National Air Quality Forecast Capability

Ivanka Stajner
NOAA NWS/OSTI

with contributions from the entire NAQFC Implementation Team

Outline:

Background on NAQFC

Recent progress and updates for AQ predictions:

- Ozone and PM2.5 predictions
- CMAQ upgrade in June 2017
- Smoke and dust predictions
- Testing of further potential CMAQ upgrades
- Display, dissemination and web presence
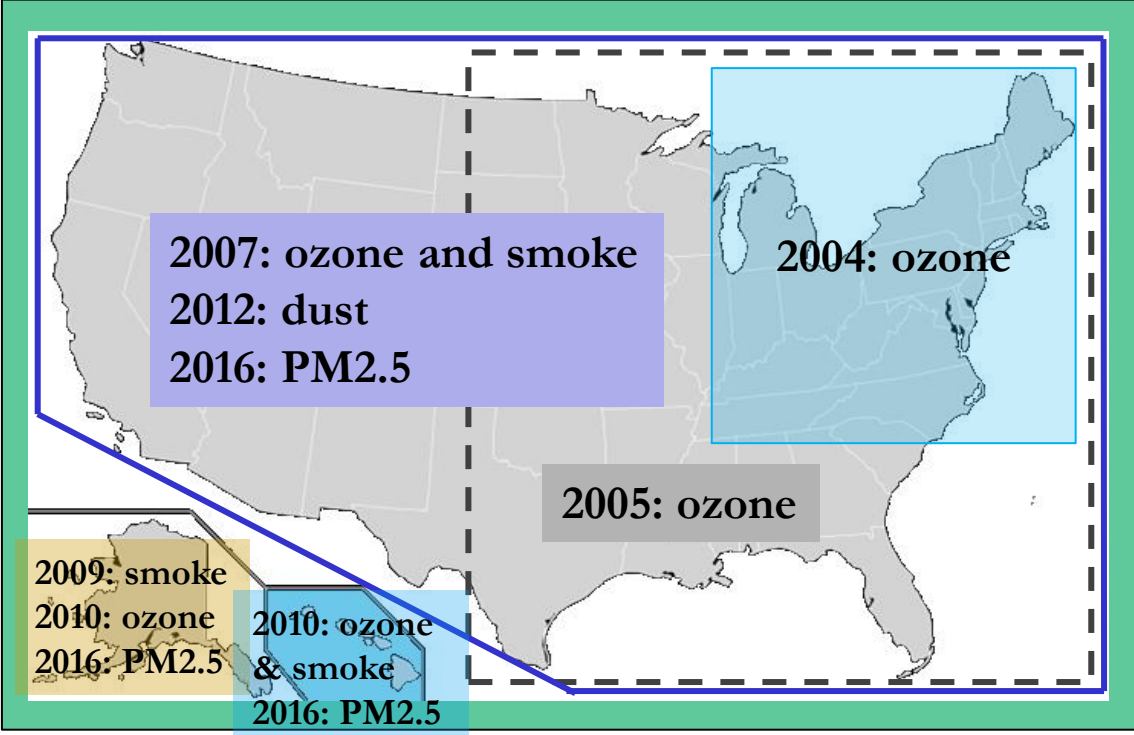- Outreach and feedback

Summary and plans

- Improving the basis for air quality alerts
- Providing air quality information for people at risk

Prediction Capabilities:

- **Operations:**

  Ozone nationwide

  Smoke nationwide

  Dust over CONUS

  Fine particulate matter (PM2.5) nationwide

- **Testing of improvements:**

  Ozone

  Smoke

  PM2.5

2007: ozone and smoke
2012: dust
2016: PM2.5

2004: ozone

2005: ozone

2009: smoke
2010: ozone
2016: PM2.5

2010: ozone & smoke
2016: PM2.5

National Air Quality Forecast Capability
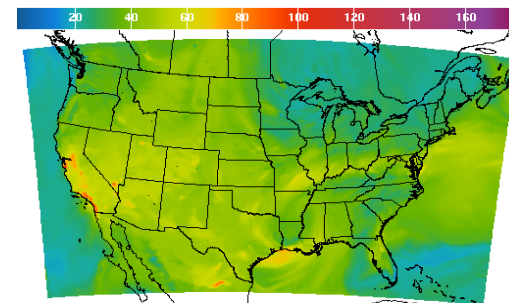## *End-to-End Operational Capability*

Model: Linked numerical prediction system

Operationally integrated on NCEP's supercomputer

- *NOAA NCEP mesoscale numerical weather prediction*
- *NOAA/EPA community model for air quality: CMAQ*
- *NOAA HYSPLIT model for smoke and dust prediction*

Observational Input:

- *NWS weather observations; NESDIS fire locations; climatology of regions with dust emission potential*
- *EPA emissions inventory*

Gridded forecast guidance products

- *On NWS servers: airquality.weather.gov and ftp-servers (12km resolution, hourly for 48 hours)*
- *On EPA servers*
- *Updated 2x daily*

Verification basis, near-real time:

- *Ground-level AIRNow observations of surface ozone and PM2.5*
- *Satellite observations of smoke and dust*

Customer outreach/feedback

- *State & Local AQ forecasters coordinated with EPA*
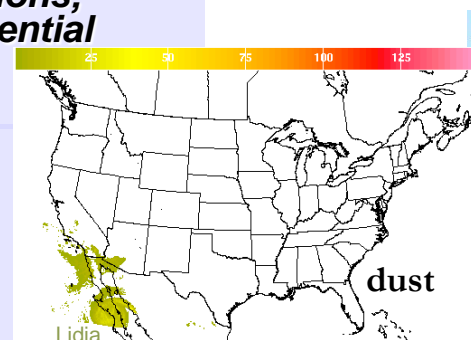- *Public and Private Sector AQ constituents*

ozone

8Hr Avg Ozone Concentration(PPB) Ending Thu Aug 31 2017 11PM EDT
(Fri Sep 01 2017 03Z)
National Digital Guidance Database
06z model run   Graphic created-Aug 31 6:29AM EDT

NOAA Peak 8-hr O$_3$ AQI Guidance
Today: September 03, 2010

AIRNow

Generated: 2010-09-03 4:17 PST

dust

Lidia

1Hr Vertical Dust (micrograms/m^3) Sat Sep 02 2017 2AM EDT
(Sat Sep 02 2017 06Z)
National Digital Guidance Database
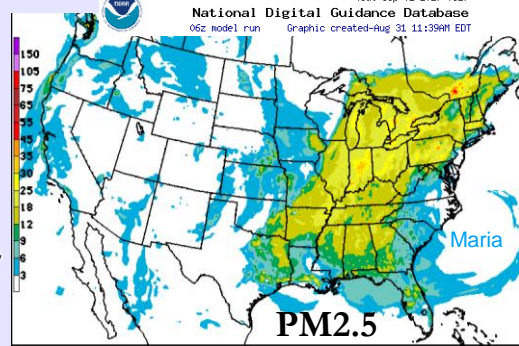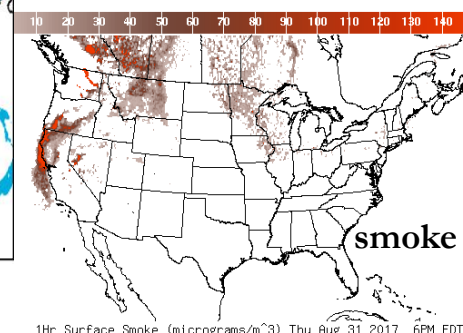06z model run   Graphic created-Aug 31 11:39AM EDT

Maria

PM2.5

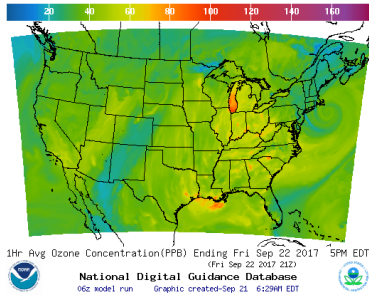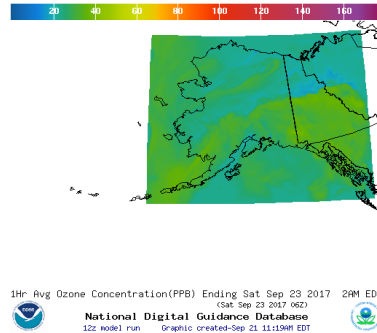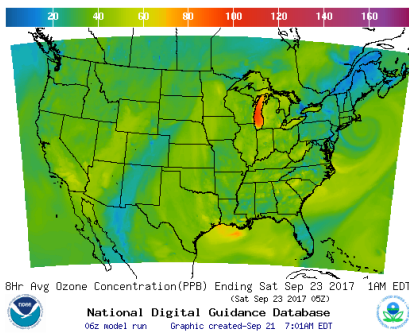PARA PROD   PM2501   OHED 170827/0000V012

smoke

1Hr Surface Smoke (micrograms/m^3) Thu Aug 31 2017 6PM EDT
(Thu Aug 31 2017 22Z)
National Digital Guidance Database
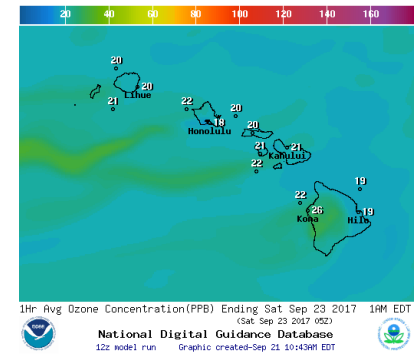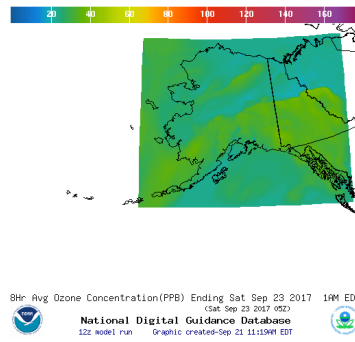06z model run   Graphic created-Aug 31 7:25AM EDT

Ozone predictions

Operational predictions at http://airquality.weather.gov

over expanding domains since 2004

1Hr Avg Ozone Concentration(PPB) Ending Fri Sep 22 2017   5PM EDT
(Fri Sep 22 2017 21Z)
National Digital Guidance Database
06z model run   Graphic created-Sep 21 6:29AM EDT

1Hr Avg Ozone Concentration(PPB) Ending Sat Sep 23 2017   2AM EDT
(Sat Sep 23 2017 06Z)
National Digital Guidance Database
12z model run   Graphic created-Sep 21 11:19AM EDT

1Hr Avg Ozone Concentration(PPB) Ending Sat Sep 23 2017   1AM EDT
(Sat Sep 23 2017 05Z)
National Digital Guidance Database
12z model run   Graphic created-Sep 21 10:43AM EDT
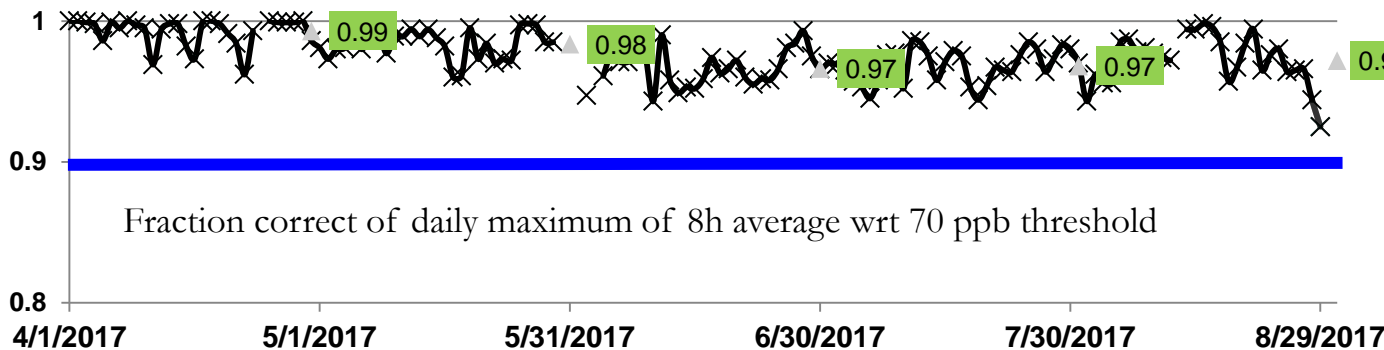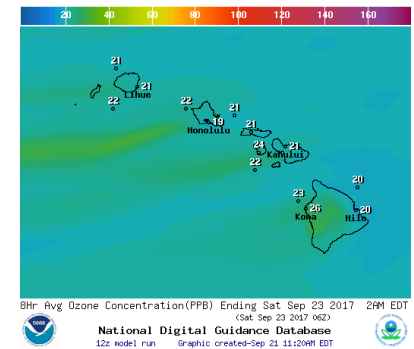
1-Hr Average Ozone

1-Hr Average Ozone

1-Hr Average Ozone

8-Hr Average Ozone

8-Hr Average Ozone

8-Hr Average Ozone

8Hr Avg Ozone Concentration(PPB) Ending Sat Sep 23 2017   1AM EDT
(Sat Sep 23 2017 05Z)
National Digital Guidance Database
06z model run   Graphic created-Sep 21 7:01AM EDT

8Hr Avg Ozone Concentration(PPB) Ending Sat Sep 23 2017   1AM EDT
(Sat Sep 23 2017 05Z)
National Digital Guidance Database
12z model run   Graphic created-Sep 21 11:19AM EDT

8Hr Avg Ozone Concentration(PPB) Ending Sat Sep 23 2017   2AM EDT
(Sat Sep 23 2017 06Z)
National Digital Guidance Database
12z model run   Graphic created-Sep 21 11:20AM EDT

0.99   0.98   0.97   0.97   0.97

Fraction correct of daily maximum of 8h average wrt 70 ppb threshold

Operational

CONUS, wrt 70 ppb Threshold

Maintaining prediction accuracy as the warning threshold was lowered and emissions of pollutants are changing

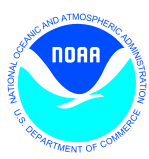4/1/2017   5/1/2017   5/31/2017   6/30/2017   7/30/2017   8/29/2017
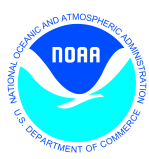
Performance of operational ozone predictions

Fraction correct for 8h daily maximum of NOAA's operational ozone predictions for CONUS with respect to three thresholds

Legend:
- 75 ppb threshold (red)
- 85 ppb threshold (black)
- 70 ppb threshold (blue)

X-axis years: 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017
Y-axis: 0.85, 0.9, 0.95, 1
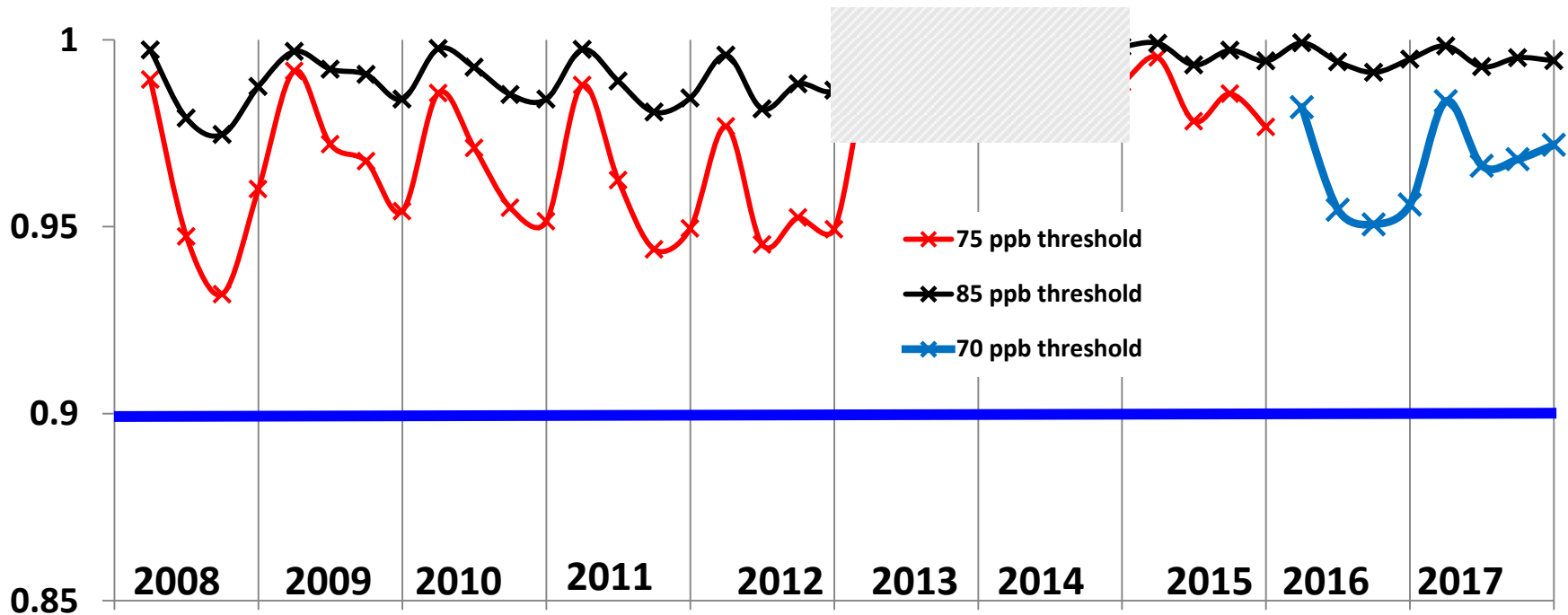
showing performance for May, June, July & August for each year

Statistical performance for Ozone (Aug 2017)

Western U.S.
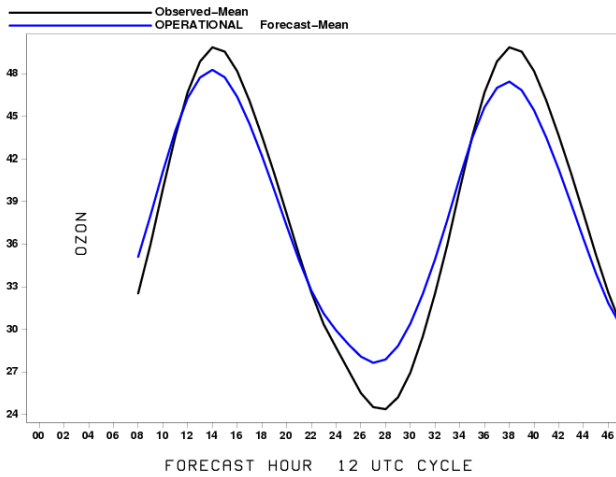
Eastern U.S.

Mean
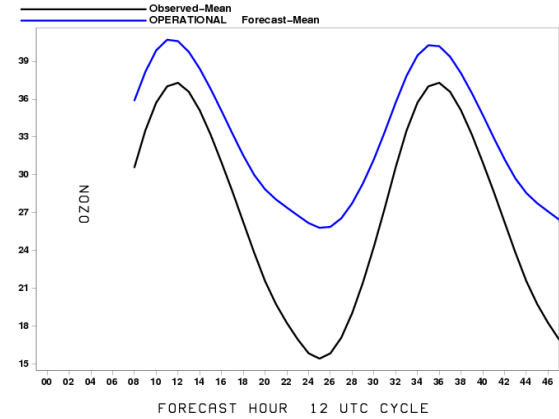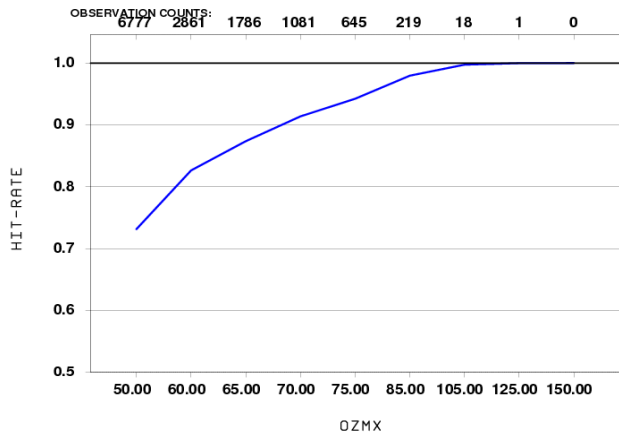
Fraction correct
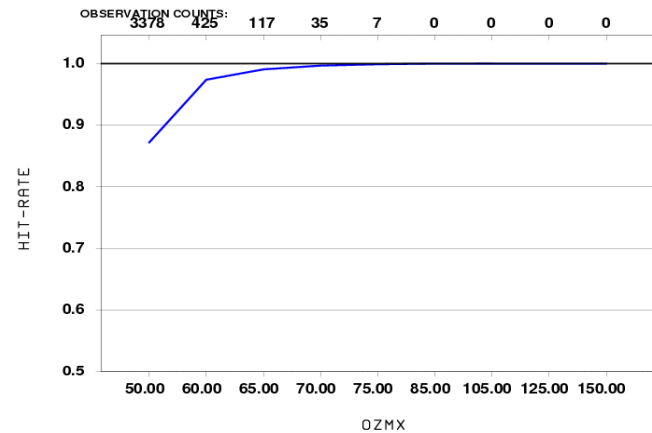
PM2.5 predictions

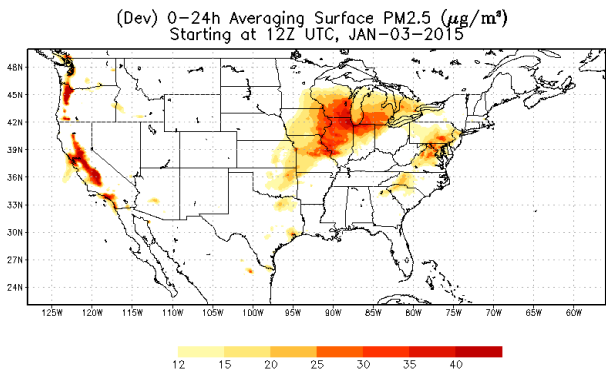**Predictions for 48h at 12km resolution over CONUS**

From NEI sources only before summer 2014

- Community Multi-scale Air Quality(CMAQ) model: CB05 gases, AERO-4 aerosols
- Sea salt emissions, wildfire and dust emissions and suppression of soil emissions from snow/ice covered terrain included since summer 2014 *(Lee et al., Weather and Forecasting 2016)*
- Model predictions exhibit seasonal prediction biases: overestimate in the winter; underestimate in summer

- Additional observational input: AIRNow PM2.5 observations for bias correction and verification

Average monthly bias: all regions
1-h avg aerosol predictions vs. EPA obs, Th=35 ug/m³

January 2009 - June 2015

Pacific Coast — Lower Middle — South East —
Rocky Mountains — Upper Middle — North East —

Daily Average PM AQI
Saturday, January 03, 2015

Puerto Rico

Generated: 2015-01-04 19:25:46Z

(Dev) 0–24h Averaging Surface PM2.5 (μg/m³)
Starting at 12Z UTC, JAN–03–2015

NAQFC PM2.5 test predictions

Forecast challenges

- *Improving sources for **wildfire smoke and dust***
- ***Chemical mechanisms eg. SOA***
- *Meteorology eg. PBL height*
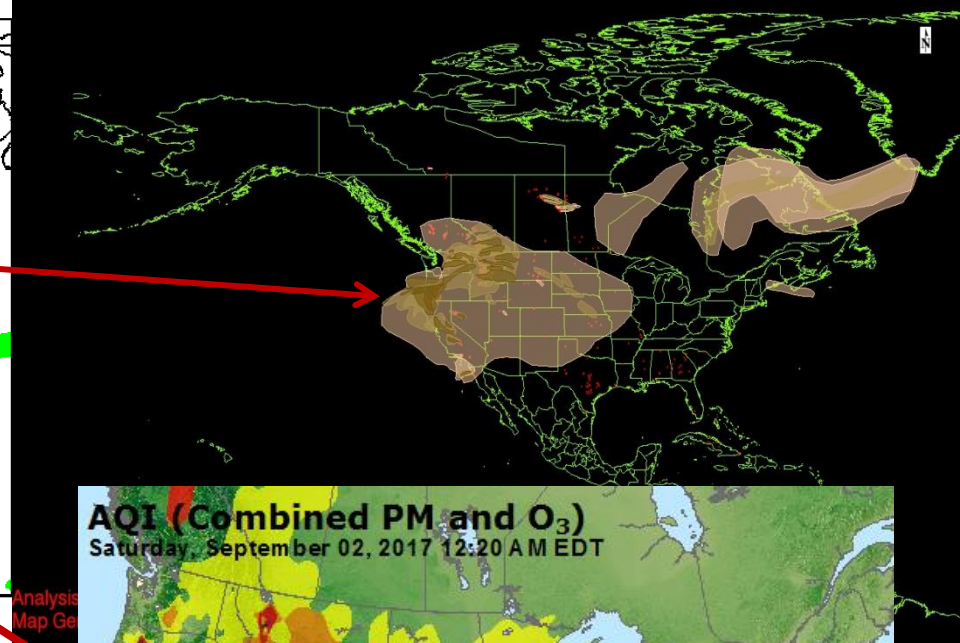- ***Chemical boundary conditions/trans-boundary inputs***

La Tuna Fire in California (September 2017)
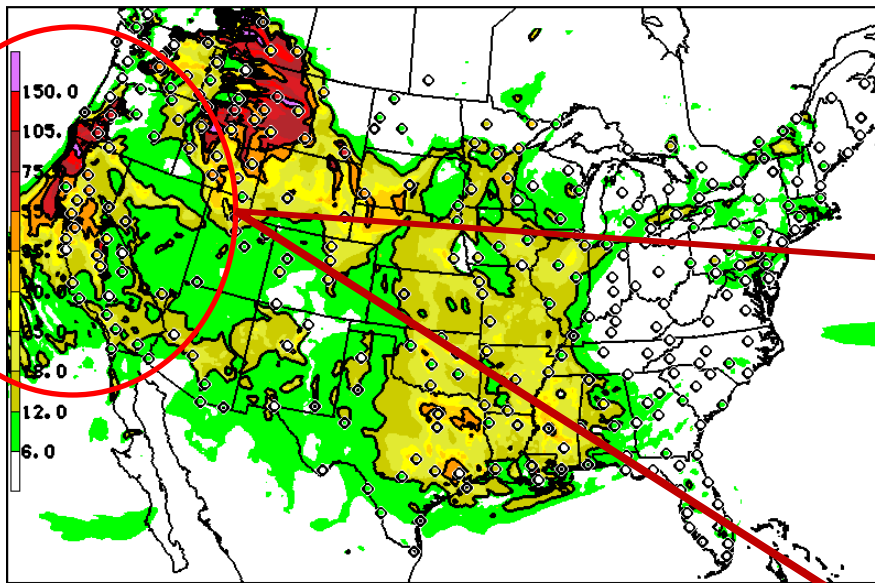
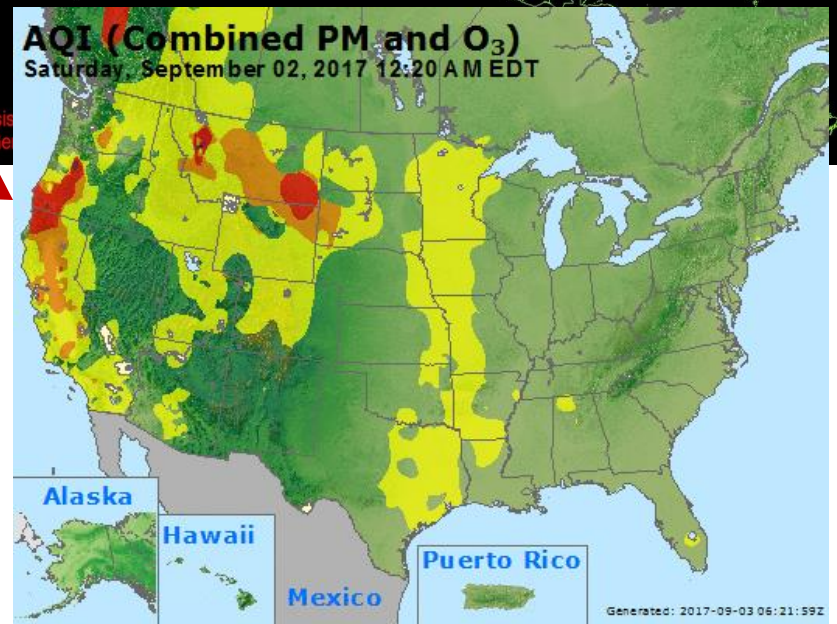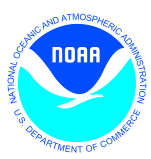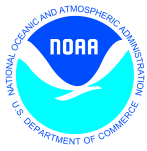Current operational PM2.5 captured the La Tuna fire in Verdugo Mountains in Los Angeles, California which caused more than 300 homes to be evacuated.


AQI (Combined PM and O₃)
Saturday, September 02, 2017 12:20 AM EDT

PROD PROD   PM2501   GAT 170902/0700V001

Generated: 2017-09-03 06:21:59Z

CMAQ UPDATE IN JUNE 2017

Recent Updates to air quality predictions in June 2017

- Update to Community Multi-scale Air Quality (CMAQ) model v5.0.2

- Update of US Forecast Service BlueSky smoke emissions system to v3.5.1

- Addition of 24-hour analysis cycle to include wildfire emissions at the time when they are observed

- Update of the bias-correction post-processing for PM2.5 forecast guidance to use the Kalman Filter Analog (KFAN) technique

- Update of point source emissions to projections for 2017

- Update of dust related aerosol species at the CMAQ lateral boundaries to use the NEMS Global Aerosol Component (NGAC) v2 forecasts
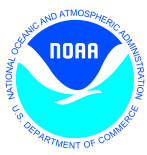
BlueSky updates in June 2017
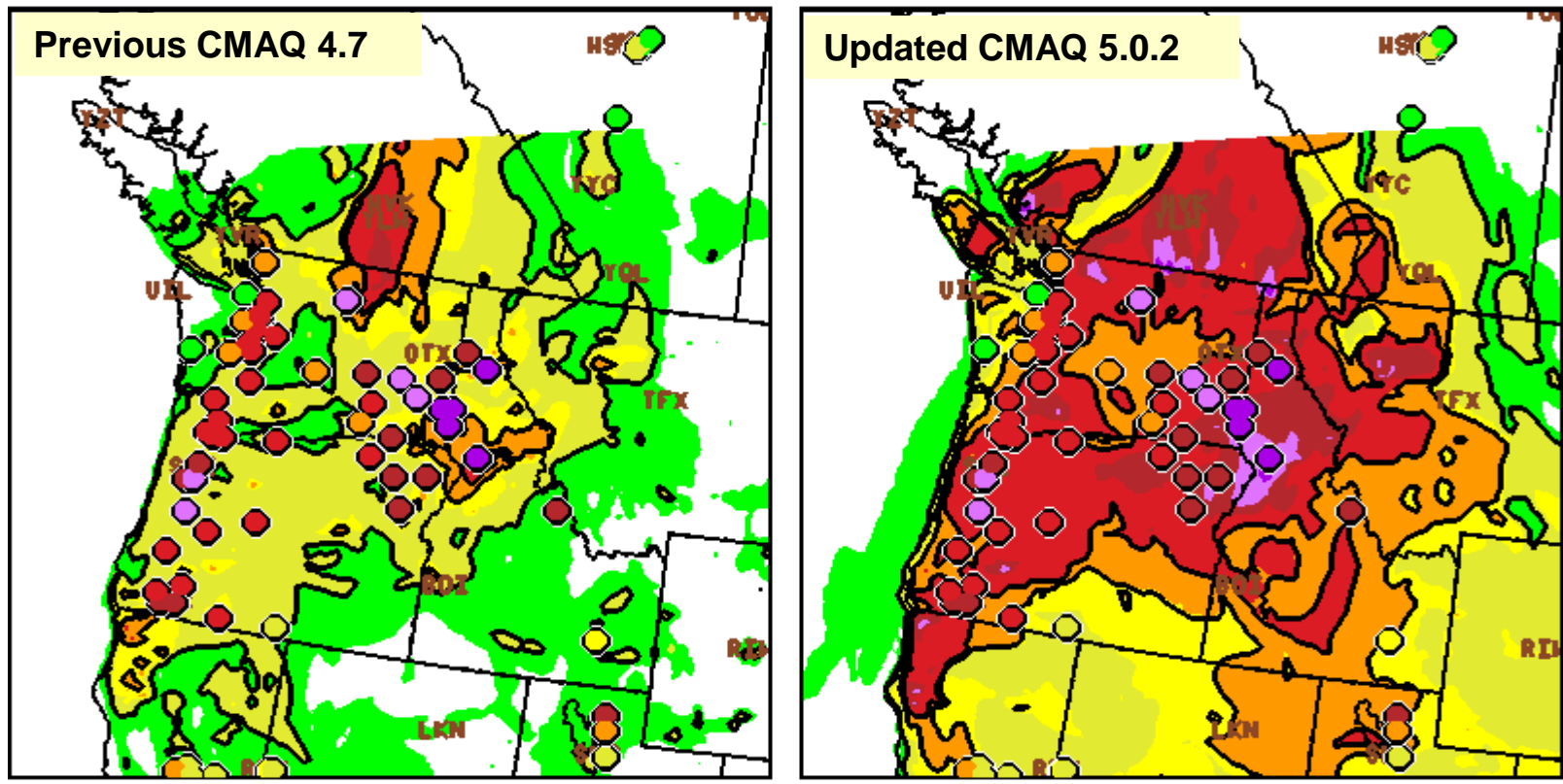
The updated BlueSky version 3.5.1 has:

- Fuel Characteristic Classification System version 2 (FCCS2), which includes a more detailed description of the fuel loadings with additional plant type categories.

- Improved fuel consumption model and fire emission production system (FEPS).

- Explicit fuel load map for Alaska (HYSPLIT only)

PM2.5 from wildfires in CMAQ

- Better representation of wildfire smoke emissions based on detections of wildfire locations from satellite imagery, BlueSky system emissions, <u>included over previous 24 hours</u> when fires were detected and projected with reduced intensity into the 48 hour forecast period

Daily mean for Western US

- Observations
- Previous model
- Current op. model
- Bias correction of previous model

PM2.5 in August 2015
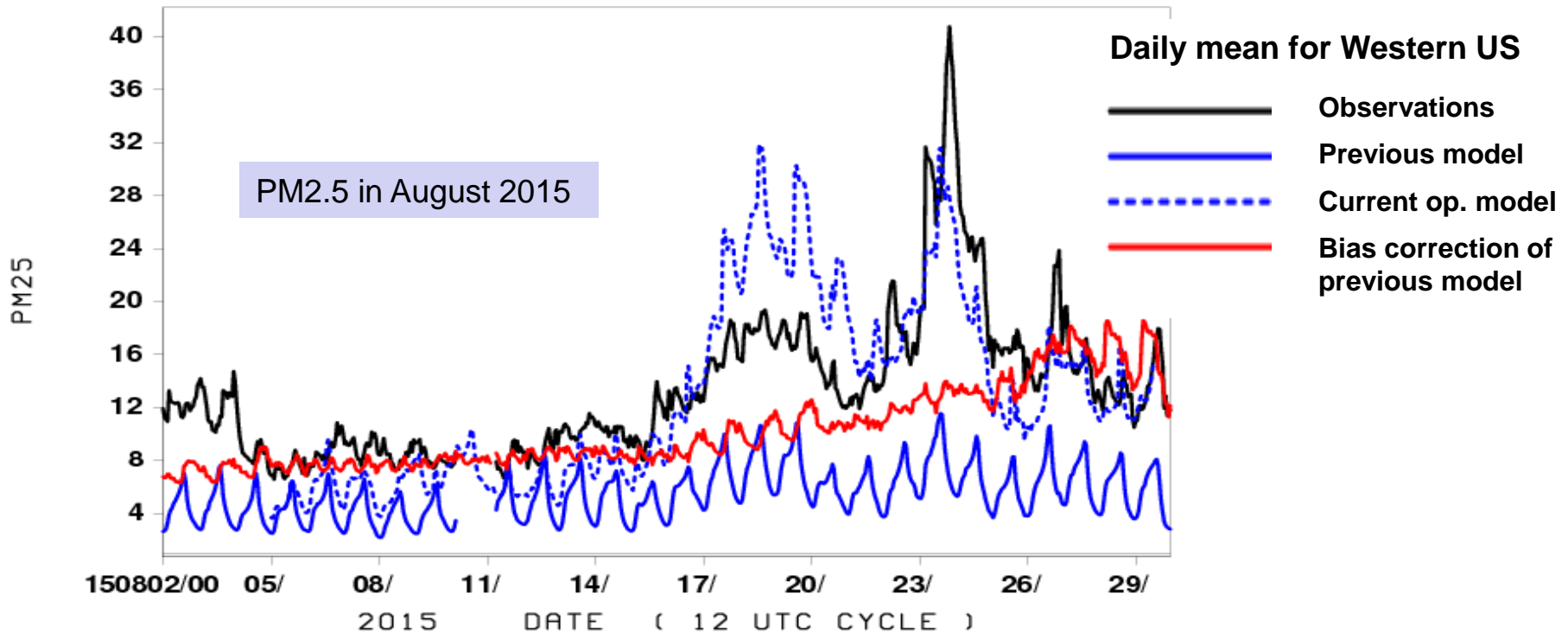
Representation of wildfires – NW U.S. example on August 23, 2015

Previous CMAQ 4.7

Updated CMAQ 5.0.2

PARA1 AQM DAY2 PMMX01 20150822 12Z CYC¯ :A2 CMAQ.V5.0.2 DAY2 PMMX01 20150822 12Z

6.0   12.0   25.0   35.5   55.5   100.0   150.5   250.5   µg/m³

- Wildfires are strongly impacting air quality in the region
- Observed daily maximum of hourly PM2.5 exceeds 55 µg/m³ and even 100 µg/m³
- Operational system predicts values below 25 µg/m³ for many of these monitors
- Updated system in testing predicts values much closer observed

13

May 11 2017 Florida/Georgia Fires

1hr PM2.5 CMAQ loop
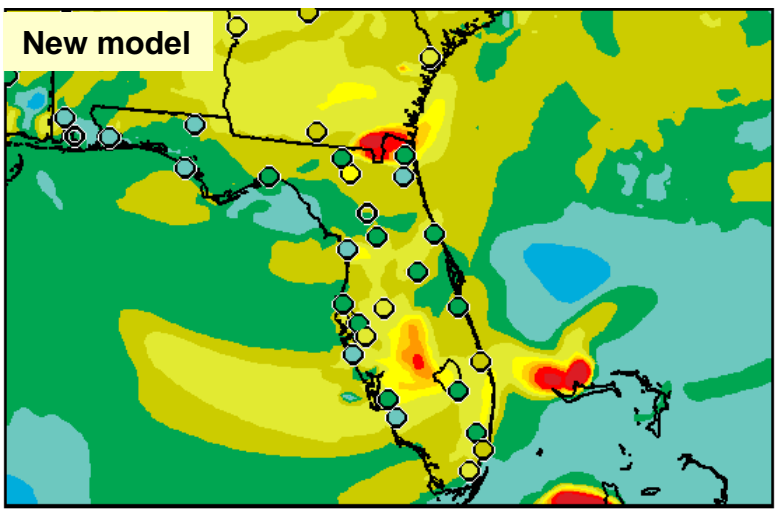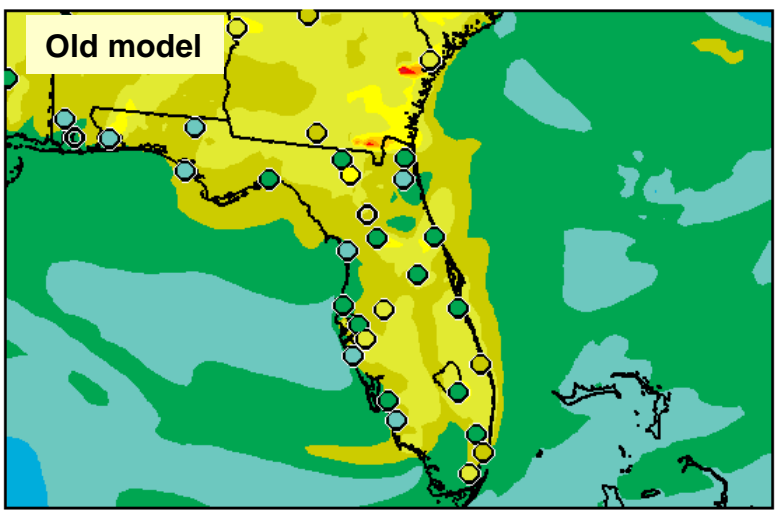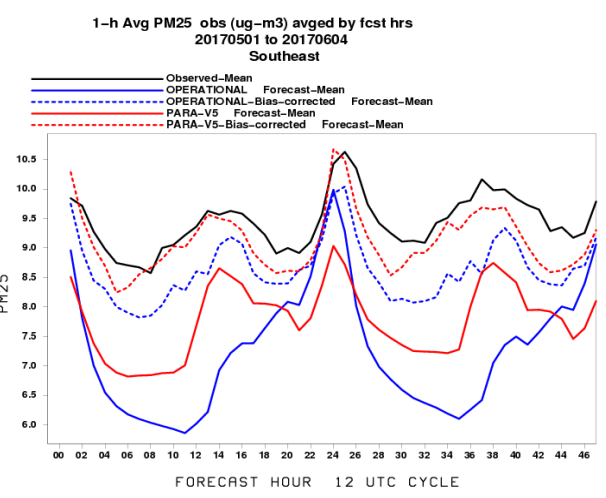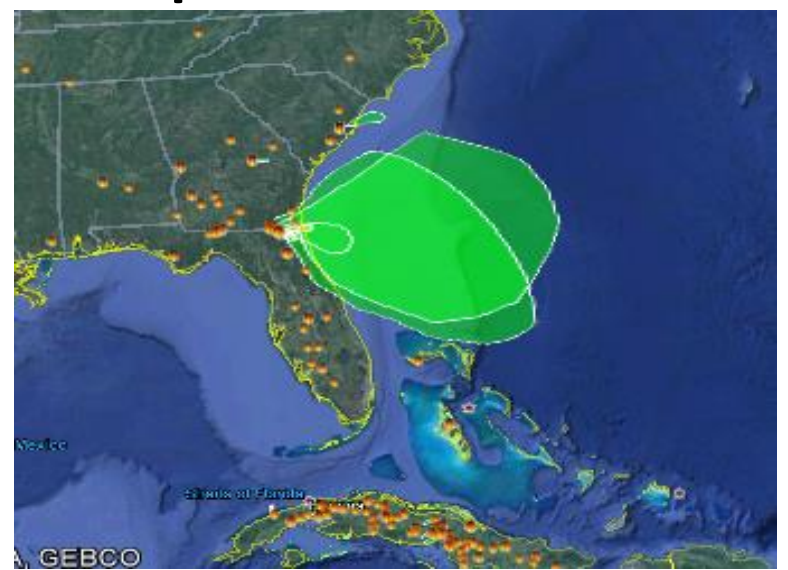
Updated model captures Fl and Bahama fires

Seasonal Bias in PM2.5 prediction
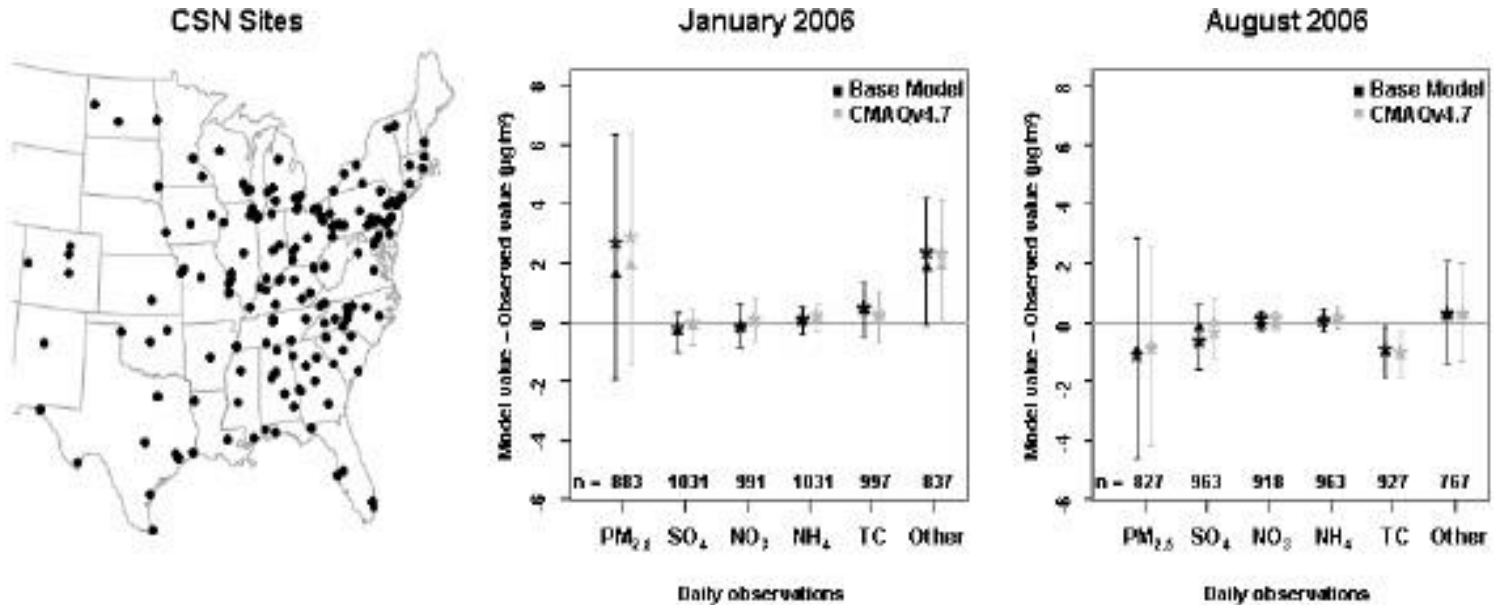
Mean (star), median (triangle), and inter-quartile ranges of model bias (model value – observed value) for multiple fine-particle species measured at CSN sites in the 12km domain. The number of model/observation pairs for each species is shown above the x-axis.

The bias in the total mass of PM2.5 is dominated by overpredictions of unspecified PM in the winter and by underpredictions of carbon aerosols in the summer. (*Foley et. al., Incremental testing of the Community Multiscale Air Quality (CMAQ) modeling system version 4.7, Geosci. Model Dev., 3, 205-226, 2010*)

Saylor et. al. found same type of seasonal speciation biases in the CMAQ v4.6 for IMPROVE sites.
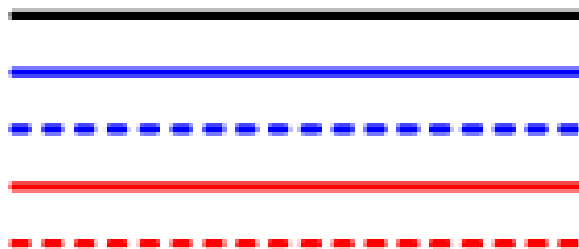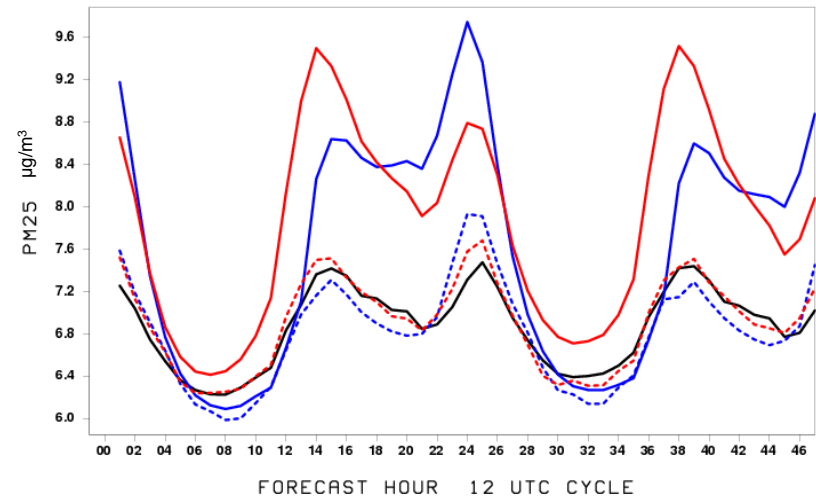
Statistical performance of PM2.5
for May 2017

Mean PM2.5 by forecast hour

Western U.S.

Eastern U.S.

	Legend
————————	Observations
————————	Previous operational model
– – – – – – –	Bias correction for previous model
————————	Current operational model
– – – – – – –	Bias correction for current model

Improvements in ozone predictions in Eastern U.S.

Current operational
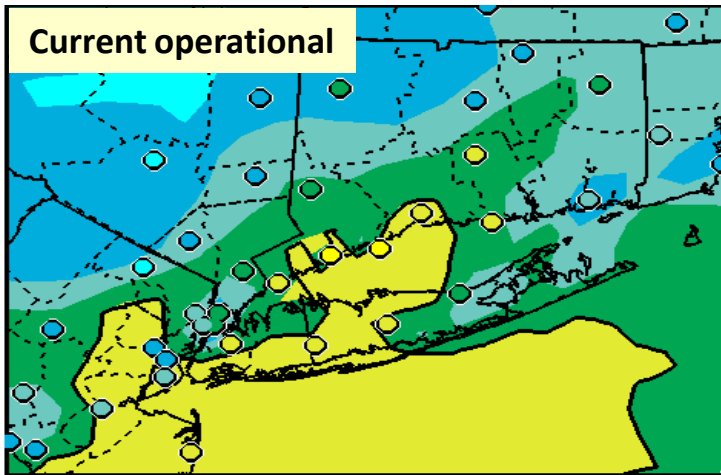
PARA 4X-DAY NAM-X NONOX   DAY1 OZMX08   20160818 12Z CY

Previously operational
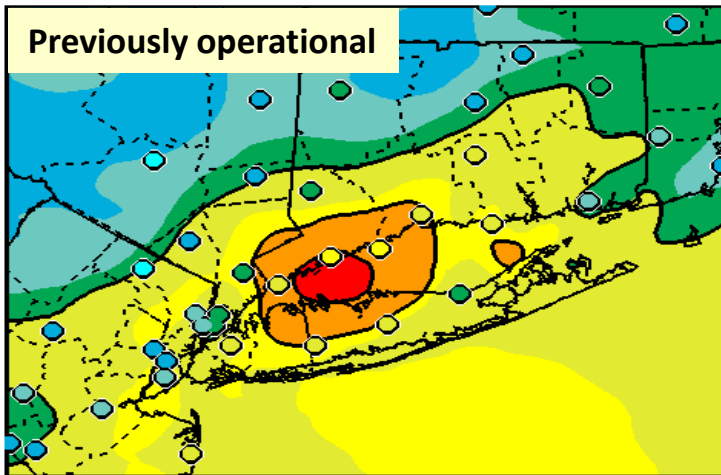
PROD AQM   DAY1 OZMX08   20160818 12Z CYC

106.0
86.0
70.5
65.0
54.5
50.0
45.0
40.0
30.0

µg/m³

Currently operational CMAQ V5.0.2 showed a great improvement over previously operational model for August 18, 2016 case

8–h Avg OZON obs (PPB) avged by fcst hrs
20160812 to 20160831
CONUS

Observations
Old operational model
State-NOx adjustment with new NAM
Grid NOx adjustment with new NAM
New operational model with no NOx adjustment and new NAM

OZON

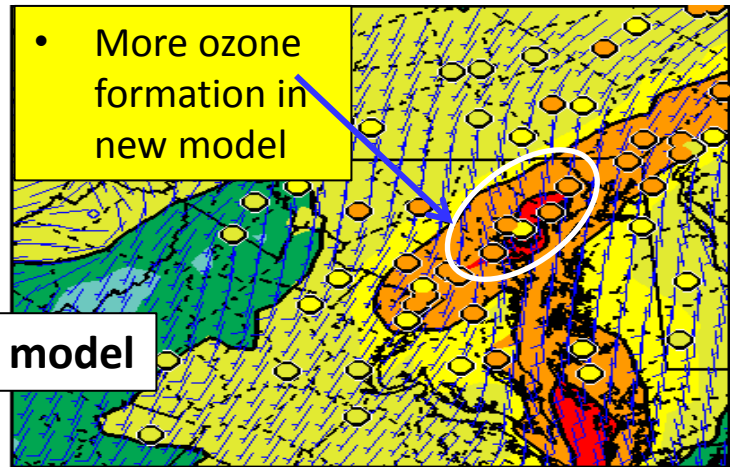FORECAST HOUR   12 UTC CYCLE
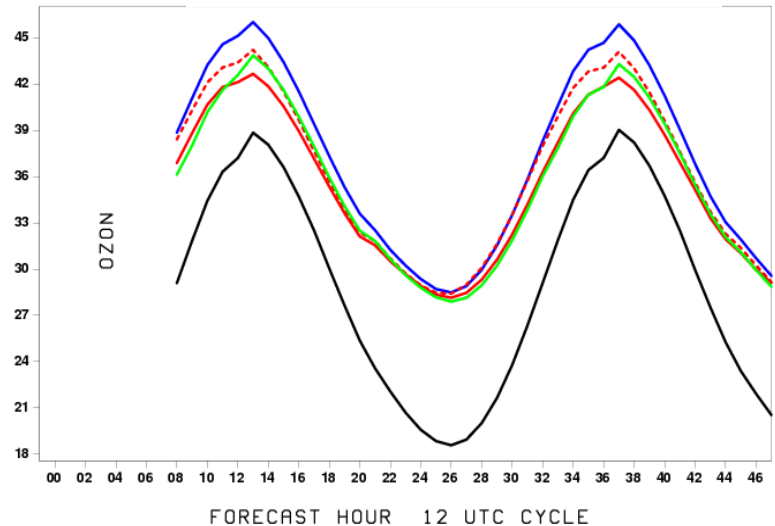
Improvements in ozone near coastal areas
Day 2 predictions for May 17, 2017 8h Max Ozone
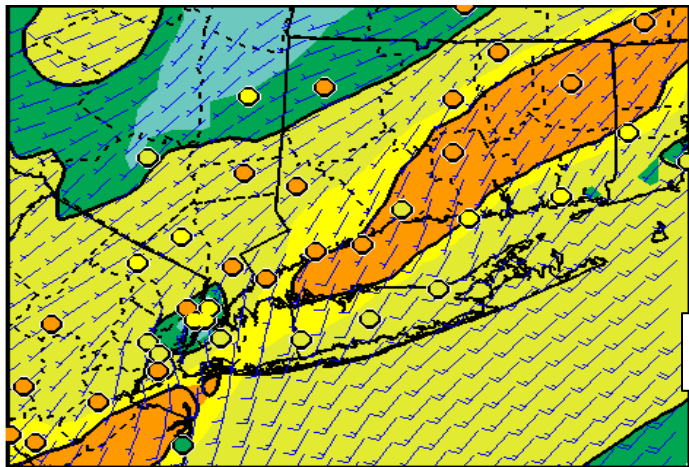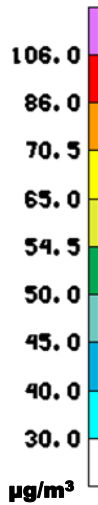
- More ozone formation in new model

Updated model
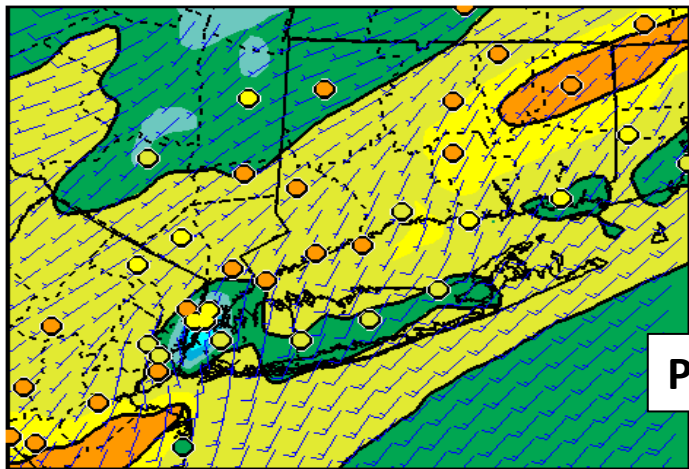
Previous model
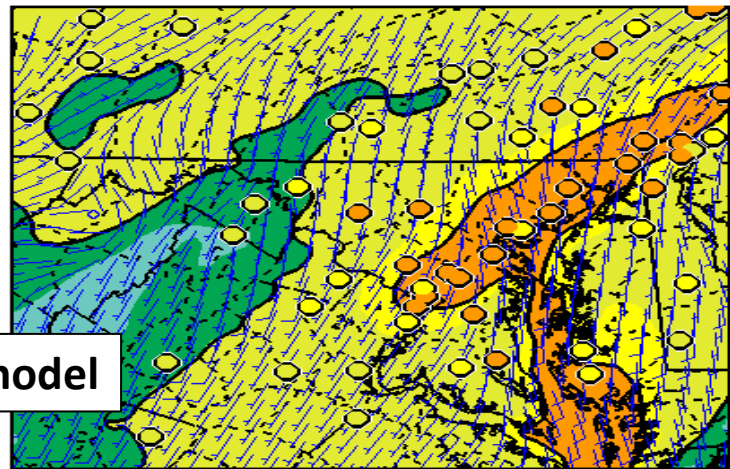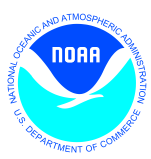
SMOKE AND DUST PREDICTIONS

Smoke predictions
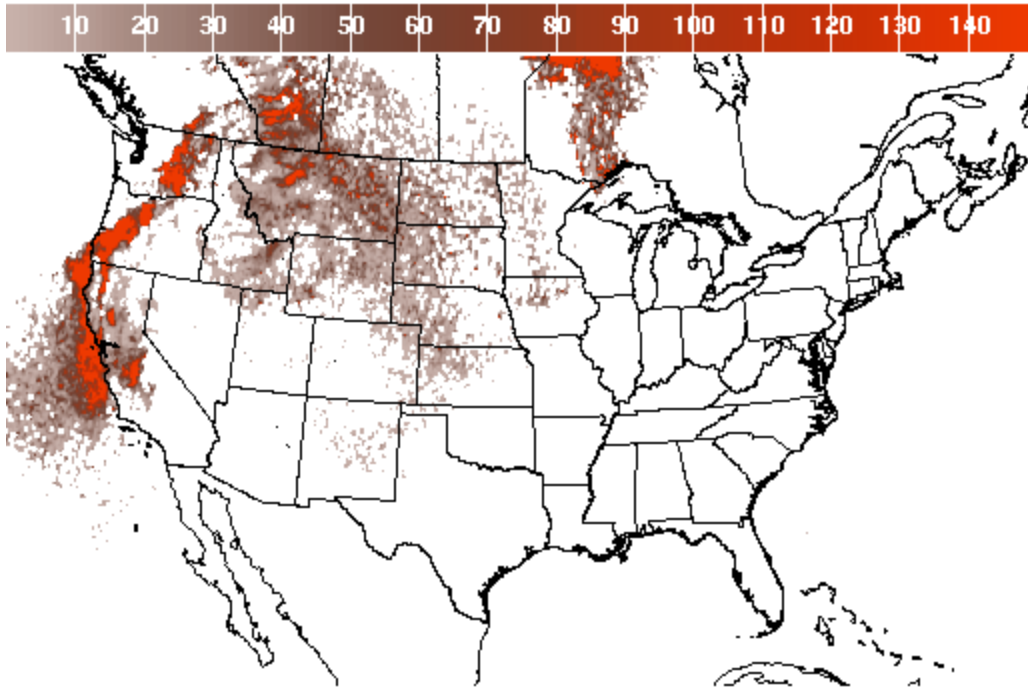
1Hr Surface Smoke (micrograms/m^3) Sat Sep 02 2017 8PM EDT
(Sun Sep 03 2017 00Z)
National Digital Guidance Database
06z model run   Graphic created-Sep 02 7:26AM EDT

- Smoke predictions for CONUS (continental US), Alaska and Hawaii

- NESDIS provides wildfire locations detected from satellite imagery

- Bluesky provides emissions estimates

- HYSPLIT model for transport, dispersion and deposition (Rolph et. al., W&F, 2009)

- Increased plume rise, decreased wet deposition, changes in daily emissions cycling

- Developed satellite product for verification (Kondragunta et.al. AMS 2008)

Since June 2017

- Updated BlueSky System v3.5.1 for smoke emissions (first BlueSky update since predictions became operational in 2007)

Verification of smoke predictions for CONUS

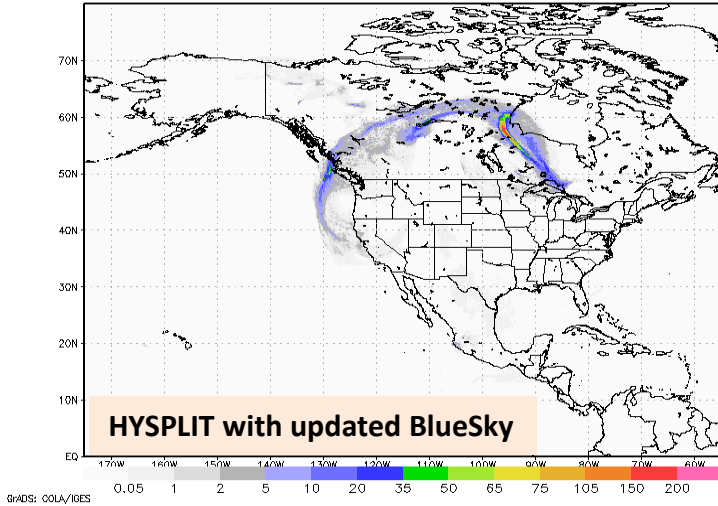**Daily time series of FMS for smoke concentrations larger than 1um/m3**
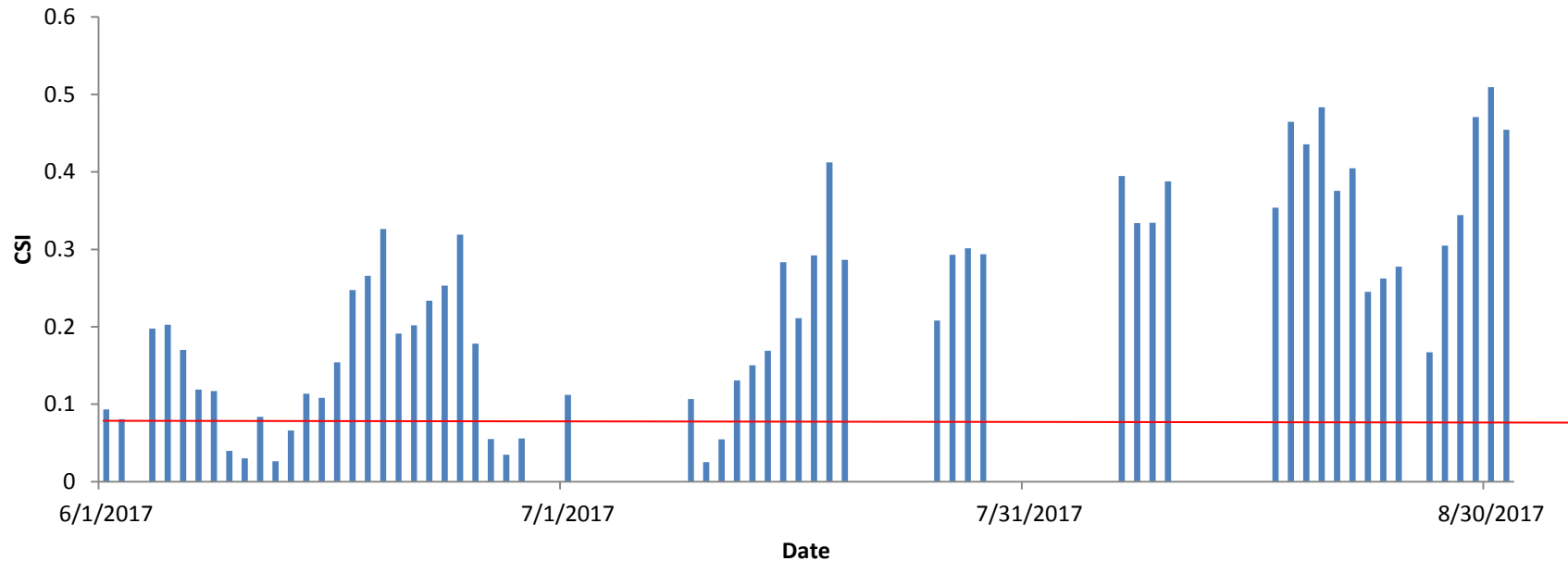
- **Figure of merit in space (FMS), which is a fraction of overlap between predicted and observed smoke plumes, threshold is 0.08 marked by red line**
- **NESDIS GOES Aerosol/Smoke Product is used for verification**
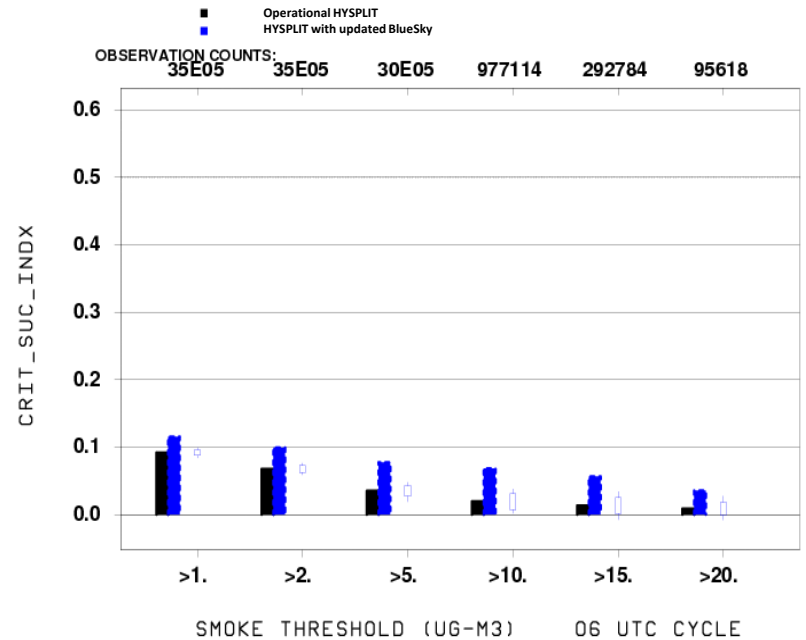
BlueSky Evaluation
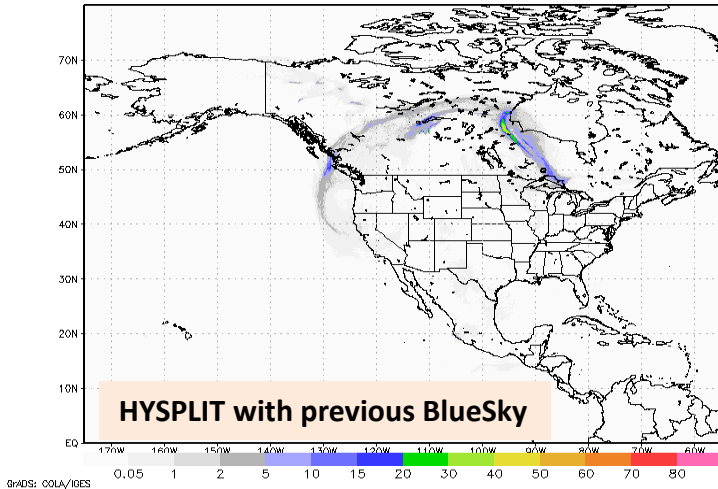
HYSPLIT DEV t06z pbl smoke 20160521/1800V012 conc ug/m3

HYSPLIT with updated BlueSky

GrADS: COLA/IGES

HYSPLIT PROD t06z pbl smoke 20160521/1800V012 conc ug/m3

HYSPLIT with previous BlueSky

GrADS: COLA/IGES

Comparing previous operational smoke predictions with those using updated BlueSky for May 2016

Improved skill scores in May from large Ft. McMurray fires for currently operational HYSPLIT with updated BlueSky

CONUS dust predictions

1Hr Vertical Dust (micrograms/m^3) Sat Sep 02 2017 2AM EDT
(Sat Sep 02 2017 06Z)

National Digital Guidance Database
06z model run   Graphic created–Aug 31 11:39AM EDT

Note: The cone contains the probable path of the storm the size of the storm. Hazardous conditions can oc

6 AM Mon
6 AM Sun
6 AM Sat
6 PM Fri
6 AM Tue
6 AM Fri
9 AM Thu

Mexico

Tropical Storm Lidia
Thursday August 31, 2017
9 AM MDT Advisory 8
NWS National Hurricane Center

Current information: ✕
Center location 22.3 N 109.7 W
Maximum sustained wind 50 mph
Movement NNW at 9 mph

Forecast positions:
● Tropical Cyclone ○ Post/Potential TC
Sustained winds: D < 39 mph
S 39-73 mph H 74-110 mph M > 110 mph

Potential track area: **Watches:** **Warnings:** **Current wind extent:**
Day 1-3 Day 4-5 Hurricane Trop Stm Hurricane Trop Stm Hurricane Trop Stm

Standalone prediction of airborne dust from dust storms:

• Wind-driven dust emitted where surface winds exceed thresholds over source regions

• Source regions with emission potential estimated from MODIS deep blue climatology for 2003-2006 (Ginoux et. al. 2010).

• Emissions modulated by real-time soil moisture.

• HYSPLIT model for transport, dispersion and deposition (Draxler et al., JGR, 2010)

• Wet deposition updates in July 2013

• Developed satellite product for verification (Ciren et.al., JGR 2014)
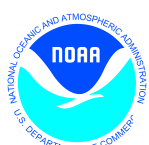
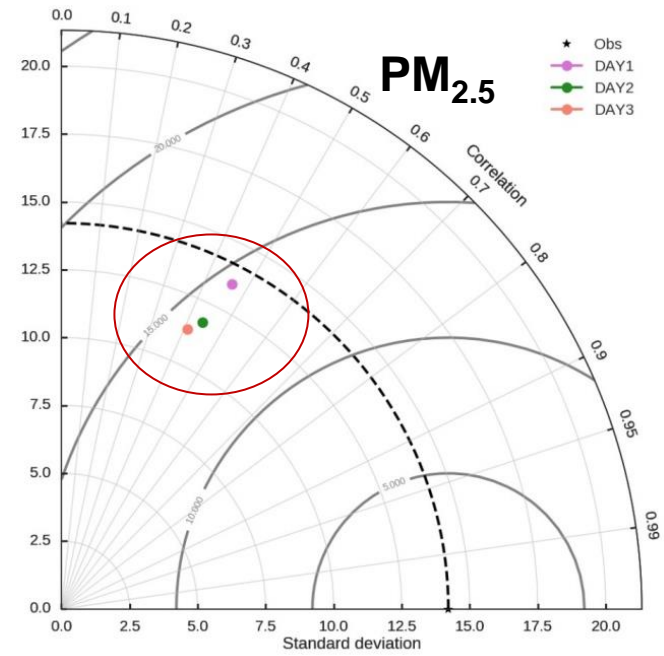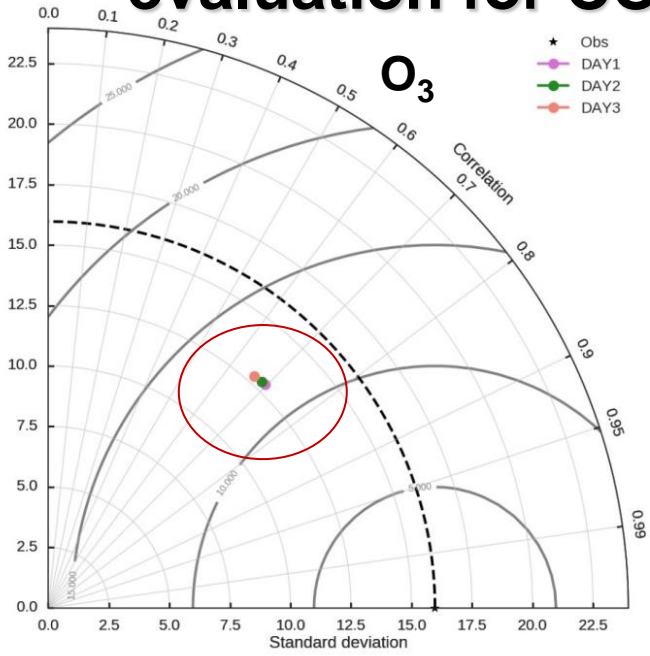23
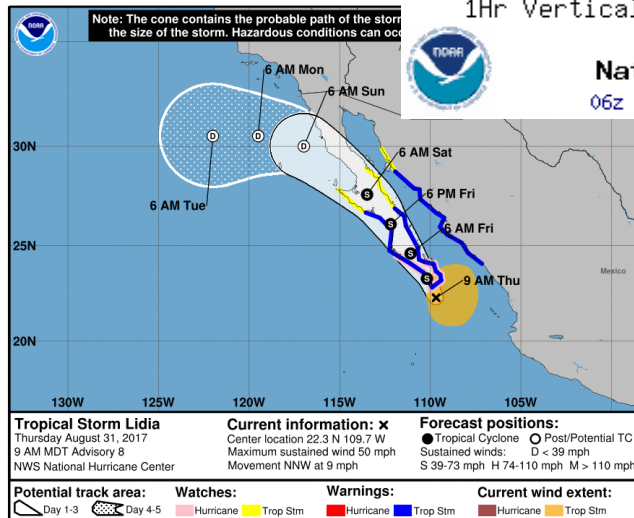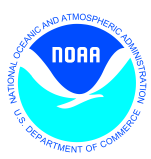
TESTING IN PROGRESS
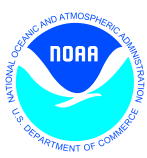
Testing in progress

- Testing the extension of predictions to 72 hours

- Emissions updates: testing of oil and gas updates, testing of NEI 2014

- Ozone bias correction

- Wildfire emissions: hourly estimates from BlueSky, ECCC emissions

# Testing of predictions for 72 hours
evaluation for CONUS

O_3

$PM_{2.5}$

Statistics for all hours

Performance of predictions for days 1, 2 & 3 over **CONUS** for August 10-19, 2017

Pollutant	Prediction day	obs	Bias	RMSE	corr, r
Daily max. of 8h average ozone [ppb] (N=27300)	D1	39.0	2.58	9.65	0.75
	D2		2.23	9.78	0.74
	D3		1.76	10.14	0.71
Daily average PM2.5 [ug/m³] (N=18560)	D1	10.61	1.55	10.32	0.59
	D2		0.92	9.88	0.58
	D3		0.76	10.28	0.53

Testing predictions for 72 hours evaluation for Pacific Southwest
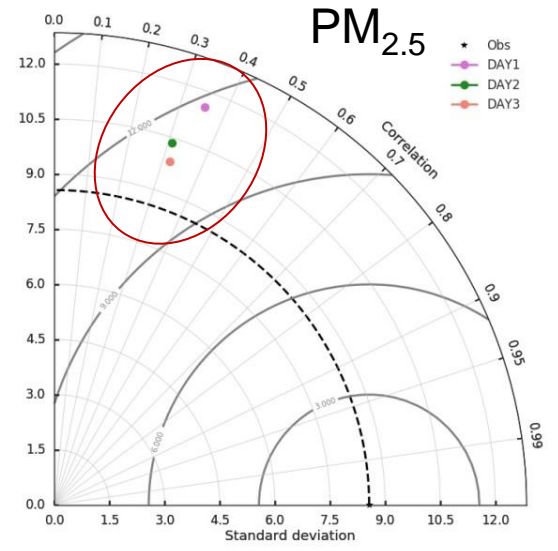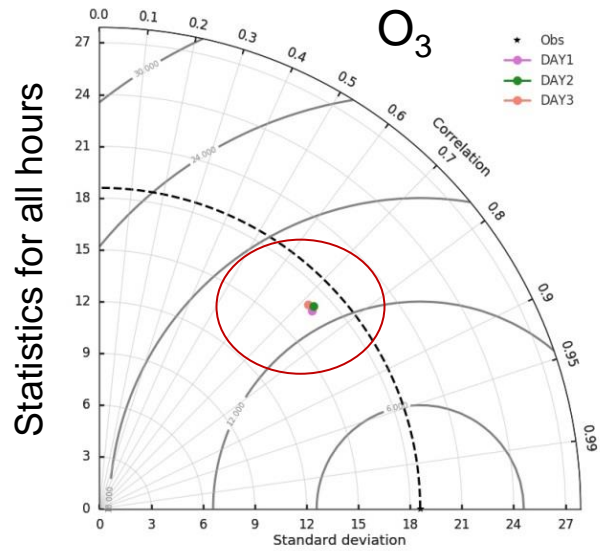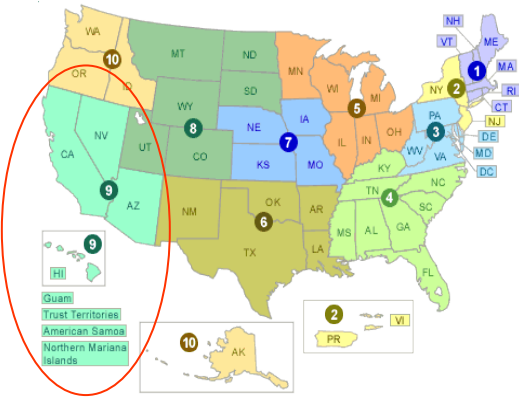
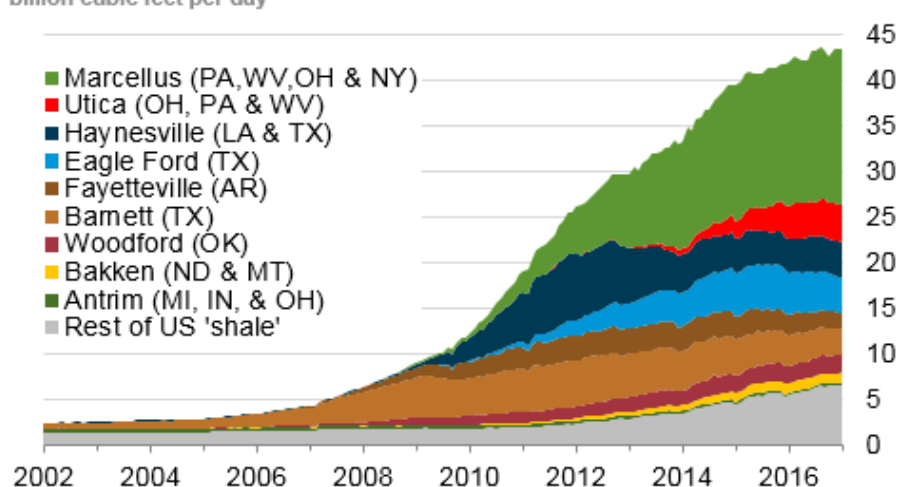Day1,2,3 Performance over Pacific Southwest (region 9) for August 10-19, 2017

| Pollutant	Obs	Bias	RMSE	corr, r
Daily max of 8h ozone (N= 4620) D1	49.7	-0.30	11.15	0.77
D2		-0.72	11.40	0.77
D3		-1.53	11.91	0.75
Daily average of PM2.5 (N= 2875) D1	11.6	1.98	10.52	0.46
D2		0.03	8.65	0.40
D3		0.53	9.59	0.38

2014 Energy Information Administration on Shale Plays
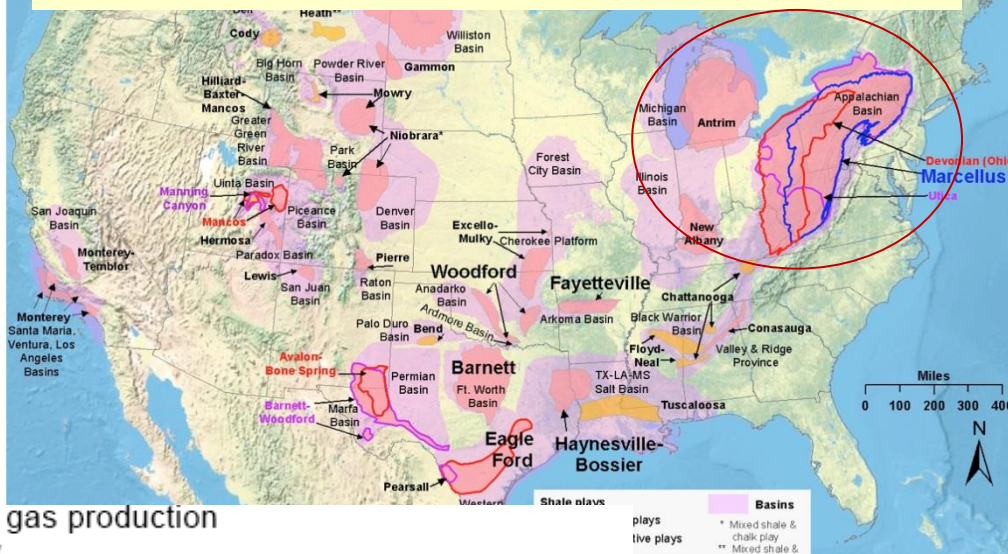
Monthly dry shale gas production
billion cubic feet per day

- Marcellus (PA,WV,OH & NY)
- Utica (OH, PA & WV)
- Haynesville (LA & TX)
- Eagle Ford (TX)
- Fayetteville (AR)
- Barnett (TX)
- Woodford (OK)
- Bakken (ND & MT)
- Antrim (MI, IN, & OH)
- Rest of US 'shale'

Sources: EIA derived from state administrative data collected by DrillingInfo Inc. Data are through January 2017 and represent EIA's official shale gas estimates, but are not survey data. State abbreviations indicate primary state(s).
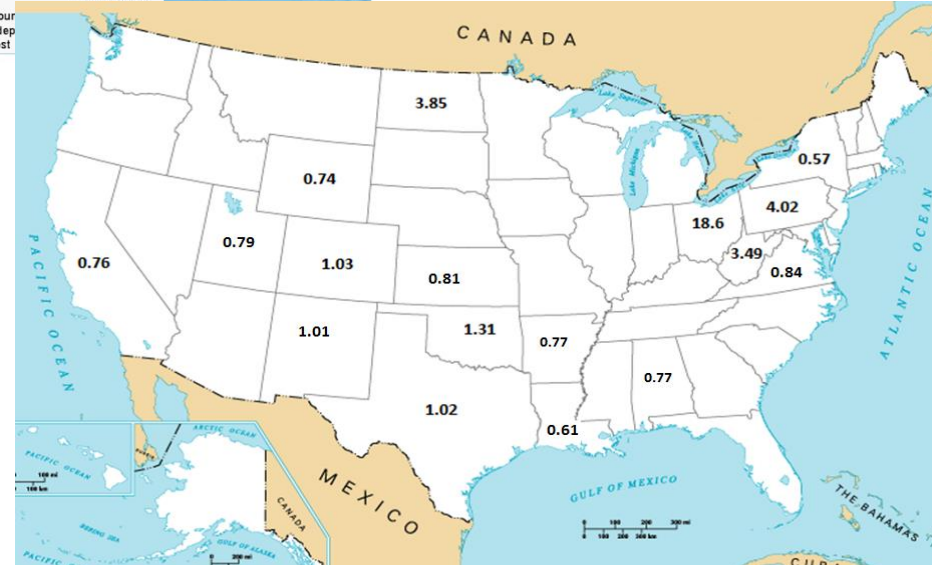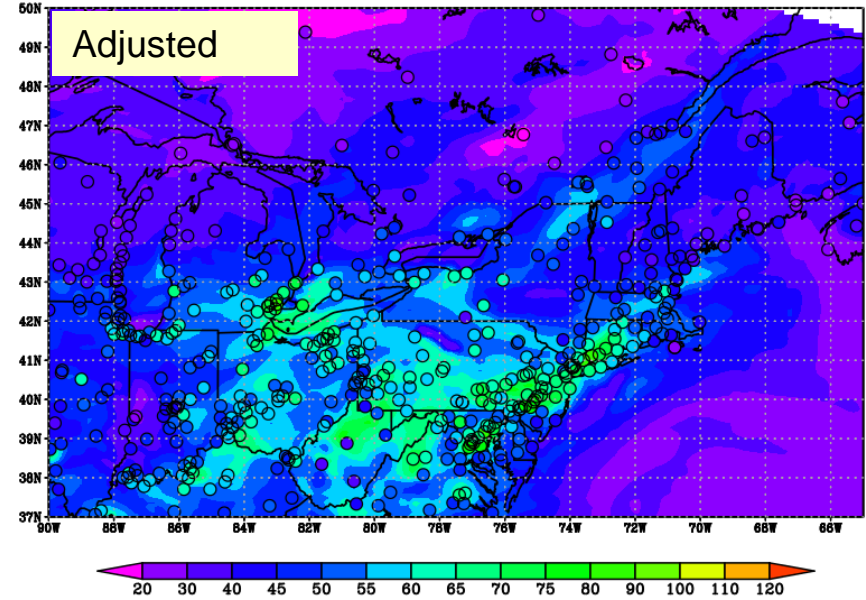
Adjustment factor applied to NEI2011 oil and gas area source sector

28

Testing of oil and gas emissions

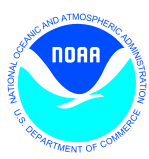Prod−Fcst Surface O_3 (ppbv) at 16Z, 07/19/2017 — Operational
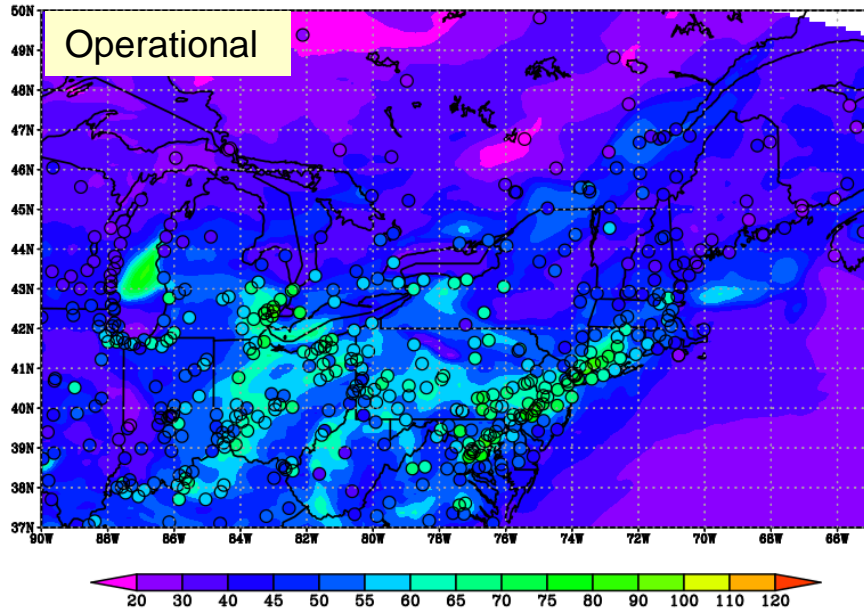
Oilgas−Fcst Surface O_3 (ppbv) at 16Z, 07/19/2017 — Adjusted
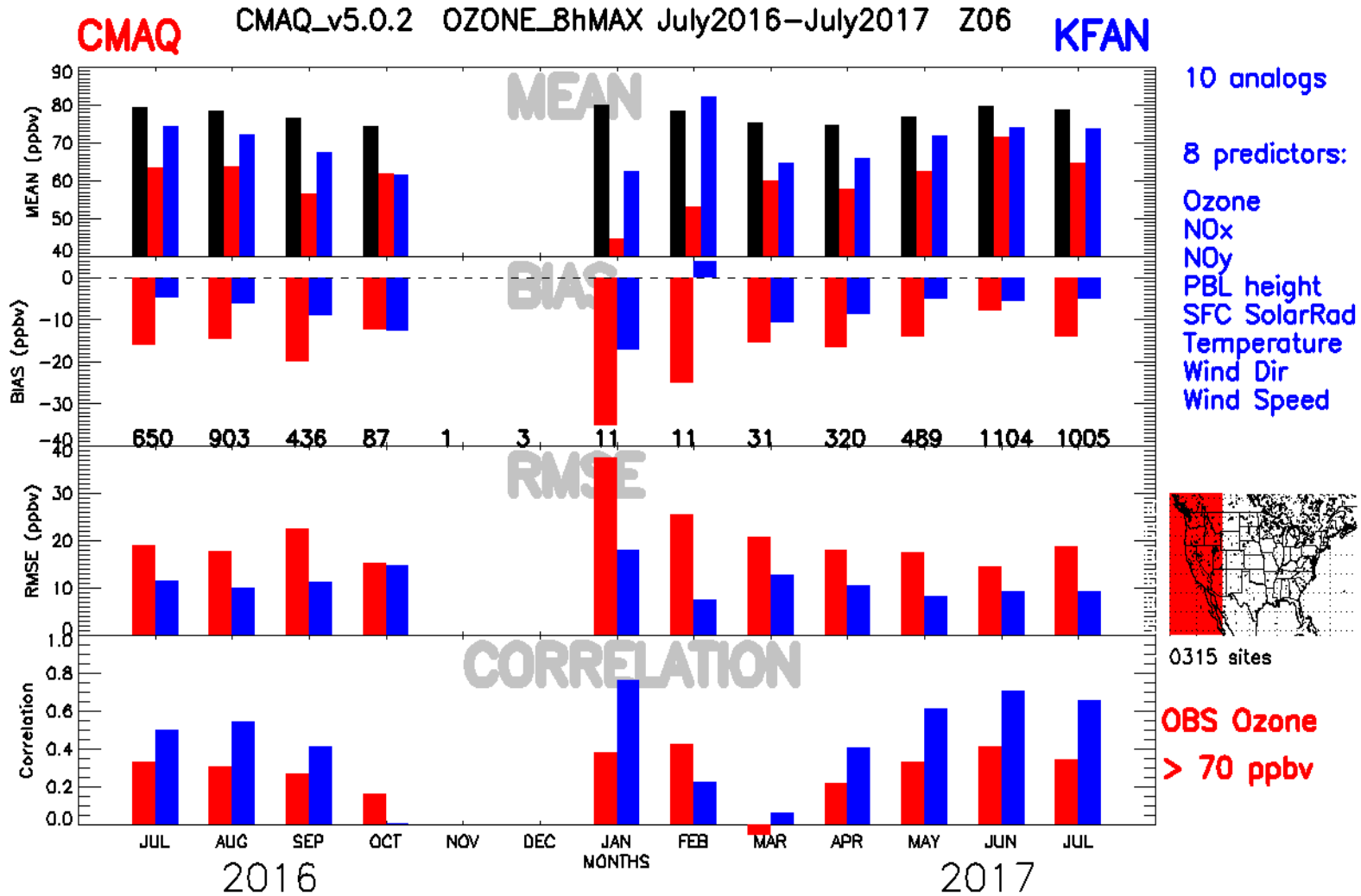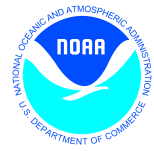
❖ Testing of State-specific scaling for Oil_n_Gas area source

➢ July 11-21 sensitivity run confirmed that Marcellus area O3 increased

➢ Under-prediction in O_3 in the Marcellus area was reduced

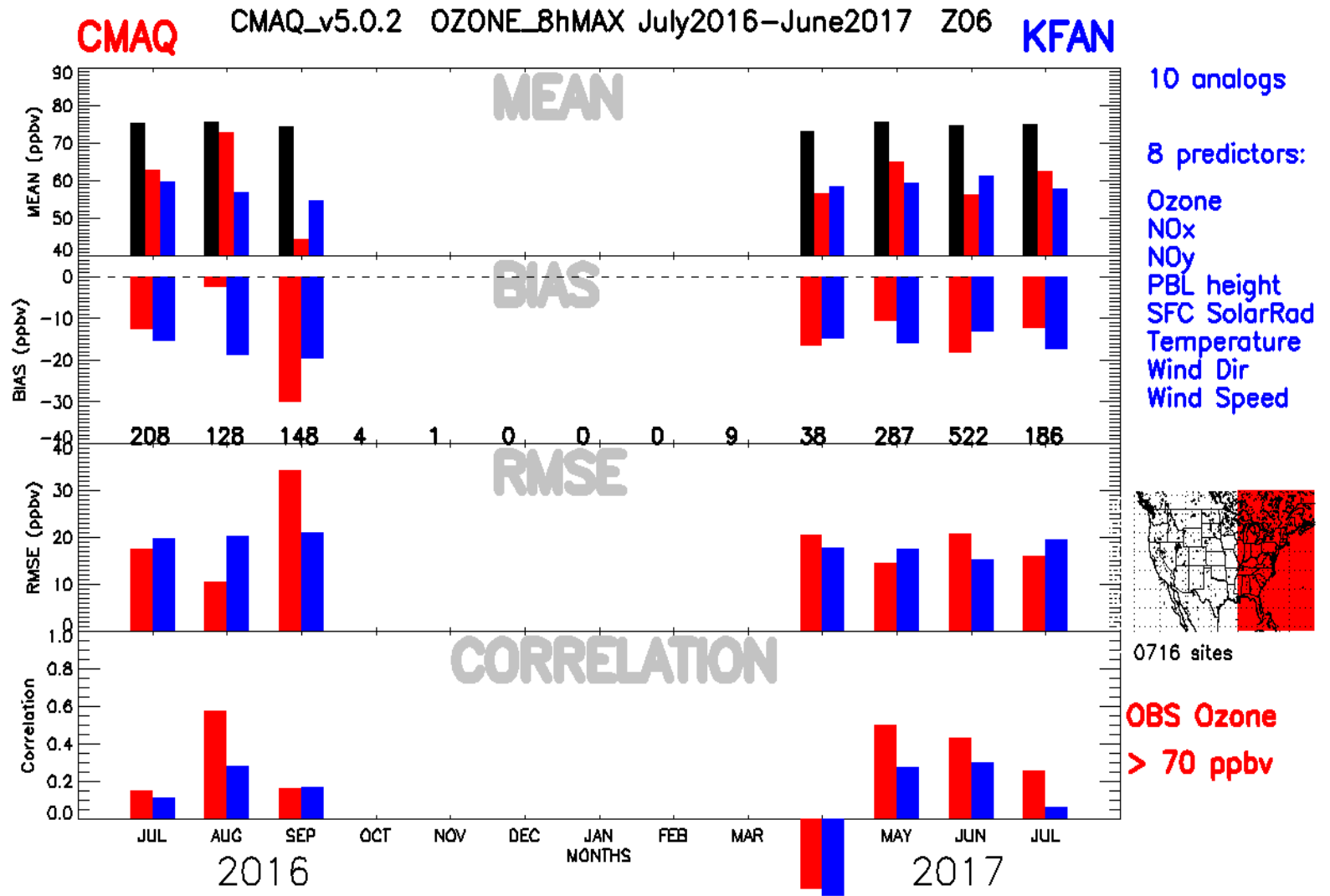➢ However the over-prediction in O_3 elsewhere was exacerbated

Testing of bias correction for ozone predictions for Pacific/Western U.S.
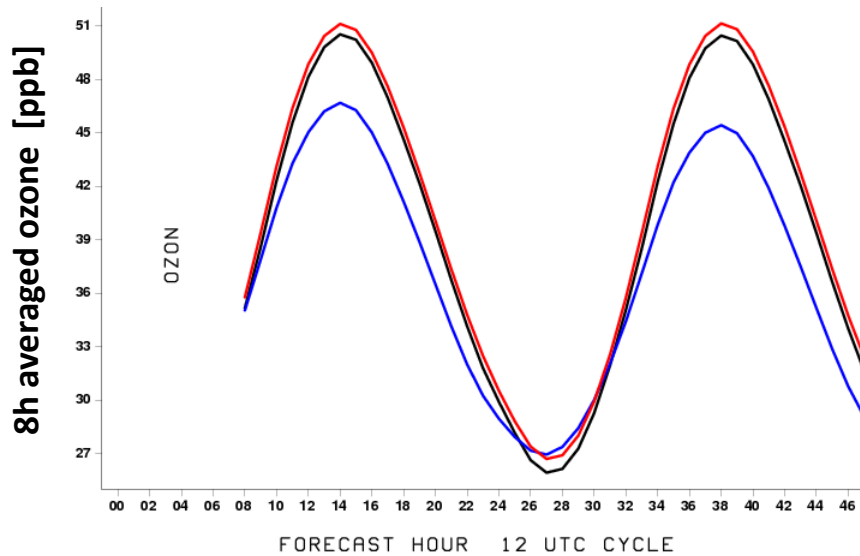

James Wilczak and Irina Djalalova

Testing of bias correction for ozone predictions for Atlantic/Eastern U.S.

James Wilczak and Irina Djalalova

Evaluation of ozone predictions (July 2017)

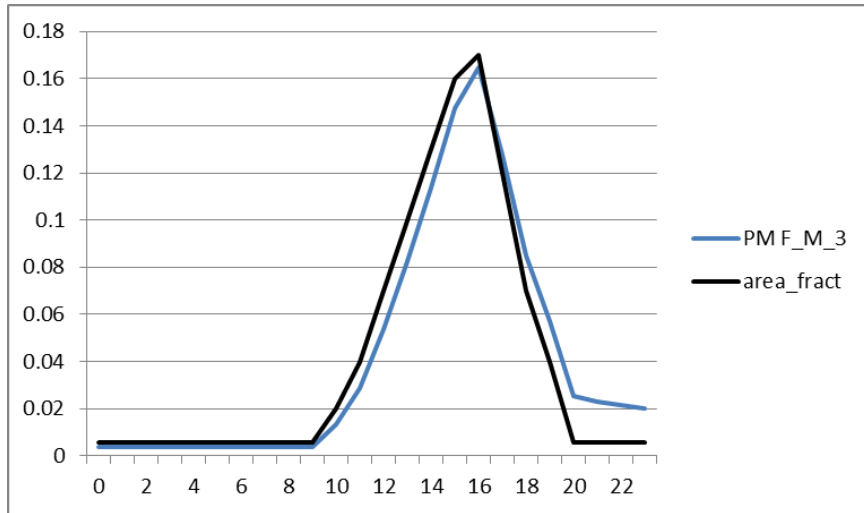Western U.S.

Eastern U.S.

8h averaged ozone [ppb]
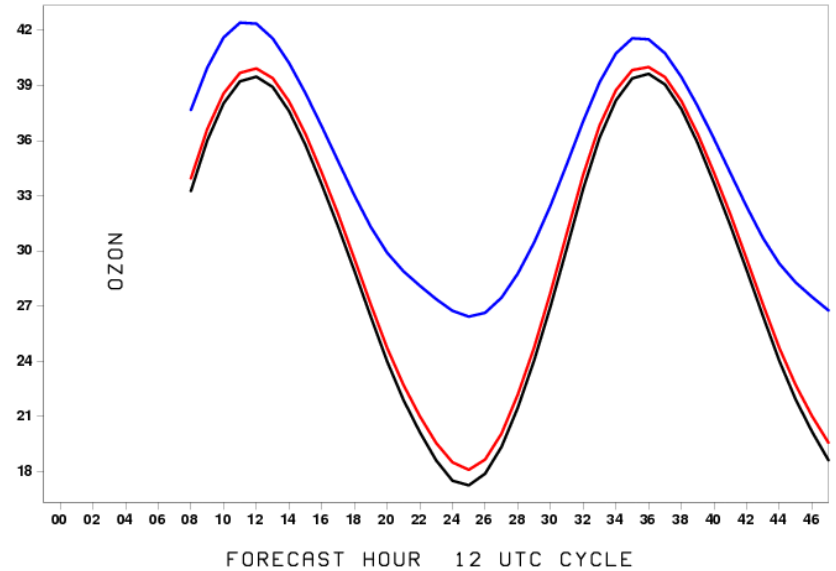
Observations

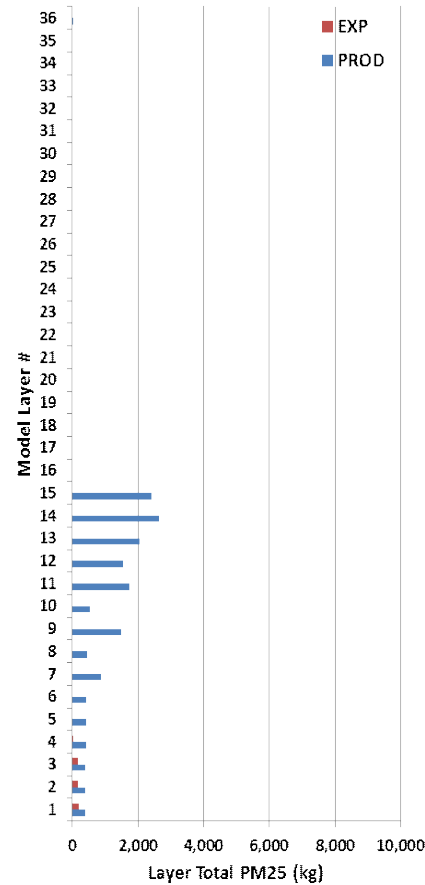Operational model predictions

Testing of bias corrected predictions

Testing of BlueSky wildfire smoke emissions changing hourly

Example PM diurnal profile for mixed forest

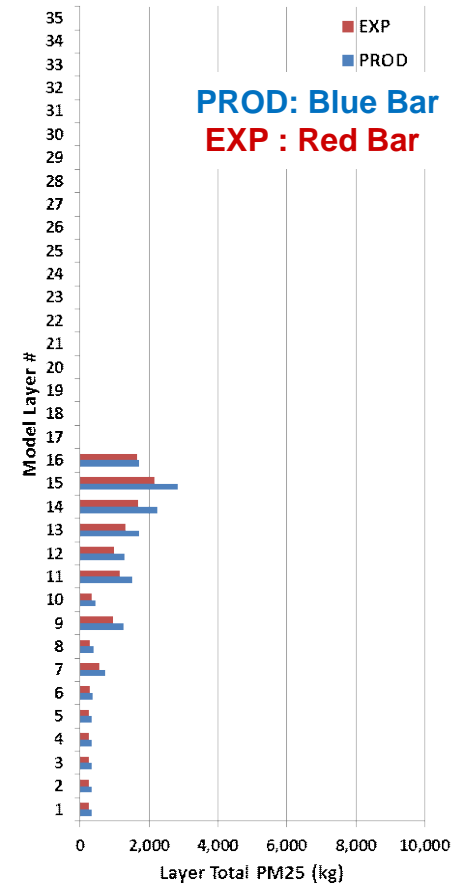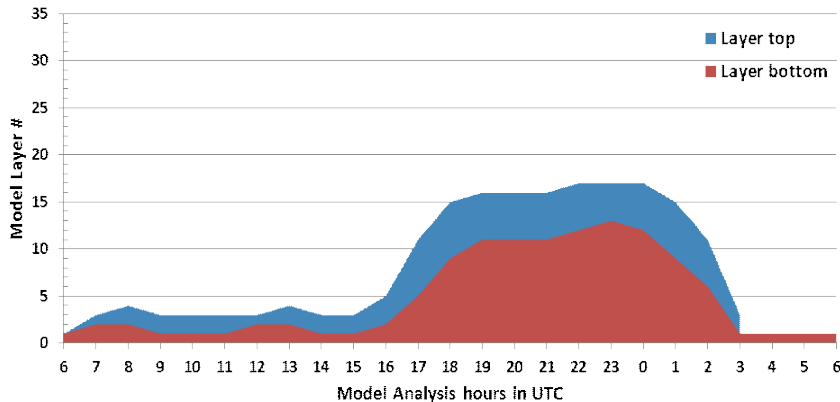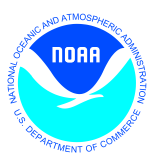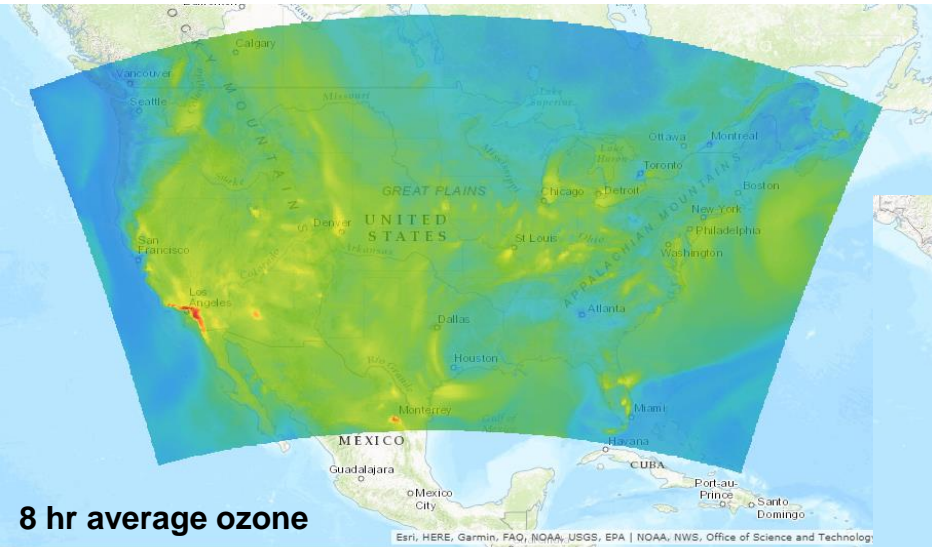Vertical Distribution of fire emissions

Testing of hourly changes in emission amounts and plume rise.

DISPLAY, DISSEMINATION AND WEB PRESENCE UPDATES

Webservices

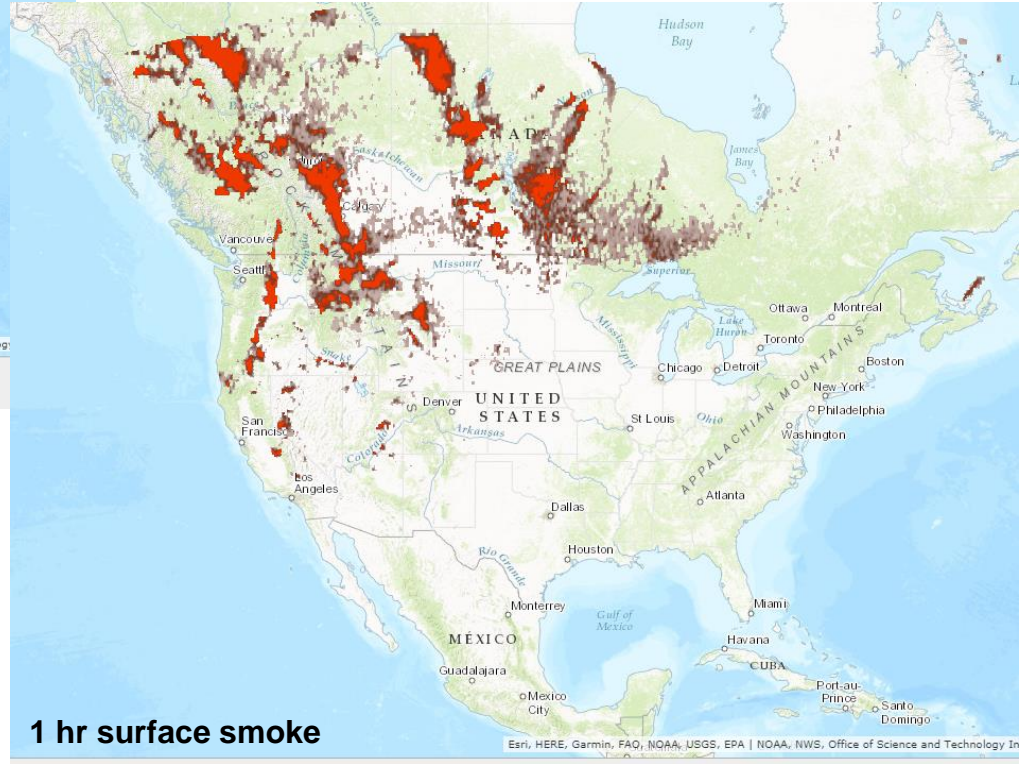8 hr average ozone
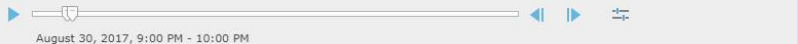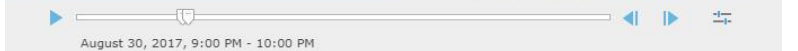
1 hr surface dust

1 hr surface smoke
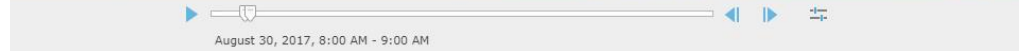
Examples of ozone predictions in web enabled map service currently in development based on GIS application

Operational AQ forecast guidance at
airquality.weather.gov
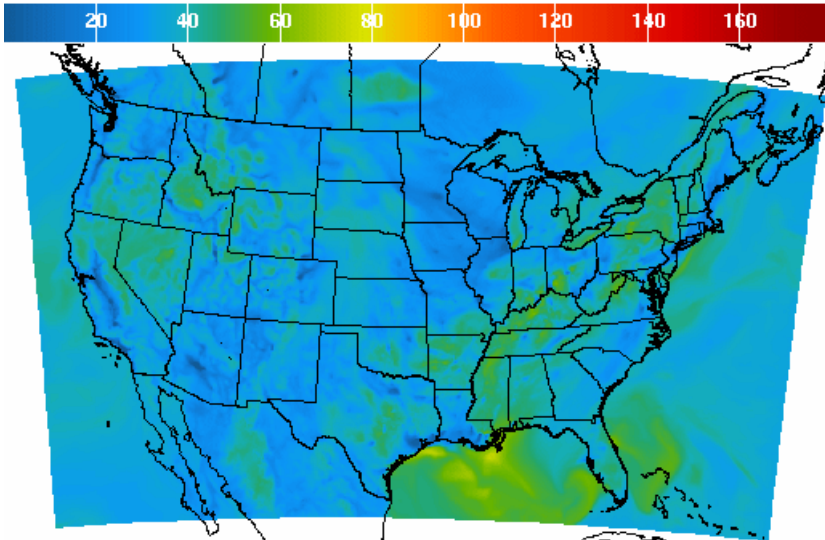
1Hr Avg Ozone Concentration(PPB) Ending Thu Sep 20 2007 10AM EDT
(Thu Sep 20 2007 14Z)
National Digital Guidance Database
06z model run   Graphic created-Sep 20 7:23AM EDT

Ozone products
Nationwide since 2010

Smoke Products
Nationwide since 2010
Dust Products
Implemented 2012
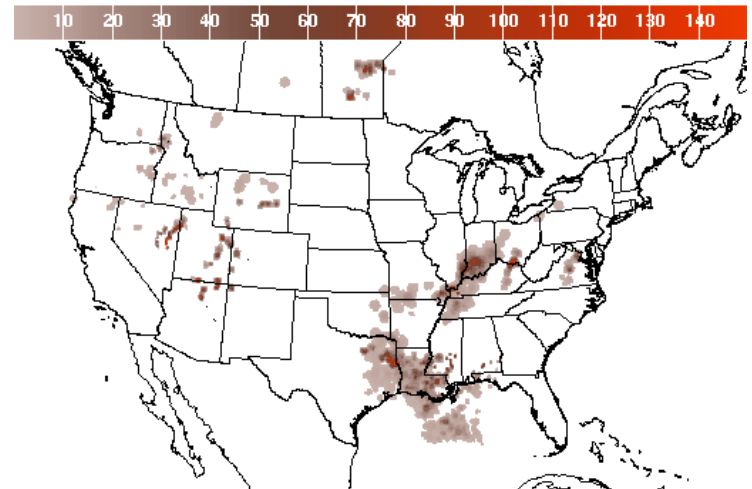
1Hr Surface Smoke (micrograms/m^3) Thu Sep 20 2007 9AM EDT
(Thu Sep 20 2007 13Z)
National Digital Guidance Database
6z model run   Graphic created-Sep 20 8:24AM EDT

New web site:

https://www.weather.gov/sti/stimodeling_airquality

Partnering with AQ Forecasters

Focus group, State/local AQ forecasters:

- Participate in real-time developmental testing of new capabilities, e.g. aerosol predictions

- Provide feedback on reliability, utility of test products

- Local episodes/case studies emphasis

- Regular meetings; working together with EPA's AIRNow and NOAA

- **Feedback is essential for refining/improving coordination**

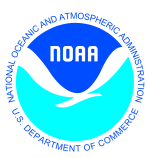## Examples of AQ forecaster feedback after emissions update in 2012:

- In Maryland, NOAA ozone predictions have improved since 2011: significant improvement in false alarm ratio (FAR) with some decrease in probability of detection (POD). *(Laura Landry, Maryland Department of the Environment)*

Evaluation in June 2017:

- Received recommendation to implement system upgrade as proposed from AQ forecasters from Virginia, Connecticut, North Carolina, Texas, Washington and Maryland.

Based on forecaster needs currently testing extension of ozone and PM2.5 predictions from 48h to 72h
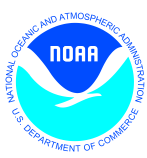
Summary and plans

US national AQ forecasting capability:

- **Ozone** prediction nationwide; updated to CMAQ version 5.0.2 and new Bluesky

- **Smoke** prediction nationwide; updated with newer BlueSky system

- **Dust** prediction for CONUS sources

- **PM2.5** predictions; include wildfire and dust emissions, dust LBCs from global predictions; refinement of bias correction using KFAN approach

Current testing and plans:

- Extension of CMAQ predictions to 72 hours

- Emissions updates (NEI 2014 including oil and gas sources)

- Ozone bias correction

- Wildfire smoke inputs: hourly evolution from BlueSky for CONUS and ECCC for Canada

- Update display, dissemination and web presence

- Finer resolution and inline with meteorology (longer term)
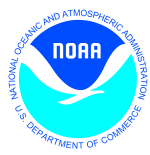
Acknowledgments:
AQF implementation team members

Special thanks to previous NOAA and EPA team members who contributed to the system development

NOAA/NWS/OSTI	*Ivanka Stajner*	*NAQFC Manager*
NWS/AFSO	*Jannie Ferrell*	*Outreach, Feedback*
NWS/OD	*Cynthia Jones*	*Data Communications*
NWS/OSTI/MDL	*Marc Saccucci,*	*Dev. Verification, NDGD Product Development*
	Dave Ruth	
NWS/OSTI	*Sikchya Upadhayay*	*Program Support*
NESDIS/NCDC	*Alan Hall*	*Product Archiving*

NWS/NCEP

Jeff McQueen, Jianping Huang, Ho-Chun Huang   AQF model interface development, testing, & integration

Jun Wang, *Sarah Lu   Global dust aerosol and feedback testing
*Brad Ferrier, *Eric Rogers,   NAM coordination
*Hui-Ya Chuang
Geoff Manikin   Smoke and dust product testing and integration
Rebecca Cosgrove, Chris Magee   NCO transition and systems testing
Mike Bodner, Andrew Orrison   HPC coordination and AQF webdrawer

NOAA/OAR/ARL

Pius Lee, Daniel Tong, Tianfeng Chai   CMAQ development, adaptation of AQ simulations for AQF

Li Pan, Hyun-Cheol Kim, Youhua Tang

Ariel Stein   HYSPLIT adaptations

NESDIS/STAR   *Shobha Kondragunta*   *Smoke and dust verification product development*

NESDIS/OSDPD   *Liqun Ma, Mark Ruminski*   *Production of smoke and dust verification products,*

HMS product integration with smoke forecast tool

EPA/OAQPS *partners:*

Chet Wayland, Phil Dickerson, Brad Johns, John White   *AIRNow development, coordination with NAQFC*

* Guest Contributors