Improving Prediction of Wildfire Impacts on Air Quality with the UFS-AQM Online System

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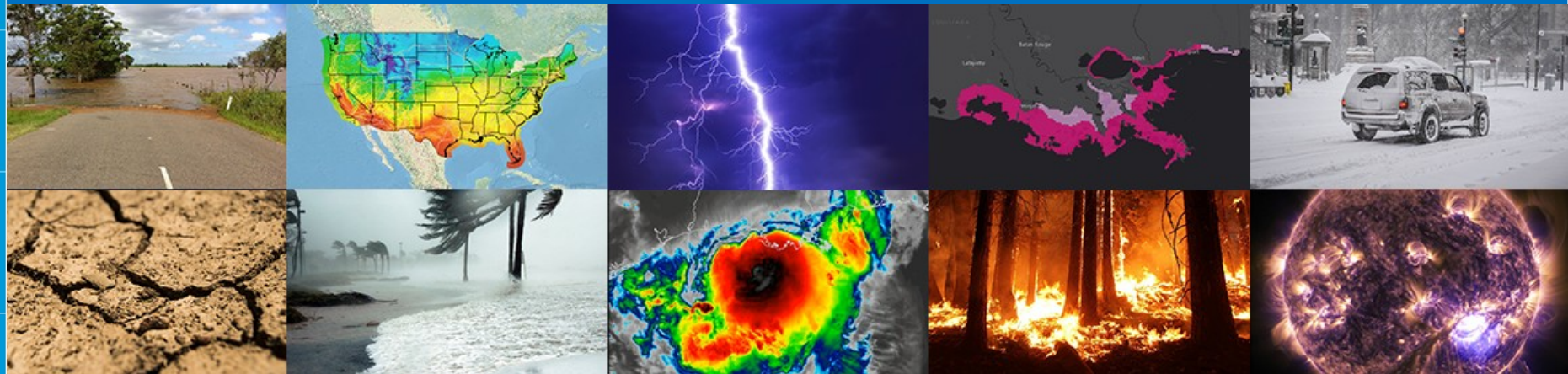


Societal Impacts of Wildfires and Trend of Burning Areas

FLOODING

EVENT, YEAR	COST
1. Midwest flooding (2008)	$12.1B
2. Louisiana flooding (2016)	$10.8B
3. Mississippi River (2011)	$3.5B
4. Houston flooding (2016)	$2.9B
5. Texas/Oklahoma flooding (2015)	$2.8B

WINTER STORMS

EVENT, YEAR	COST
1. Central/Eastern storm (2015)	$3.3B
2. Freeze (2007)	$2.6B
3. Midwest/Eastern storm (2014)	$2.4B
4. Northeast storm (2018)	$2.3B
5. Groundhog Day blizzard (2011)	$2.1B

WILDFIRES

EVENT, YEAR	COST
1. Camp Fire, others (2018)	$24.5B
2. Tubbs Fire, others (2017)	$18.7B
3. Western wildfires (2007)	$3.5B
4. Western/Alaskan wildfires (2015)	$3.3B
5. Western fires/Gatlinburg, TN (2016)	$2.6B

HURRICANES

EVENT, YEAR	COST
1. Hurricane Katrina (2005)	$168.8B
2. Hurricane Harvey (2017)	$130.0B
3. Hurricane Maria (2017)	$93.6B
4. Hurricane Sandy (2012)	$73.5B
5. Hurricane Irma (2017)	$52.0B

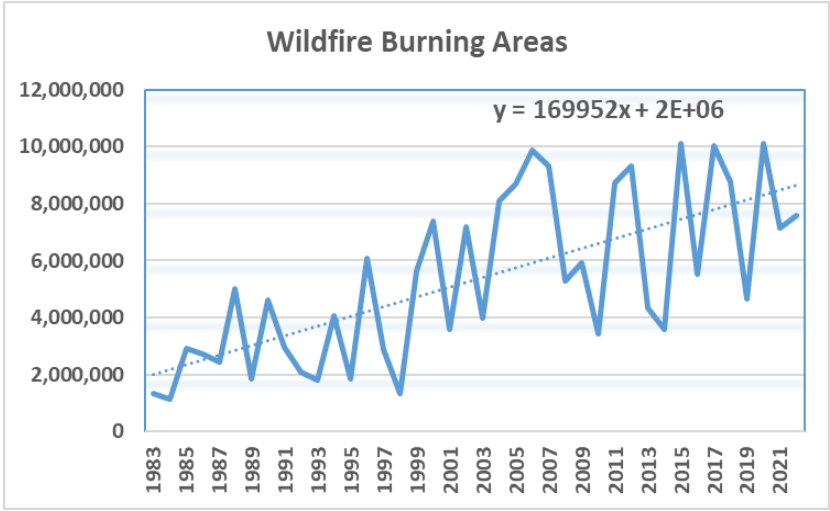
HEAT/DROUGHT

EVENT, YEAR	COST
1. Heat/drought (2012)	$33.9B
2. Southern Plains drought (2011)	$13.9B
3. Western Plains drought (2013)	$11.6B
4. U.S. drought (2008)	$8.6B
5. Midwest Plains drought (2006)	$7.7B

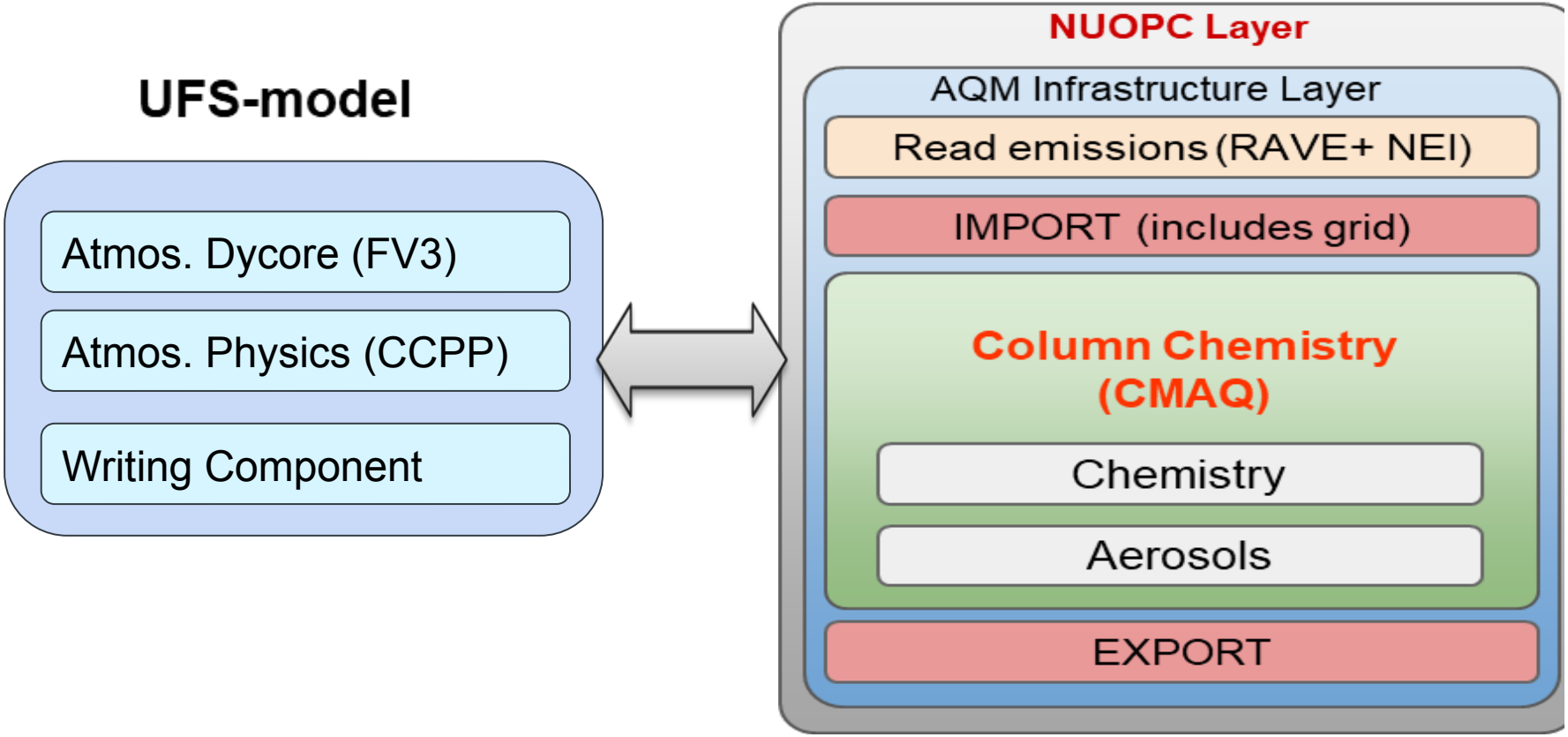
NOTE: Costs from hurricanes Dorian and Imelda (both Sept. 2019) and 2019 Midwest flooding events are still TBD. Costs are in CPI-adjusted dollars.

SOURCE: NOAA

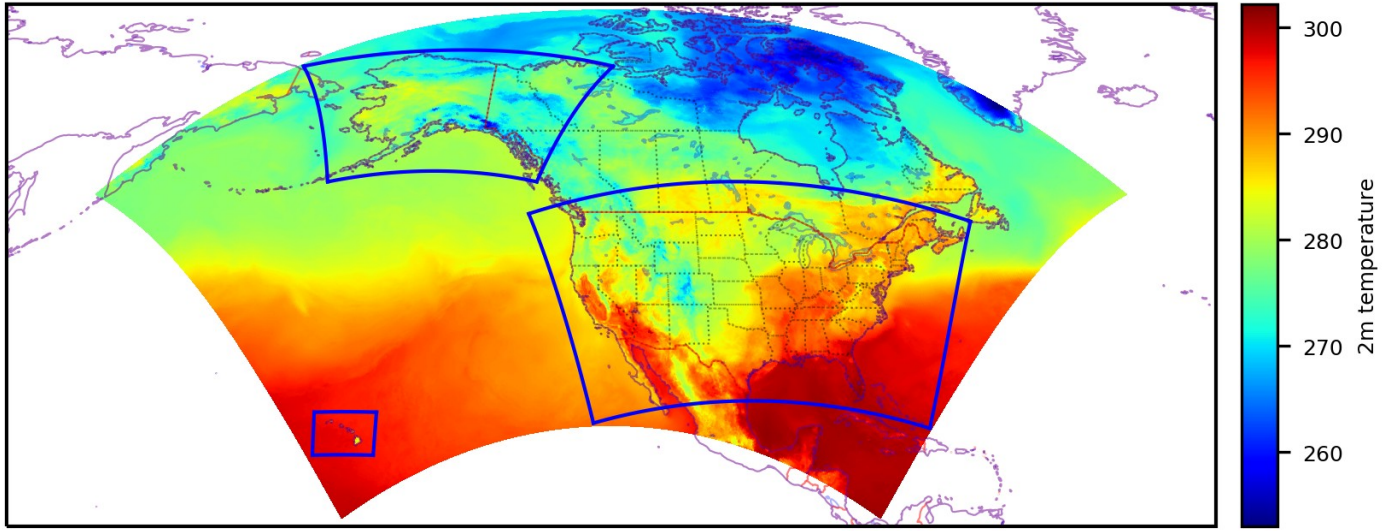
InsideClimate News



Online-CMAQ within the UFS framework



Online-CMAQ (UFS-AQM) in UFS: a single large North American domain (13 km)



The next candidate for operations at 13 km resolution

- **<u>Near-real-time</u> online-CMAQ has been running since July 8, 2022 over the North American large domain that covers all 3 current operational product domains: CONUS, AK and HI.**
- **Updates are being integrated into this near-real-time run.**
- CCPP: GFSv16
- Anthropogenic and biogenic emissions for the large domain (NEIC 2016v1 plus global)
- Hourly RAVE wildfire emissions and Sofiev plume-rise algorithm
- Updated LBC (AM4 + GEFS-Aerosols) and wet deposition
- Fengsha dust module
- Bias correction
- Post-processing for 8h ozone maximum and daily average $PM_{2.5}$

Satellite-detected firepoints and wildfire emissions during Quebec fires in June 2023

- **UFS-AQM (Dev): Near-real-time** **R**egional **A**dvanced Baseline Imager (ABI) and **V**isible infrared Imaging Radiometer Suite (VIIRS) **E**missions (**RAVE**) **hourly** data improved by applying scaling factors based on biome type.
- **Operational (Prod)**: The **B**lended **G**lobal **Bi**omass **B**urning **E**missions **P**roduct version 3 **(GBBEPx** V4)

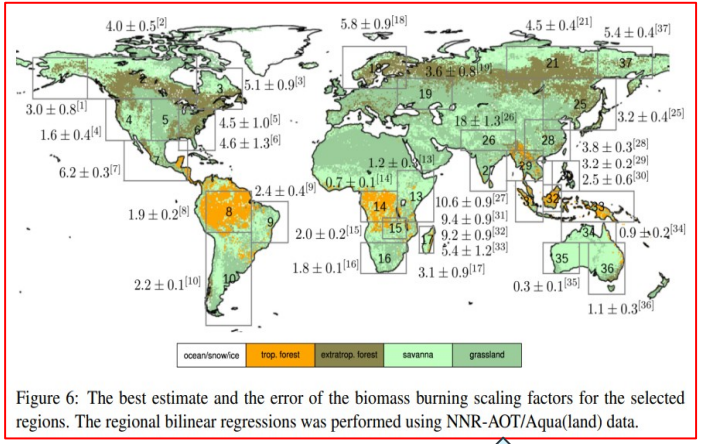
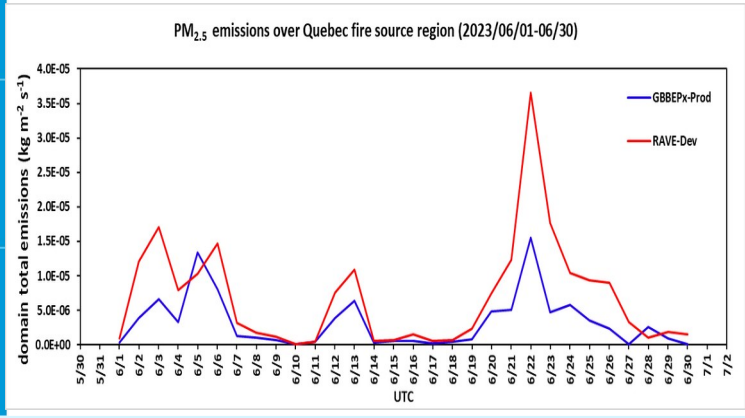
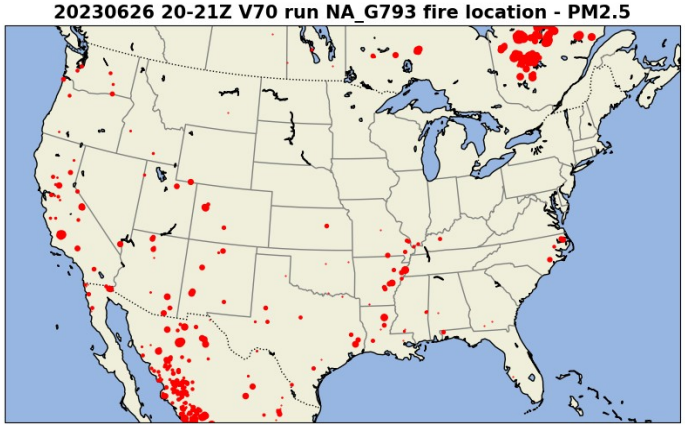


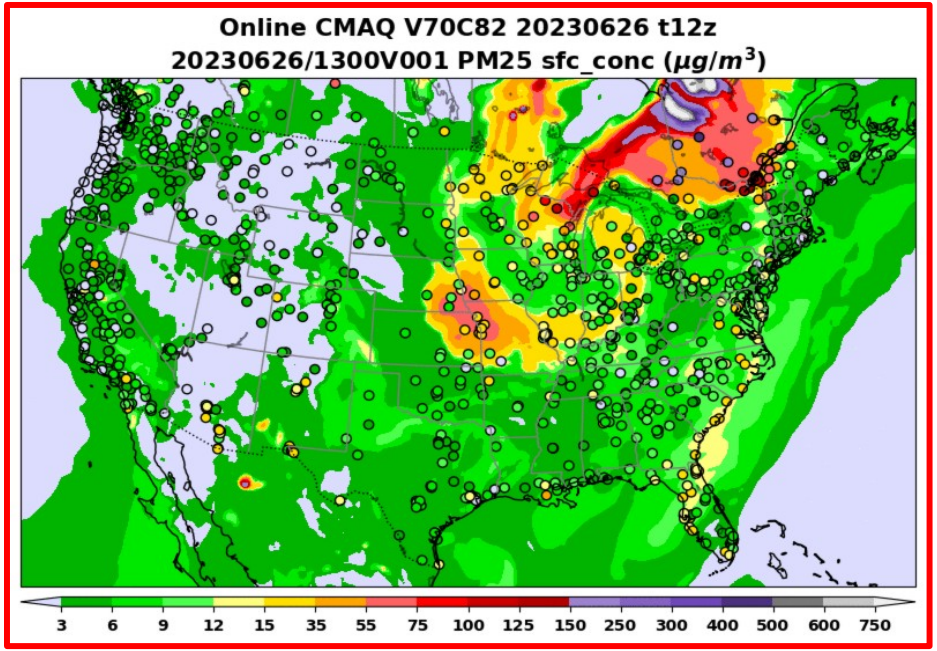
Figure 6: The best estimate and the error of the biomass burning scaling factors for the selected regions. The regional bilinear regressions was performed using NNR-AOT/Aqua(land) data.



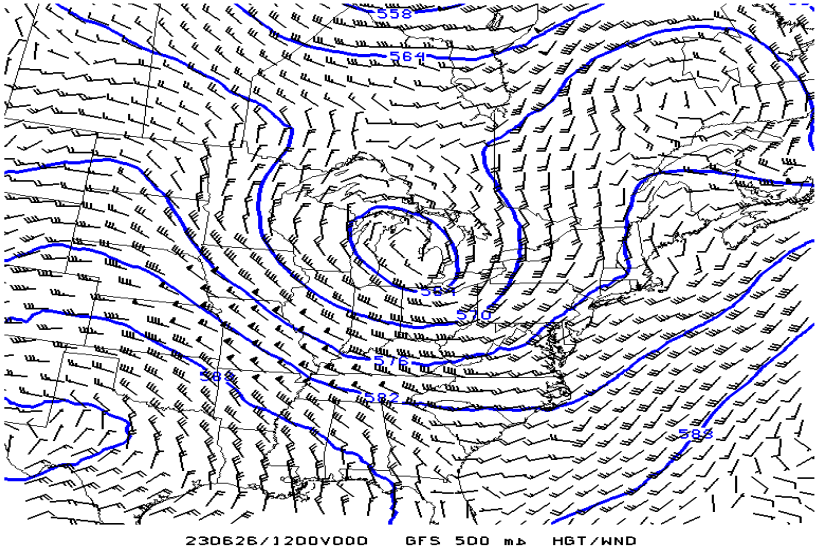


Biome-dependent scaling factors:
Tropical forest: 4.5
Extratropical forest: 2.5
Savanna: 1.8
Grassland: 1.8

$PM_{2.5}$ predictions during Quebec wildfires June 26, 2023

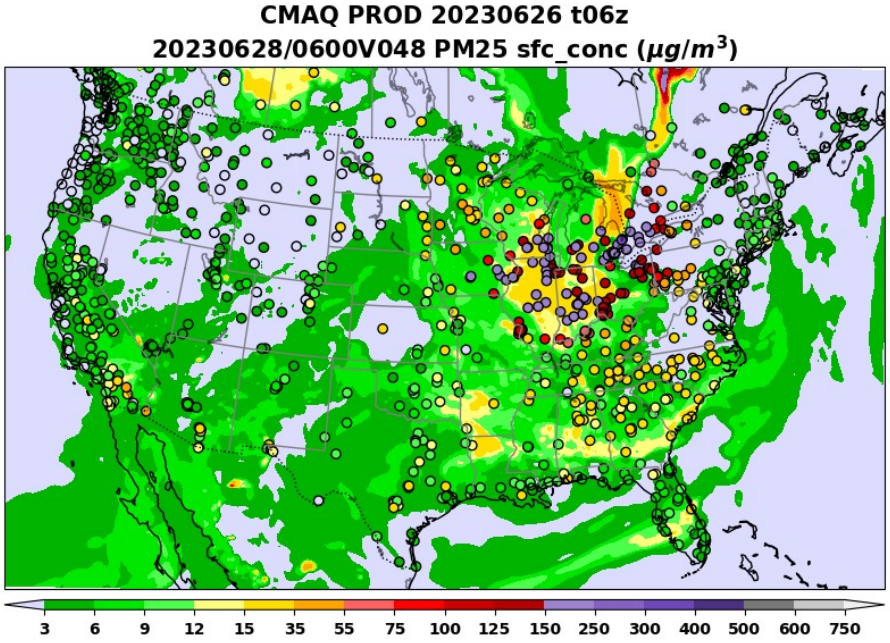


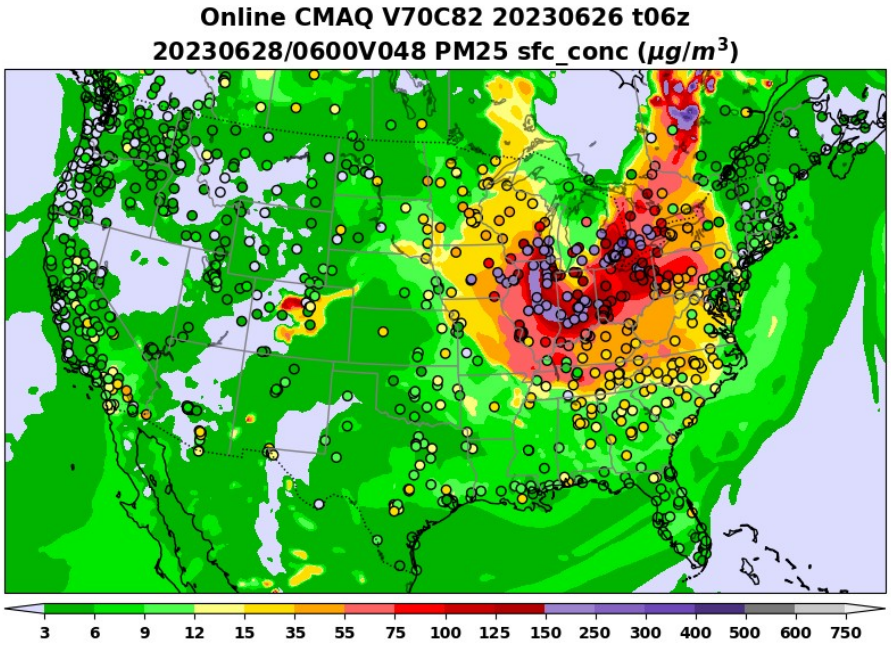
Geopotential Heights and Winds at 500 hPa



- A storm system located northeast of the Great Lakes produced a counterclockwise wind, channeling the smoke produced by wildfires in Canada south into US, affecting air quality in the Midwest regions substantially.
- Evolution of predicted $PM_{2.5}$ is shown for 72-hour predictions initialized on June 26, 2023 together with independent AirNow observations of $PM_{2.5}$ (in filled circles). High values of $PM_{2.5}$ were attributed to wildfires.

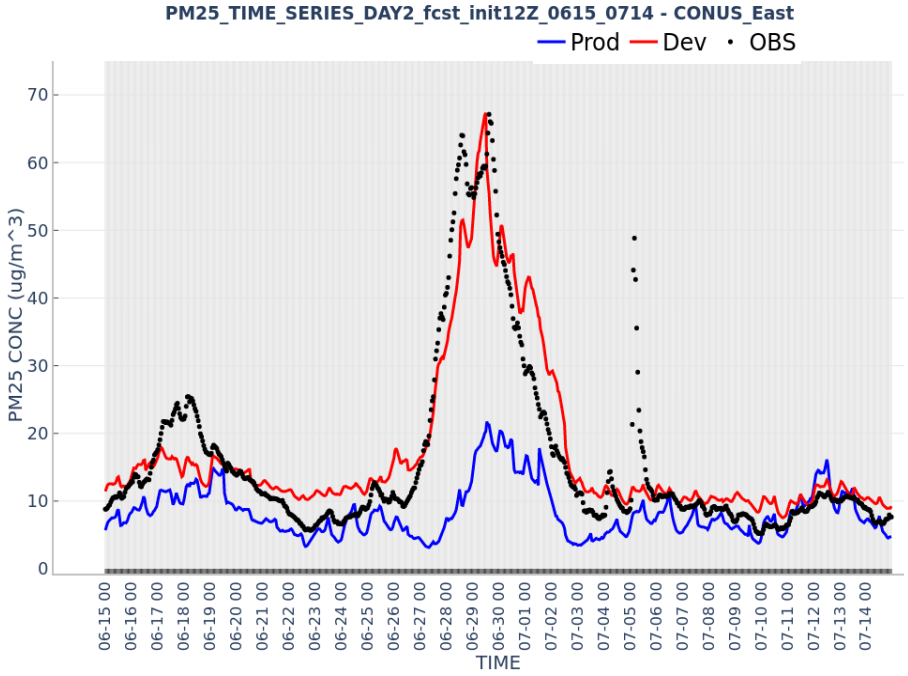
UFS-AQM-predicted $PM_{2.5}$ (v7.0c82) versus operational forecast (Prod) during Quebec wildfire events on June 26, 2023

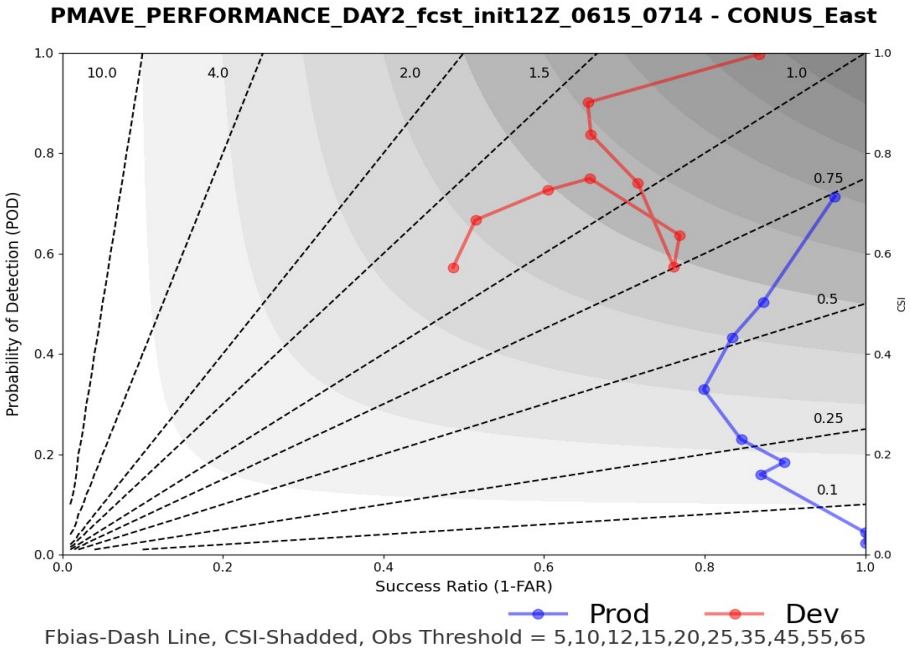




- The UFS-AQM system (v70c82) predicted higher $PM_{2.5}$, showing better agreement with AirNow observations as compared with operational forecast during Quebec wildfire intrusion.

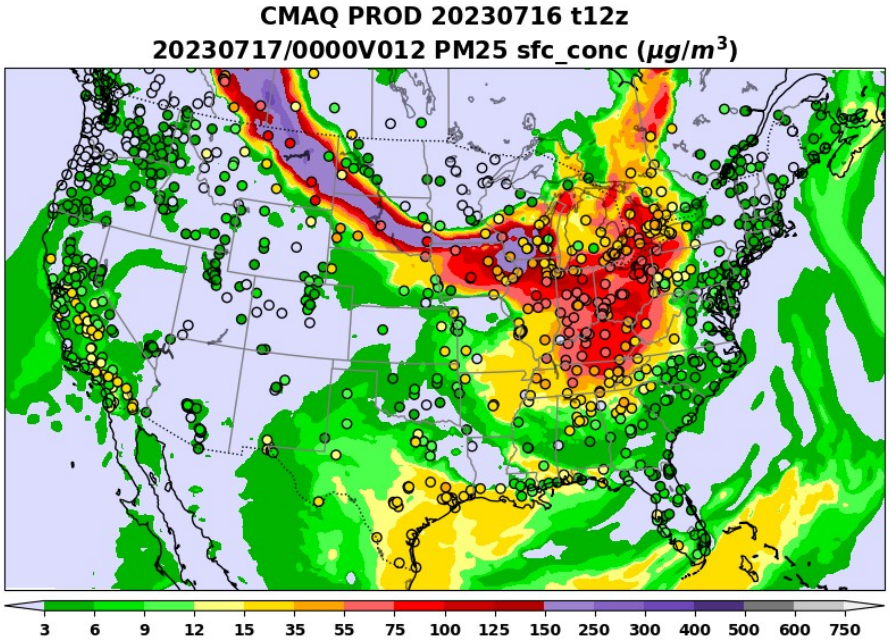
Evaluation of the UFS-AQM system-predicted hourly $PM_{2.5}$

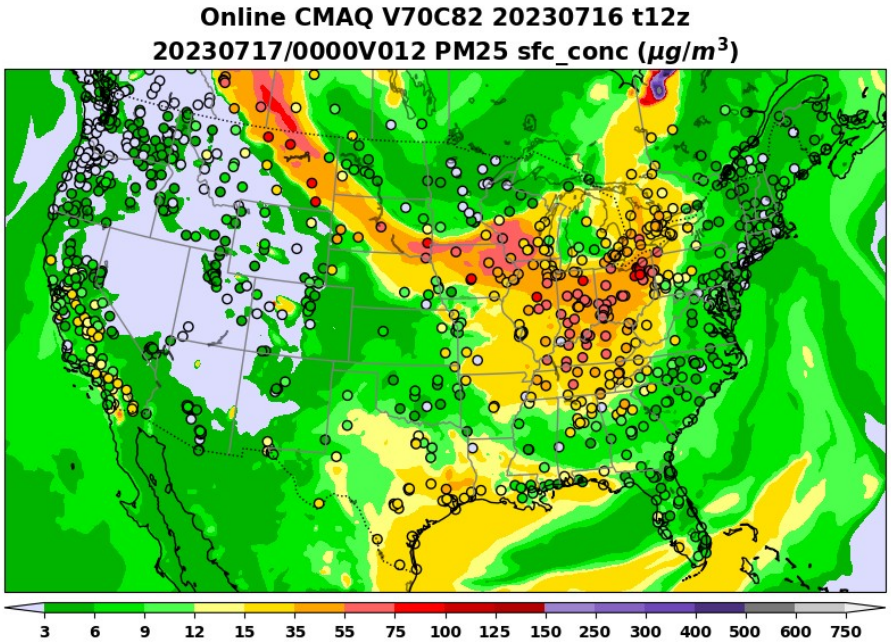




- The UFS-AQM system (Dev: v70c82) well captured $PM_{2.5}$ peak values than the operational (Prod) system over East CONUS during Quebec fires in June and July, 2023.

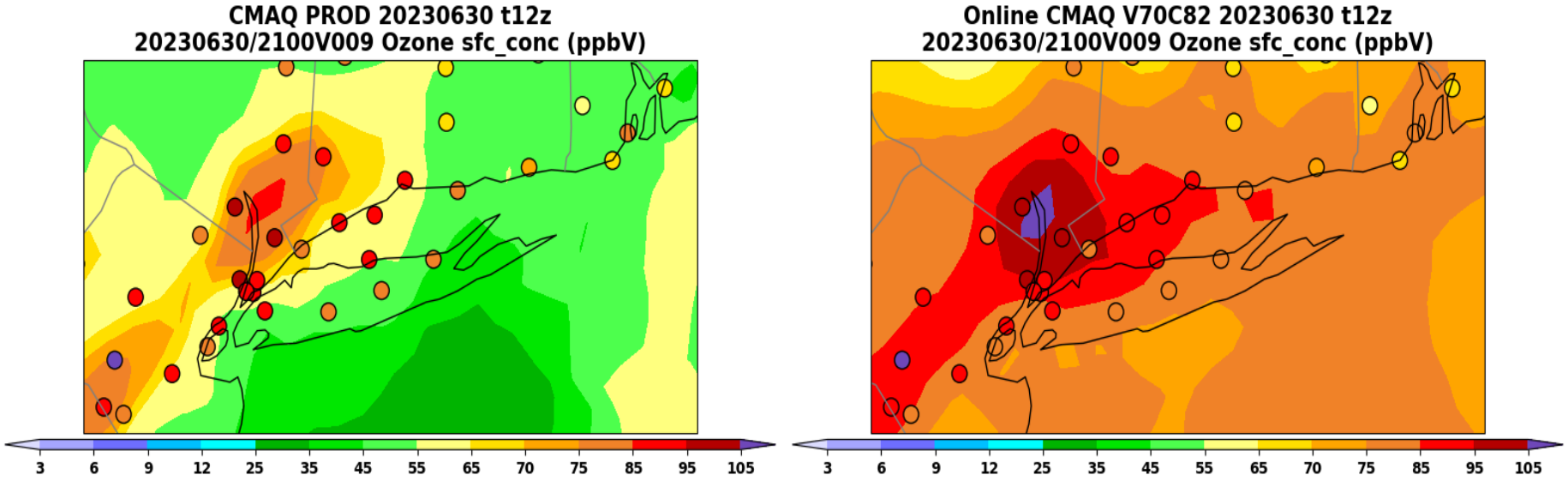
UFS-AQM-predicted $PM_{2.5}$ (v7.0c82) versus operational forecast (Prod) during the Alberta wildfire event on July 17, 2023





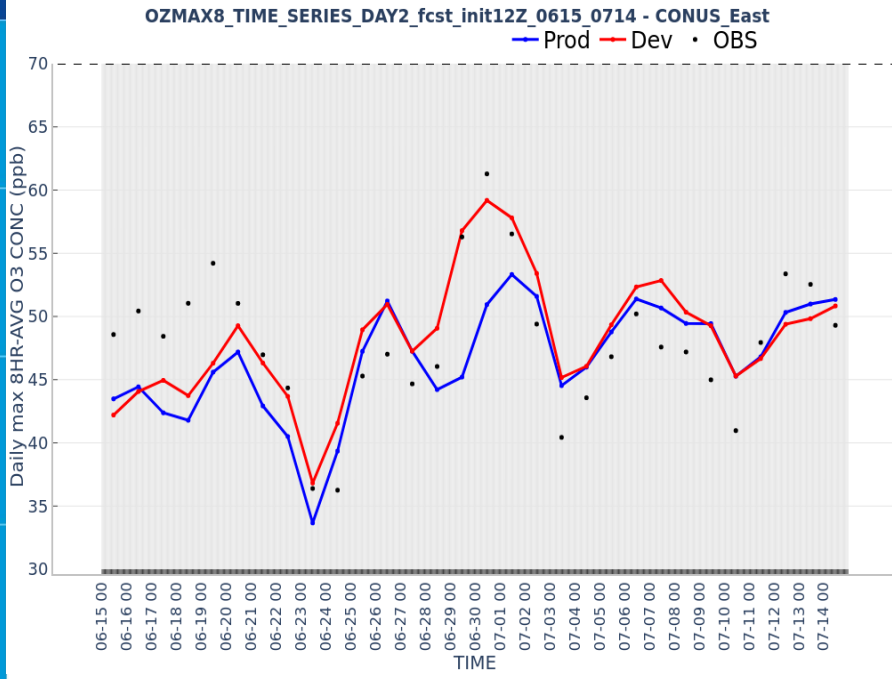
- Another case shows that the UFS-AQM captured the smoke intrusion spatial pattern reasonably.
- However, it still underpredicted over the areas near the northern border when compared to the operational predictions on July 17 at 00z UTC.

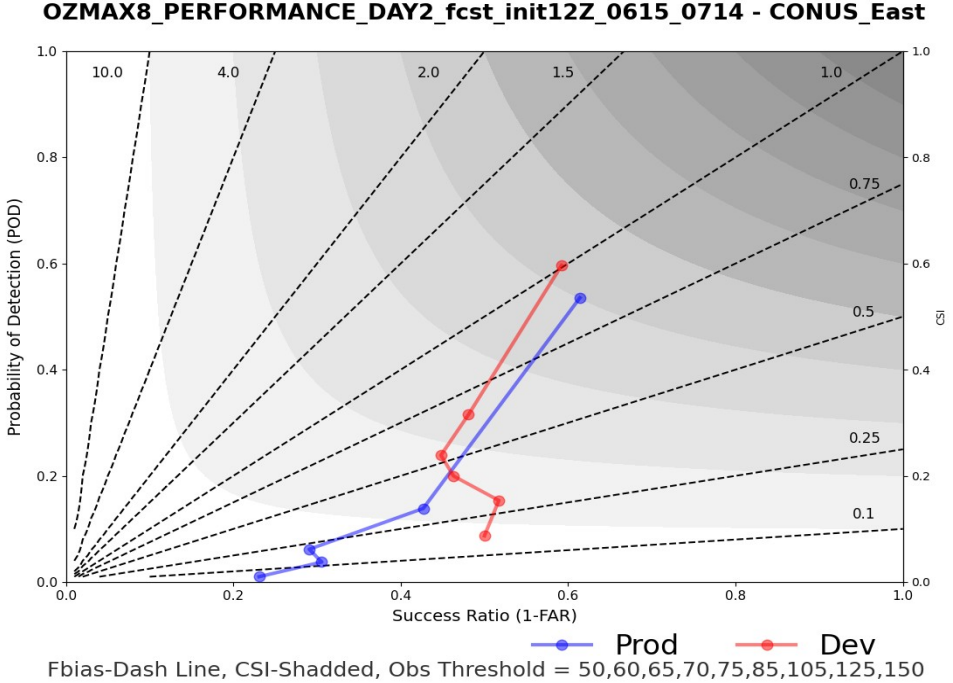
Evaluation of the UFS-AQM system: O_3 episodes



- Several O_3 exceedance events were observed over the affected region during dissipation stage of Quebec fire events.
- The UFS-AQM system (Dev: V70C82) predicts higher O_3 than the operational (Prod) system over east coastal region such as Long Island Sound on June 202

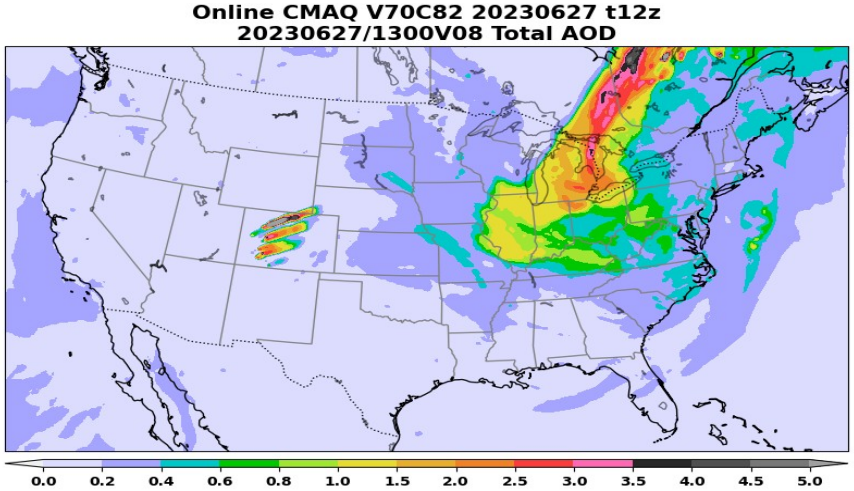
Evaluation of the UFS-AQM system: Daily 8-hr Max O_3

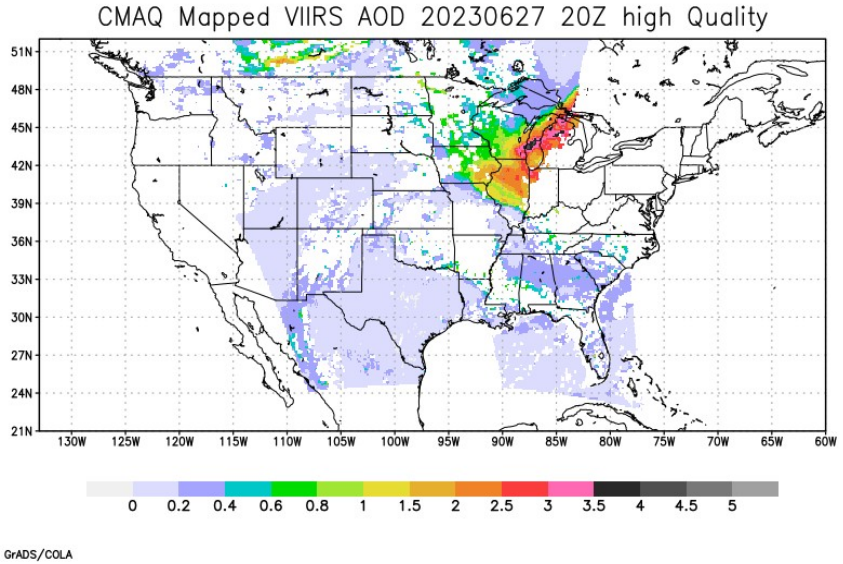




- CONUS-East categorical performance of development system (v70c82) is improved over the operational (Prod): higher CSI and POD.

A comparison of predicted AOD with VIIRS retrieval





- AQMv7 captured spatial pattern of AOD with value higher than 3.5 during Quebec fires.

Summary

- NOAA has developed an Online-CMAQ system within the UFS framework to enhance representation of wildfire emissions and their impact on air quality predictions.
- The UFS-AQM, also known as Online-CMAQ, is currently being evaluated as a potential replacement for the existing operational air quality forecast system.
- The UFS-AQM, incorporating hourly RAVE data, significantly improved $PM_{2.5}$ predictions compared to the operational system during the Quebec wildfires in June 2023.
- Moreover, the UFS-AQM exhibited superior performance in capturing O_3 episodes when compared to the operational model.

Next steps

- Will incorporate emissions of volatile organic compounds (VOCs) released by wildfires to enhance O_3 predictions near fire source and downstream regions.
- Will test the system at a higher resolution to address prediction challenges over complex terrain and coastal regions.
- Will update the CMAQ model along with anthropogenic emissions, refine wildfire emissions and plume rise algorithm, and utilize more advanced CCPP, data assimilation techniques as well as short-period training for bias correction to further improve wildfire predictions.