Exploring a Multiscale Aerosol Data Assimilation System

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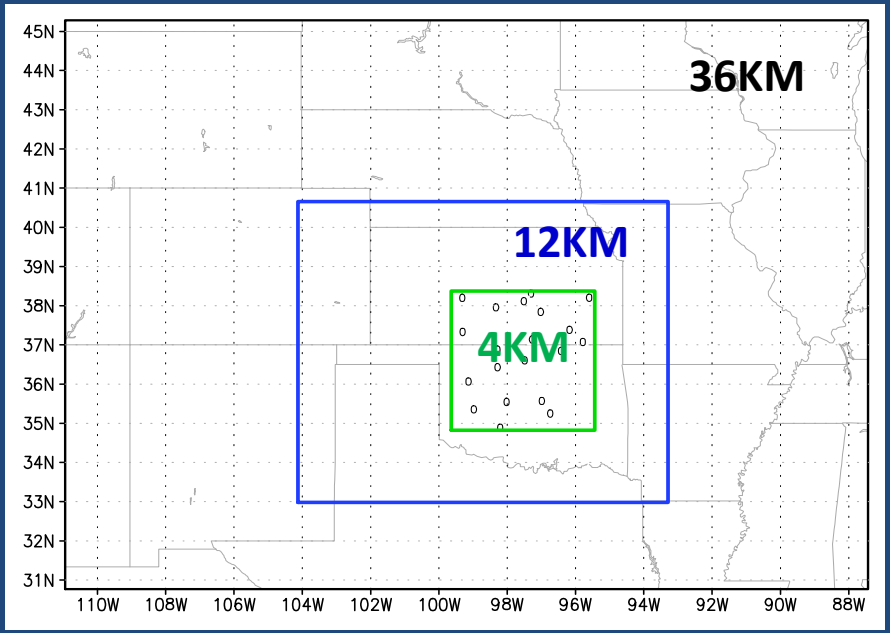
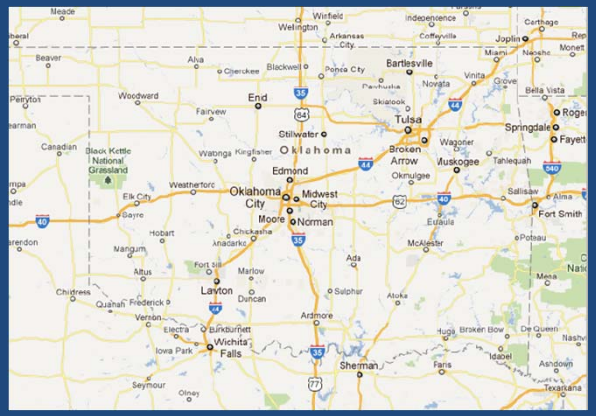
Overview

- Data assimilation with WRF is continuing
- WRF is extended to WRF/Chem for aerosol analysis and modeling
- Aerosol data assimilation has been implemented

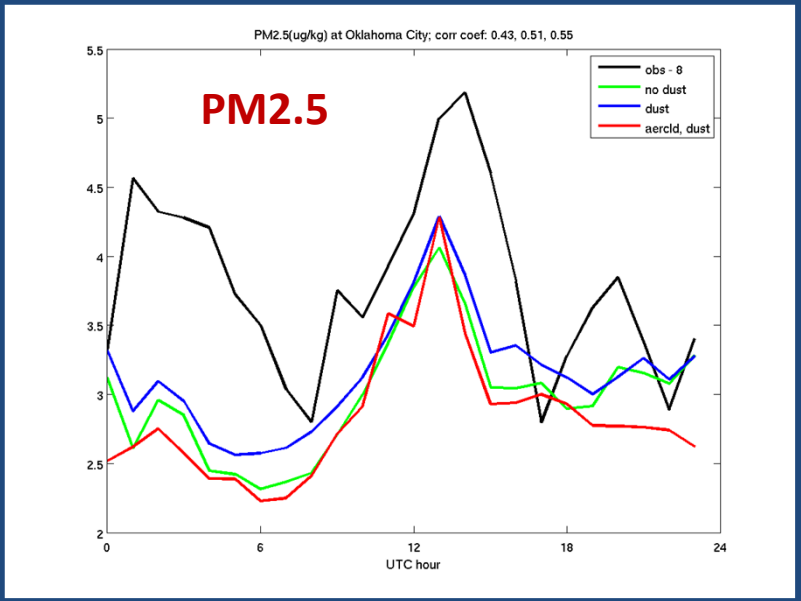
WRF/Chem Configurations

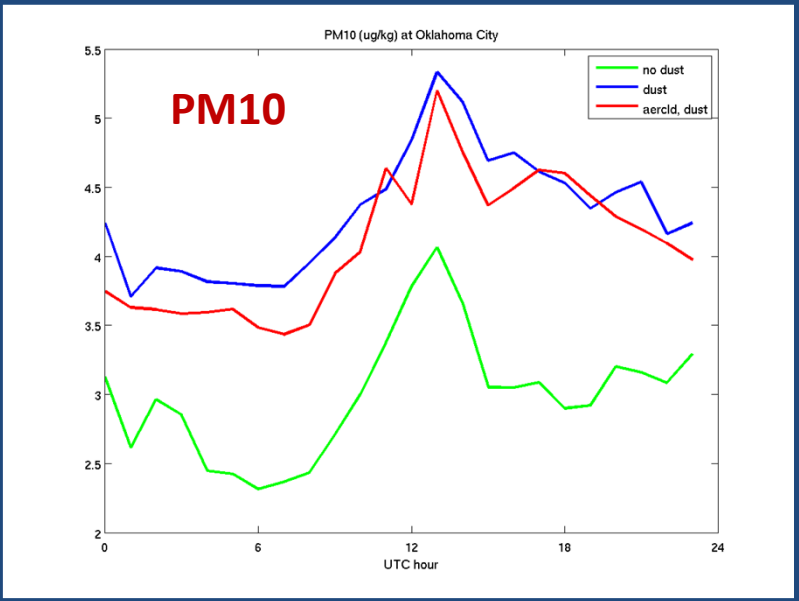


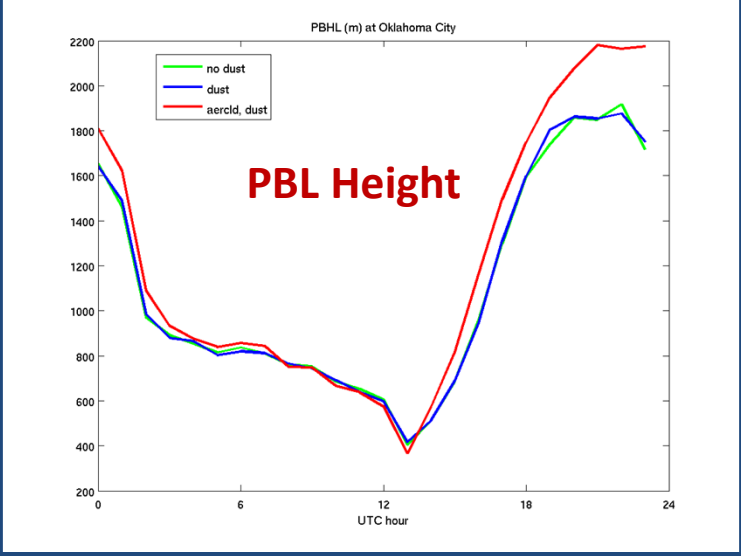


- Three domain nesting WRF/Chem 3.3
- 40 levels in the vertical
- MOSAIC aerosol scheme
- CBM-Z gas-phase chemical processes
- National Emission Inventory 2005 (NEI'05)

Diurnal Variations of Aerosol Mass Concentrations: June, 2009







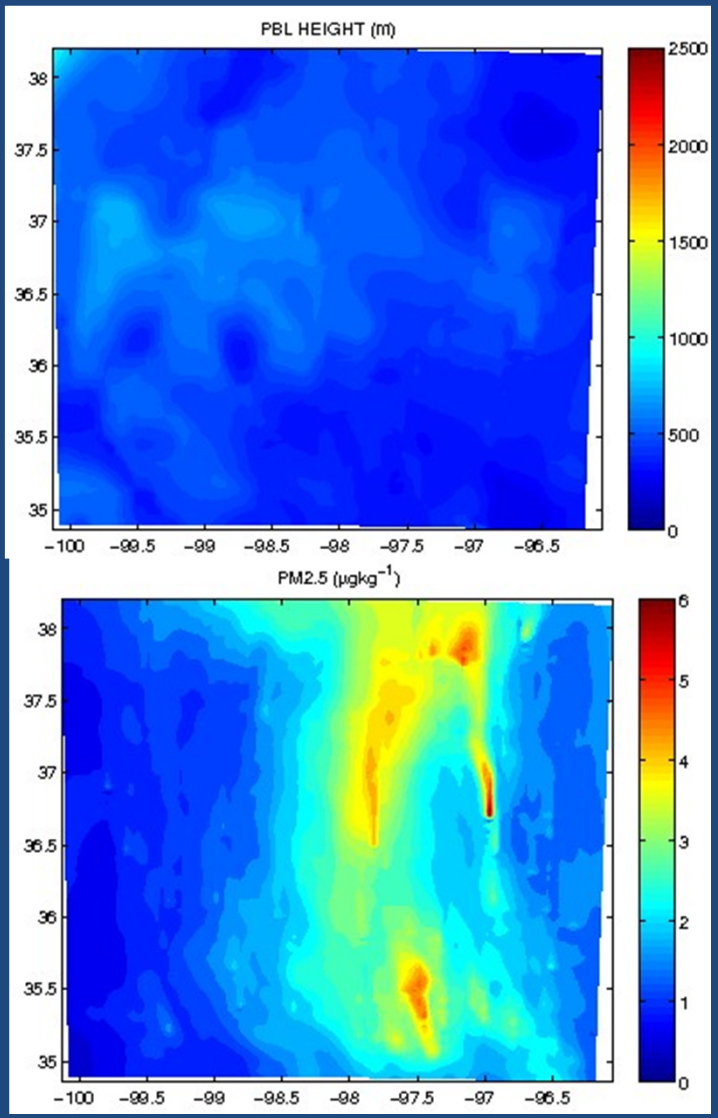
Connection between PBL Heights and PM2.5

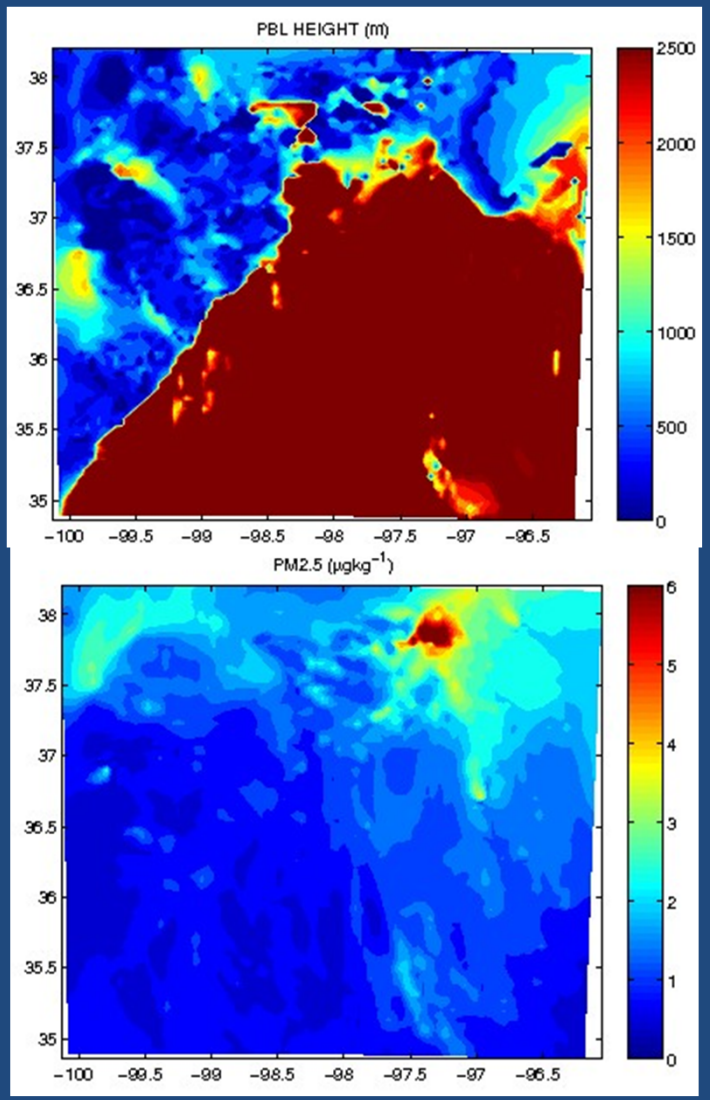
08 LT, 27 June, 2009

20 LT, 27 June, 2009

PBL Height

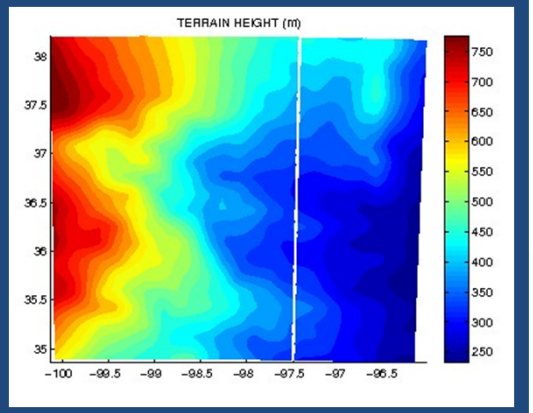
PM2.5





Vertical Section of Number Concentrations

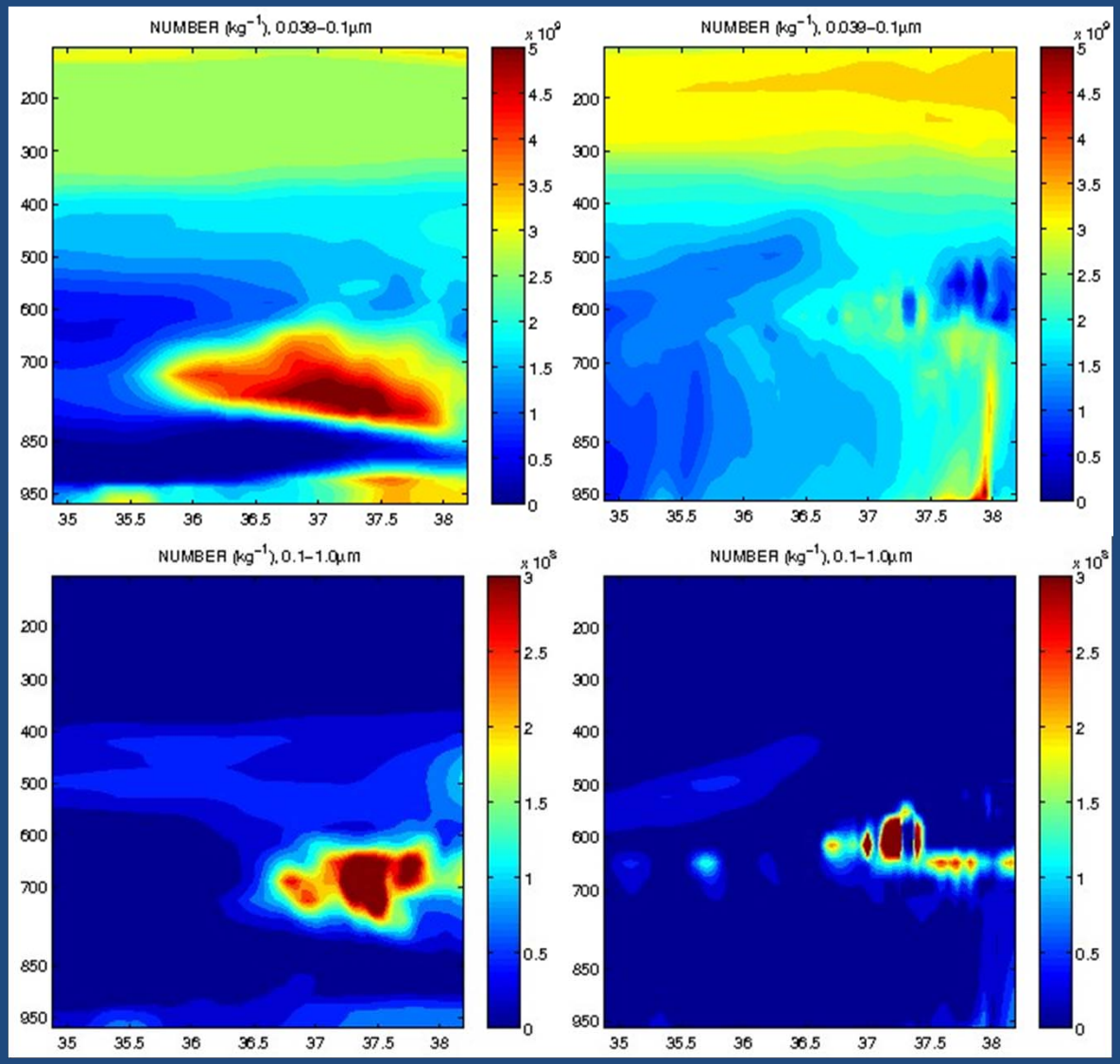
Number Concentration
0.039-0.1 µm
Nucleation



0.1-1.0 µm
Accumulation

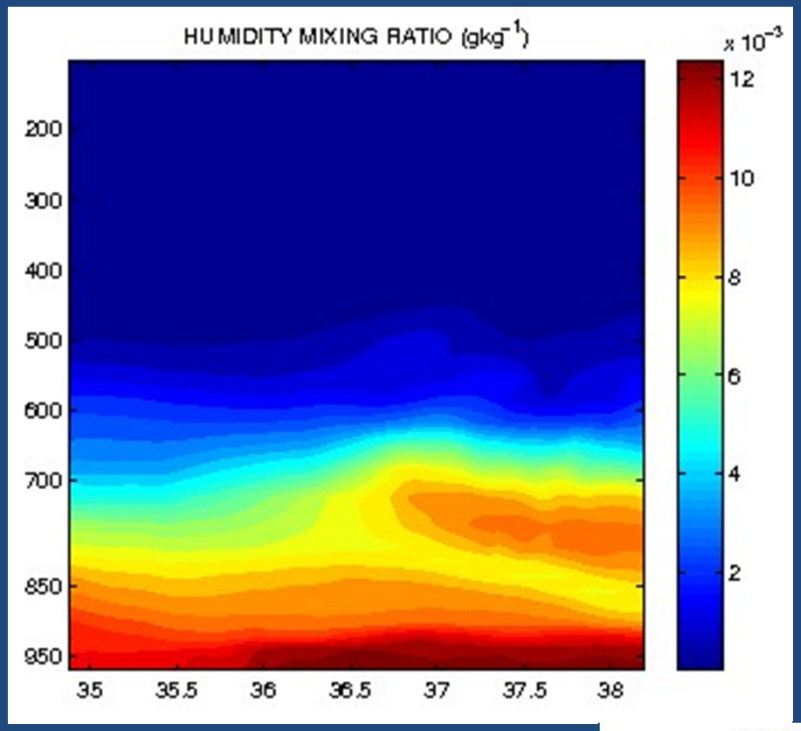
08 LT, 27 June, 2009

20 LT, 27 June, 2009

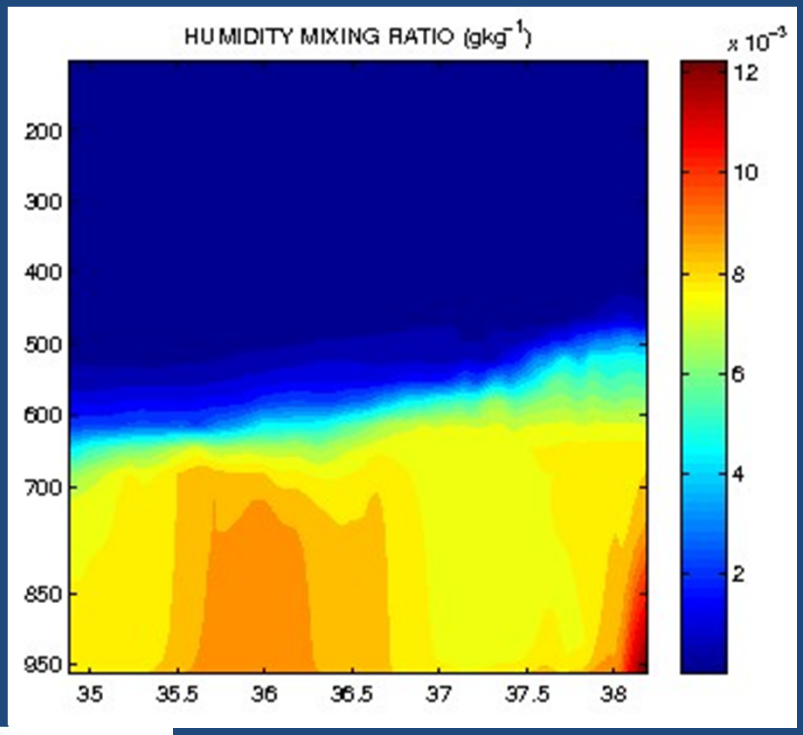


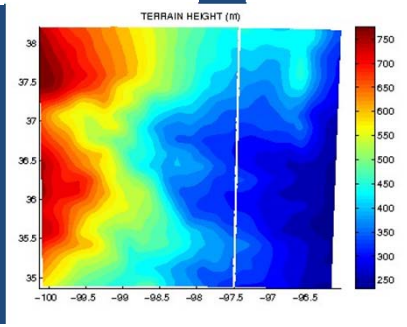
Vertical Section of Moistures

08 LT, 27 June, 2009

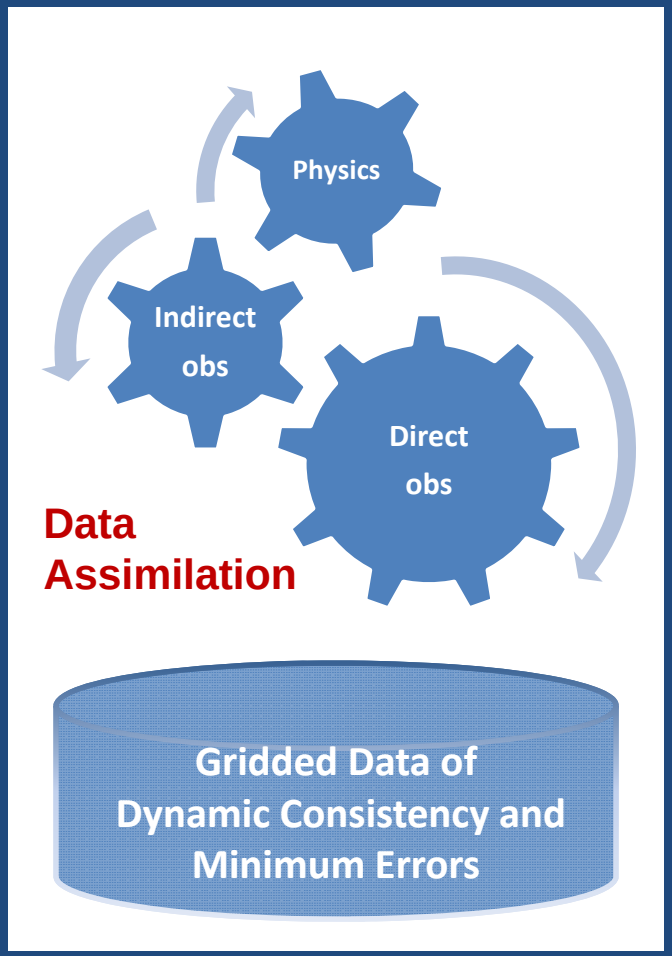


20 LT, 27 June, 2009

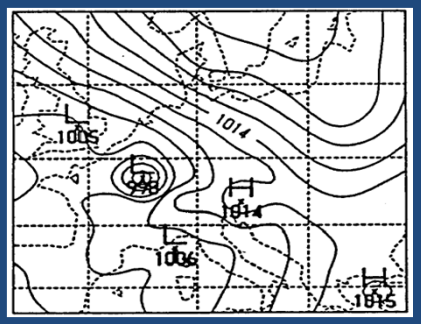




What Is Data Assimilation



1. Synoptic analysis

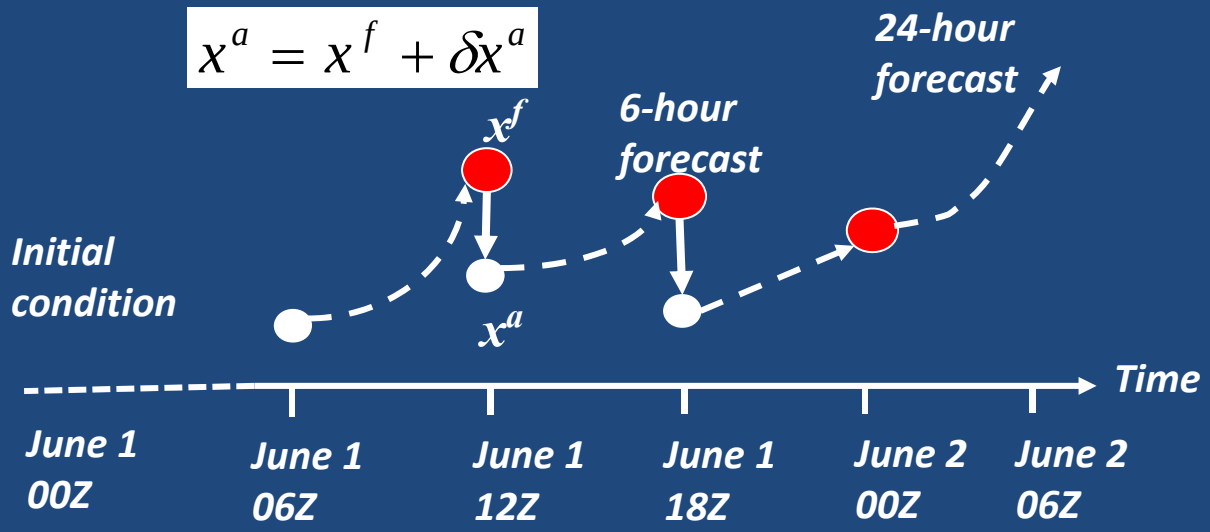


2. Initial conditions for prediction

3. Balance and budget diagnostics

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

Data Assimilation and Forecast Cycles



x consists of the MOSAIC aerosol variables

MS-3DVAR: a Background Error Covariance of Multi-Decorrelation Length Scales

$$x = x_L + x_S$$

$$B = B_L + B_S$$

$$\min_x J(\delta x) = \frac{1}{2}\delta x^T \left(B_L + B_S\right)^{-1} \delta x + \frac{1}{2}(H\delta x - \delta y)^T R^{-1}(H\delta x - \delta y)$$

3DVAR

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

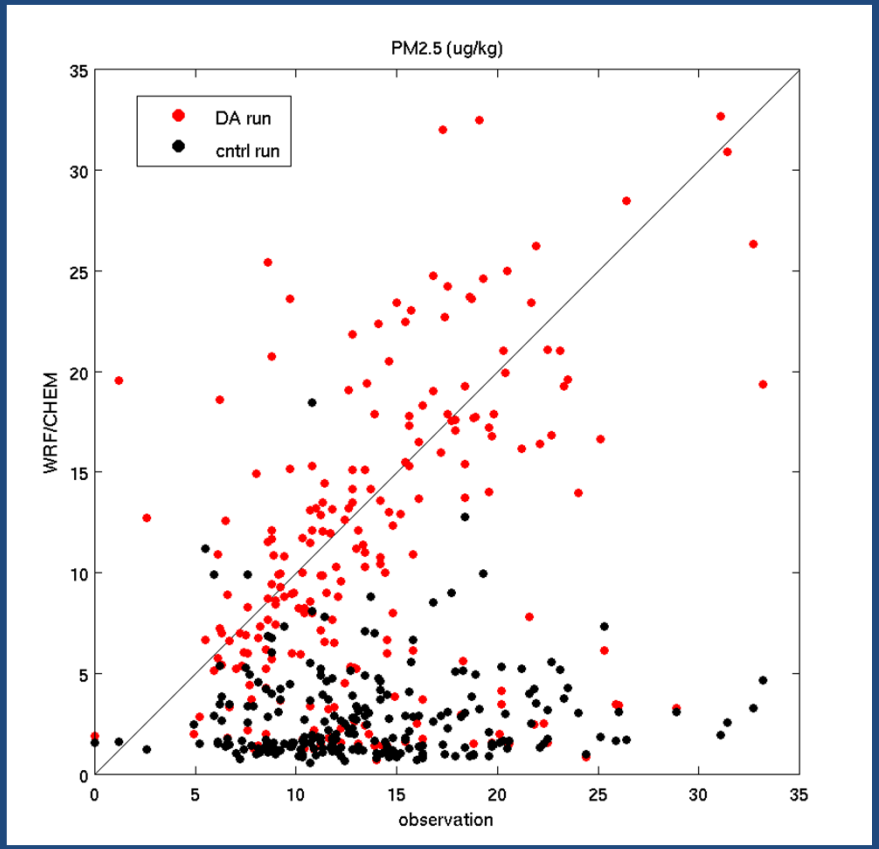
$$\min_{\delta x_S} J(\delta x_S) = \frac{1}{2}\delta x_S{}^T B_S^{-1} \delta x_S + \frac{1}{2}(H\delta x_S - \delta y)^T \left(HB_L H^T + R\right)^{-1}(H\delta x_S - \delta y)$$

MS-3DVAR

(Li et al., 2012, QJRMS, accepted)

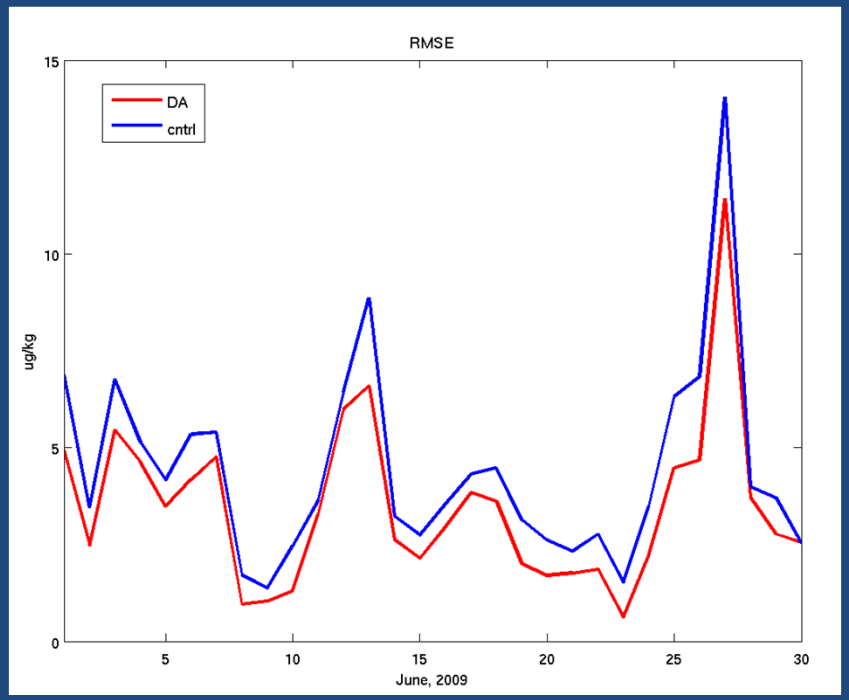
Data Assimilation Analysis vs Assimilated Observations

- **Simulation:** Down scaling from the NCEP North American Regional Reanalysis (NARR).
- **MS-3DVAR:** Assimilation of surface PM2.5 every 6h for all three domains.

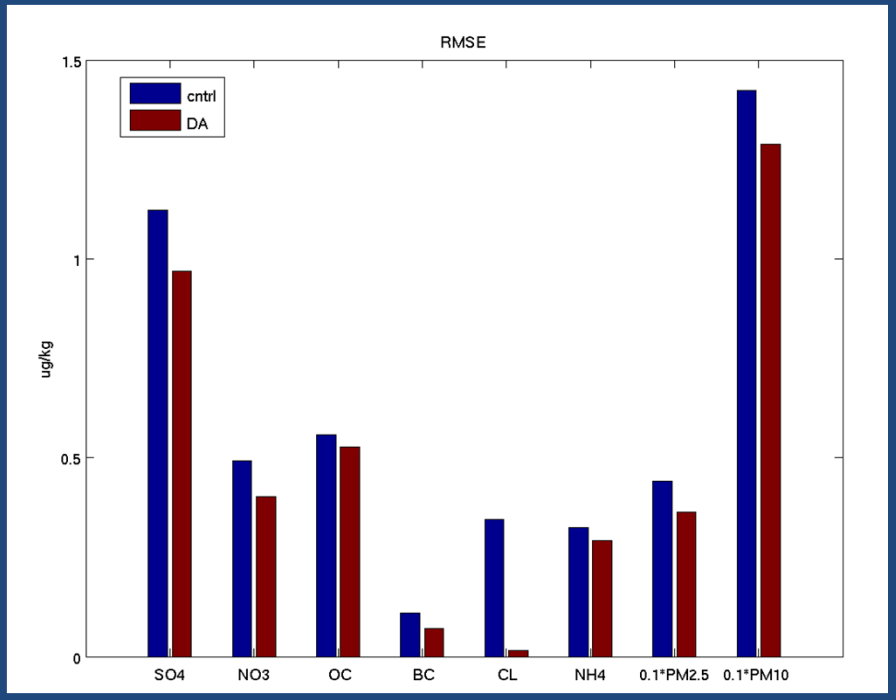


Improved PM2.5 and Specie Concentrations by Assimilating PM2.5 Observations

PM2.5



Species



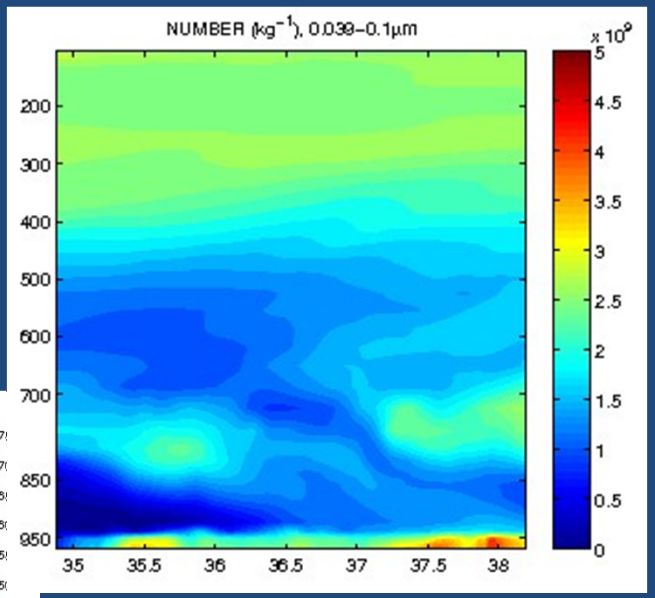
Ongoing Development

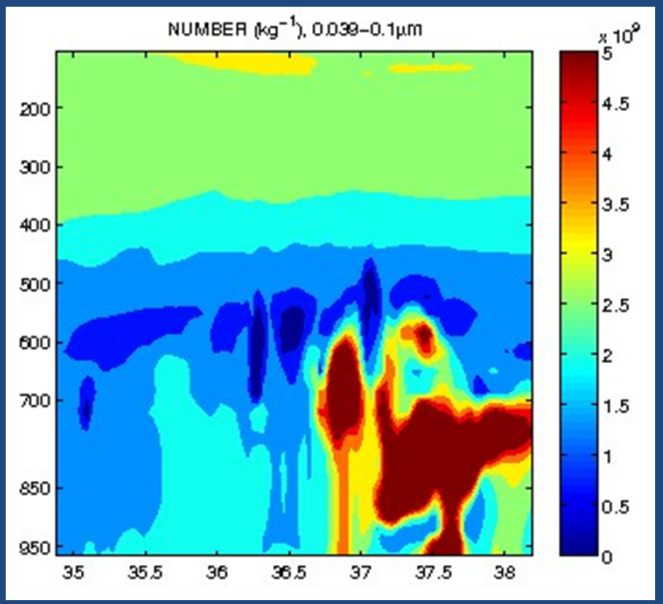
1. Experiments on assimilation of aircraft observations: data processing and evaluations
2. Assimilation of satellite aerosol optical depths (AODs)

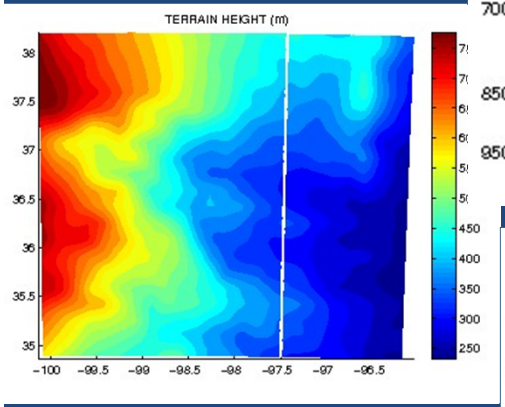
08 LT, 23 June, 2009

20 LT, 23 June, 2009

Number







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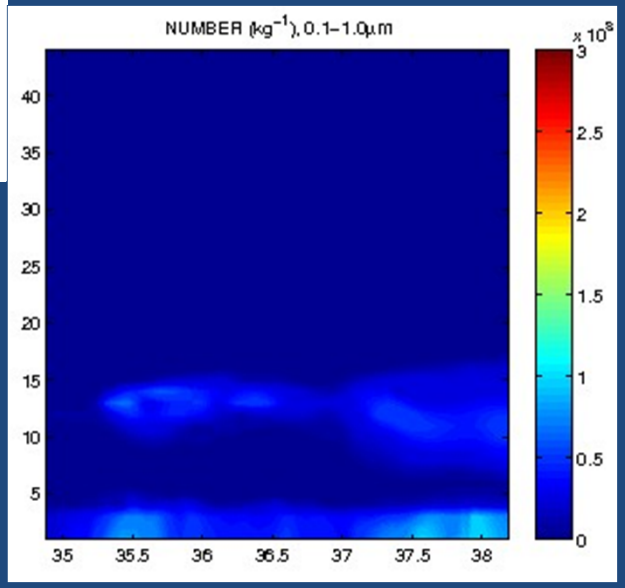

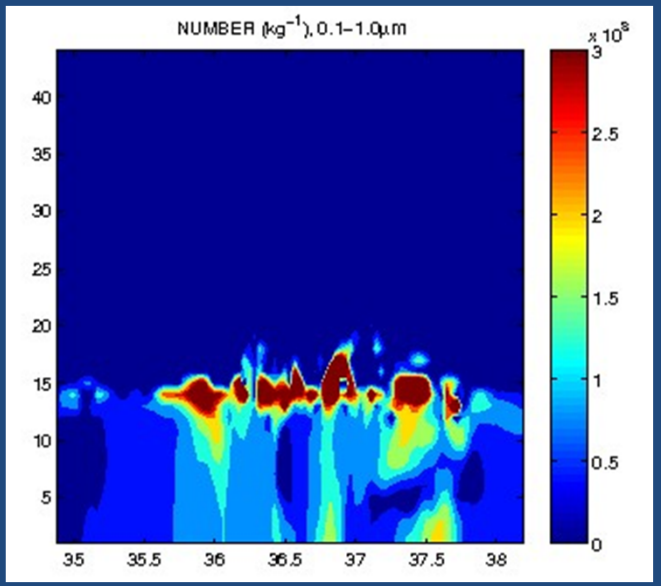

Redistribution of Analysis increments to WRF-Chem State Variables

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

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

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