NAQFC Upgrades

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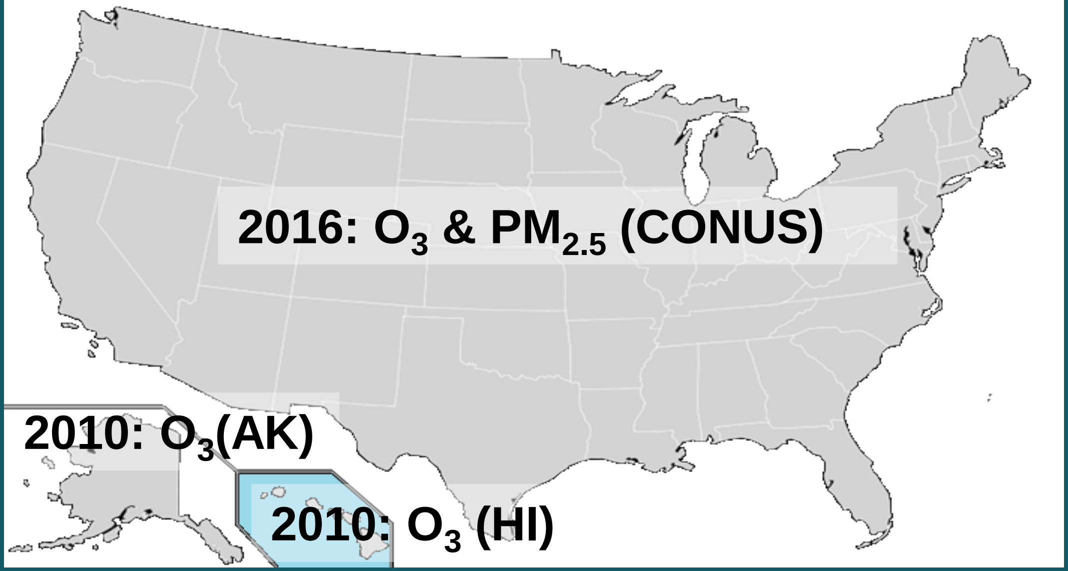
Current NAQFC: Prod

Chemical Transport Model:

- **CMAQ4.6** for **CONUS, AK & HI**
- CB05 gas chemistry
- Aero4 aerosol chemistry
- LBC: monthly varying GEOS-CHEM
  Dynamic LBC for dust
  derived from NGAC

- **O_3 product dissemination: TOC**



Lee, McQueen, Stajner et al., *Weather & Forecasting* 2016
DOI: WAF-D-15-0163.1

O_3 Performance (FVS by NCO):

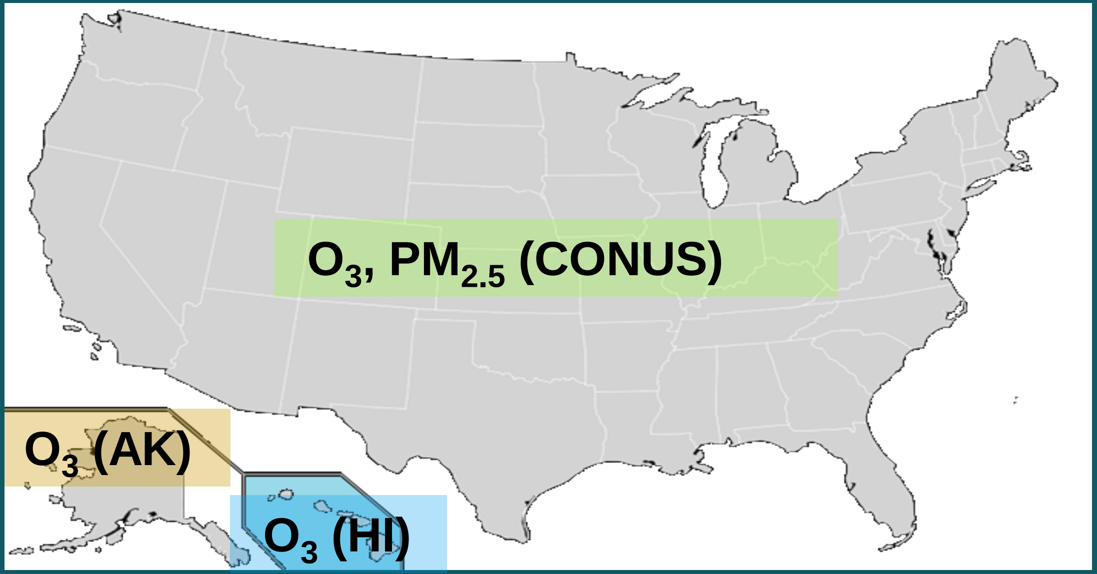
Max Daily 8h (MDA8) O_3 for domains above: Bias, RMSE, and % Hit Rate

Feed of EPA AIRNow O_3 and $PM_{2.5}$ in Bufr format

NAQFC: Prod targeting 2017

Chemical Transport Model:

- **CMAQ5.0.2** for **CONUS, AK, HI**
  - CB05 gas chemistry: increased from 135 to 157 species
  - Aero6 aerosol chemistry



- For **CONUS:**
- LBC: Static from GEOS-CHEM + Dynamic LBC for dust derived from NGAC
- 24 h analysis PM field for initialization adjustment
- Follow Prod SMOKE for assumed fire duration, speciation and strengths
- New Bluesky

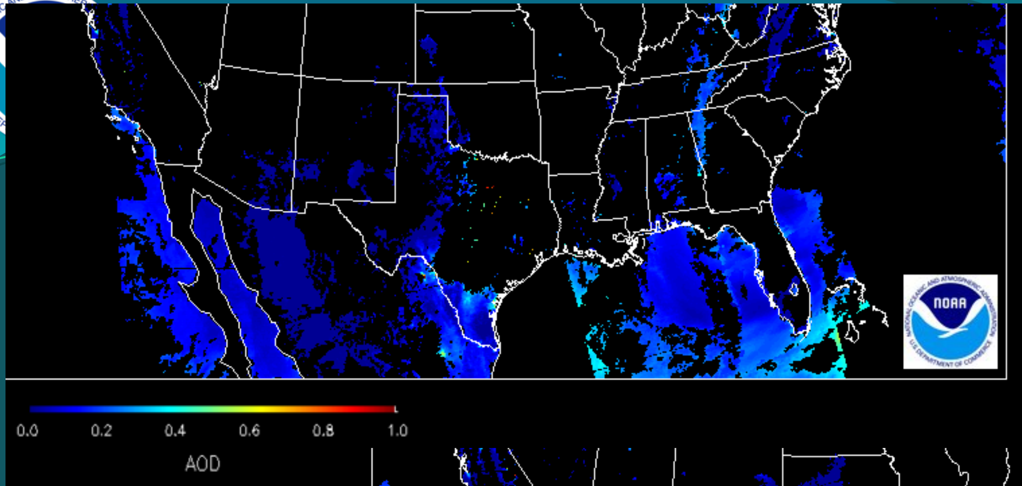
$PM_{2.5}$ Performance (Exceedance w.r.t 35 µg/m^3): EMC website mmb/aq
24 h averaged $PM_{2.5}$ for the above domains: Bias, RMSE, and % Hit Rate

Emissions accompany CMAQ5.0.2

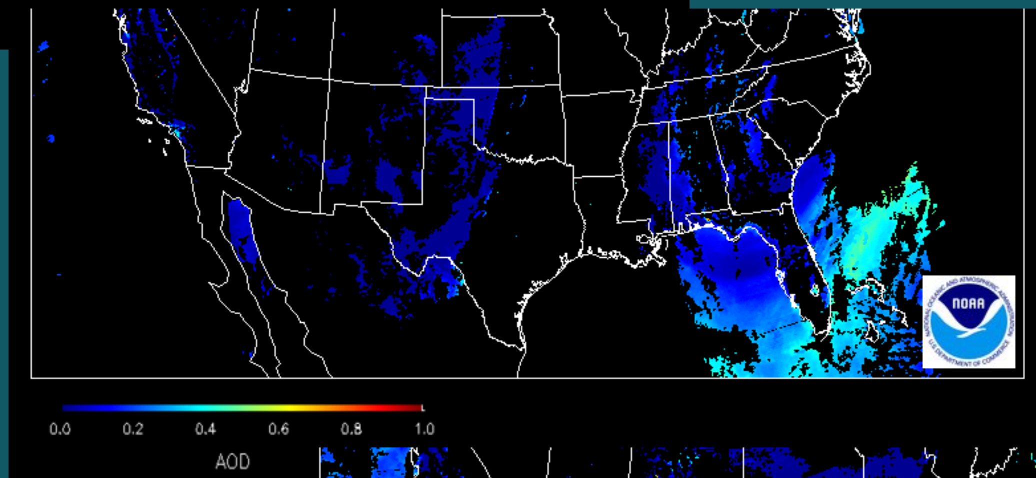
- Point source: Baselined from NEI2011v1 & updated by 2014 CEM & 2016 DoE Energy Outlook
  Canada: Environment Canada 2006 Inventory made available as part of US EPA NEI2011;
  Mexico: Inventory (MI) 2012 version2.2 northern states & 2.1 other states
- Area Sources
  US EPA 2011 NEIs;
  Canada 2006 Emission Inventories (in NEI2011 package);
  Mexico 2012 EI for six border states (in NEI2011 package);
  New US residential wood combustion and oil and gas sectors;
  Snow/Ice effect on fugitive dust emissions;
- Mobile Sources (onroad)
  NEI 2005 projected to 2011 using Cross-State Air Pollution Rule (CSAPR) projection for US sources and then adjusted further to the forecast year using trends from surface and satellite observations from 2011 to 2014; Canada 2006 Emission Inventories; Mexico 2012 EIs;
- Natural Sources
  Terrestrial biogenic emission: BEIS model v3.14;
  Sea-salt emission: CMAQ online Sea-salt emission model based on 10m wind;
  Fire emissions based on HMS fire detection and BlueSky emission model;
  Windblown dust emission: FENGSHA model

LBC: e.g., Sahara Dust Intrusion

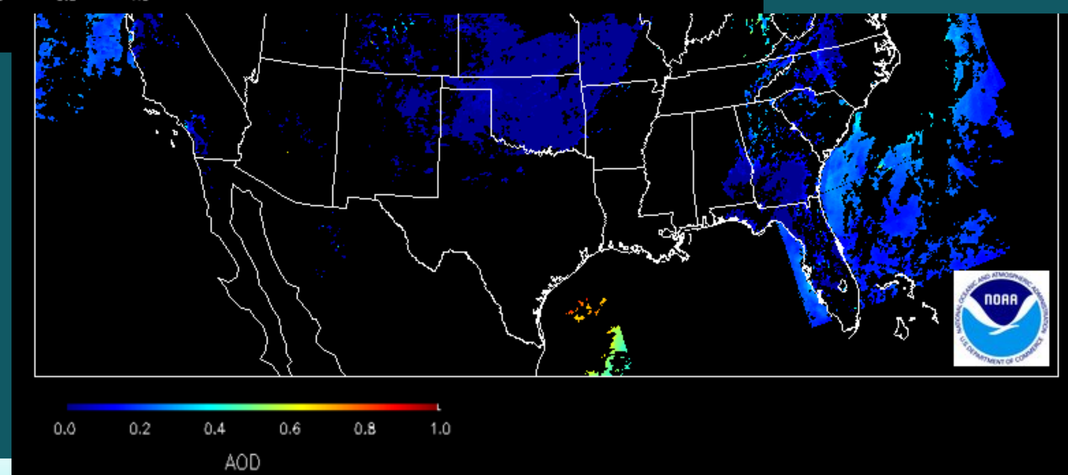
Sahara dust event May 9-11 2015
VIIRS AOD
Courtesy: Shobha Kondragunta
(NESDIS)



12 UTC May 9



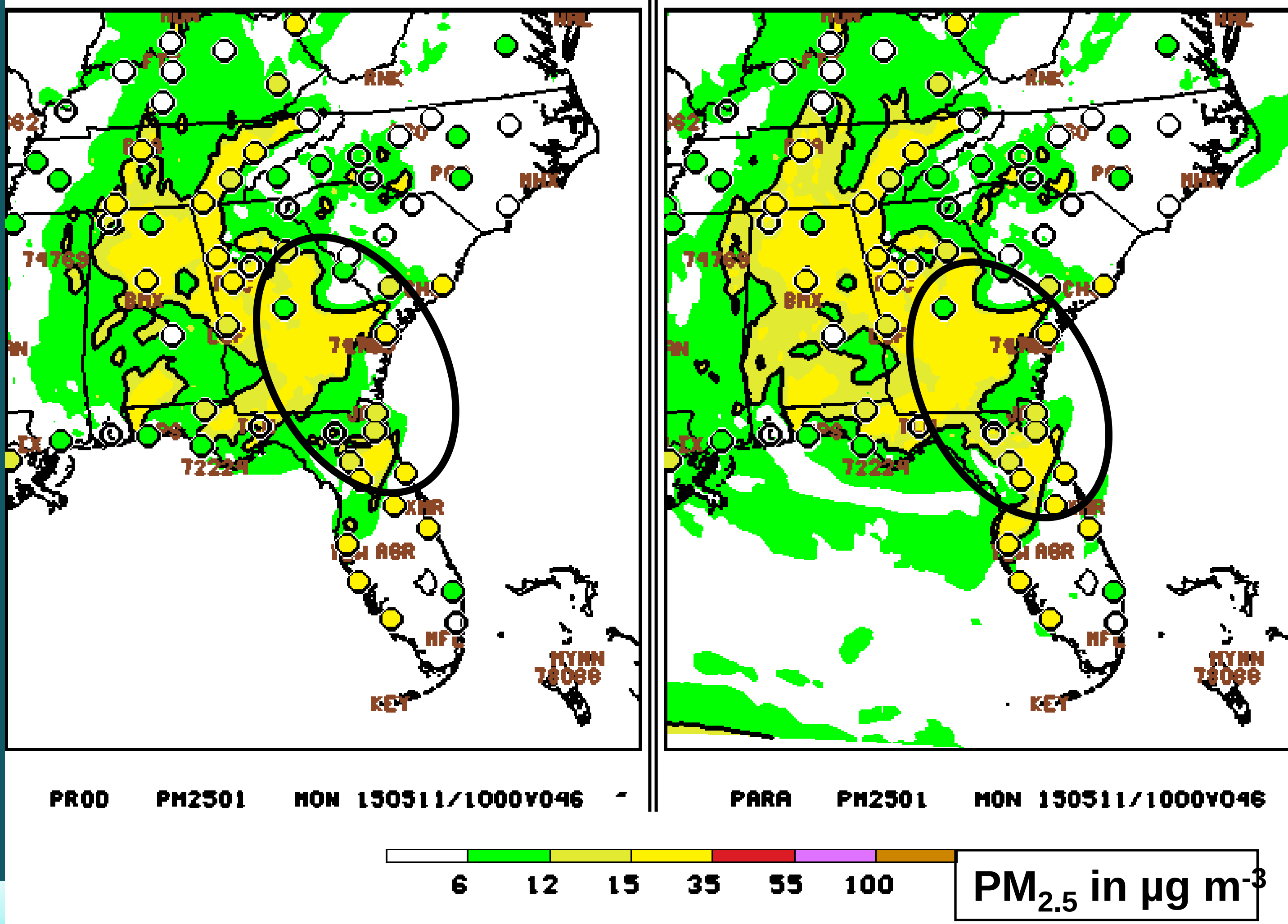
12 UTC May 10



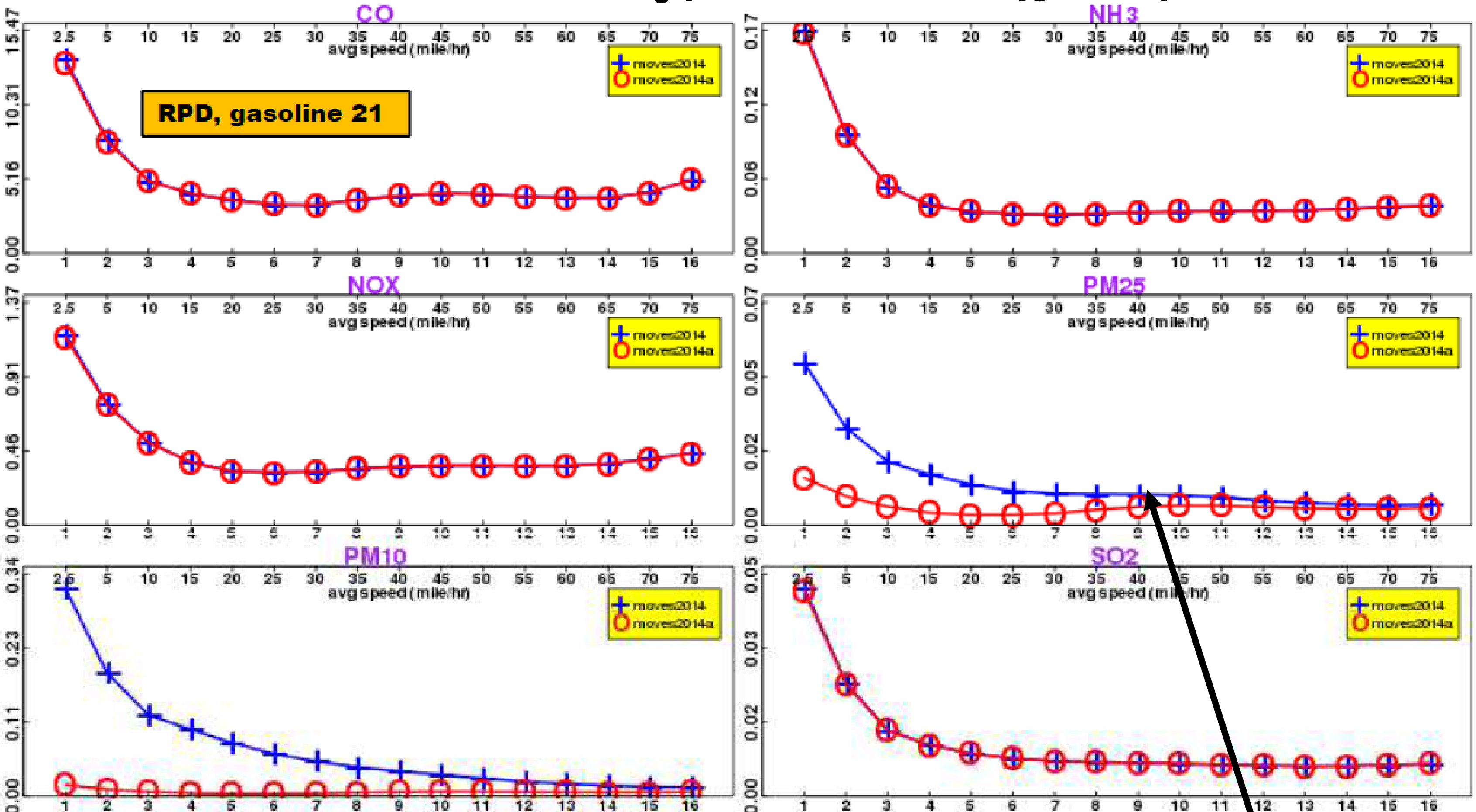
12 UTC May 11

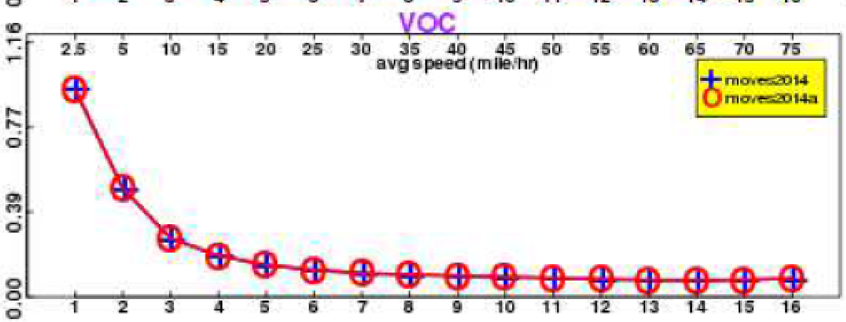
Surface concentration of $PM_{2.5}$ at 10 UTC May 11 2015: modeled (background shading), measured (filled circle)

Without dynamic boundary condition | **With dynamic boundary condition**

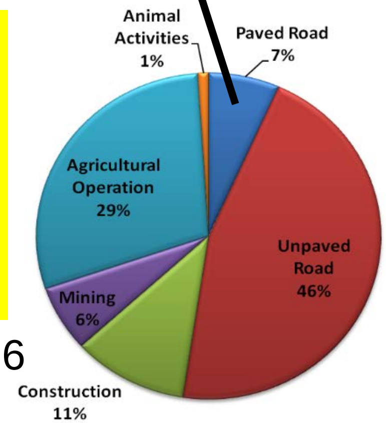


MOVES2014a has similar O_3 precursor rate (g/mile) as MOVES2014





Helps $PM_{2.5}$ but exacerbate O_3 over-prediction

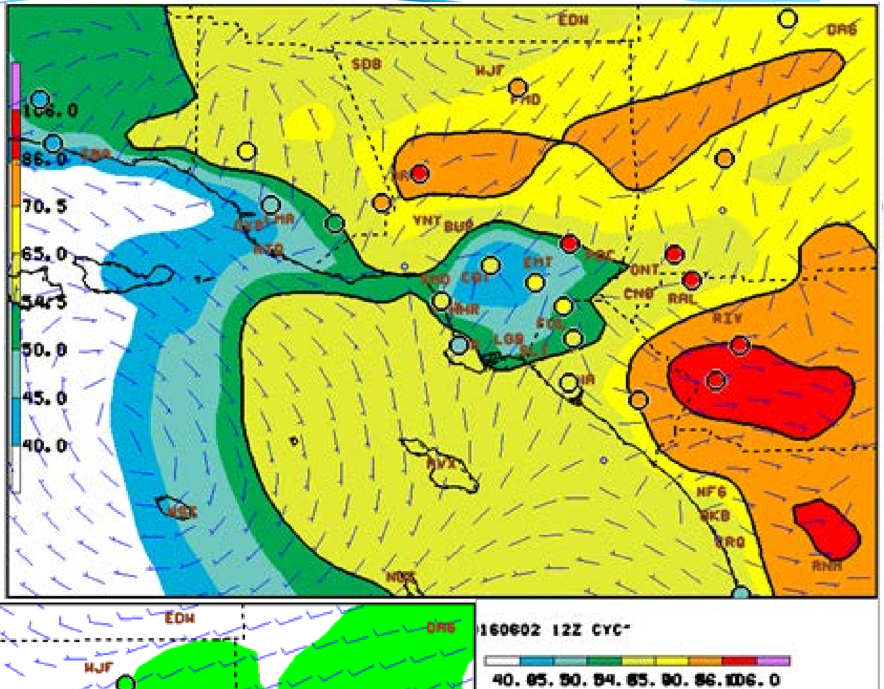


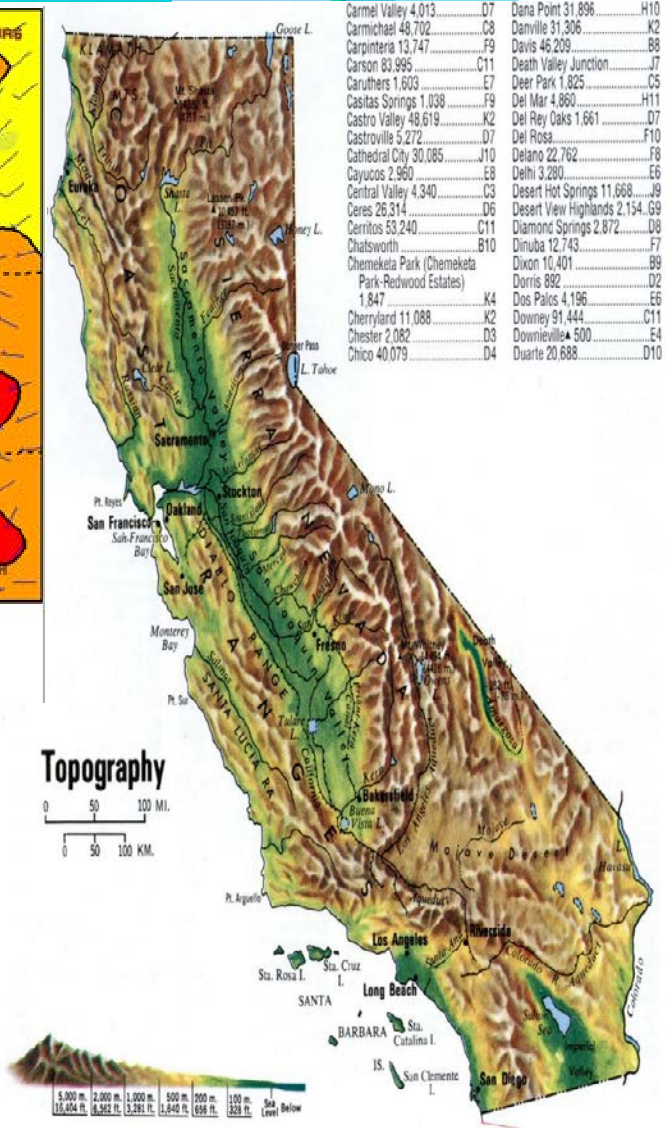
Pie chart shows % of $PM_{2.5}$ emission

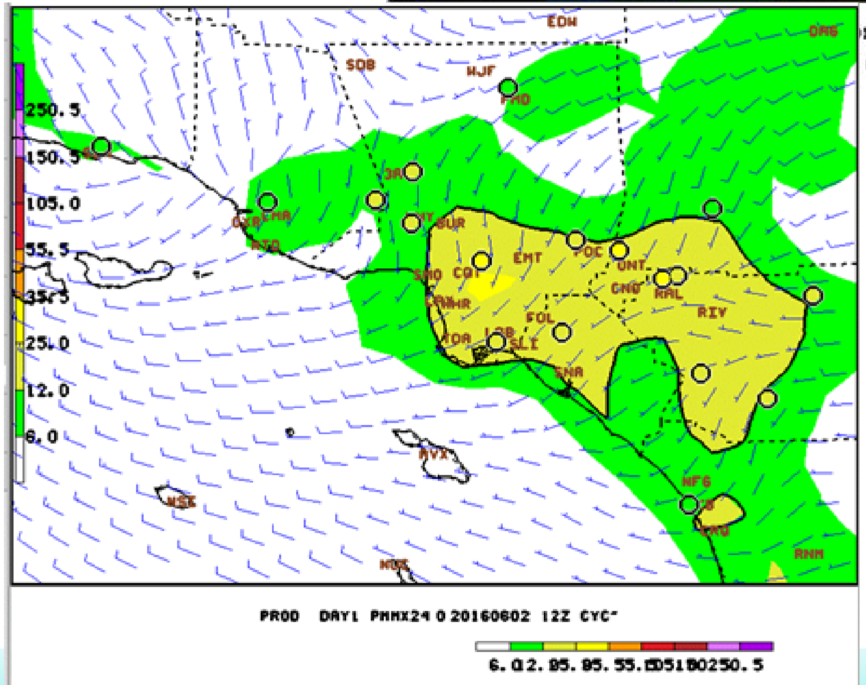
Courtesy: Jin-Sheng Lin et al., VDEQ, 2016

complex terrain e.g., South Coast poses challenge

MDA8 O_3 on June2 2016



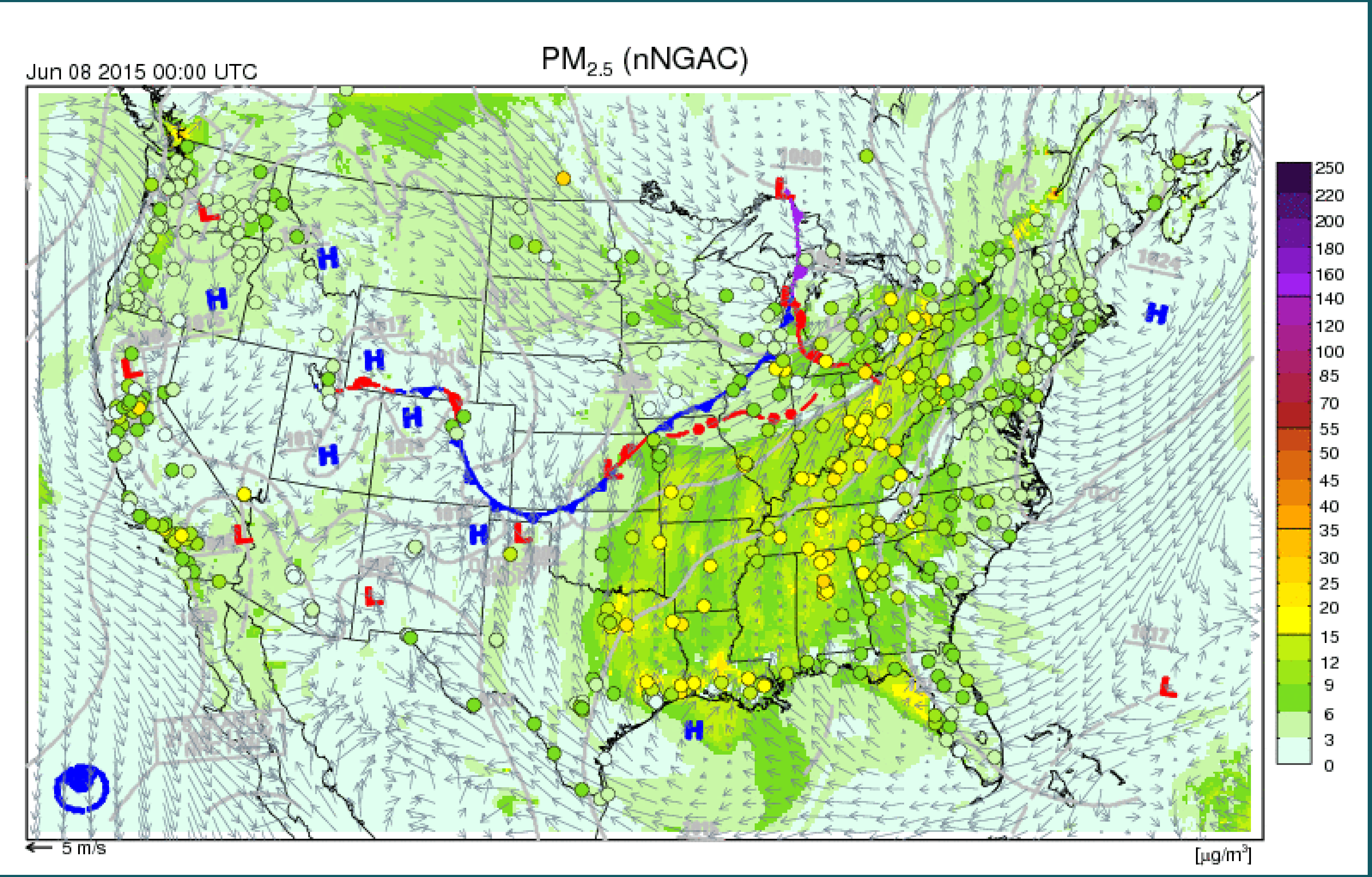




24 h avg $PM_{2.5}$ on June2 2016

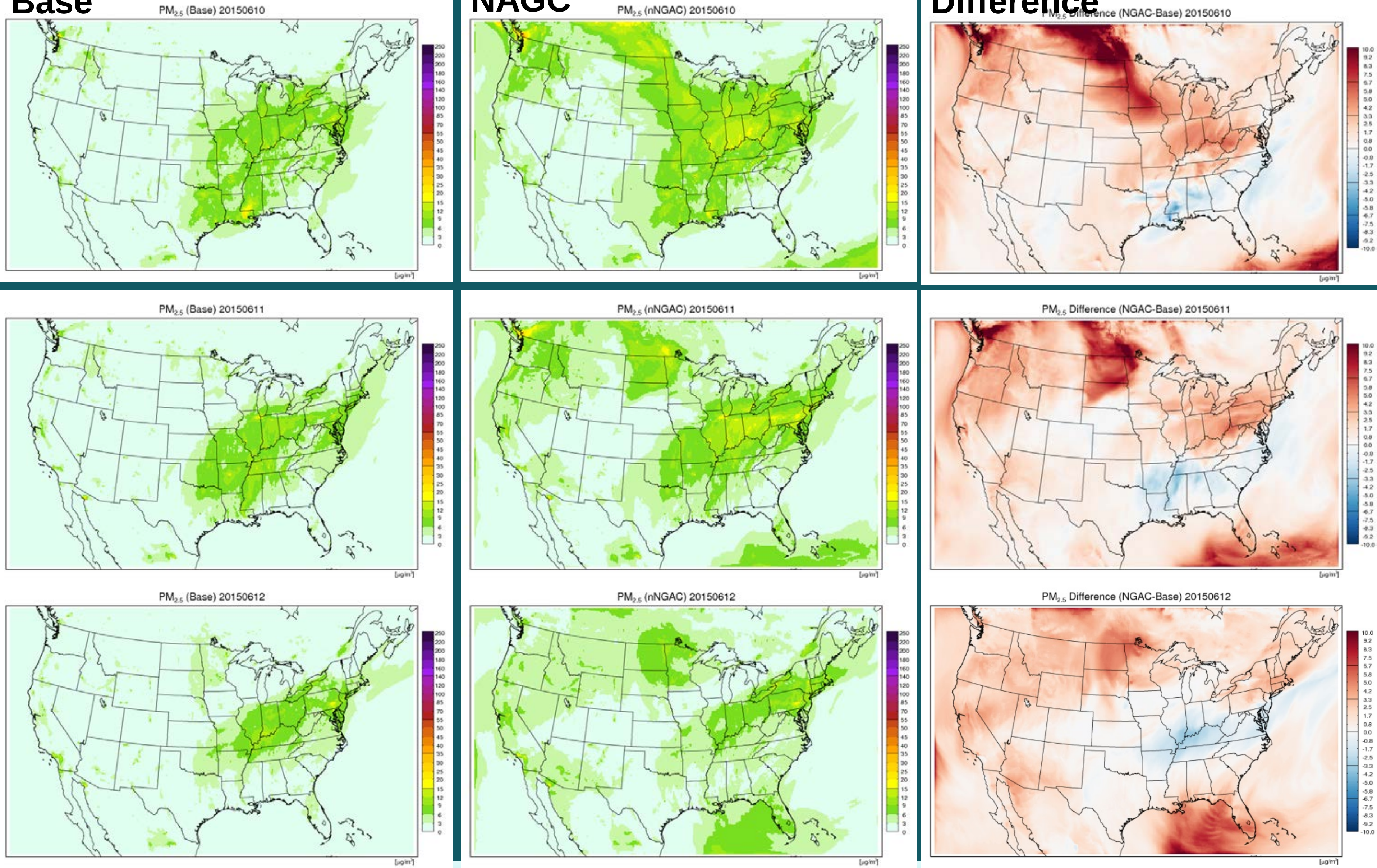
Courtesy A. Sleinkofer et al. EMC intership

Analysis of the June 9-12 2015 Canadian fire: Surface $PM_{2.5}$ with frontal passages

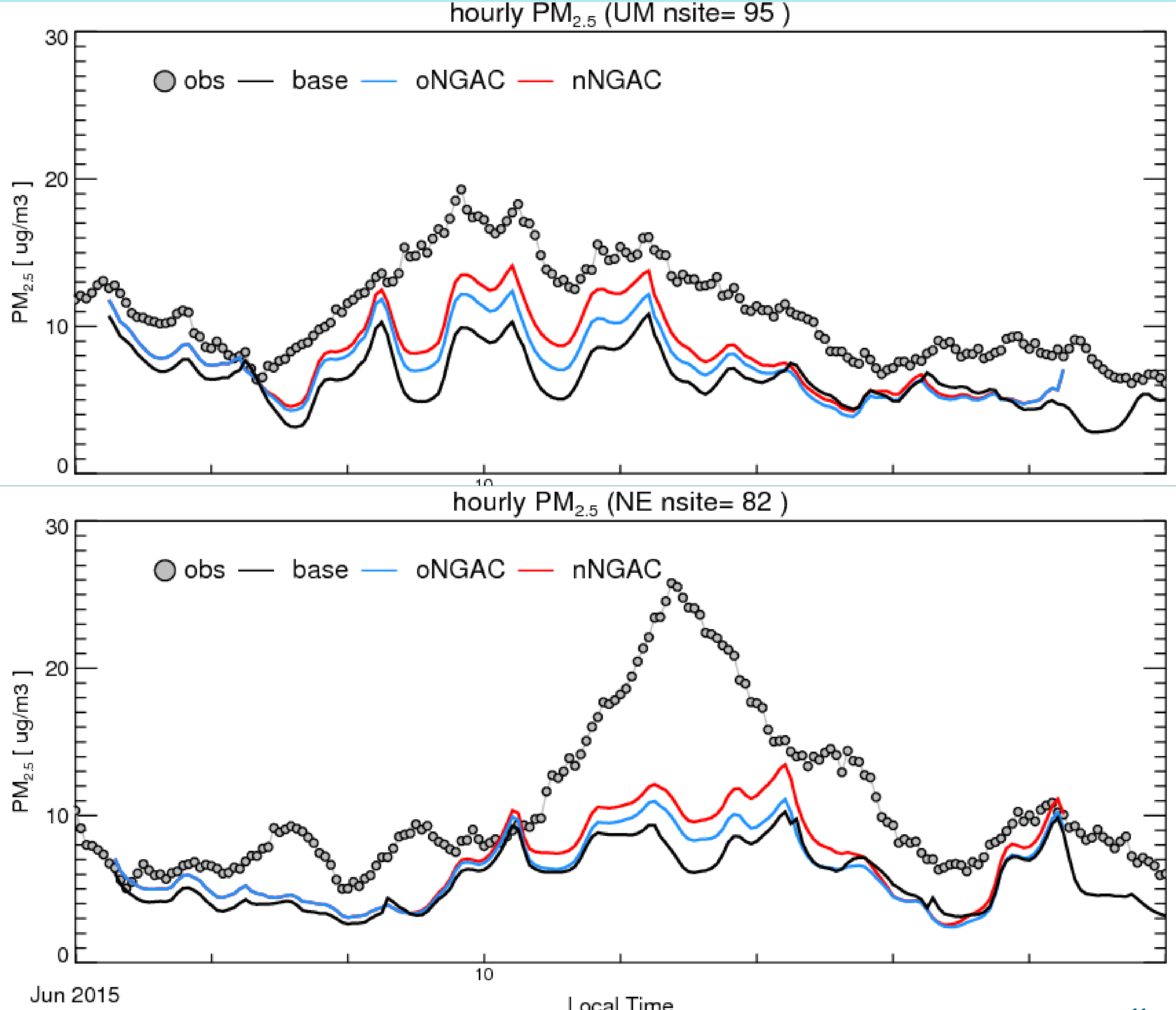


Analysis of the June 9-12 2015 Canadian fire (cont’d) Surface $PM_{2.5}$ with frontal passages

Base | NAGC | Difference



Analysis of the June 9-12 2015 Canadian fire (cont'd)
Surface $PM_{2.5}$ with frontal passages



Analysis of the June 9-12 2015 Canadian fire (cont'd)
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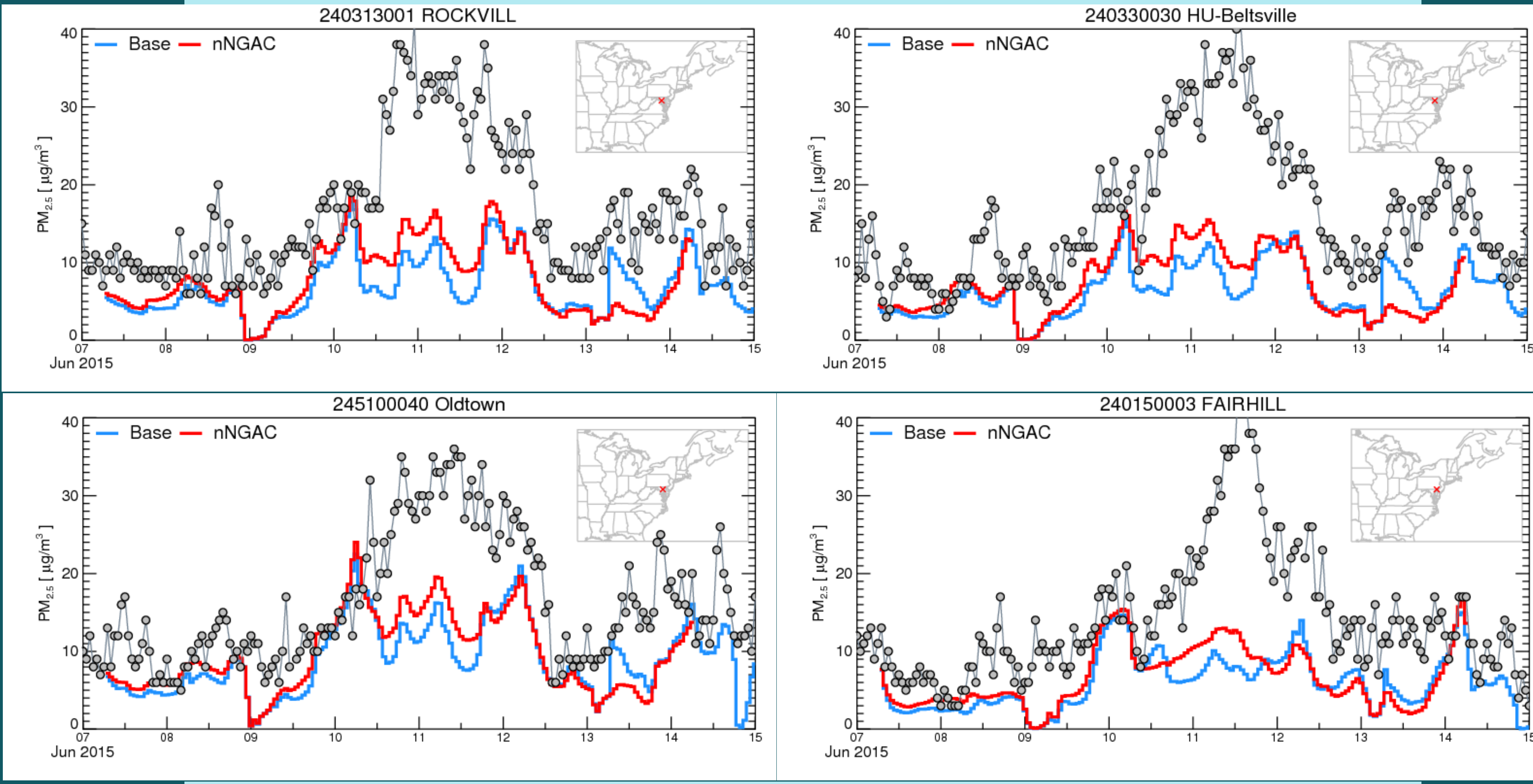


Showed improved skills and awaits NGAC upgrades

CMAQ upgrade to accommodate 3 km and/or 72 h

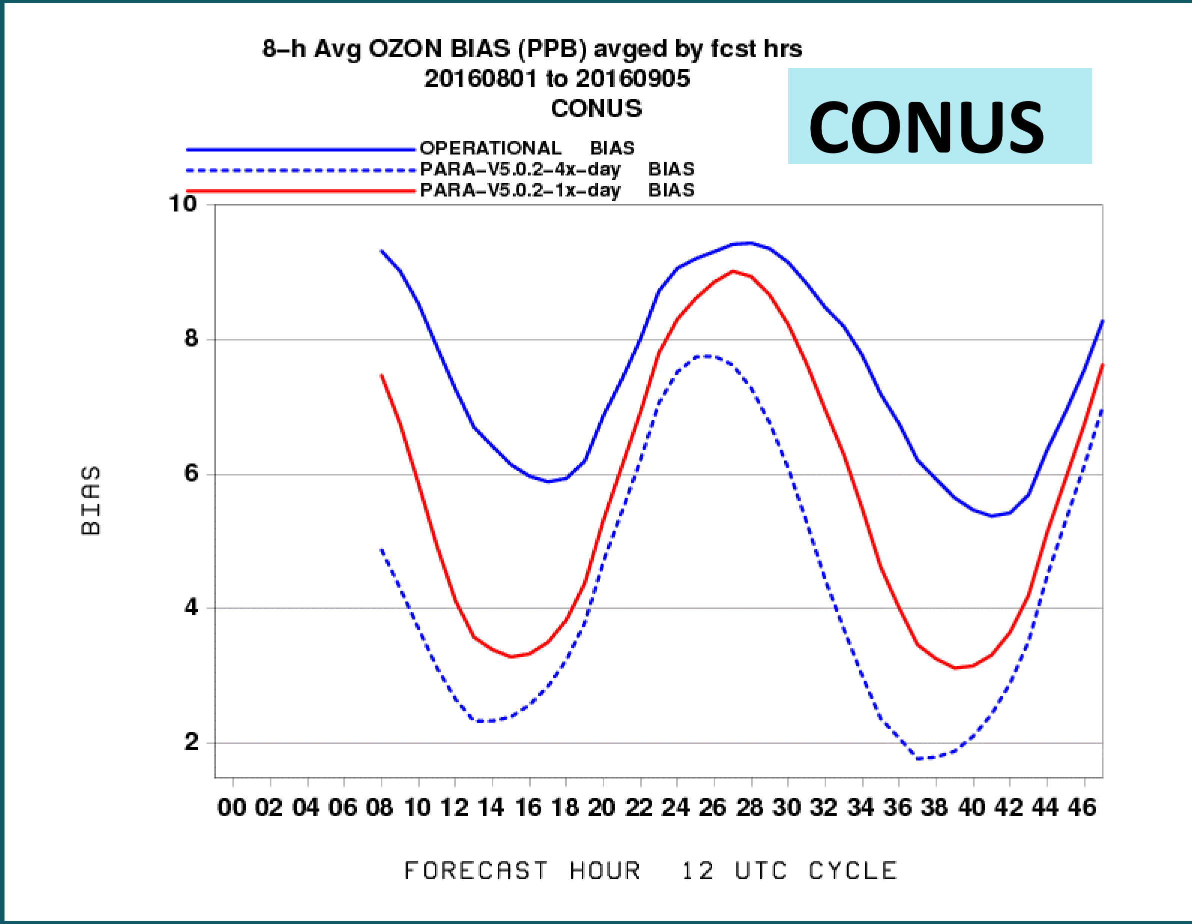
pnetCDF: In newer versions of CMAQ to tackle the I/O bottleneck known for emission & conc file handling

- Northwestern University and Argonne National Laboratory
- Build on top of MPI2
- Based on netCDF format
- Requires Parallel File System (e.g. Lustre, GPFS)
- Publicly available free software

Courtesy D. Wong et al. CMAS 2015

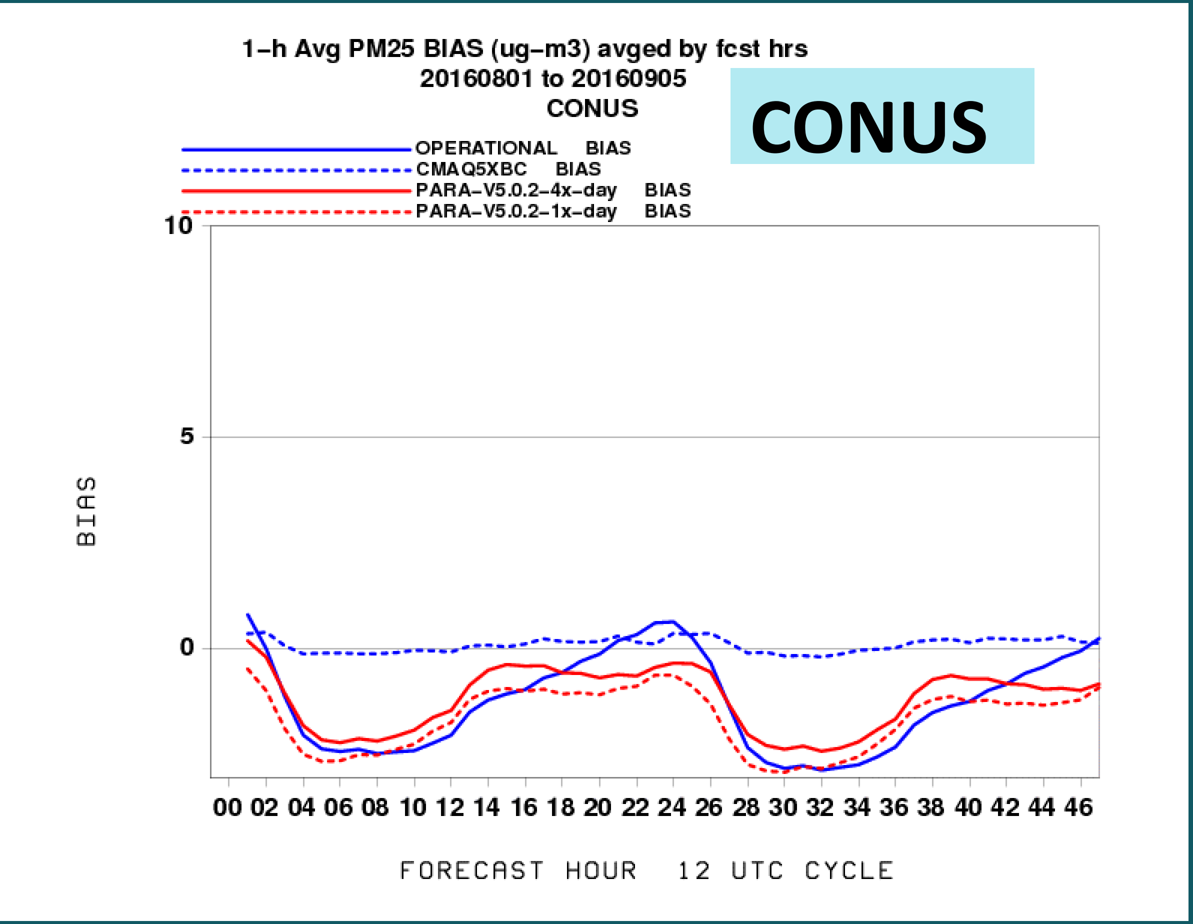
Performance comparison between Prod & CMAQ5.0.2

Bias for MDA8 O_3 8/01-9/15/2016: Prod; CMAQ5.0.2 12Z 1/day; bias correct



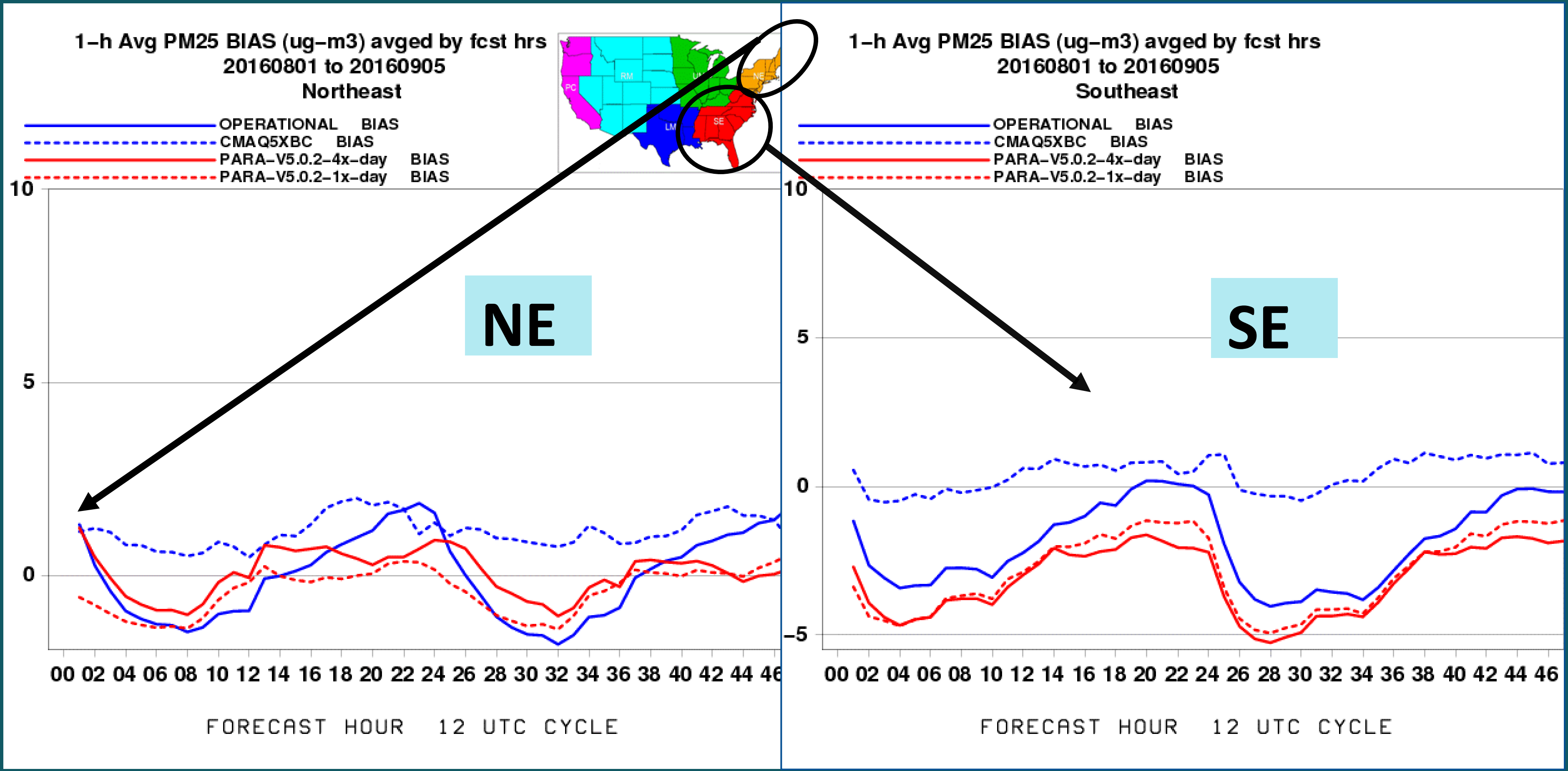
Performance comparison between Prod & CMAQ5.0.2 cont'd

Bias for hourly $PM_{2.5}$ 8/01-9/15/16: Prod; CMAQ5.0.2 12Z 1/day; bias correct



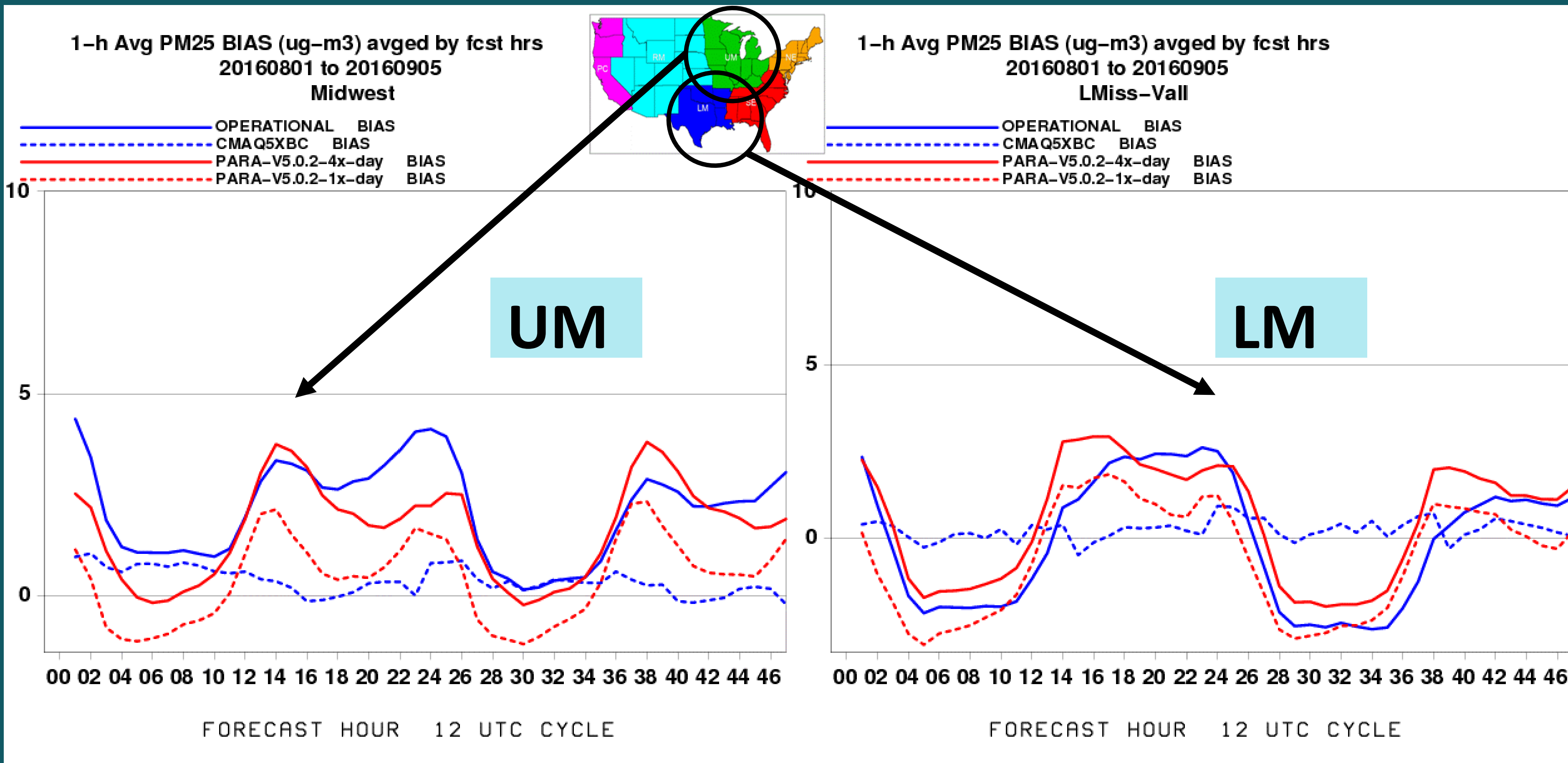
Performance comparison between Prod & CMAQ5.0.2 cont'd

Bias for hourly $PM_{2.5}$ 8/01-9/15/16: Prod; CMAQ5.0.2 12Z 1/day; bias correct



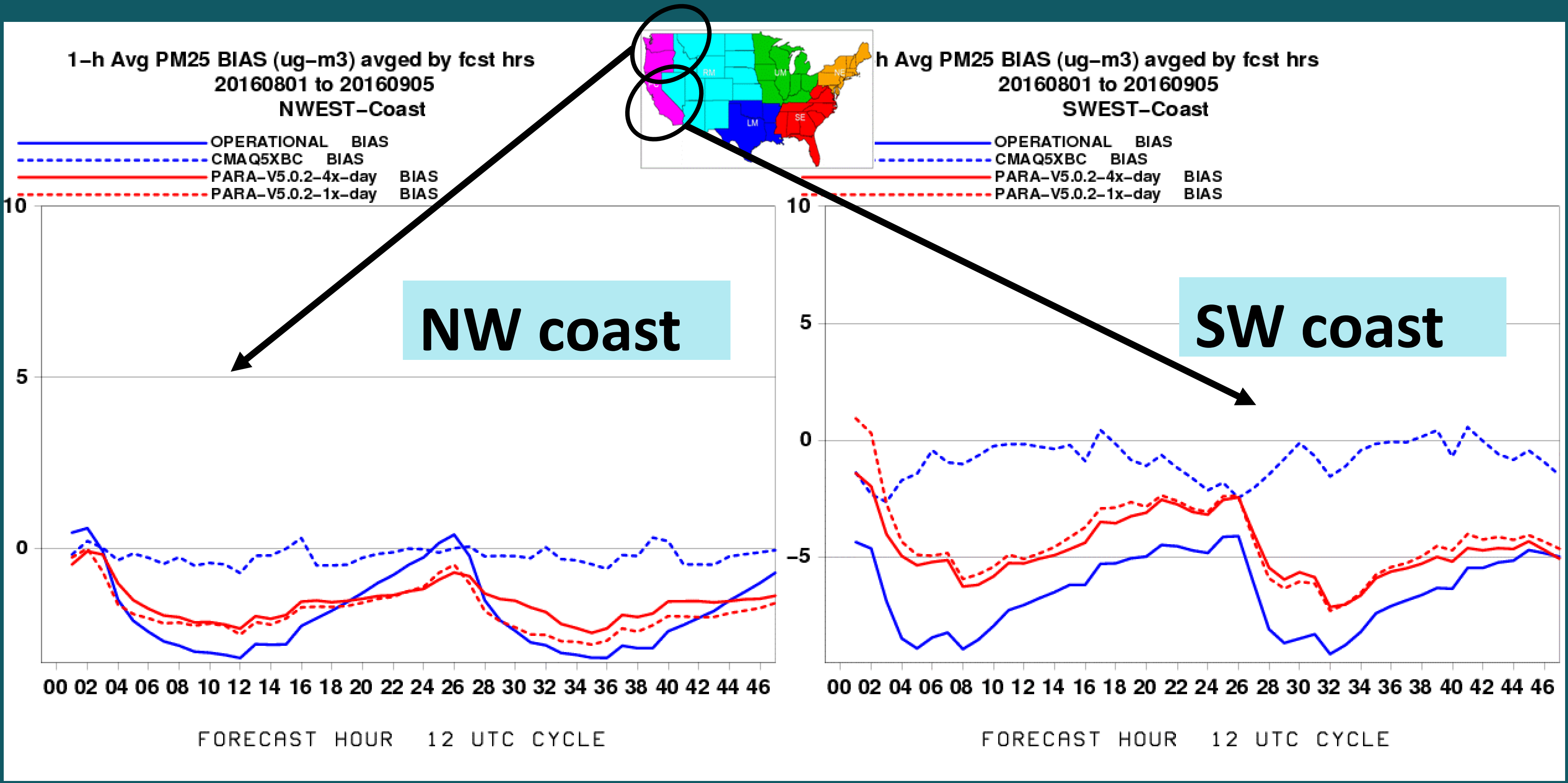
Performance comparison between Prod & CMAQ5.0.2 cont'd

Bias for hourly $PM_{2.5}$ 8/01-9/15/16: Prod; CMAQ5.0.2 12Z 1/day; bias correct



Performance comparison between Prod & CMAQ5.0.2 con'd

Bias for hourly $PM_{2.5}$ 8/01-9/15/16: Prod; CMAQ5.0.2 12Z 1/day; bias correct



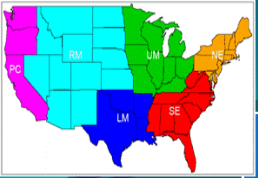
Evaluation Metrics:

$$N\_Mean\_Bias = \frac{1}{N}\sum_{i=1}^{N}\frac{(P_i - O_i)}{O_i}$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y-\bar{y})^2}$$

e.g., Willmott et al., 2011
I.J. Climatology
doi:10.1002/joc.2419

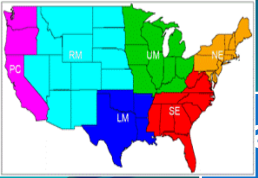
$$index\_agreement = 1 - \frac{\sum_{i=1}^{n}(P_i - O_i)^2}{\sum_{i=1}^{n}(|P_i - \overline{O}| + |O_i - \overline{O}|)^2}$$



MDA8 O_3 (ppb) performance metrics between Prod and CMAQ5.0.2

Aug 1-Sep 5 2016

Day-1 performance		obs	Bias	Normalized mean bias%	RMSE	Coeff corr, r	Index of agreement
CON	**PROD**	**40.0**	**6.8**	**17.0**	**11.5**	**0.70**	**0.60**
	502		**3.1**	**7.8**	**9.8**	**0.70**	**0.64**
PC	**PROD**	**45.2**	**0.12**	**0.27**	**10.0**	**0.85**	**0.72**
	502		**-1.1**	**-2.4**	**9.9**	**0.85**	**0.72**
RM	**PROD**	**48.0**	**2.1**	**4.9**	**8.7**	**0.70**	**0.60**
	502		**-1.8**	**-3.6**	**8.4**	**0.70**	**0.60**
UM	**PROD**	**36.0**	**9.0**	**25.0**	**11.4**	**0.86**	**0.58**
	502		**4.5**	**12.33**	**8.8**	**0.82**	**0.64**
LM	**PROD**	**34.0**	**11.6**	**33.5**	**14.4**	**0.75**	**0.47**
	502		**9.0**	**26.5**	**13.5**	**0.65**	**0.48**
NE	**PROD**	**40.2**	**9.7**	**31.4**	**12.5**	**0.80**	**0.55**
	502		**3.9**	**15.5**	**8.2**	**0.80**	**0.65**
SE	**PROD**	**33.2**	**10.1**	**30.3**	**12.5**	**0.82**	**0.54**
	502		**6.1**	**18.1**	**9.5**	**0.81**	**0.60**



24h avg $PM_{2.5}$ ($\mu g\ m^{-3}$) performance between Prod and CMAQ5.0.2

Aug 1-Sep 5 2016

ay-1 performance		obs	Bias	Normalized mean bias%	RMSE	Coeff corr, r	Index of agreement
CON	PROD	7.3	-0.75	-10.0	7.6	0.19	0.41
	502		-0.80	-11.0	7.6	0.24	0.43
PC	PROD	8.0	-3.3	-40.0	8.3	0.23	0.44
	502		-3.0	-38.0	8.9	0.26	0.45
RM	PROD	7.2	-2.4	-33.9	10.3	0.13	0.40
	502		-2.3	-31.3	10.3	0.22	0.43
UM	PROD	7.0	2.6	37.7	7.5	0.33	0.43
	502		2.1	29.3	6.5	0.39	0.44
LM	PROD	8.2	-1.1	-12.8	5.8	0.30	0.44
	502		-2.0	-24.1	6.4	0.22	0.42
NE	PROD	6.4	0.40	6.1	5.3	0.31	0.41
	502		0.91	14.6	5.3	0.34	0.42
SE	PROD	7.8	-0.8	-10.6	5.5	0.36	0.47
	502		-1.0	-13.0	5.5	0.36	0.45

Summary

- Anticipated FY17 implementation of CMAQ5.0.2

Improves O_3 forecasting skill

- Reduced RMSE → improved spatial & temporal accuracy

This improvement is attributable to NAM and chemistry in CMAQ5.0.2 & the use of the most updated trend to modulate mobile NOx

Improve $PM_{2.5}$ forecasting skill, esp. during the wildfire season

- Reduced under-estimation of $PM_{2.5}$ in the initialization fields by including a 24 h analysis assisted initialization adjustment
- New BlueSky improves fuel and consumption models
- The NGAC-provided dust boundary condition
- Fugitive dust -- crustal elements, are explicit in cmaq5.0.2

Challenges remains beyond FY17:

- Finer resolution
- Evaluation metrics for fine resolution output
- Complex terrains
- Coastal region over-estimation of O_3
- CMAQ I/O operation bottle-neck
- Test and improve NGAC-Smoke derived dynamic BC
- Irregularity of oil and gas emission inventory
- Mobile emission sources modeled by MOVES2014a