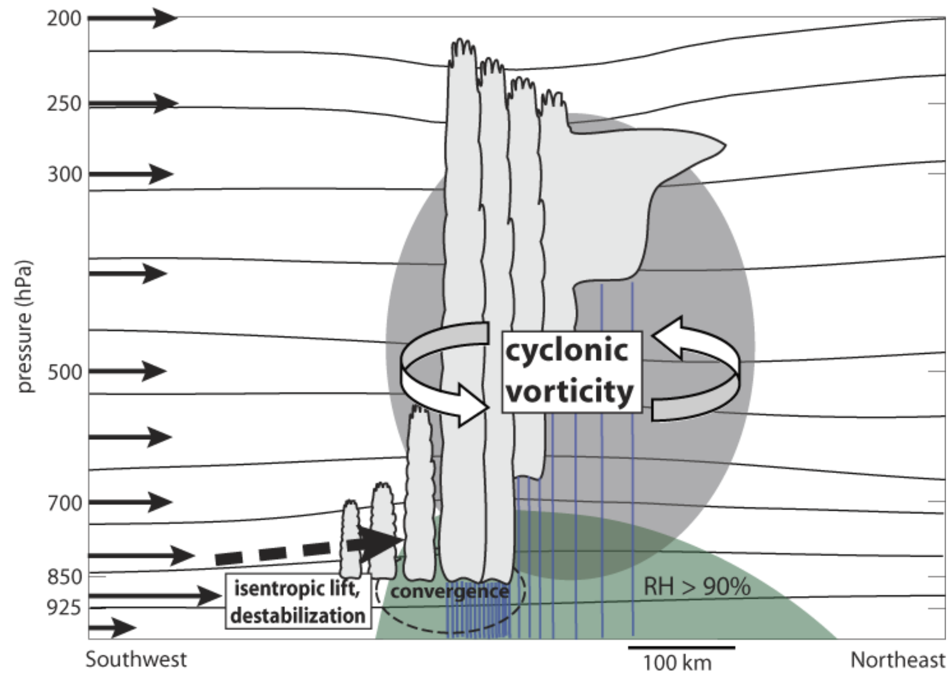
Extreme local rainfall near mesoscale vortices

- Extreme local rainfall and flash flooding sometimes occurs near pre-existing mesoscale vortices (e.g., Bosart and Sanders 1981; Fritsch et al. 1994; Trier and Davis 2002)

- Schumacher and Johnson (2009) synthesized the common conditions for these events, including lifting where a low-level jet interacts with the vortex





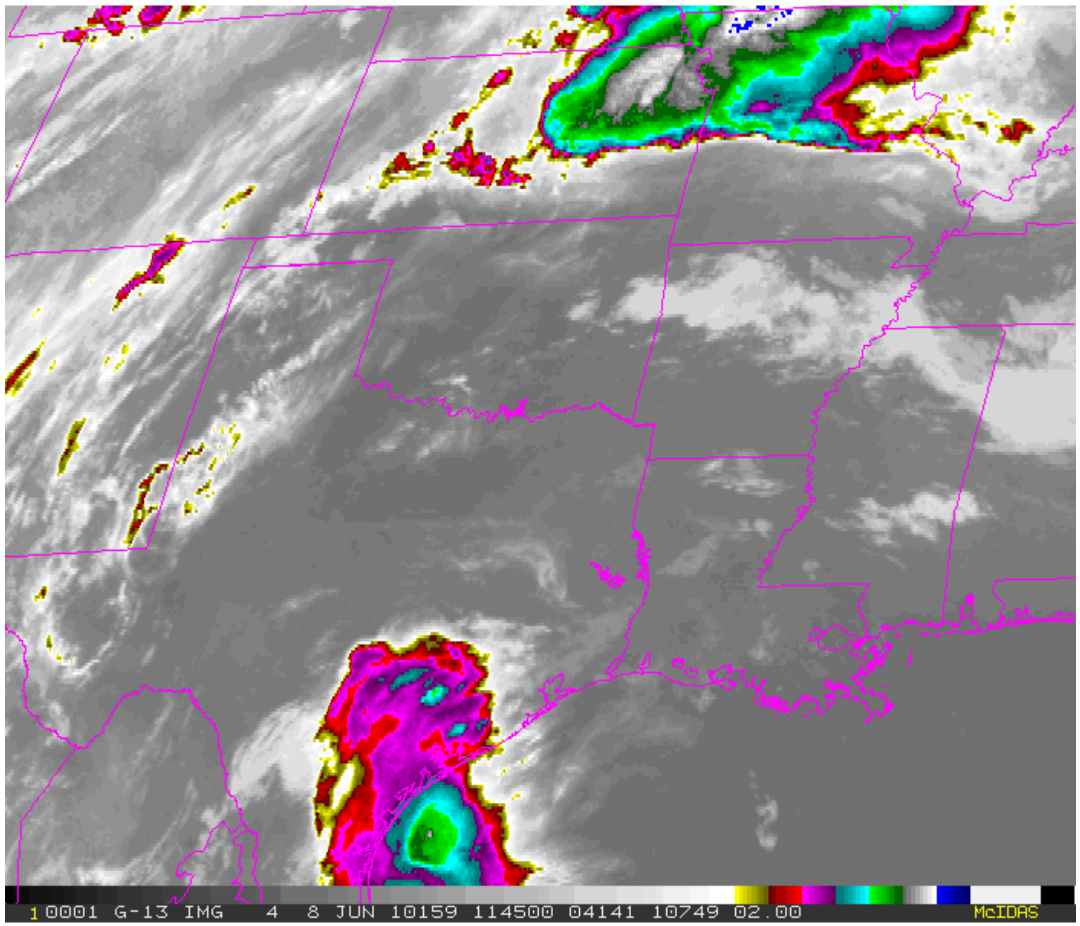
Schumacher, R. S. and R. H. Johnson, 2009: Quasi-stationary, extreme-rain-producing convective systems associated with midlevel cyclonic circulations. *Weather and Forecasting*, **24**, 555-574.

An unanswered question…

- How often are these synoptic/mesoscale conditions present, but an extreme rain event does **not** occur?
  - Or, put another way, what factors are both necessary and sufficient for this sort of event?
- We will use an ensemble of high-resolution numerical forecasts to attempt to answer this question

9-11 June 2010

- Flooding on Guadalupe River (near San Antonio) on the 9th, east of Dallas on the 10th, deadly Caddo Gap flood on the 11th



IR satellite imagery courtesy of Dan Lindsey, CSU/CIRA

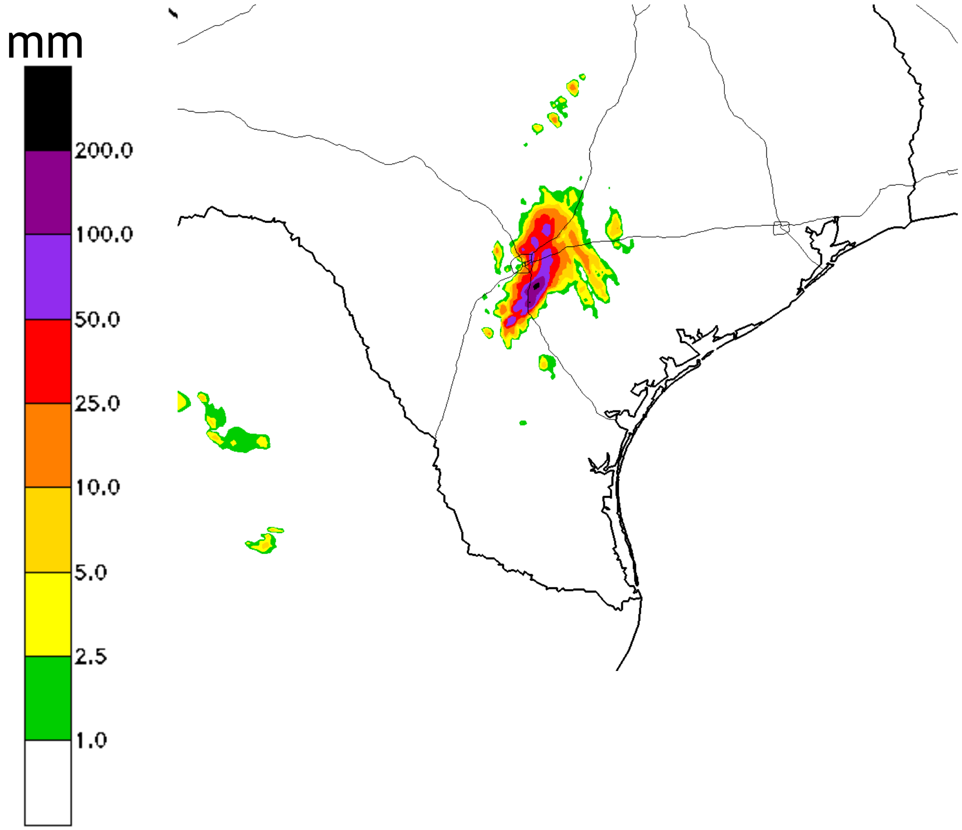
IR loop

CAPS 4-km ensemble

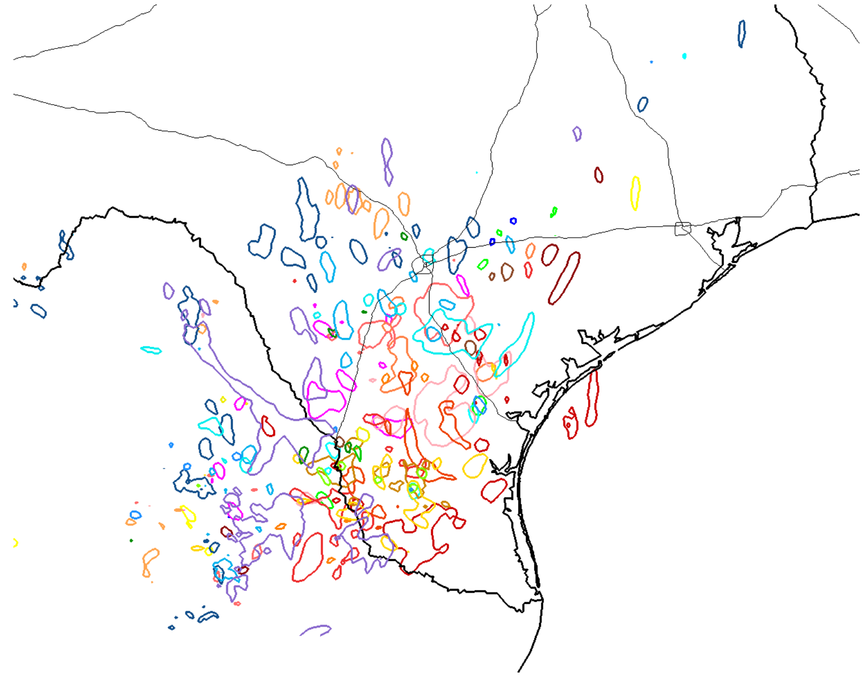
- To determine the factors that were favorable for, or detrimental to, the production of extreme rainfall, an ensemble of high-resolution forecast data are used
- The 26-member CAPS ensemble was run in support of the NSSL/SPC/HPC Hazardous Weather Testbed spring experiment from April-June 2010
- Ensemble includes diversity of models (ARW, NMM, ARPS), physics, and initial conditions
- Thanks go to all those involved in setting up and running the Spring Experiment – many more talks tomorrow at 10:30 am (session 9A)

9 June 2010

Stage IV analysis, 6 hr ending 06Z/09 June

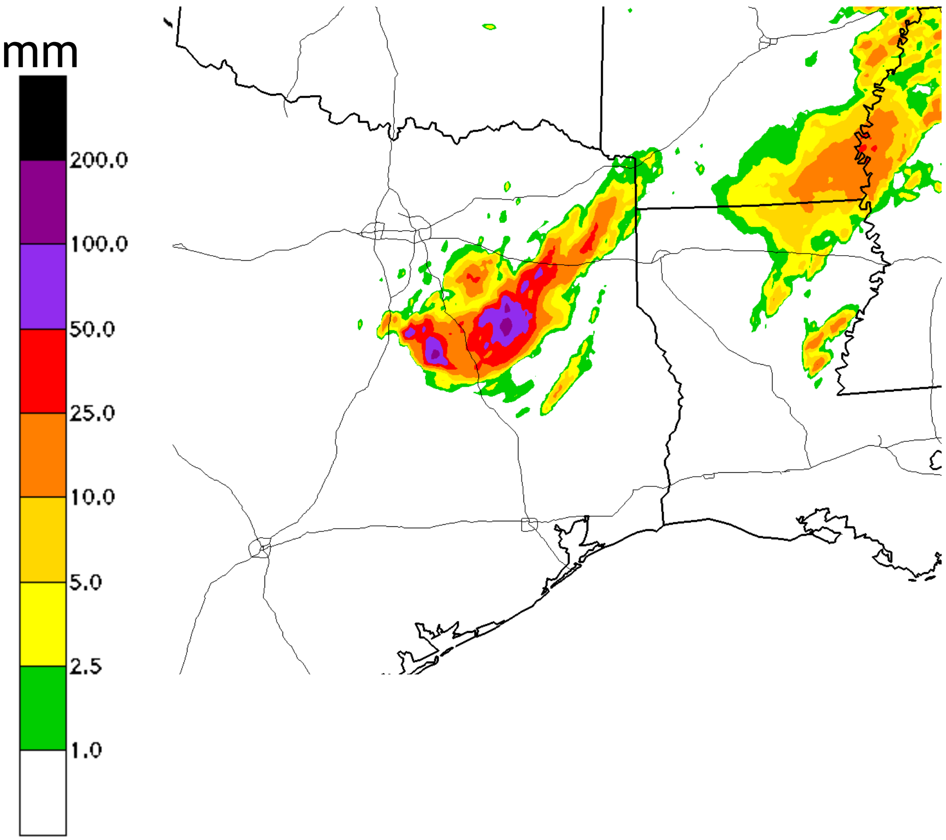


Ensemble spaghetti plot for 50 mm
24-30 hour forecast (init 00Z/08)

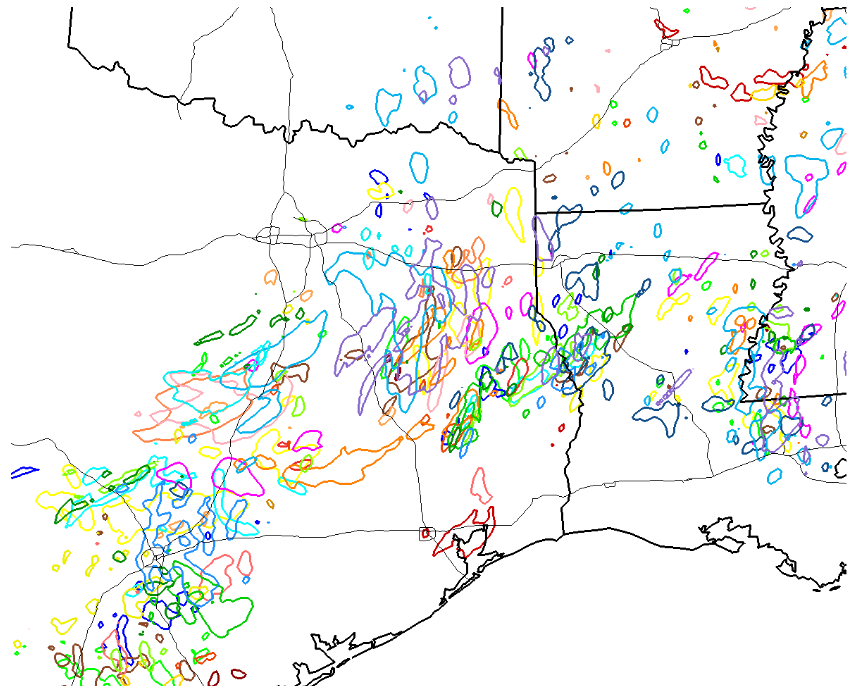


10 June 2010

Stage IV analysis, 6 hr ending 06Z/10 June

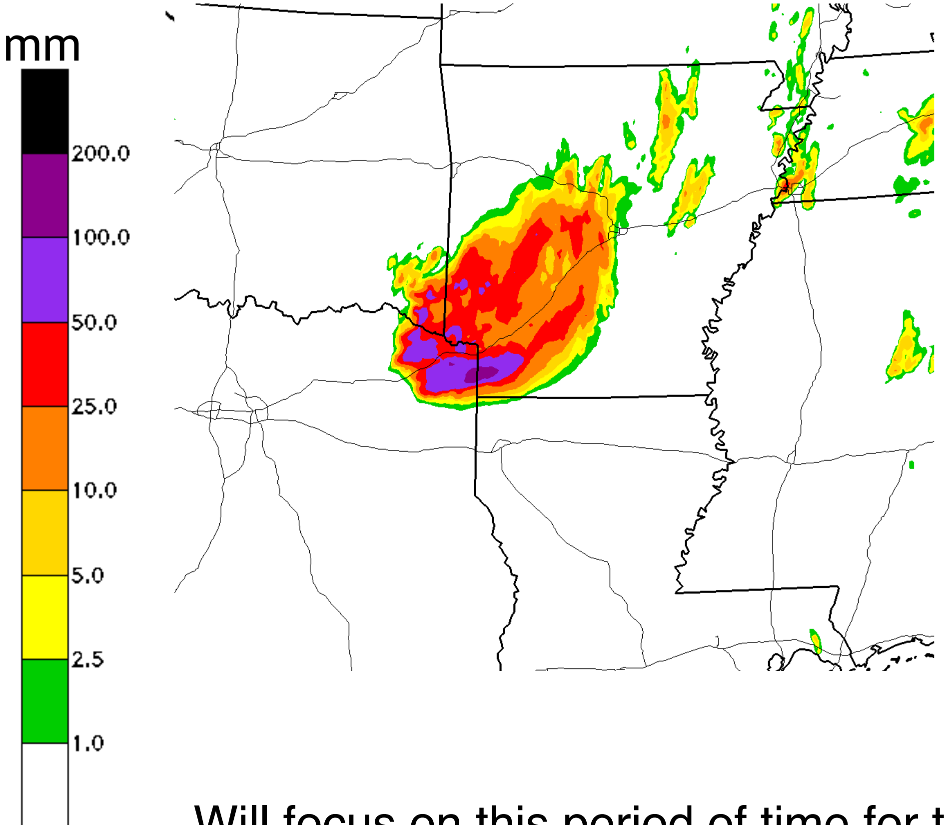


Ensemble spaghetti plot for 50 mm
24-30 hour forecast (init 00Z/09)

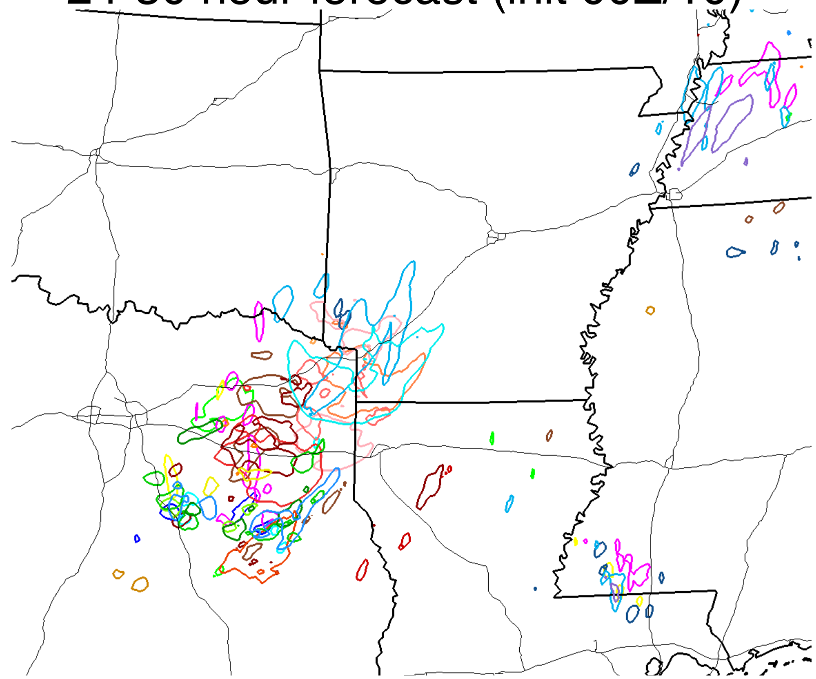


11 June 2010

Stage IV analysis, 6 hr ending 06Z/11 June



Ensemble spaghetti plot for 50 mm
24-30 hour forecast (init 00Z/10)



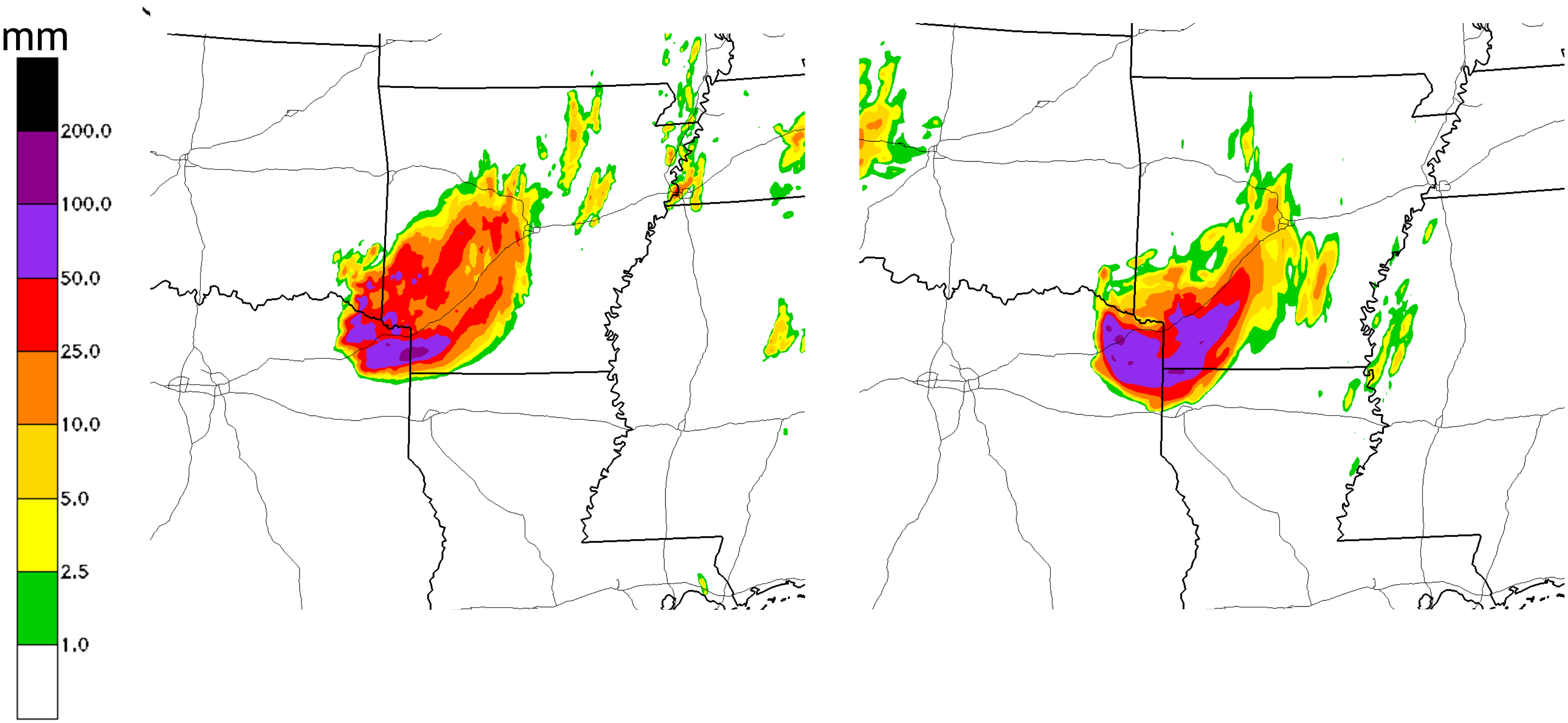
Will focus on this period of time for the rest of the presentation…
(This is the 6 hours leading up to the Caddo Gap flood.)

11 June 2010

Ensemble member forecasts range from very good…

Stage IV analysis, 6 hr ending 06Z/11 June

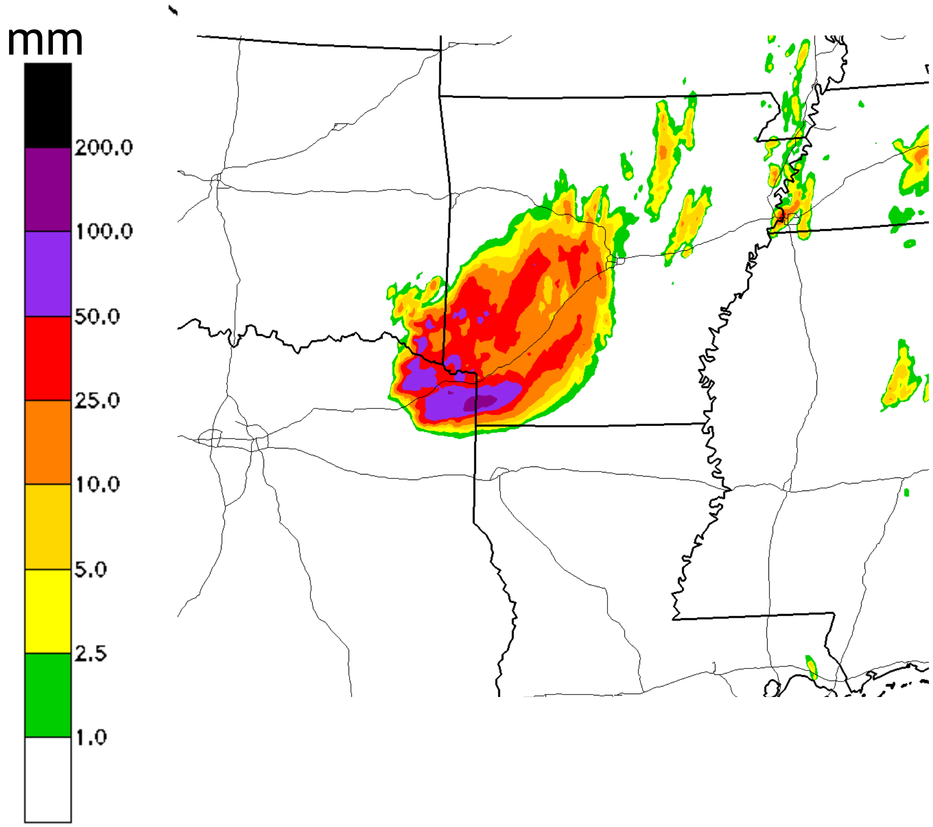
24-30 hour forecast (init 00Z/10)
Member s4m5_arw



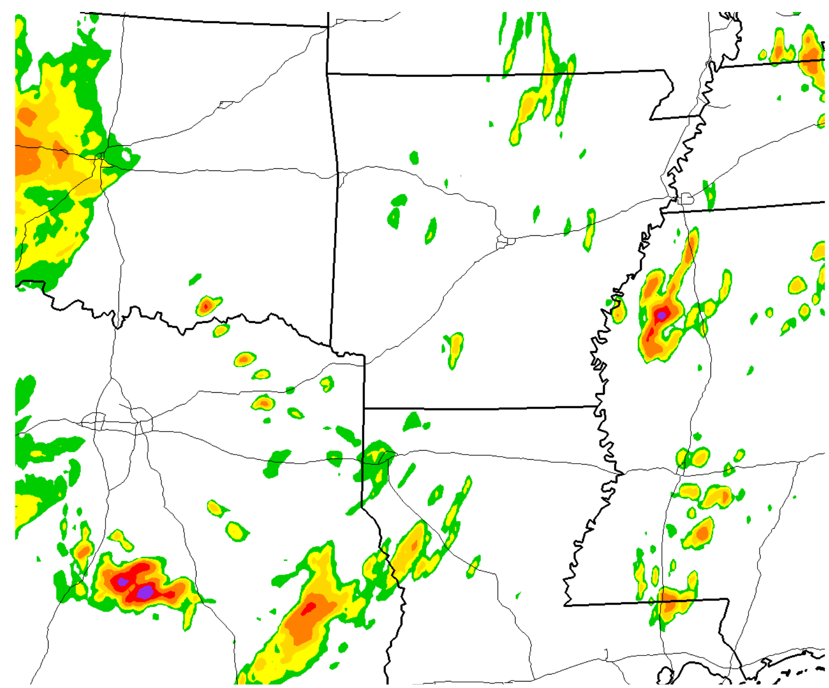
11 June 2010

…to not so good

Stage IV analysis, 6 hr ending 06Z/11 June



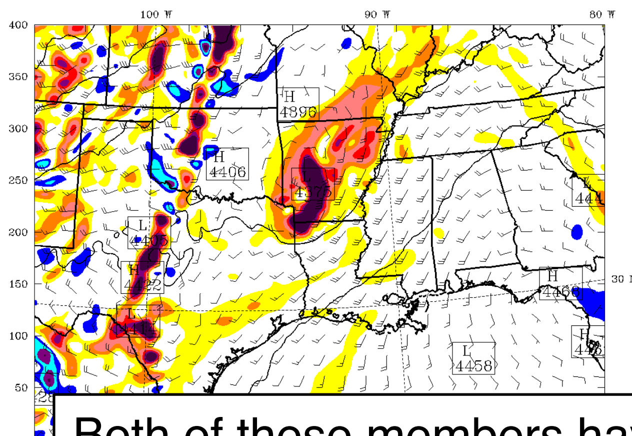
24-30 hour forecast (init 00Z/10)
Member s4m15_arw

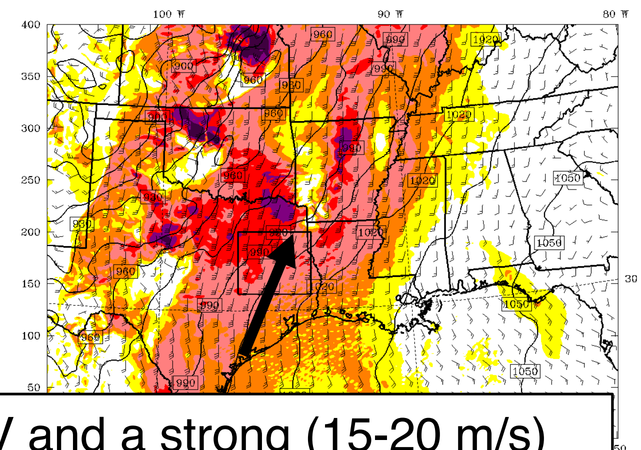


11 June 2010: 0600 UTC (30-h fcst)

600-hPa heights, winds, abs. vorticity

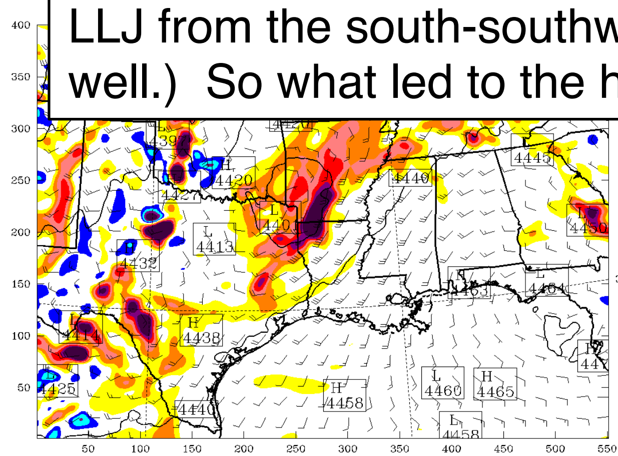
900-hPa heights, winds, isotachs

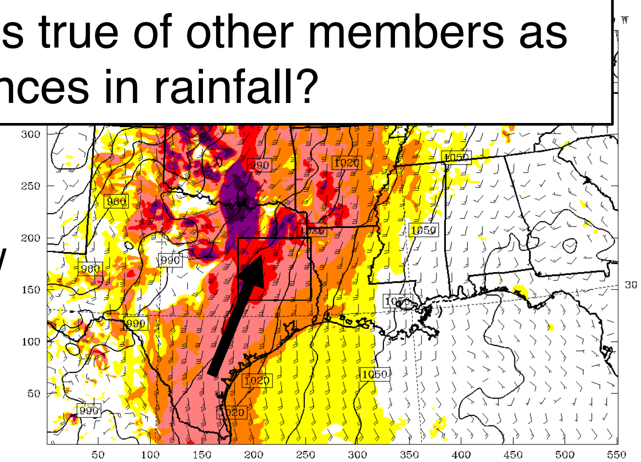




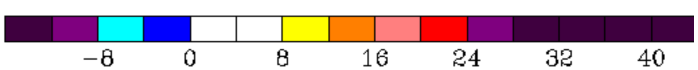
s4m5_arw
(wet)

Both of these members have the MCV and a strong (15-20 m/s) LLJ from the south-southwest. (This is true of other members as well.) So what led to the huge differences in rainfall?





s4m15_arw
(dry)



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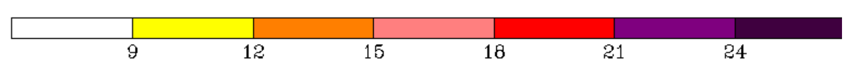
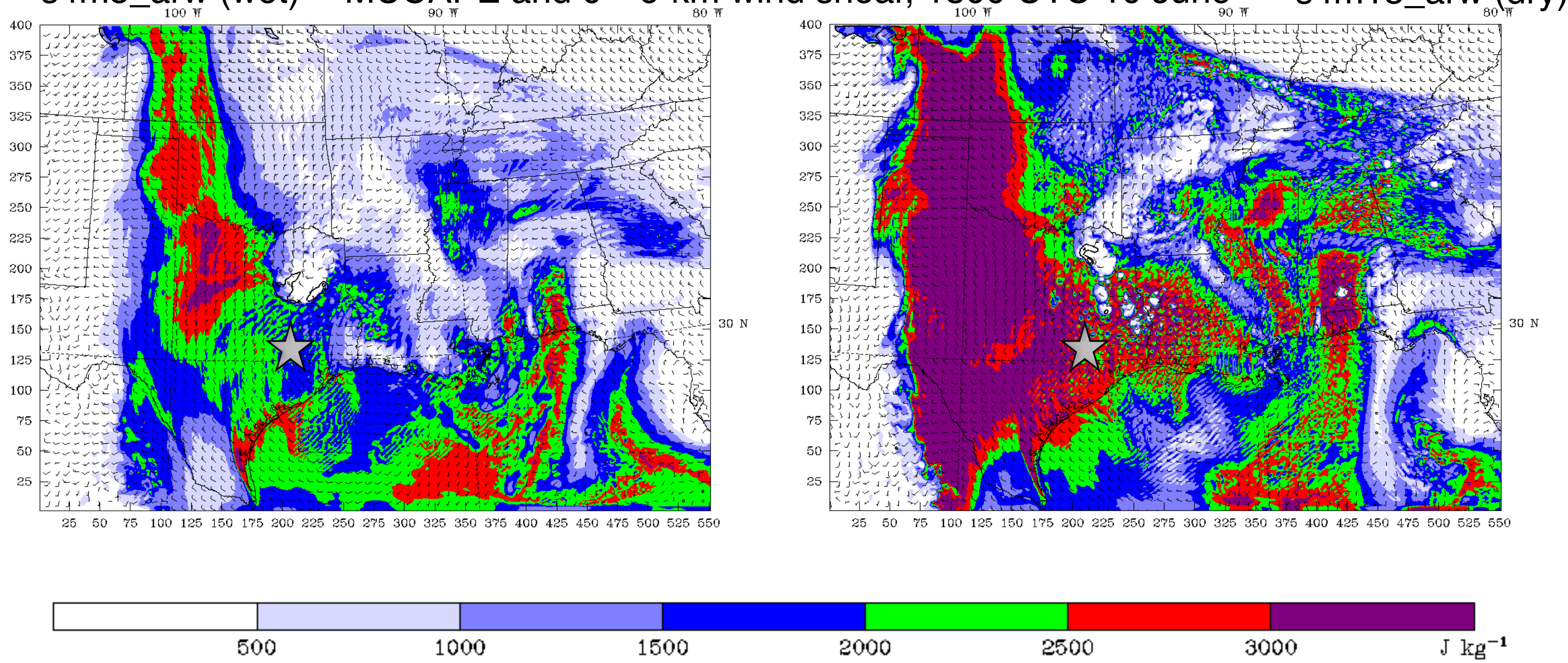


m/s

Afternoon CAPE

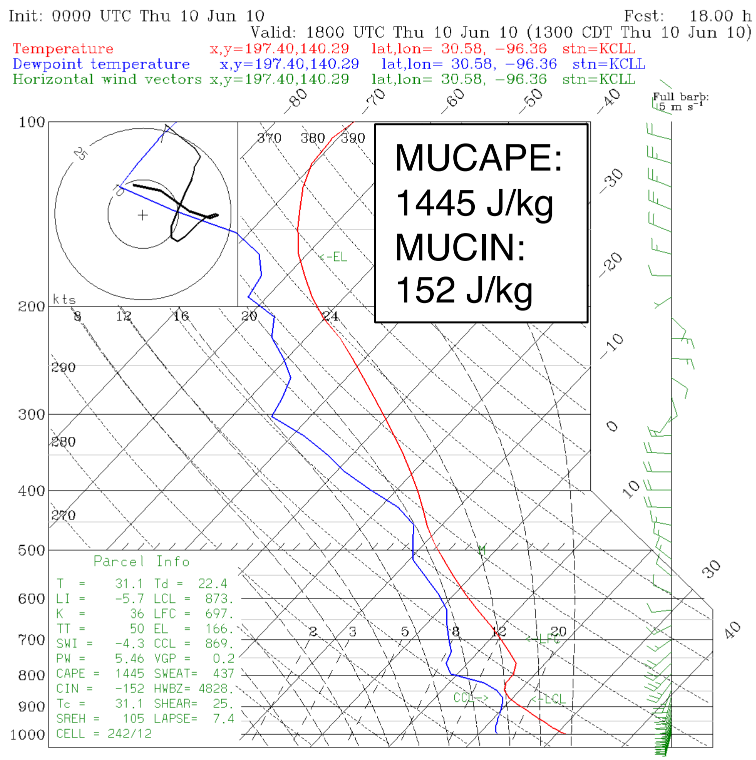
- Substantially less CAPE (and more CIN) during the day in the run that correctly predicted the nighttime heavy rain

s4m5_arw (wet) MUCAPE and 0—6-km wind shear, 1800 UTC 10 June s4m15_arw (dry)

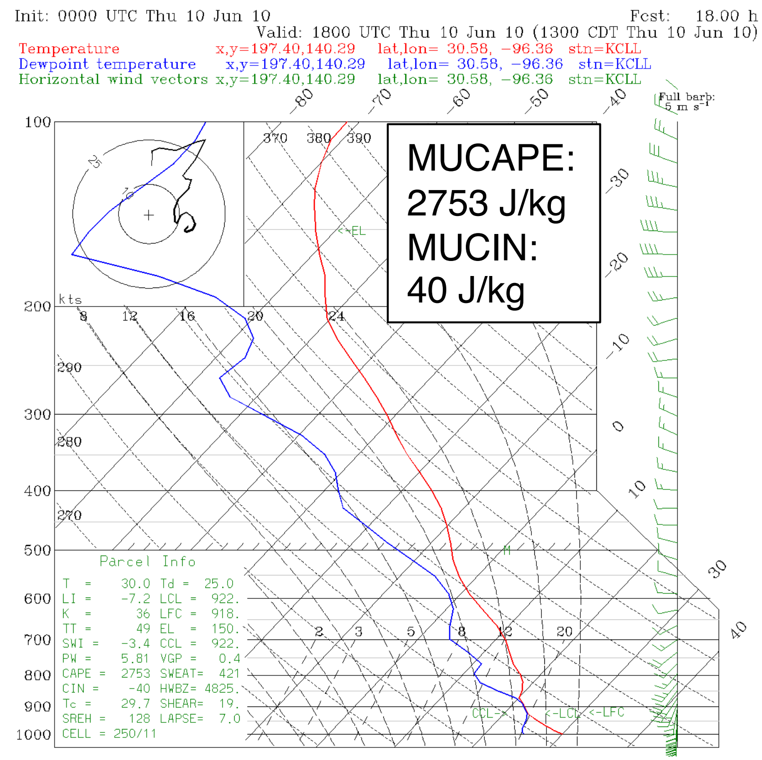


Soundings from 18Z at CLL

s4m5_arw: RUC LSM; YSU PBL
Deep, dry PBL; less CAPE, more CIN



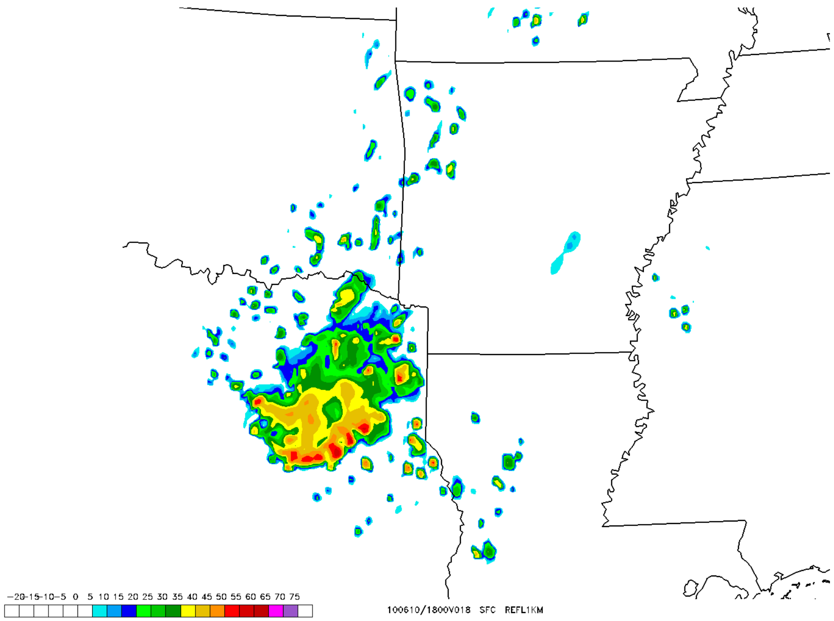
s4m15_arw: Noah LSM; MYJ PBL
Shallow, moist PBL; more CAPE, less CIN



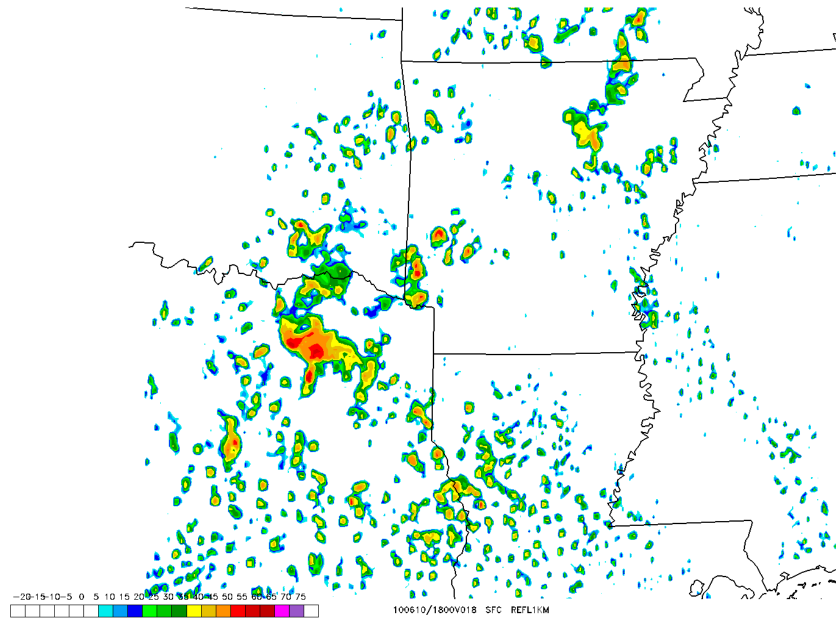
Similar results from other YSU vs. MYJ members; consistent with findings of Weisman et al. (2008) that YSU typically creates deeper PBL than MYJ scheme

Evolution of convection

Convection mainly suppressed during day; focuses near MCV after dark; moves slowly



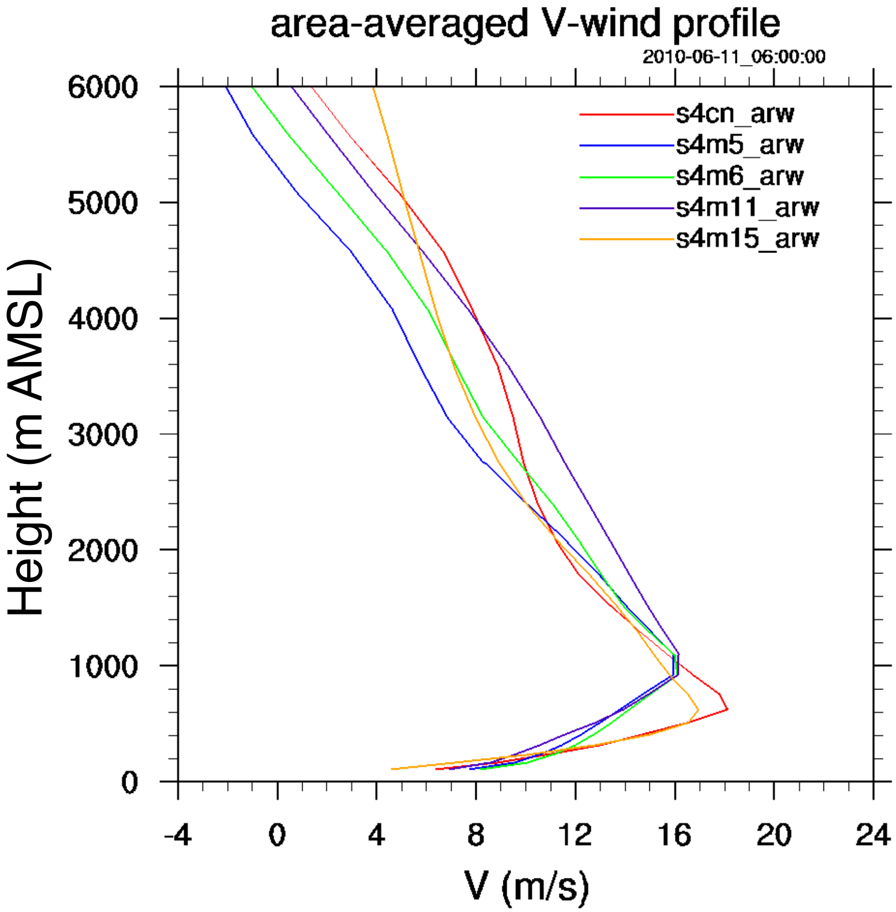
Fast-moving squall line develops in afternoon; stabilizes environment; no nighttime convection



Simulated reflectivity from 18 UTC 10 June – 06 UTC 11 June

Vertical structure of LLJ

- (Apparently) because of differences in depth of daytime PBL, the vertical structure of LLJ differs also
- MYJ members (warm colors) have lower, stronger LLJ
- YSU (cool colors) members have higher, weaker LLJ
- Nearby profilers don't capture the wind structure in the lowest 500 m; underscores need for more observations of low-level winds at night!
- Storm et al. (2009, *Wind Energy*) found that simulated LLJs are often too weak and maximum is too high



(averaged over box shown on 900-mb map)

Conclusions

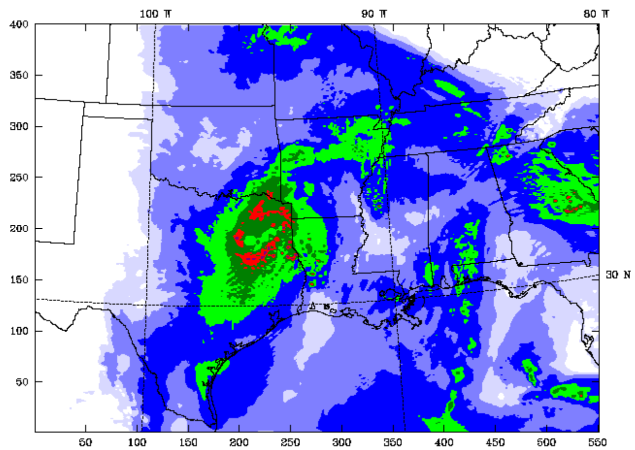
- An ensemble of high-resolution forecasts was analyzed to determine the factors favorable for, or detrimental to, extreme rainfall on 9-11 June 2010
- Even within a synoptic environment known to be conducive to extreme local rainfall, there was relatively large spread in the ensemble's rainfall predictions
- Differences in the predictions of extreme rainfall on 11 June appear to have come from differences in the afternoon boundary layer
- In YSU members: deep, dry boundary layer → convection holds off during day (more CIN), → moisture converges around MCV → big nocturnal rainstorm (very similar to obs)
- In MYJ members: shallow, moist boundary layer → convection initiates during day → forms cold pool → stabilizes area surrounding MCV → little nocturnal convection

Ensemble-related questions for future investigation…

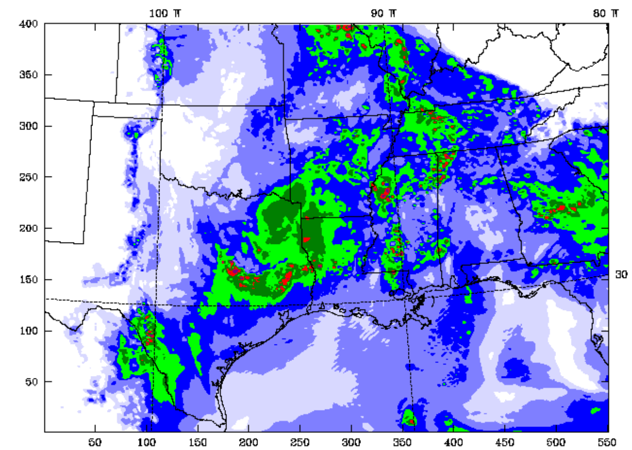
- Similar analysis for other events: are findings similar?
- Determine the importance of different soil moisture/land-surface models in the evolution of convection in this case
- What is the character of modeled low-level jets, do they reflect reality, and how do they affect forecast precipitation?
- Is this ensemble reasonably reflecting the uncertainty in these situations?
- Given this uncertainty information, and the high spatial variability in heavy rainfall, how best to communicate this information, and to apply it when making a deterministic forecast? (And how will users understand it/interpret it?)

11 June 2010: Precipitable water

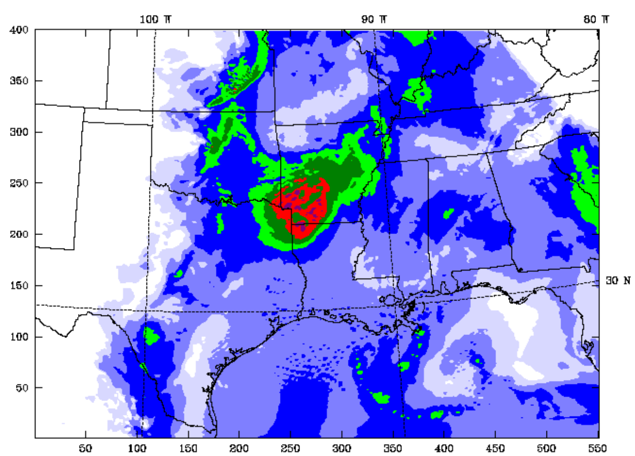
00Z/11



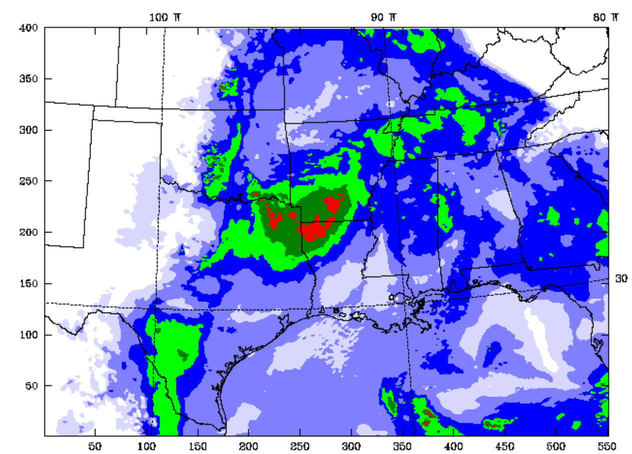
s4m5_arw
(wet)

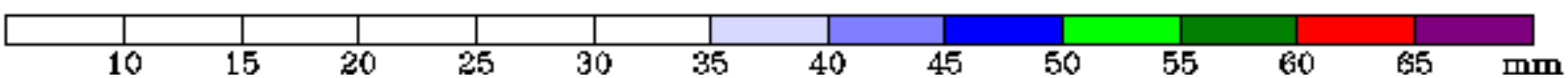


06Z/11



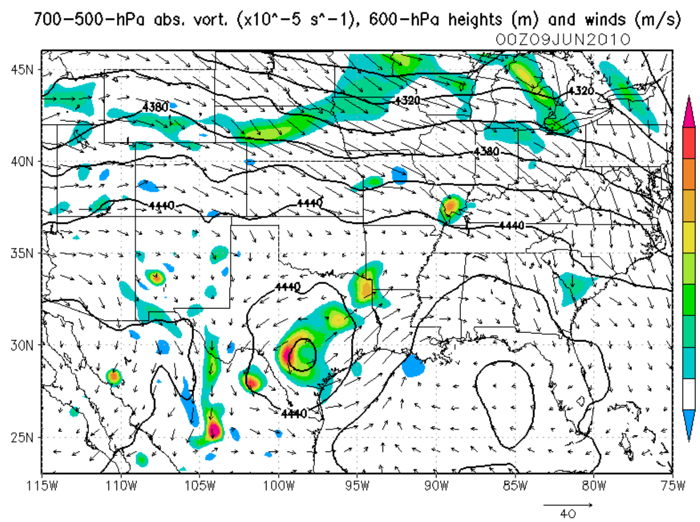
s4m15_arw
(dry)



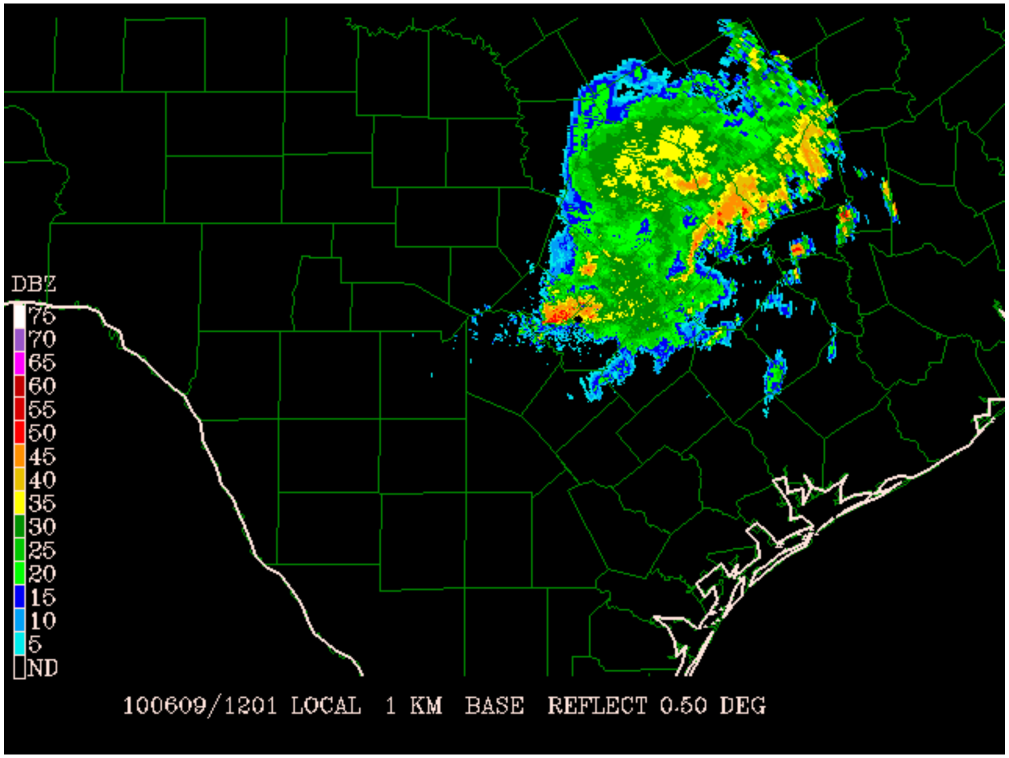


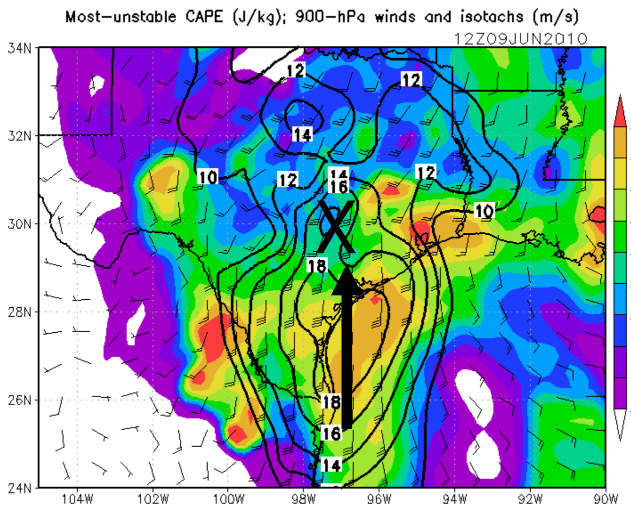
9 June 2010

This series of events has many similarities to others occurring near LLJs and midlevel vortices…



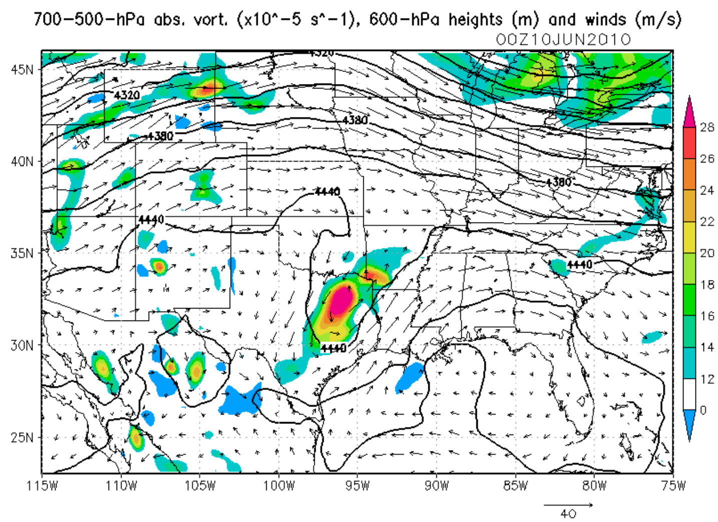
←Average vorticity in 700-500-hPa layer at 00Z



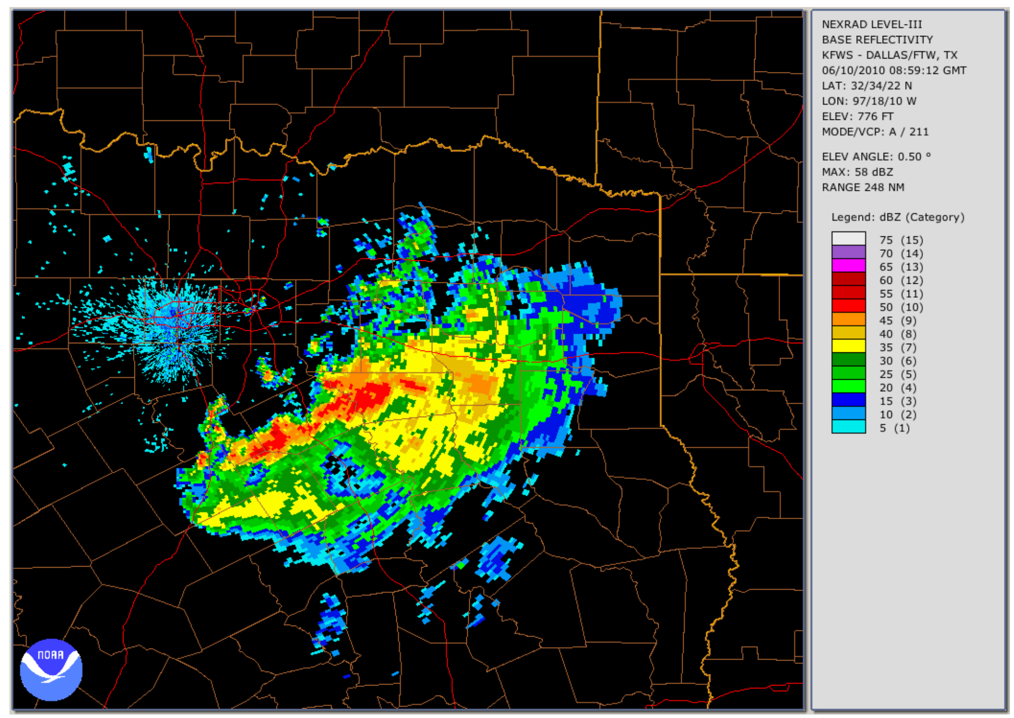


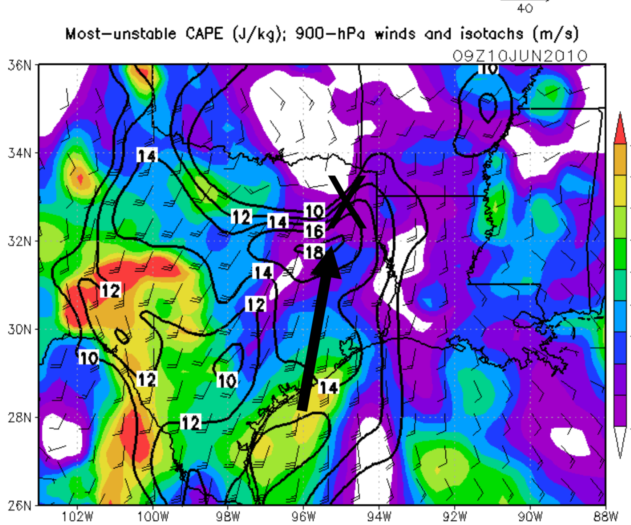
←Most-unstable CAPE (colors), 900-hPa winds and isotachs (m/s) at 12Z

10 June 2010



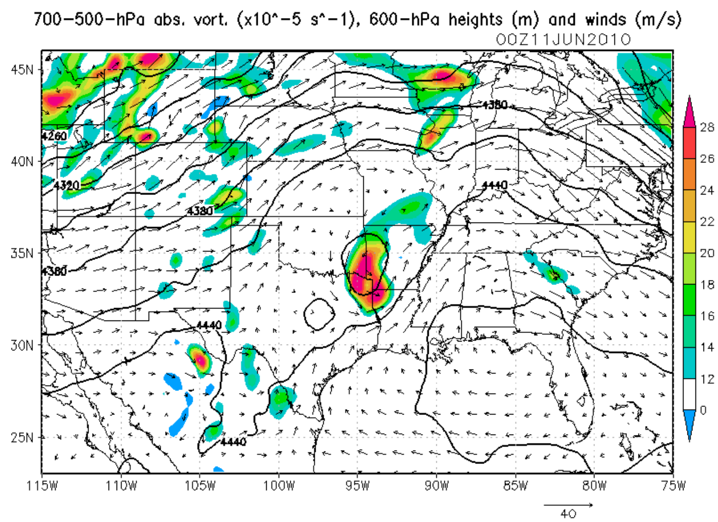
←Average vorticity in 700-500-hPa layer at 00Z



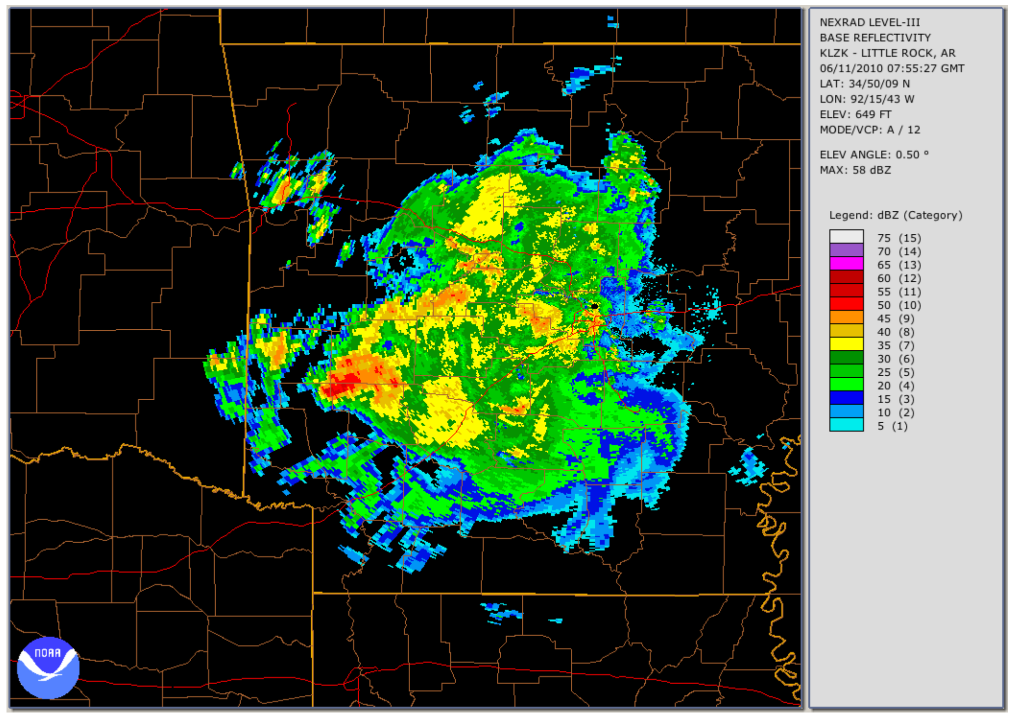


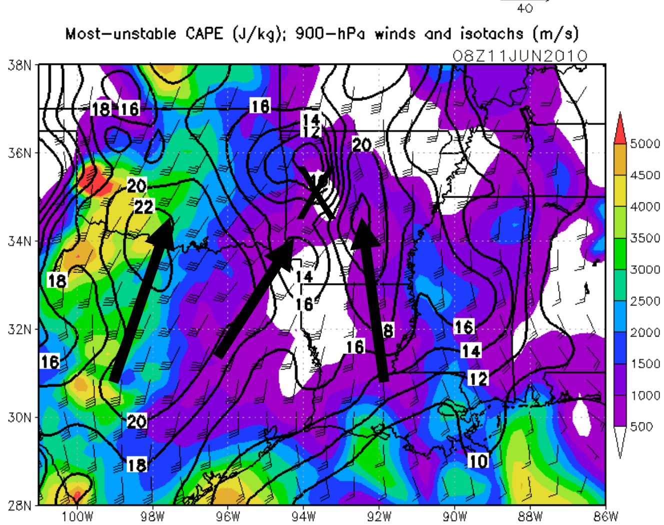
←Most-unstable CAPE (colors), 900-hPa winds and isotachs (m/s) at 09Z

11 June 2010



←Average vorticity in 700-500-hPa layer at 00Z





←Most-unstable CAPE (colors), 900-hPa winds and isotachs (m/s) at 08Z