

Evaluation of the Southwest warming effects on cloud microphysics of convective systems in the central U.S.

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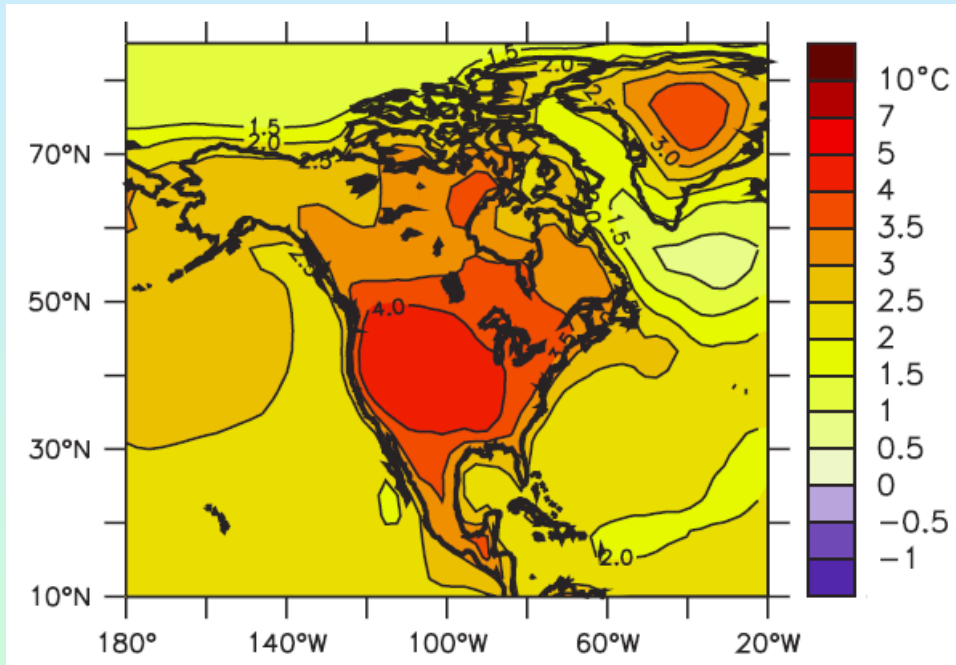
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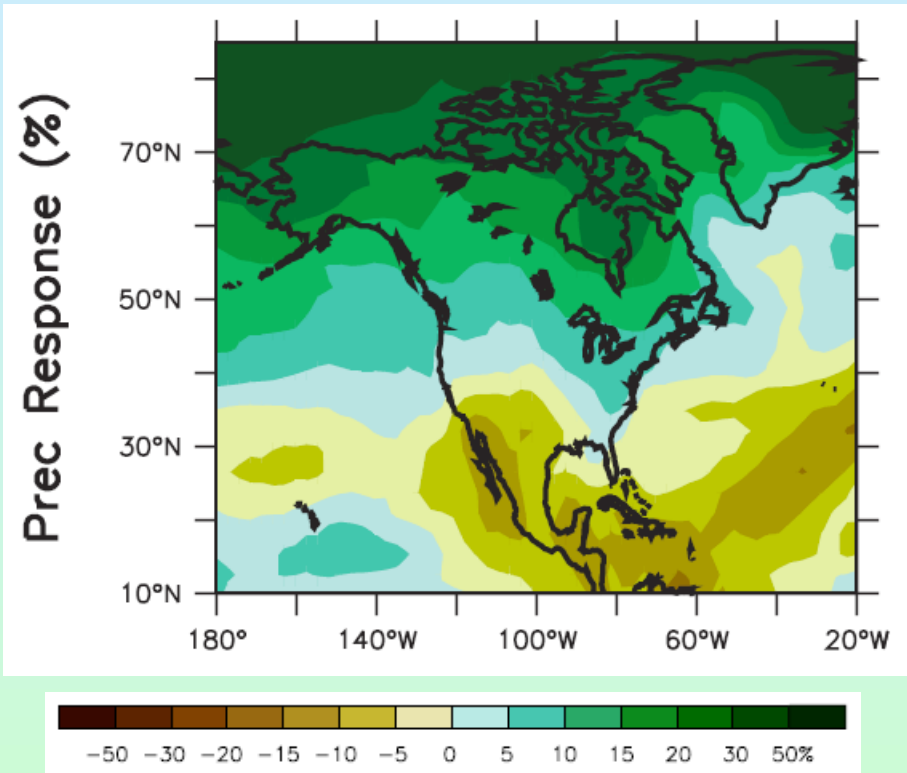
Introduction

- Global warming is not uniform; the southwestern U.S. and northern Mexico is one of “hot spots” globally.
- The U.S. has two unique climate change features in the past:
 - southwestern U.S. strong warming
 - central-eastern U.S. slight cooling (summer)
- The IPCC AR4 ensemble models project a 4-5 °C warming in SW by 2090, compared to 2-3 °C in central-eastern U.S.
 - some regional models even predicted summer cooling in central-eastern U.S. in future
- What is the implications of this contrasting warming to cloud dynamics and microphysics, aside from influencing storm propagation and development?

Warming and drying in the southwestern U.S. (IPCC AR4)

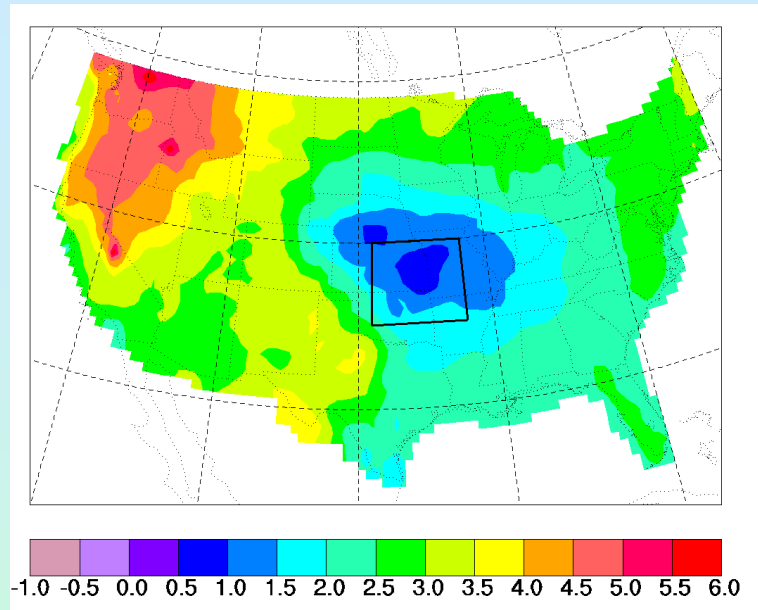


Summer temperature changes over North America from A1B simulations between 1980 to 1999 and 2080 to 2099, averaged over 21 models.



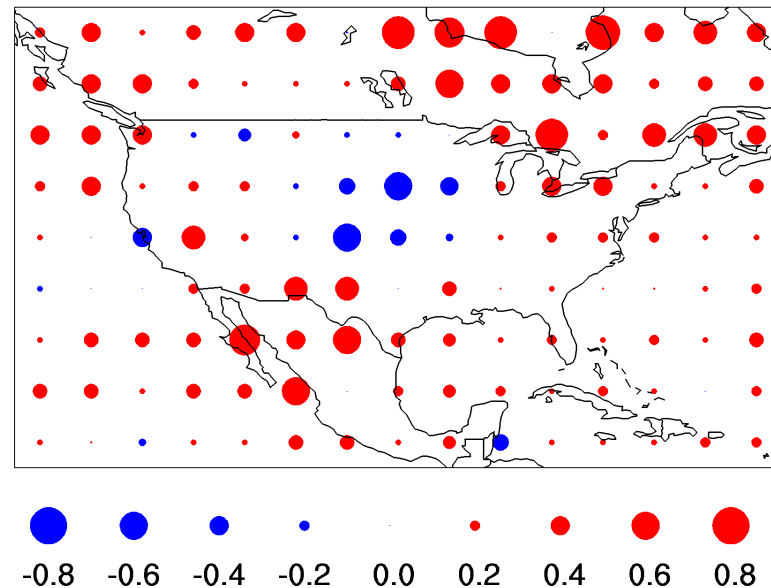
Annual precipitation change from 1980-2000 to 2080-2099.

Summer “warming hole” in central U.S.



Summer daily maximum temperature change (C) between 2040's and 1990's as simulated by a regional model (Pan et al. 2004, GRL)

Observed summer daily mean temperature changes (C/decade) between 1976-2000



Possible warming impacts - Dynamics

- Higher PBL height
 - Stronger turbulence
 - Deeper convection
- Stronger low-level jet
 - Larger inertial effect in night (Blackadar)
 - More horizontal convergence
 - Stronger nocturnal storms
- Stronger inversion lid
 - Fewer, but more severe storms
 - Later storm development

Possible warming impacts - Microphysics

- Higher cloud top and stronger updraft
 - More chance of cold cloud processes
 - Deeper cold (sub-zero) layer deep
- Drier environment
 - Entrainment becomes more important
 - More aerosols (through windblown dust, wildfire)
- Static stability change
 - Weaker night inversion – earlier convection triggering (locally)
 - Stronger daytime instability

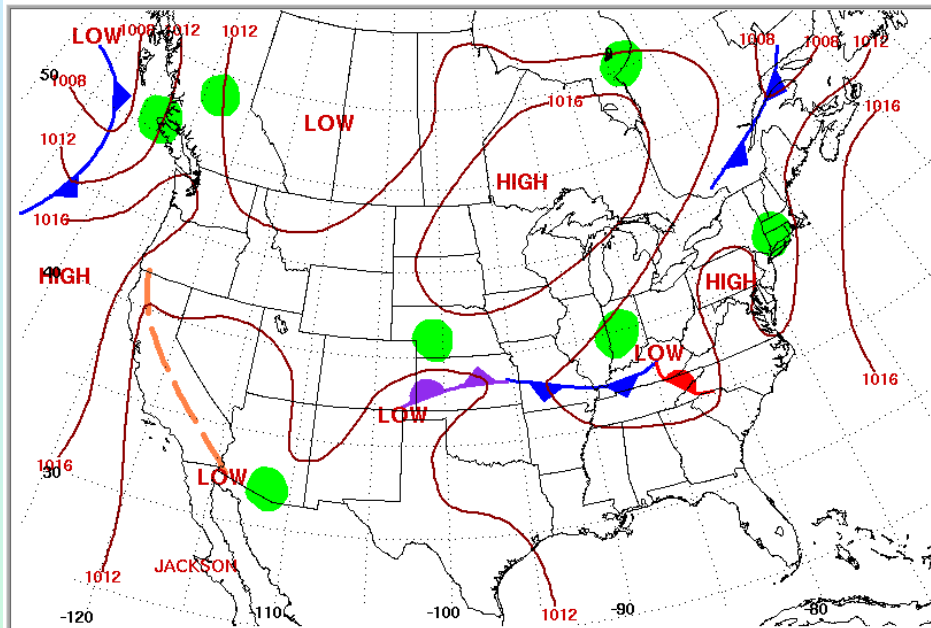
Mimic warmer climate

- The long-term (>decadal) simulations resolving clouds are prohibitively expensive
 - Long-term simulations
 - Large amount of variables
- Short-term simulations mimic future warmer climate
 - Warming is mostly near surface
 - Alter lower boundary conditions
 - Maintaining dynamic consistency
- Drying the soil – warming the lower atmosphere

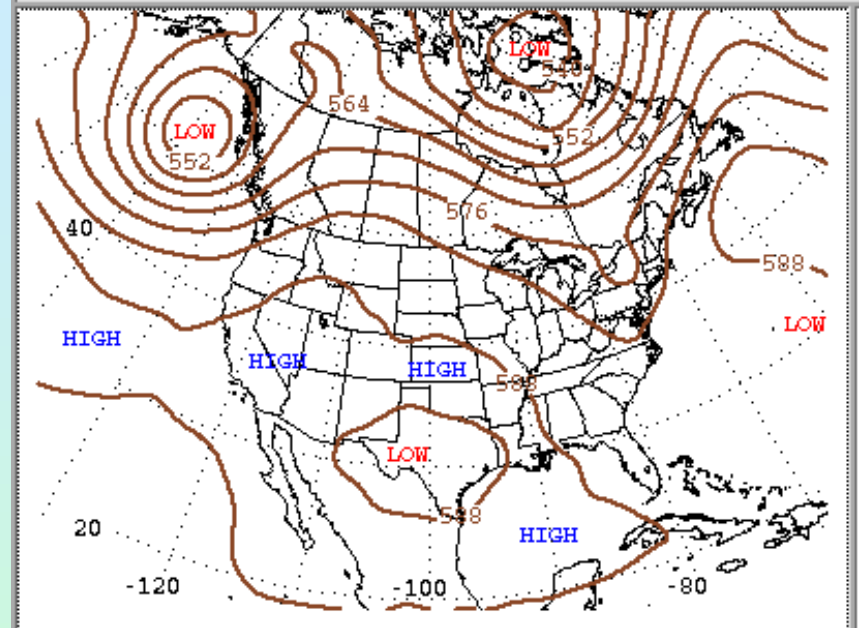
WRF Configuration and simulations

- The case - a typical weak forcing case in summer
- Two simulations
 - Control – “observed” soil moisture
 - Dry – set soil to be extremely dry in SW U.S.
- Triply nested domains with 35 vertical levels
 - D1 (24 km) covers the continental U.S.
 - D2 (8 km resolution) western U.S.
 - D3 (2.7 km) Focus on convective areas
- Model physics options:
 - WSM3 microphysics scheme
 - Dudhia short wave radiation schemes
 - KF CPS for domain 1 and 2, explicit for domain 3
 - Noah LSM

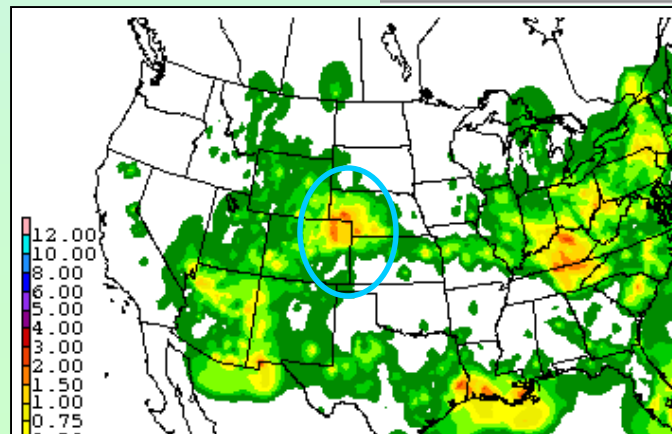
Weather Situation - July 28, 2007



Surface Weather Map at 7:00 A.M. E.S.T.

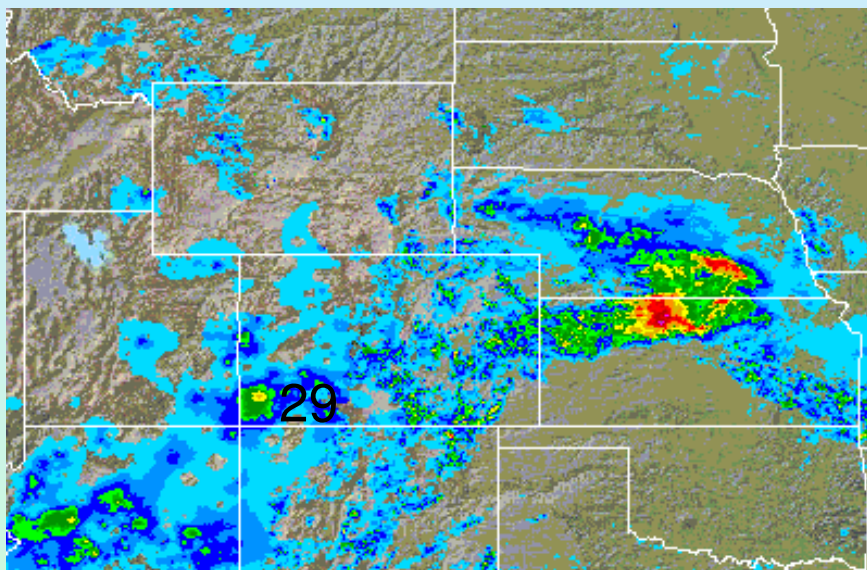


500-Millibar Height Contour at 7:00 A.M. E.S.T.

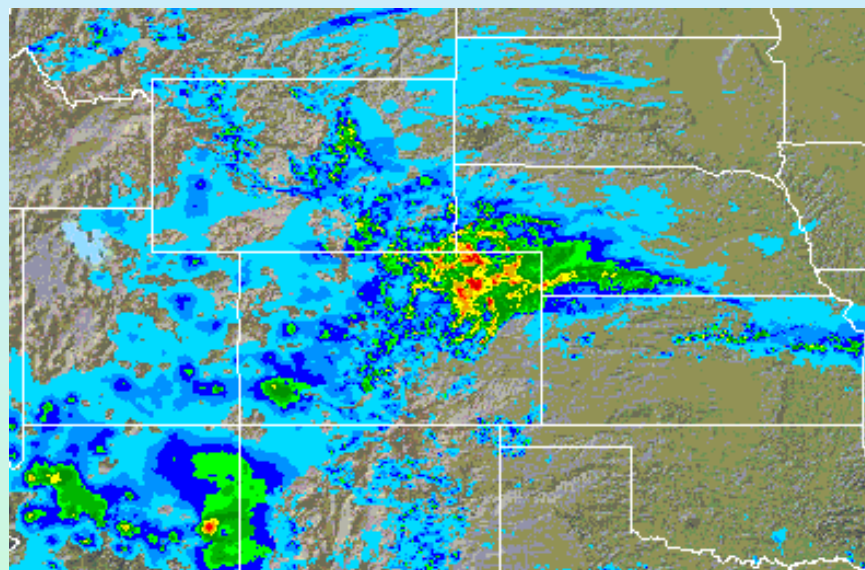


http://www.hpc.ncep.noaa.gov/dailywxmap/index_20070728.html

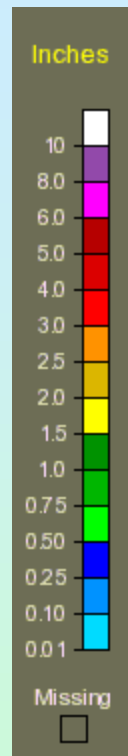
Observed daily rainfall



12 Z July 28, 2007

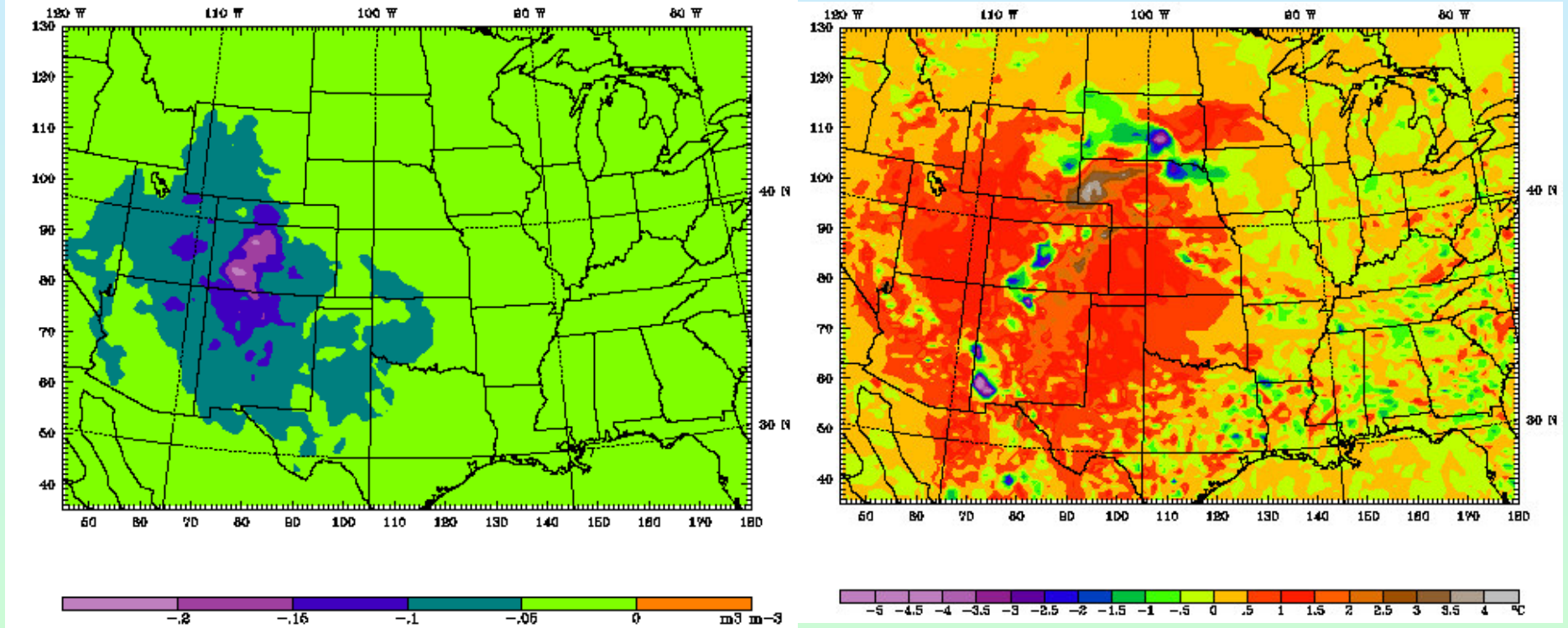


12 Z July 29, 2007



http://www.srh.noaa.gov/rfcshare/precip_analysis_new.php

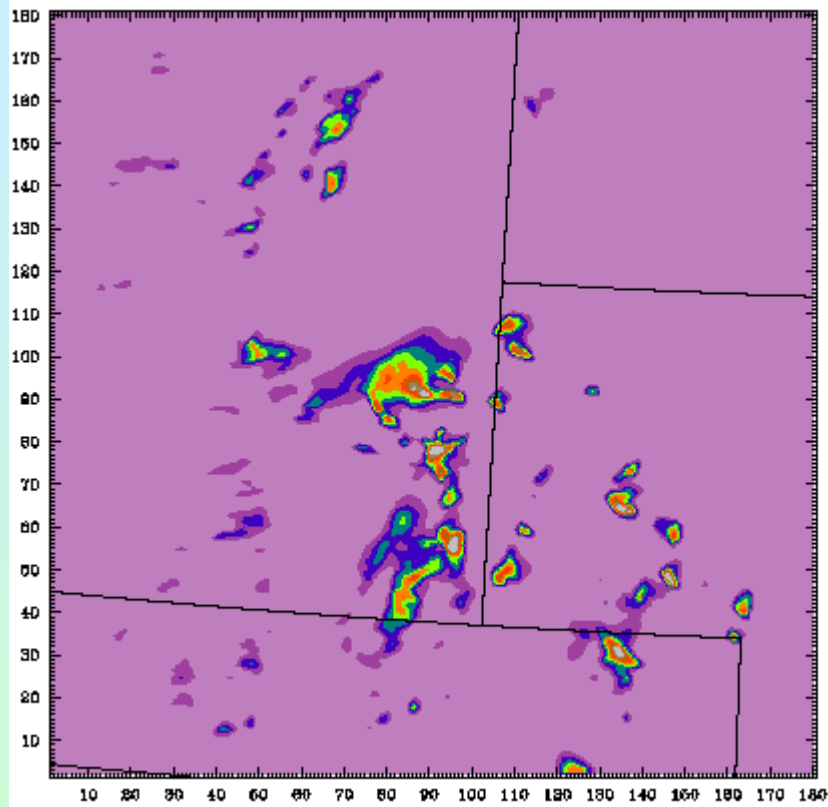
Mimicked warming and drying in SW U.S. – Difference between drying and control



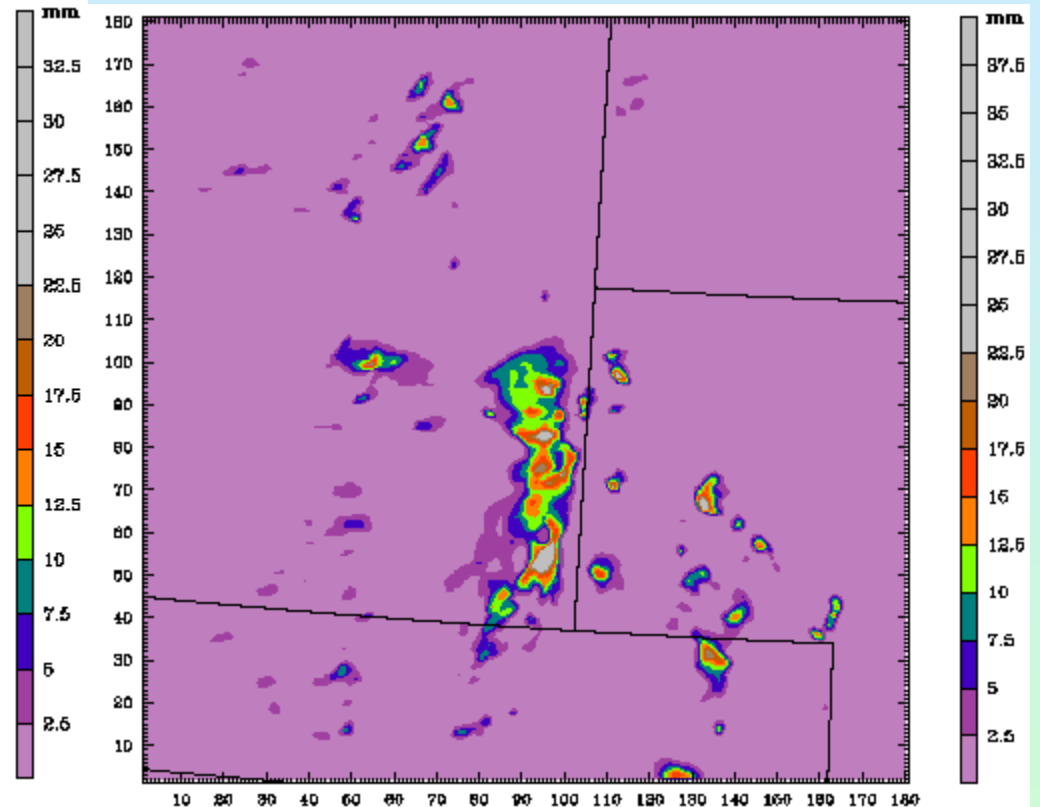
Soil moisture difference at 0 f

Surface temperature difference at 24 h

Hourly precipitation at 23 h validated at 1700 UTC, 27 July, 2007

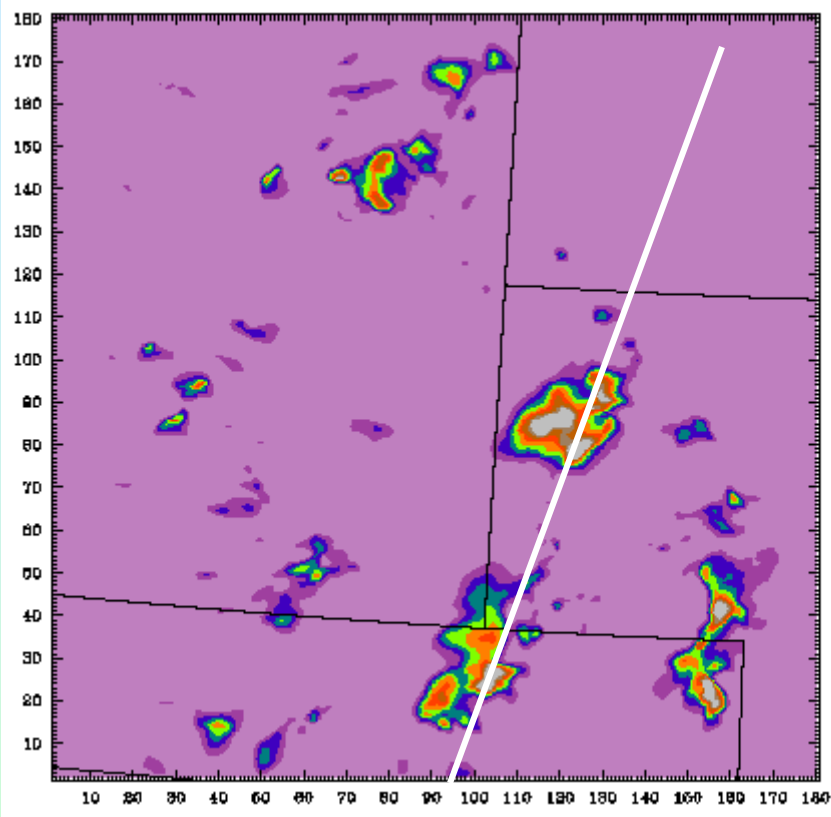


Control

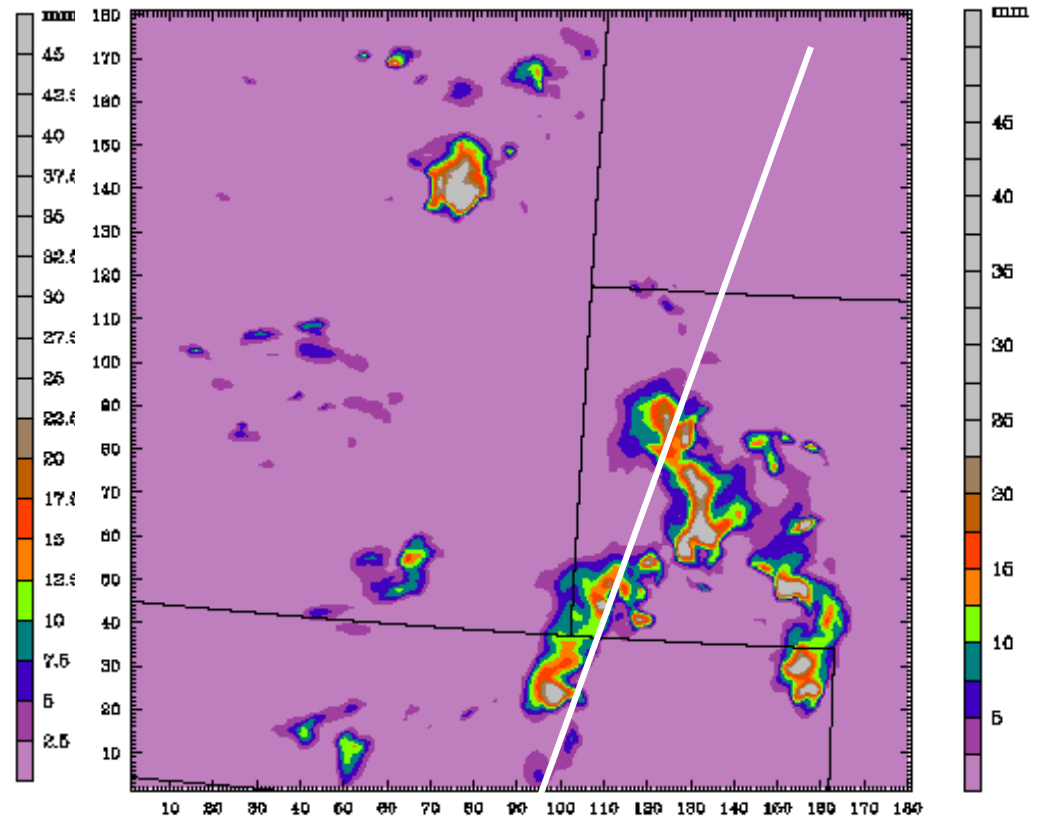


Dry

Hourly precipitation at 26 h validated at 20 UTC, 27 July, 2007

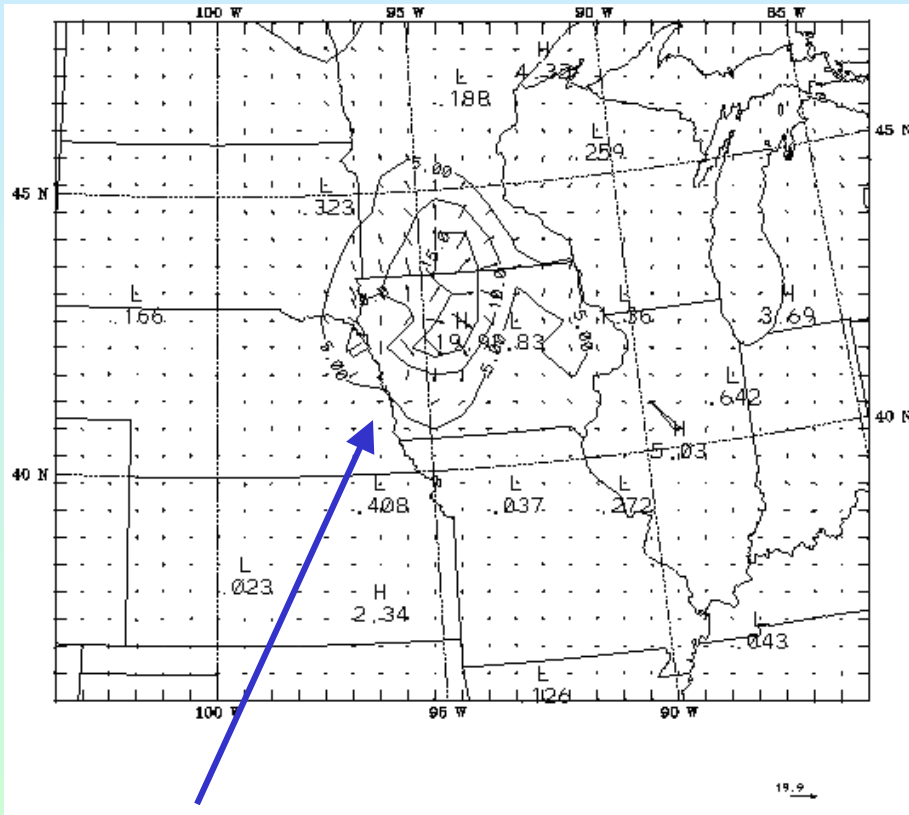


Control



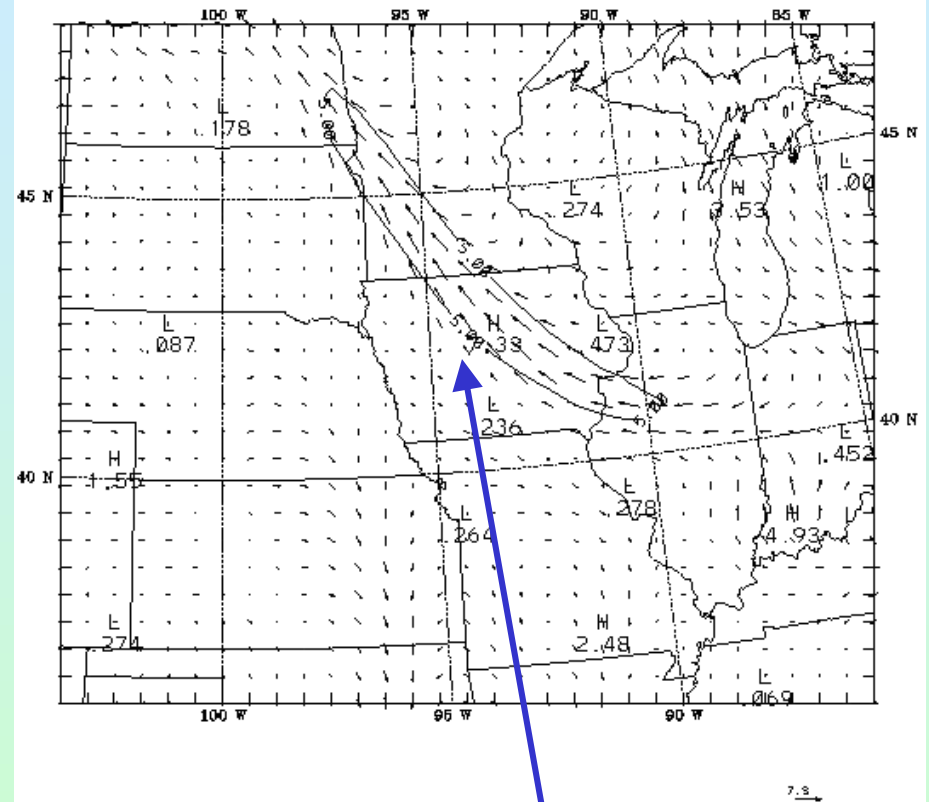
Dry

Mid-Tropospheric wind anomaly (Pan, et al. 1996)



MCC-like

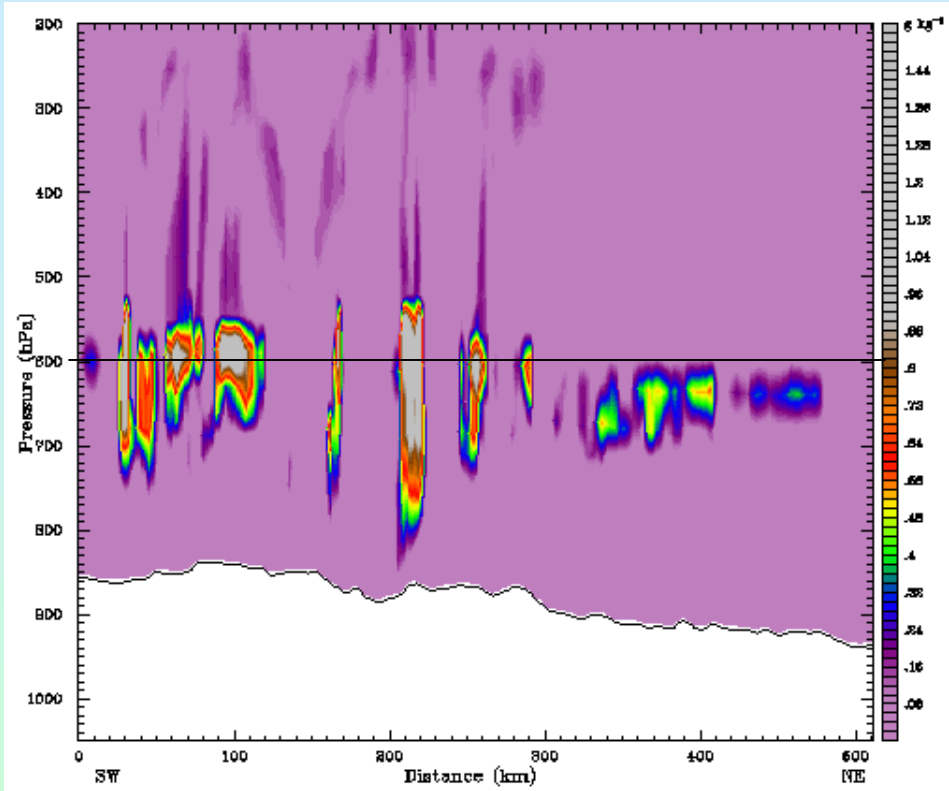
Wet/cold



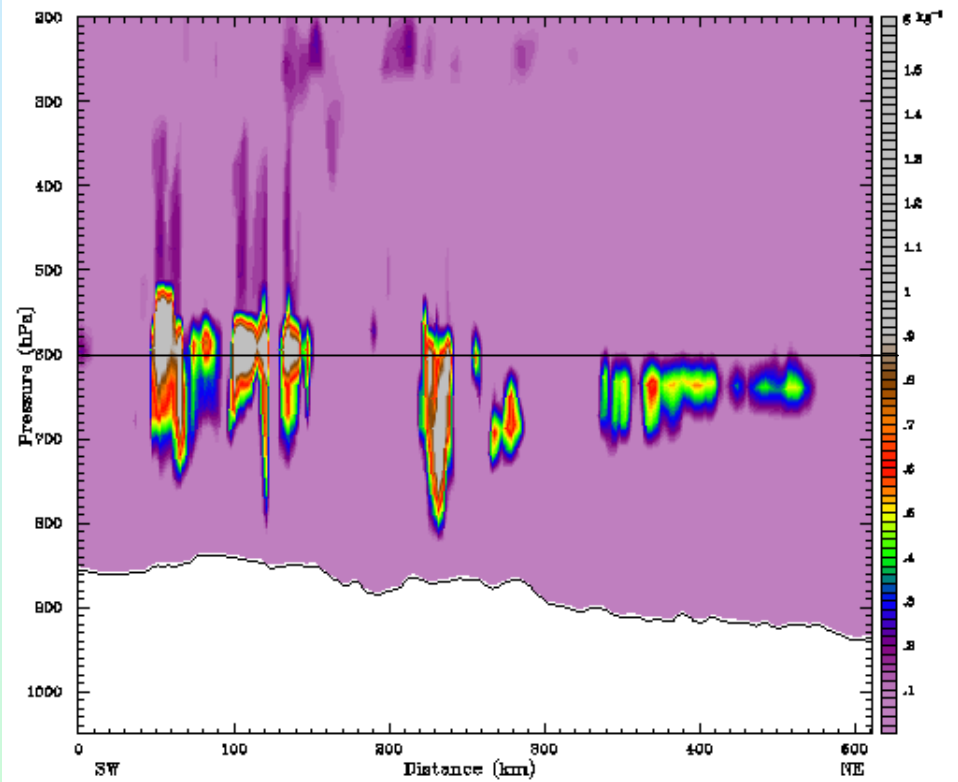
Squall line-like

Dry/warm

Cross-section of total cloud water content

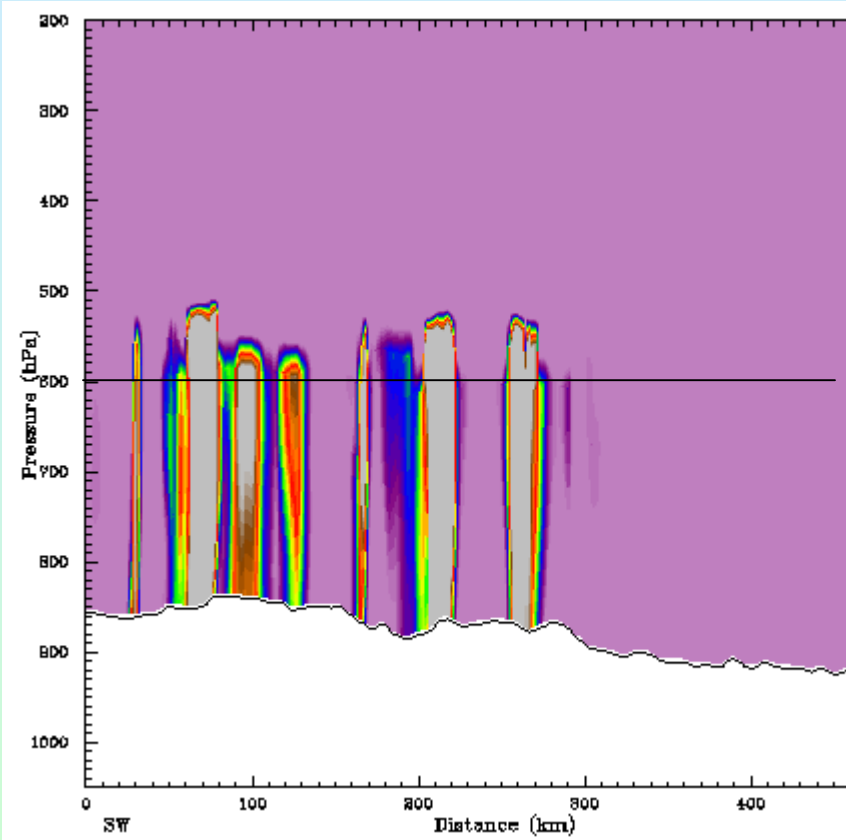


Control

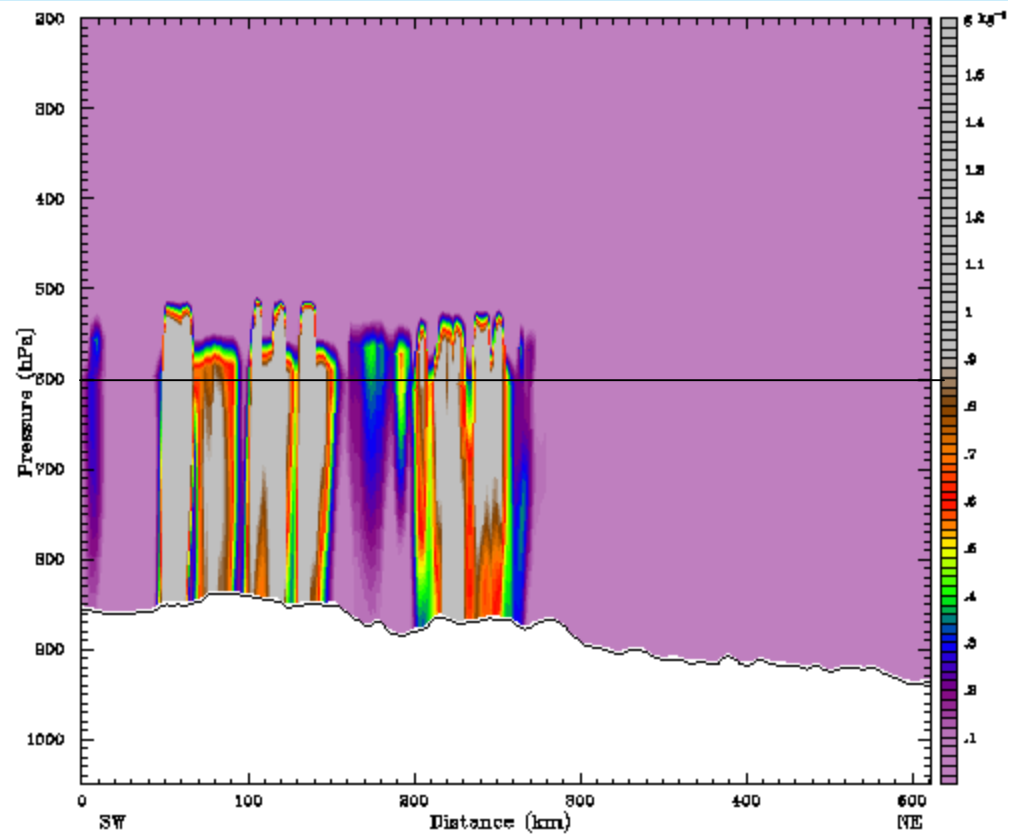


Dry

Vertical rainwater distribution at 25 h

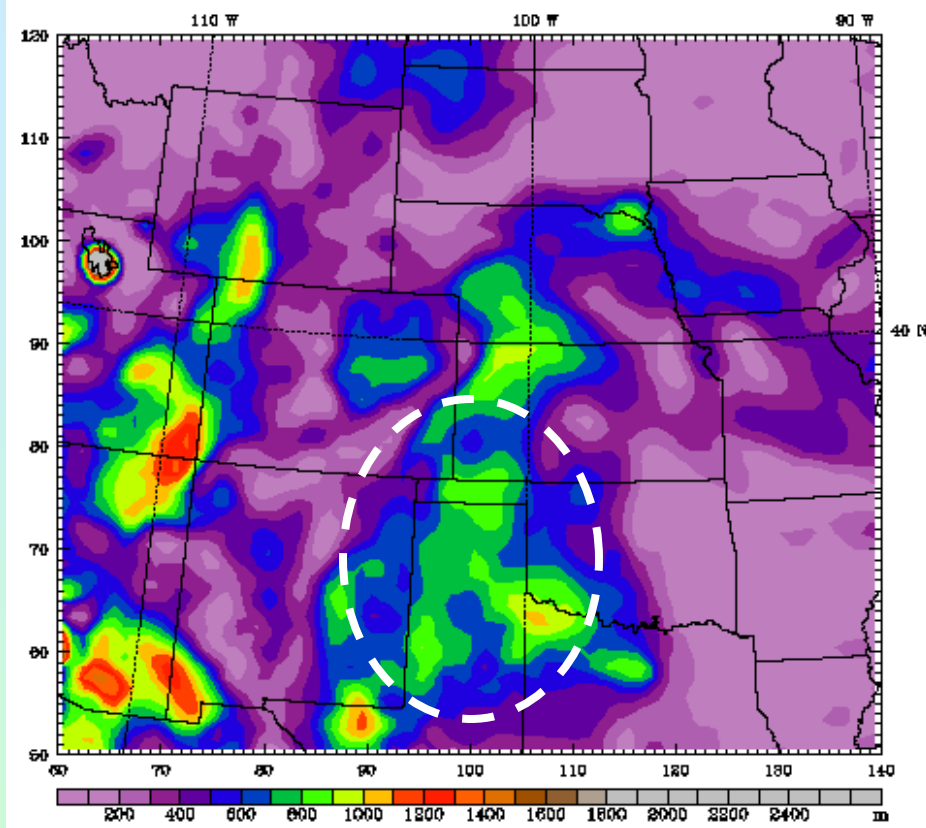


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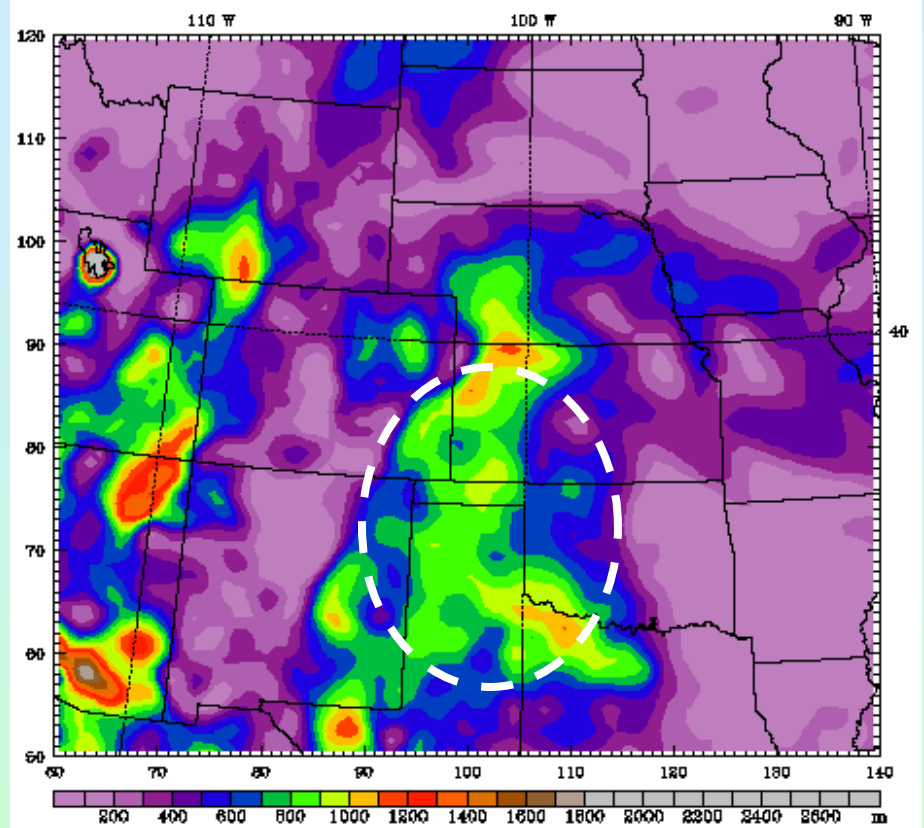


Dry

Boundary-layer height

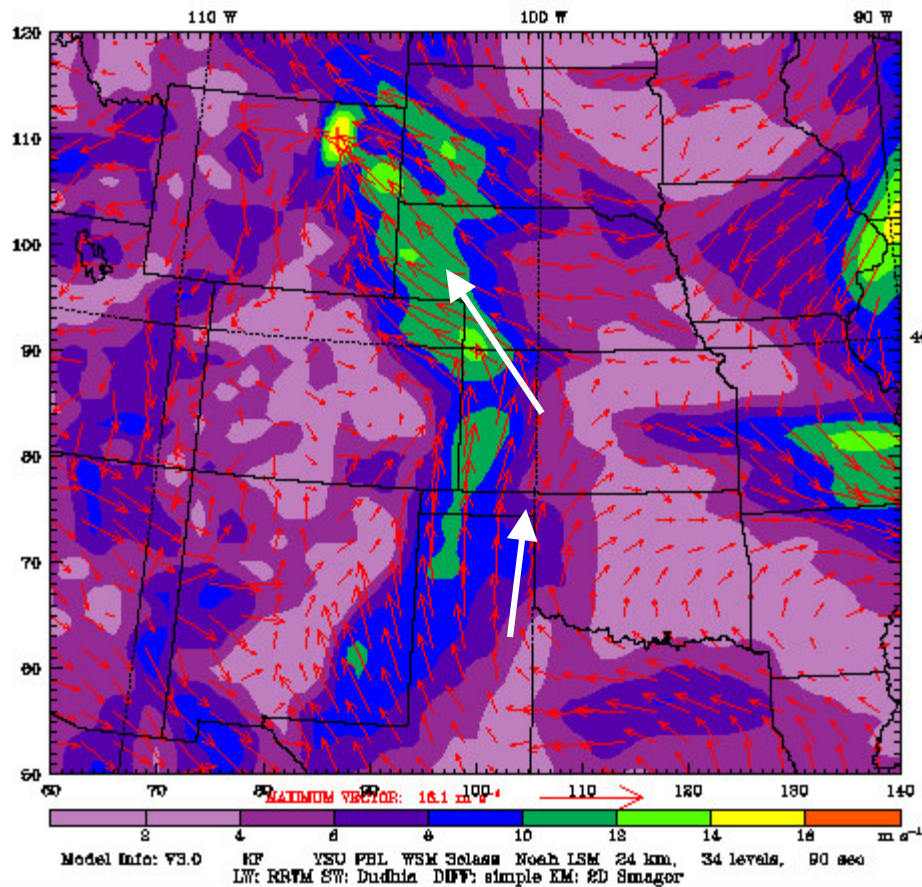


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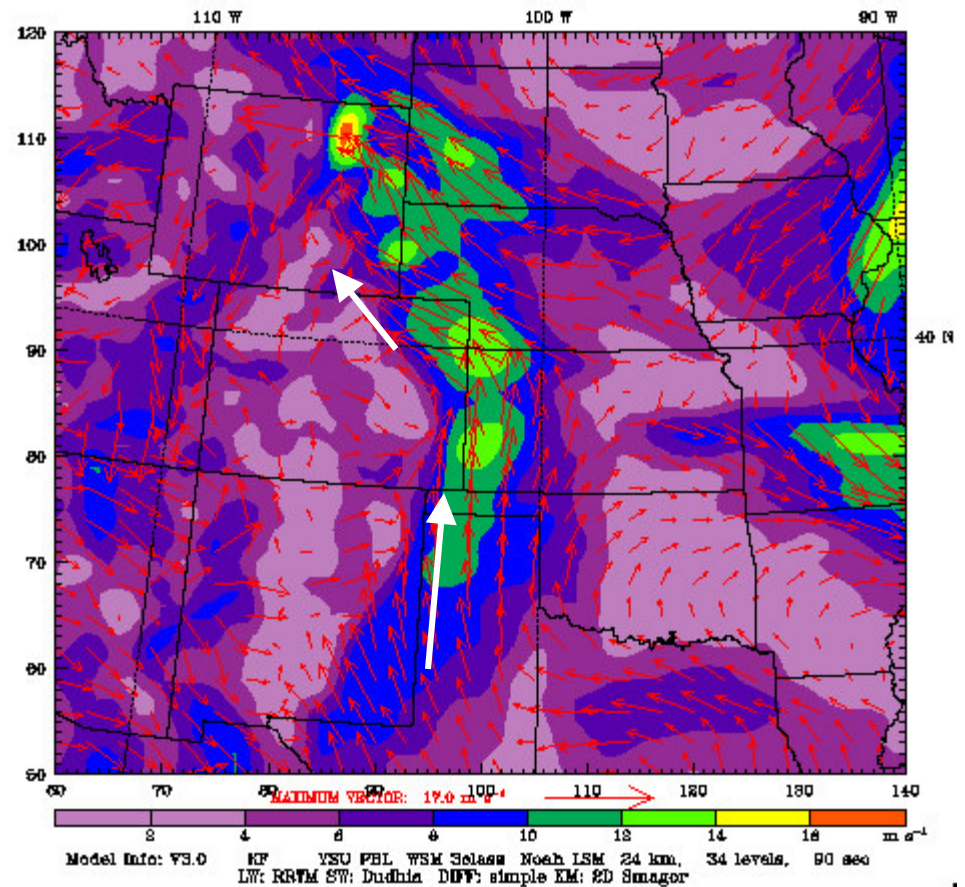


Dry

Low-level jet as measured by 850 mb winds



Control



Dry

Summary and Discussions

- A simple soil-drying method is used to mimic the future warming (and drying) in SW U.S.
- Dynamic effects of the warming likely to be:
 - Stronger low-level jet
 - Stronger daytime instability - more intense daytime convection!
 - More likelihood of line-shaped convection over round-shaped
 - Weaker night local inversion, yet stronger downstream inversion lid
- Cloud microphysics effects of warming (not really analyzed yet)
 - Deeper cold (sub-zero) layer deep
 - Entrainment/detrainment may be more important
 - More aerosols (through windblown dust, wildfire)

Future work

- We primarily present ideas/hypotheses. Apparently more analyses and sophisticated experiments.
- Experiments – either ensemble high resolution or course-resolution, decadal-slice
- Warming effect analyses
 - Morphology: stratus vs. convective
 - Composition: ice vs. liquid, rainwater vs. cloud water
 - Propagation: local vs. remote