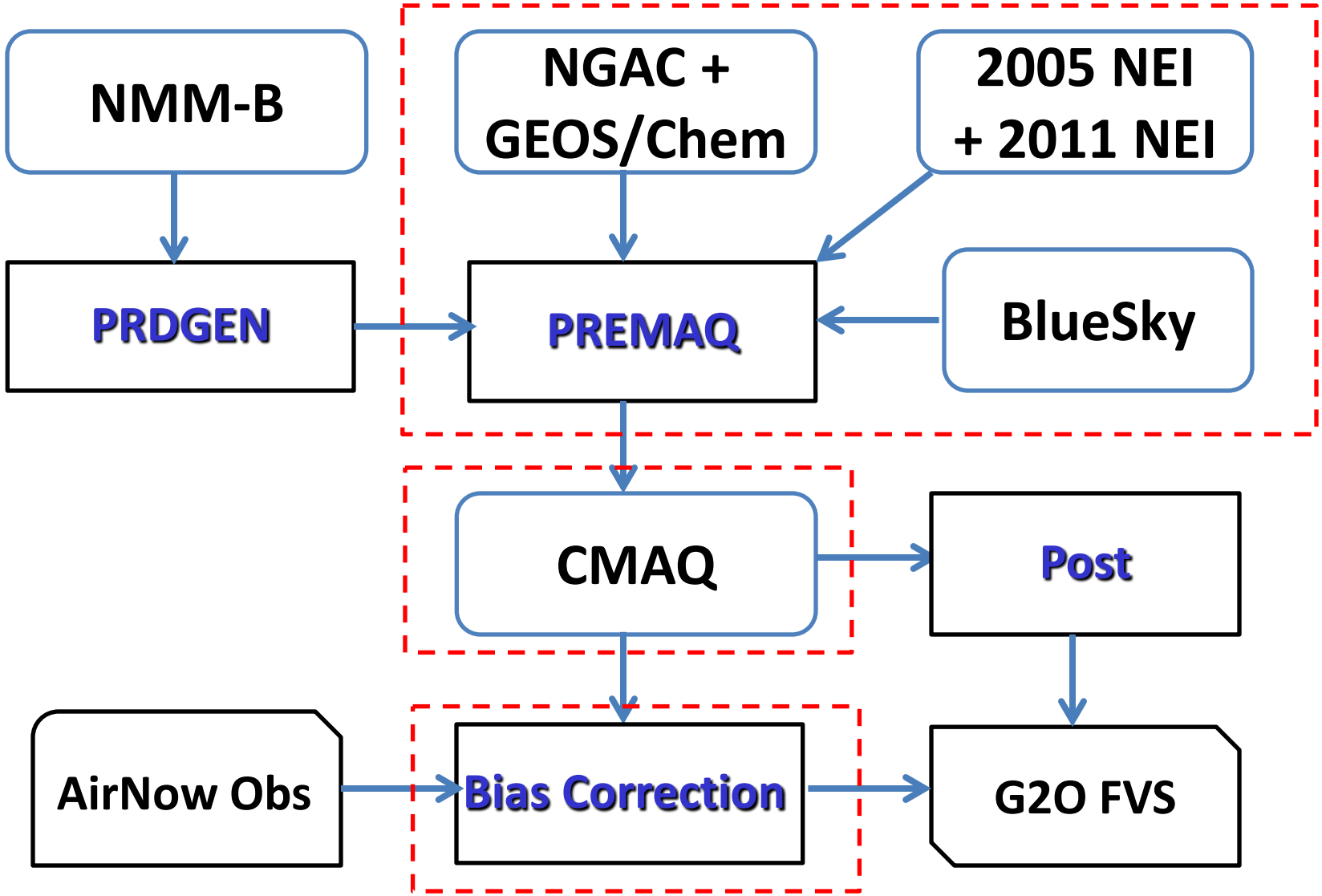
Upgrade to the air quality prediction model NAM-CMAQ V4.6.6

Pius Lee and Jianping Huang on behalf of NAQFC NCEP, ARL and ESRL team

07-10-2015

Overview of Changes

- Update emissions to NEI base year 2011
- Increase vertical levels from 22 to 35
- Provide dust boundary conditions from NGAC
- Test a bias correction scheme for particulate matter prediction

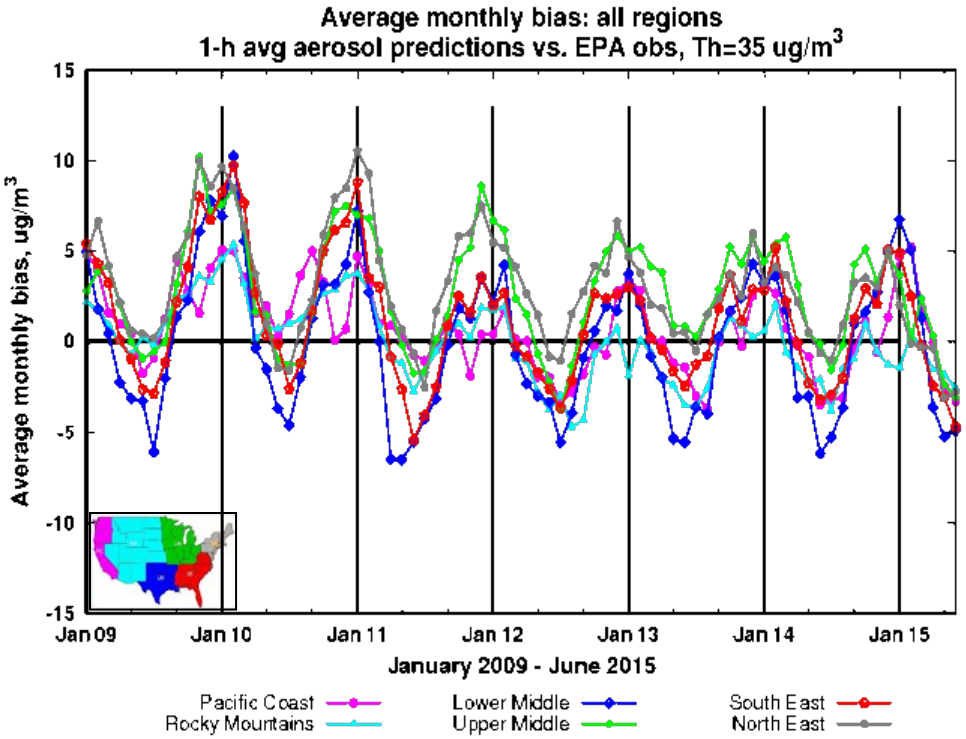


A flow chart of CMAQ v4.6.6 (new Changes as indicated by the red dashed boxes)

Current issues of $PM_{2.5}$ predictions in NAQFC

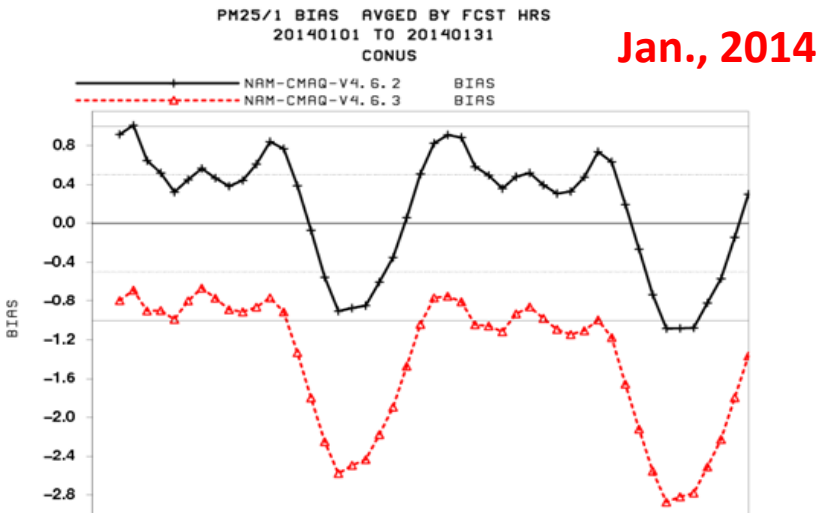
- Significant seasonal bias
  - over-prediction in winter
  - under-prediction in summer

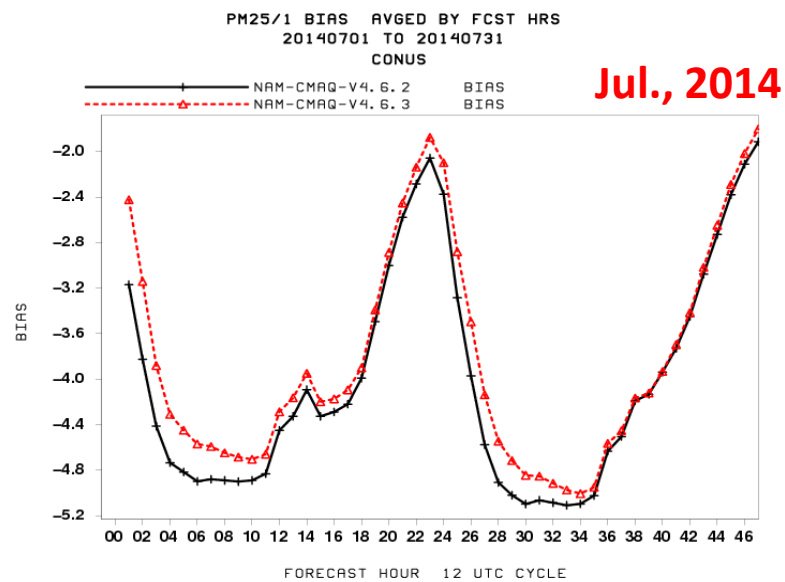
- Sources of the bias
  - emissions ?
  - Met inputs like PBLH ?
  - CMAQ itself?
  - LBCs?



Current issues of $PM_{2.5}$ predictions in NAQFC (cont.)

- Diurnal bias
  - Large bias during nighttime in winter
  - Large bias during daytime in summer

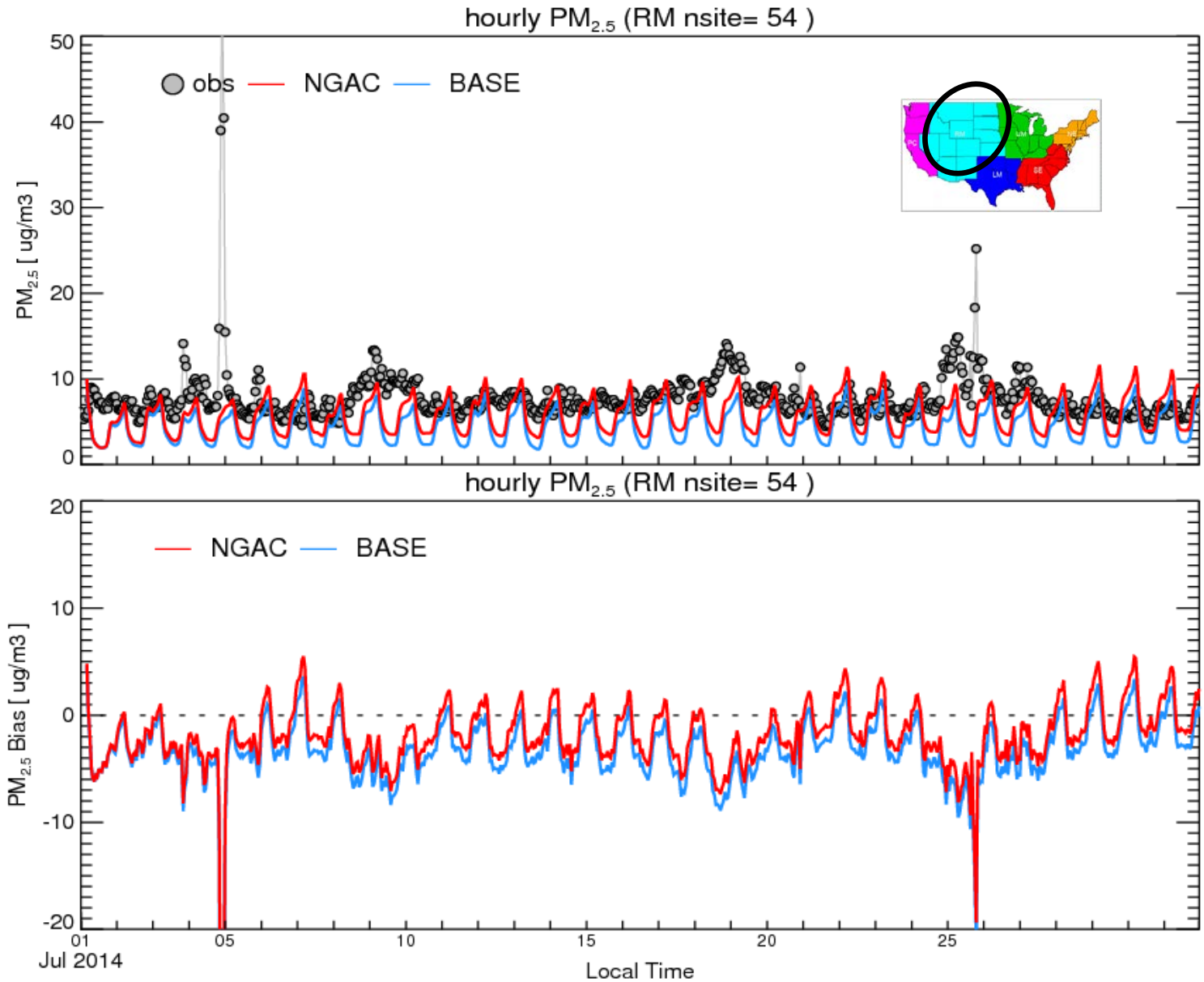




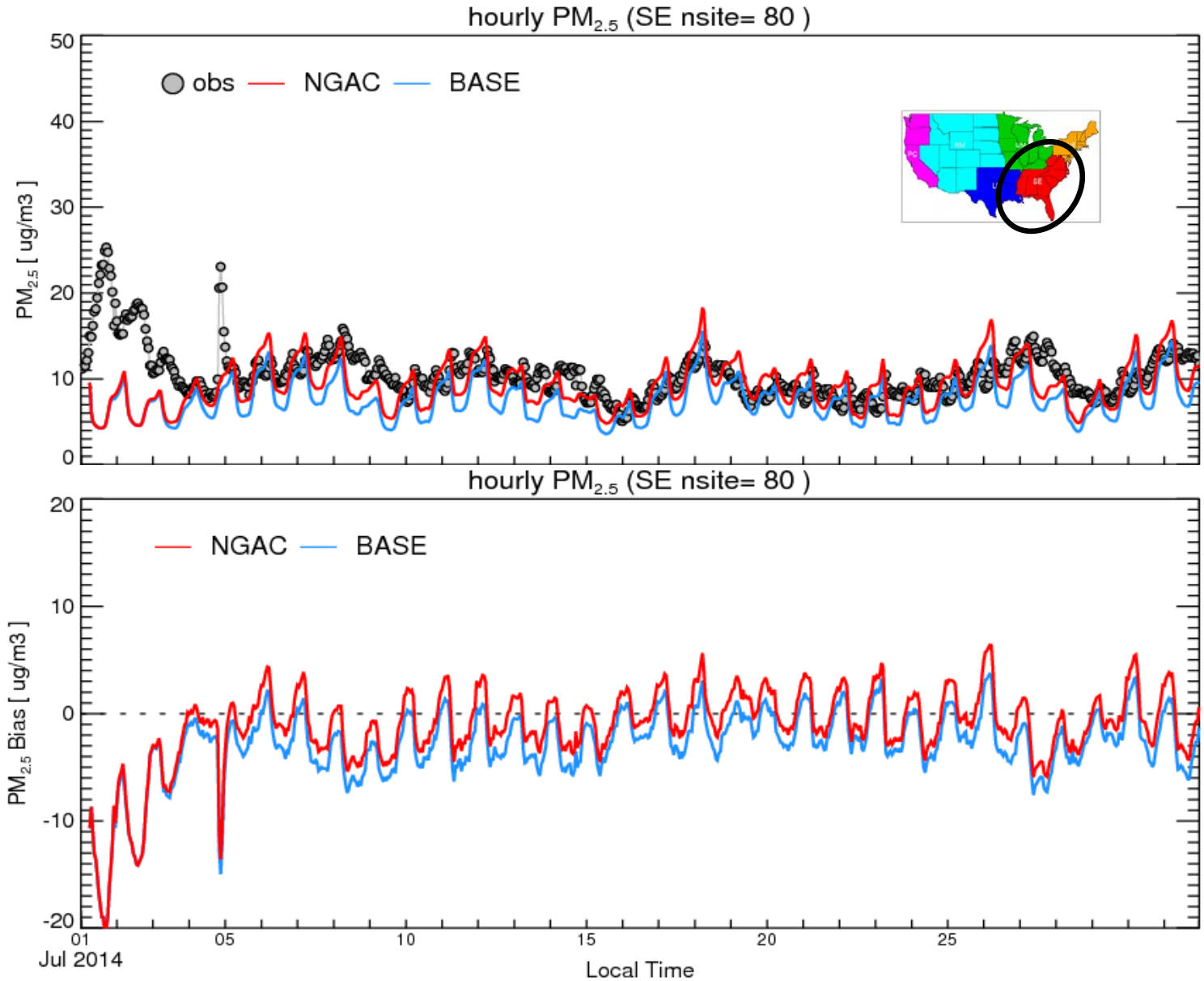
Configurations of NMMB-CMAQ runs

- Met inputs: NMMB 12-km (bgrd3d files)
- Emissions: 2005 NEI + part of **2011 NEI** (without mobile sources) + Blue Sky fire/smoke emissions (no gas)
- CMAQ: CB05 gas-phase mechanism + Aero 4 module + **35** vertical levels
- Lateral Boundary Conditions: **NGAC dust** + 2006 GEOS/Chem simulations (for gas + others of $PM_{2.5}$)

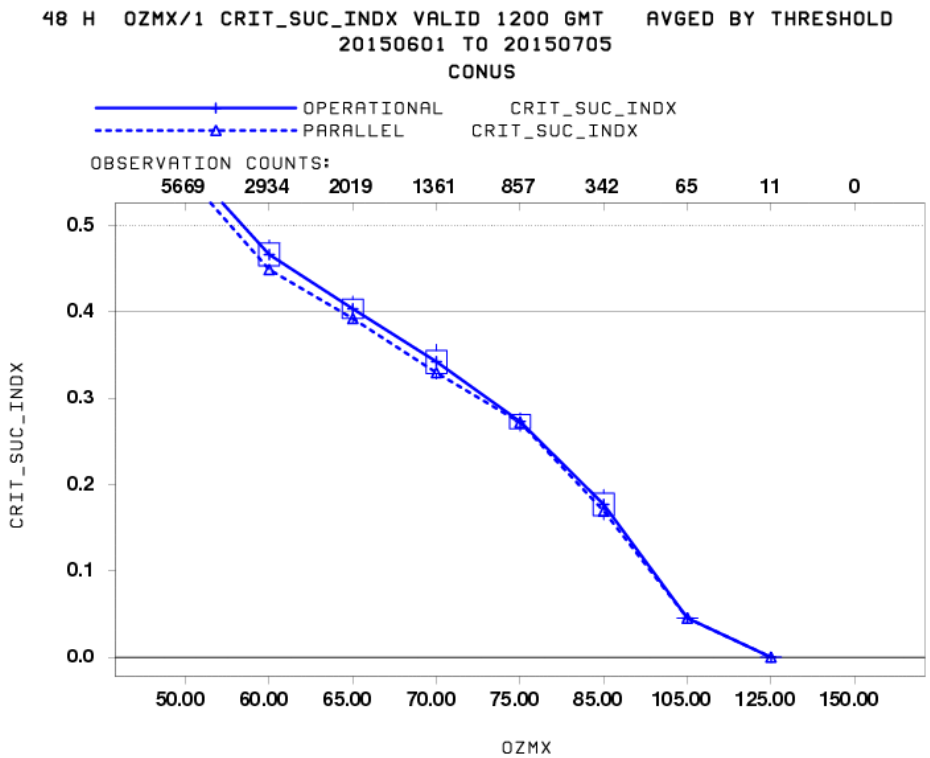
Impact on $PM_{2.5}$ Prediction (retro.)

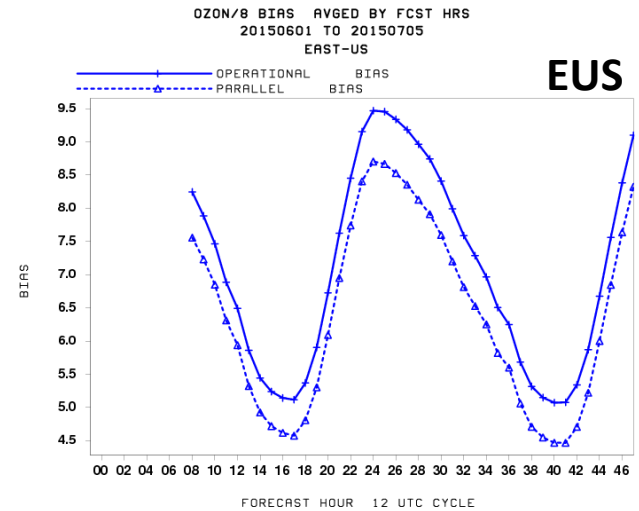


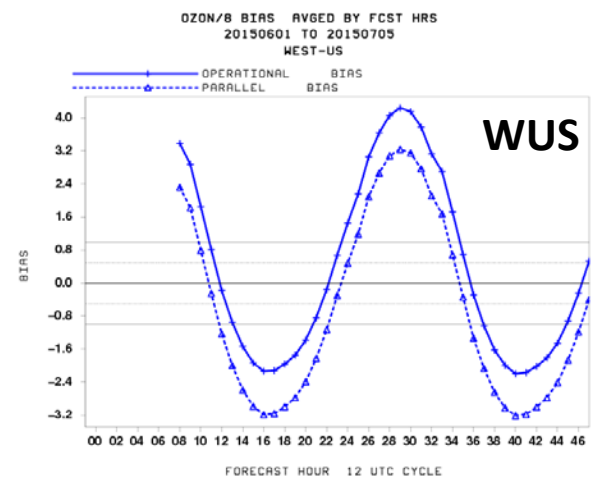
Impact on $PM_{2.5}$ Prediction (retro.)



Impact on ozone predictions real-time EMC parallel runs



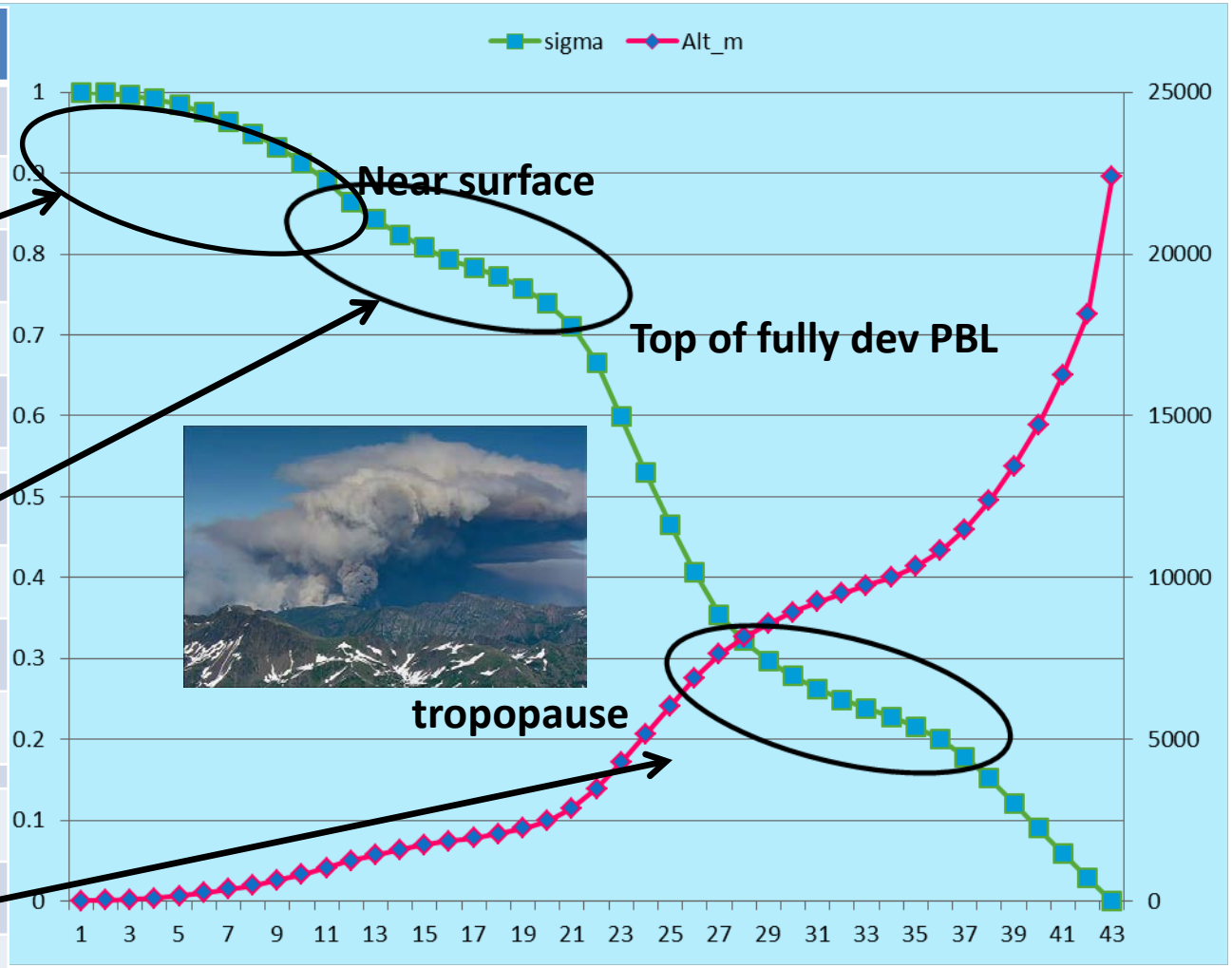




Small reduction in ozone concentrations after emission update

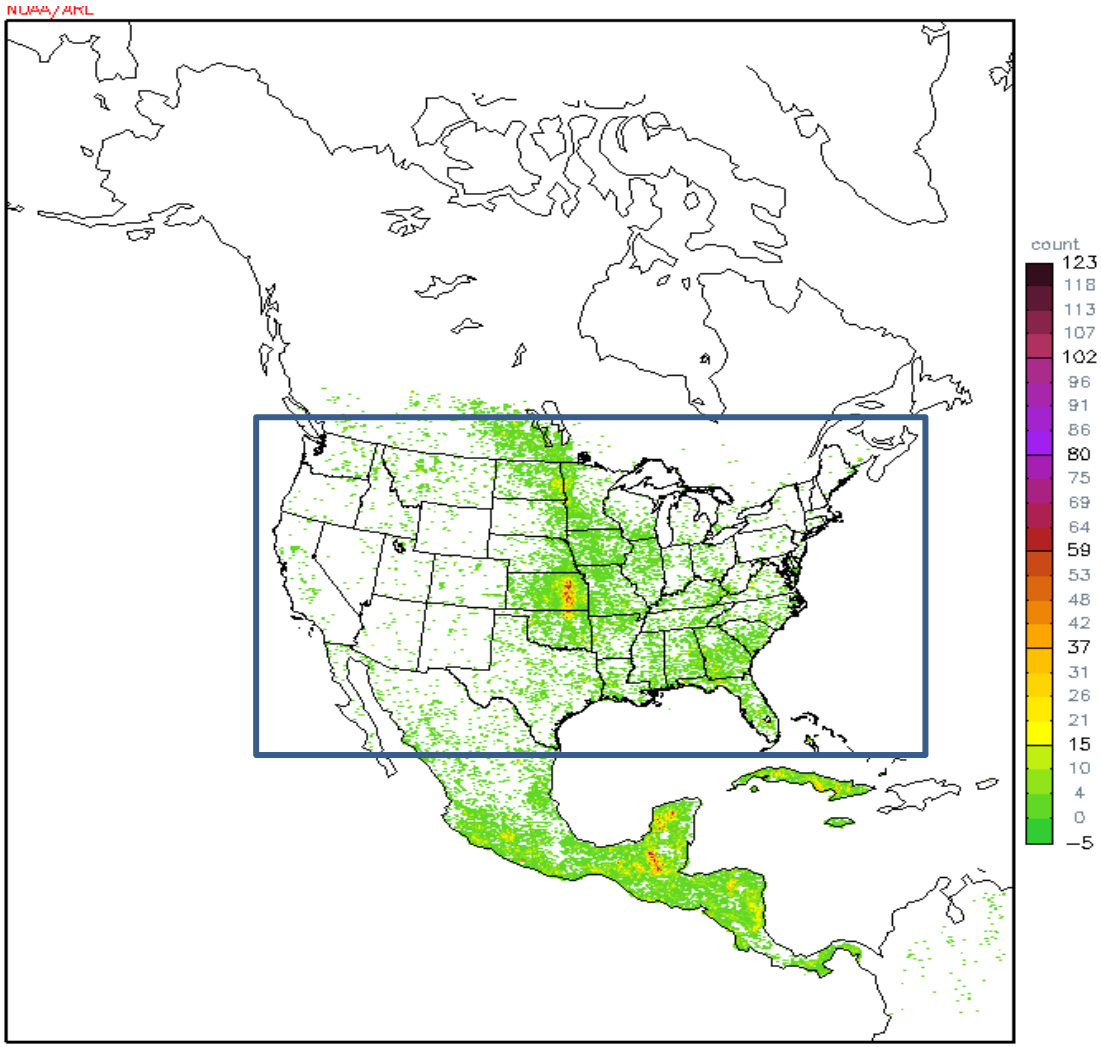
Re-fine vertical structure: Increase from 22 Layer to 35 Layers between sfc & 100hPa

sigma	Pres (hPa)	Z (m)
1	1013	0
0.999	1012	4
0.996	1010	20
0.992	1007	48
0.985	993	92
0.864	872	1245
0.843	852	1430
0.824	836	1590
0.808	821	1735
0.322	348	8150
0.297	326	8580
0.278	310	8940
0.262	296	8580

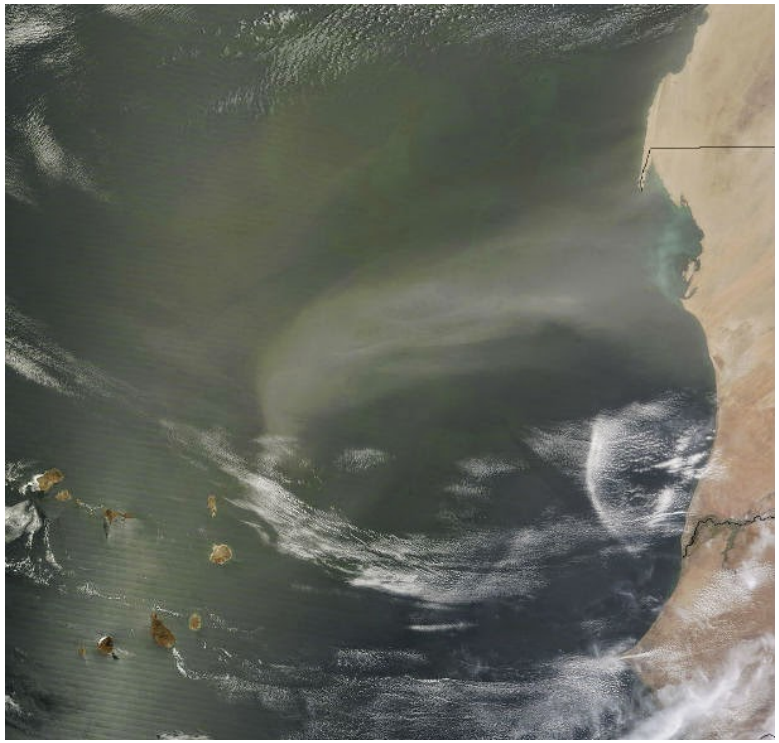


35L V 22L: 60% more CPU due to CFL criteria

Exo-domain emissions exhibit the dynamic nature of chemical BCs



A typical monthly hot-spot fire count in April



July 2 2014 Dust storm plume transported from West Africa

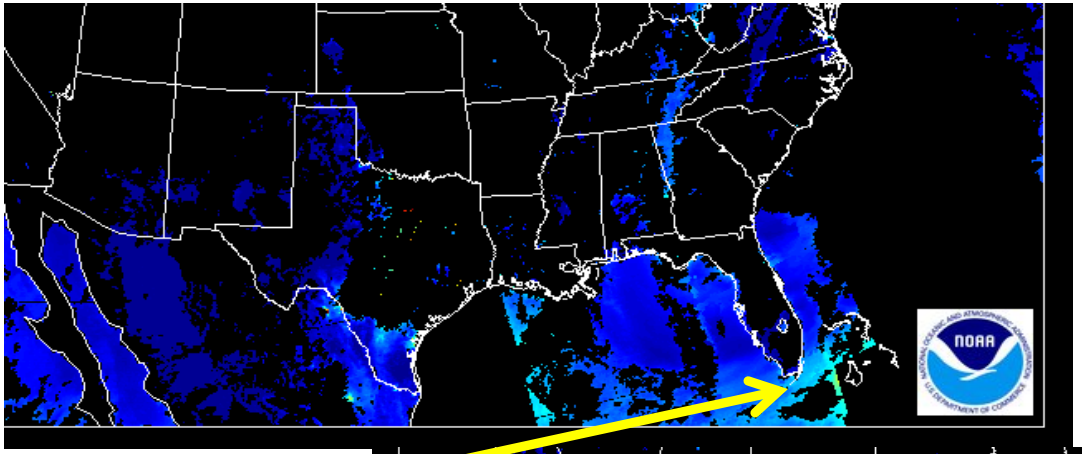
Courtesy: LANCE Rapid response team, NASA

Modify static Chemical LBC with NGAC 3-hourly output
Dynamic BC data are fed into CMAQ (Dust only for this implementation)

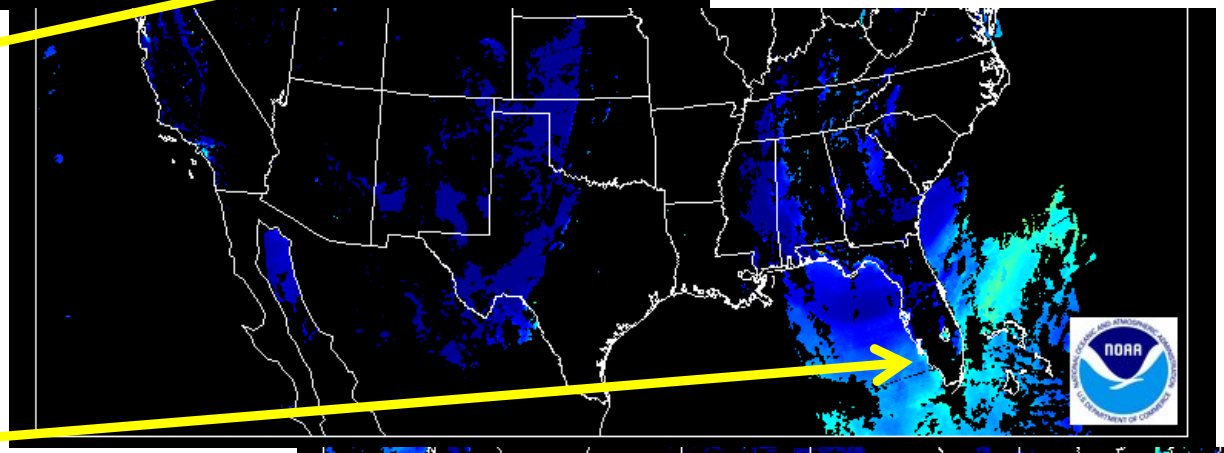
NGAC species		CMAQ species (multiplicative factor)	
Dust	**001,002**	**A25J**	**1.0, 0.42; respectively (R.)**
Dust	**002,003,004**	**ASOIL**	**0.58,1.0,0.76; (R.)**
Sea salt	001,002	ANAJ	0.39,0.27; (R.)
Sea salt	001,002	ACLJ	0.61,0.42(R.)
Sea salt	002,003	ANAK	0.12,0.39; (R.)
Sea salt	002,003	ACLK	0.18,0.61; (R.)
SO2		SO2	1.0
SO4		ASO4J	1.0
bcphobic		AECJ	1.0
bcphilic		AECJ	1.0
ocphobic		AORGPAJ	1.0
ocphilic		AORGPAJ	1.0

A Recent Sahara Dust Intrusion

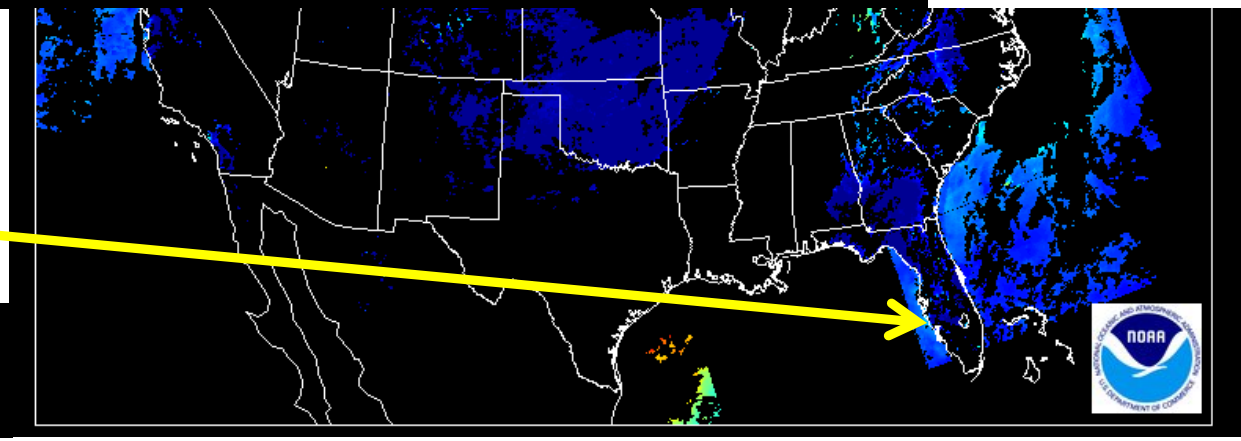
Sahara dust event May 10 2015
VIIRS AOD
Courtesy: Shobha Kondragunta (NESDIS)



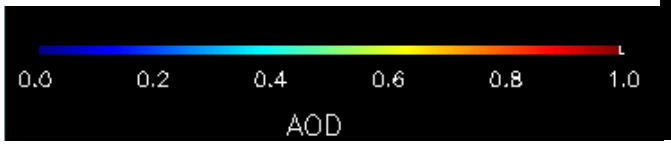
12 UTC May 9



12 UTC May 10

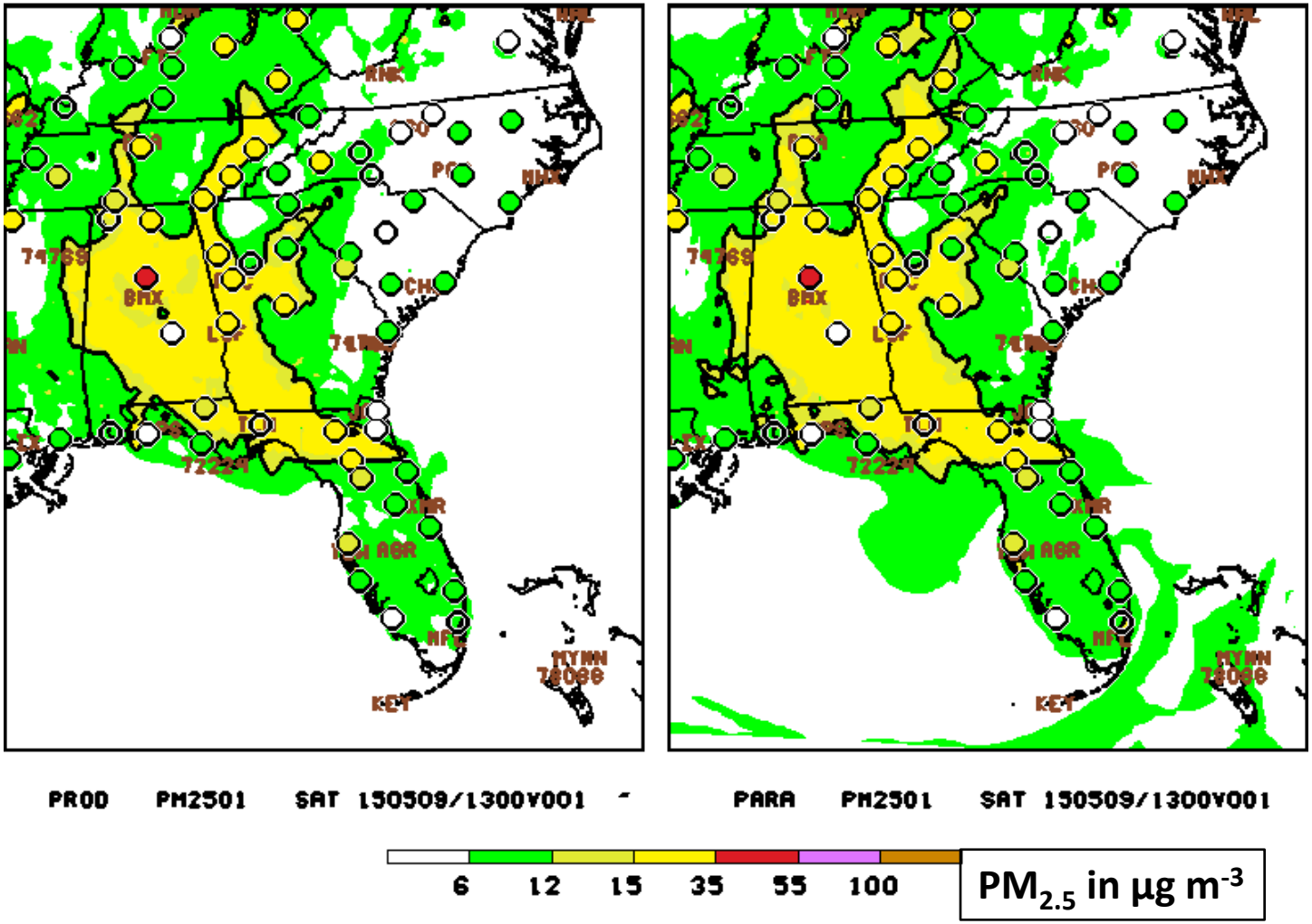


12 UTC May 11



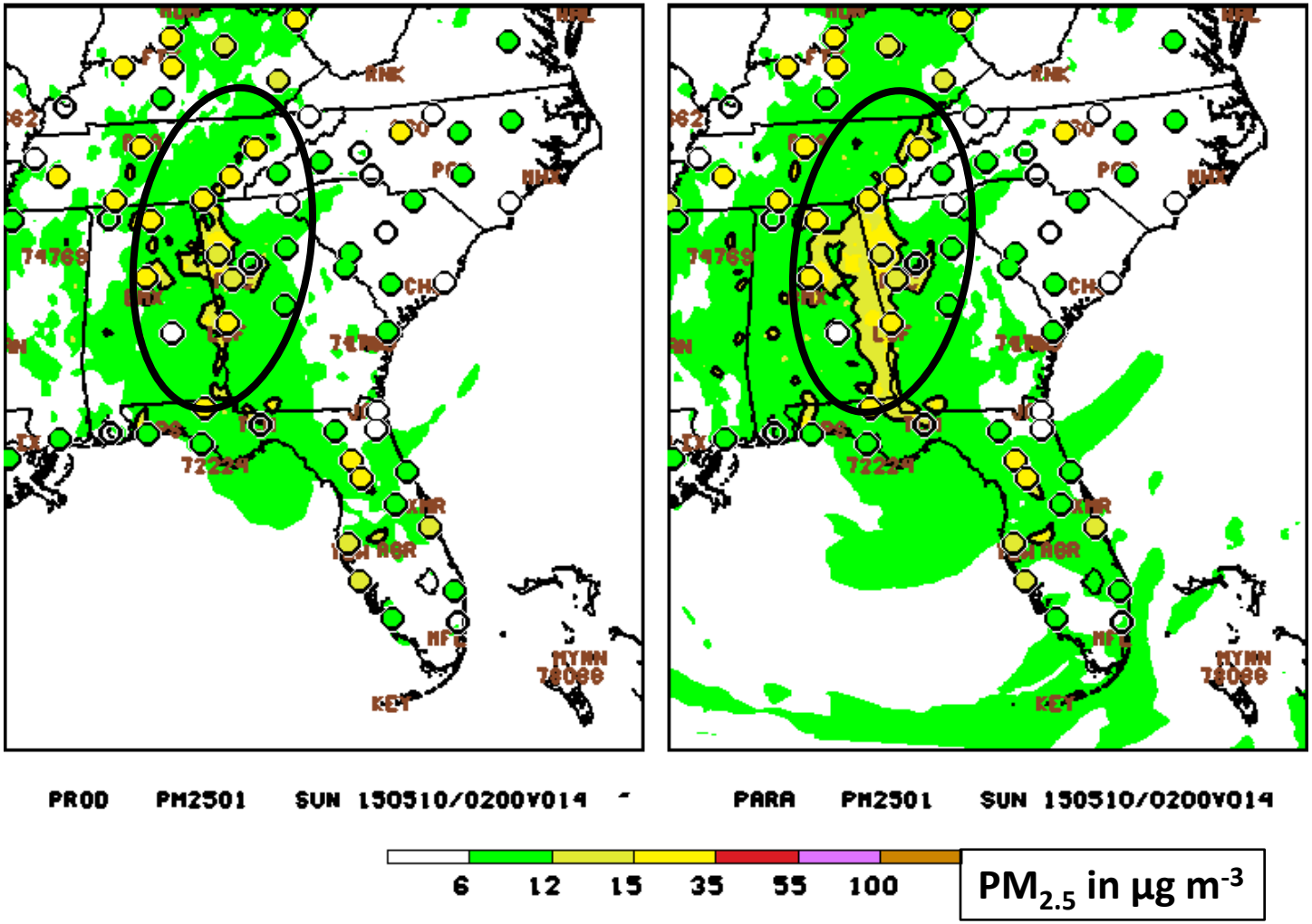
Surface PM2.5 concentration between May 9 and May 11 2015 over SE U.S.

(Left) Prod **(Right) para = Prod + NGAC + emission**



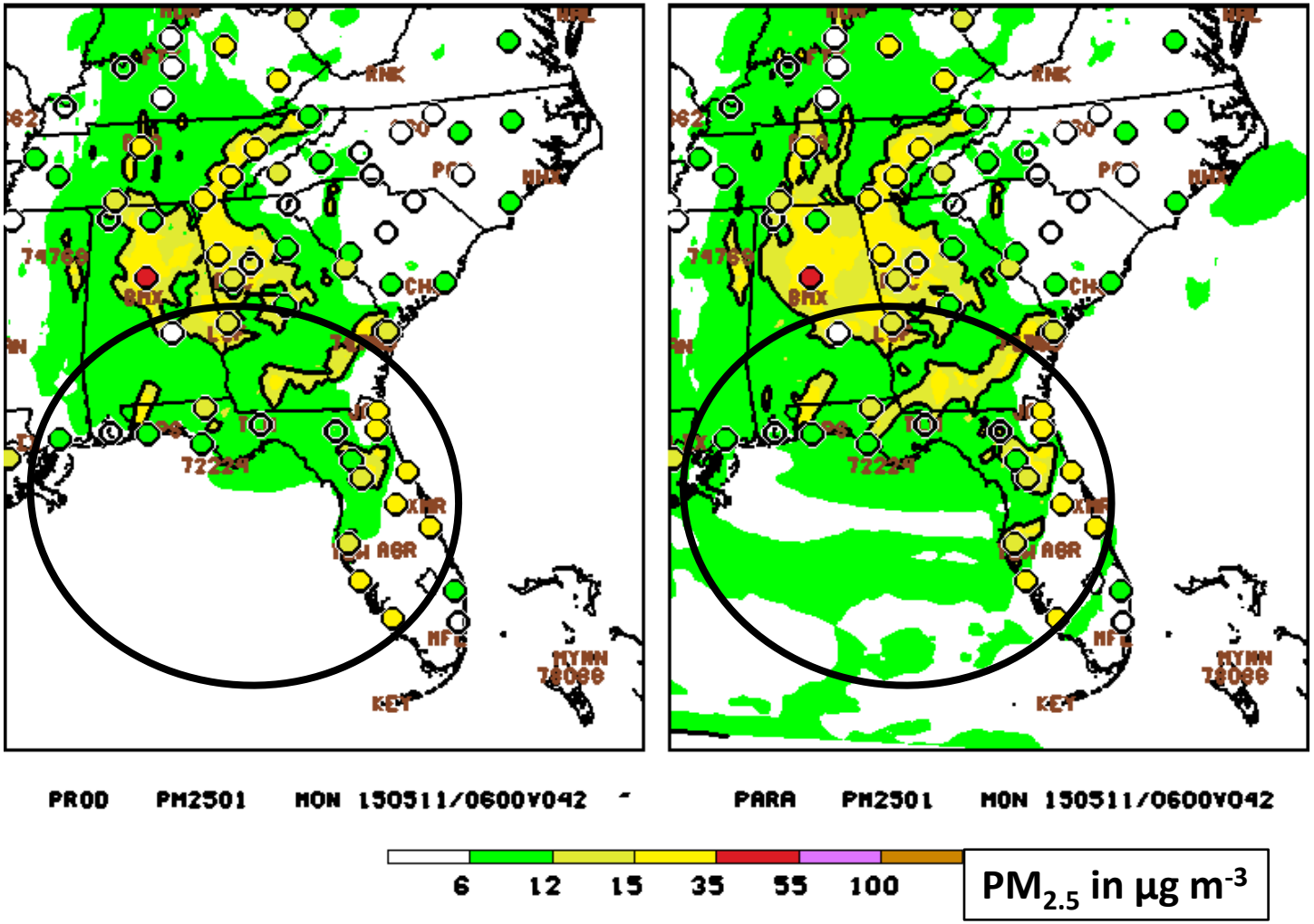
At 02 UTC May 10 2015: reflects intruded dust reached sfc north to Gulf

(Left) Prod (22Layers) **(Right) para = Prod + NGAC + 35Layers**



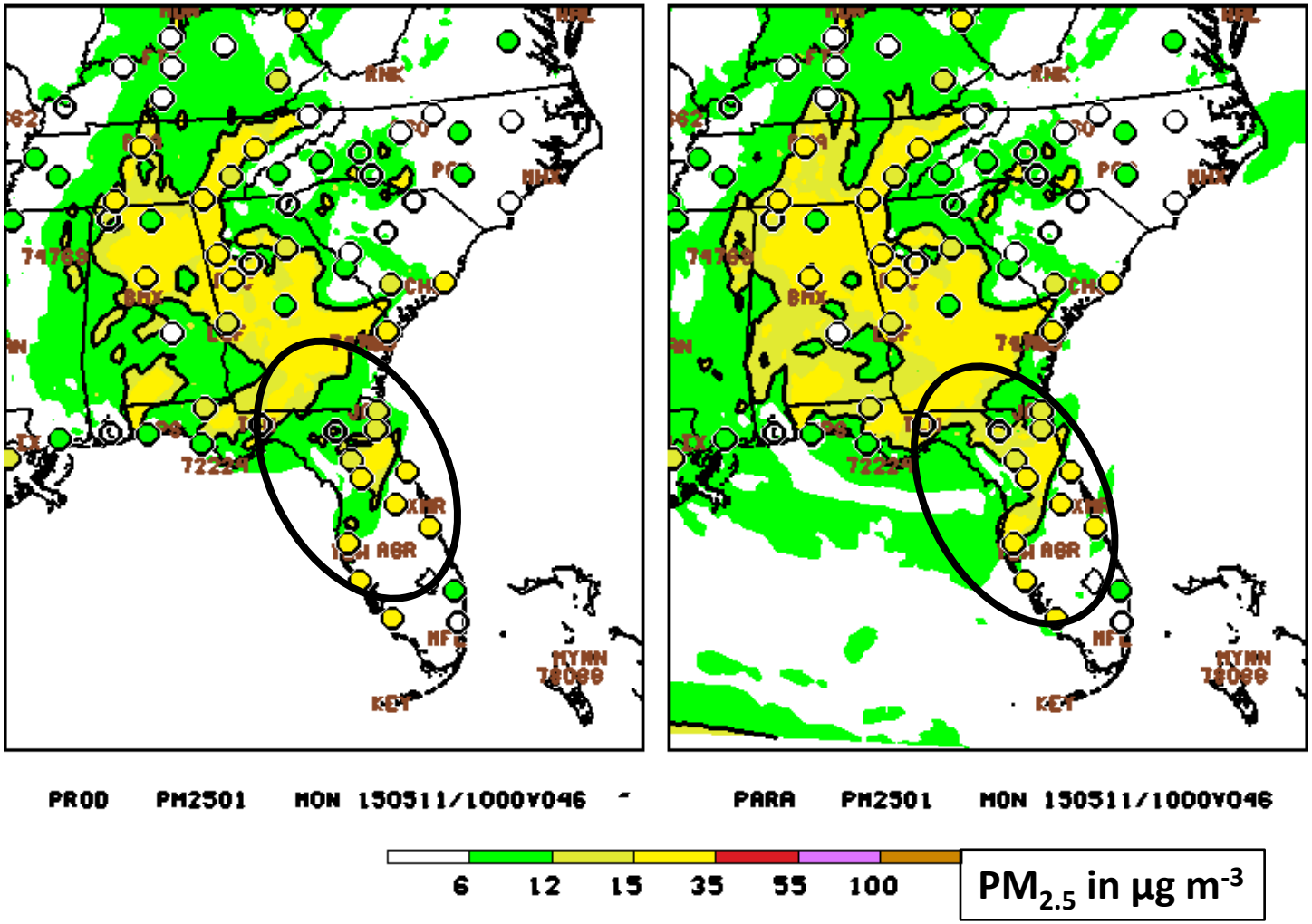
At 06 UTC May 11 2015: Remnants of intruded dust reached sfc in FL

(Left) Prod (22Layers) **(Right) para = Prod + NGAC + 35Layers**



At 10 UTC May 11 2015: Remnants of intruded dust still affected model result

(Left) Prod (22Layers) **(Right) para = Prod + NGAC + 35Layers**



Testing of a bias correction scheme for particulate matter prediction

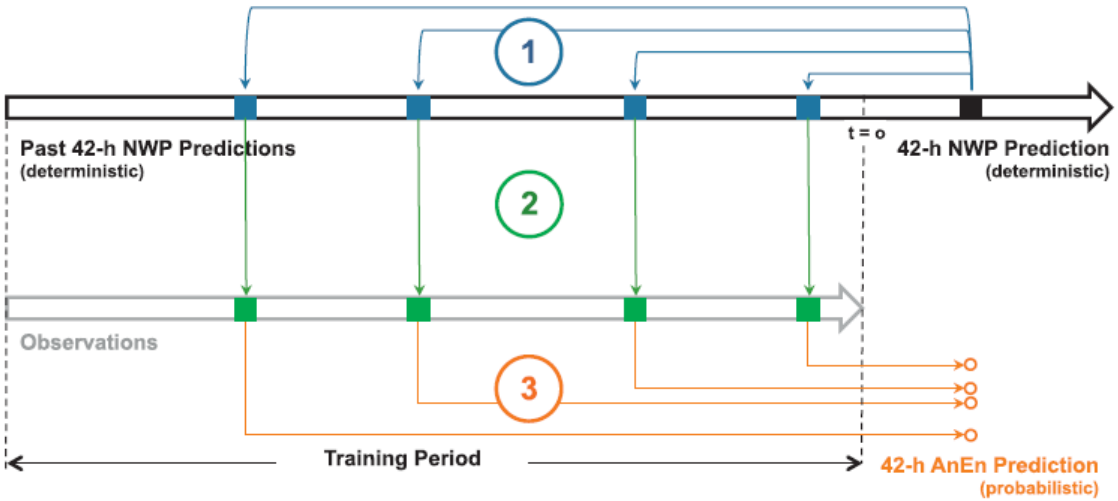
Jianping Huang

Approaches of $PM_{2.5}$ Bias Correction

- Running-mean
- Kalman-Filter (KF) approach (Delle Monache et al., 2006)
- Analog Ensemble forecast (AnEn) (Hamill and Whitaker, 2006; Monache et al., 2013)
- Combined Analog with the Kalman-Filter (KFAS) (KF applied to standard time series of data)
- Combined Analog with the Kalman-Filter (KFAN) (applying the KF to the AN time series)

Djalalova et al. (Atmos. Environ. 2015)

Analog Ensemble in Probabilistic Weather Prediction (Monache et al. 2013)



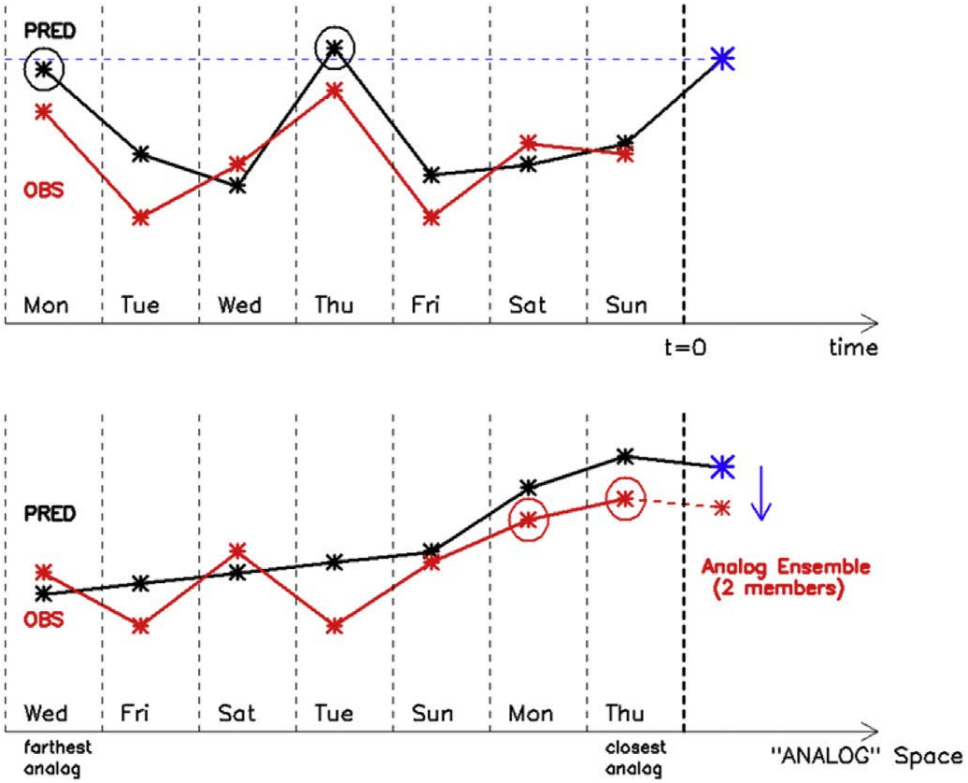
Analog metric is determined by (Monache et al. 2011)

$$\|F_t, A_{t'}\| = \sum_{i=1}^{N_v} \frac{w_i}{\sigma_{f_i}} \sqrt{\sum_{j=-\tilde{t}}^{\tilde{t}} (F_{i,t+j} - A_{i,t'+j})^2},$$

Where F_t is current NWP forecast valid at future time t, $A_{t'}$ is analog at past time t', N_v is the number of variables , $\tilde{t}$ is half the number of additional computation time, w_i weight, σ_{f_i} standard deviation

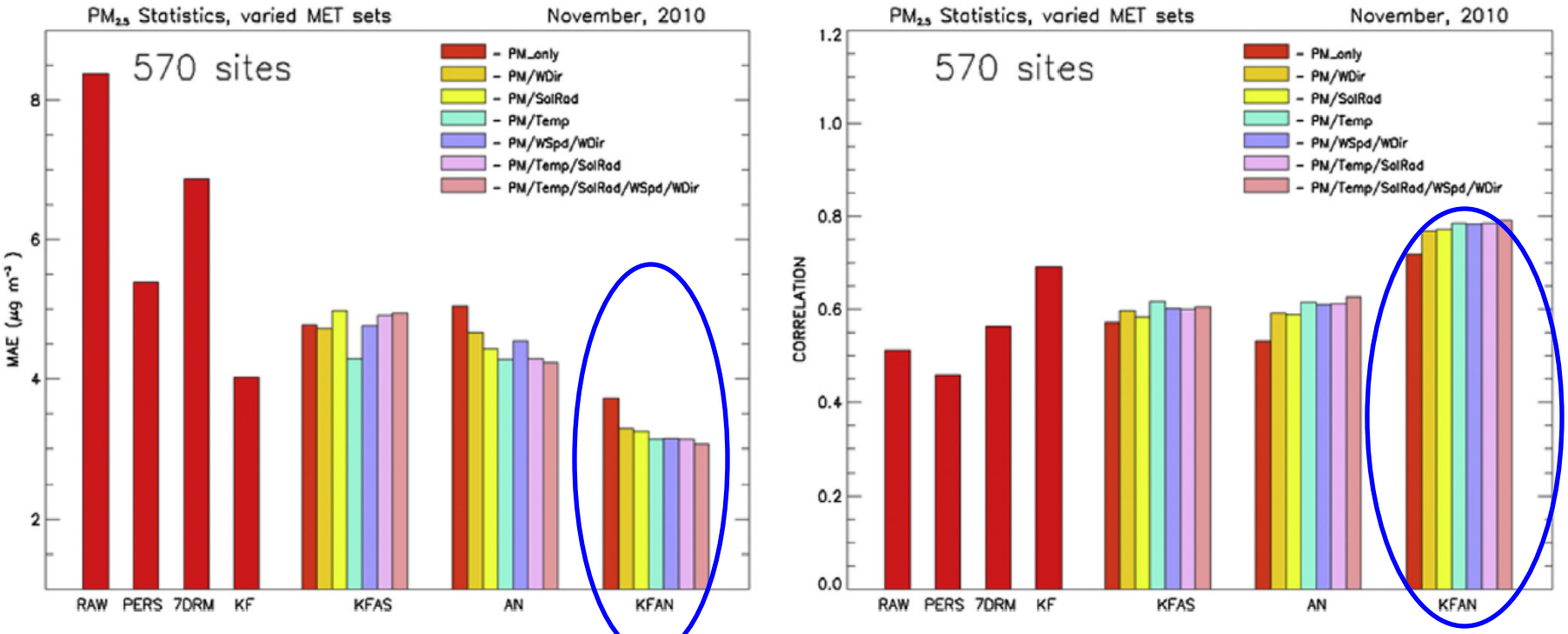
Analog Ensemble for $PM_{2.5}$ Bias Correction

- Interpolate CMAQ outputs into AIRNow observational sites
- Search for similar patterns from the historical data (combining $PM_{2.5}$ with T, SR, WS/WD)
- Calculate the forecast biases at the observational sites
- Spread the forecast biases to the entire domain



Djalalova et al. (Atmos. Environ. 2015)

Analog Ensemble for $PM_{2.5}$ Bias Correction (cont.)



MAE (left panel) and correlation coefficient (right panel) using hourly observed and forecast $PM_{2.5}$ values for the month of November, 2010 for the raw CMAQ model, persistence, and five different post-processing schemes. For the three analog methods, the color bars indicate the various combinations of search variables (i.e., analog predictors) used. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

KFAN shows the best performance

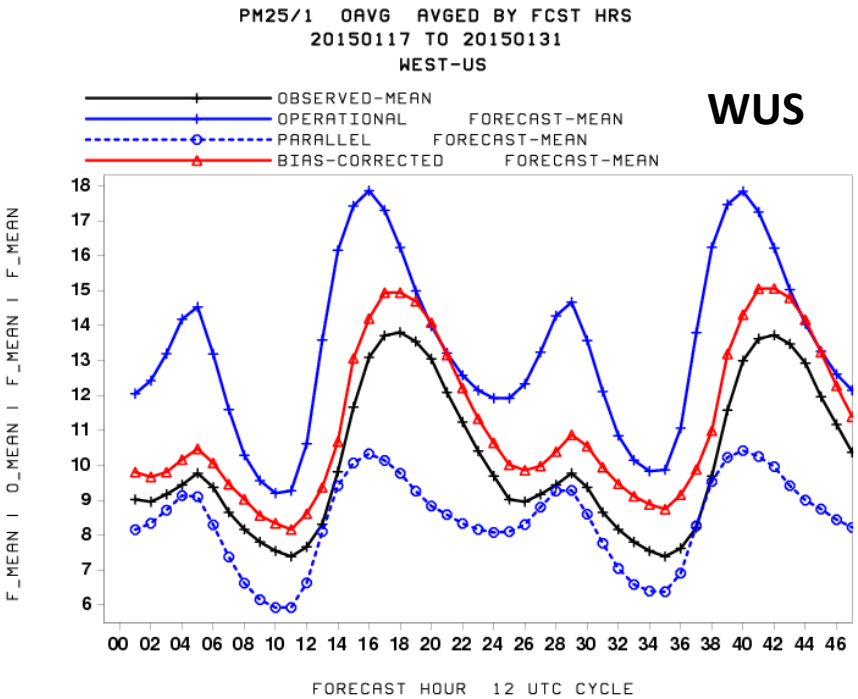
Analog search variables: $PM_{2.5}$, T, SR, WD, and WS

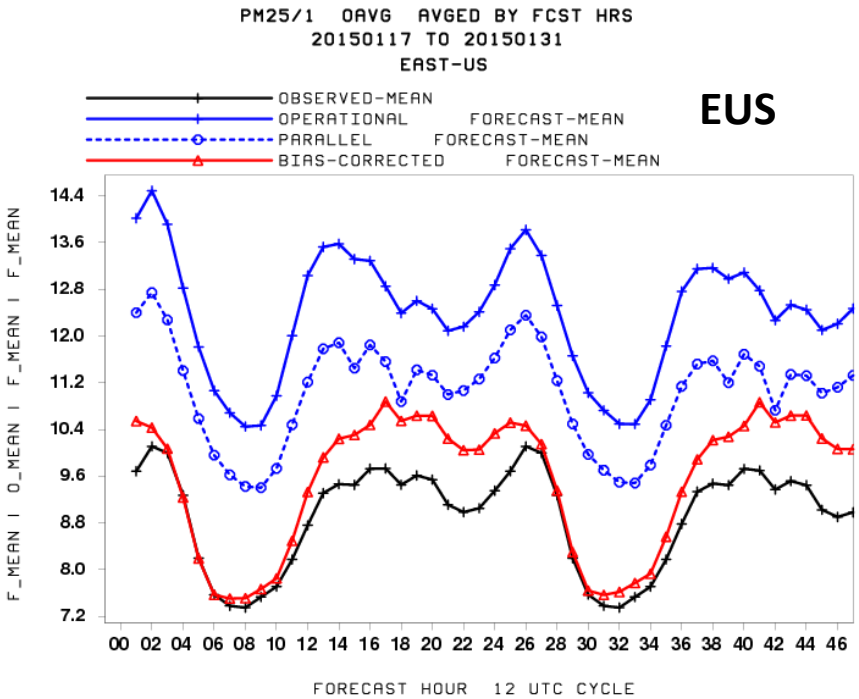
Djalalova et al. (Atmos. Environ. 2015)

Configurations of NMMB-CMAQ runs

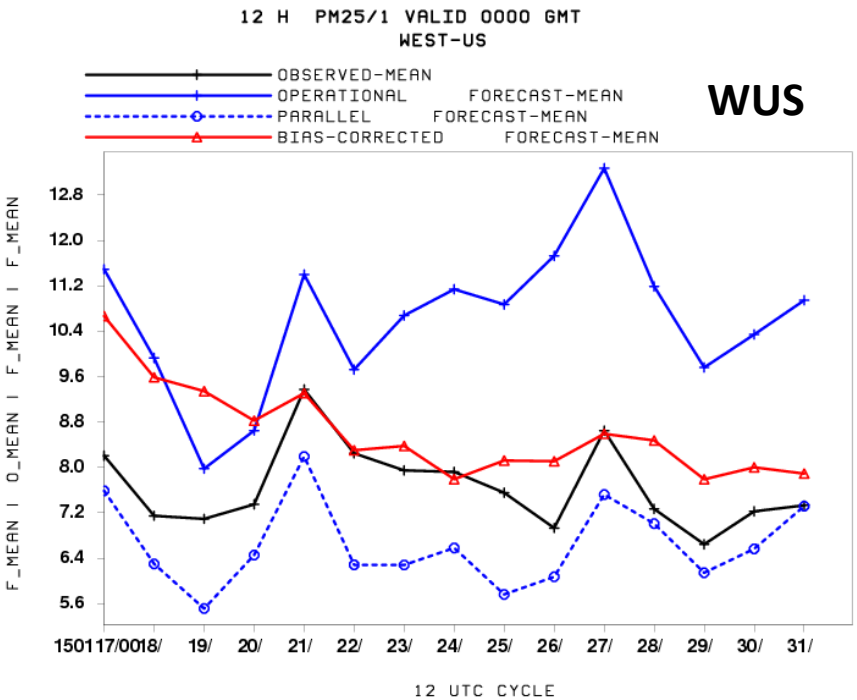
- Met inputs: NMMB 12-km (bgrd3d files)
- Emissions: 2005 NEI + part of 2011 NEI (without mobile sources) + Blue Sky fire/smoke emissions (no gas)
- CMAQ: CB05 gas-phase mechanism + Aero 4 module + 35 vertical levels
- Lateral Boundary Conditions: NGAC dust + 2006 GEOS/Chem simulations (for gas + others of $PM_{2.5}$)
- Bias Correction for $PM_{2.5}$: Analog Ensemble with training period of 4 weeks, 10 analog ensemble members and using $PM_{2.5}$ + T+WS/WD as analog search variables.

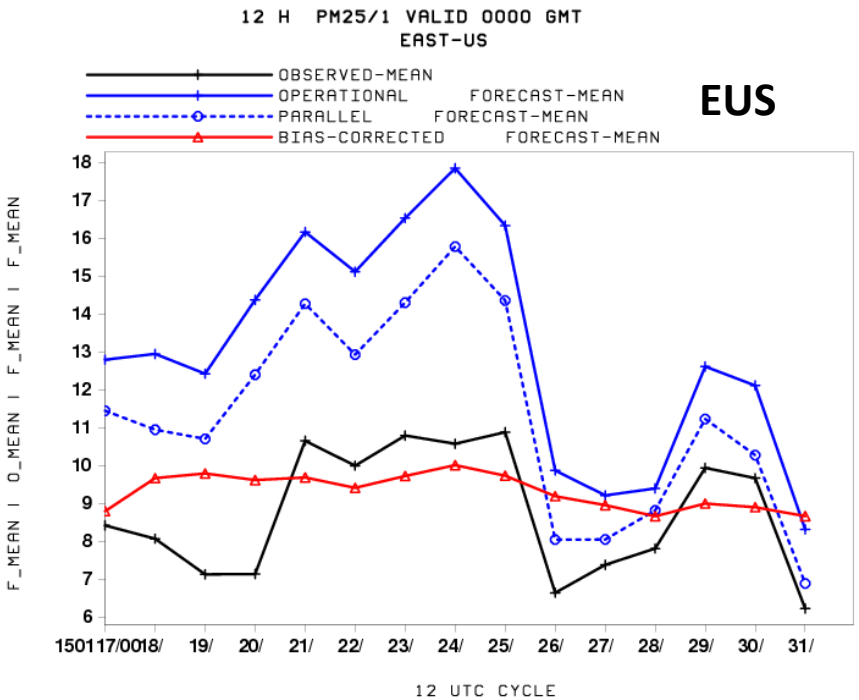
Diurnal Time Series
Bias correction in winter (Jan, 2015)



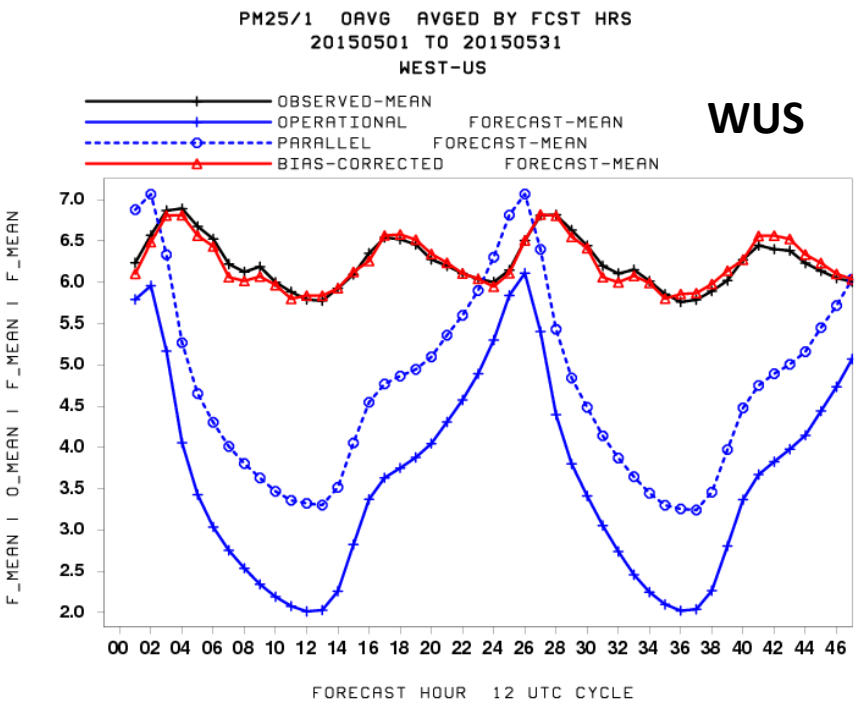


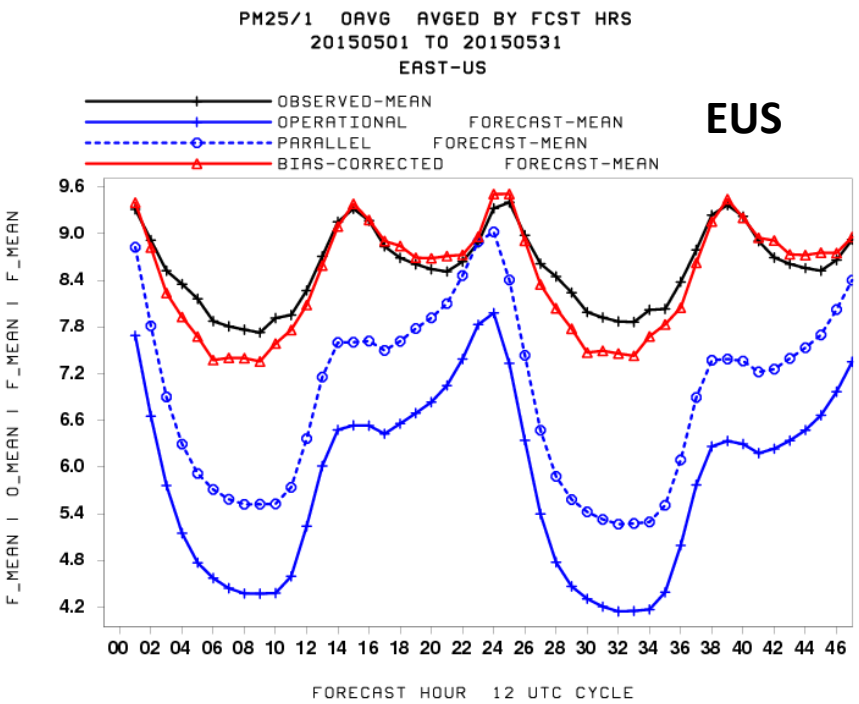
Daily Time Series Valid 00 UTC (+12h) Bias correction in winter (Jan, 2015)



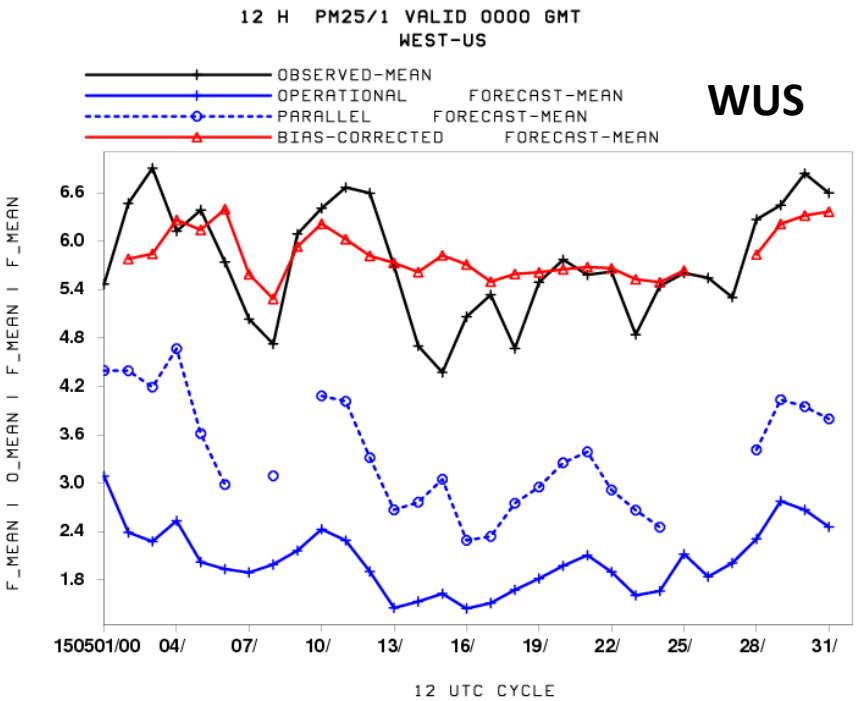


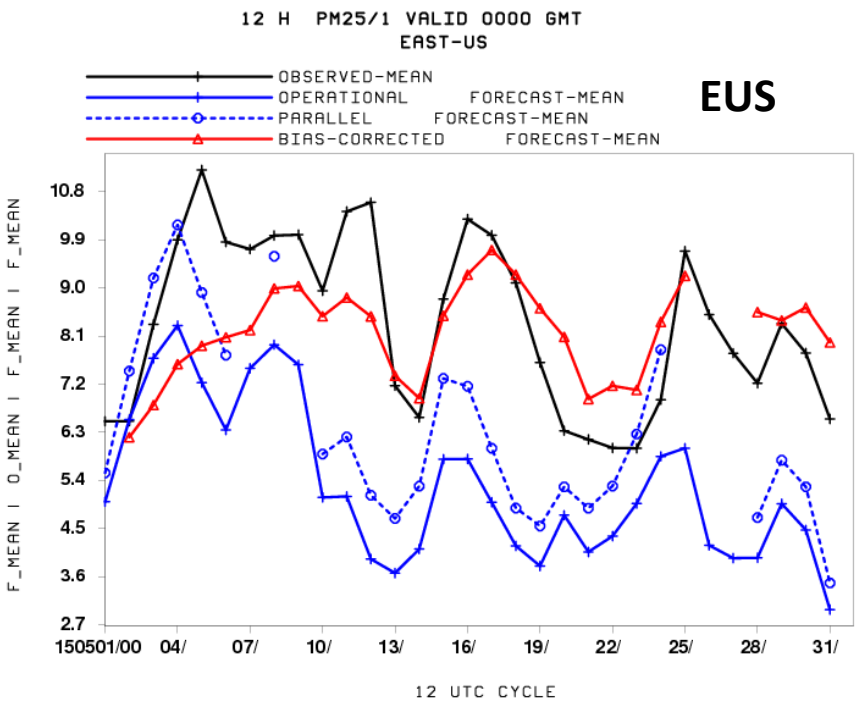
Diurnal Time Series
Bias correction in summer (May,2015)



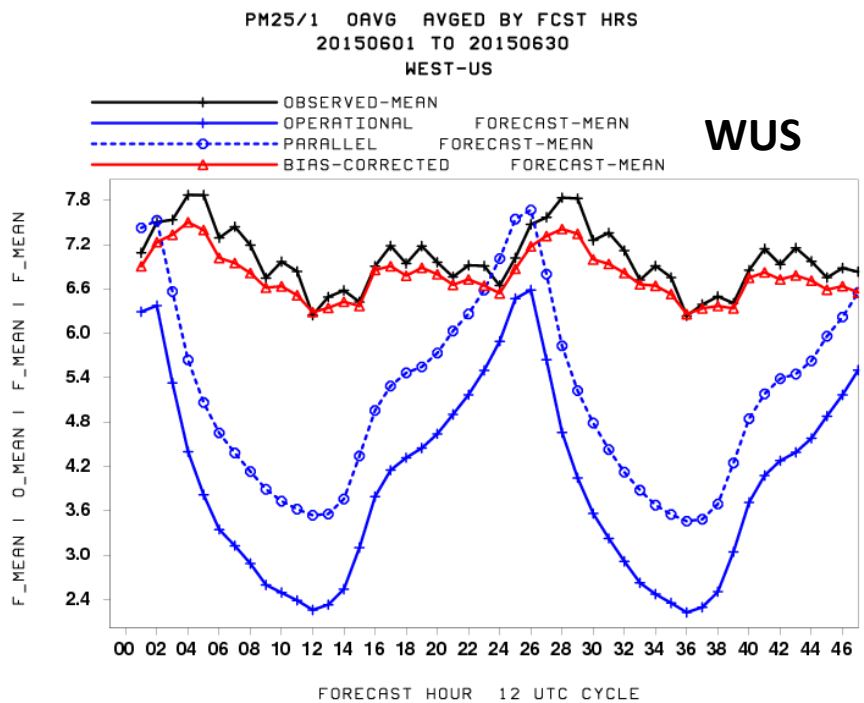


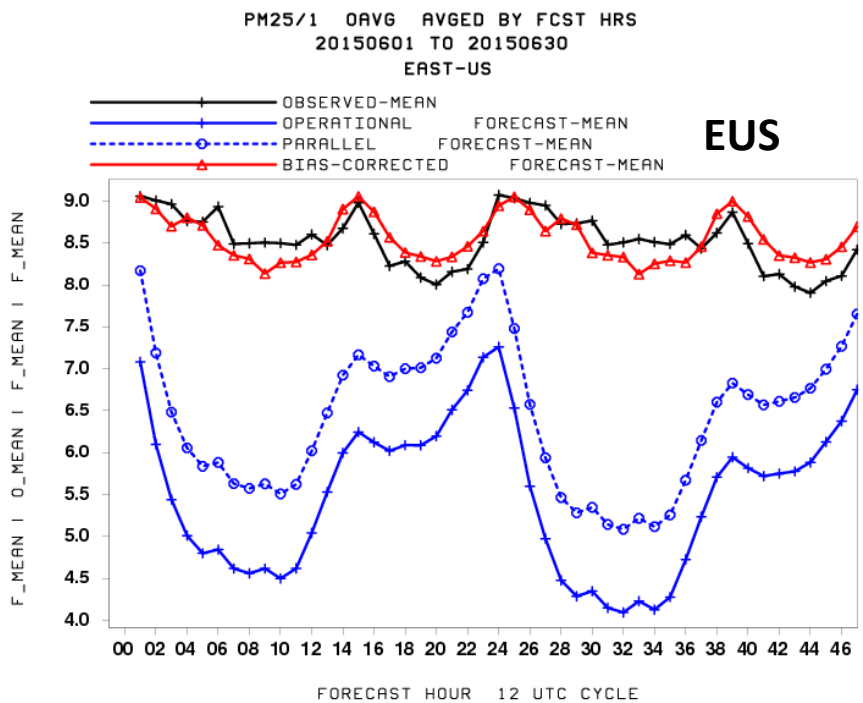
Daily Time Series Valid 00 UTC (+12h) Bias correction in summer (May, 2015)



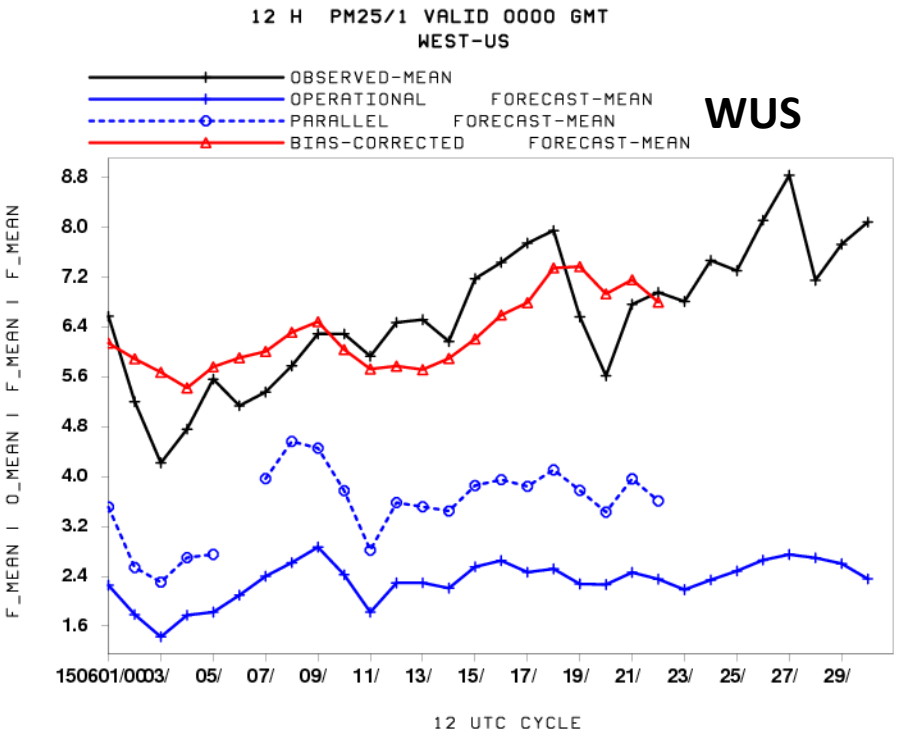


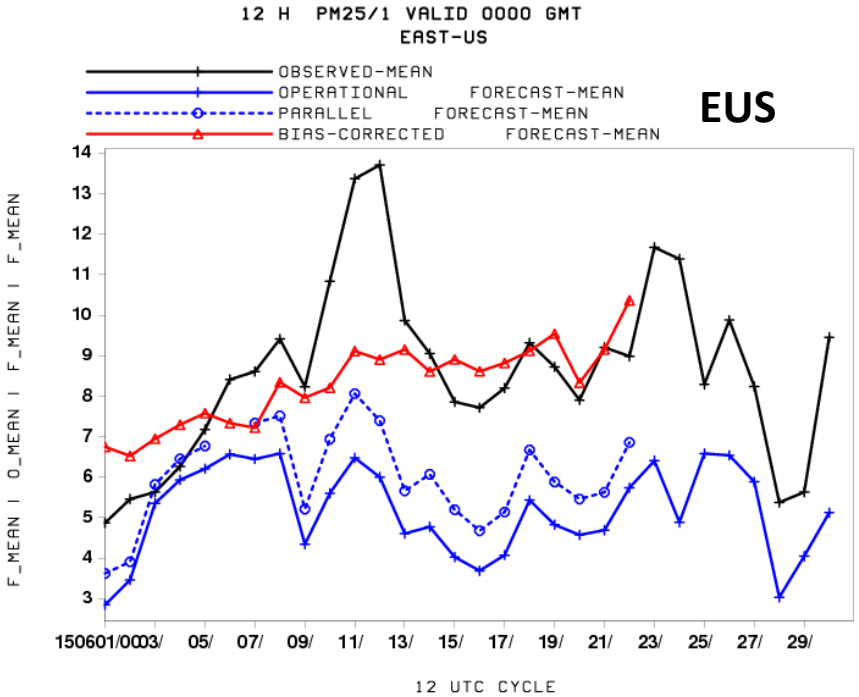
Diurnal Time Series
Bias correction in summer (June,2015)





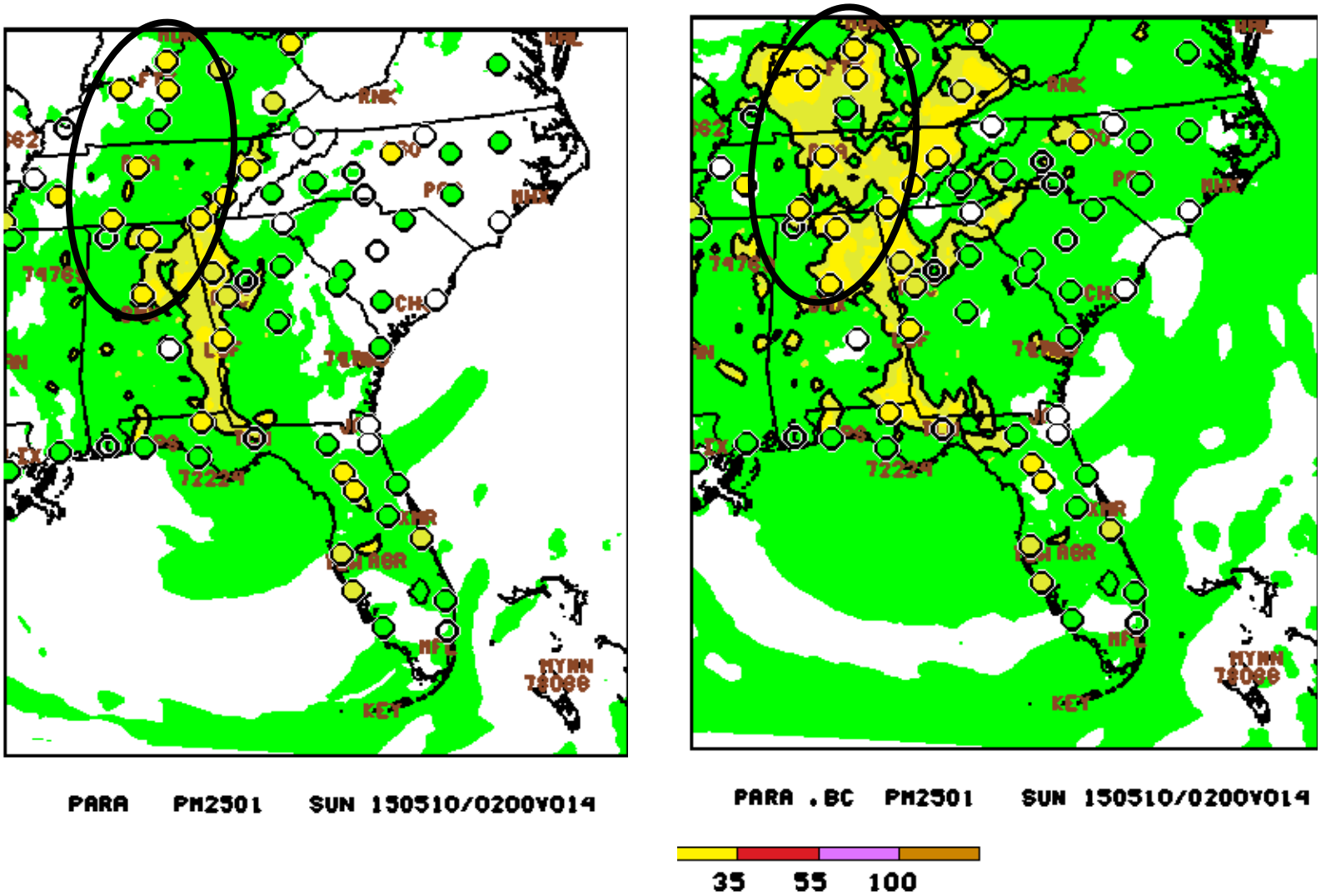
Daily Time Series Valid 00 UTC (+12h)
Bias correction in summer (June,2015)





At 02 UTC May 10, 2015: Bias Correction Impact

(Left) Para **(Right) para + bias correction**



Timing changes

Jobs	Operational	Experimental
JAQM_PREMAQ_CS	20 minutes (one task, Phase I, significantly increased with smoke fires)	20 minutes (one task, Phase II, increased to 40 minutes with smoke fires)
JAQM_FORECAST_CS	36 minutes (Phase I, 127 tasks, 7 nodes)	51 minutes (Phase II, 127 tasks, 6 nodes) 30 minutes (Phase II, 257 tasks, 11 nodes)
JAQM_POST_BiCor_CS	None	One task (Phase II, 8 minutes for one-month training period)

No Changes for Alaska and Hawaii

Summary

Ozone

- Update to 2011 Base year for anthropogenic sources → Positive impact
- Little impact from increased levels

Fine Particulate Matter

- NGAC dust LBCs + 35 levels → Positive
- Bias correction :
  - Improved diurnal cycle
  - But some day to day variability is lost