NOAA's National Air Quality Forecast Capability operational and experimental updates

Dorothy Koch[1], Ivanka Stajner[2], Jeff McQueen[2,] Pius Lee[3], Jianping Huang[2,5], Ho-Chun Huang[2,5], Li Pan[2,5], Youhua Tang[3,6], Daniel Tong[3,6], Patrick Campbell[3,6], Ariel Stein[3], James Wilczak[4], Irina Djalalova[4,8], Dave Allured[4,8], Phil Dickerson[7], Jose Tirado[1,9]

(1) NOAA NWS/STI
(2) NOAA NWS/NCEP
(3) NOAA ARL
(4) NOAA ESRL
(5) IMSG
(6) Cooperative Institute for Satellite Earth System Studies (CISESS)
(7) EPA
(8) CIRES, University of Colorado
(9) ERG

with contributions from the entire NAQFC Implementation Team

CMAS Conference, Chapel Hill, NC October, 2019

NAQFC related presentations

- Implementation of new satellite-based source maps in the FENGSHA dust module and initial application with the CMAQ-based NAQFC system, Daniel Tong (next speaker).
- Development of a Fast Fire Emission Processor and Its application with HMS-Bluesky and GBBEPx Inventories, Youhua Tang (Tue, Oct 22, 10:40 AM - 11:00 AM, Dogwood Room).
- Evaluation of GFS-driven CMAQ predictions of PM2.5 and O3 at NOAA, Jianping Huang (poster session, Tue, Oct 22, 05:00 PM - 07:45 PM, Main Atrium).

NWS context

The Office of Science and Technology Integration (OSTI) Modeling Division (about $29M/yr)
Includes:

- NGGPS (Next Generation Global Prediction System)
- HFIP (Hurricane Forecast Improvement Program)
- “Weeks 3-4”
- Air Quality
- COASTAL Act

- ❏ We are moving towards “unification”, reducing the number of model component versions, for example using the FV3 dynamical core for all atmospheric applications, including AQ
- ❏ We are collaborating closely with the Research office (OAR) and community, to bring “Research to Operations” and vice versa.
- ❏ The Unified Forecast System (UFS) is becoming a central effort, started from our office, now also supported by OAR/OWAQ, and we are planning to extend the collaboration to other NOAA Offices and beyond: http://ufscommunity.org
- ❏ The UFS has 8 “applications”, including air quality, and an atmospheric chemistry working group
- ❏ Most of our air quality development work will now be supported under the UFS project, and we are in the project and proposal development stage now.

National Air Quality Forecast Capability

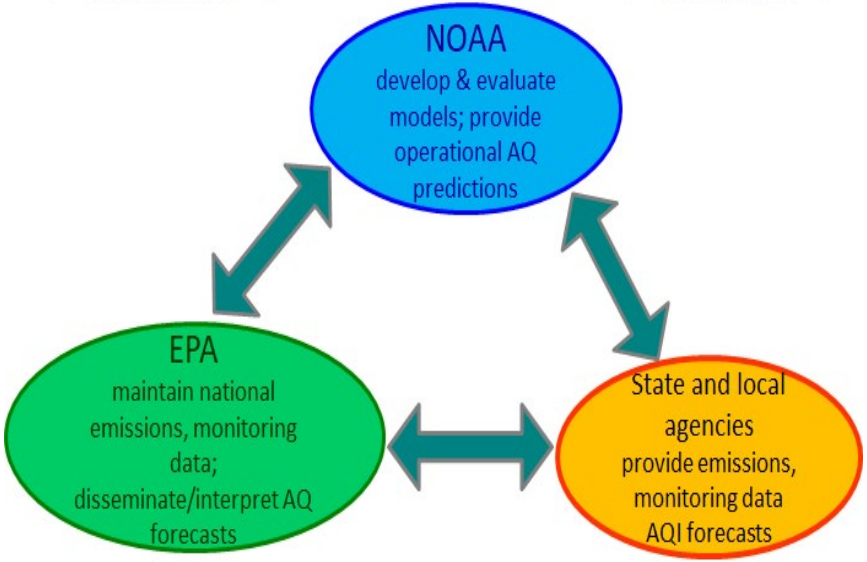
We improve the basis of air quality alerts and provide air quality information to people at risk to further NWS mission of protecting life and property and the enhancement of the national economy.

National Air Quality Forecast Capability (NAQFC) develops and implements operational air quality forecast guidance for the United States.

Current operational Prediction Capabilities are:

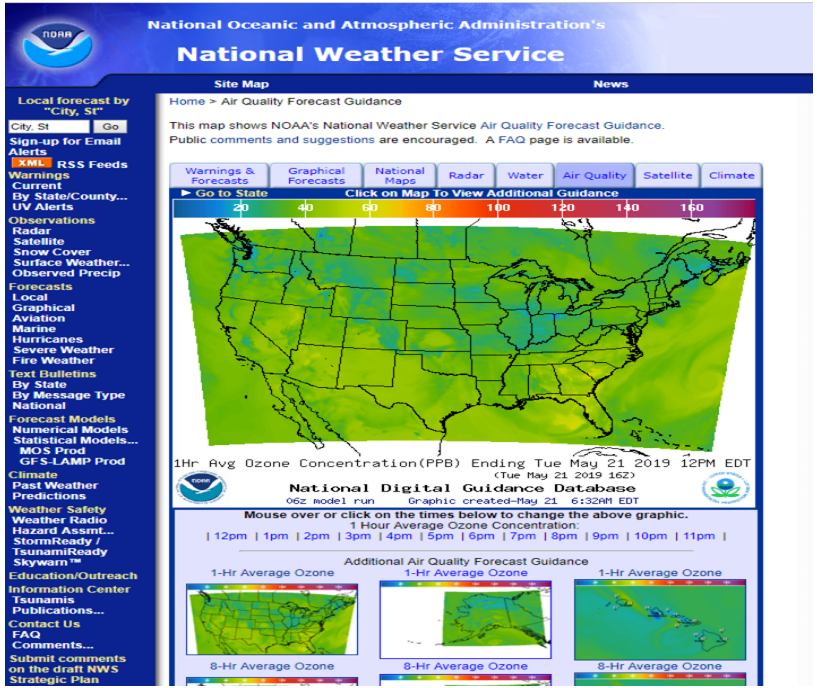
- Ozone nationwide
- Smoke nationwide
- Dust over CONUS
- Fine particulate matter (PM2.5) nationwide

These capabilities rely on a strategic partnership with the Environmental Protection Agency (EPA) and state and local air quality forecasters.

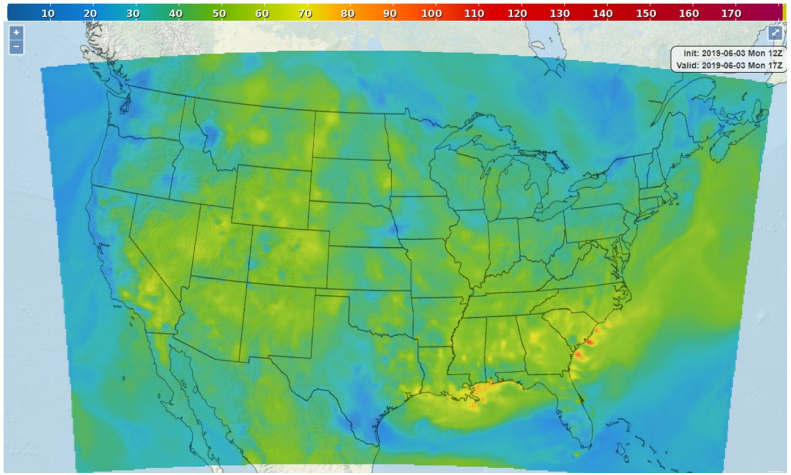


Our products are available @

Realtime images @ airquality.weather.gov and as GRIB files from ftp://tgftp.nws.noaa.gov/SL.us008001/ST.opnl/DF.gr2/DC.ndgd/GT.aq/AR.conus/



In GIS format @ https://idpgis.ncep.noaa.gov/arcgis/rest/services/NWS_Forecasts_Guidance_Warnings



Historical database available from the National Digital Guidance Database@ https://www.ncdc.noaa.gov/data-access/model-data/model-datasets/national-digital-guidance-database-ndgd

Operational centers Forecast performance analysis

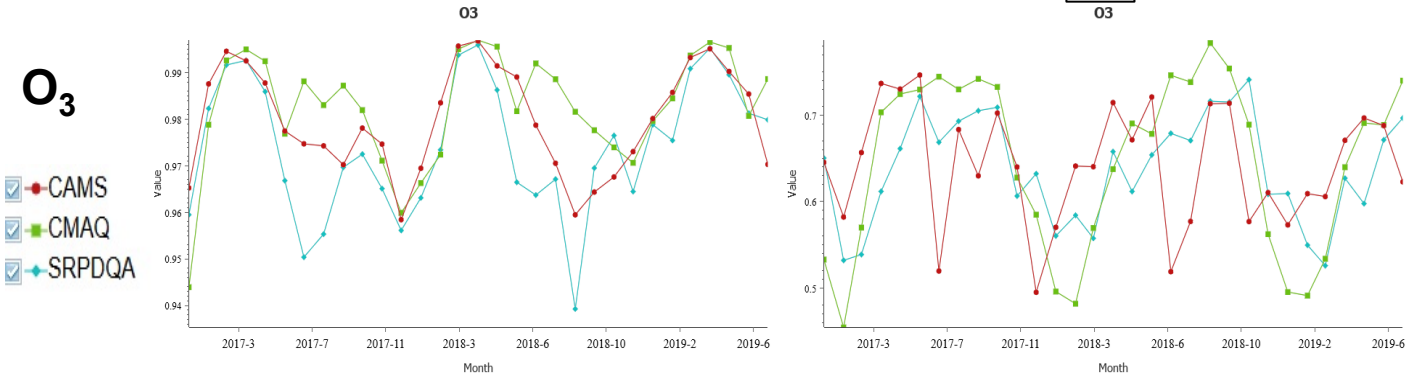
- NAQFC/CMAQ has the best performance based on several metrics against other operational centers models, ECCC (Regional AQ Deterministic Prediction system) Canada and ECMWF (CAMS-IFS)
- NAQFC/CMAQ has best overall Factor of 2 fraction (FAC2) scores for O3 and PM2.5.
- For ozone in the summertime, NAQFC/CMAQ has the best correlations.
- NAQFC/CMAQ has best (closest to 0) Mean Fractional Bias for daily max O3 and PM2.5
- NAQFC/CMAQ has best overall performance (AQPI) for summertime daily max O3
- NAQFC/CMAQ has best overall performance (AQPI) for daily max PM2.5
- All comparison statistics based on CMAQ raw output

Time Series of O_3 and $PM_{2.5}$ Mean Monthly Values for Factor-of-2 and Correlation: 2017/01–2019/07, Continental Domain

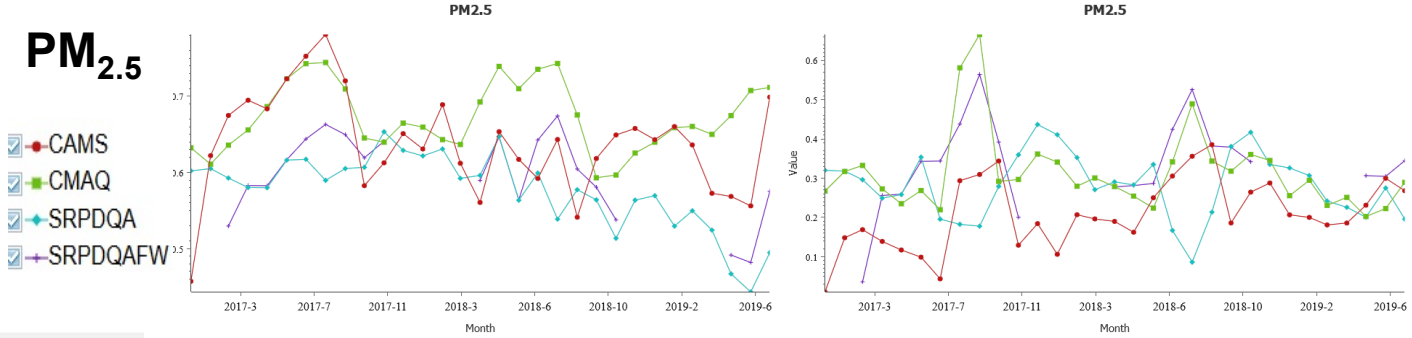
FAC2

R

O_3



$PM_{2.5}$



Moran, et al

*Statistics are calculated using **daily MAX** observed and forecasted concentrations*

Operational updates implemented last December

Updated fine particulate matter (PM2.5) bias correction system to use:

- Consistent model predictions for training of the unified KFAN bias correction system
- Increased number of observation sites for model bias correction to over 900 monitors
- Improvements to forecast extreme events by adding the difference between the current raw model forecast and historical analogs' mean to the KFAN bias-corrected predictions

New ozone bias correction with the same unified codes and configuration

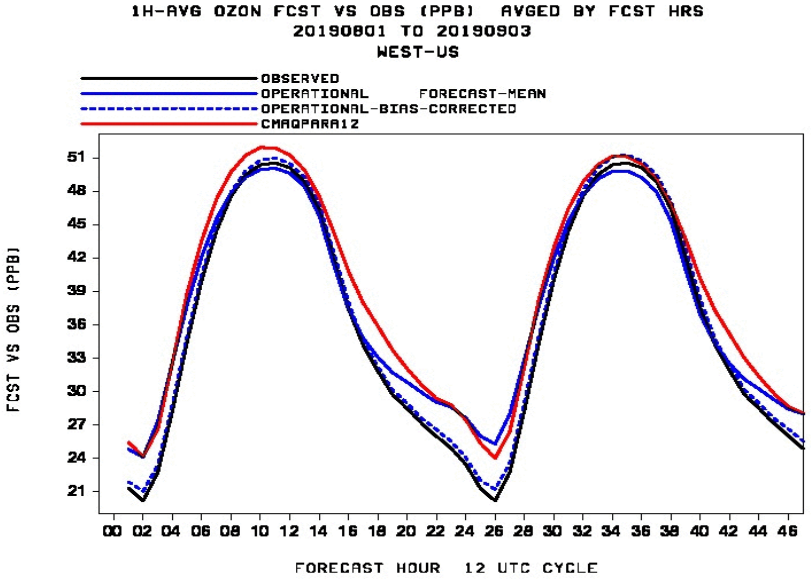
- Uses ozone, wind direction, wind speed, temperature, solar radiation, NOx, NOy and PBL height as parameters to identify analogs
- airquality.weather.gov display bias corrected ozone instead of raw ozone

Updated anthropogenic emissions (NEI2014v2)

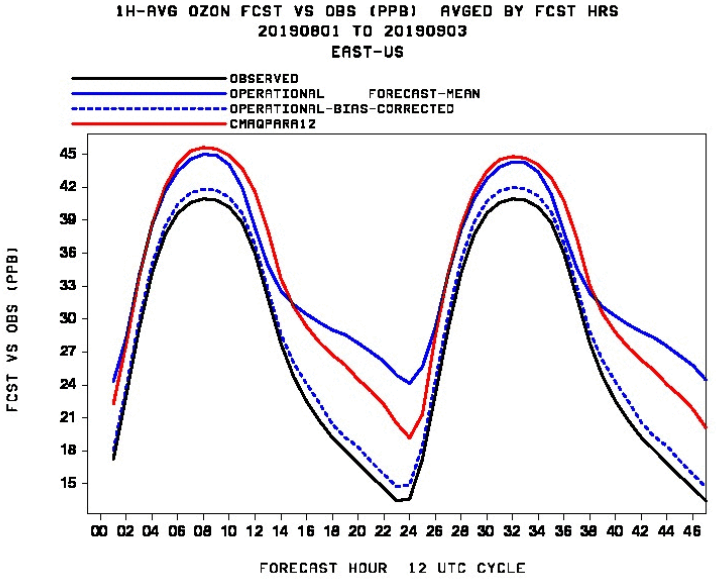
Update Alaska and Hawaii domain CMAQ code to the same version used for CONUS:

- CB05 gas-phase and aero6 aerosol chemistry (155 species)
- Improved heterogeneous, aqueous, winter-time reactions
- Improved SOA and coarse mode PM

Performance of Ozone predictions:
Observed Vs predicted 1 hr averaged Diurnal variability, August 2019

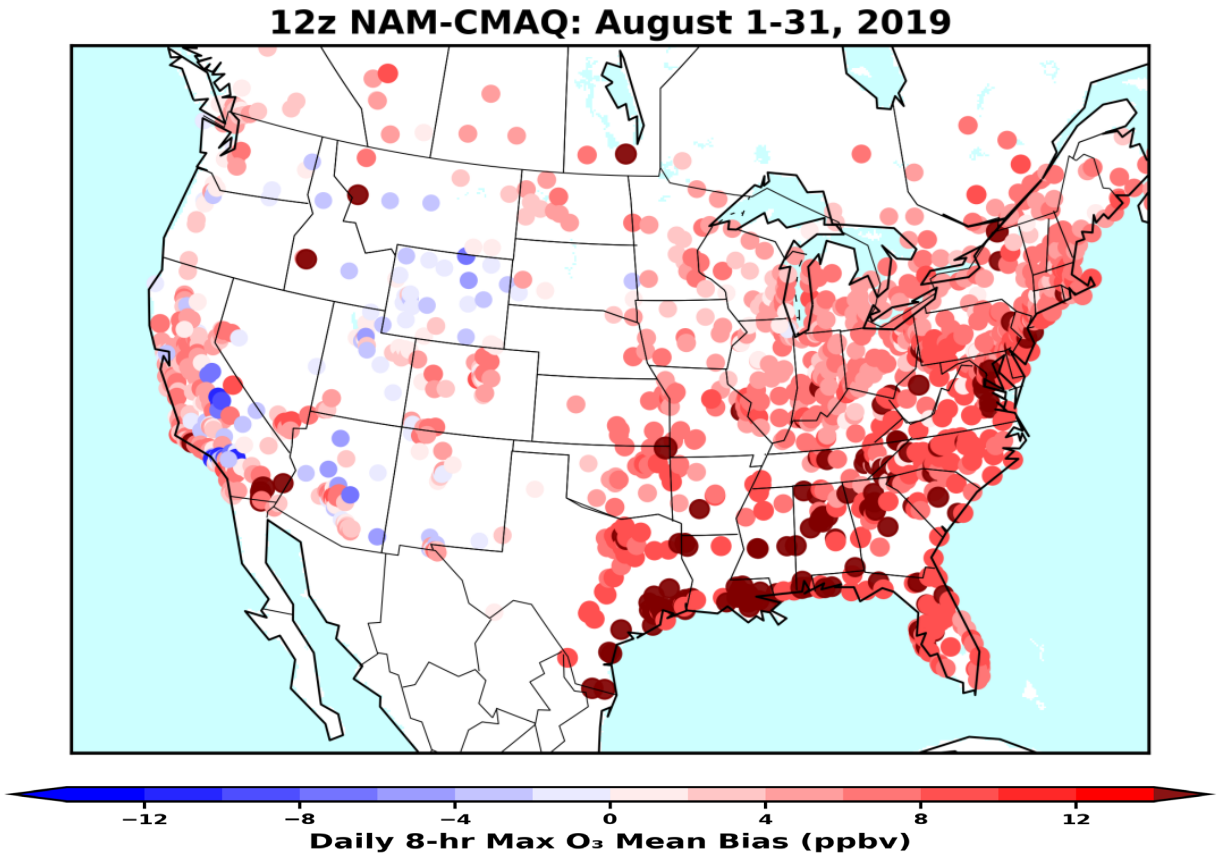


Western U.S.

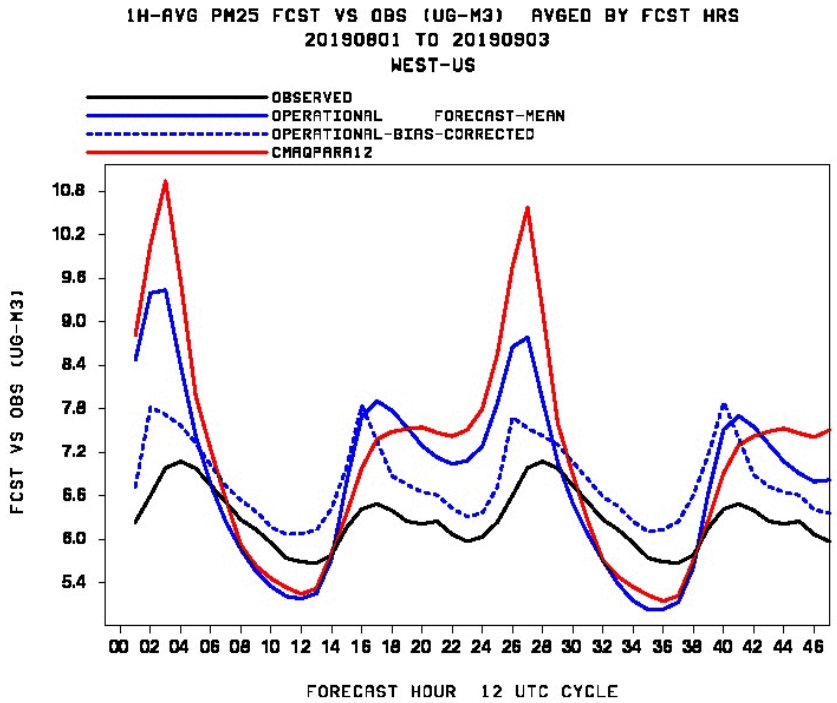


Eastern U.S.

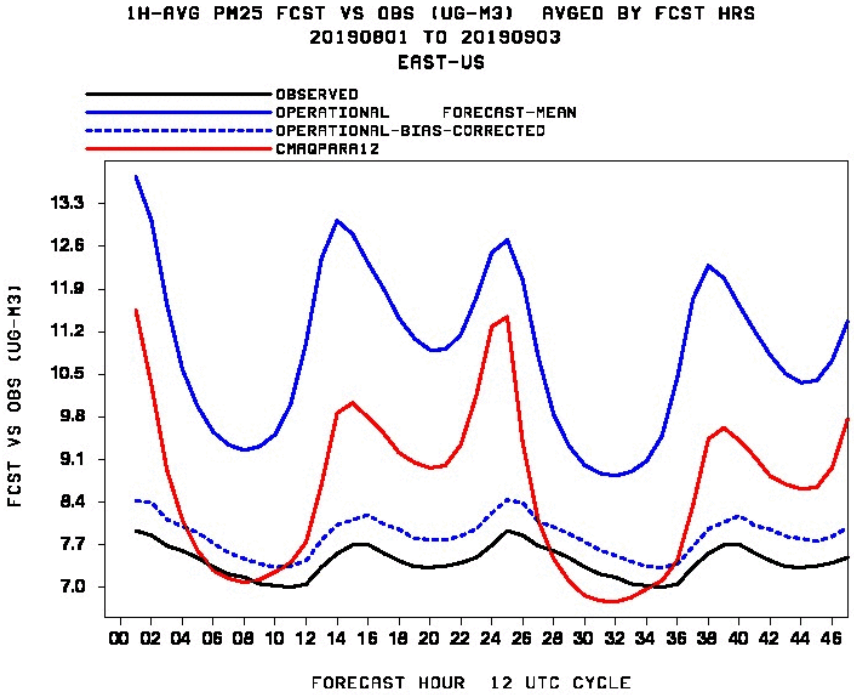
Performance of Ozone predictions:
Daily 8 hr max mean bias, August 2019



Performance of PM predictions:
Observed Vs predicted 1 hr averaged Diurnal variability, August 2019

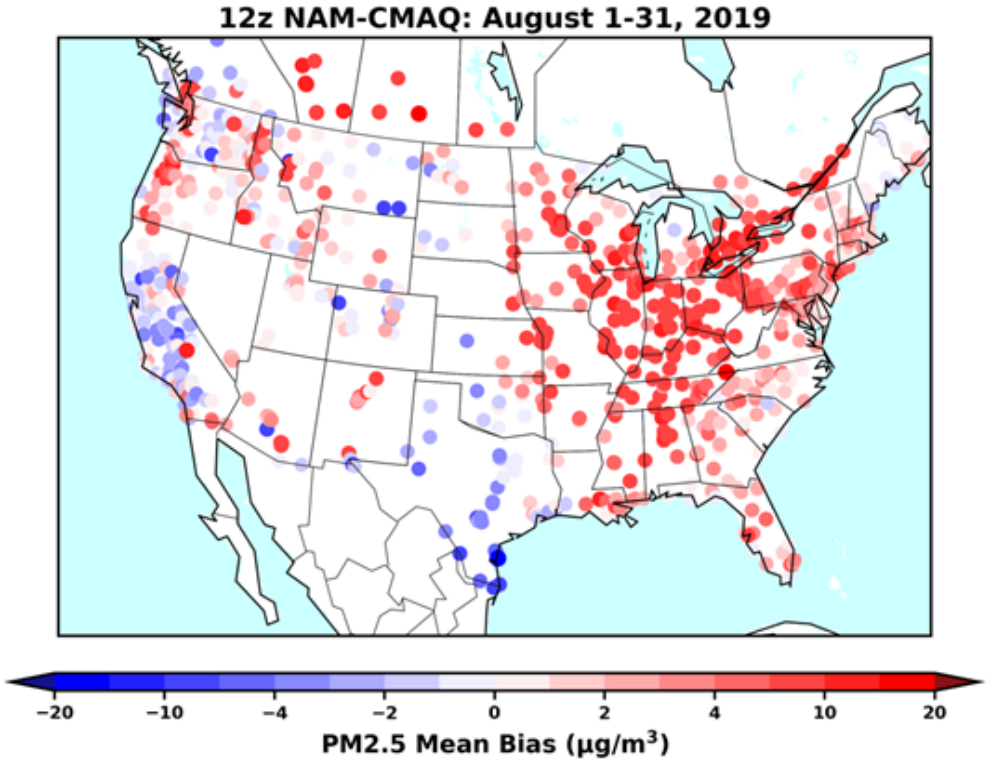


Western U.S.



Eastern U.S.

Performance of PM predictions:
1 hr daily max PM2.5 August 2019 Monthly Average Bias

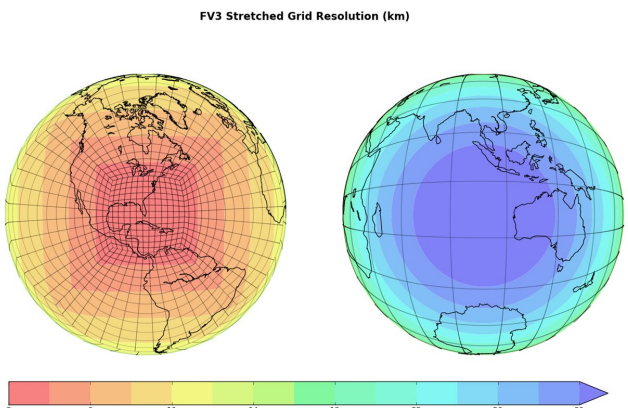


NAQFC Future updates and work in progress

- Couple and drive CMAQ with FV3GFS, NOAA's Next Generation Global Prediction System.
- Extend the range of CMAQ predictions from 48 hours to 72 hours
  - Including the KFAN/Bias corrected products
- Updates to fire emission scheme (Global Biomass Burning Emissions Product eXtended (GBBEPx)
- Use of GEFS-Aerosols for lateral boundary conditions
- Develop new probabilistic forecast product for ozone and PM2.5
- Working on initiating display of operational PM 2.5 products on NWS websites and ozone bias correction on GIS web services

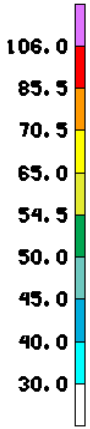
Transitioning to FV3GFS-CMAQ

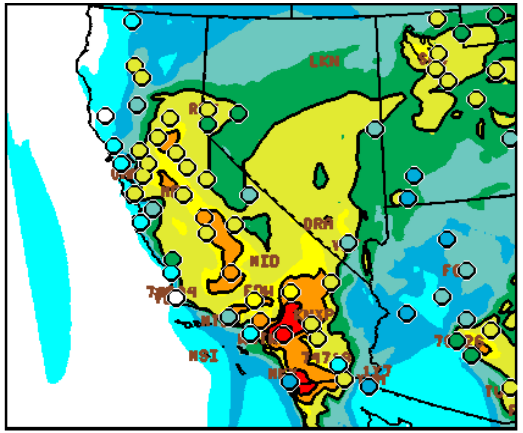
- The new dynamic core, Finite-Volume on a Cubed-Sphere (FV3)
- NOAA next generation global prediction system
- Allows for higher resolution and extension of weather forecast through 14 days
- Implemented last June



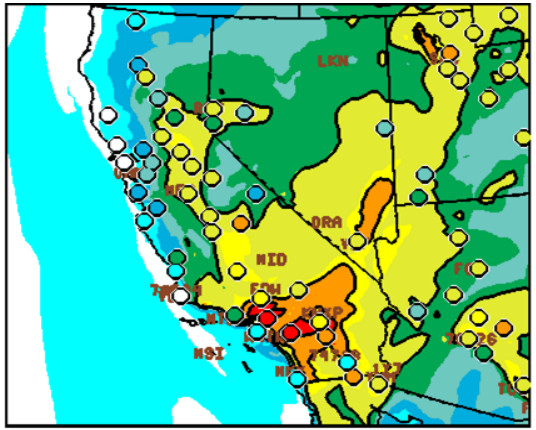
noaa.gov

CMAQ Ozone driven by FV3GFS 13 km

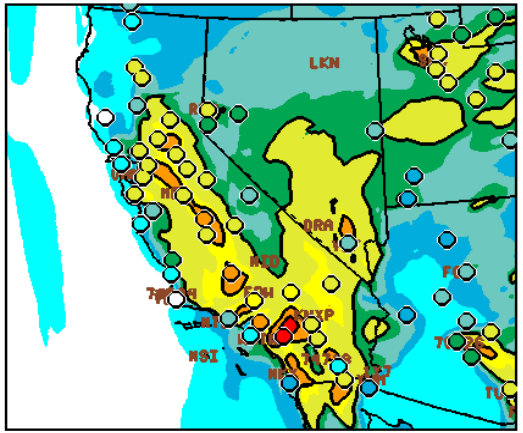




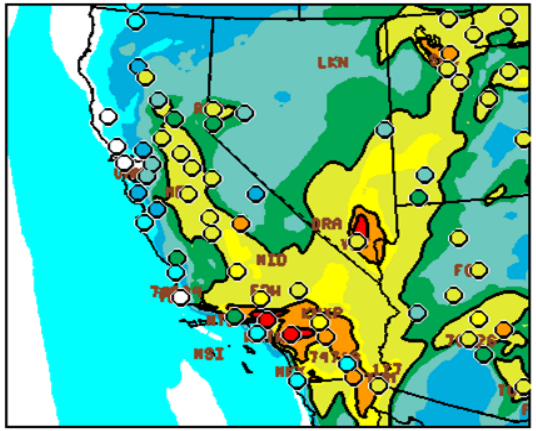
FV3GFS V502 PARA12 DAY1 OZMX08 (PPB) 20190813 12Z CYC



FV3GFS V502 PARA12 DAY2 OZMX08 (PPB) 20190820 12Z CYC



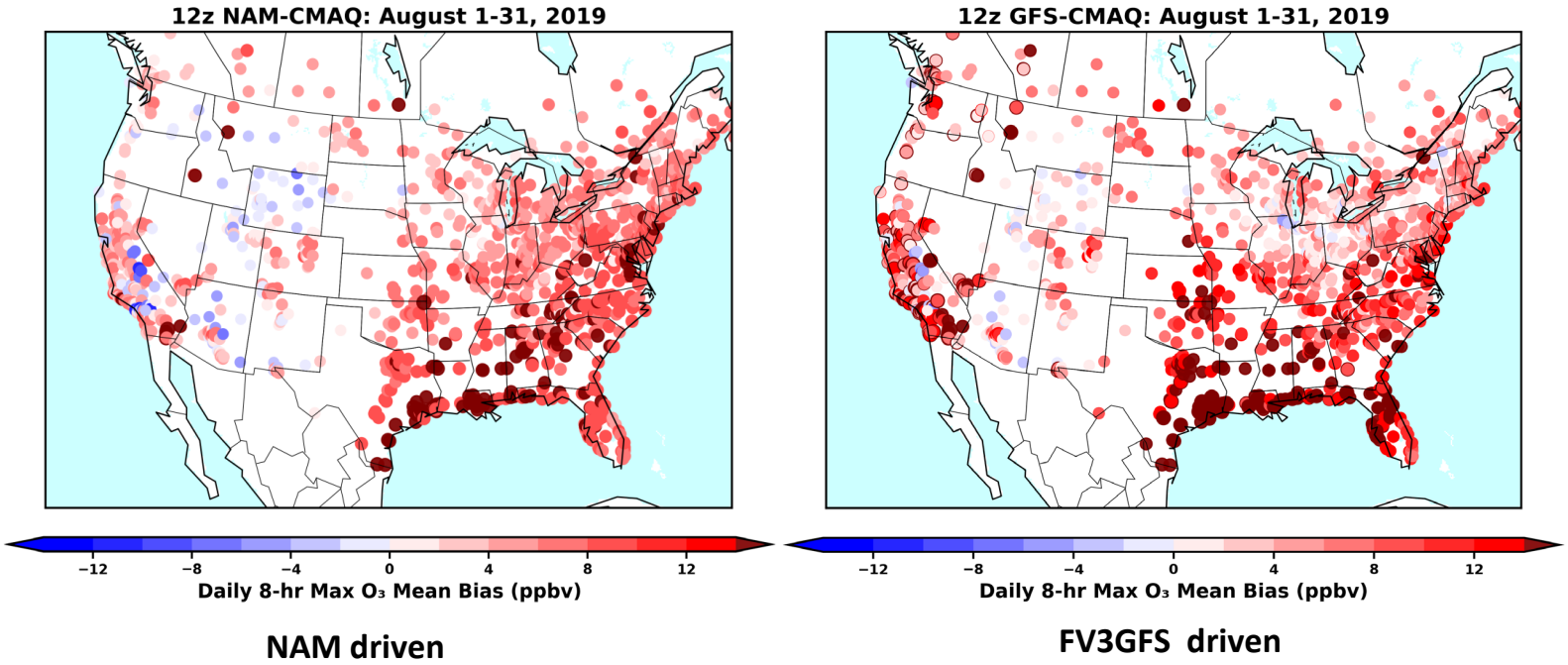
NAM V502 PROD DAY1 OZMX08 (PPB) 20190813 12Z CYC



NAM V502 PROD DAY2 OZMX08 (PPB) 20190820 12Z CYC

- FV3 and operational predictions are similar

8 hr daily max Ozone (day 1)
August 2019 Monthly Average Bias



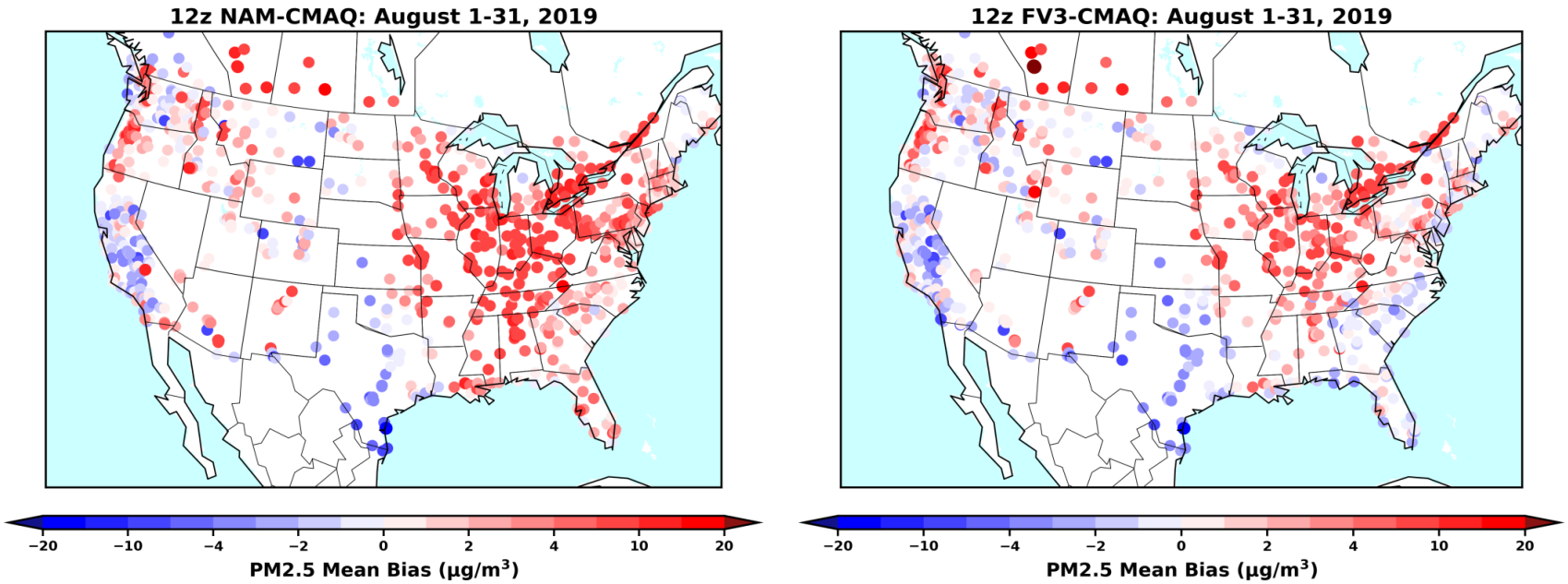
NAM driven

FV3GFS driven

Both models over predict Ozone, for FV3-CMAQ in SE and Mid-Atlantic slightly larger over prediction

Jianping Huang, EMC
Benjamin Yang, PSU

1 hr daily max PM2.5
August 2019 Monthly Average Bias



Both models over predict PM over north
FV3-CMAQ: under prediction over south

Jianping Huang, EMC
Benjamin Yang, PSU

Global Biomass Burning Emissions Product eXtended (GBBEPx)

- Currently also testing a new fire emissions scheme with FV3GFS-CMAQ
- GBBEPx calculates biomass burning emissions from wildfires using the Fire Radiative Power (FRP) derived from satellites.
- Uses observations from MODIS, VIIRS and Geostationary satellites like GOES
- Developed by NOAA, NESDIS and scientist from NASA and South Dakota State University
- Currently testing 2 configurations in near real time and a retrospective run from last year's Camp fire event in California
- We also participated in this year multiagency Fire Influence on Regional to Global Environments and Air Quality (FIREX-AQ) field campaign and will be using the data to evaluate our system

Case study
GBBEPx Mean Fire Radiative Power

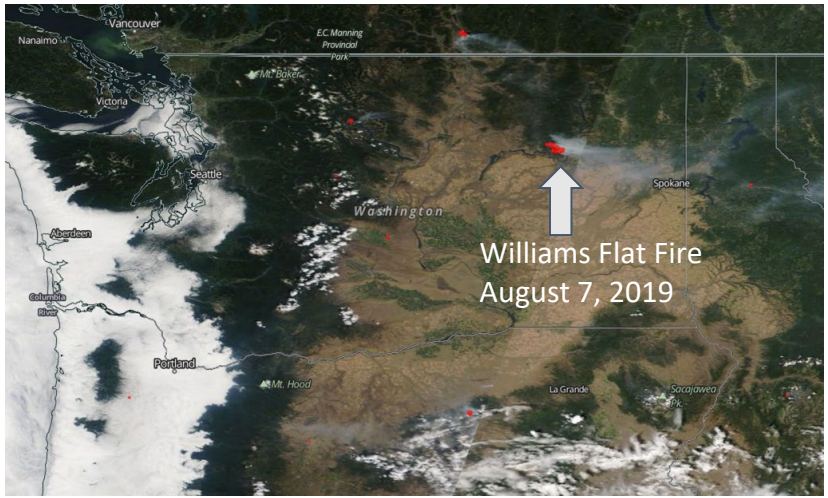
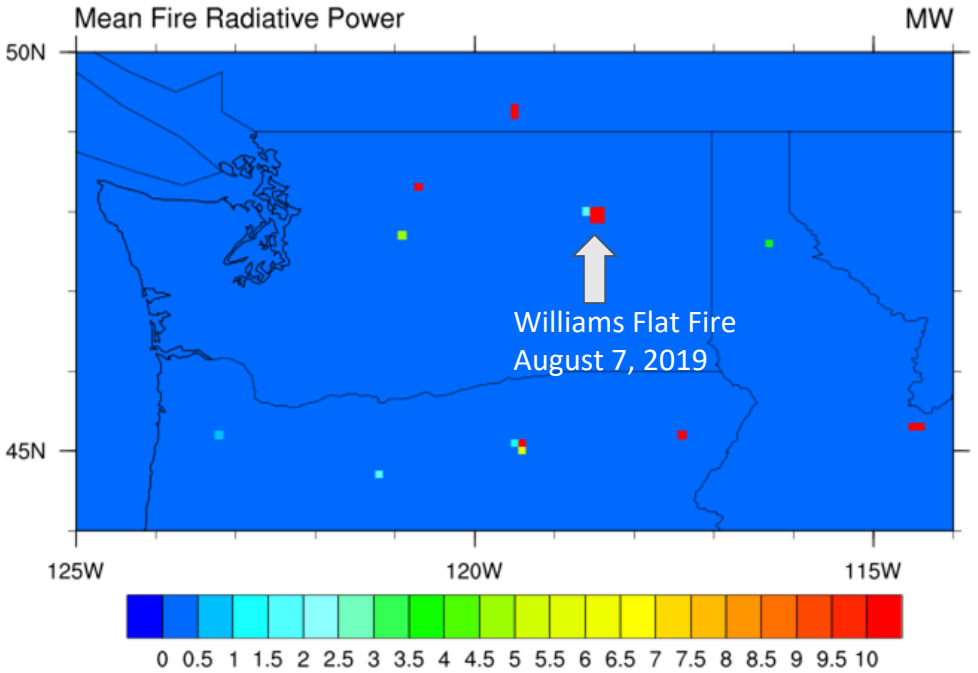
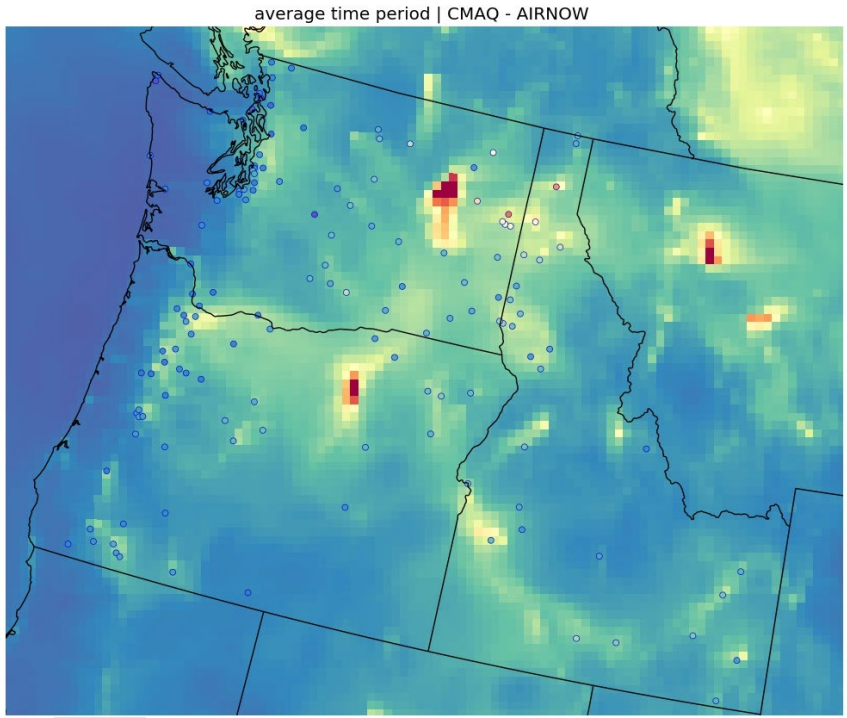


Image credit: NASA

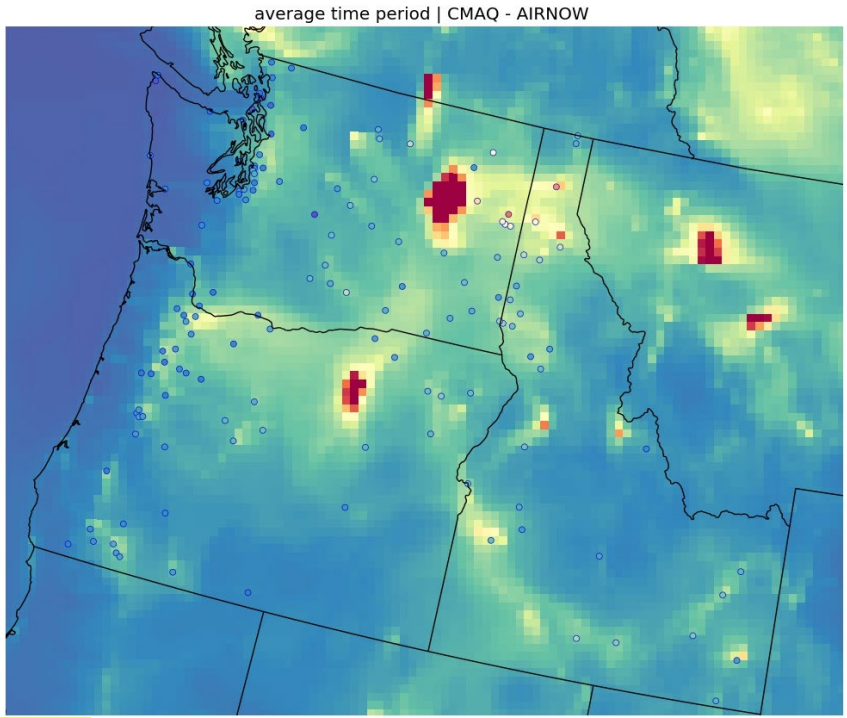


Suomi NPP satellite natural-color image using the VIIRS (Visible Infrared Imaging Radiometer Suite)

CMAQ-AIRNOW $PM_{2.5}$ Evaluation - Region 10



Exp#2



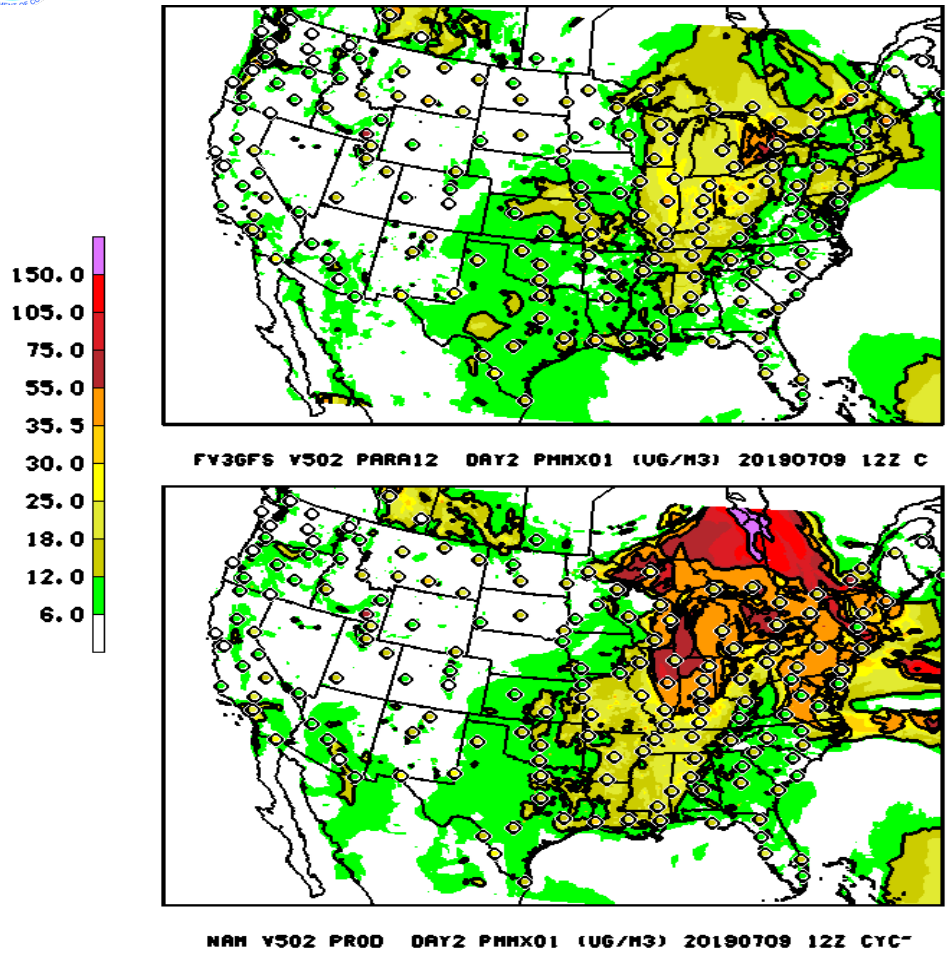
Exp#4

MONET
AIR RESOURCES LABORATORY

Average of 24-hr forecasts for 2019-08-06_13 to 2019-08-08_12

ARL AQ team, Experimental product

NAM vs FV3 fire cases



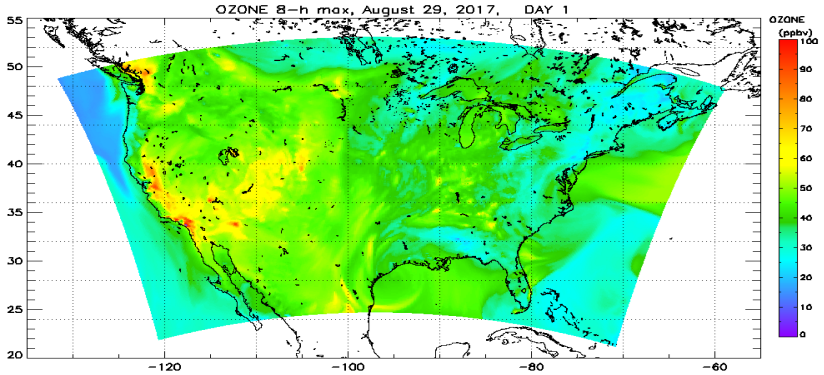
- Para12 GBx run performs best especially during fire events
- FV3 runs under predict over SE away from fires

Probabilistic forecast

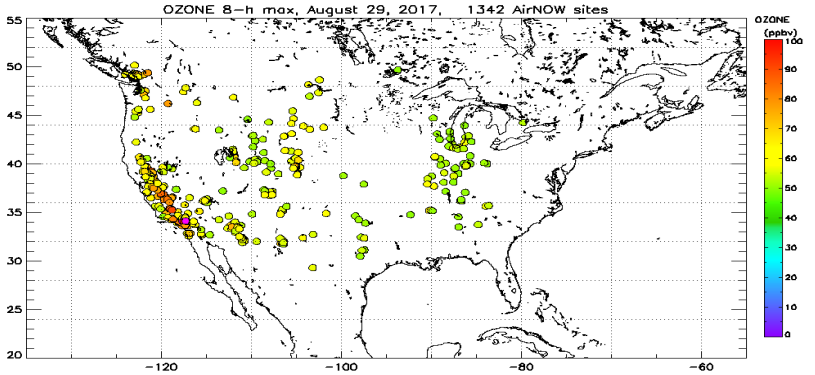
- In collaboration with partners from NOAA Earth System Research Laboratory probabilistic forecast for Ozone and PM2.5 is being developed
- The probabilities are calculated from a climatology first guess of previous CMAQ predictions and computed analogs from AirNOW observation sites around the nation.
- The following are examples for Ozone > 50 ppbv and Ozone > 70 ppbv respectively

Ozone > 50 ppbv

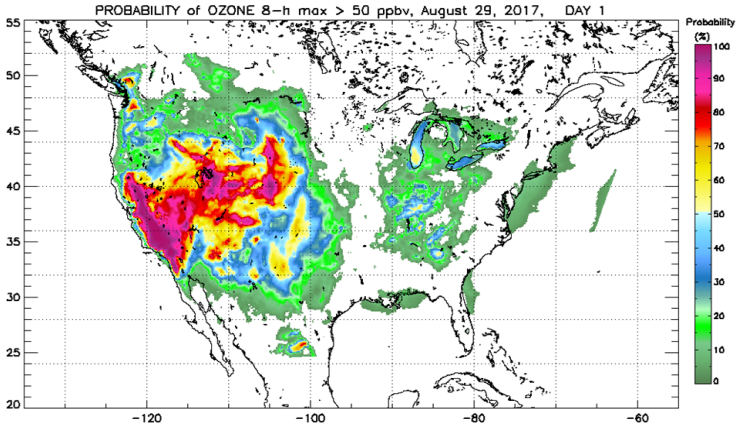
CMAQ guidance



AirNow stations



Probability

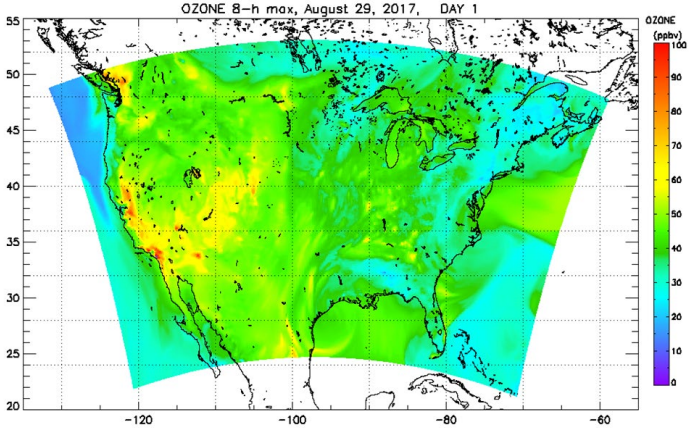


James Wilczak & Irina Djalalova, ESRL

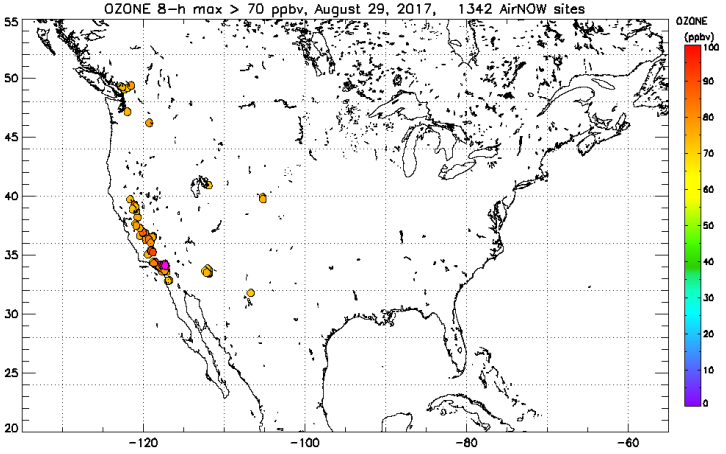
Experimental product

Ozone > 70 ppbv

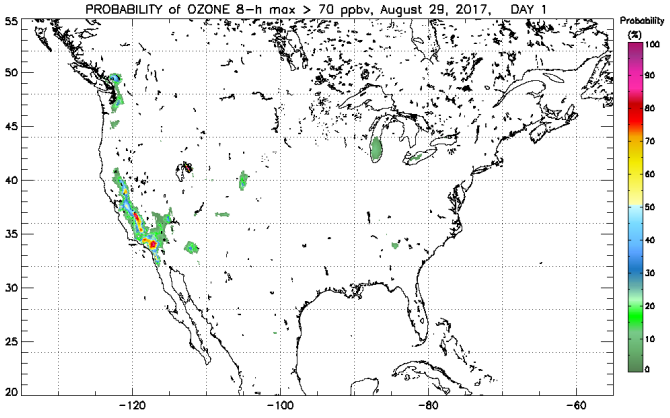
CMAQ guidance



AirNow stations

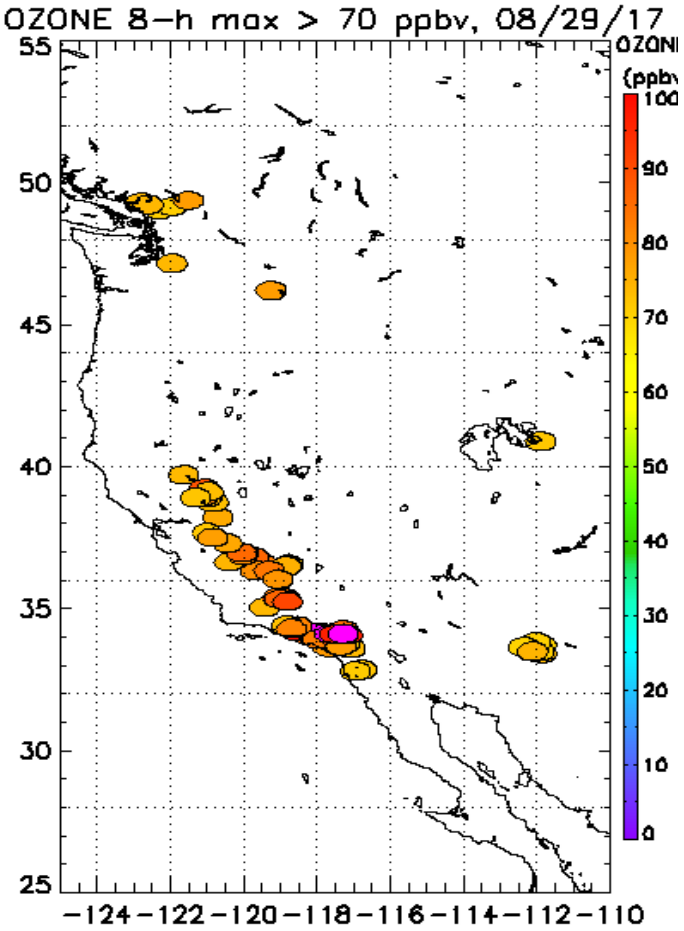


probability



James Wilczak & Irina Djalalova, ESRL

Experimental product


OZONE 8-h max > 70 ppbv, 08/29/17
OZONE
(ppbv)
100
90
80
70
60
50
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10
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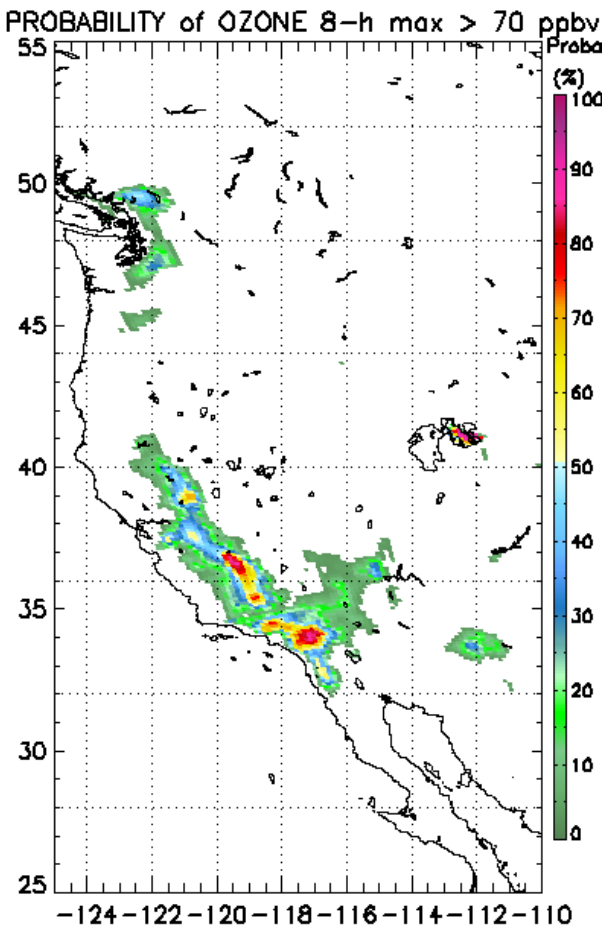
25
-124 -122 -120 -118 -116 -114 -112 -110


August 29, 2017, DAY 1
PROBABILITY of OZONE 8-h max > 70 ppbv
Proba
(%)
100
90
80
70
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50
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30
20
10
0
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-124 -122 -120 -118 -116 -114 -112 -110

Summary

- We provide real time hourly predictions of ozone, particulate matter, smoke and dust to the nation
- Our work relies on a strategic partnership with the Environmental Protection Agency (EPA) and state and local air quality forecasters.
- Our products are freely available online (airquality.weather.gov, others)

December 18 implementation:

- New bias-corrected ozone predictions
- Updated fine particulate matter (PM2.5) bias correction
- Updated anthropogenic emissions from NEI2014v2
- Updated Alaska and Hawaii domain CMAQ code to the same version used for CONUS

Work in progress:

- Future improvements will include coupling of CMAQ with FV3GFS, extension to 72 hour predictions and new fire emissions processing

Thank you for your attention

Questions?

Contact me @ jose.tirado-delgado@noaa.gov

Acknowledgments:
AQF implementation team members

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

NOAA/NWS/STI	***Dorothy Koch***	***STI modeling program lead***
NWS/OD	***Cynthia Jones***	***Data Communications***
NWS/OSTI/MDL	***David Miller, Dave Ruth***	***Dev. Verification, NDGD Product Development***
NWS/STI	***Jose Tirado-Delgado***	***Program Support***
NESDIS/NCDC	***Alan Hall***	***Product Archiving***

NWS/NCEP

Ivanka Stajner, Jeff McQueen, Jianping Huang, Ho-Chun Huang	**AQF model interface development, testing, & integration**
Jun Wang, Li Pan, *Sarah Lu	**Global dust aerosol and feedback testing**
***Brad Ferrier, *Eric Rogers,**	**NAM coordination**
***Hui-Ya Chuang, Perry Shafran, Boi Voung**	
Geoff Manikin	**Smoke and dust product testing and integration**
Rebecca Cosgrove, Steven Earle, Chris Magee	**NCO transition and systems testing**
Mike Bodner, Andrew Orrison	**HPC coordination and AQF webdrawer**

ESRL/PSD

Jim Wilczak, Irina, Djalalova, Dave Allerud,	***bias correction development***

NOAA/OAR/ARL

Pius Lee, Daniel Tong, Youhua Tang	**CMAQ development, adaptation of AQ simulations for AQF**
Barry Baker, Patrick Campbell	
Ariel Stein	**HYSPLIT adaptations**

NESDIS/STAR	***Shobha Kondragunta***	***Smoke and dust verification product development***
NESDIS/OSDPD	***Liqun Ma***	***Production of smoke and dust verification products***

EPA/OAQPS ***partners:***

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

* Guest Contributors