Chemical Data Assimilation of MODIS AOD with CMAQ

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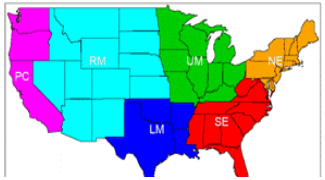
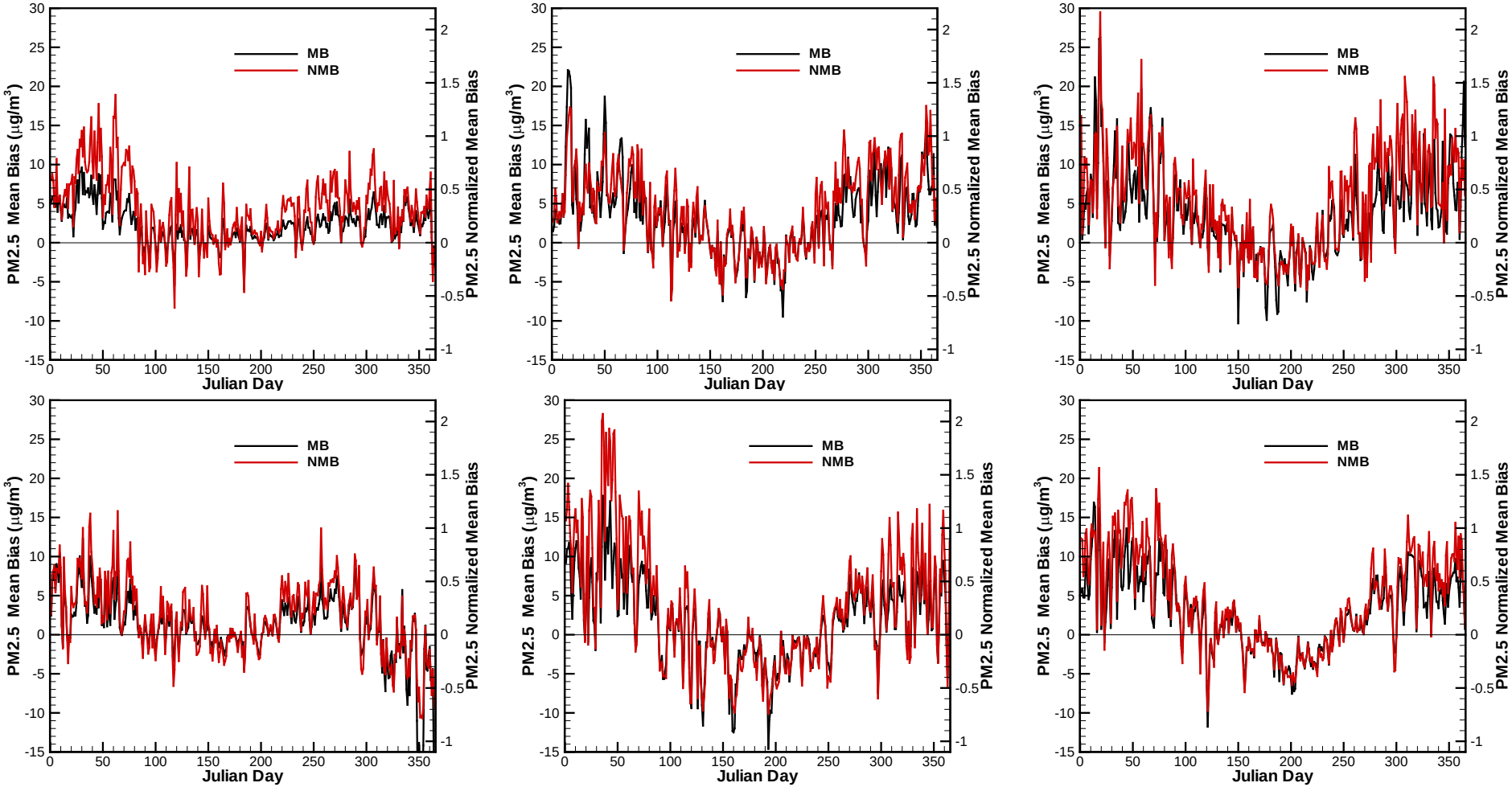
2009 NAQFC (CMAQ4.6) PM2.5 Biases



Rock Mountain Region	Upper Midwest	Northeast US
Pacific Coast Region	Lower Middle	Southeast US



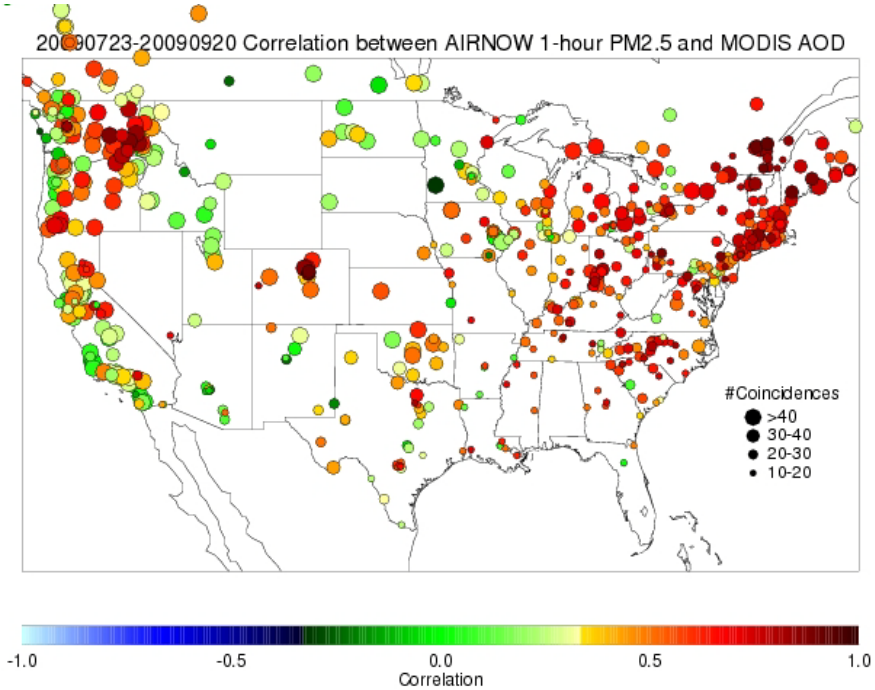
Constraining CMAQ with MODIS AOD

Orbit: 705 km, **10:30 a.m**. descending node (Terra) or **1:30 p.m**. ascending node (Aqua), sun-synchronous, near-polar, circular

Swath Dimensions: 2330 km (cross track) by 10 km (along track at nadir)

Spatial Resolution: 250 m (bands 1-2)
500 m (bands 3-7)
1000 m (bands 8-36)

http://terra.nasa.gov/About/



http://www.star.nesdis.noaa.gov/smcd/spb/aq/

MODIS (Moderate Resolution Imaging Spectroradiometer) Aerosol optical Depth provides near real time observations with good spatial resolution and coverage.

Candidates of Data Assimilation Schemes

- Optimal interpolation (OI)
  - Easy to apply, with localization assumption
- 3D-Var
  - Adjusts all variables in the whole domain simultaneously. GSI developed at NOAA/NASA/NCAR is available
- 4D-Var
  - Provides more flexibility, suitable for inverse modeling, requires adjoint model and is computationally expensive
- Kalman Filter
  - Ensemble Kalman Filter is easy to apply and parallelize

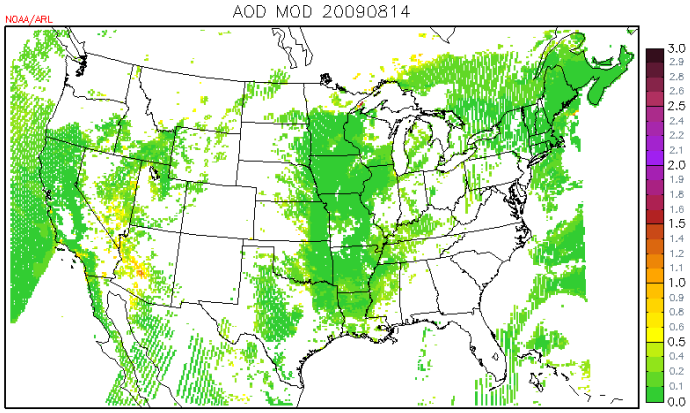
Optimal Interpolation (OI)

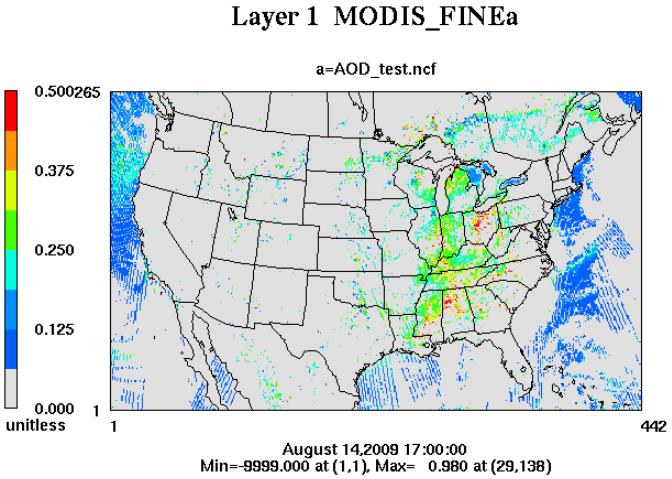
- OI is a sequential data assimilation method. At each time step, we solve an analysis problem

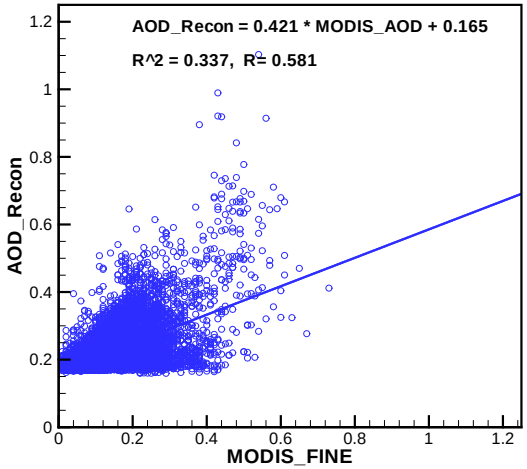
$$X^a = X^b + BH^T(HBH^T + O)^{-1}(Y - HX)$$

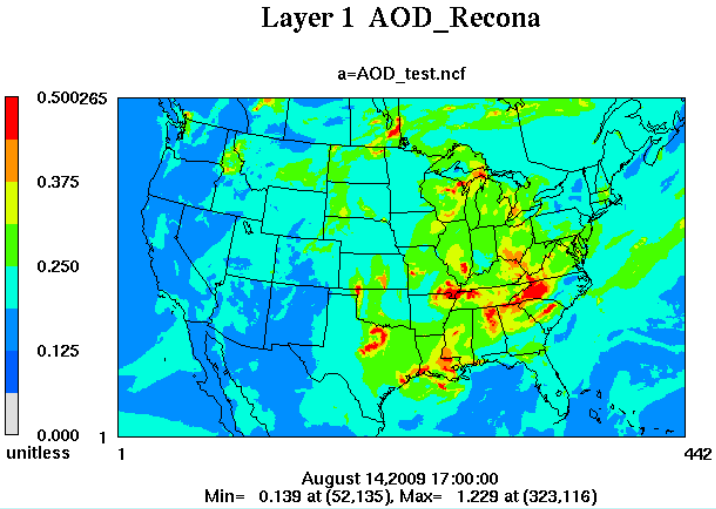
- We assume observations far away (beyond background error correlation length scale) have no effect in the analysis
- In the current study, the data injection takes place at 1700Z daily

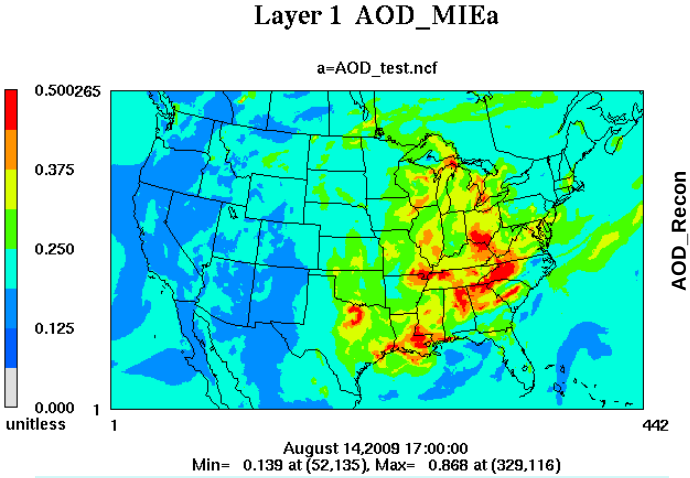
MODIS & CMAQ AOD

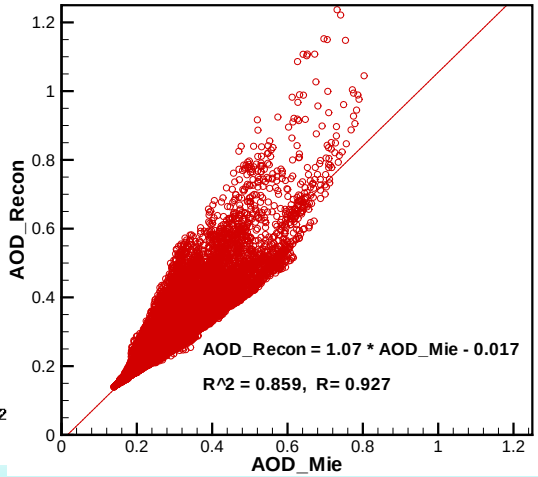






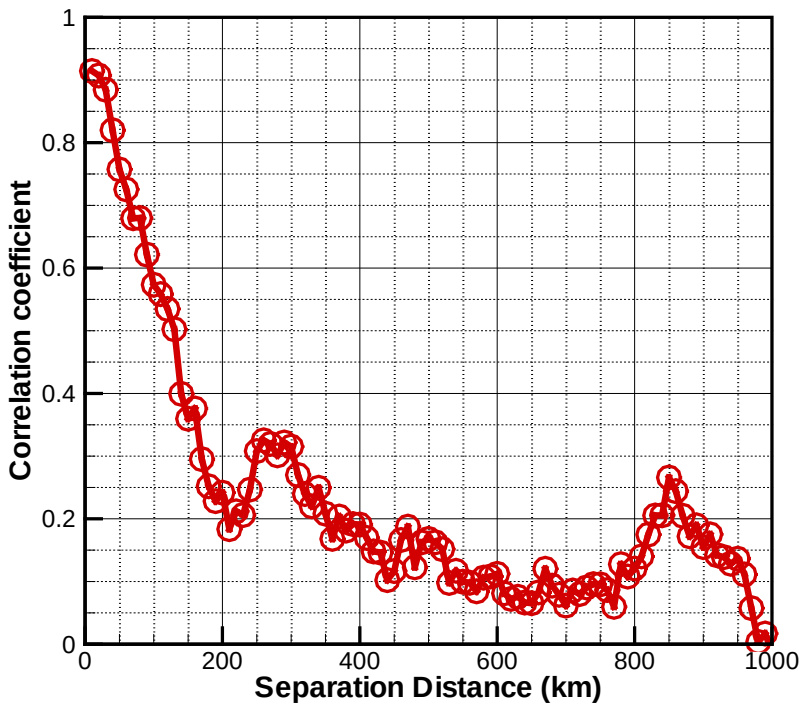






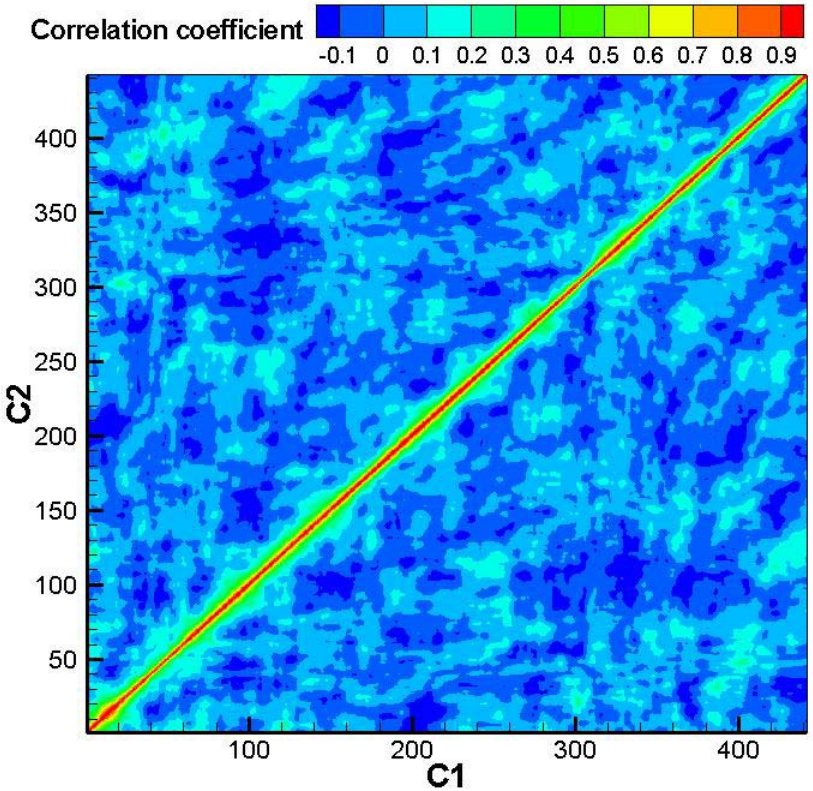
Estimate Model Error Statistics with Hollingsworth-Lonnberg (observational) Method

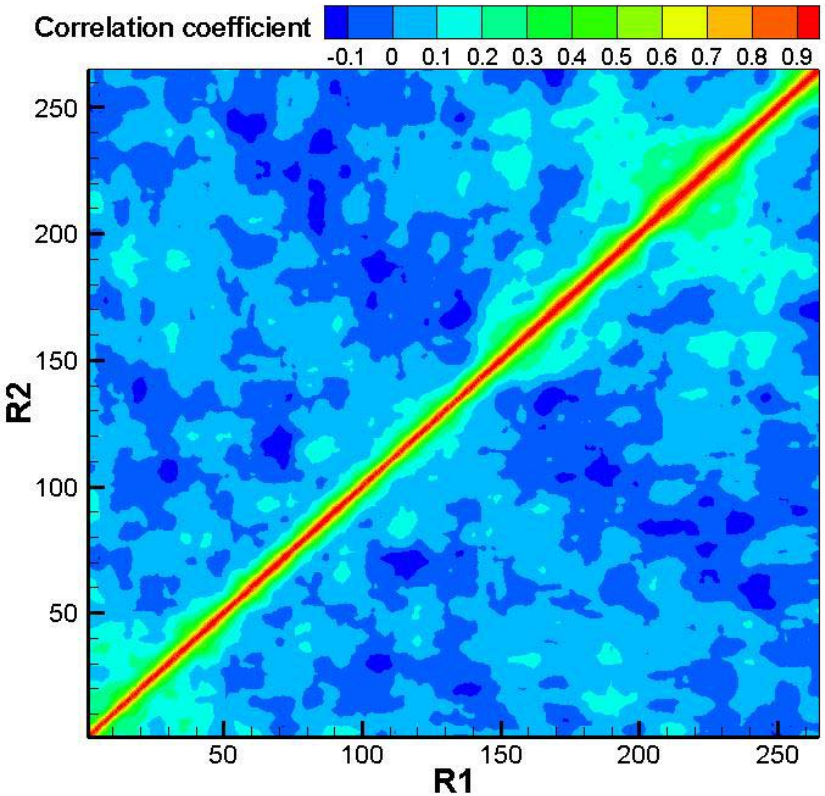
$$R_z = \frac{E_B^2}{E_B^2 + E_O^2}$$



- At each data point, calculate differences between forecasts (B) and observations (O)
- Pair up data points, and calculate the correlation coefficients between the two time series
- Plot the correlation as a function of the distance between the two stations,

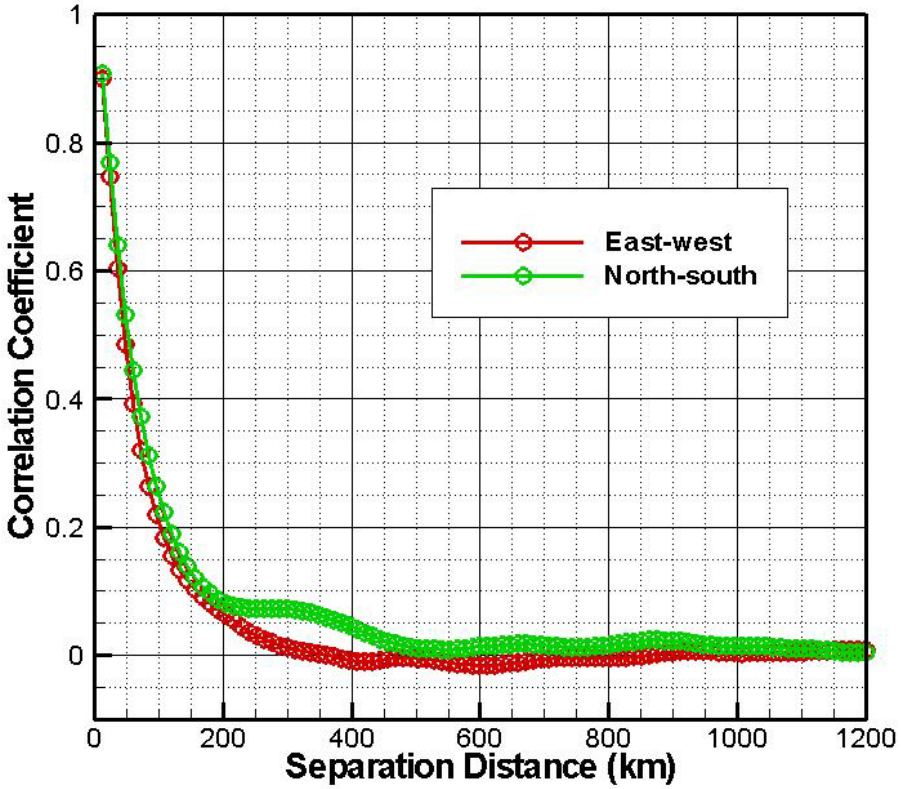
Model Error Statistics with NMC approach

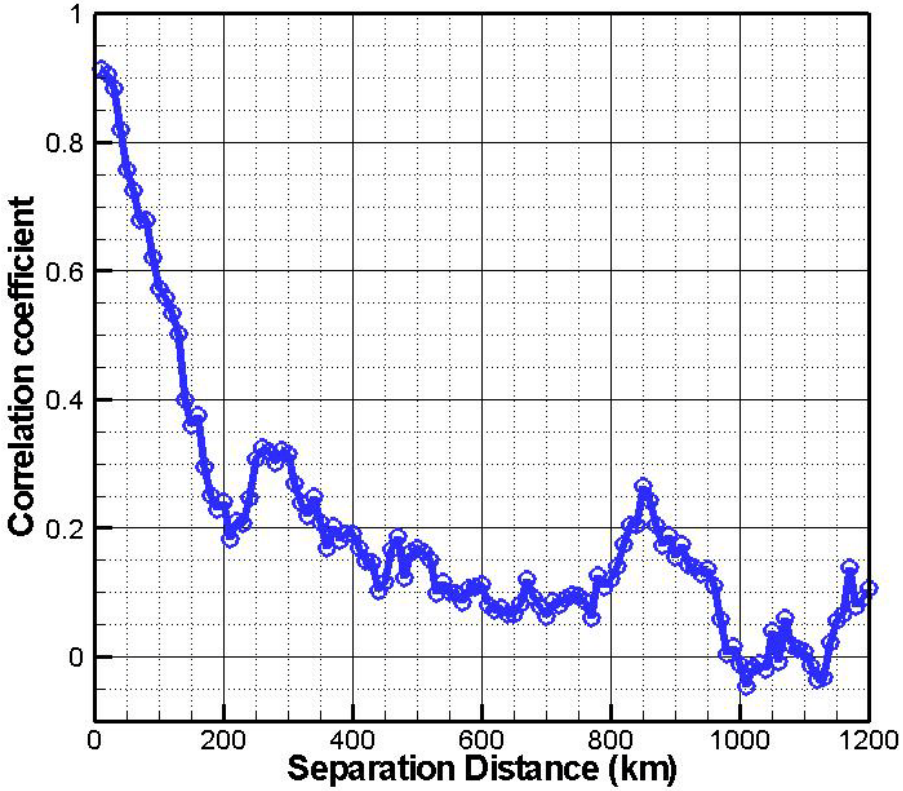




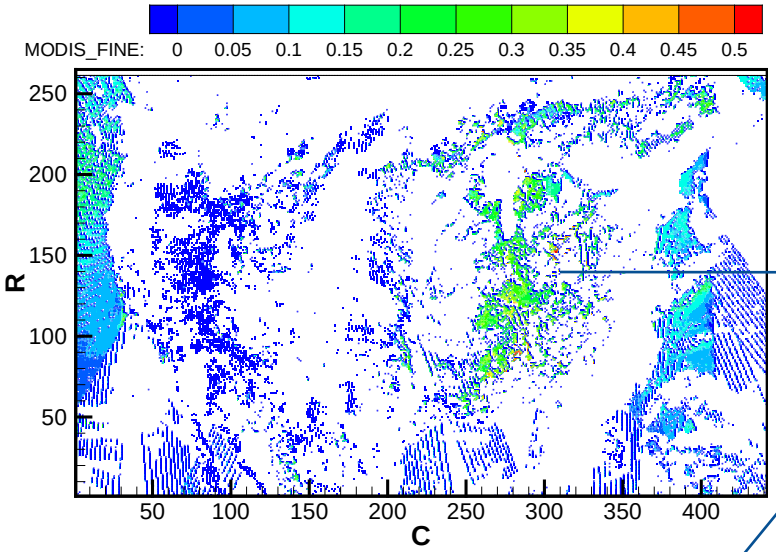
AOD differences between 8/15/11 and 8/16/11 12Z cycle experimental/developmental 48-hr CMAQ runs from13Z on 8/16/11 to 12Z on 8/17/11 are used in NMC approach. AOD is calculated using reconstructed extinction coefficients. Numbers shown on both axes are in units of number of 12-km grid cells.

Error statistics results through NMC (left) and Hollingsworth-Lönnberg (right) approaches.



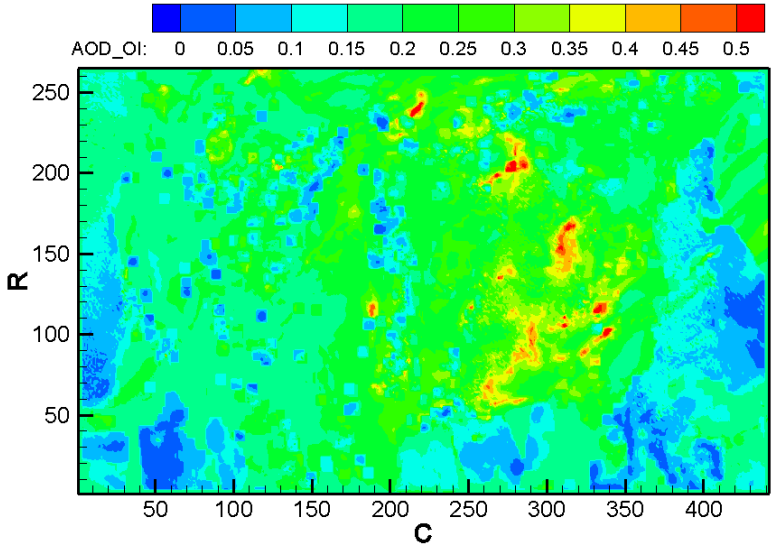


8/14/2009



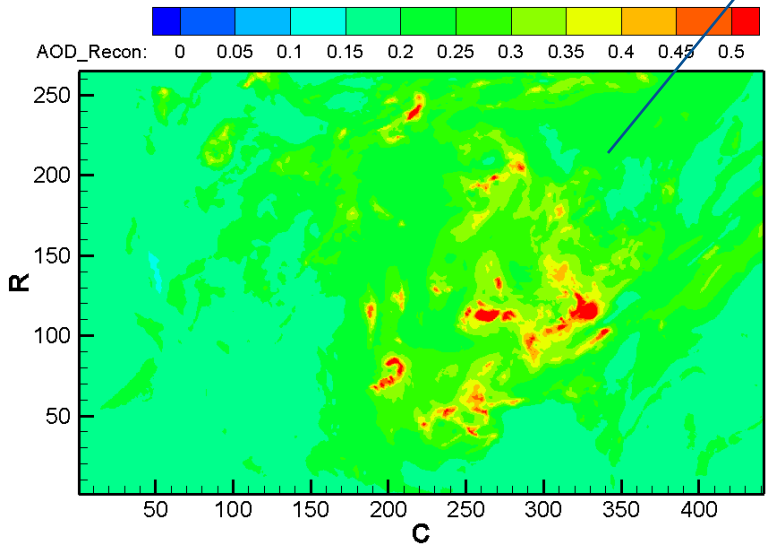
MODIS AOD Observation Input

OI



Analysis output

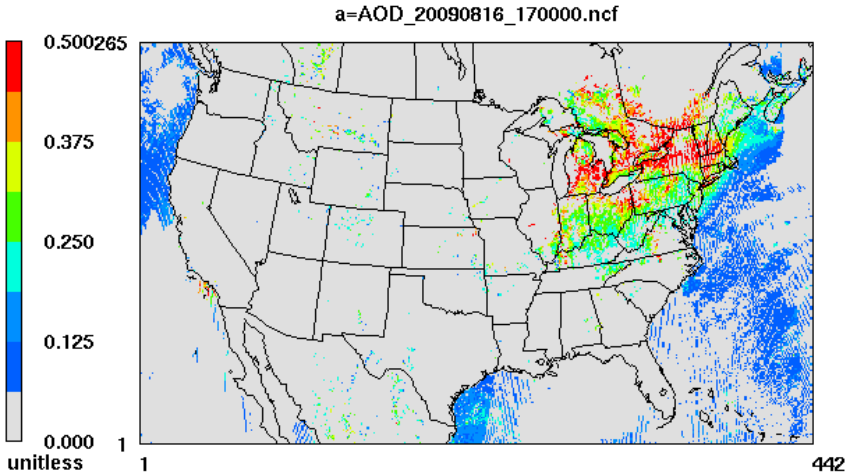
Background Input



Use AOD Analysis/Background as scaling factors to adjust aerosol variables:

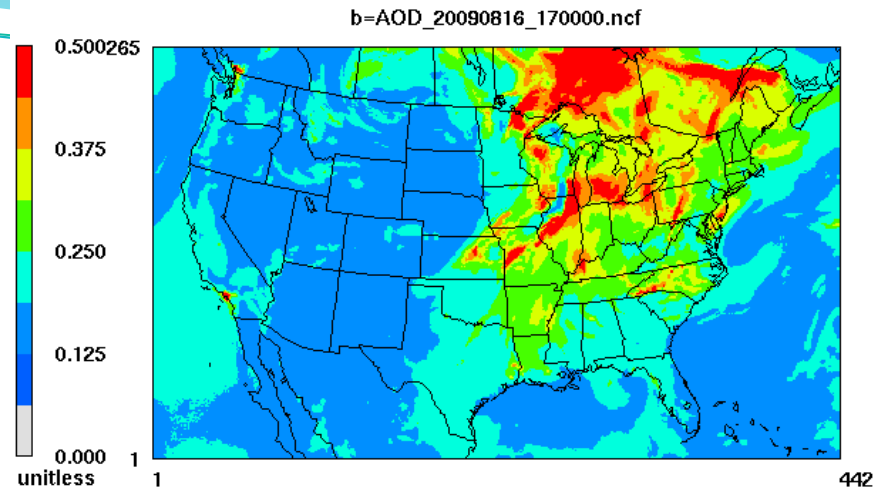
VSO4AI, VSO4AJ,
VNO3AI, VNO3AJ, VNH4AI, VNH4AJ, VORGAI,
VORGAJ, VORGPAI, VORGPAJ, VORGBAI, VORGBAJ,
VECI, VECJ,
VP25AI, VP25AJ

Layer 1 MODIS_FINEa



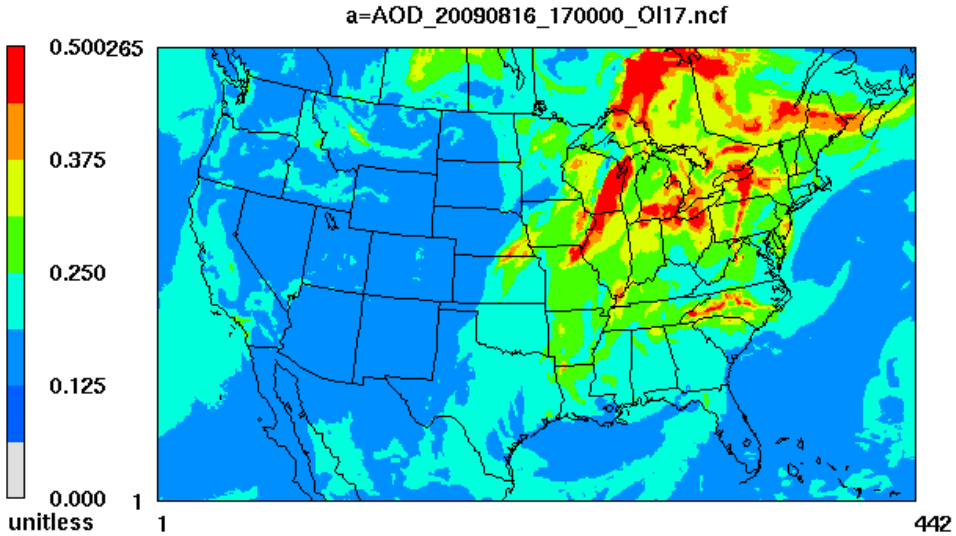
August 16,2009 17:00:00
Min=-9999.000 at (1,1), Max= 0.940 at (327,189)

Layer 1 AOD_Reconb



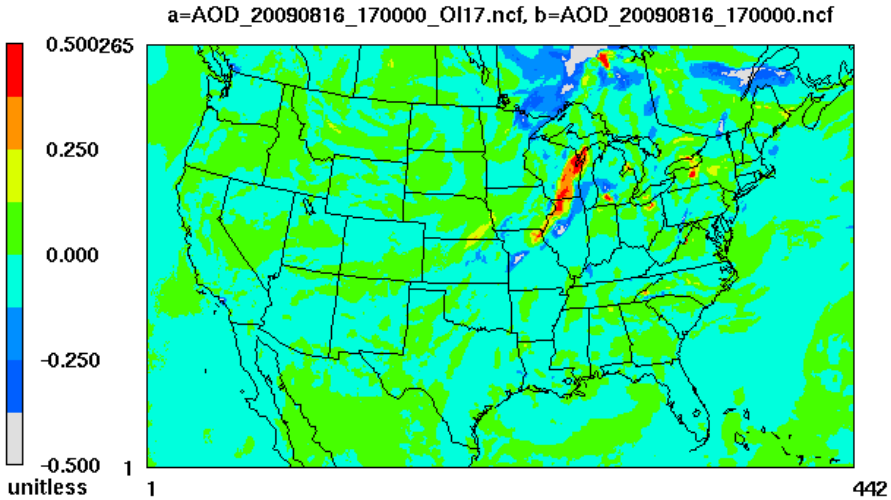
August 16,2009 17:00:00
Min= 0.141 at (51,137), Max= 1.242 at (282,265)

Layer 1 AOD_Recona



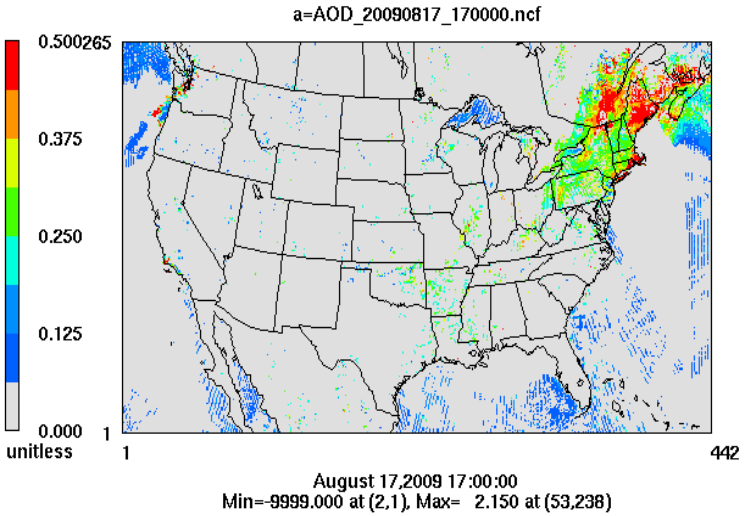
August 16,2009 17:00:00
Min= 0.140 at (148,151), Max= 1.550 at (288,256)

Layer 1 AOD_Recona-AOD_Reconb

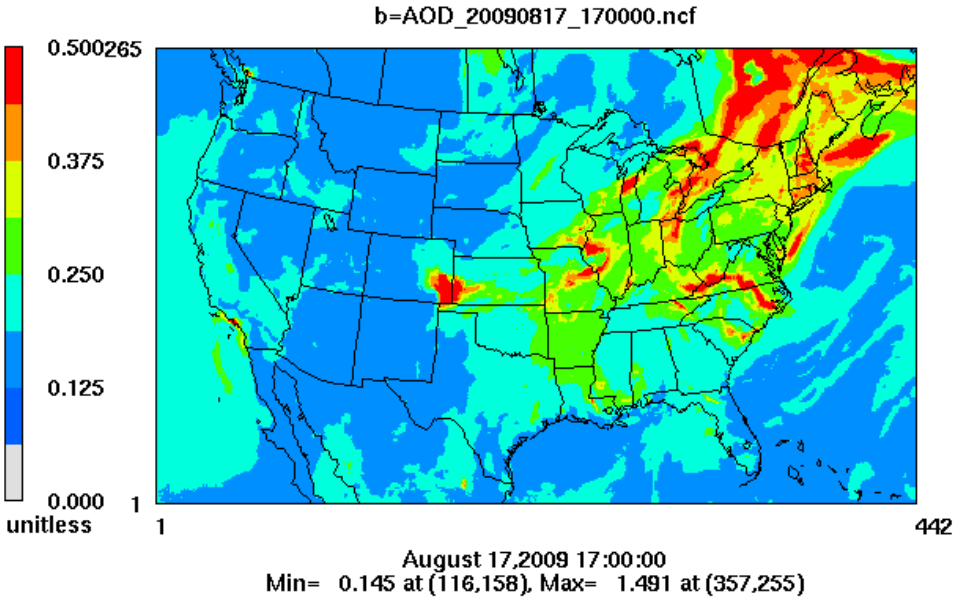


August 16,2009 17:00:00
Min= -1.010 at (281,265), Max= 0.988 at (343,185)

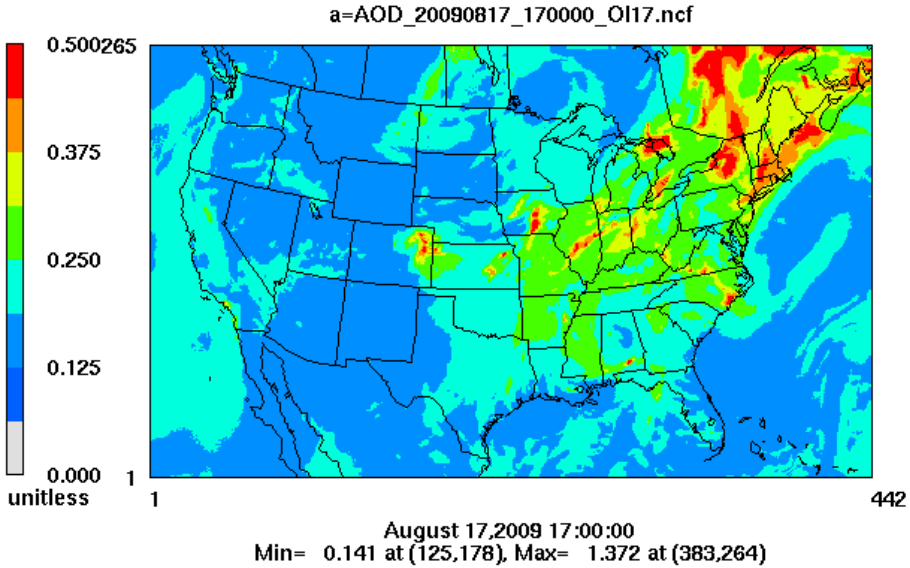
Layer 1 MODIS_FINEa



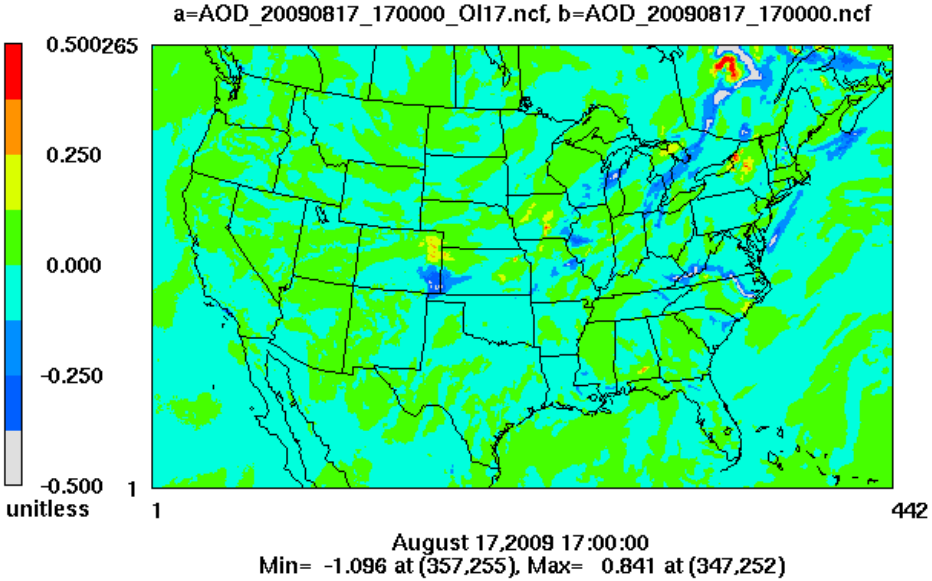
Layer 1 AOD_Reconb

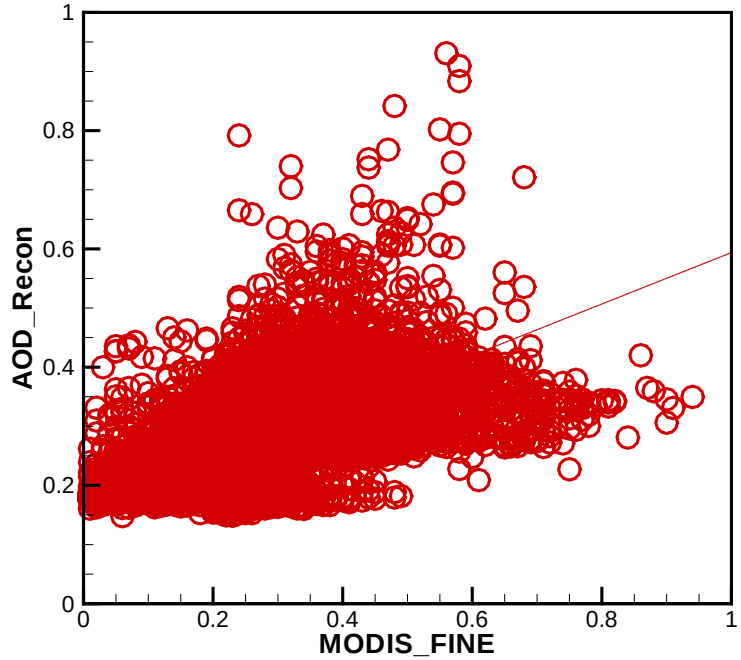


Layer 1 AOD_Recona



Layer 1 AOD_Recona-AOD_Reconb





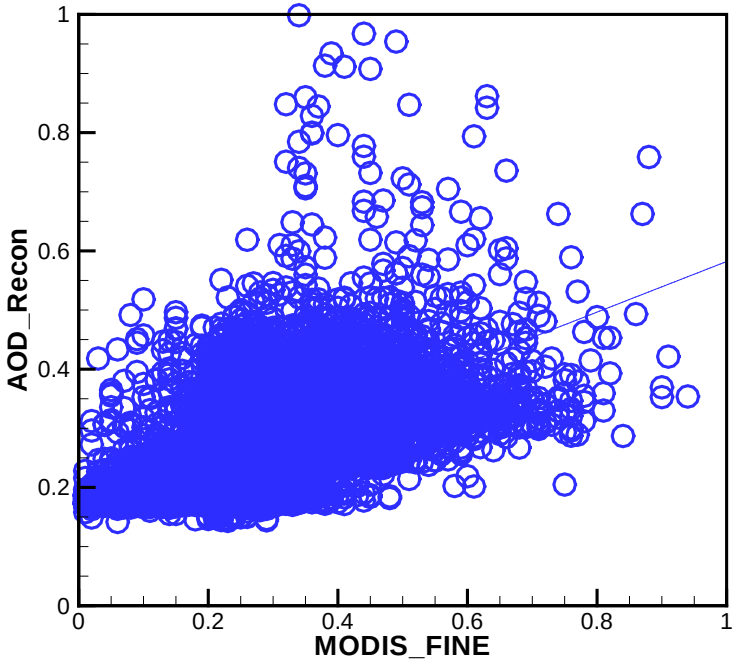
8/16/2009

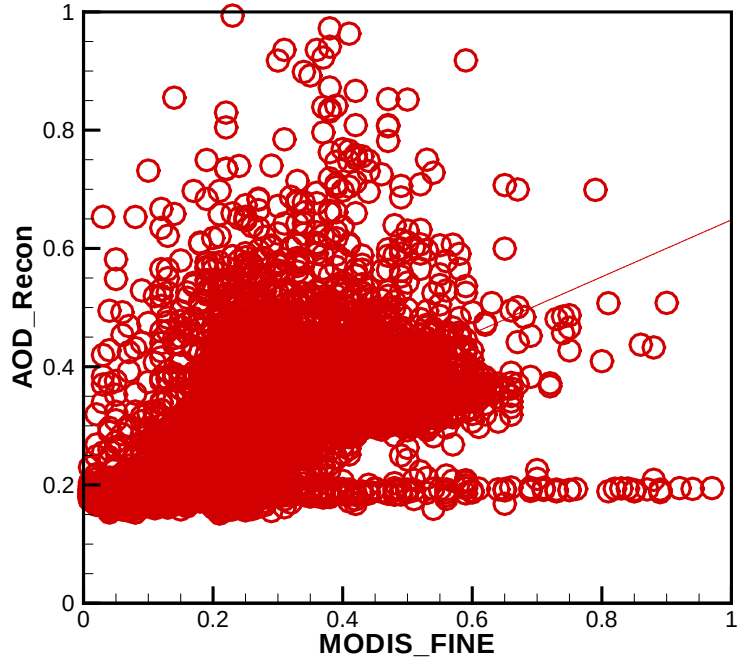
Base:

R=0.778

OI:

R=0.757





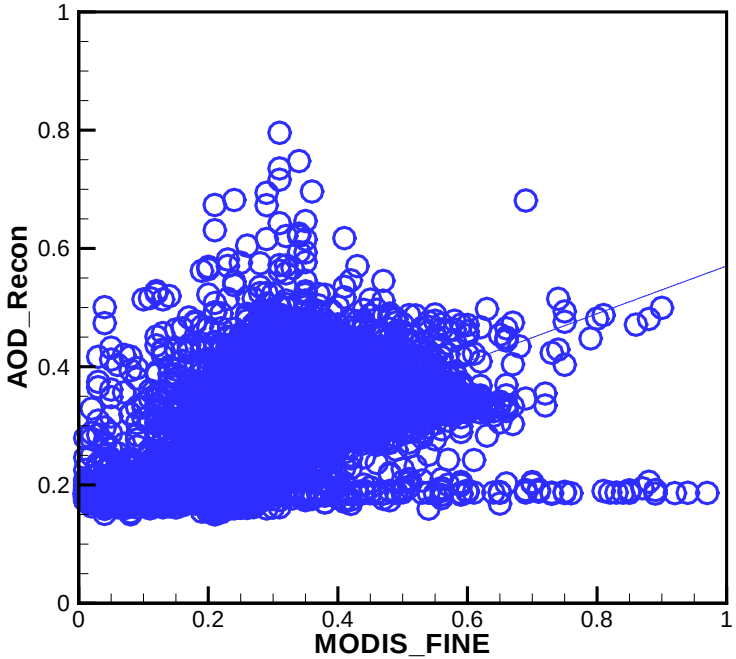
8/17/2009

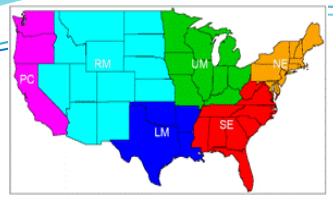
Base:

R=0.668

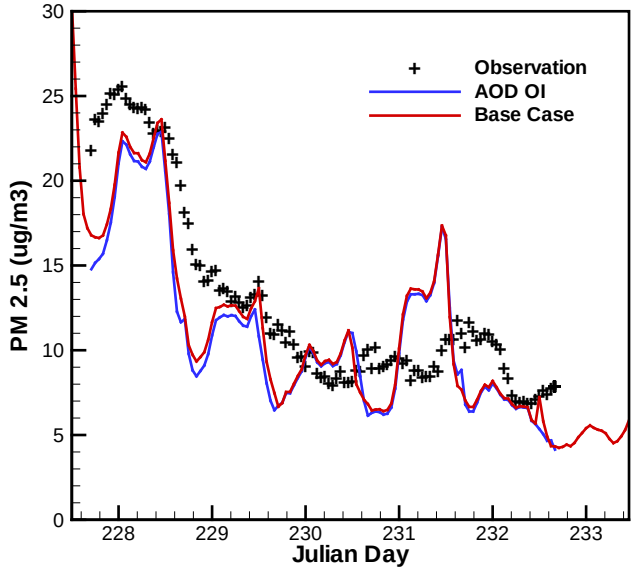
OI:

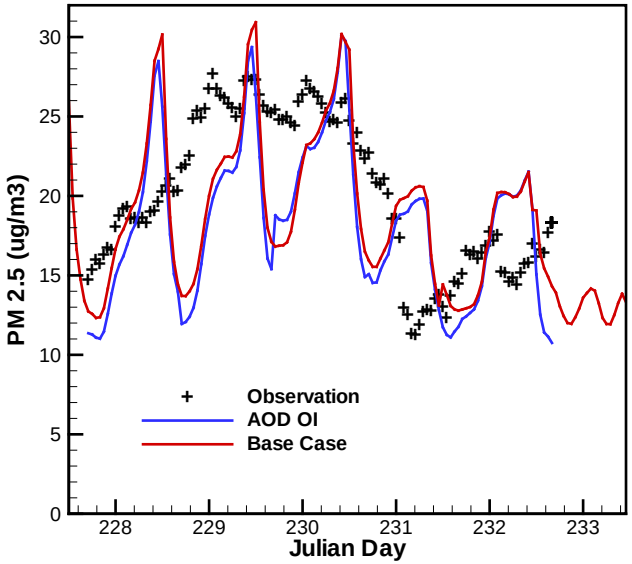
R=0.710

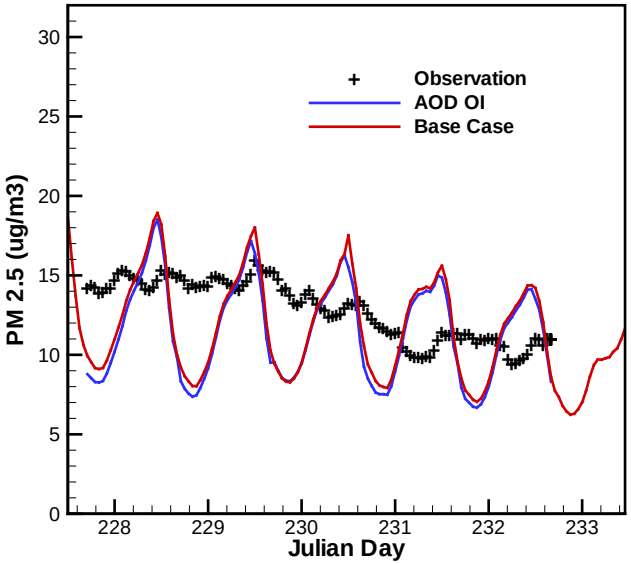


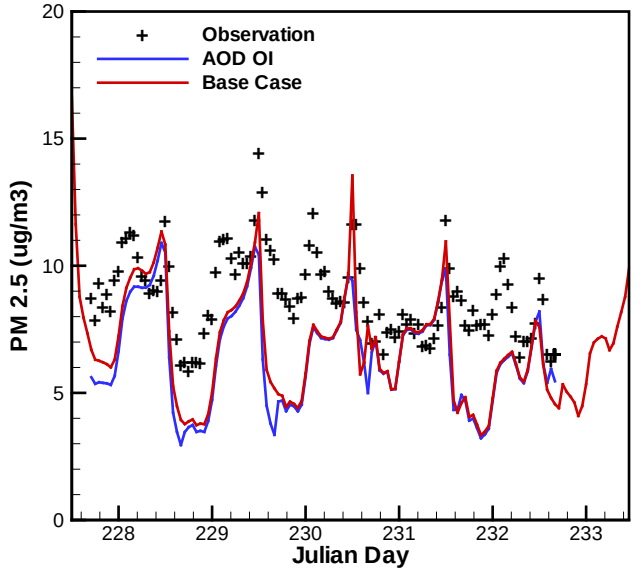


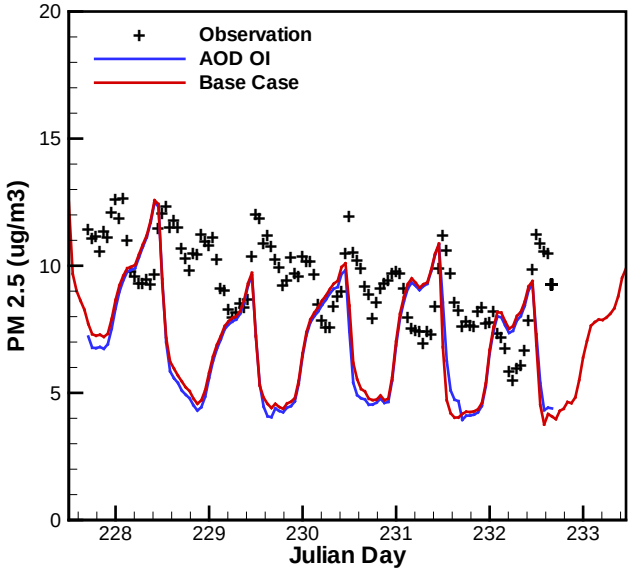
Rock Mountain Region	Upper Midwest	Northeast US
Pacific Coast Region	Lower Middle	Southeast US

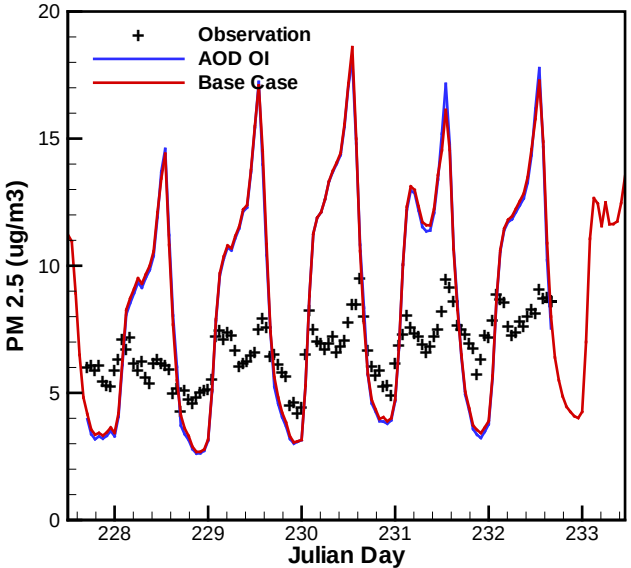




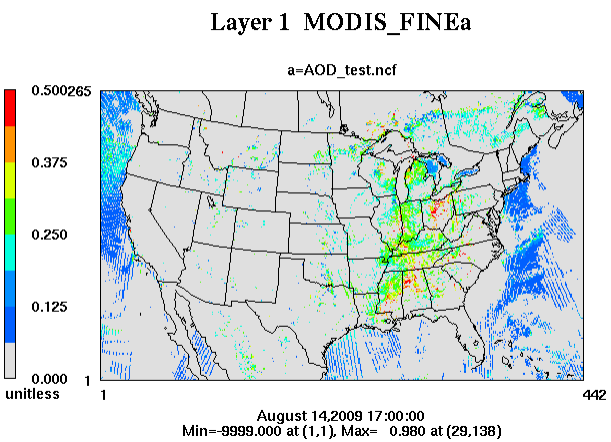


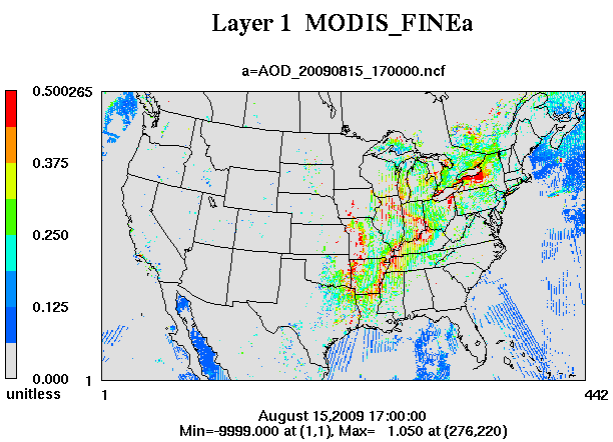


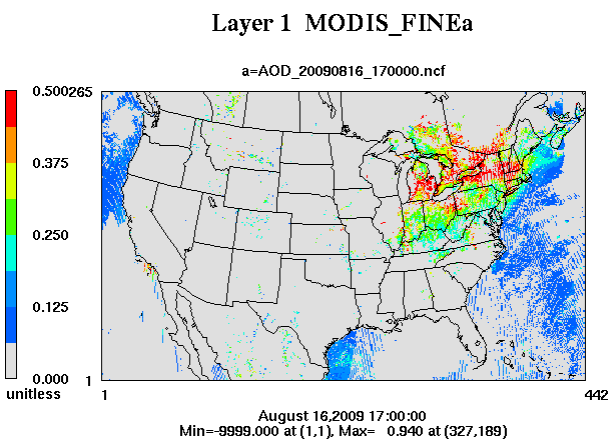


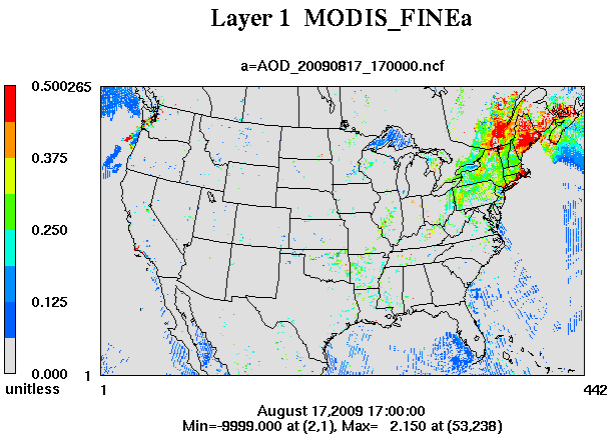


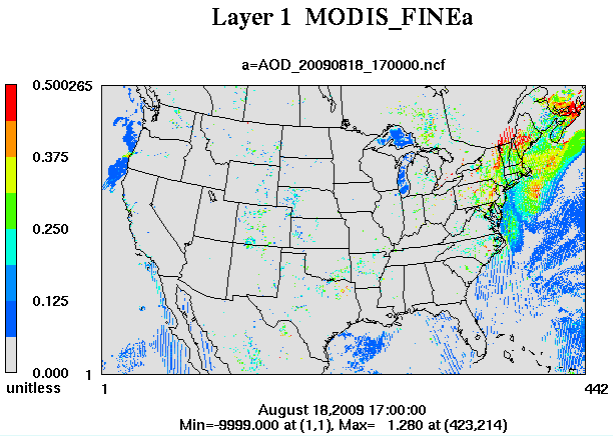
Availability of MODIS data during 8/14-19, 2009

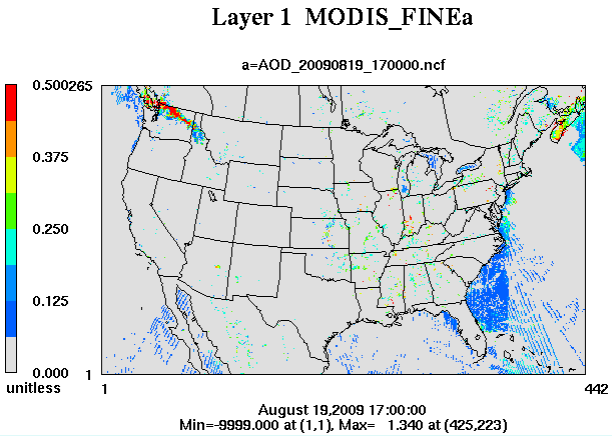












Correlation between predicted and observed PM2.5 at 17Z in Upper Midwest

R	8/15/09	8/16/09	8/17/09	8/18/09	8/19/09	8/20/09
Base	0.648	0.371	0.596	0.392	0.484	0.145
OI	0.632	0.422	0.558	0.424	0.520	0.202

Correlation between predicted and observed PM2.5 at 17Z in Northeast US

R	8/15/09	8/16/09	8/17/09	8/18/09	8/19/09	8/20/09
Base	0.503	0.645	0.311	0.265	0.395	0.466
OI	0.553	0.606	0.332	0.455	0.414	0.454

Summary and future work

- Assimilating MODIS AOD using OI method is able to improve AOD and PM2.5 predictions in selected regions
- AOD observations may contain bad data (8/17/09)
- CMAQ PM2.5 shows too much diurnal variations
- Assimilating both MODIS AOD and AIRNow PM2.5 is expected to have better results and will be tested
- Using data assimilation methods to adjust emissions will be studied in the future