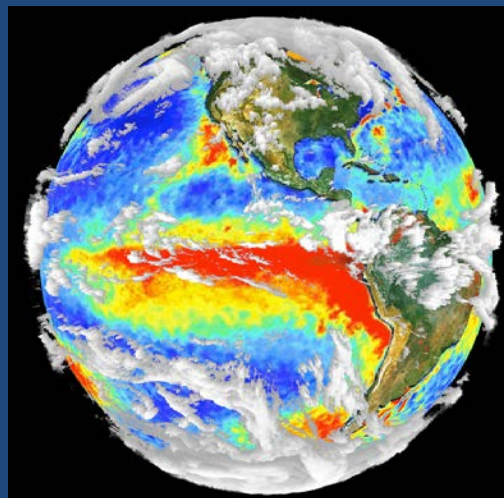


Improved Simulations of Clouds and Precipitation Using Data Assimilation



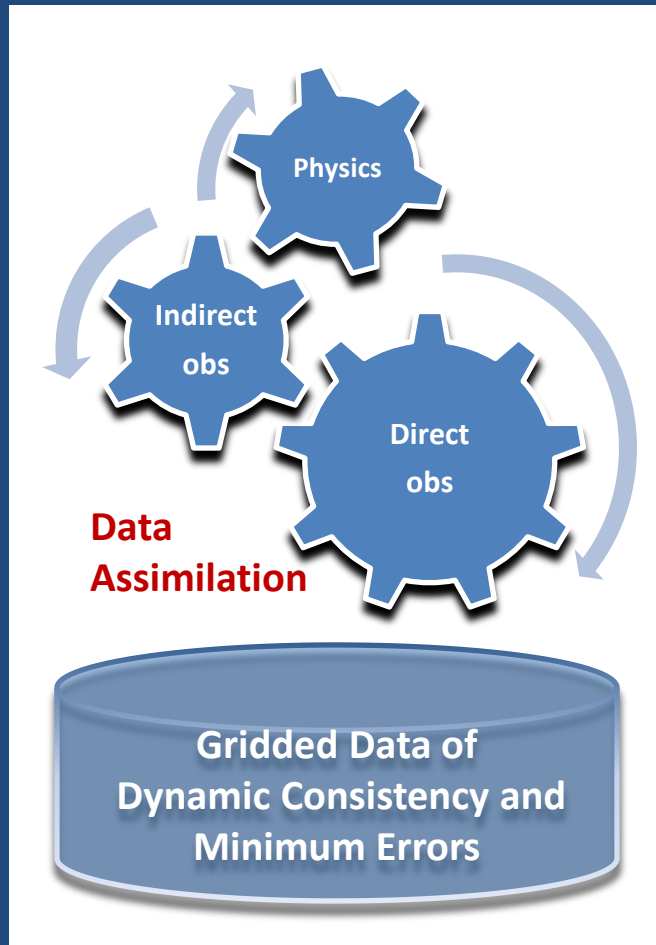
Zhijin Li

2011 Science Team Meeting, San Antonio, Texas, March 28, 2011

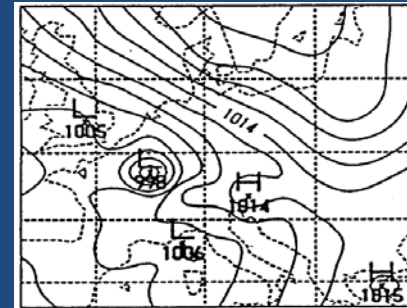
Outline

1. Overview
2. Case during the March 2000 Cloud IOP
3. Case during the June 2007 CLASIC IOP
4. Conclusions
5. Ongoing work

What Is Data Assimilation



1. Analysis



2. Forecast/Initialization

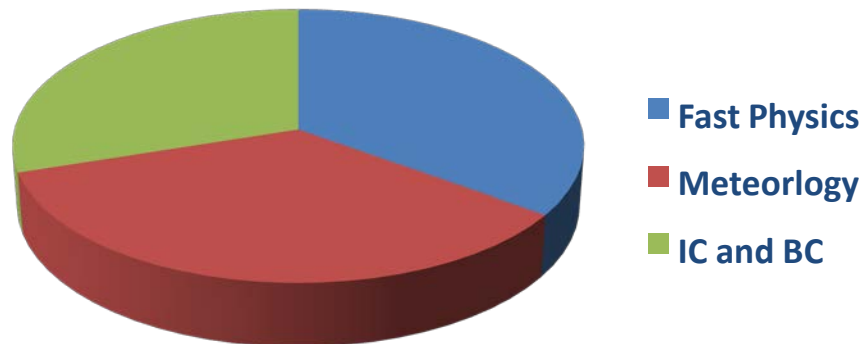


3. Balance and budget diagnostics

$$\frac{\partial C}{\partial t} = -\vec{v} \cdot \nabla C + S + R$$

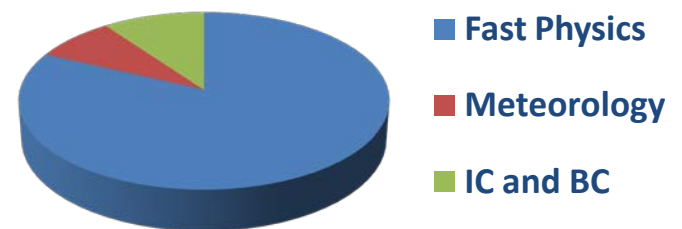
Data Assimilation for FASTER: Reducing Errors in Meteorological Fields, Initial and Boundary Conditions

Without Data Assimilation



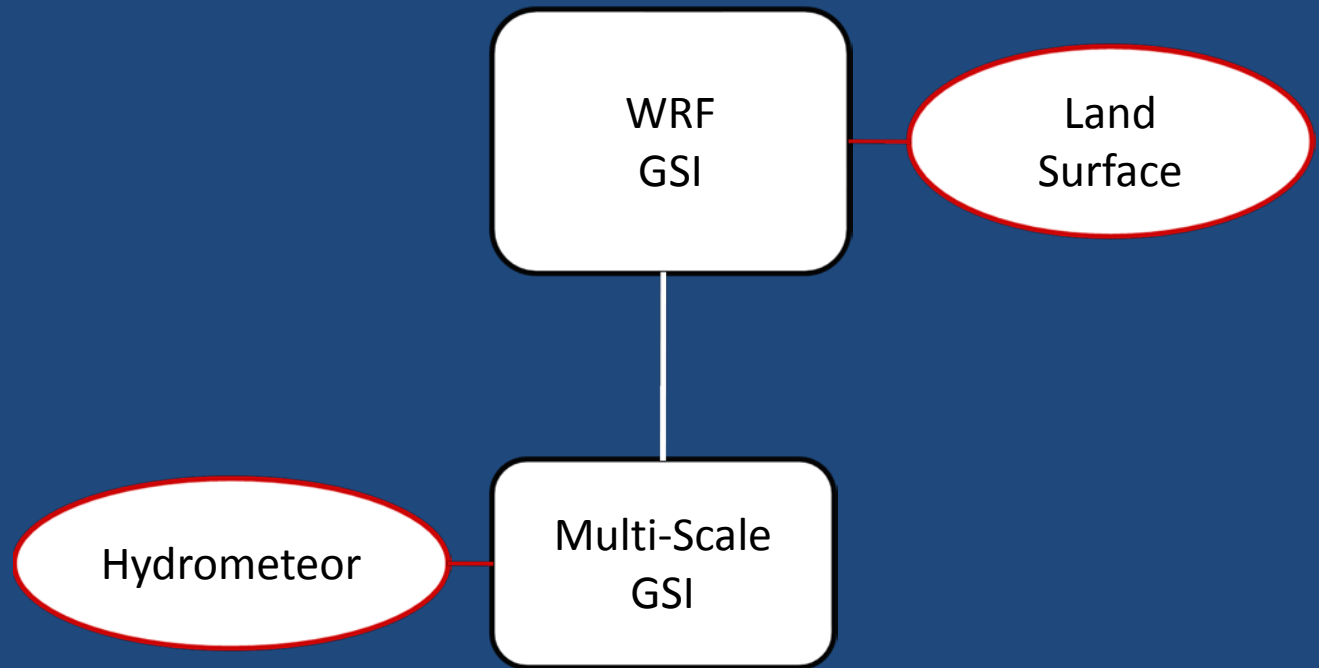
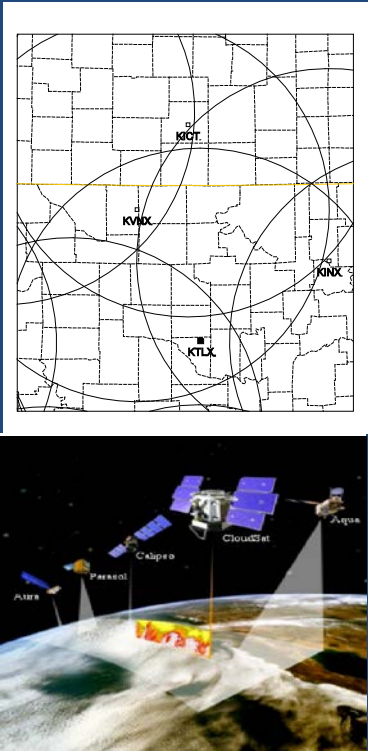
Error Distribution

With Data Assimilation



Error Distribution

Data Assimilation: Augmented WRF GSI



GSI: NCEP Gridspace Statistical
Interpolation Data Assimilation System

Multi-Scale 3DVAR: Multi-Scale Background Error Covariance

Background

$$x = x_L + x_S$$

$$e = e_L + e_S$$

$$\langle e_L e_S^T \rangle = 0$$

$$B = B_L + B_S$$

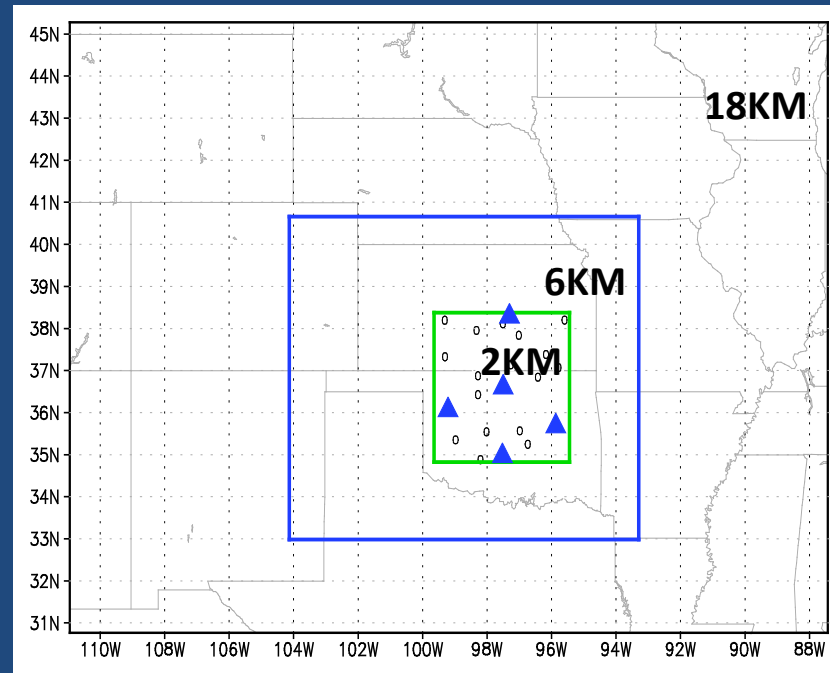
Multi-scale DA

$$\min_{\delta x_L} J = \frac{1}{2} \delta x_L^T B_L^{-1} \delta x_L + \frac{1}{2} (H \delta x_L - \delta y)^T (H B_S H^T + R)^{-1} (H \delta x_L - \delta y)$$

$$\min_{\delta x_S} J = \frac{1}{2} \delta x_S^T B_S^{-1} \delta x_S + \frac{1}{2} (H \delta x_S - \delta y)^T (H B_L H^T + R)^{-1} (H \delta x_S - \delta y)$$

(Li et al., 2011, QJRMS, in review)

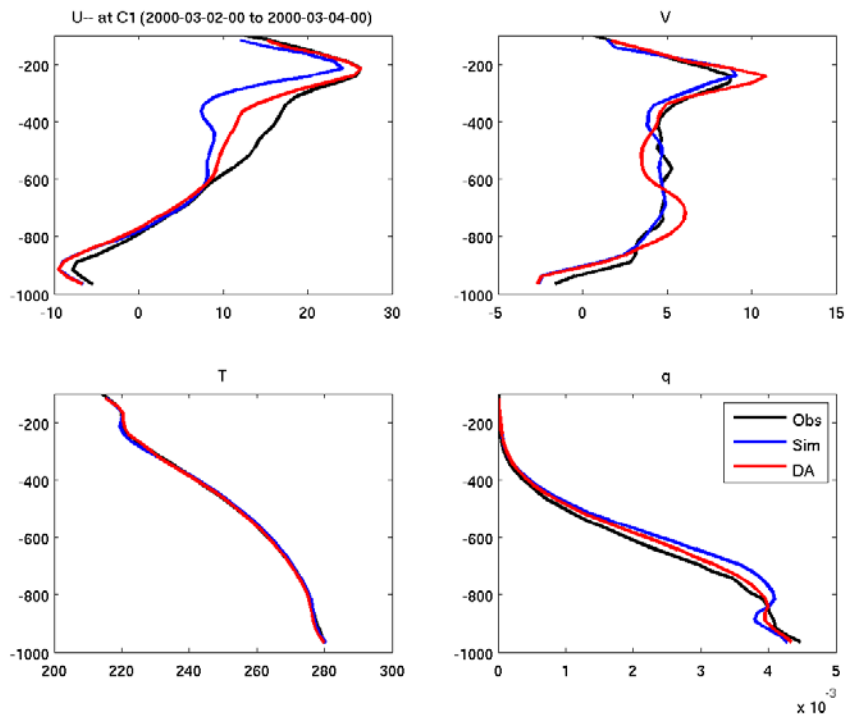
WRF and Data Assimilation Configuration: Case during the March 2000 Cloud IOP



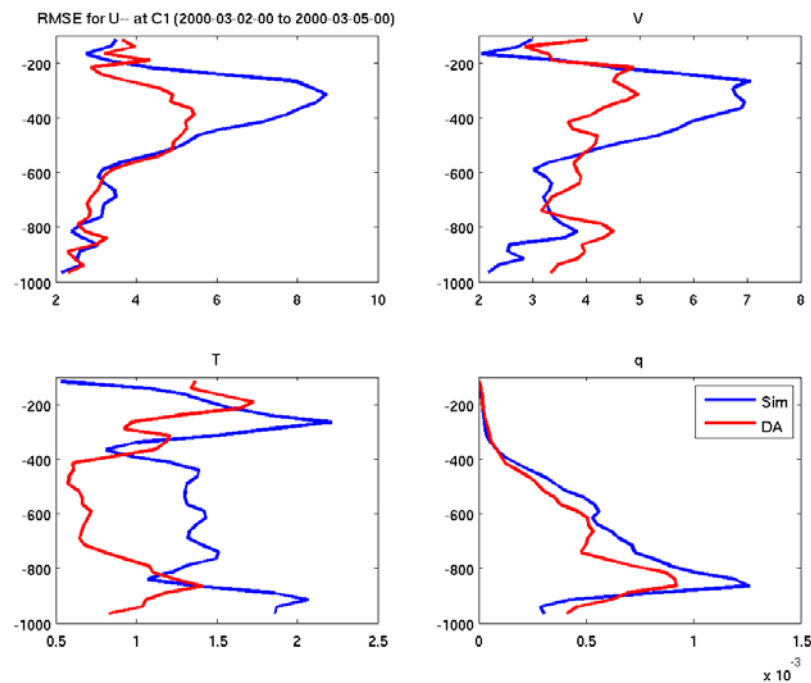
- The North American Regional Reanalysis (NARR) : Initialization and the lateral boundaries
- Observations: SONDE profiles and surface observations

Improved Meteorological Fields

Mean Profiles

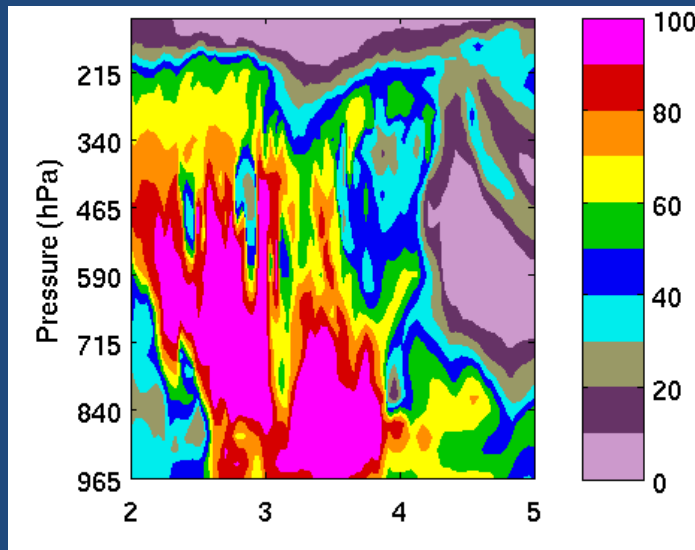


RMSEs

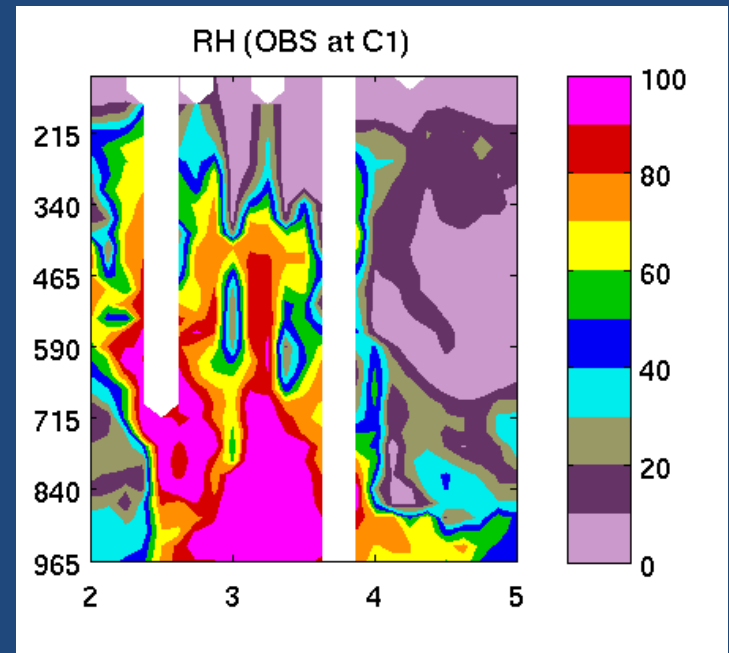
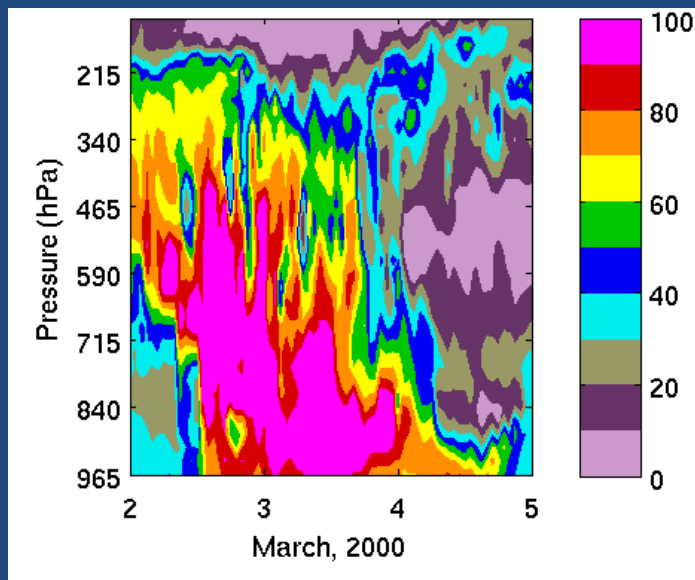


Improved Relative Humidity and Challenges

NO DA

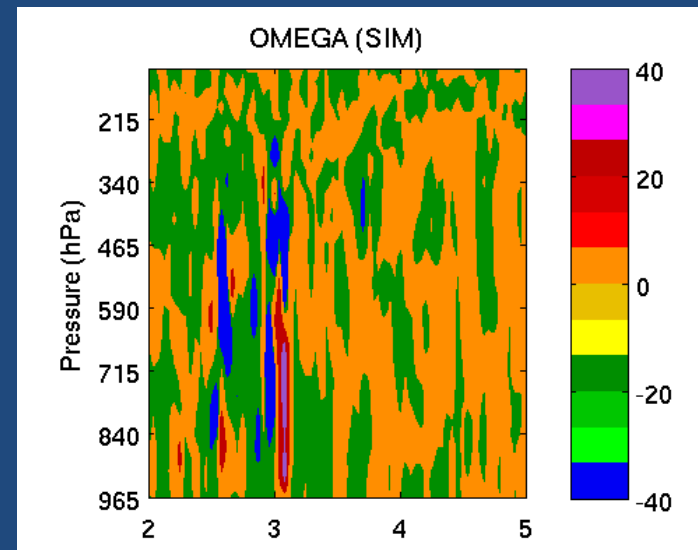
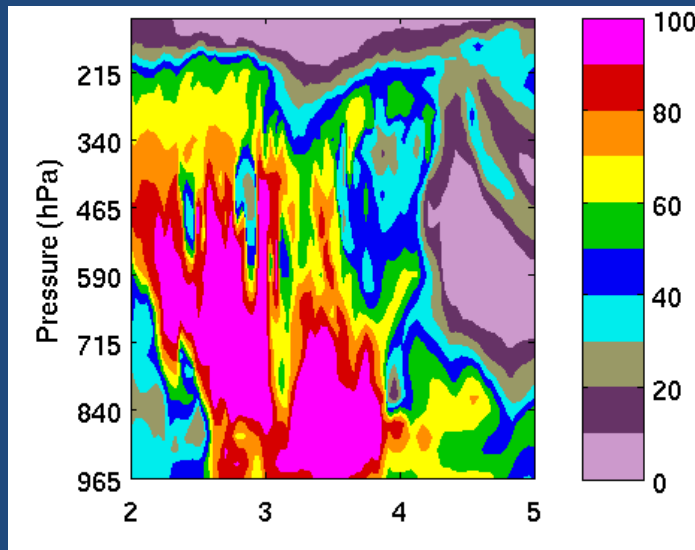


DA

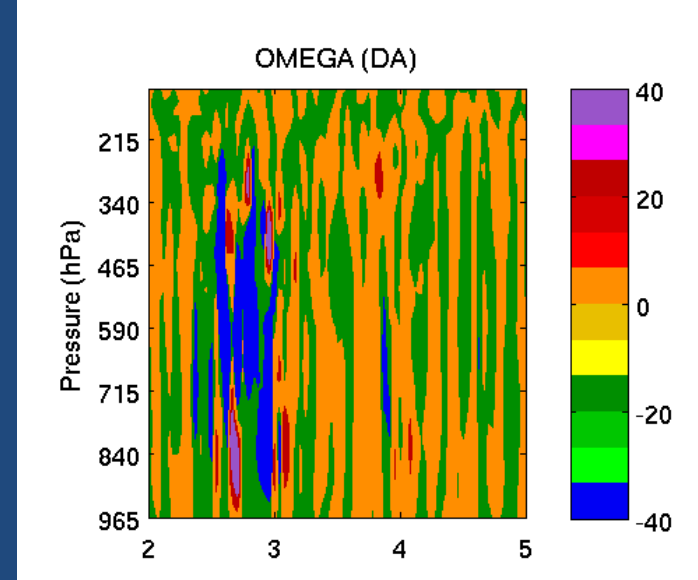
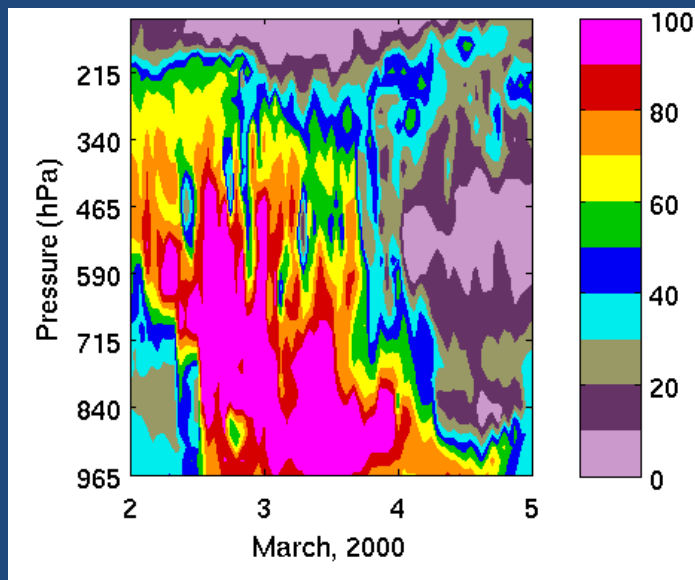


Improved Vertical Velocities and Challenges

NO DA

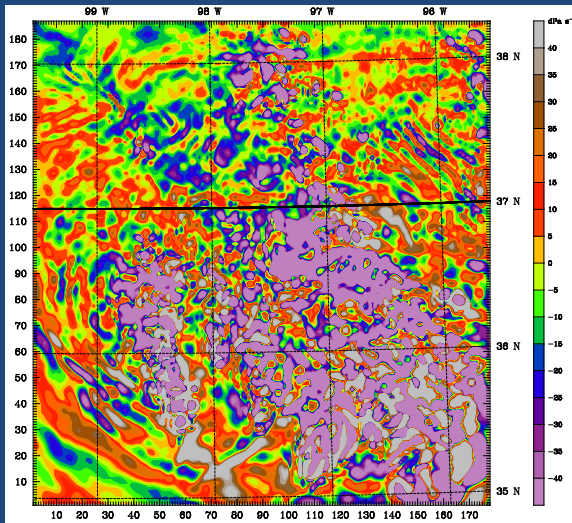


DA



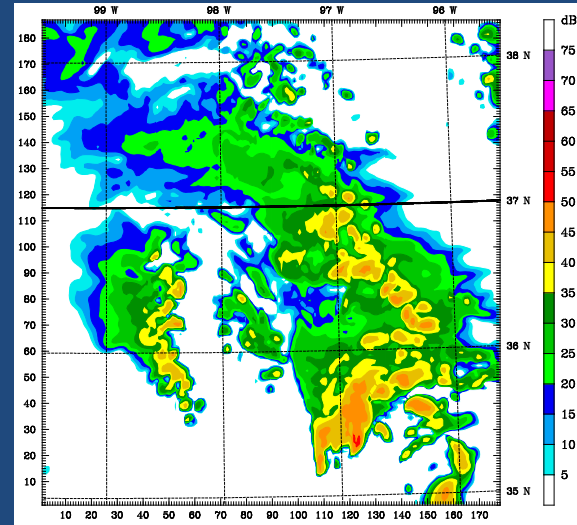
Simulated Vertical Velocity and Reflectivity

Vertical Velocity
500 hPa, UTC 00, 3 March

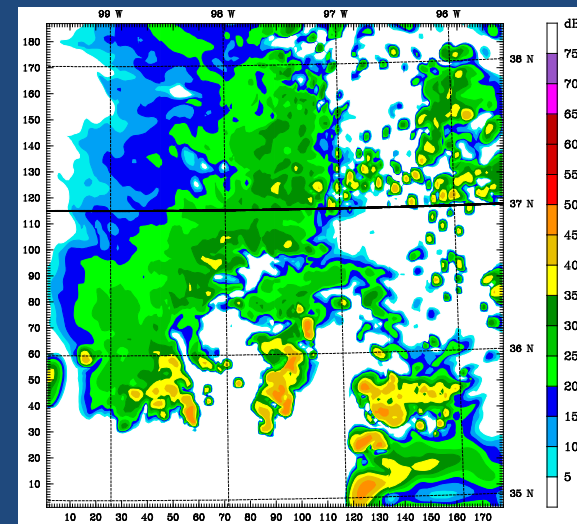
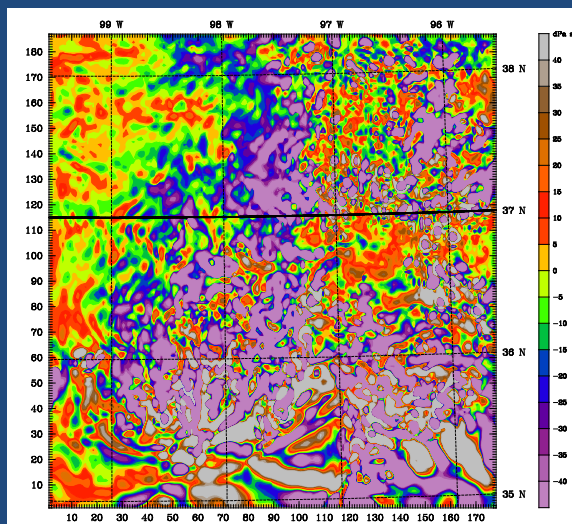


NO DA

Reflectivity
500 hPa, UTC 00, 3 March

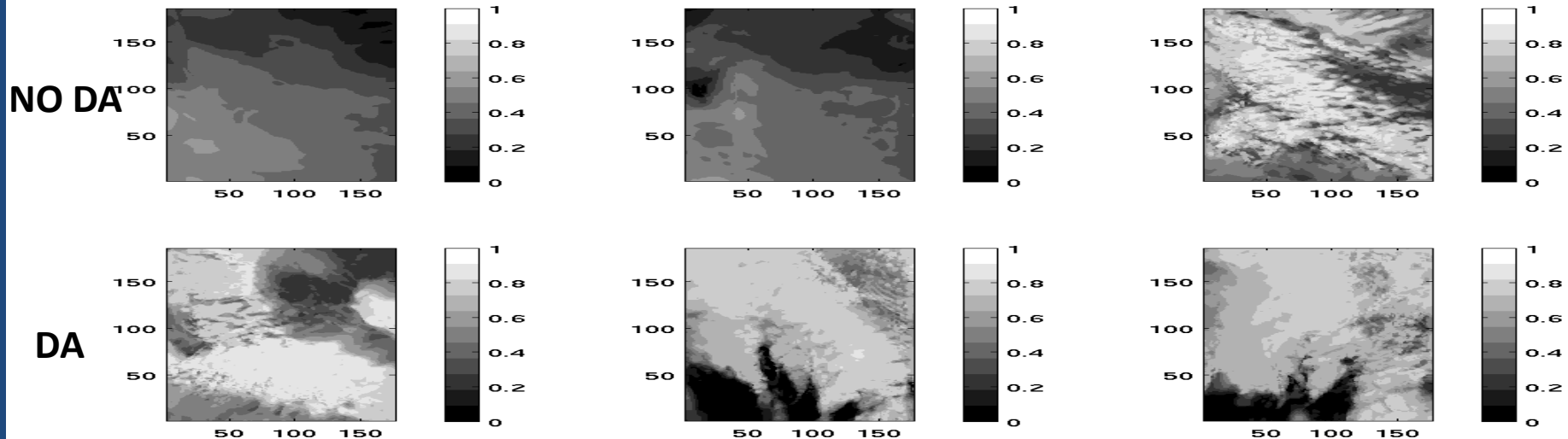
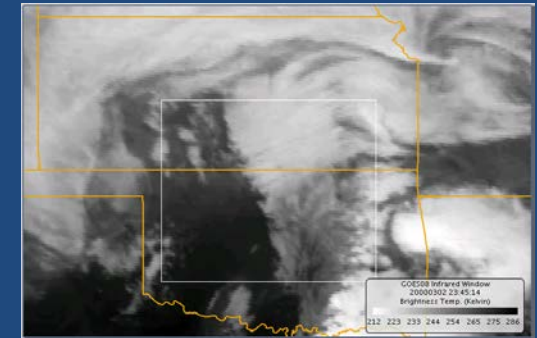
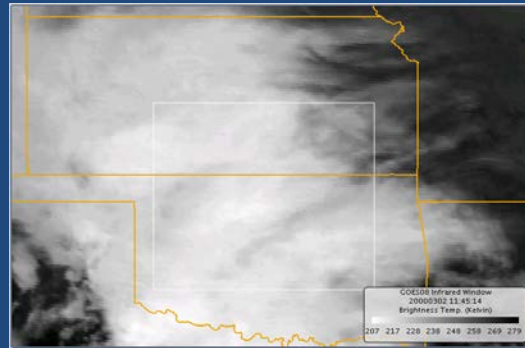
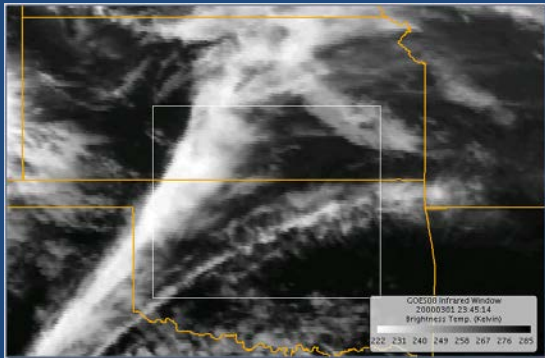


DA

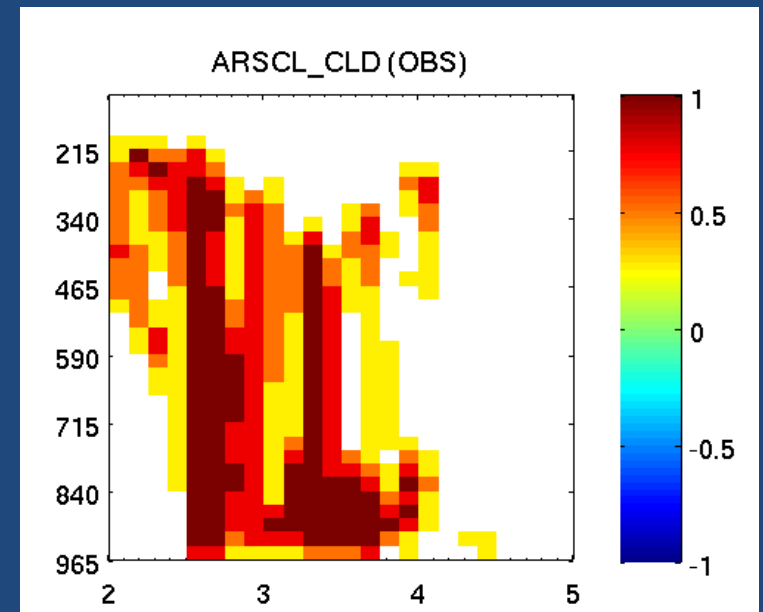
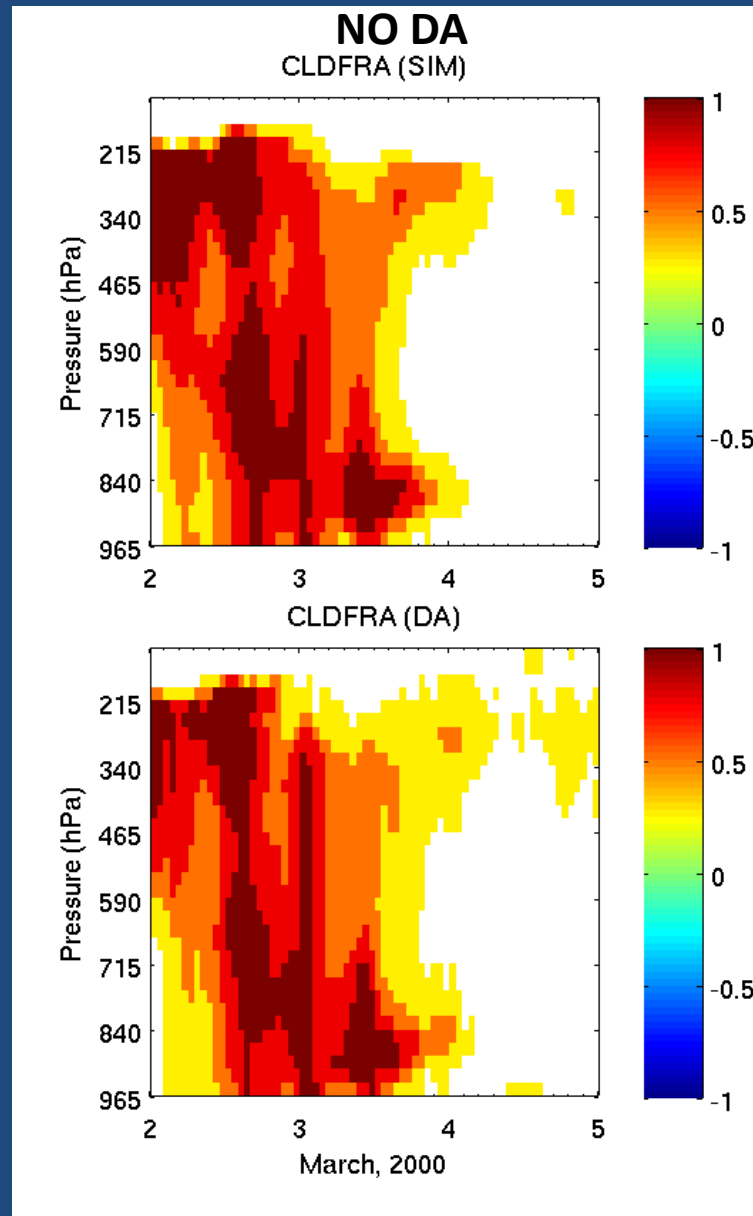


Improved Spatial Structures of Clouds

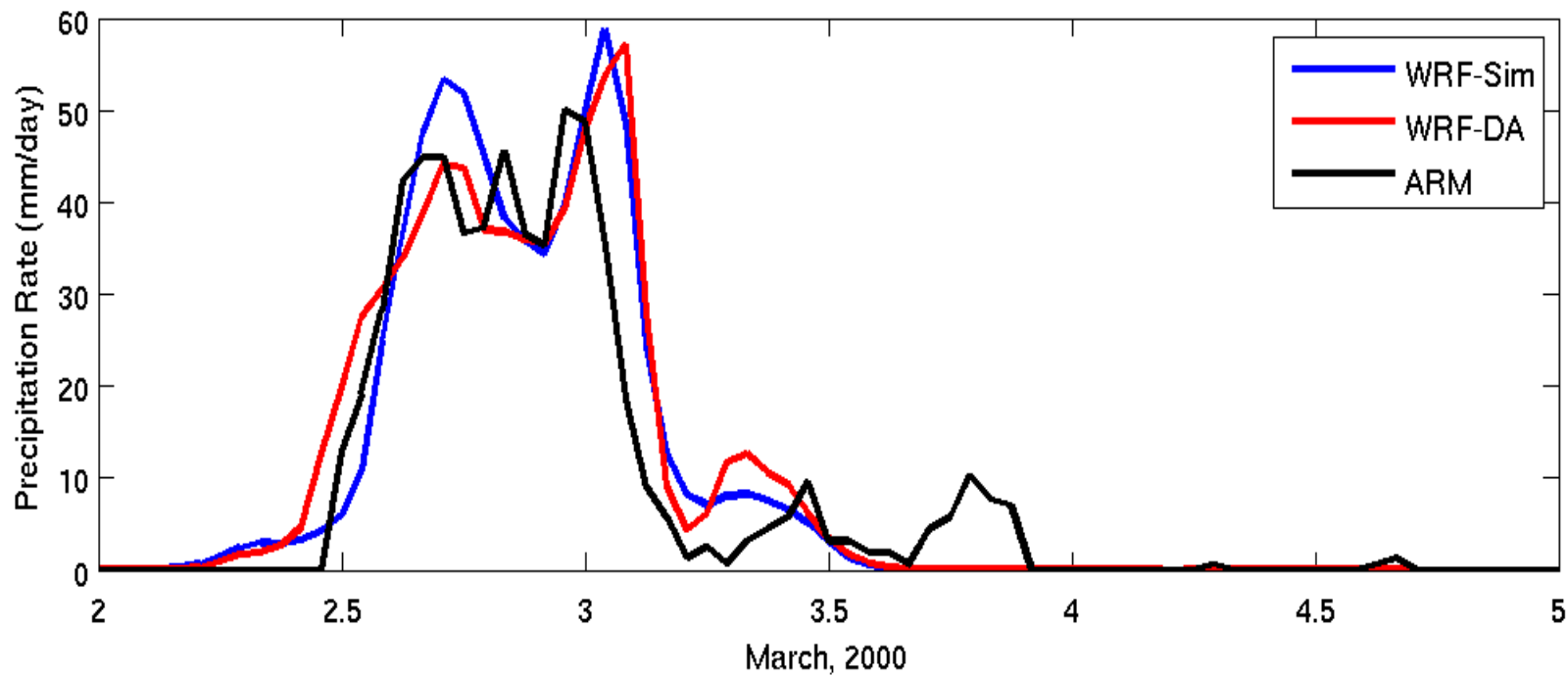
UTC 00, 03/02-----UTC 12, 03/02-----UTC 00, 03/03



Improved Cloud Fractions and Challenges

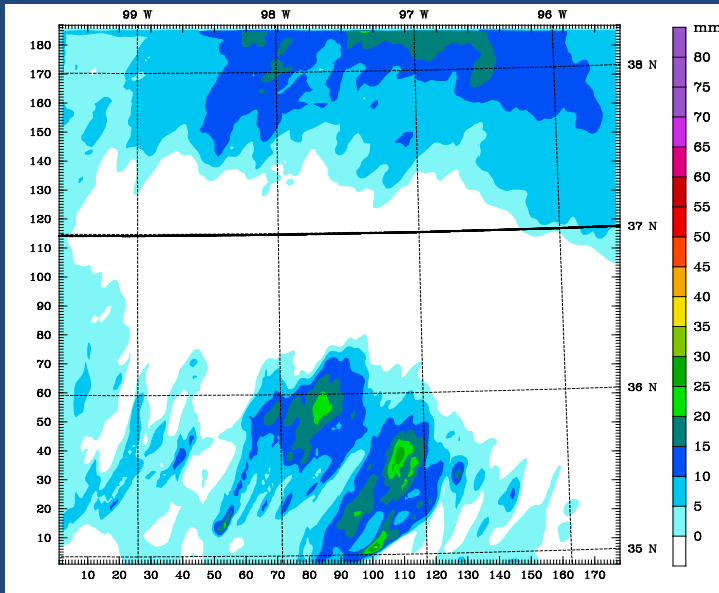


Domain Average Precipitation

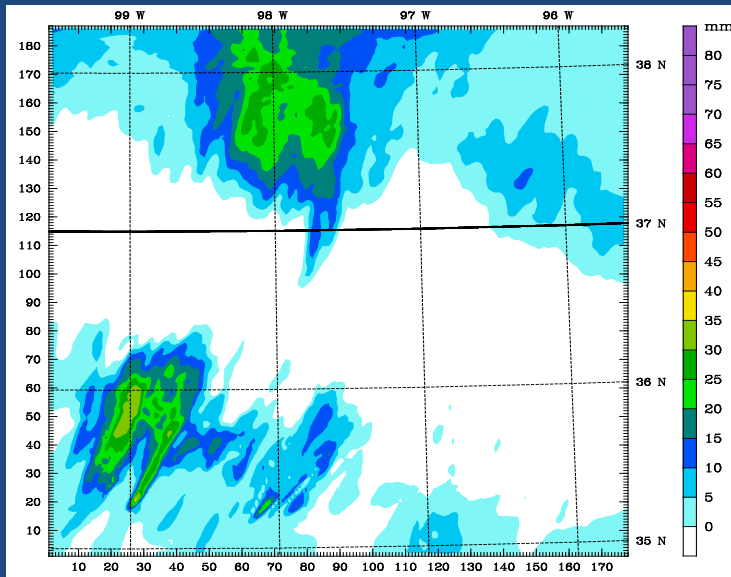


Improved Spatial Structures of Precipitation

NO DA

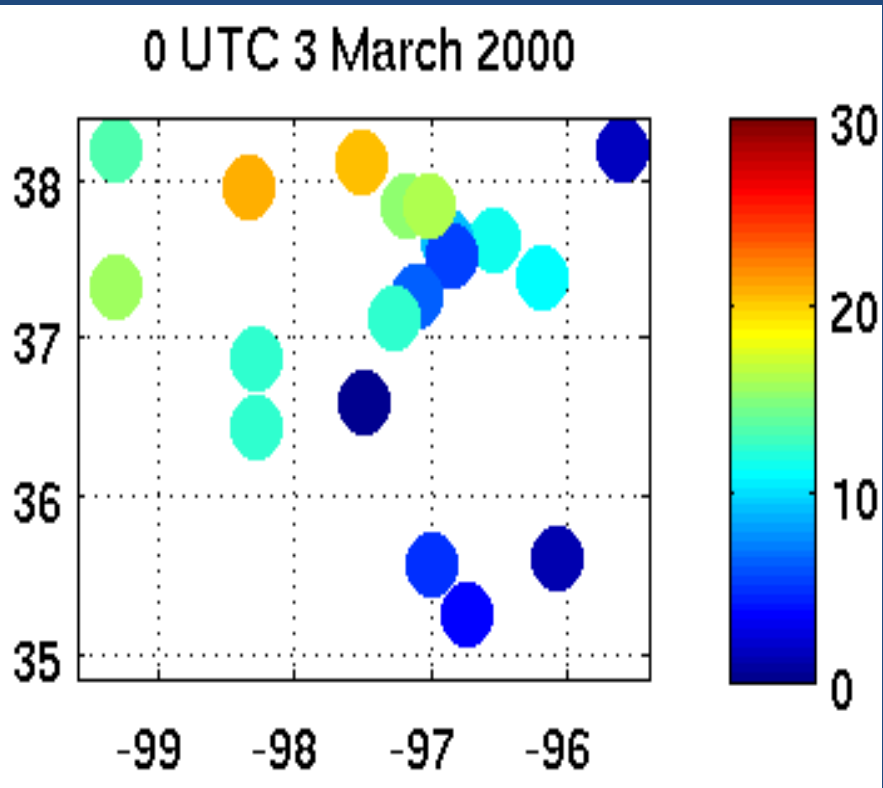


DA



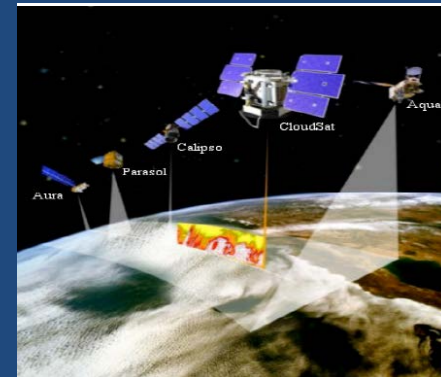
OBS

0 UTC 3 March 2000

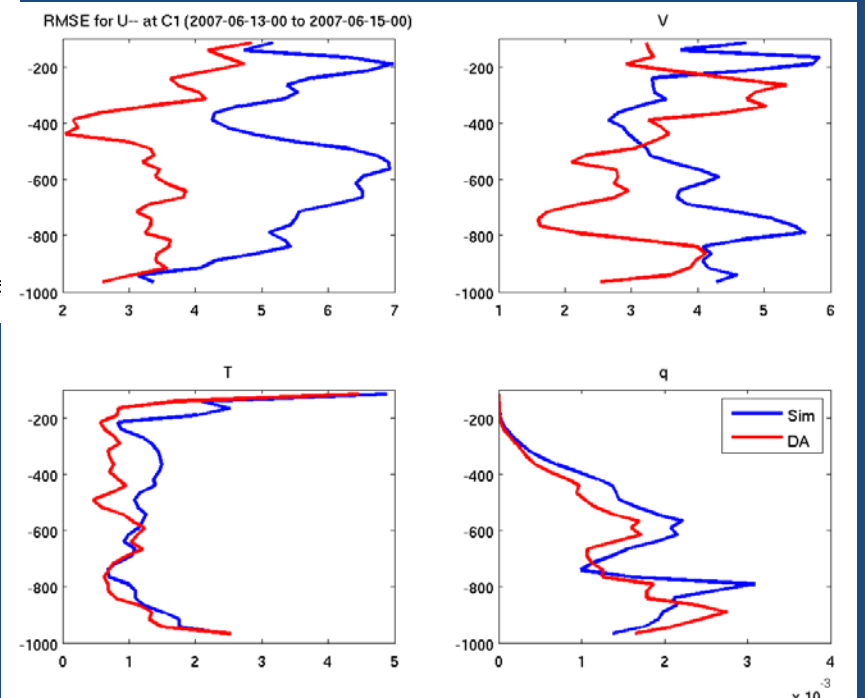
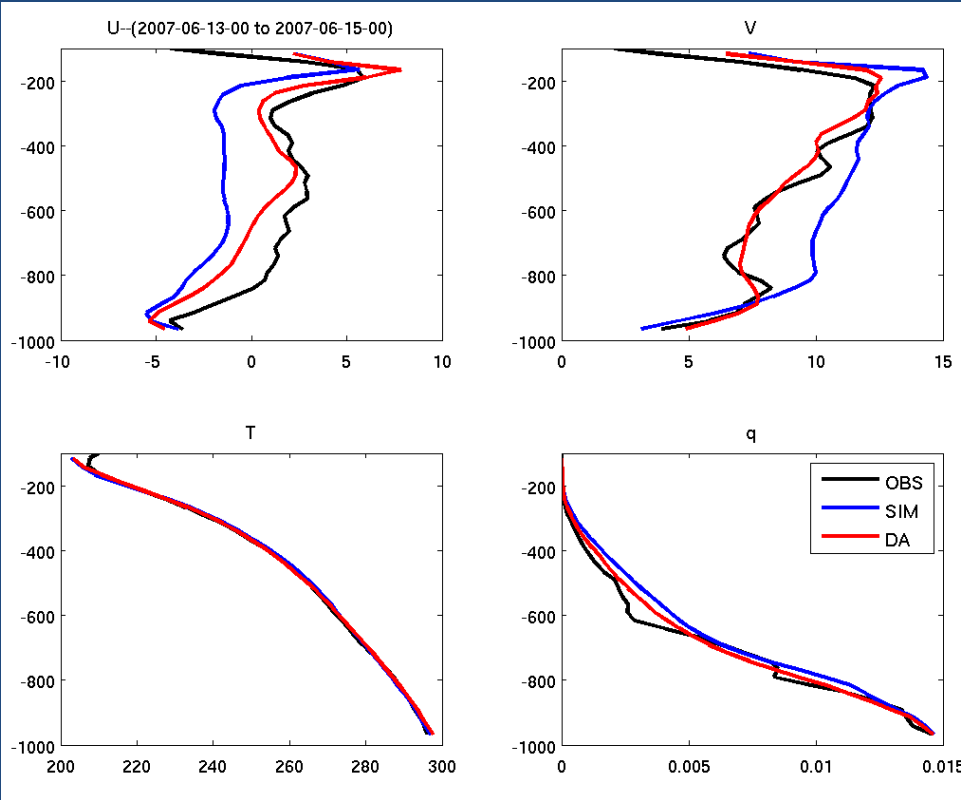


Impact of ARM and Satellite Data Case during the June 2007 CLASIC IOP

- Conventional data
- Satellite data assimilation:
 - amsua: Radiance (Brightness Temp) from
NOAA 16, 17, 18, metop-a
 - amsub: NOAA 15,16,17
 - hirs3: NOAA 16, 17
 - airs : NASA AQUA
 - mhs : NOAA 18, metop-a

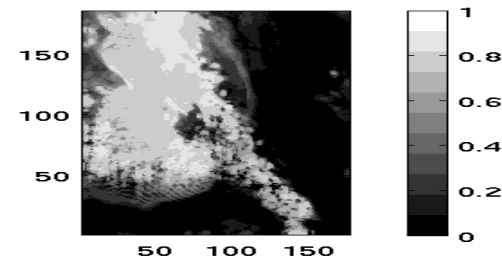
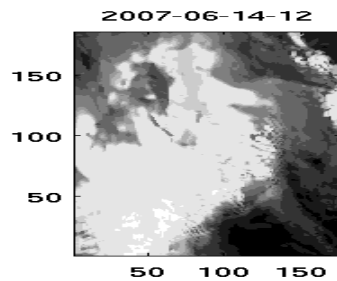
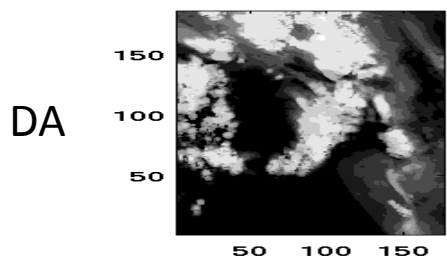
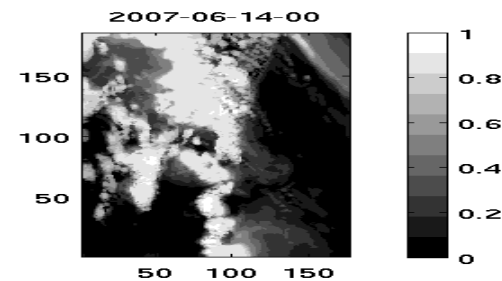
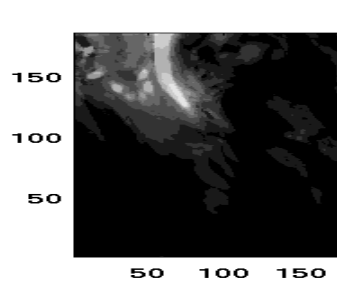
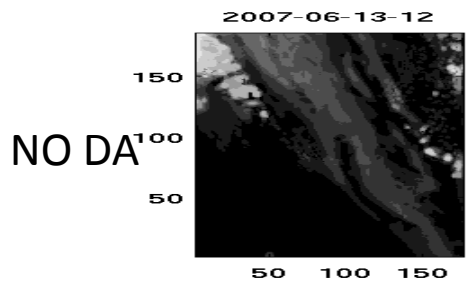
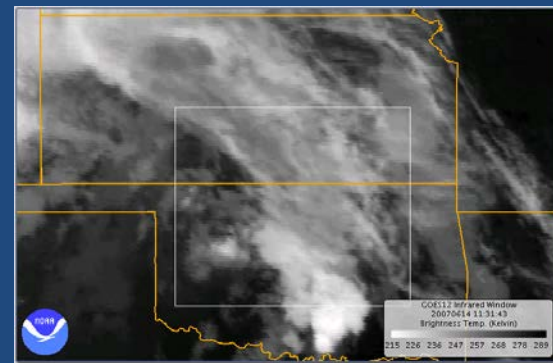
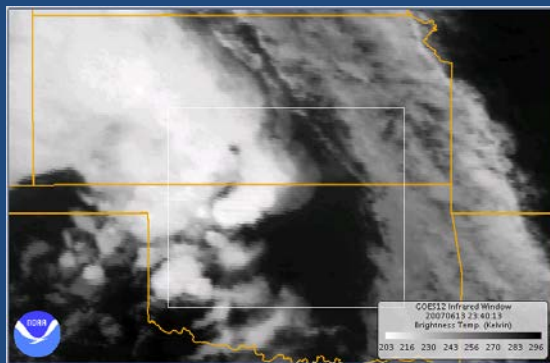
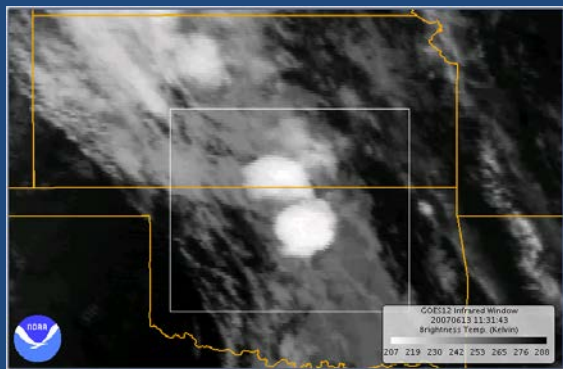


Improved Meteorological Fields



Improved Simulation of A Meso-scale Convective System

UTC 12, 06-13-2007-----UTC 00, 06-14-----UTC 12, 06-14

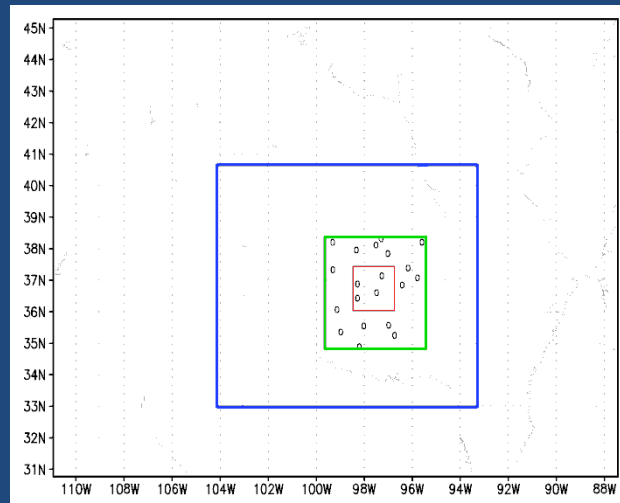


Conclusions

- **Impacts of ARM observations**
 1. improved meteorological fields
 2. improved cloud and precipitation spatial structures
 3. reduced the over-predicted high cloud amounts
- **Vertical velocities need to be investigated**
- **Potential of using data assimilation for FASTER demonstrated**

Ongoing Work

- Validate and evaluate land surface data assimilation
- Assimilate radar radial velocities
- Implement a quadruple nesting WRF to a resolution of 0.75km
- Perform experiments with more cases



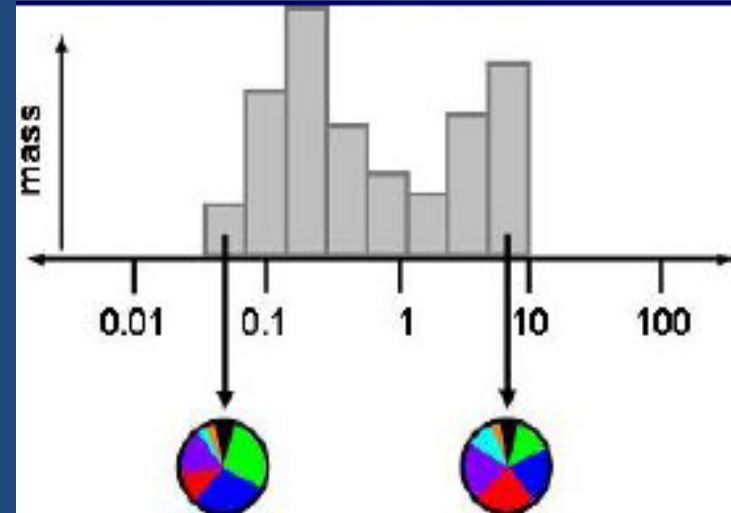
MS-3DVAR for WRF-Chem Aerosols

$$\delta x = \begin{bmatrix} \delta x_{SO4} \\ \delta x_{NO3} \\ \delta x_{OC} \\ \delta x_{EC} \\ \delta x_{RPM} \end{bmatrix}$$



$$\delta x_s = \sum_{n=1}^N w_n \delta s_n$$

$$\delta s_n = \frac{w_n \sigma_n^2}{\sum_{i=1}^N w_i^2 \sigma_i^2} \delta x_s$$



Los Angeles Basin PM2.5 Prediction for 12-24 h

