

Development of Multi-Scale Large-Scale Forcing for MC3E Cloud Modeling Studies

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Acknowledgments

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and all MC3E Participants***



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Analysis Method – The Constrained Variational Analysis



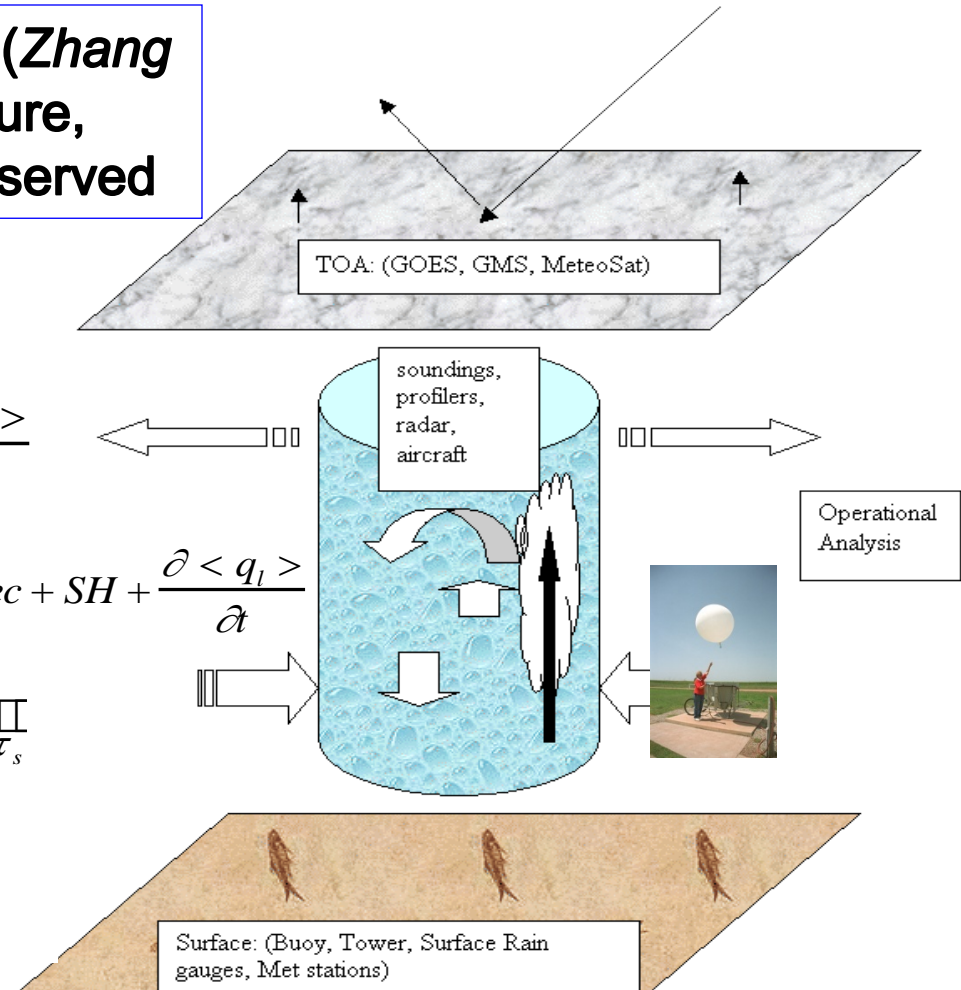
Constrained Variational Analysis (Zhang and Lin, 1997) – Mass, Moisture, Energy, and Momentum are conserved

$$\frac{\partial \langle \nabla \cdot \mathbf{V} \rangle}{\partial t} = -\frac{1}{g p_s} \frac{d p_s}{d t}$$

$$\frac{\partial \langle q \rangle}{\partial t} + \langle \nabla \cdot \mathbf{V} q \rangle = E_s - Prec - \frac{\partial \langle q_l \rangle}{\partial t}$$

$$\frac{\partial \langle s \rangle}{\partial t} + \langle \nabla \cdot \mathbf{V} s \rangle = R_{TOA} - R_{SRF} + L Prec + SH + \frac{\partial \langle q_l \rangle}{\partial t}$$

$$\frac{\partial \langle \mathbf{V} \rangle}{\partial t} + \langle \nabla \cdot \mathbf{V} \mathbf{V} \rangle - f \mathbf{k} \times \langle \mathbf{V} \rangle - \nabla \langle \phi \rangle = \tau_s$$



(Courtesy of Dr. M. Zhang of SBU)

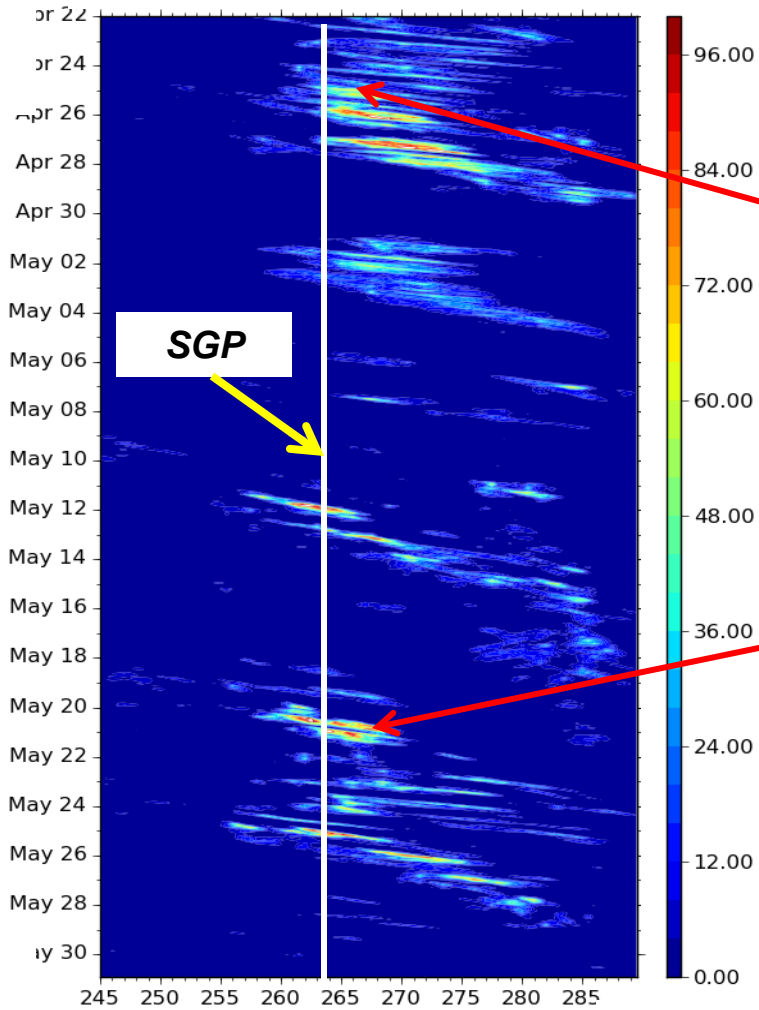
Derived forcing from VA is dynamically and thermodynamically consistent with surface and TOA observations

Observed Cloud and Precipitation Systems During MC3E

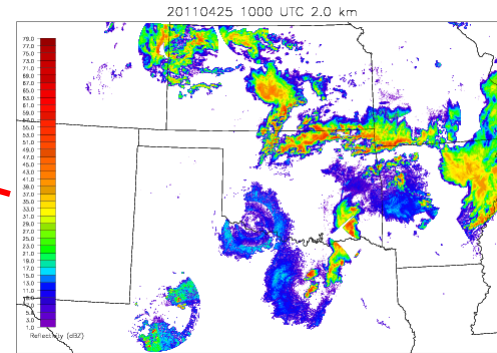
NEXRAD Pr Radar
Averaged over 30N-40N

ARM Cloud Radar

Apr. 22,
2011

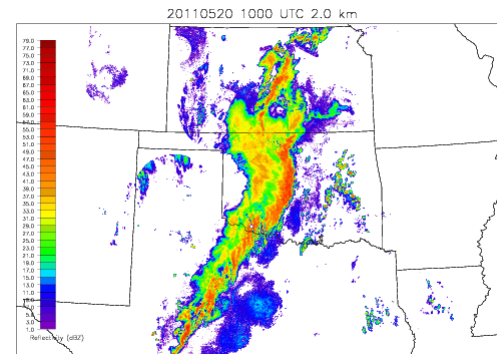


0425



**Strong spatial
variability**

0520



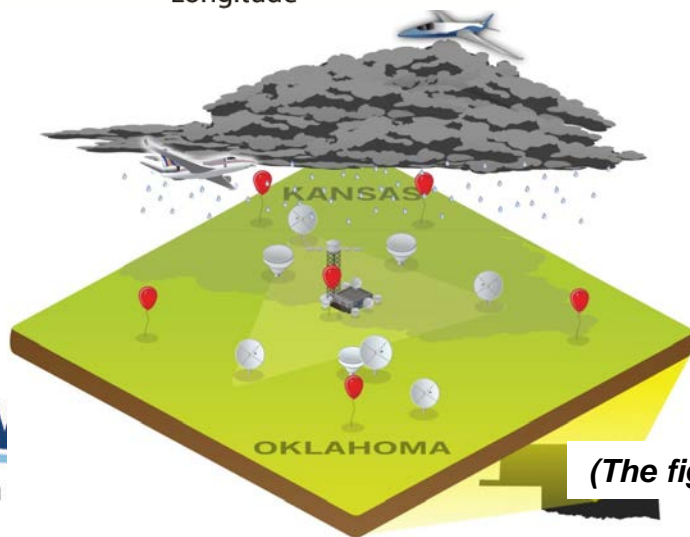
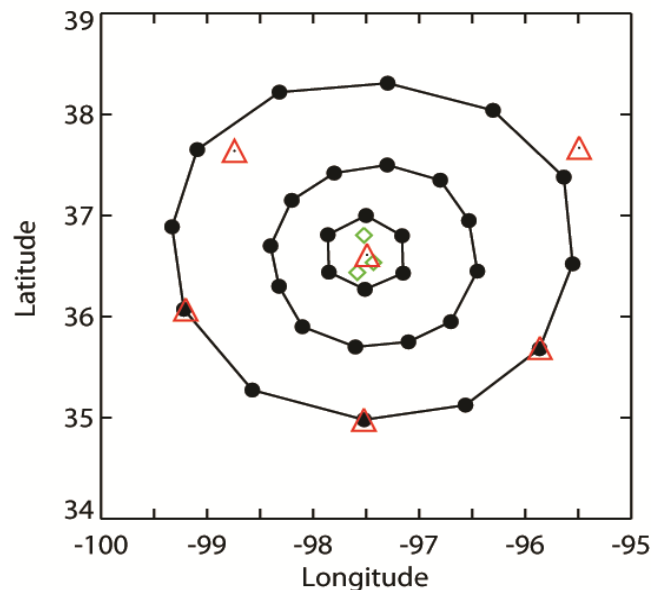
May 30,
2011

Longitude

(Courtesy of Jim Boyle of LLNL and Scott Giangrande of BNL)

Analysis Details

Multi-Scale Domains



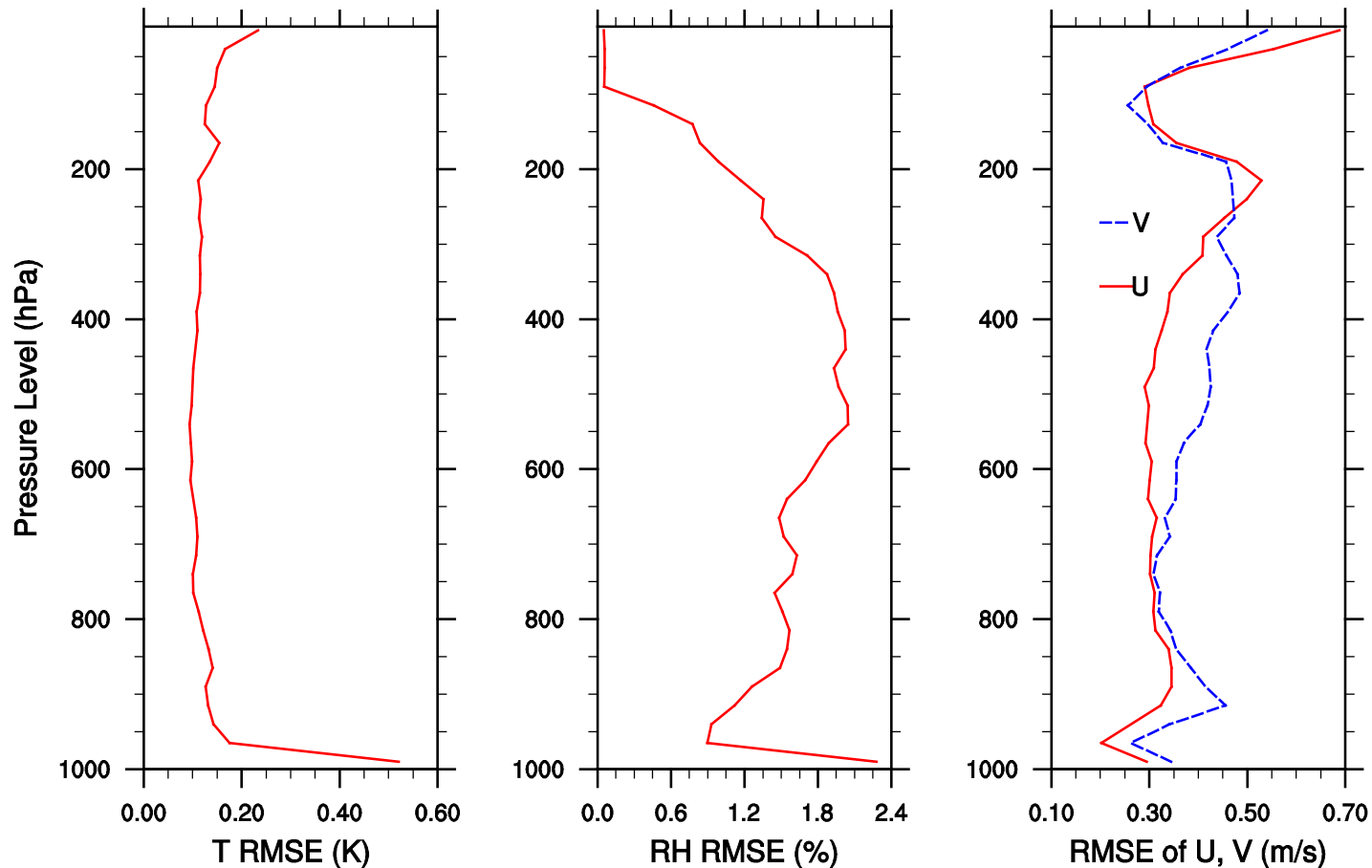
Some details

- Multi-scale forcing (300kmx300km, 150kmx150km, and 75kmx75km)
- 3 hours, 25mb
- 4/22/2011 - 5/26/2011
- Soundings
- RUC analysis as first guess
- ABRFC precip + ARM surface flux measurements
- ARM SMOS + OKM/KAS mesonets
- Satellite measured radiative fluxes at TOA
- RUC analysis plays more important role for smaller domains

Quality of RUC analysis



RMS Errors Compared to Soundings



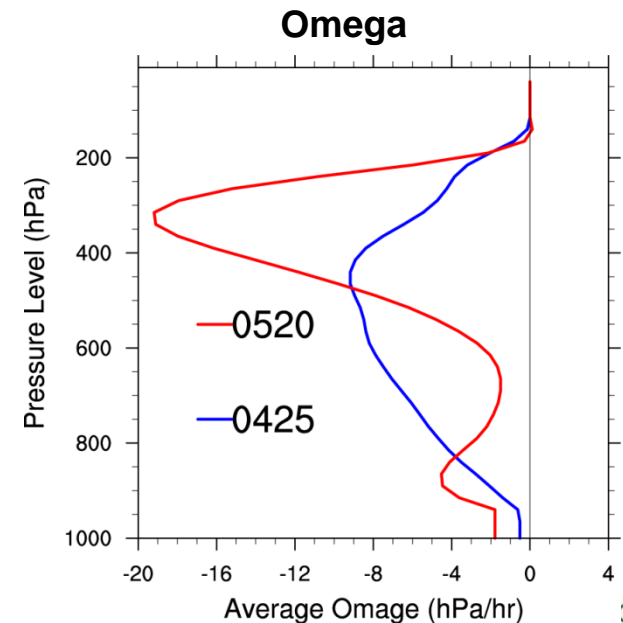
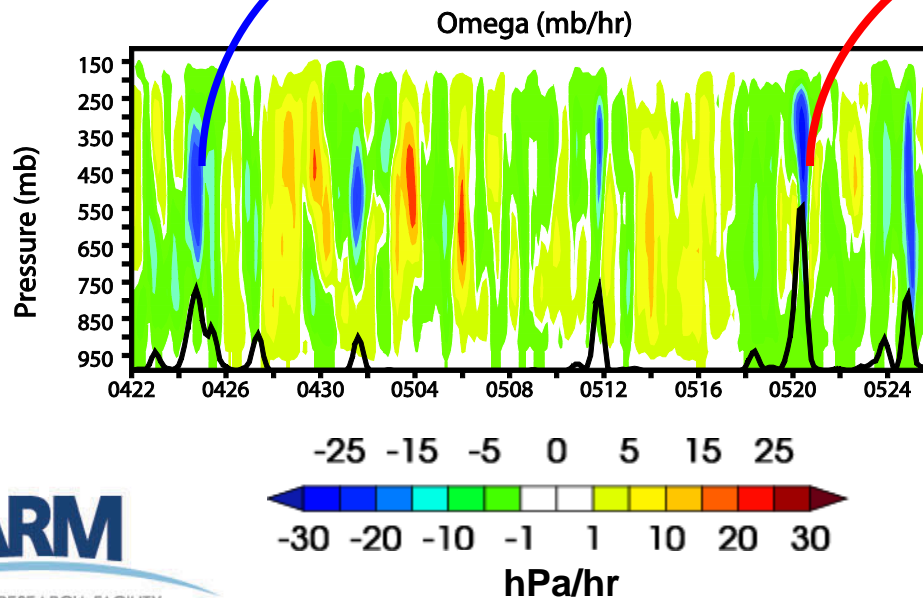
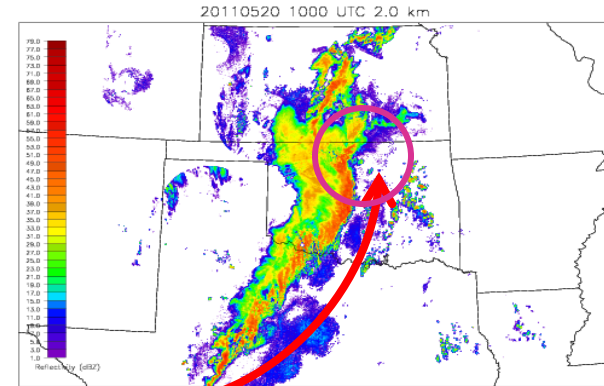
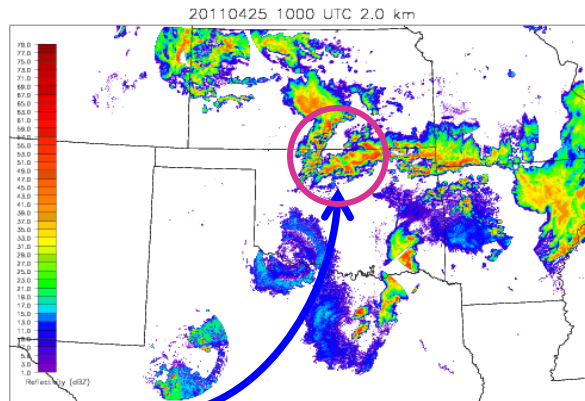
RMSE: < 0.2K in T, <2% in RH, < 0.5 m/s in u, and v

Characteristics of the derived forcing for different cloud systems



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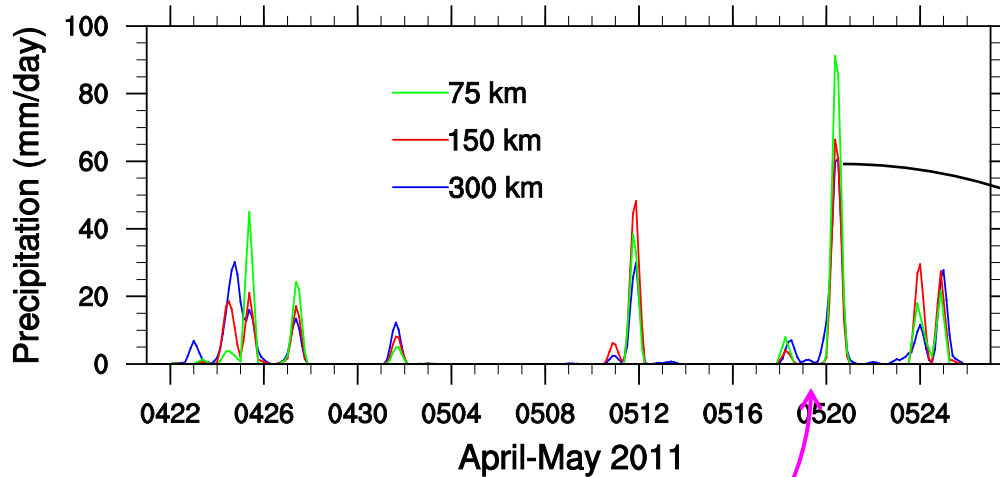


Forcing varies with domain sizes

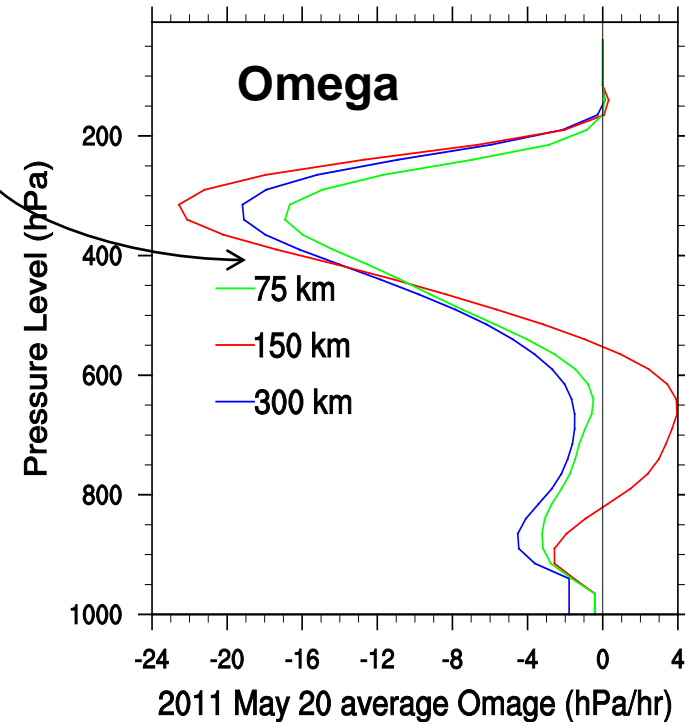
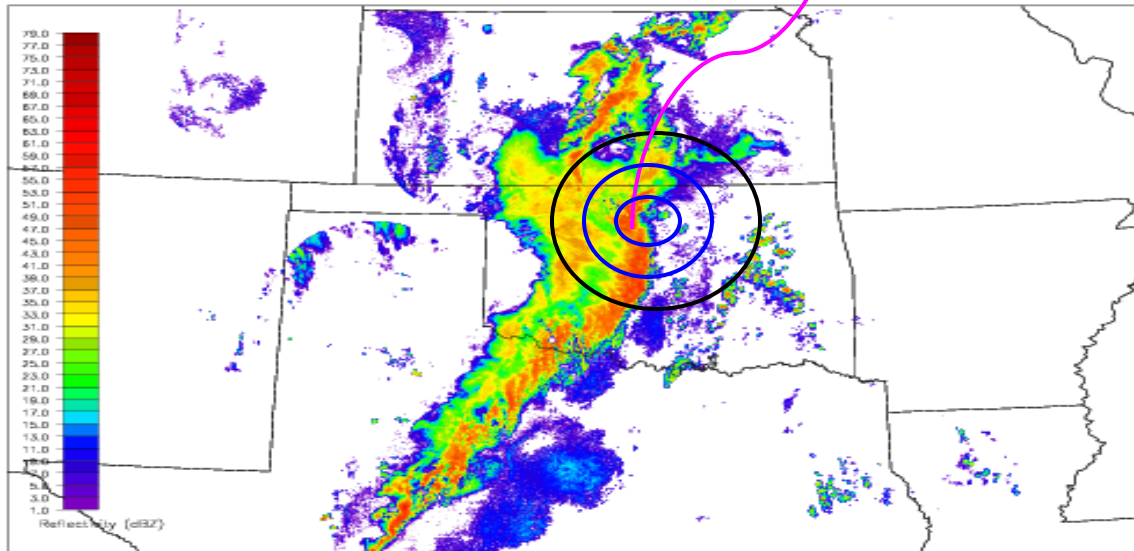
The 20 May 2011 Strong Mesoscale Convective Case



Surface Precipitation Rates



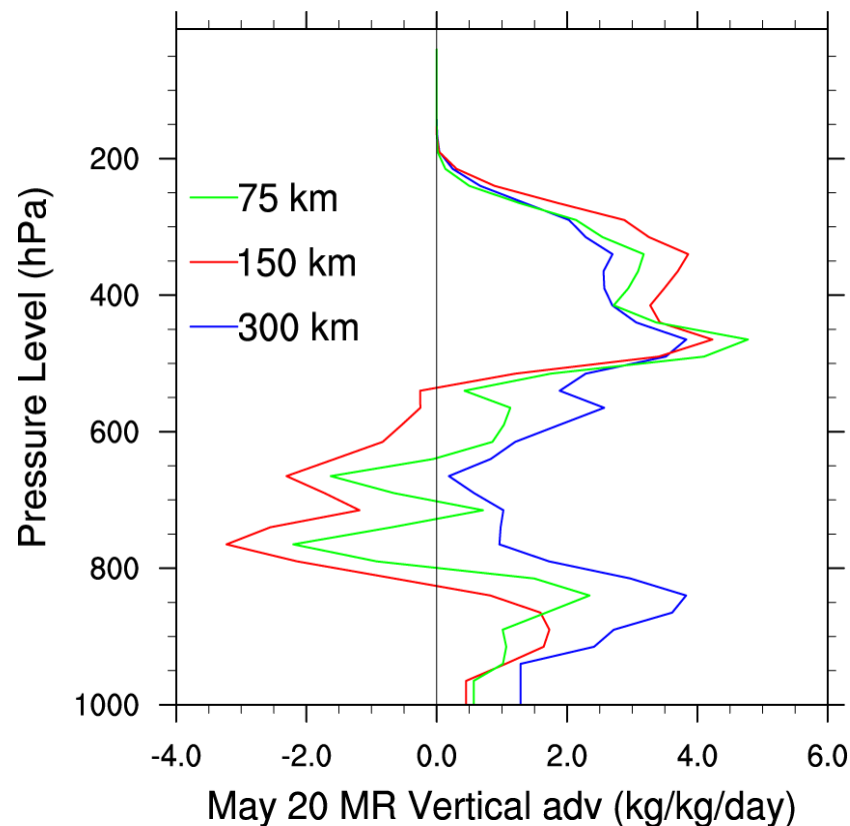
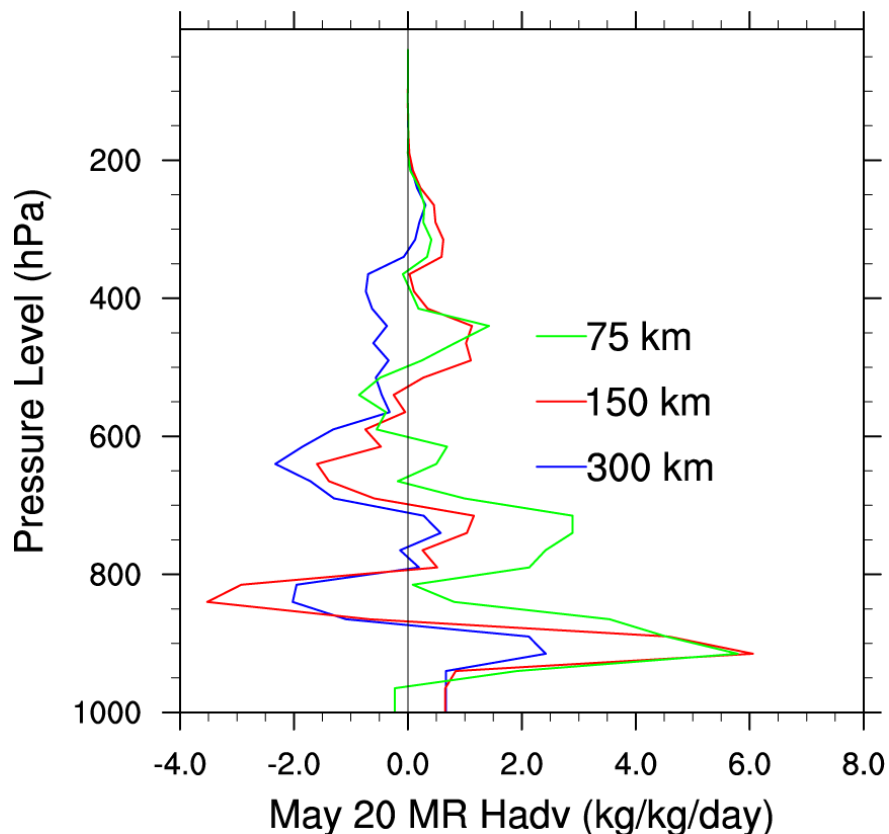
20110520 1000 UTC 2.0 km



Moisture Advection



The 20 May 2011 Strong Mesoscale Convective Case

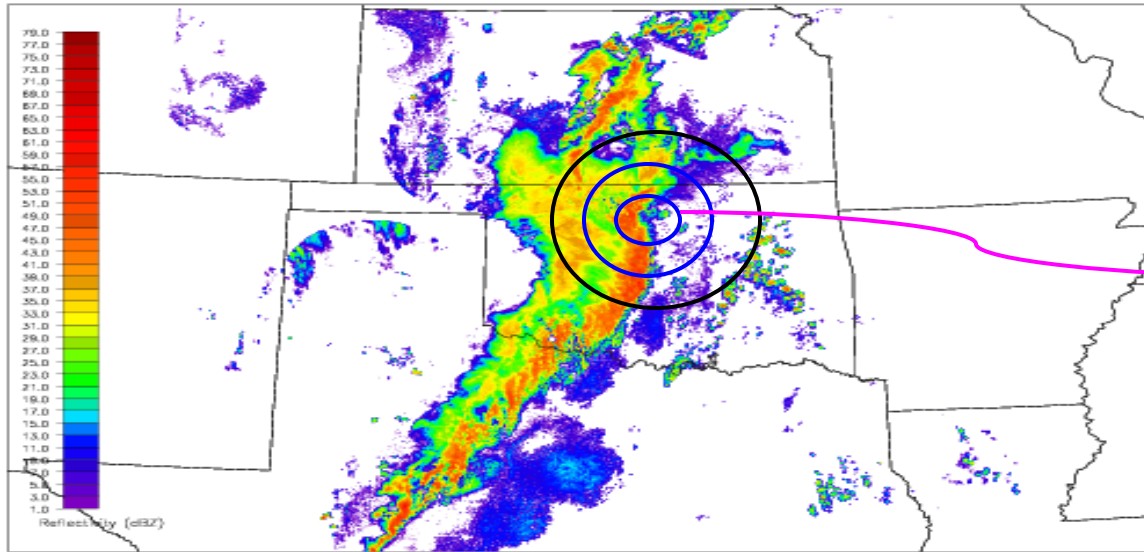




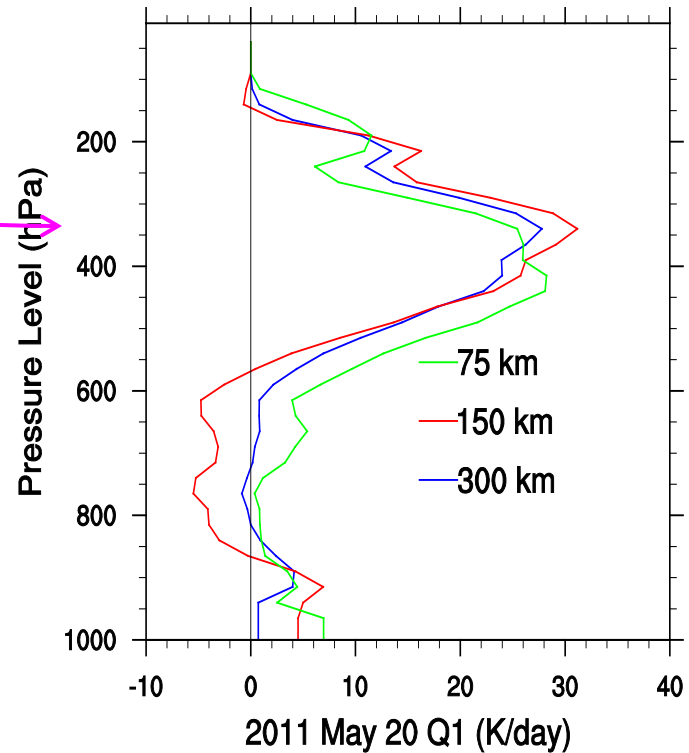
Q1 varies with domain sizes

The 20 May 2011 Strong Mesoscale Convective Case

20110520 1000 UTC 2.0 km



Diabatic Heating Rate



Summary and Future Plan



- **Multi-scale forcing datasets have been developed**
- **Forcing and diabatic heating/moistening vary with different convective systems**
- **Forcing and diabatic heating/moistening show strong spatial variability**
- **Future work:**
 - **Improve the forcing with improved sounding data**
 - **Dry bias corrected sondes (BNL)**
 - **High resolution merged sounding and wind profiler data (Paul Ciesielski, CSU)**
 - **Ensemble forcing to address uncertainties in the constraints**
 - **Forcing at 10 mb resolution to better resolve the boundary layer structure**
 - **Collaborative study with the CSU group**
 - **Compare the variational analysis forcing with the forcing data derived from the CSU group**

Issues with the corrected sondes

Original

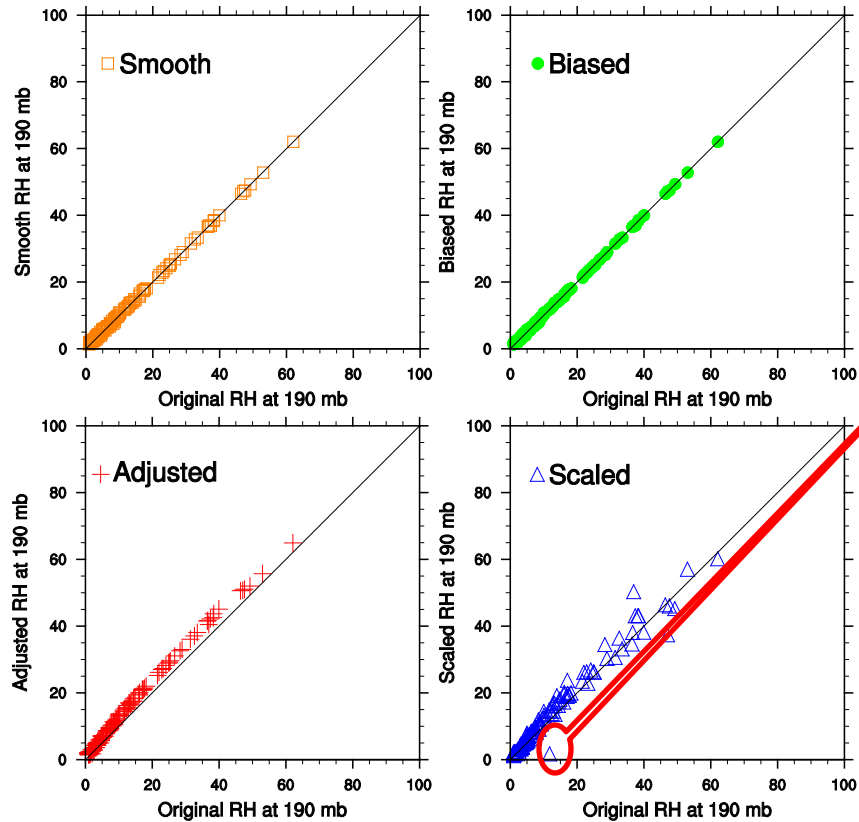
Smooth

Biased

Adjusted

Scaled

RH at 180 hPa
Corrected vs. Original



May 20 2030

