



**NATIONAL
WEATHER
SERVICE**

Update of the AQM operational forecast systems for the National Air Quality Forecasting Capability

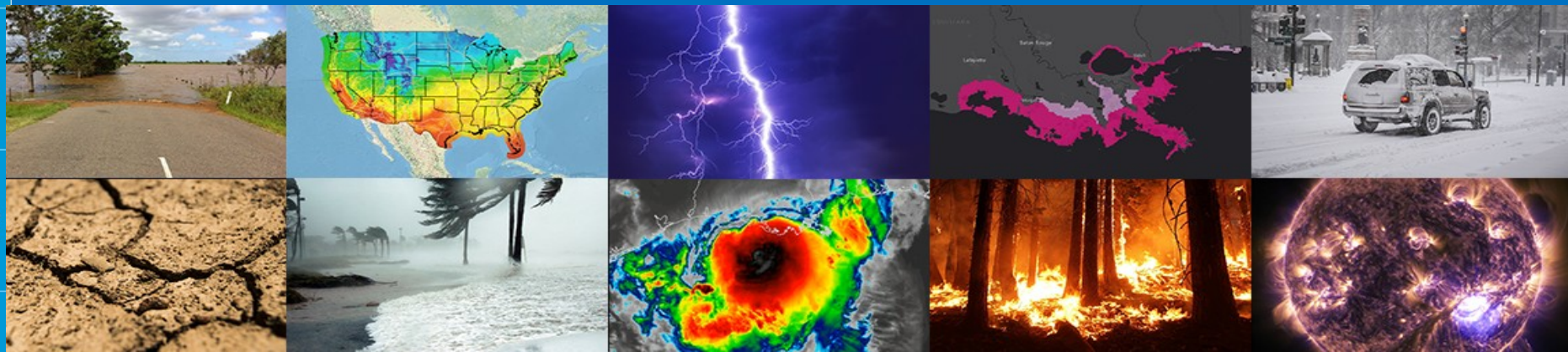
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2024 AQ Forecaster Focus Group Workshop

College Park, MD, October 10, 2024



Outline

- AQM v7.0.7 Implementation (May 14, 2024)
 - Major Changes
 - Model Configurations
 - Performance Highlights
- AQM v7.0.8 Implementation (October 1, 2024)
 - Major Changes
 - Performance Highlights
- AQM v8.0 Development (Planned for Q1 2026)
 - Major Changes Proposed
 - Preliminary Results
- Future Plans

Major Changes for AQM v7.0.7

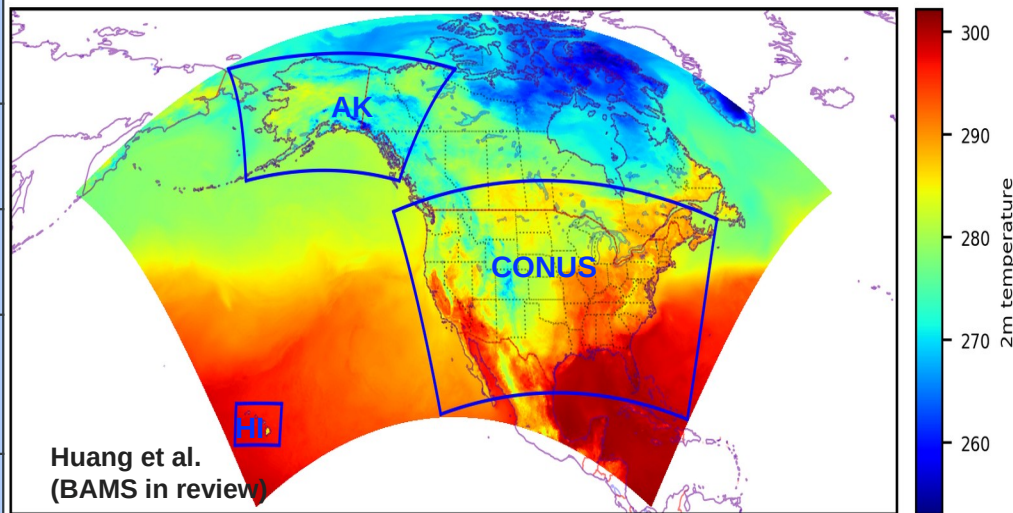
- Transition operational AQM from the GFS-CMAQ offline-coupled system to a UFS-based online-coupled atmosphere-air quality system, UFS-AQM.
- Replace individual model domains for CONUS, Alaska, and Hawaii with a single unified domain at 13-km horizontal resolution.
- Increase the model's vertical levels from 35 to 65 and extending the model's top from 60 hPa to 0.2 hPa.
- Replace daily Blended Global Biomass Burning Emissions Product (GBBEPx) inputs with hourly Regional ABI and VIIRS fire Emissions (RAVE) data at higher horizontal resolution (0.03 degrees) to improve diurnal variation, intensity, and vertical distribution of wildfire emissions.
- Replace the Biogenic Emissions Inventory System (BEIS) with aerosol and gaseous emissions estimated using the Model of Emissions of Gases and Aerosols from Nature (MEGAN).
- Apply the Kalman Filter Analog (KFAN) bias correction technique over the large unified domain to improve near-surface ozone (O₃) and fine particulate matter (PM_{2.5}) predictions.



Model Configurations for the AQMv7.0.7 Implementation



Atmos. & air quality models	UFS-Atmos + CMAQv5.2 Online-coupling
Gas mechanism & aerosol model	CB6r3 + Aero6
Grid_spacing & vertical levels	13 km & 65 levels (topped at 0.2 hpa)
Anthropogenic emissions	NEI 2016v1 for CONUS + EDGAR-for-HTAPv2, CEDSv2 & OMI-HTAP for O-CONUS
Fire emissions	RAVE v1 (hourly, 0.03 deg) + Sofiev plumerise algorithm, linearly-distributed, VOCs off
Biogenic & dust emissions	MEGANv2 & Fengsha
Dynamics & physics	FV3 & CCPP GFSv16 suite
Chem-LBCs	AM4 for gases + GEFS for aerosols



- A single large North American domain covers three operational product domains (i.e., CONUS, AK and HI)
- NOAA's UFS-AQM based AQMv7.0.7 was implemented on May 14, 2024

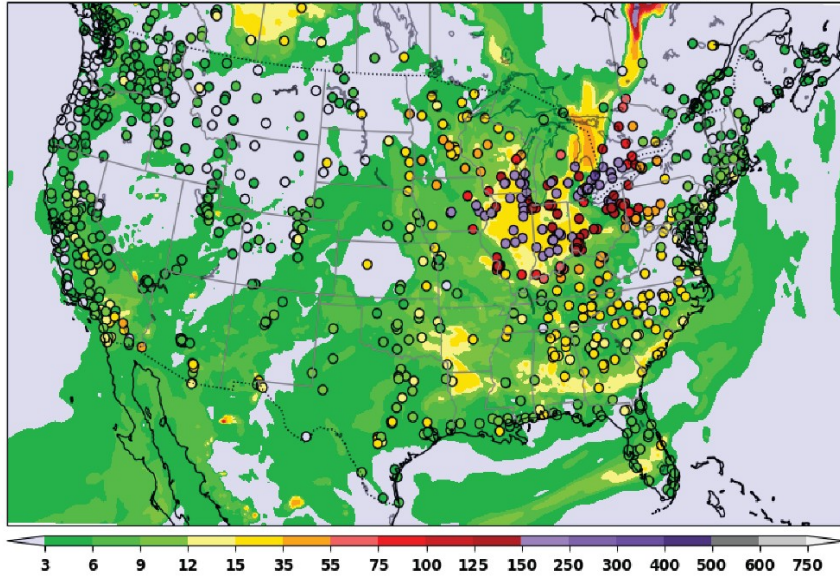




AQMv6 (GBBEPx) vs. AQMv7.0.7 (RAVE v1): PM_{2.5} Predictions

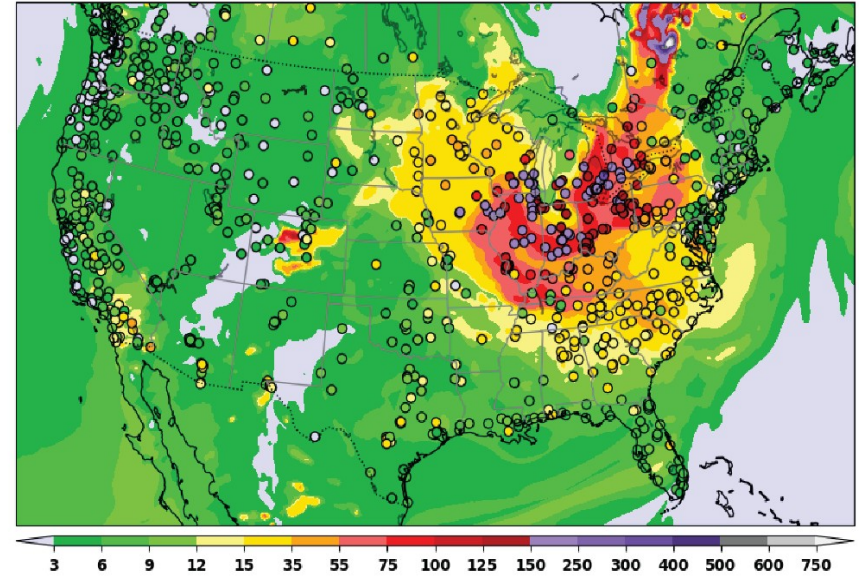


AQMv6 20230626 t06z
20230628/0600V048 PM25 sfc_conc ($\mu\text{g}/\text{m}^3$)



(a)

AQMv7 20230626 t06z
20230628/0600V048 PM25 sfc_conc ($\mu\text{g}/\text{m}^3$)



(b)

Huang et al. (BAMS submission, 2024)



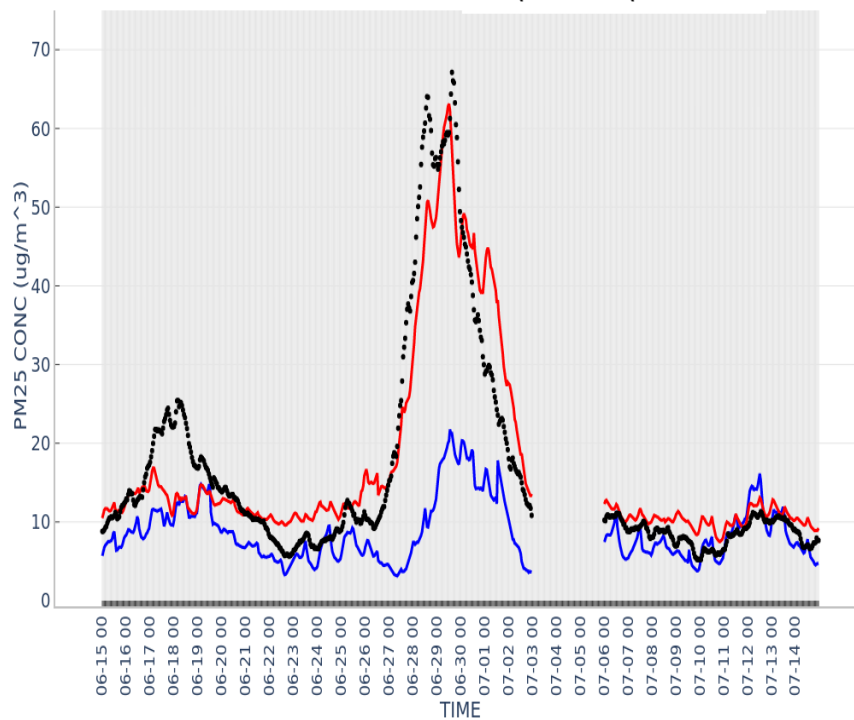


AQMv7 Improves PM_{2.5} during Quebec Fire 2023

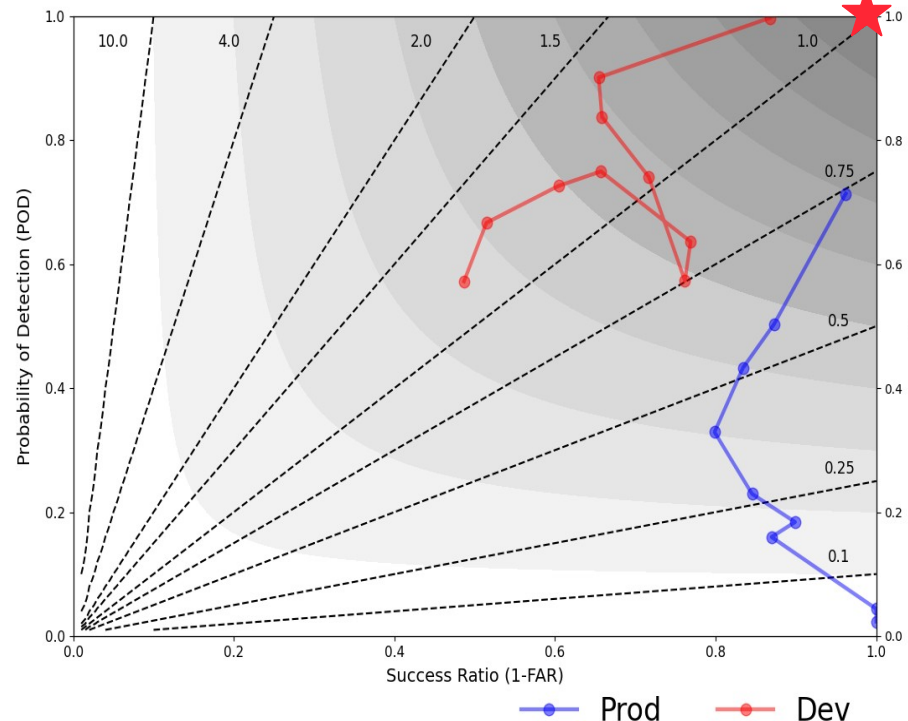


PM25_TIME_SERIES_DAY2_fcst_init12Z_0615_0714 - CONUS_East

— AQMv6 — AQMv7 • OBS



PMAVE_PERFORMANCE_DAY2_fcst_init12Z_0615_0714 - CONUS_East

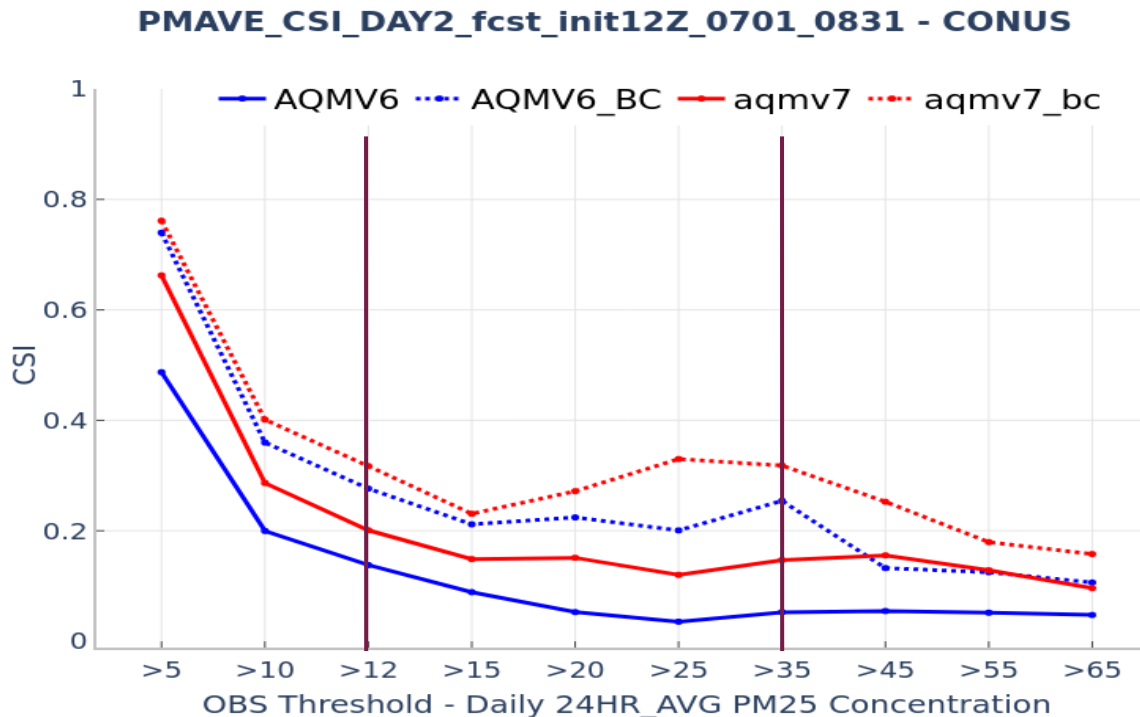


Prod Dev
Fbias-Dash Line, CSI-Shaded, Obs Threshold = 5,10,12,15,20,25,35,45,55,65



AQMv7.0.7 Improves 24-hr ave. PM_{2.5} in Summer

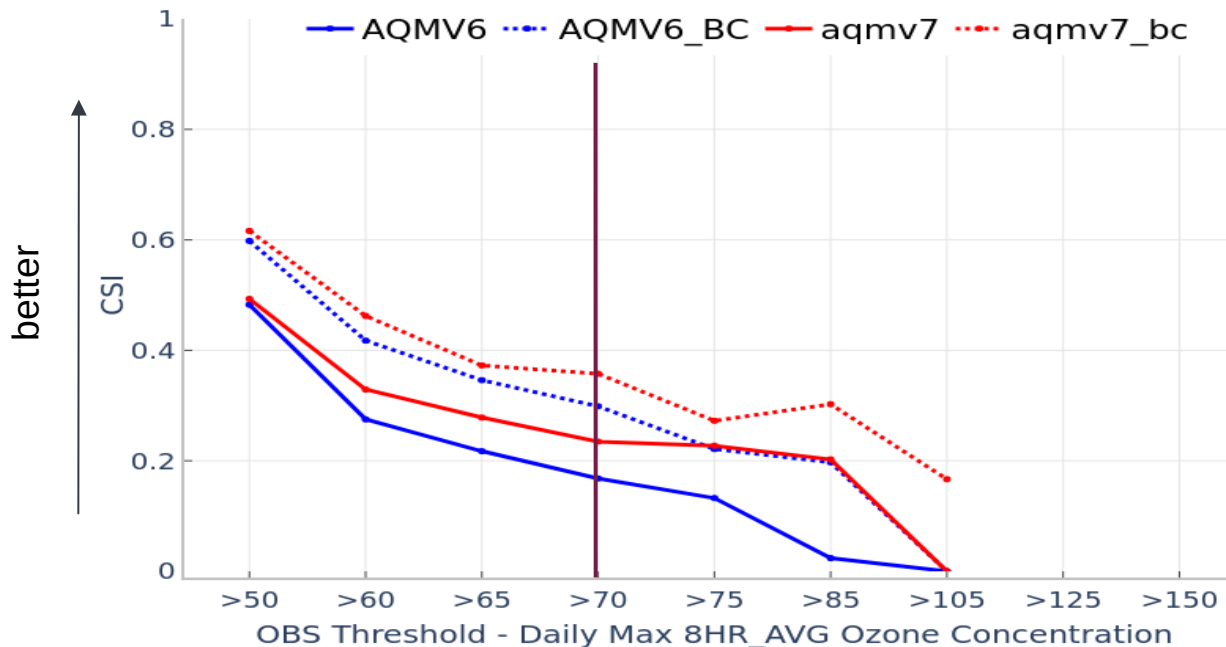
- AQMv7 demonstrates higher CSI values for 24-hr ave. PM_{2.5} for both the raw model and bias-corrected (BC) products (dashed) than AQMv6.
- AQMv7 exhibits enhanced predictive capabilities for PM_{2.5} exceedance events ($\geq 35 \mu\text{g}/\text{m}^3$).



AQMv7.0.7 Improves O₃ Exceedance Predictions in Summer

- AQMv7 demonstrates higher Critical Success Index (CSI) values for daily max. 8-hour ave. O₃ for both the raw model (solid) and bias-corrected (BC) products (dashed) than AQMv6.
- AQMv7 exhibits enhanced predictive capabilities for O₃ exceedance events (≥ 70 ppb).

OZMAX8_CSI_DAY2_fcst_init12Z_0701_0831 - CONUS



Upgrade of the AQM Operational System: v7.0.8

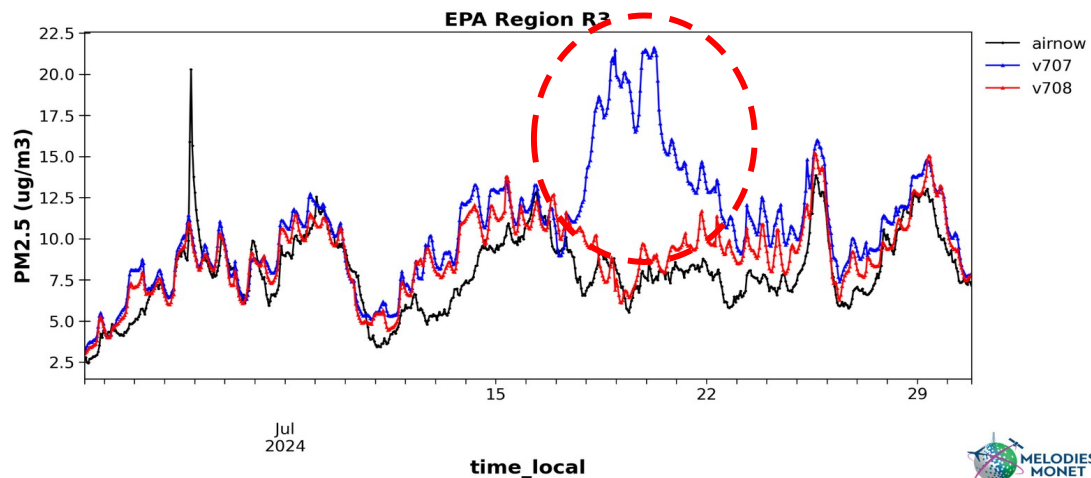
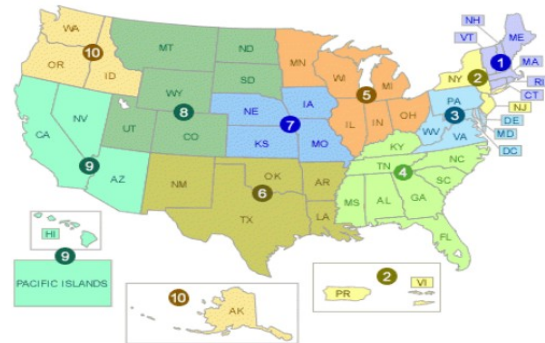
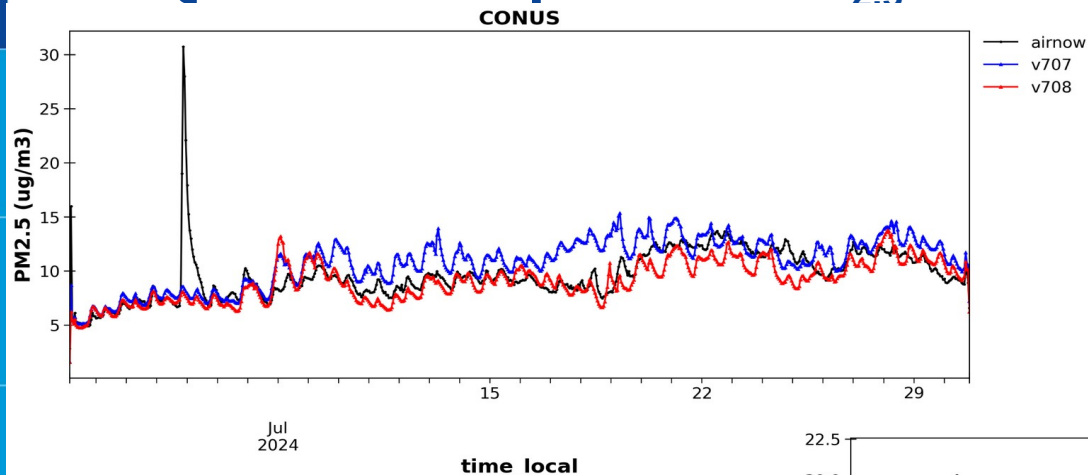
- **Major Changes:**

- Update the Regional hourly Advanced Baseline Imager (ABI) and Visible Infrared Imaging Radiometer Suite (VIIRS) Emissions (RAVE) input datasets from version 1.3 to version 2.0, which use observations from NOAA's latest generation of U.S. polar-orbiting satellites (NOAA-21).
- Update the list of AirNow's observational surface sites for ozone (O_3) and fine particulate matter ($PM_{2.5}$) to improve bias-corrected products.
- Mitigate overprediction of fugitive dust.
- Increase accuracy of predicted dry deposition velocities for small gravitational settling and aerodynamic resistance values.
- Implement bug fixes and other code improvements.

- **Implemented:** Oct. 1, 2024



AQMv7.0.8 Improves PM_{2.5} Predictions in July 2024





Proposed Changes for AQM v8.0



- Increase model grid-spacing resolution from 13-km to 9-km.
- Update the Finite-Volume Cubed-Sphere (FV3) dynamical core based UFS-Atmosphere model.
- Upgrade the Common Community Physics Package (CCPP) to align with the version used in the Global Forecast System (GFS) v17.
- Upgrade CMAQ from version 5.2.1 to version 5.4.
- Update the National Emission Inventory (NEI) from 2016 to 2019.
- Refine fire emission representations and activate Volatile Organic Compound (VOC) emissions from wildfires.
- Implement a short training period for $\text{PM}_{2.5}$ bias correction during intense wildfire events.
- The implementation is planned for December 2025.

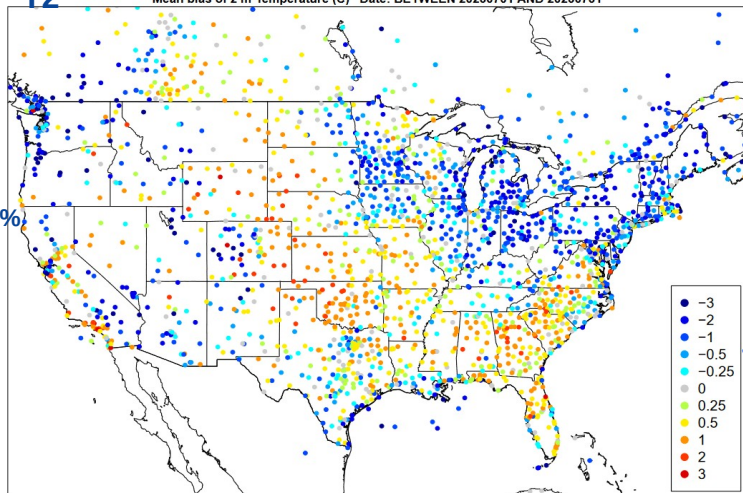




T2

Mean bias of 2 m Temperature (C) Date: BETWEEN 20230701 AND 20230731

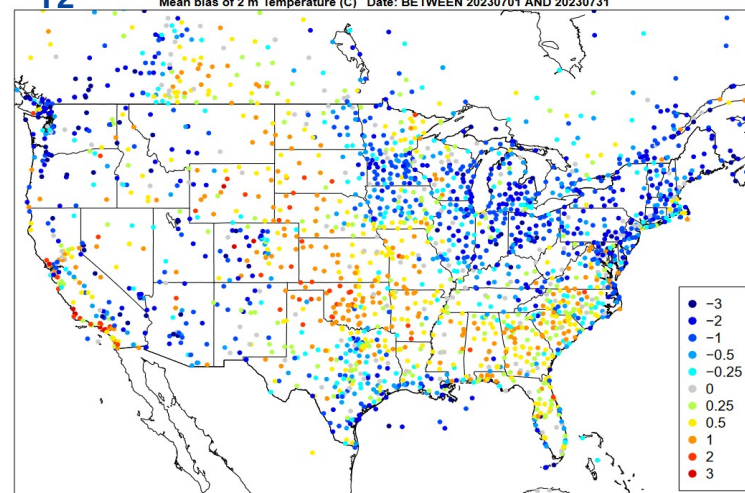
Bias
-0.03%



T2

Mean bias of 2 m Temperature (C) Date: BETWEEN 20230701 AND 20230731

Bias
-0.04%

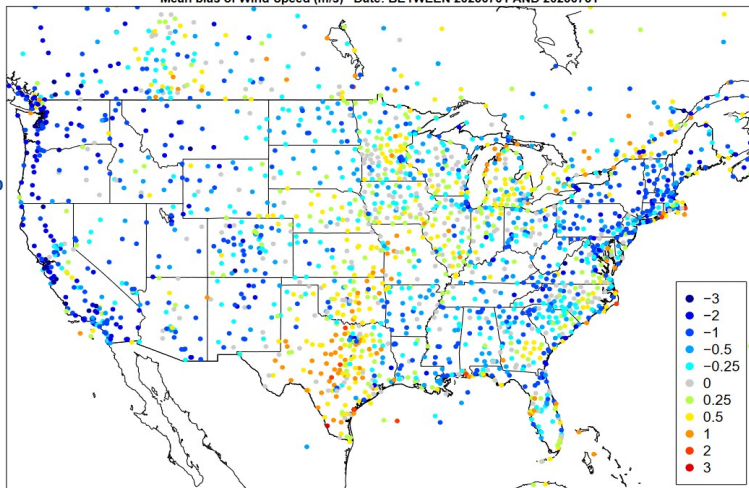


WS10

Mean bias of Wind Speed (m/s) Date: BETWEEN 20230701 AND 20230731

AQM v7

Bias
-11.2%

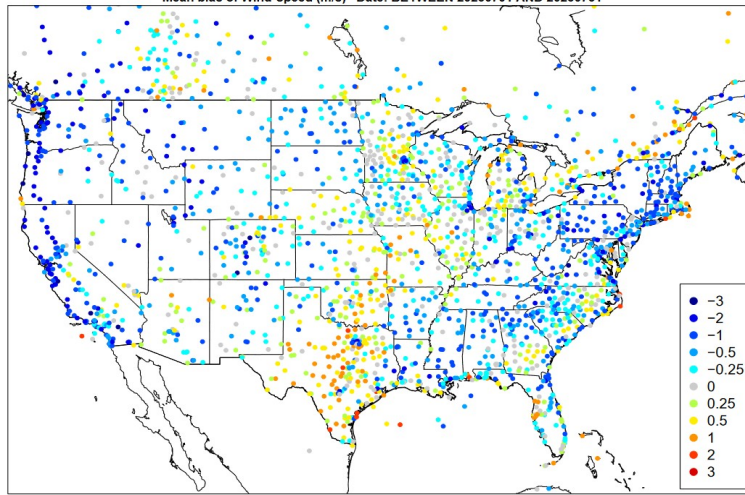


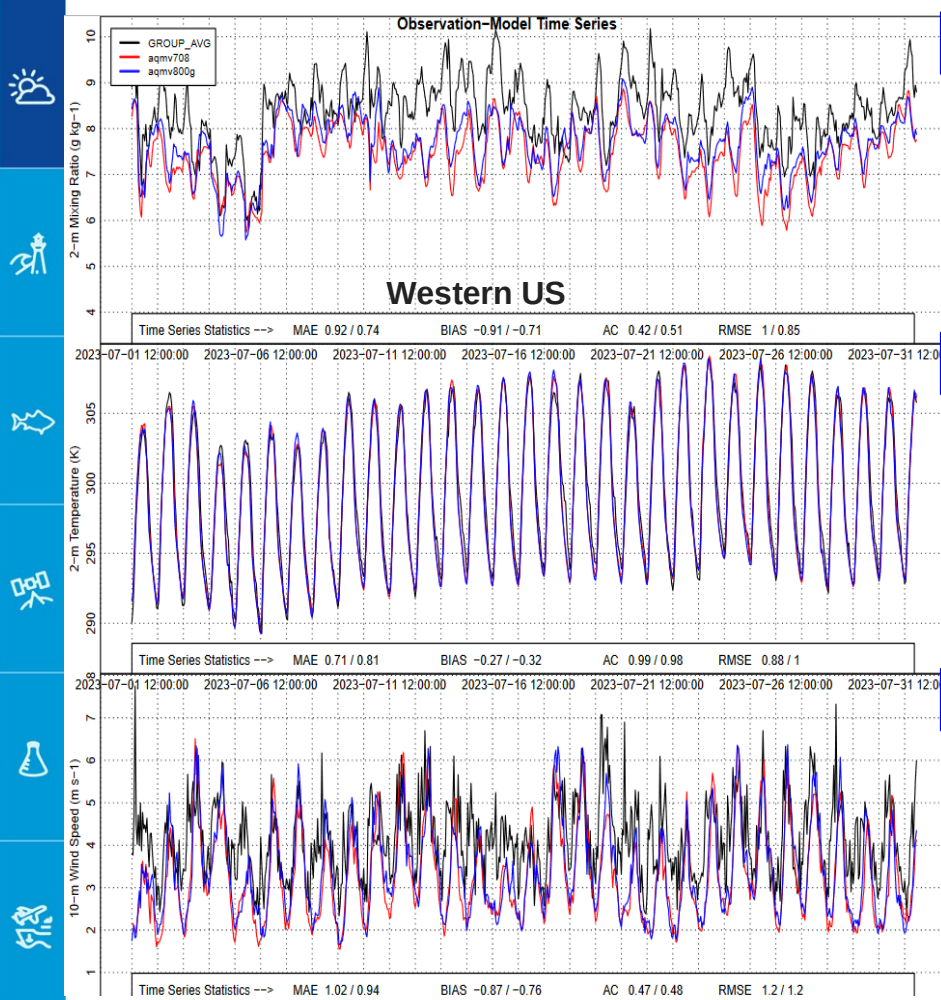
WS10

Mean bias of Wind Speed (m/s) Date: BETWEEN 20230701 AND 20230731

AQM v8

Bias
-8.3%

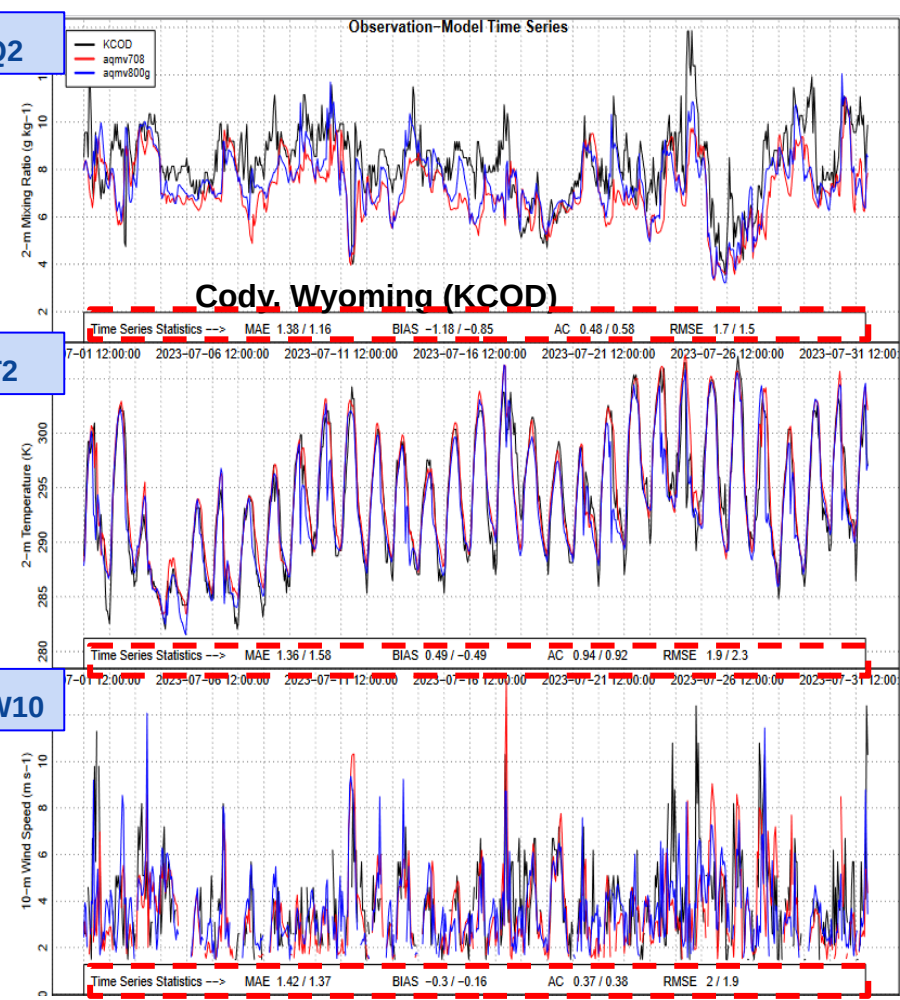




Q2

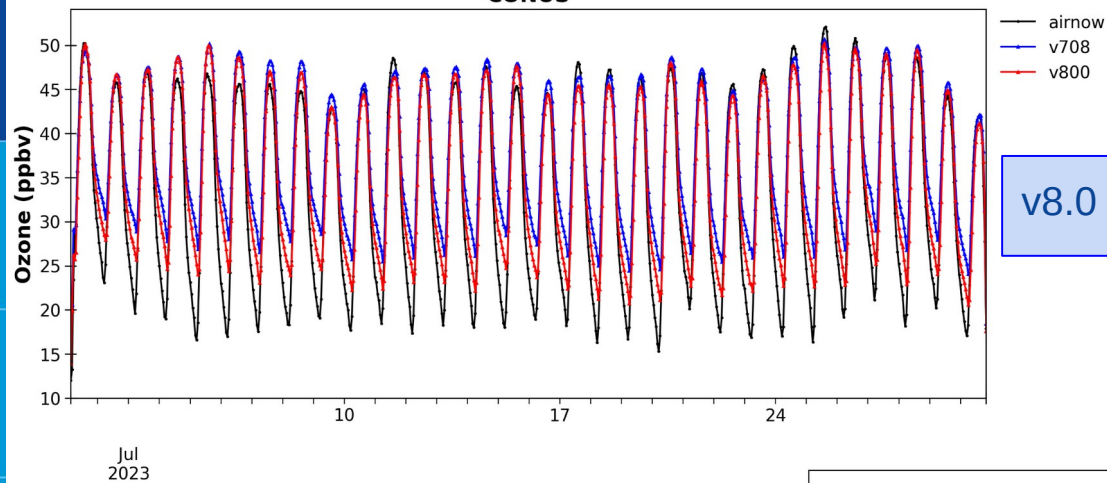
T2

W10





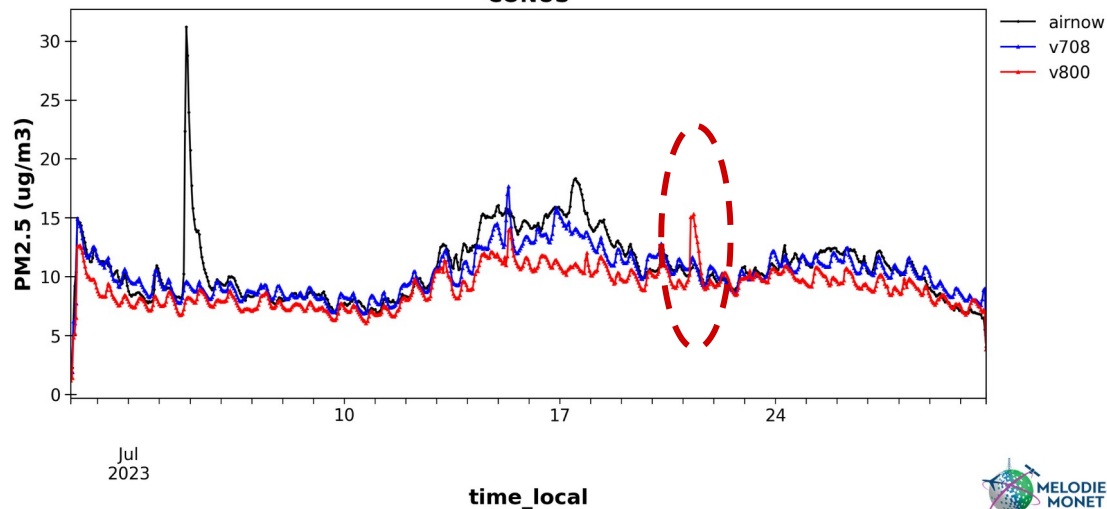
CONUS



v8.0 improves O₃ predictions (e.g., nighttime)

v8.0: dust module
requires refinement

CONUS





Summary

- The UFS based online-coupled [AQMv7.0.7](#) was successfully implemented on May 14, 2024, showing substantial improvements in performance during intense wildfires and O₃ exceedance events.
- An updated version ([AQMv7.0.8](#)) was implemented along with code bug fixes to support the upgrade of RAVE v2 fire emission products on Oct. 1, 2024.
- Development of **AQM v8.0** is underway by refining model grid-spacing, upgrading CMAQ, the UFS-Atmosphere model, and the National Emission Inventory, with implementation **planned for Q1 FY 2026 with a possible delay.**



Future Plans

- Incorporate data assimilation (i.e., **JEDI**) to constrain chemical initial conditions.
 - Use Tropospheric Monitoring Instrument (TROPOMI) and Tropospheric Emissions: Monitoring of Pollution (TEMPO) retrieval data to constrain ICs of NO_2 , O_3 , and other chemical species
 - Use AirNow surface $\text{PM}_{2.5}/\text{O}_3$ and satellite-retrieved AOD to constrain ICs of $\text{PM}_{2.5}/\text{O}_3$
- Switch to the MPAS dynamic core.
- Employ higher resolution (e.g., 3-km) or nested domain for CONUS.
- Develop an AI/ML based forecast model for AQM.