WRF Model Simulations of a Quasi-Stationary, Extreme-Rain-Producing Mesoscale Convective System

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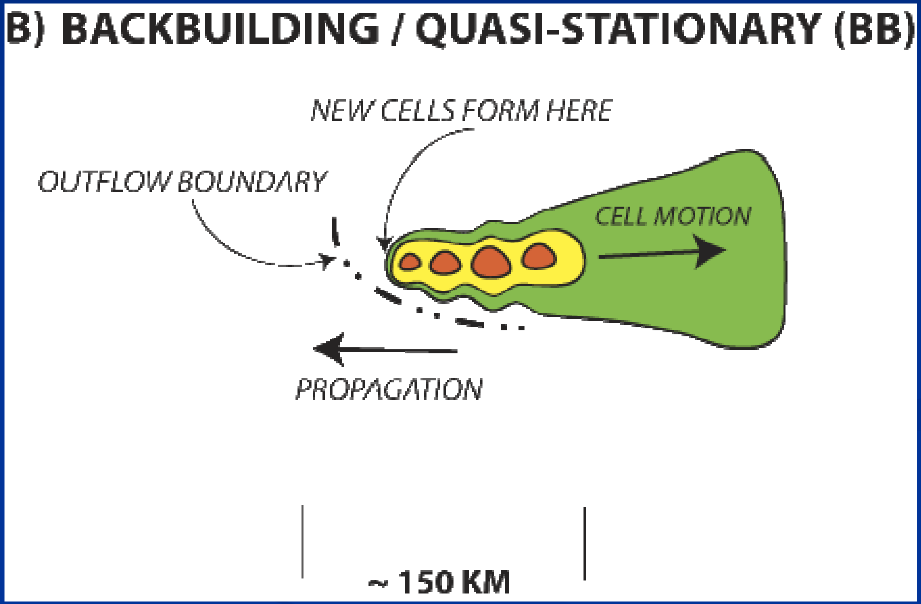
Colorado State University
Knowledge to Go Places

Purpose

- To determine the utility of the WRF model for simulating prolonged heavy-rain-producing convection
- To gain understanding of the processes responsible for initiating, organizing, and maintaining such convection using both real-data and idealized initializations

Background

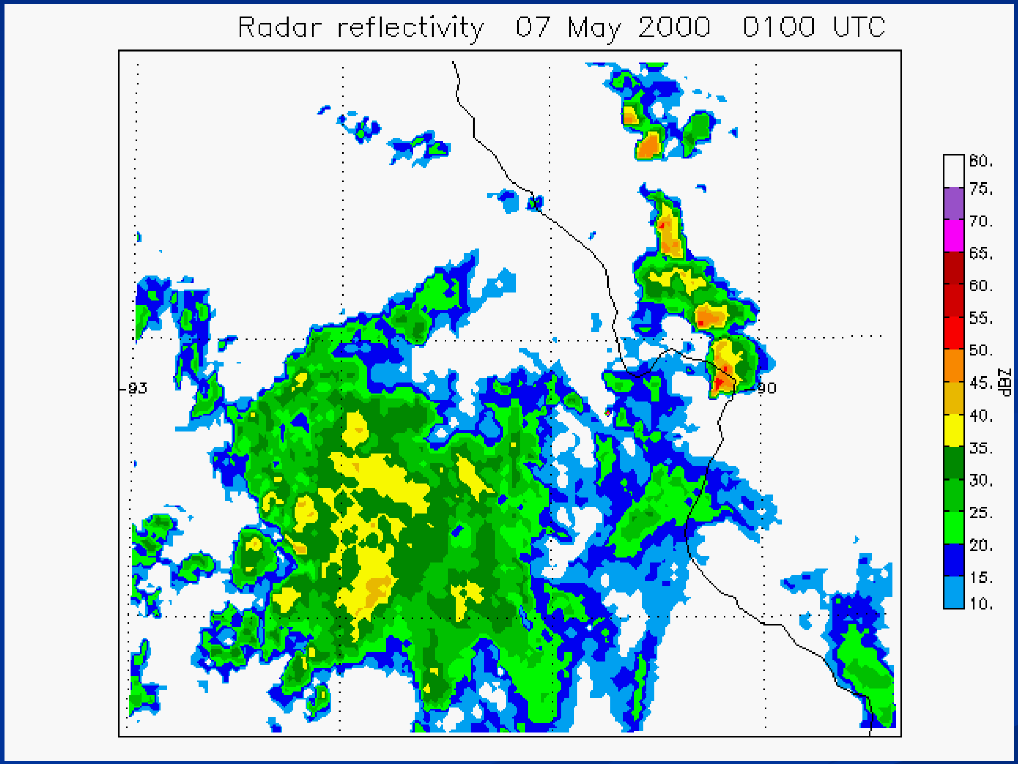
- Schumacher and Johnson (2005, 2006) found that MCSs are responsible for 66% of extreme rain events in the eastern 2/3 of the US
- The "backbuilding/quasi-stationary" MCS type often produces extreme rainfall and may present significant forecast challenges
- Considering the lack of high-resolution observations of these types of events, a numerical model will be used to simulate one of them



Schumacher and Johnson (2005)

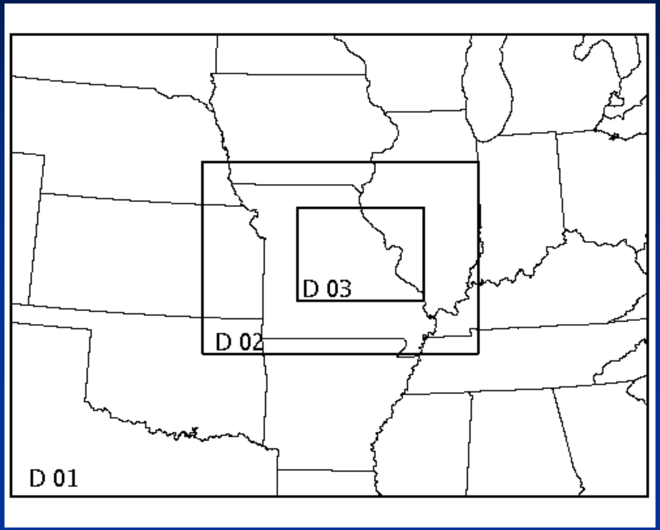
Description of the event

- BB MCS on 6-7 May 2000 in eastern Missouri
- Produced up to 309 mm (12.15 in) of rain in 8 h
- Prior to the onset of convection, there were no apparent synoptic or mesoscale boundaries at the surface
- The convection developed near a midlevel mesoscale convective vortex (MCV)



Model configuration

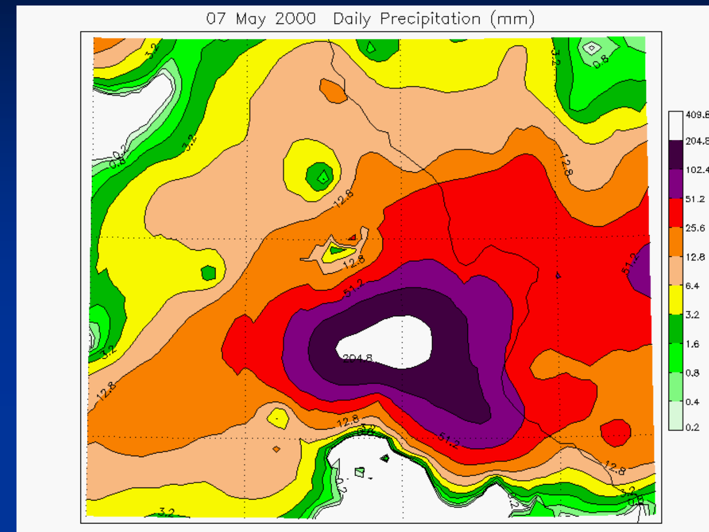
- WRF model, version 2.1.1, Advanced Research WRF (ARW) solver
- Nested grid, with 9-km grid spacing on outer, 3-km on middle, and 1-km on inner and 39 vert. levels
- KF convection on outer, explicit on middle and inner
- Simulations carried out for 24 h from 0000 UTC 7 May
- Setup very similar to that used at NCAR in real-time from 2003-2005
- However, initialized only ~6 h before convection onset, so the results shown herein couldn't have been a real-time "forecast"



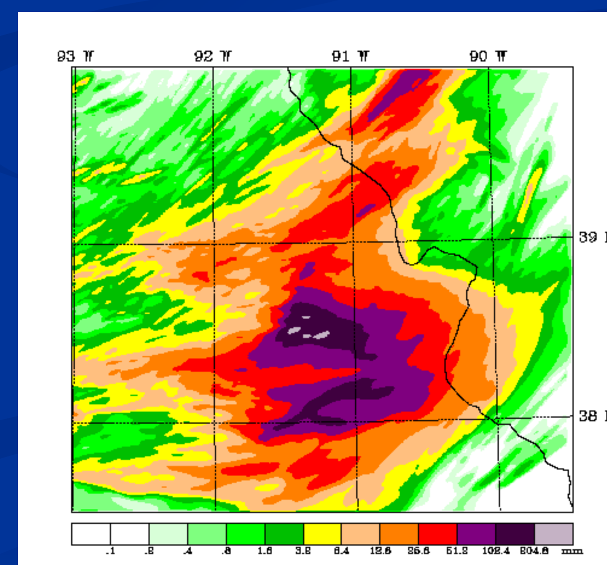
Initial and boundary conditions	40-km Eta
PBL	Yonsei University
Surface layer	Monin-Obukhov
Microphysics	Purdue Lin (6 class)
Land surface	Noah
Turbulence	2D Smagorinsky
Shortwave radiation	Dudhia
Longwave radiation	RRTM

Results – comparison with observations

- Model is successful in producing a quasi-stationary MCS similar to the observed system
- Model slightly underestimates maximum rainfall (model maximum=256 mm), but location is very accurate
- Model doesn't capture the observed stratiform rain out ahead of the convection

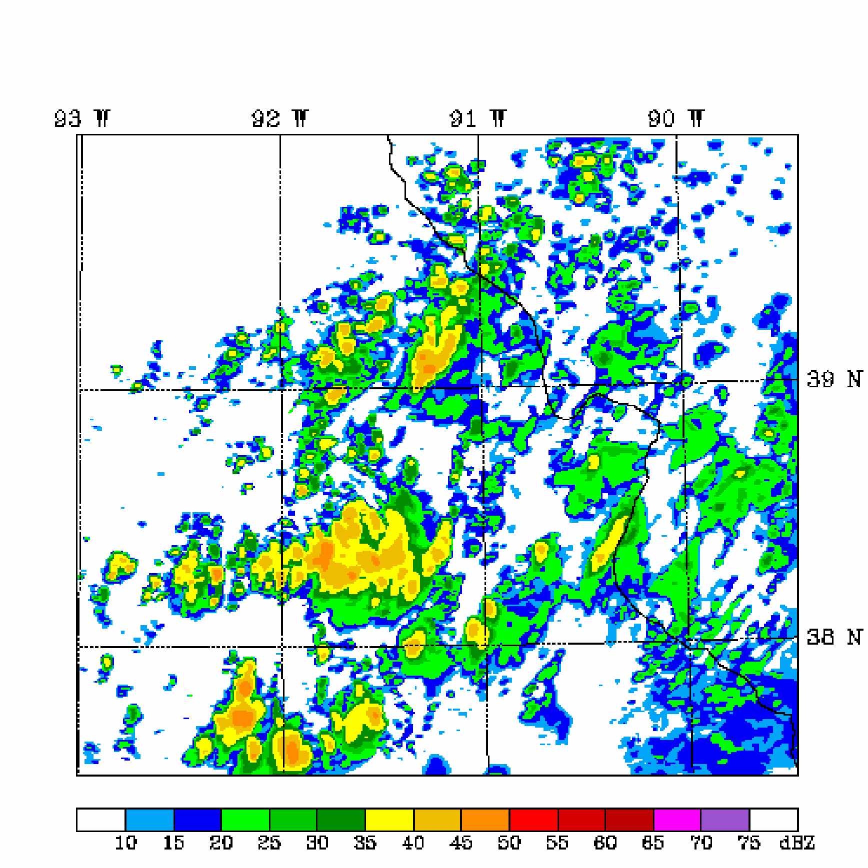


Observed (mm)



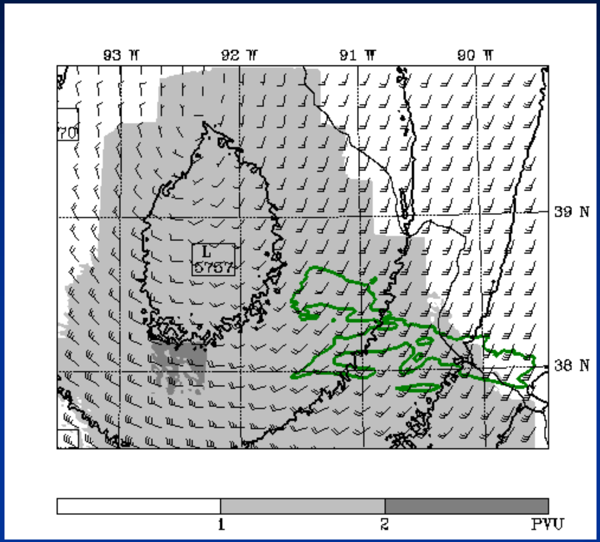
Model (mm)

Results – simulated reflectivity animation

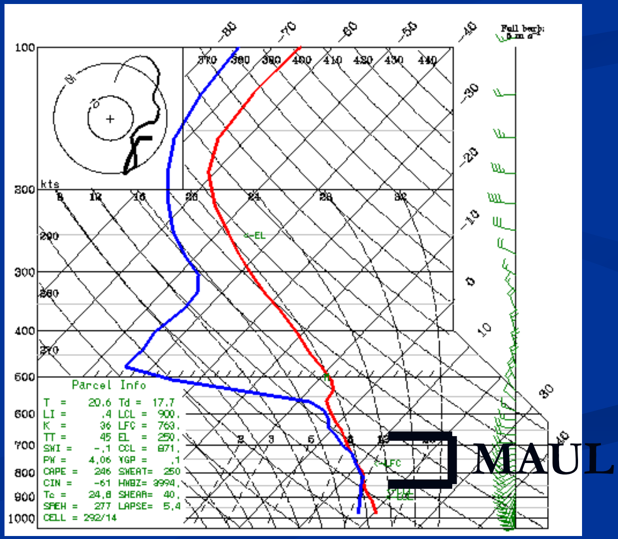


Possible effect of MCV

- MCV is initialized within the innermost domain
- Balanced motions from an MCV in shear can lead to persistent convection under or just downshear of vortex (e.g., Trier and Davis 2002)
- These upward motions can also lift moist and conditionally unstable layers to saturation, resulting in moist absolutely unstable layers (MAULs, Bryan and Fritsch 2000)
- The results from this case are generally consistent with previous hypotheses regarding heavy rainfall associated with an MCV



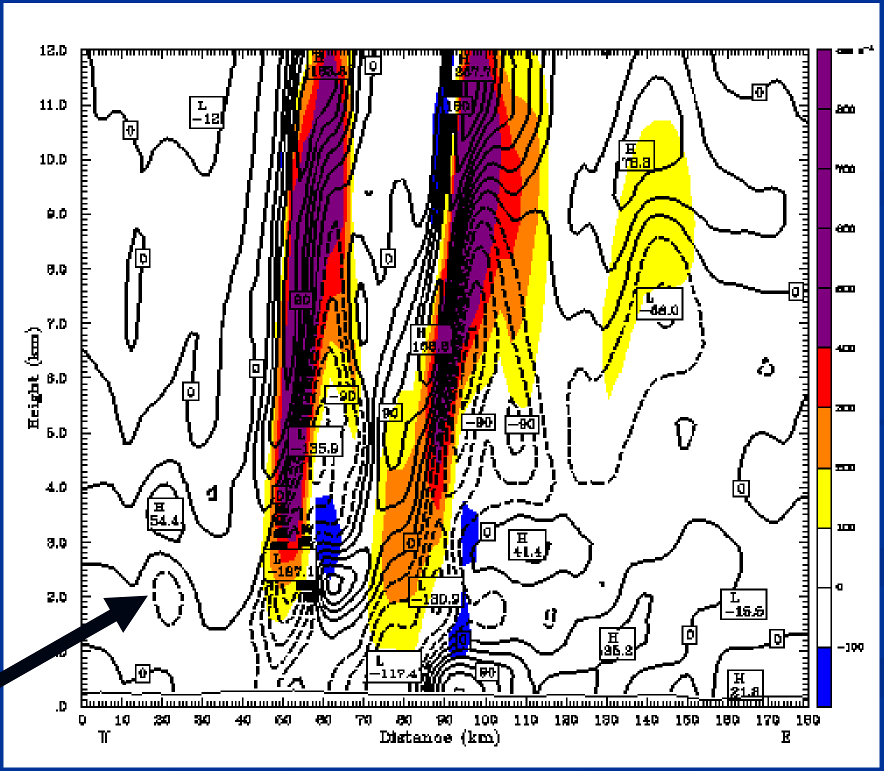
500-hPa PV, height, winds at 0000 UTC (initial)



Model skew-T at 0600 UTC from Kaiser, MO (KAIZ)

Initiation of upstream convective cells

- Model results indicate that during most of the MCS's life, the convection is elevated rather than surface based, and new cells form somewhat upstream of previous ones
- Small pockets of convergence form around 2 km and eventually develop into mature cells



Vertical motion (colors), Divergence (contours)

0905 UTC

Initiation of upstream convective cells

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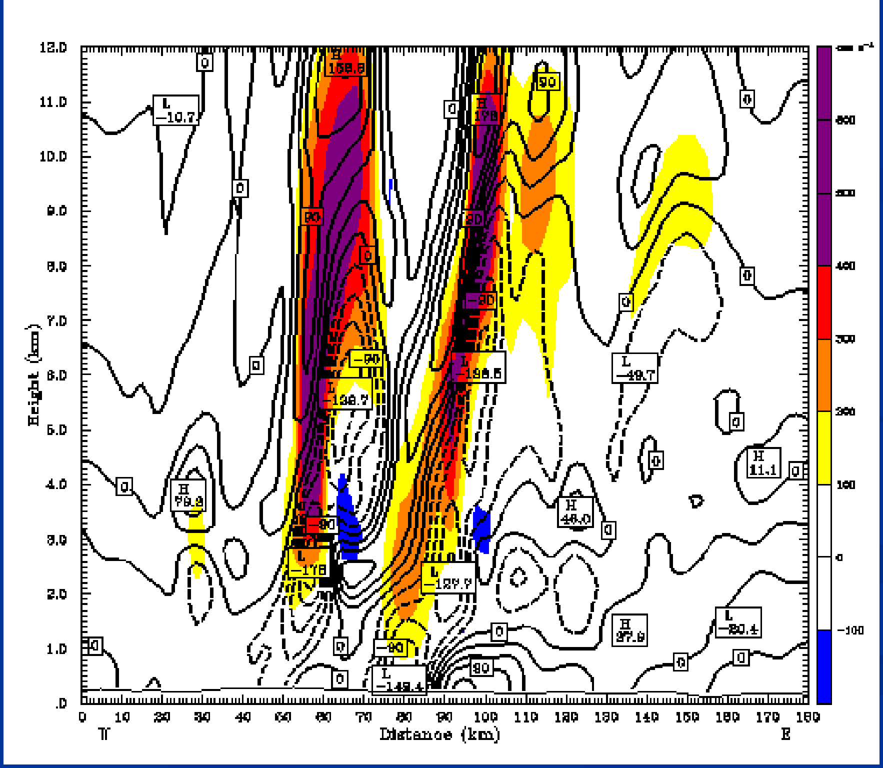

0915 UTC

Initiation of upstream convective cells

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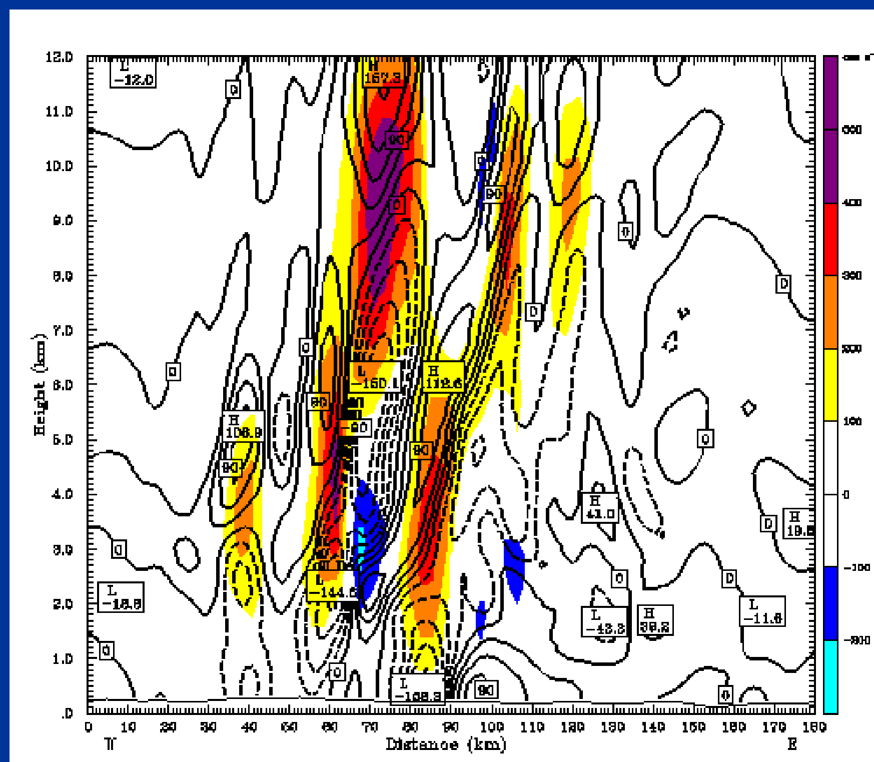

0925 UTC

Initiation of upstream convective cells

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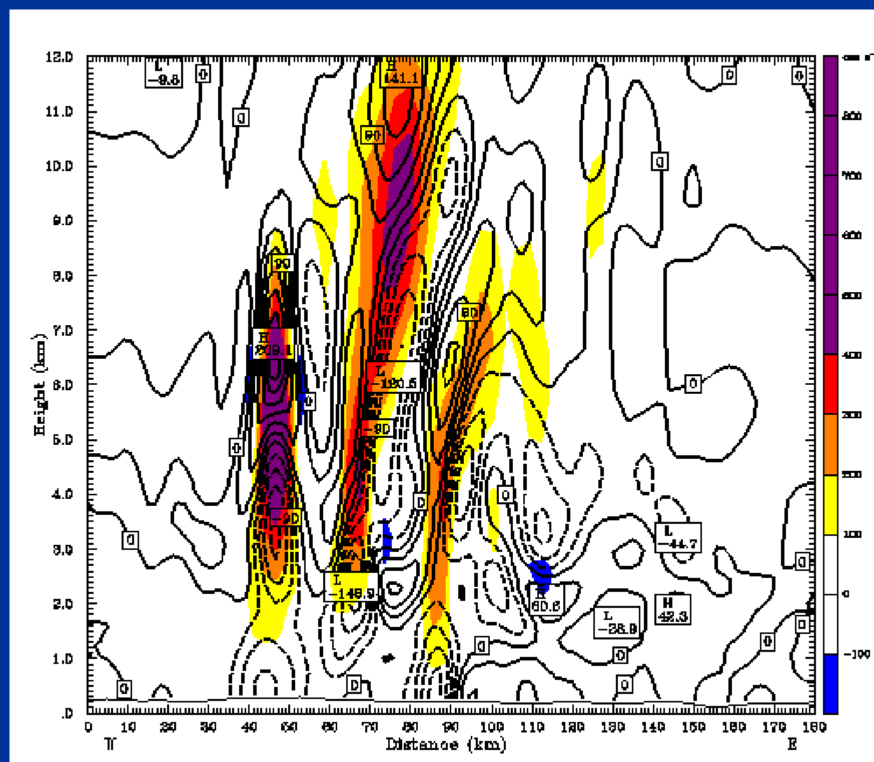
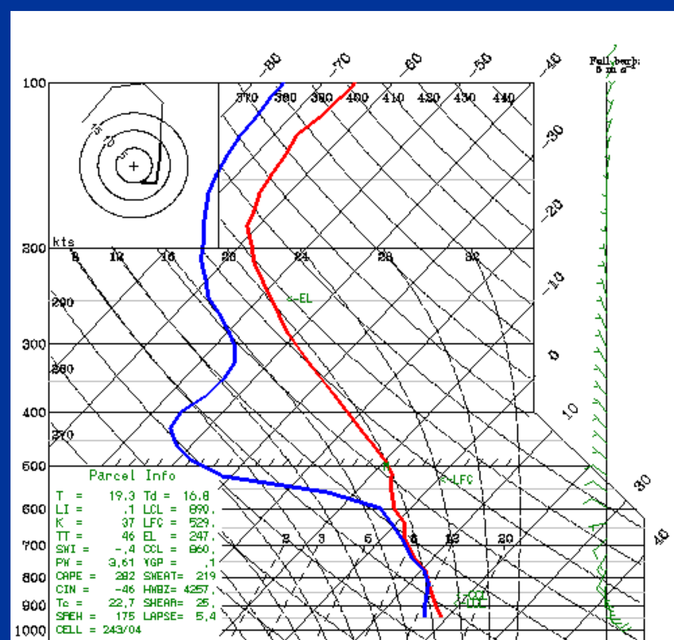


0935 UTC

Idealized results

- Model initialized using horizontally homogenous base state, with sounding with MAUL shown previously
- Convection is initiated with random θ perturbations of up to +/- 2 K and 20 km x 20 km in size



Initial sounding

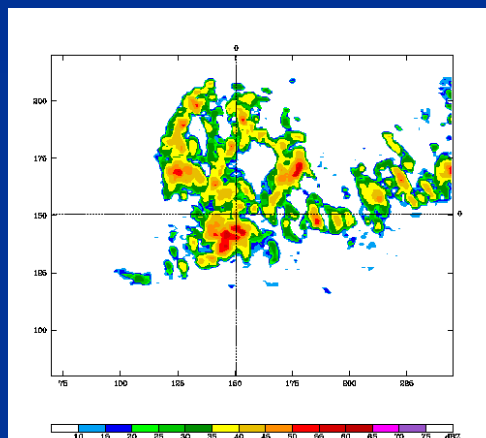
Idealized results

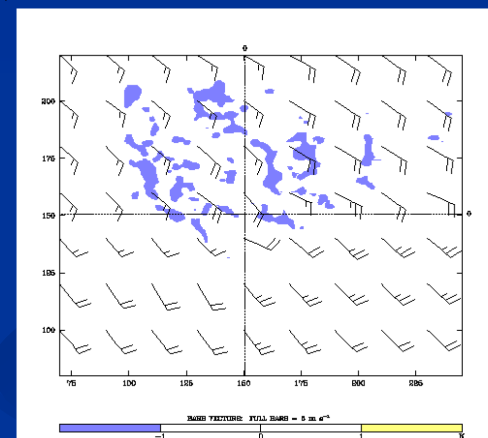
- A long-lived, backward-propagating MCS organizes within several hours
- The simulated MCS is maintained with essentially no mesoscale cold pool

Simulated reflectivity

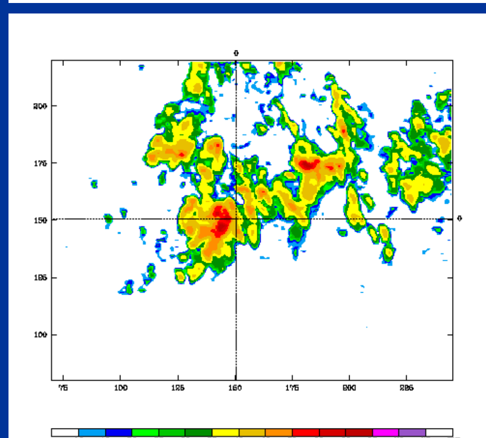
θ_v perturbations at 10 m AGL

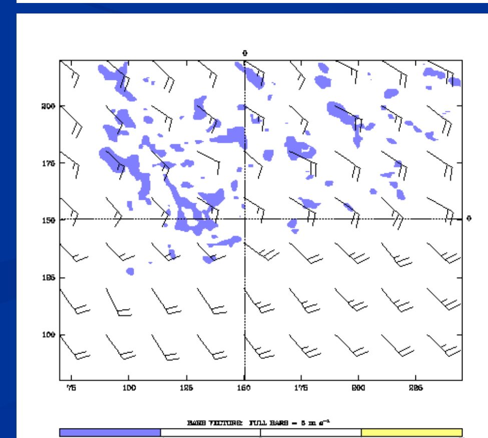
t = 9 h





t = 12 h





Conclusions

- The WRF model is able to successfully simulate a backbuilding, quasi-stationary MCS
- Convective structures and precipitation distribution compare well with observations
- The effects of an MCV and MAUL on convection appear to be consistent with previous hypotheses
- Much of the backbuilding convection appears to be elevated and forms without the benefit of strong cold-pool lifting
- Preliminary idealized simulations also suggest that when a MAUL is present, a long-lived MCS can form without much of a cold pool