Post-processing air quality model predictions of fine particulate matter (PM2.5) at NCEP

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What is PM2.5, and why is it important?

Particulate matter smaller than 2.5 microns in diameter.

Health impacts: 65,000-130,000 premature deaths/year in US (American Lung Association[1])

Why is it difficult to predict PM2.5 accurately?

PM2.5 concentration forecasts depend on initial concentrations, emissions, chemical reactions, and weather conditions.

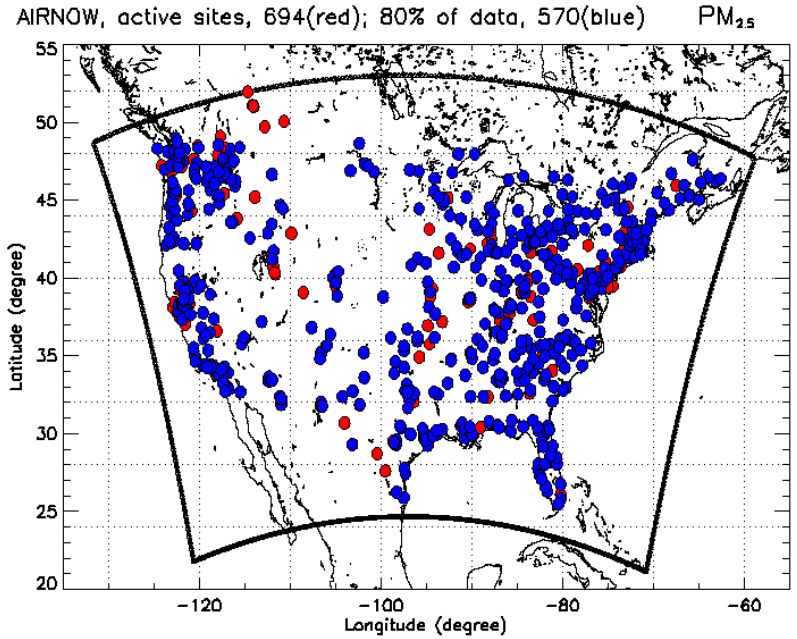
- Initial conditions are known well only at a relatively few surface observing sites. Limited satellite information (forest fires and dust storms).
- Emissions are poorly known: based on inventories several years old, and are allocated by month and by day of the week and according to specified diurnal profiles (except for forest fires and dust).
- Uncertainty in chemical transformations.
- Weather forecast uncertainty.

[1]http://www.lung.org/assets/documents/advocacy-archive/epa-proposed-particle-soot-standard-technical.pdf

NCEP PM2.5 Forecast System

- CMAQ (Community Multi-scale Air Quality modeling system), regional chemical model
- NAM (NMM-B) meteorological model
- NEI static emissions inventory
- Forest fire emissions from NESDIS satellite fire detection with US Forest Service emission estimates.
- Global chemical prediction model -> monthly mean lateral boundary conditions; daily dust
- Initial conditions from previous forecast; no chemical data assimilation

PM2.5 verification at ~600 EPA AIRNow sites



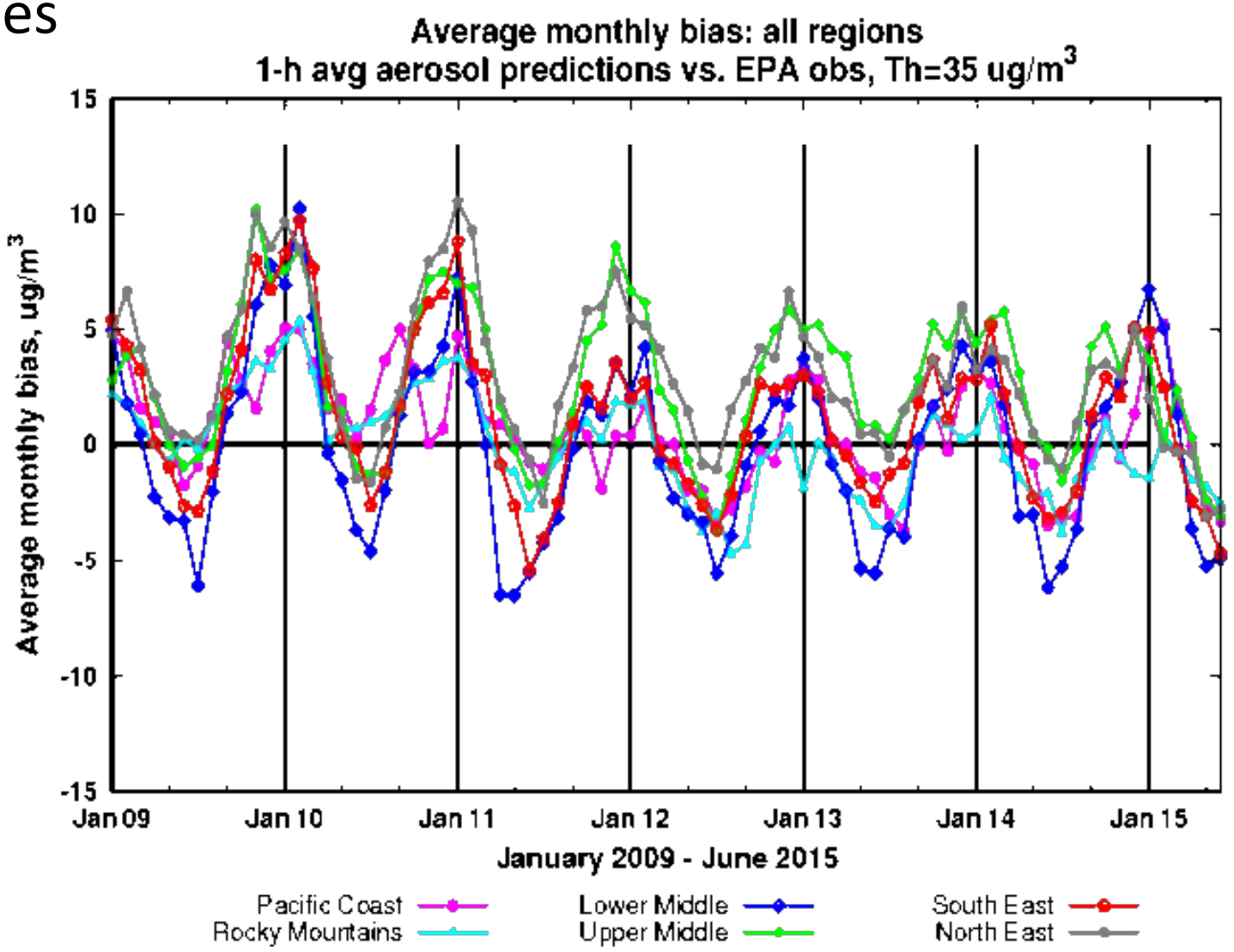
EPA PM2.5 violation thresholds

- 15 micrograms/m^3 annual average
- 35 micrograms/m^3 24-hour average

7 years of CMAQ PM2.5 biases

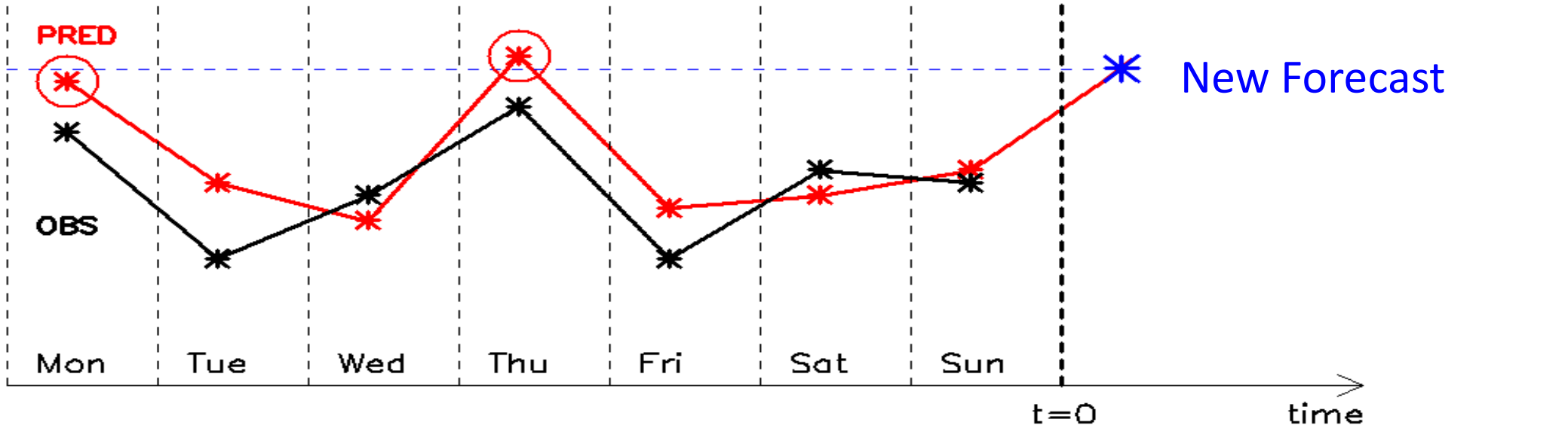
- Significant seasonal biases
  - over-prediction in winter
  - under-prediction in summer

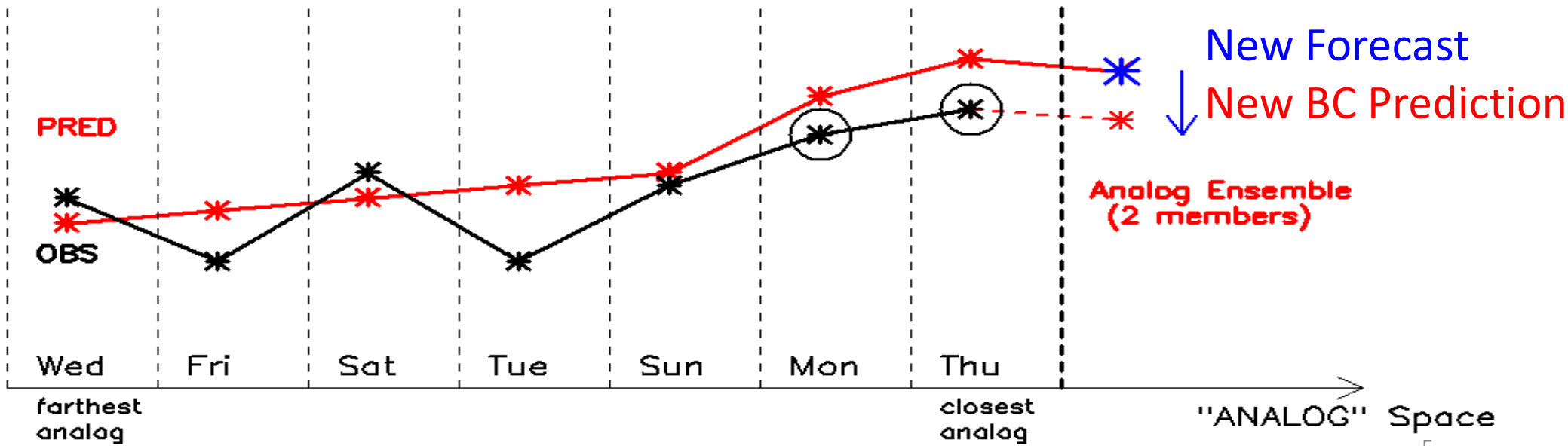
- Sources of biases
  - Emissions?
  - Meteorological forcing?
  - Chemical transformations?



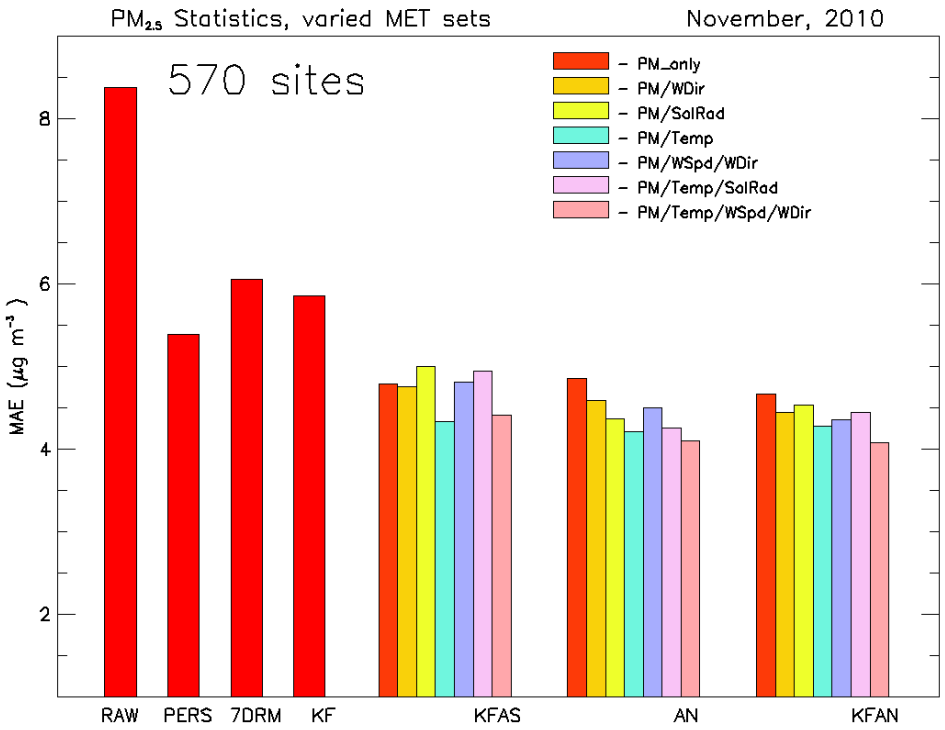
Over-prediction in winter has improved
Under-prediction in summer is unchanged

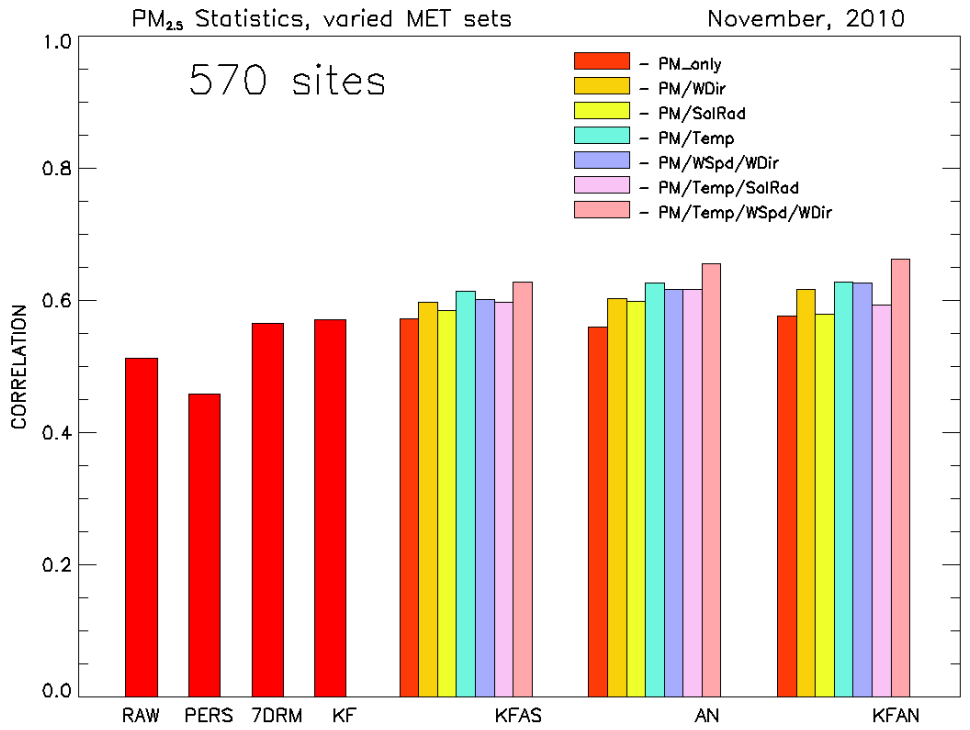
Analog Bias Correction



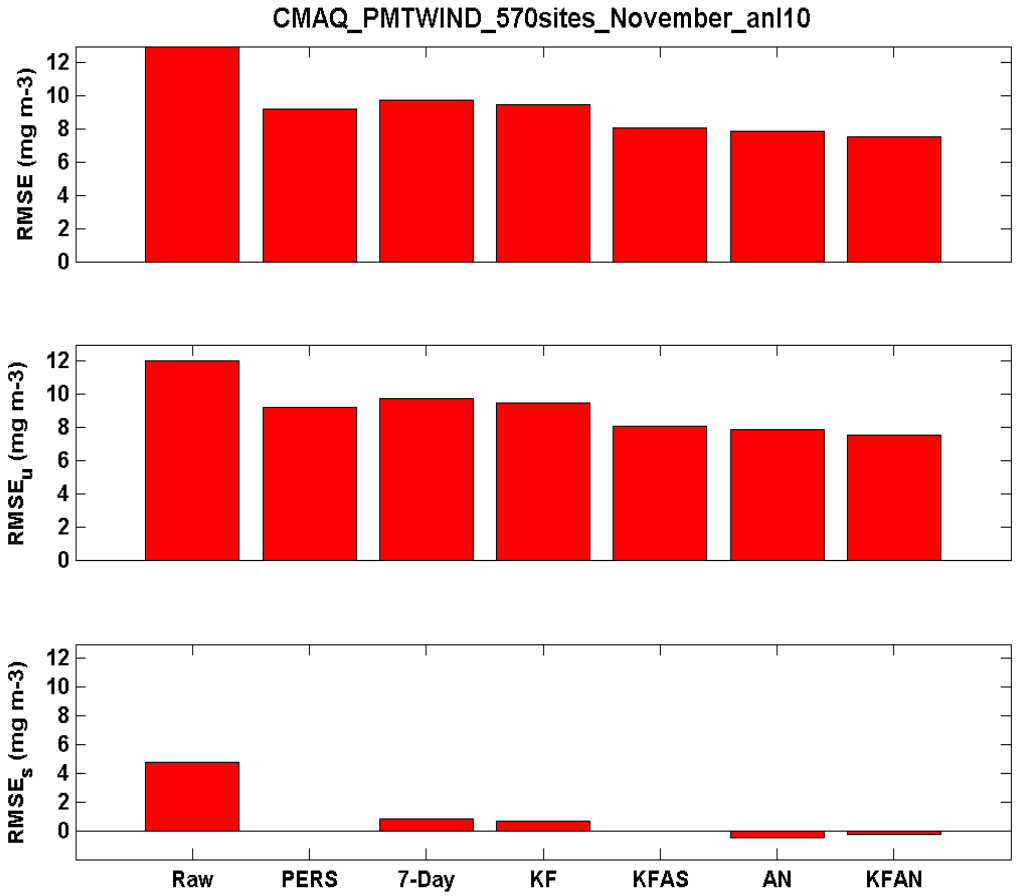


Post-processing sensitivity to search variables

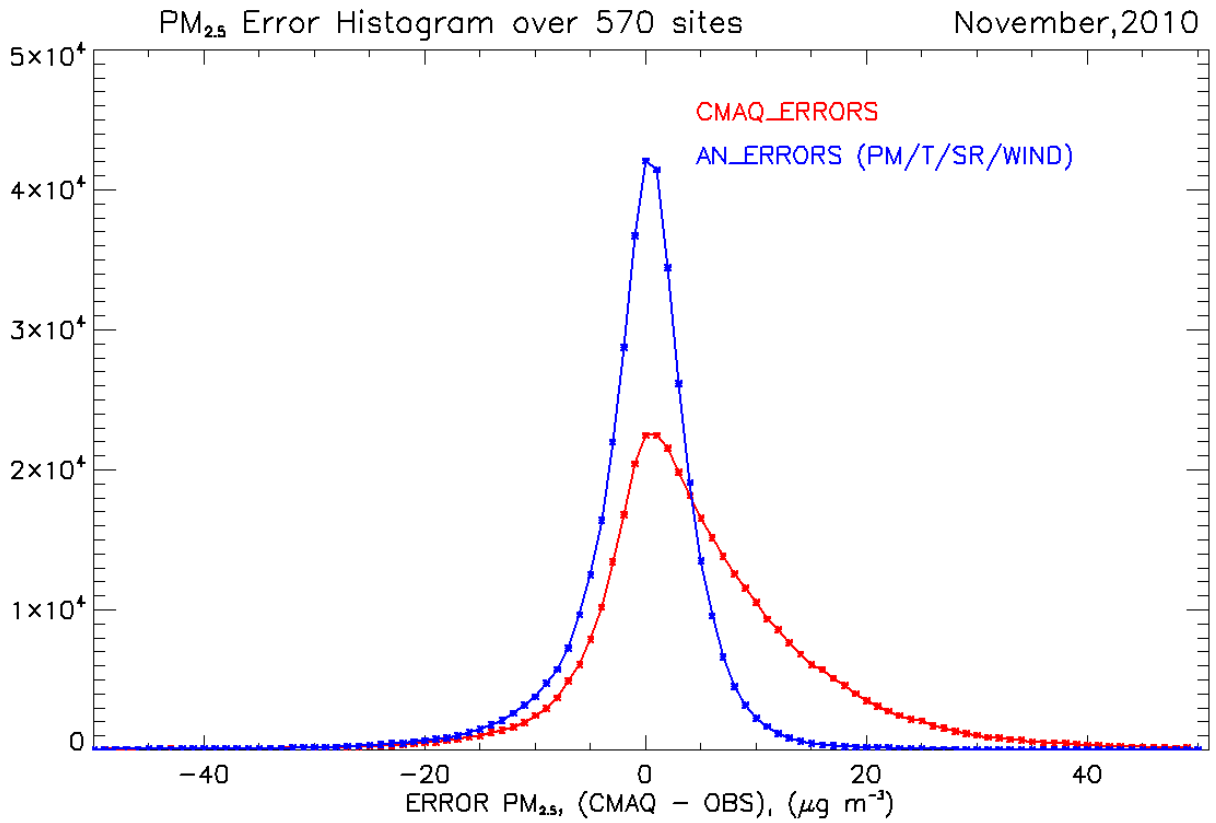




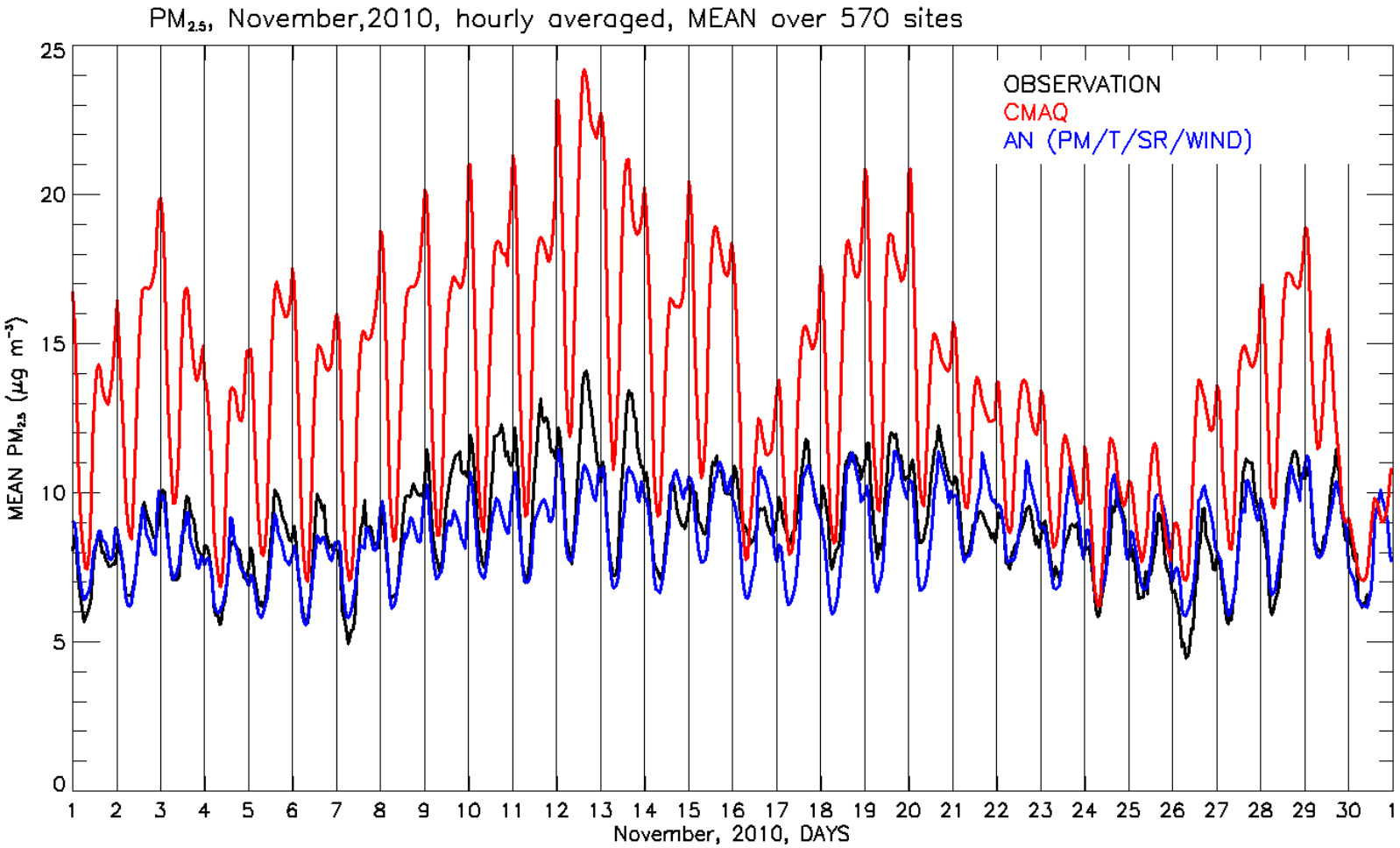
Systematic and Unsystematic RMSE Improvements



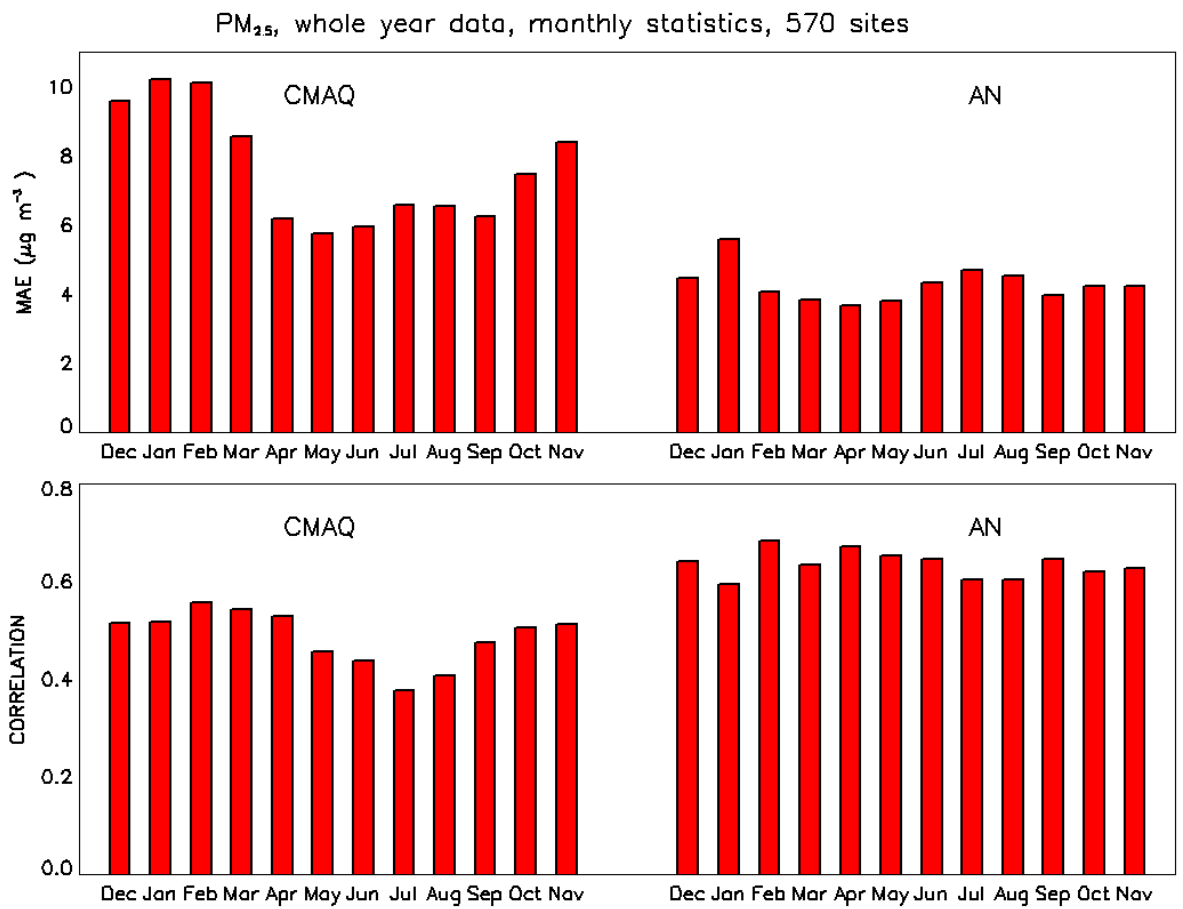
PM2.5 Error Histogram



CONUS averaged hourly values of PM2.5 for November 2010



Monthly MAE and Correlation AN Improvements for 2010



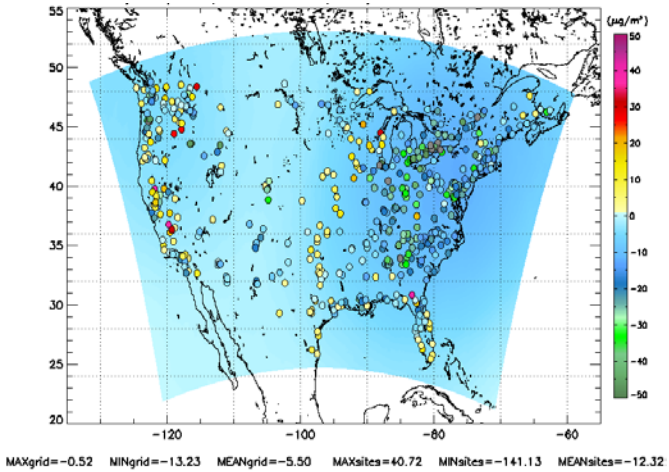
Spreading of point corrections to model grid

- Iterative objective analysis scheme based on the work of Glahn et al. (2012)
- 8-pass Gaussian scheme
- Radius of influence: 2000 km, 1000 km, 500 km, 250 km, 125 km, 62 km, 31 km, 15 km

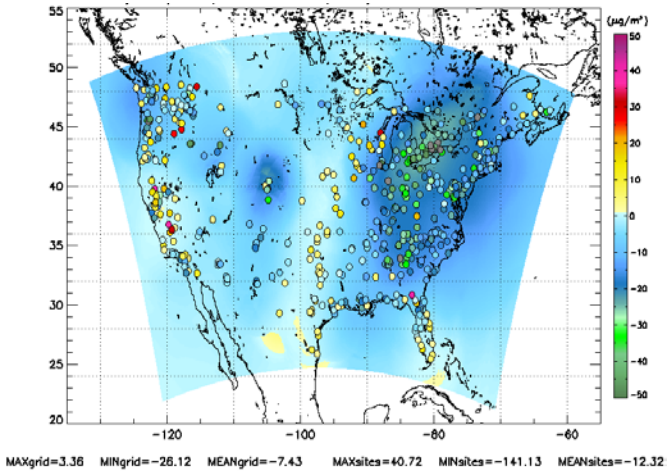
$$Gbias_{ij(m+1)} = \frac{1}{N_k} \sum_{d_k < R} \frac{R * R - d_k * d_k}{R * R + d_k * d_k} \left(Sbias_k - Gbias_{ijm}\right) + Gbias_{ijm}$$

$where\ G = grid, \quad S = site, \quad Sbias_k = ANk - CMAQk, \quad d = distance\ from\ site\ to\ gridpoint, \quad R = radius\ of\ influence$

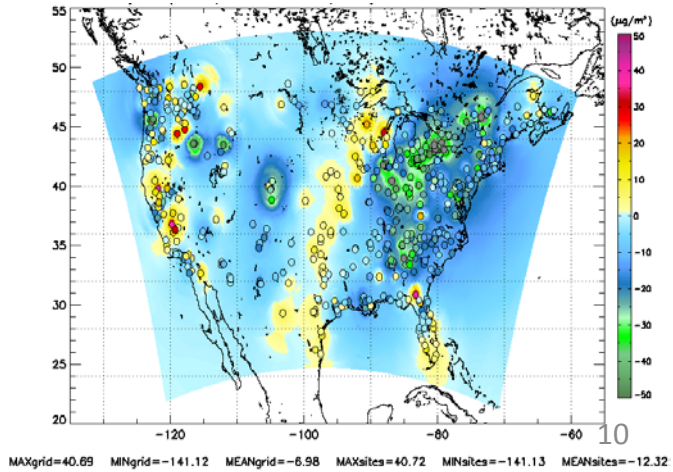
2000km radius



500km radius

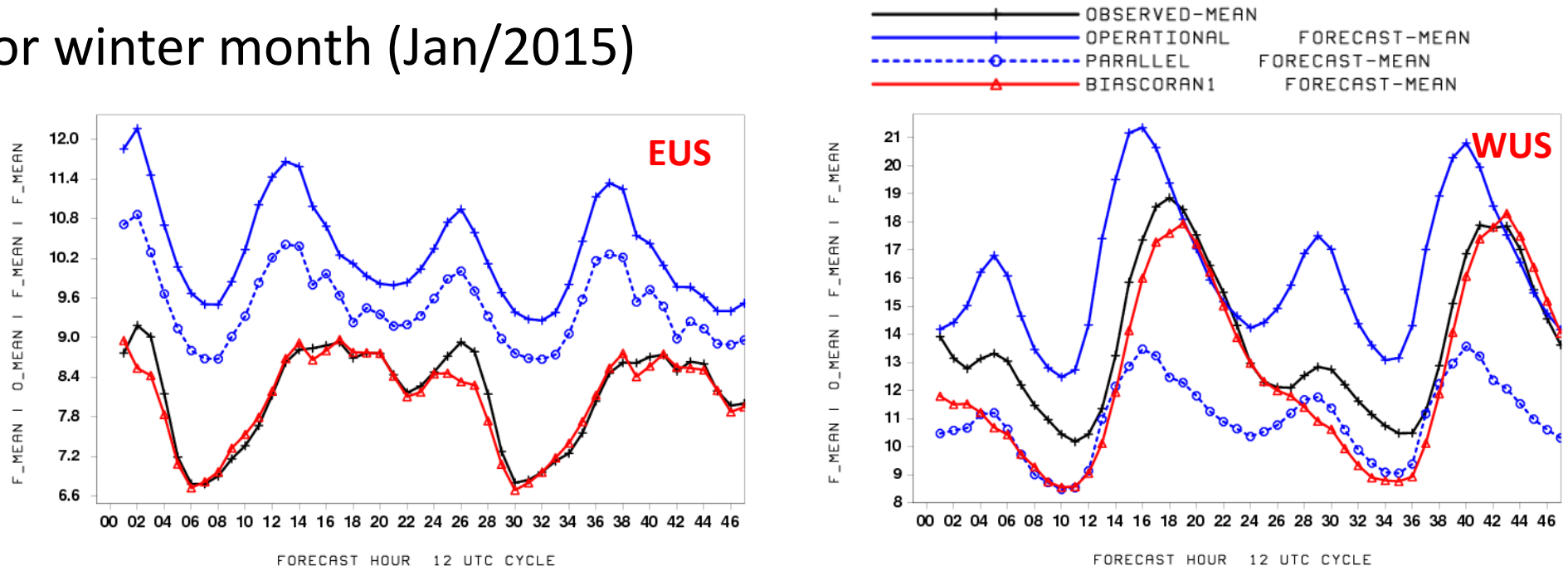


15km radius

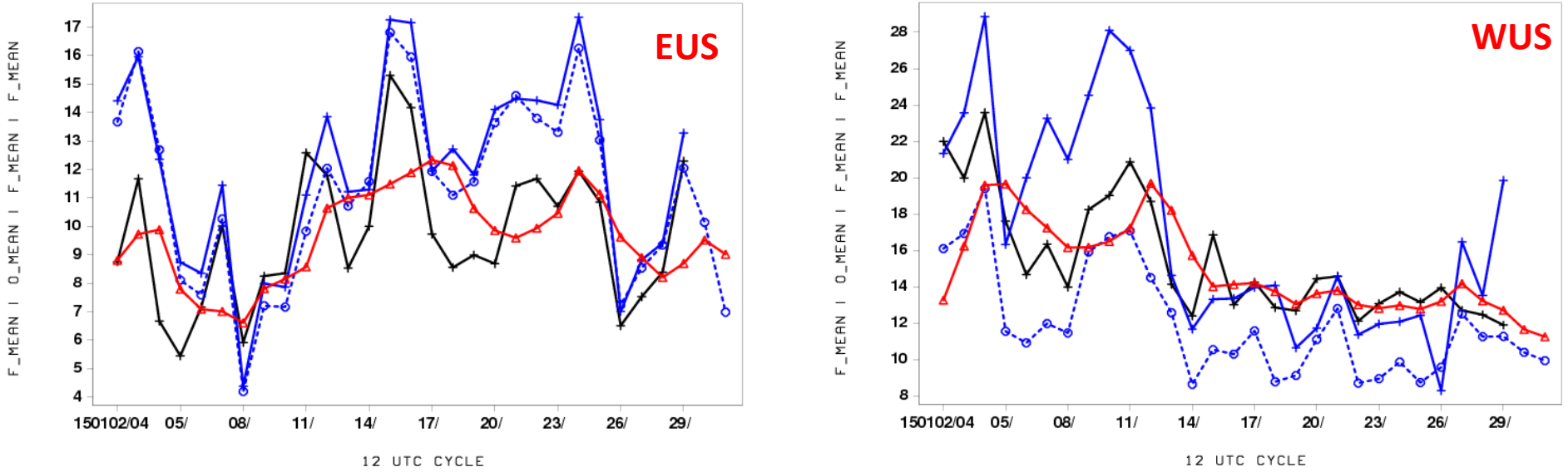


NCEP tests for winter month (Jan/2015)

Mean Diurnal Cycle

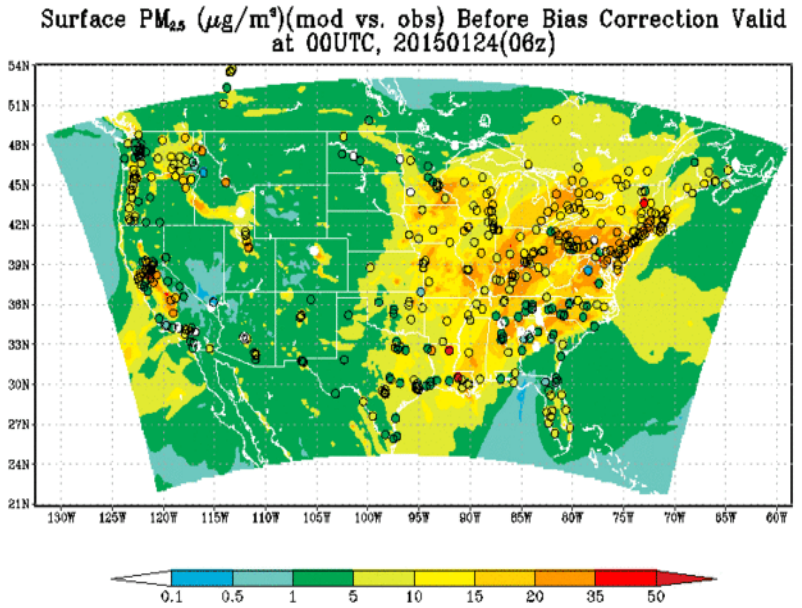


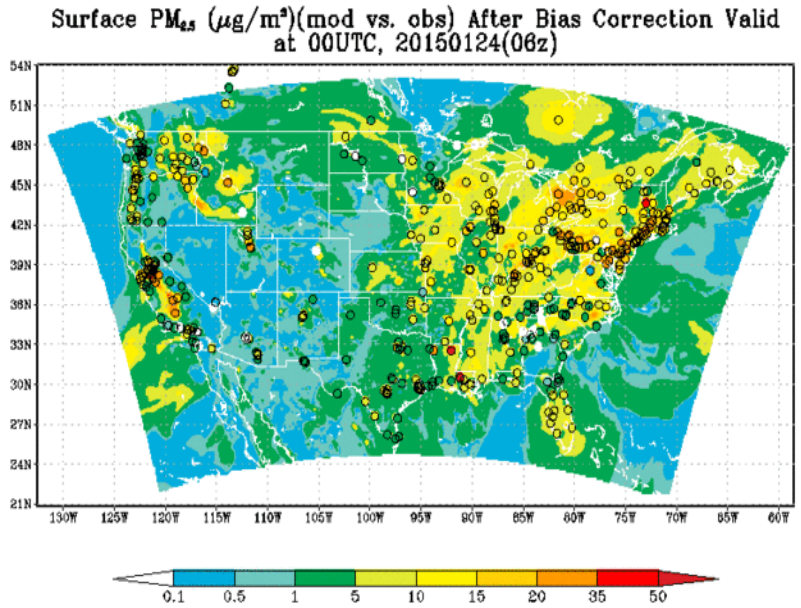
Daily Variation Valid at 04 UTC



NCEP tests for winter month (cont.)

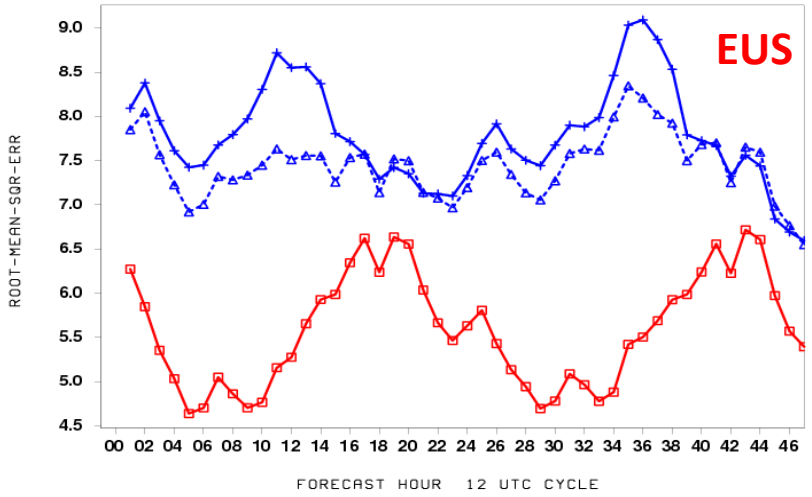
Raw CMAQ

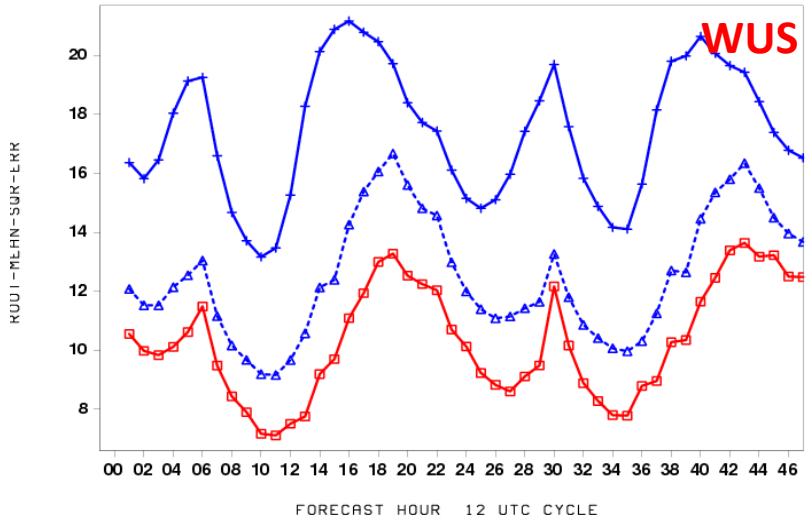




AN Corrected

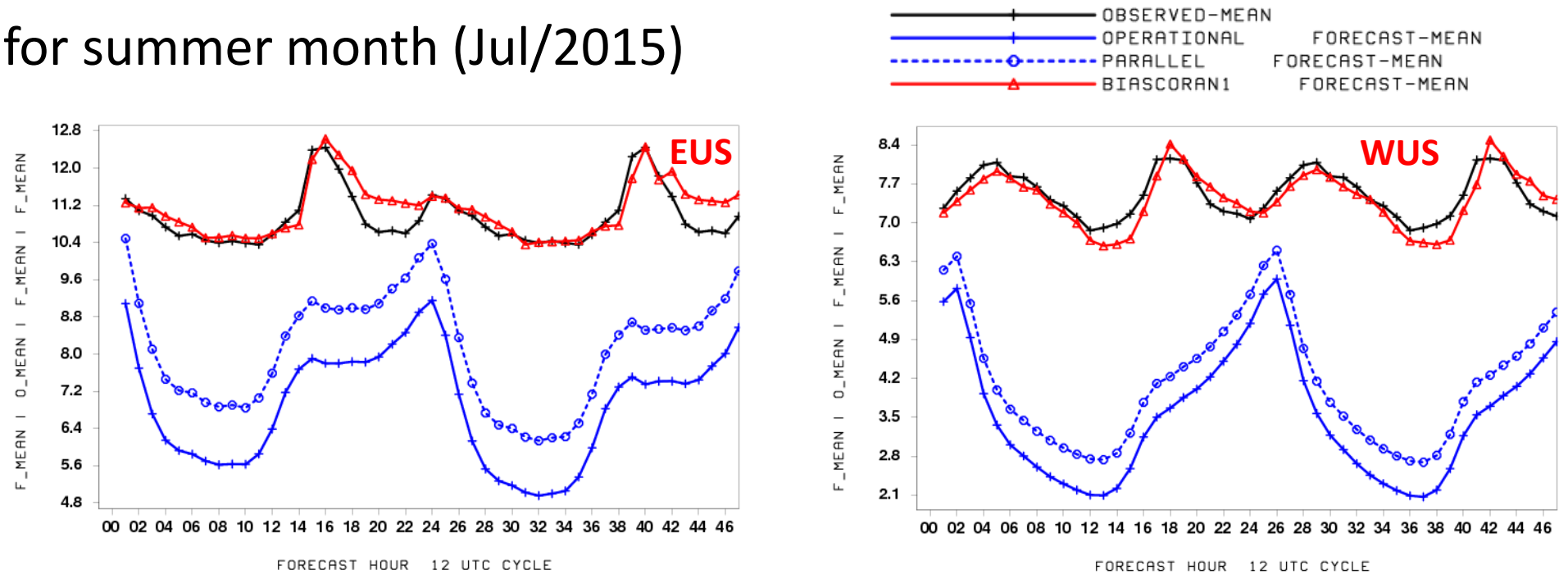
RSME



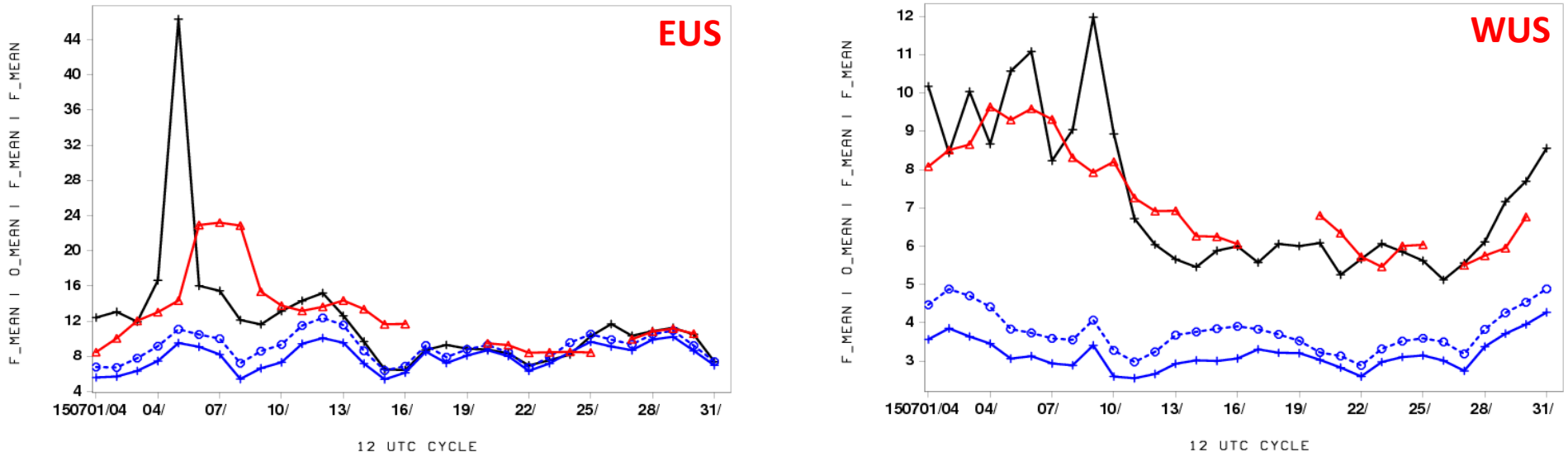


NCEP tests for summer month (Jul/2015)

Mean Diurnal Cycle

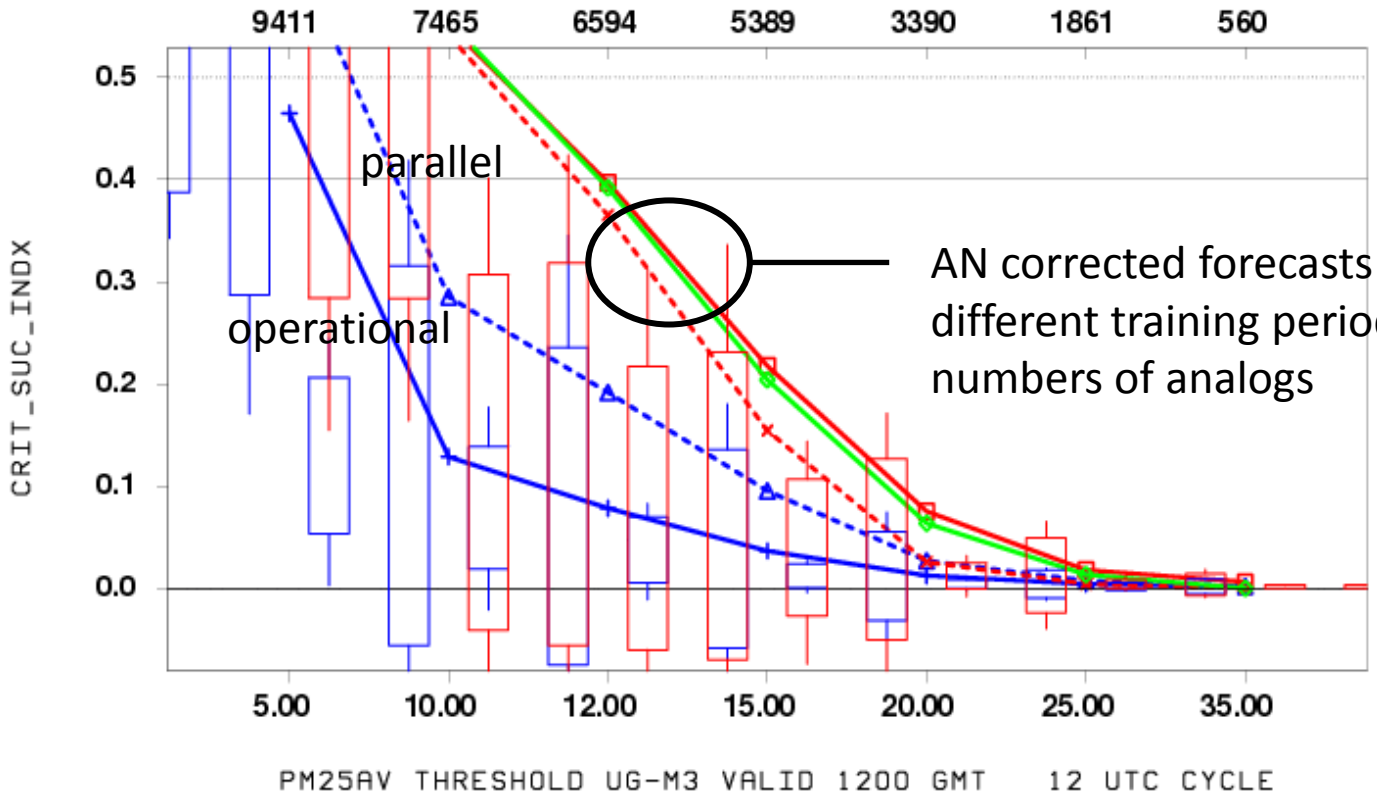


Daily Variation Valid at 04 UTC



NCEP tests for summer month (cont)

Categorical Forecast Evaluation: Critical Success Index



AN corrected forecasts using 3 different training period lengths and numbers of analogs

Current Status and Future Plans

AN scheme is in developmental testing at NCEP with limited dissemination to a select users/evaluation group.

Pending evaluation results, AN bias correction for PM2.5 forecast guidance is planned to be released to the public later in this fiscal year.

Development of post-processing techniques will continue, with research focusing on:

- KFAN implementation
- parallelization of post-processing code
- regional optimization of analog searches
- better treatment of forest fire episodes