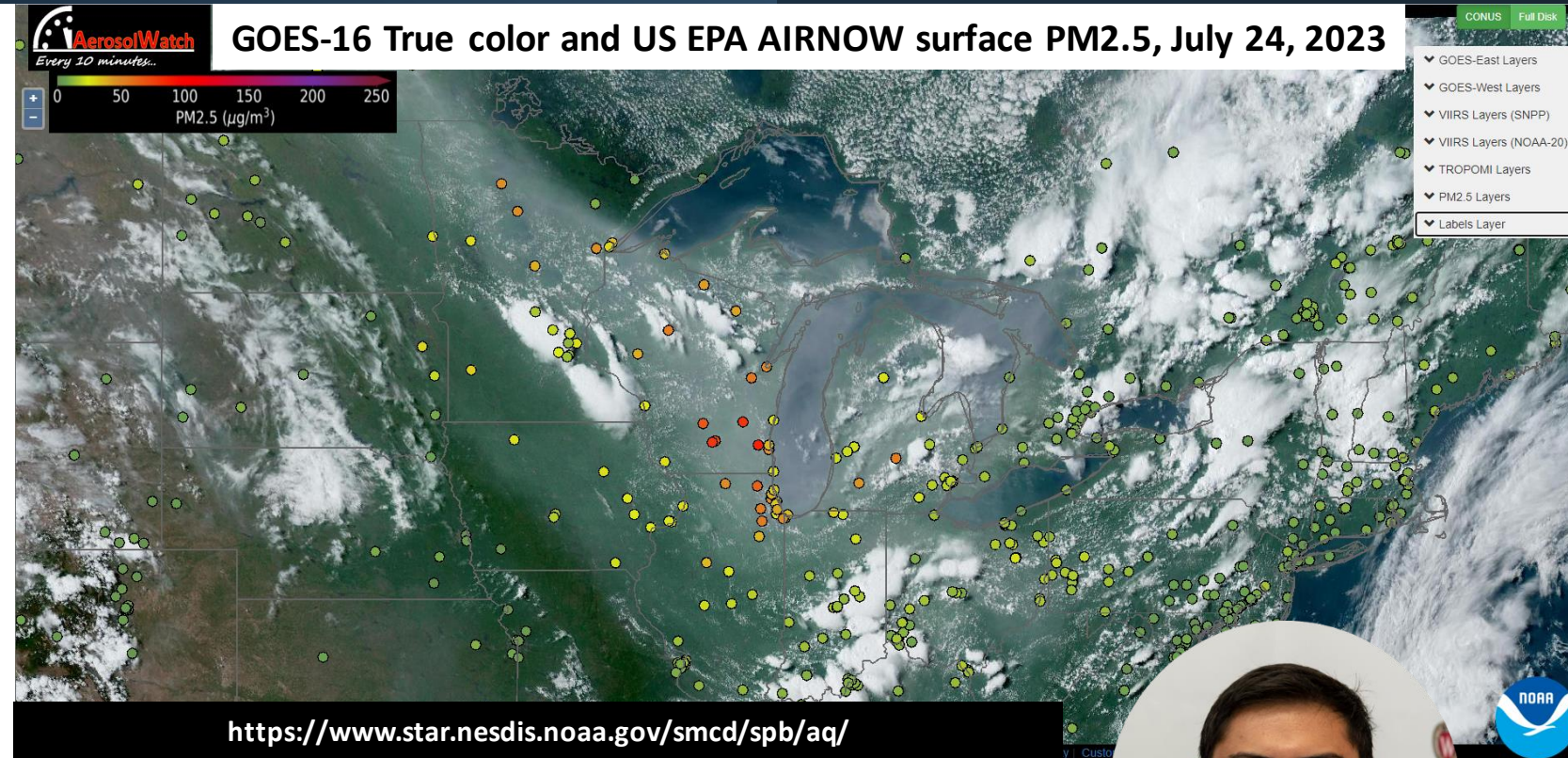


Session 6B: Calculating Long-Range Pollution Transport and Forecasting Air Pollution

R. Bradley Pierce
UW-Madison

Impacts of Canadian Wildfires on Lake Michigan Air Quality during July 2023



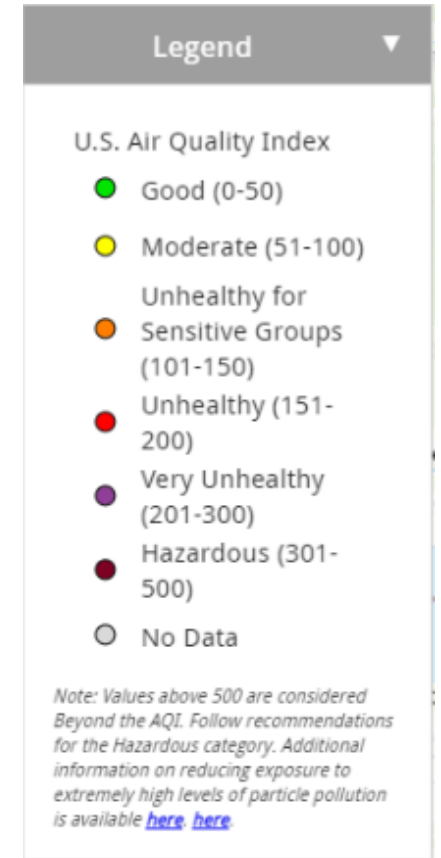
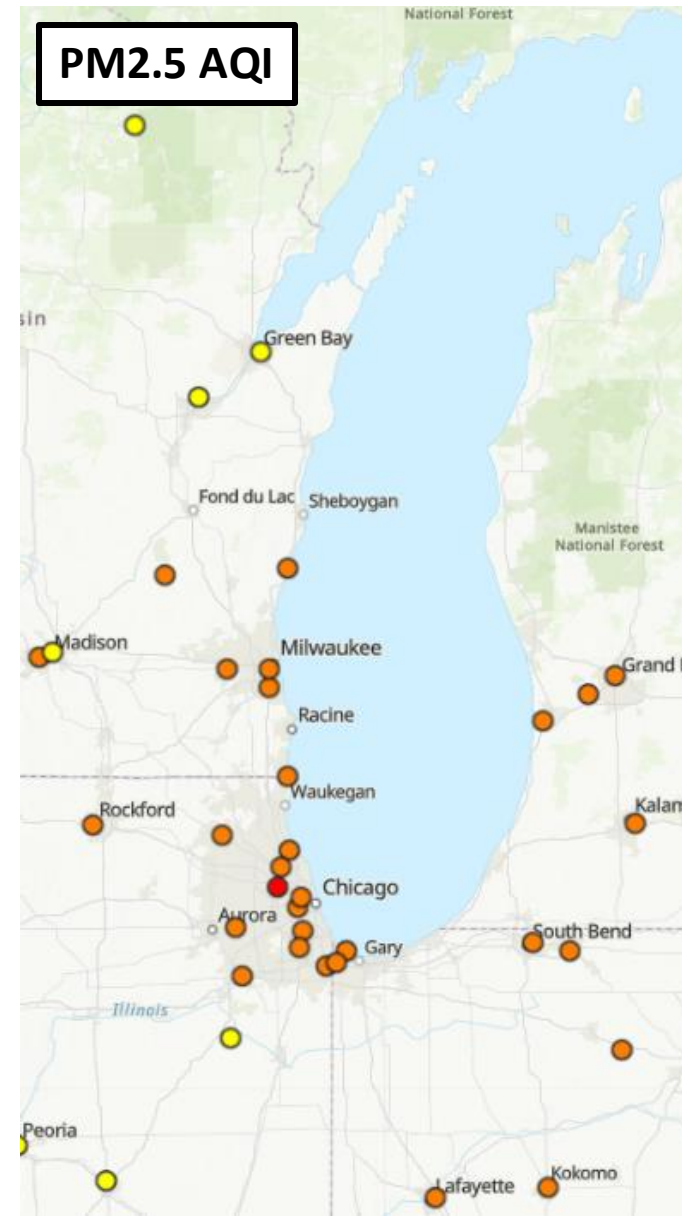
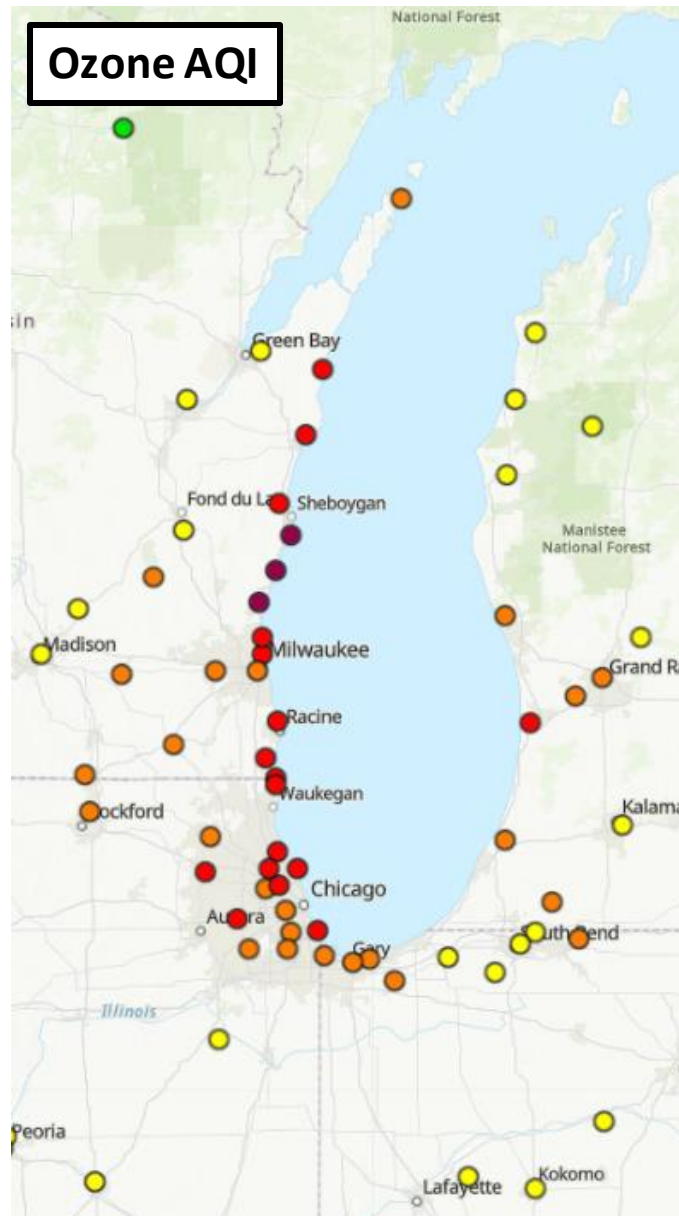
The WRF-Chem regional simulations presented in this talk were designed, conducted, and analyzed by Jerrold Acdan (UW-Madison). Jerrold is supported by NASA's Future Investigators in NASA Earth and Space Science and Technology (FINESST) Program



NASA Health and Air Quality Applied Sciences Team, June 4th and 5th, 2024, MIT, Cambridge, Massachusetts

Case Study: July 25, 2023

Poor AQI
(Unhealthy/Very Unhealthy Ozone and Unhealthy for Sensitive Groups/Unhealthy PM2.5) was observed along the Western shore of Lake Michigan on July 25, 2023



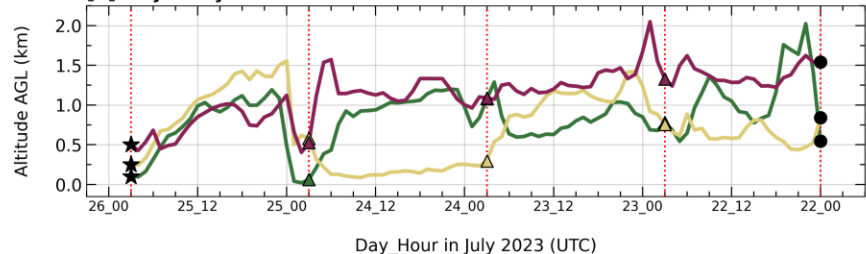
Case Study: July 25, 2023

NOAA HYSPLIT trajectories driven by HRRR meteorological data

[a] Trajectory horizontal paths

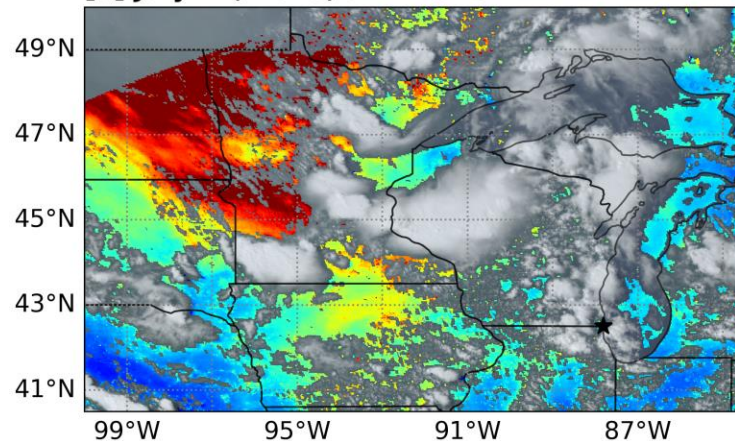


[b] Trajectory altitudes

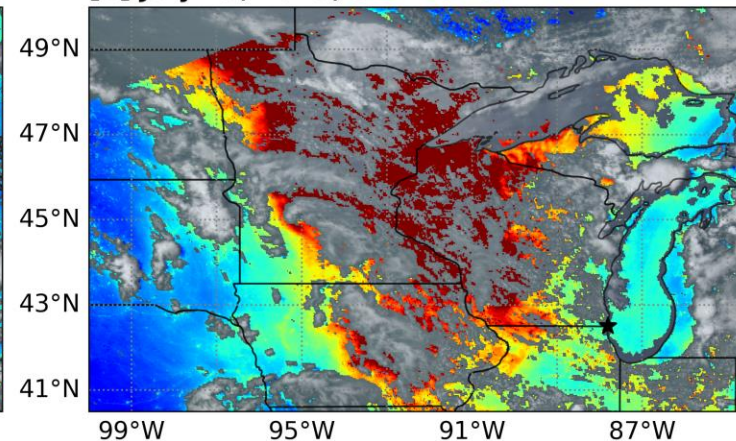


GOES-16 true color and AOD imagery time series from July 22-25, 2023

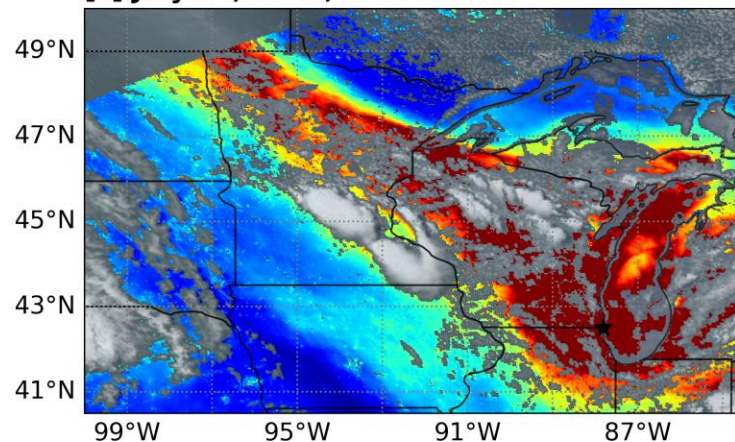
[a] July 22, 2023, at 21 UTC



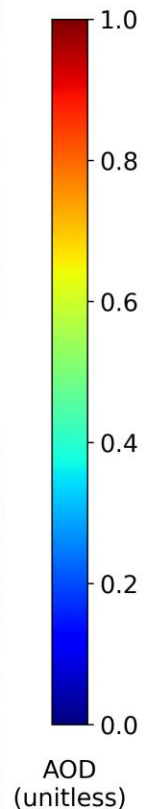
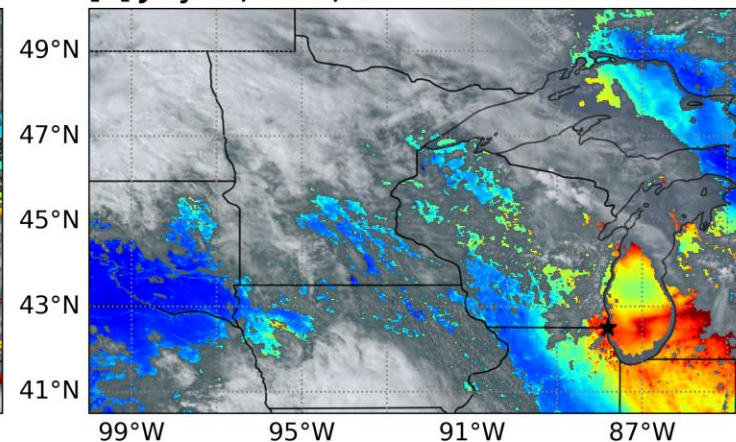
[b] July 23, 2023, at 21 UTC



[c] July 24, 2023, at 21 UTC



[d] July 25, 2023, at 21 UTC

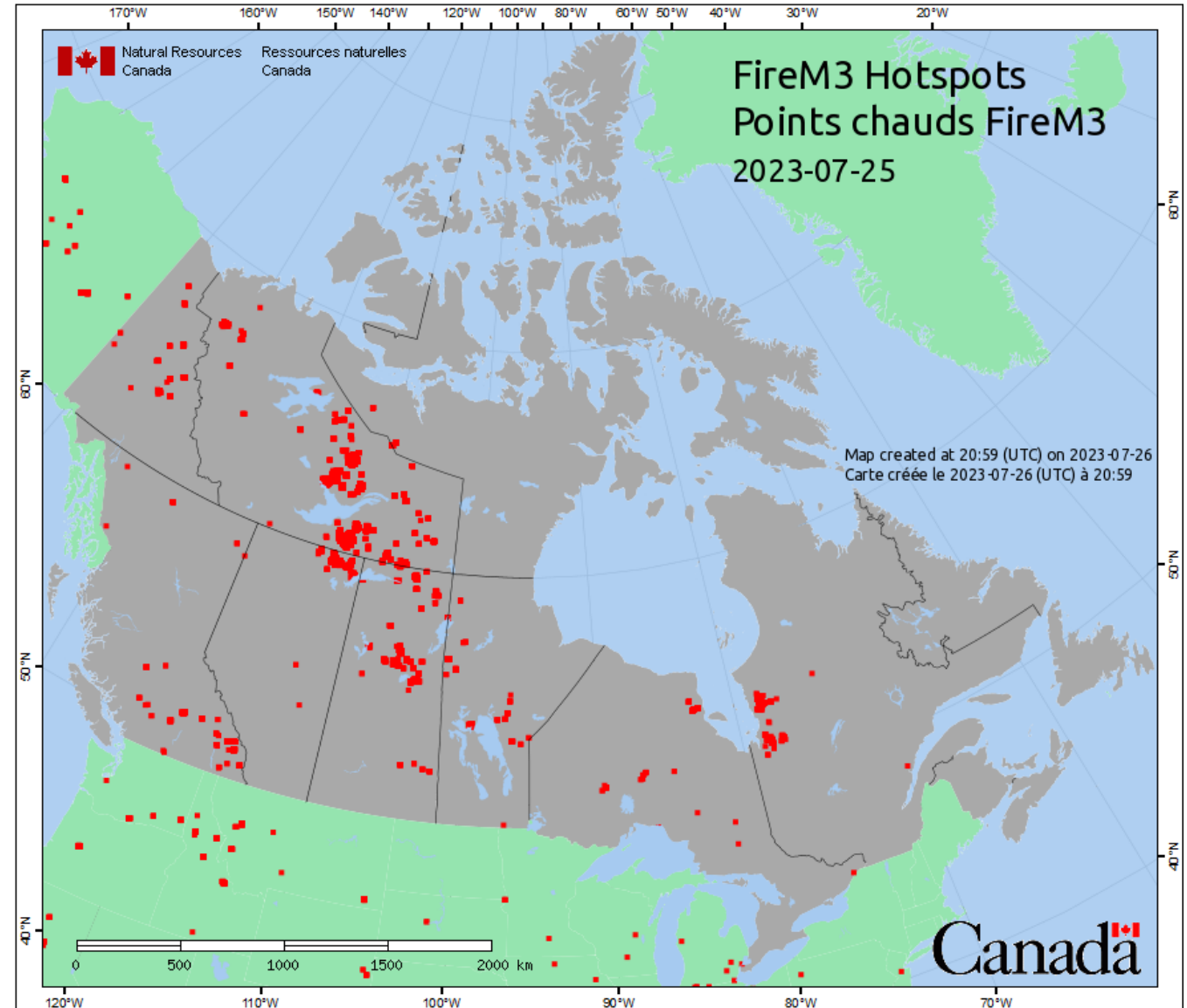


Chiwaukee is influenced by Chicago urban emissions during the previous 24 hours preceded by long-range transport from Canada

Regional scale aerosol enhancements are associated with transport of smoke from Canada

- By September 5, 2023, 16.5 million hectares had been burned, more than double the 1989 record
- 2023 was the warmest May to July period in over 80 years (breaking records by 0.8°C)
- Climate change contributed to record high temperatures and dry conditions

(<https://natural-resources.canada.ca/simply-science/canadas-record-breaking-wildfires-2023-fiery-wake-call/25303>)

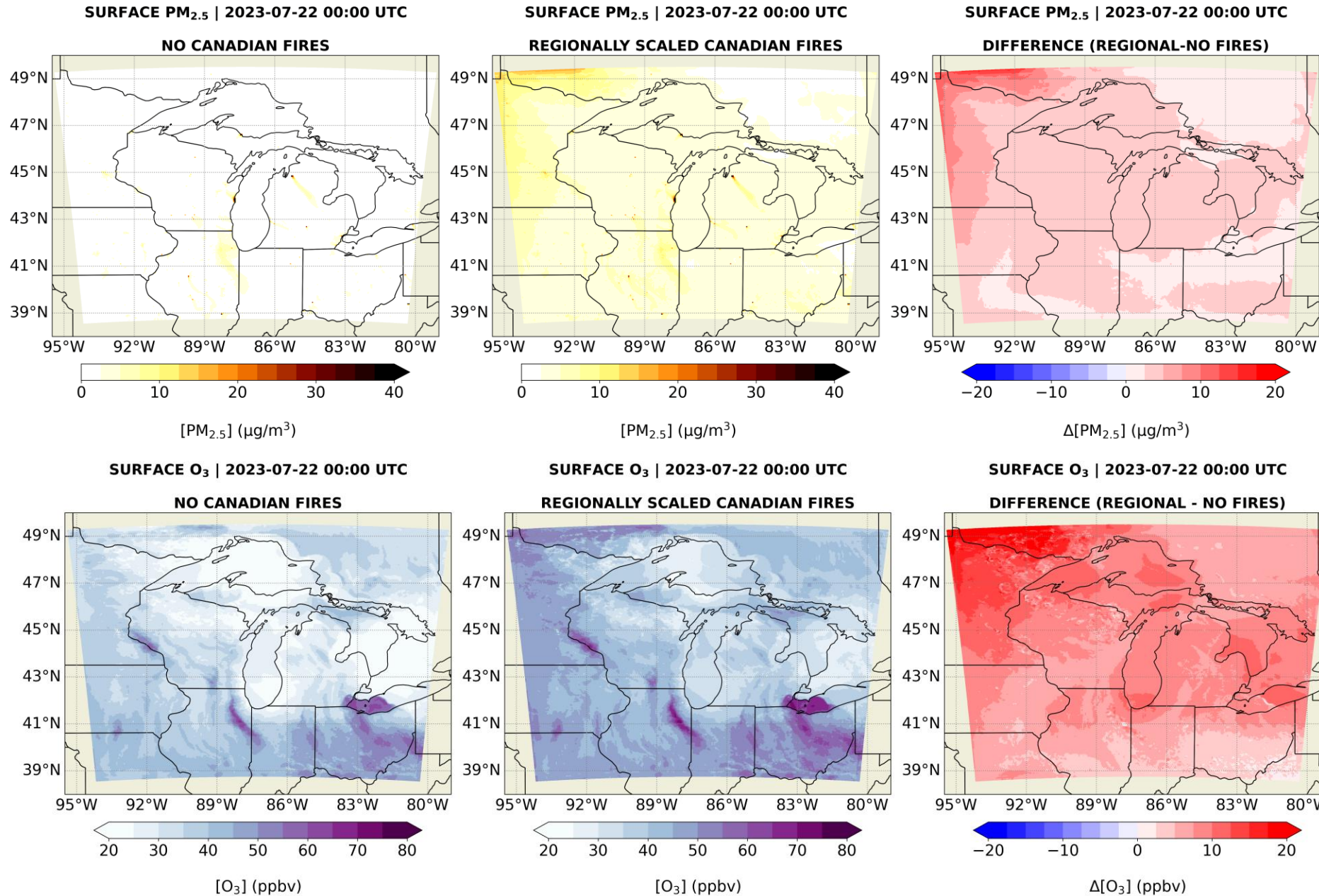


WRF-Chem Configuration

Domains	4-km centered on Chicago
Vertical levels	40, high resolution below 2 km
Meteorology	HRRR 3-km
Chemical boundary and initial conditions: <u>Control</u>	WACCM <u>without</u> Canadian wildfires
Chemical boundary and initial conditions: <u>Regionally Scaled Canadian Wildfires</u>	WACCM <u>with</u> Canadian wildfires scaled by physiographic region → QFED fire detections with FINNv1.5 emissions ratios applied
Anthropogenic emissions	NEMO 1-km based on NEI17 → Non-trended; upscaled to 4-km
Biogenic emissions	MEGAN v2
sf_surface_physics	Noah-MP LSM
Chemistry mechanism	T1_MOZCART (updated MOZART chemistry, GOCART aerosols)

Acronyms

- ▶ HRRR: High-Resolution Rapid Refresh
- ▶ QFED: Quick Fire Emissions Dataset
- ▶ FINN: Fire INventory from NCAR

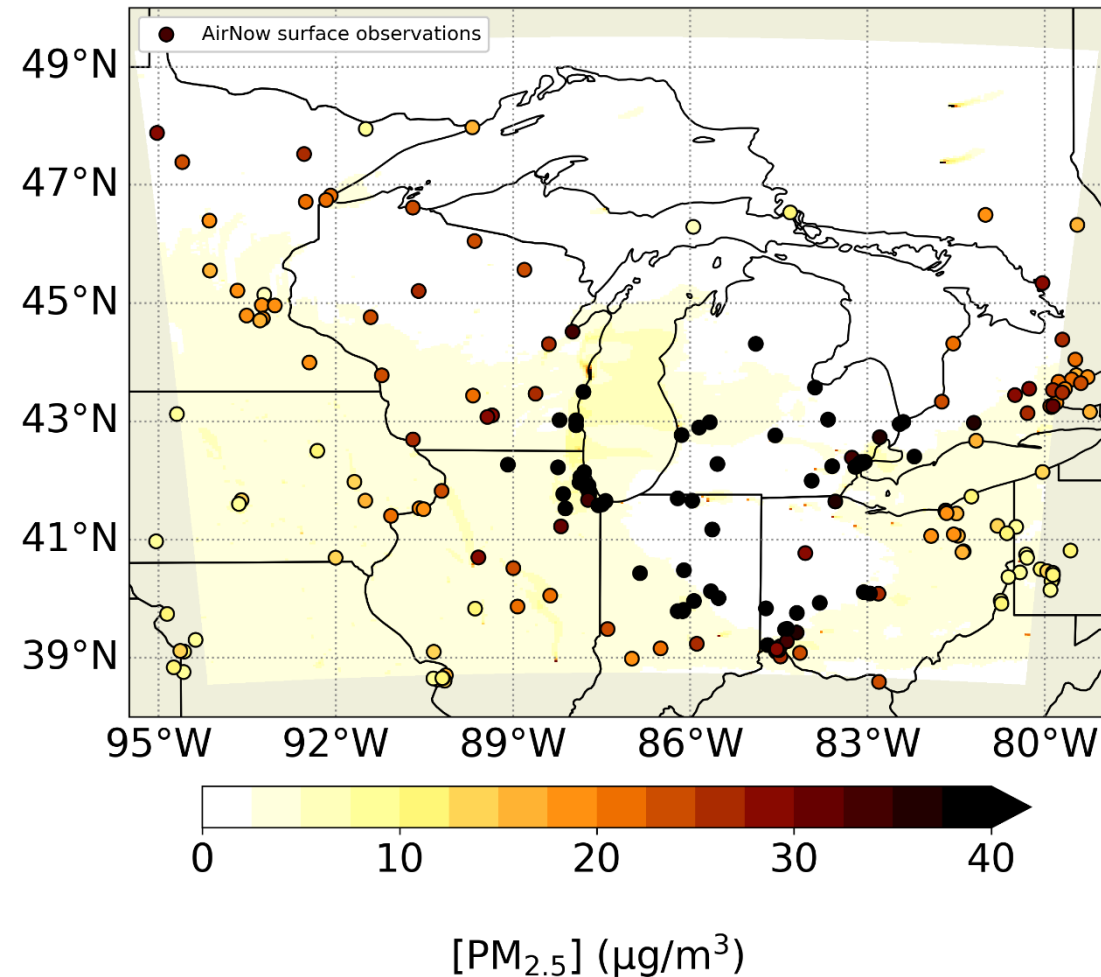


Case Study: July 25, 2023

Significant underestimate of surface PM_{2.5} **without** Canadian Wildfires
Good agreement in surface ozone along western shore of Lake Michigan
Underestimate in surface ozone over surrounding region

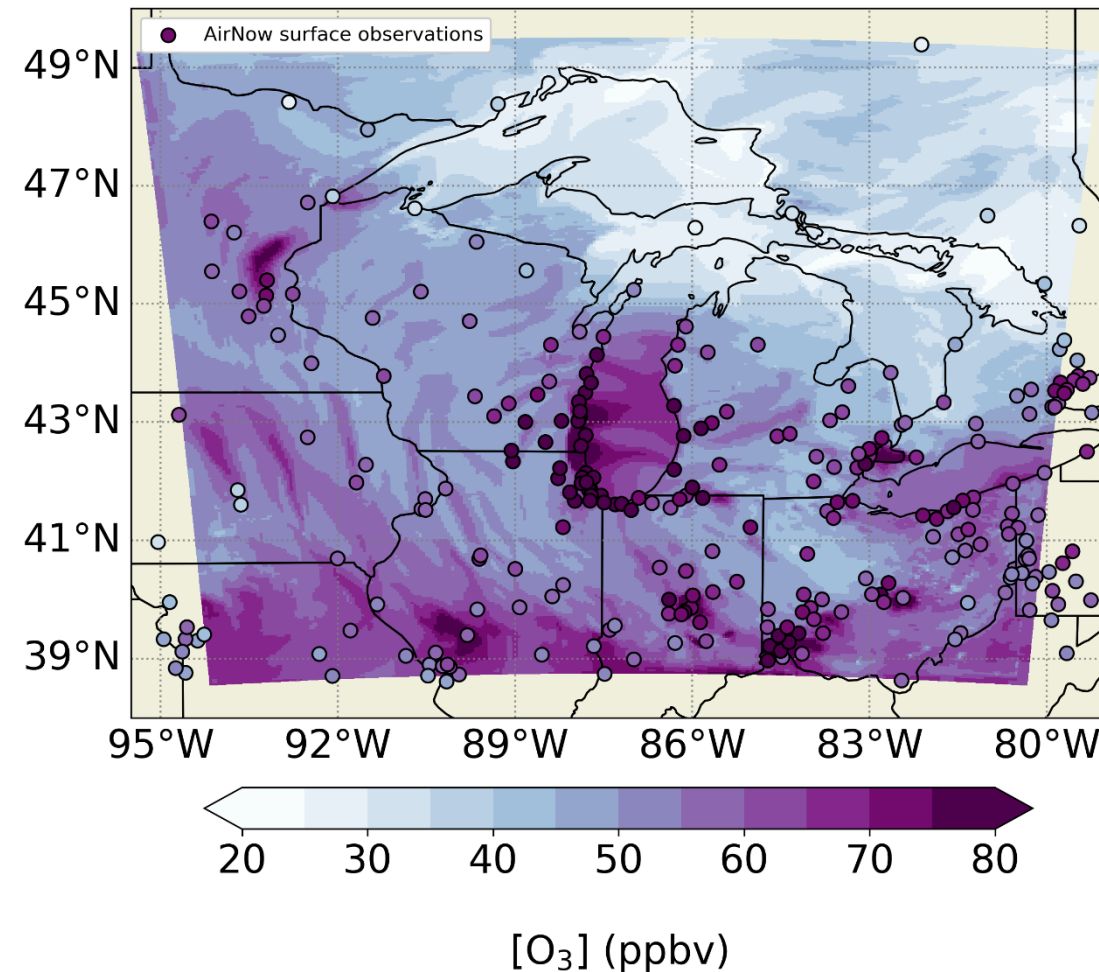
SURFACE PM_{2.5} | 2023-07-25 21:00 UTC

NO CANADIAN FIRES



SURFACE O₃ | 2023-07-25 21:00 UTC

NO CANADIAN FIRES

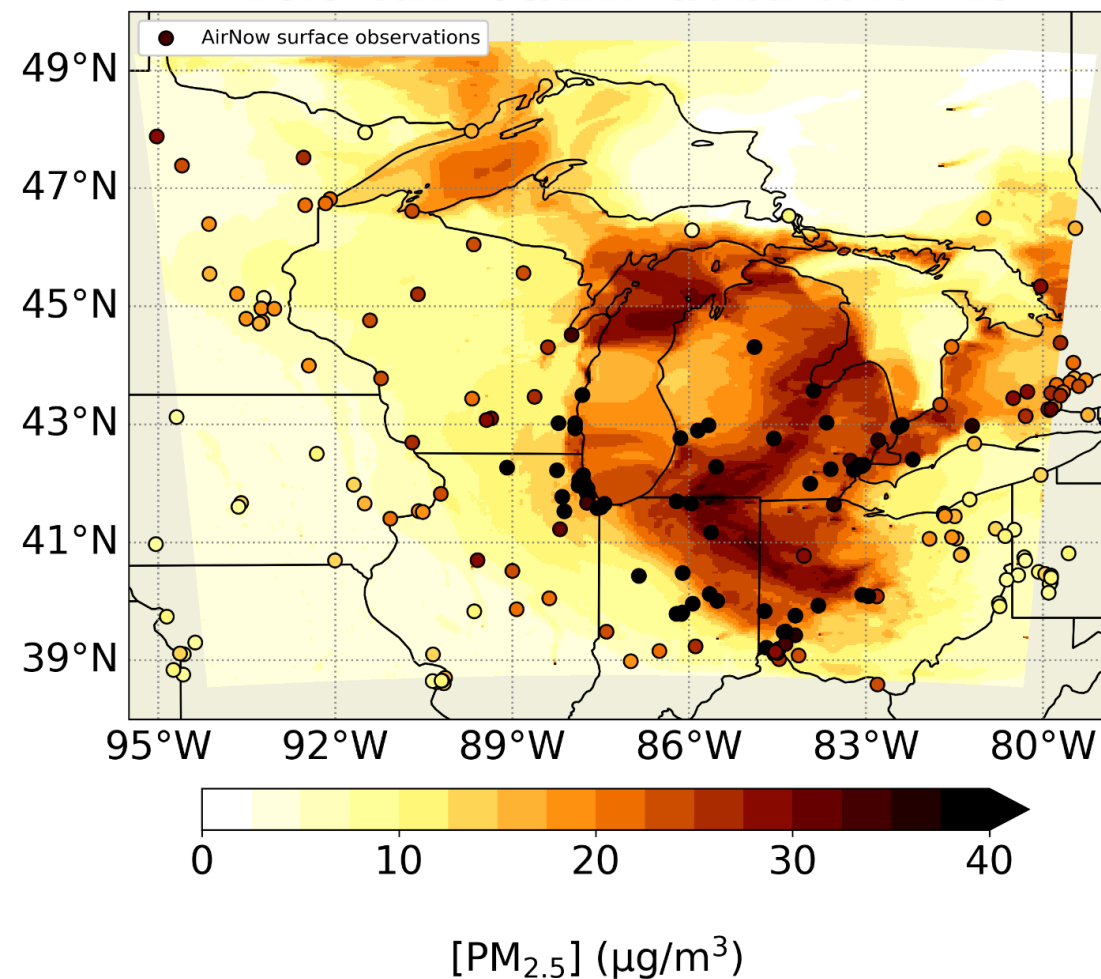


Case Study: July 25, 2023

Reduction in underestimate of surface PM_{2.5} **with** Canadian Wildfires
Good agreement in surface ozone along western shore of Lake Michigan
Reduction in underestimate in surface ozone over surrounding region

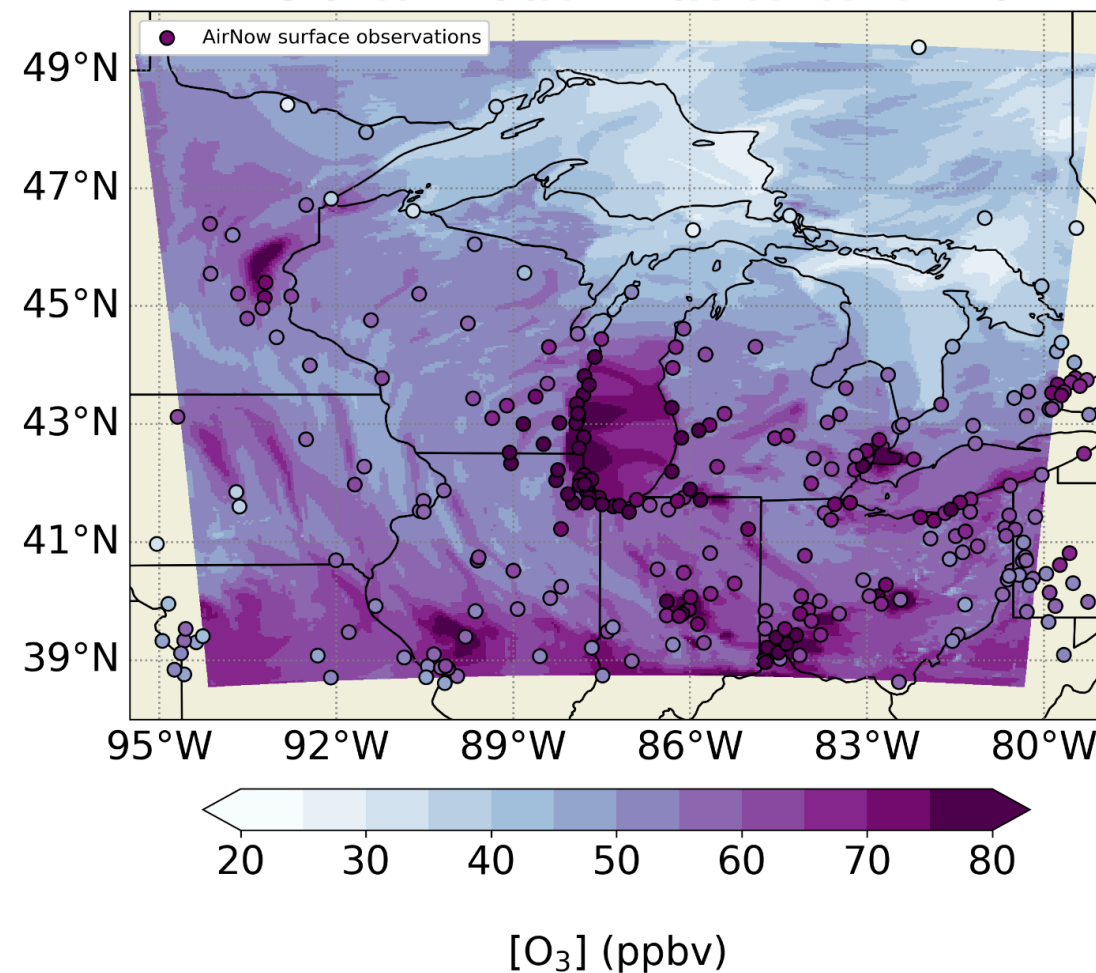
SURFACE PM_{2.5} | 2023-07-25 21:00 UTC

REGIONALLY SCALED CANADIAN FIRES



SURFACE O₃ | 2023-07-25 21:00 UTC

REGIONALLY SCALED CANADIAN FIRES

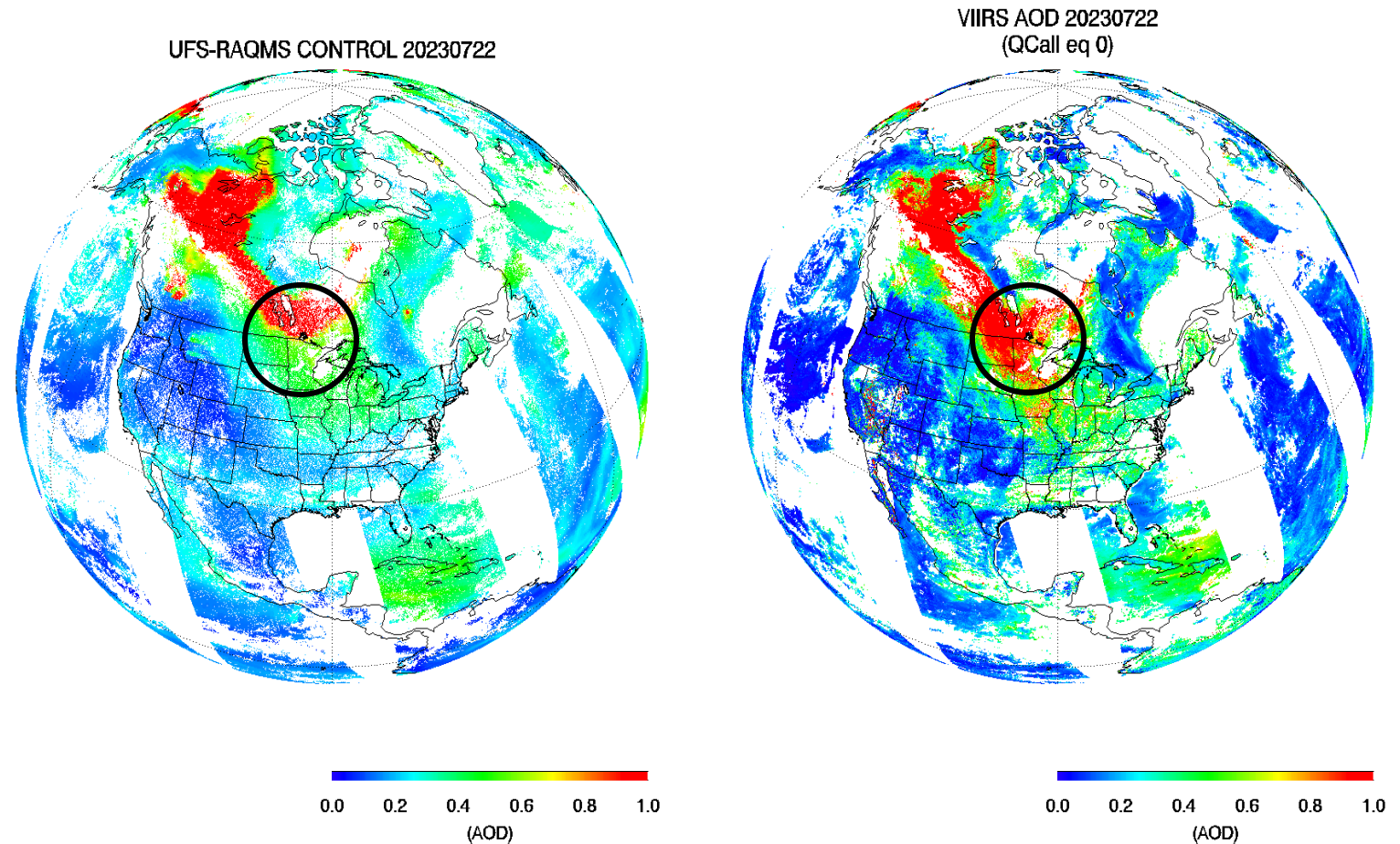


Uncertainties in Lateral Boundary Conditions

- QFED wildfire emissions underestimate aerosol and ozone precursor emissions within WACCM
- Relatively coarse ($0.95^{\circ} \times 1.25^{\circ}$) horizontal resolution

Composition Forecasting and Assimilation

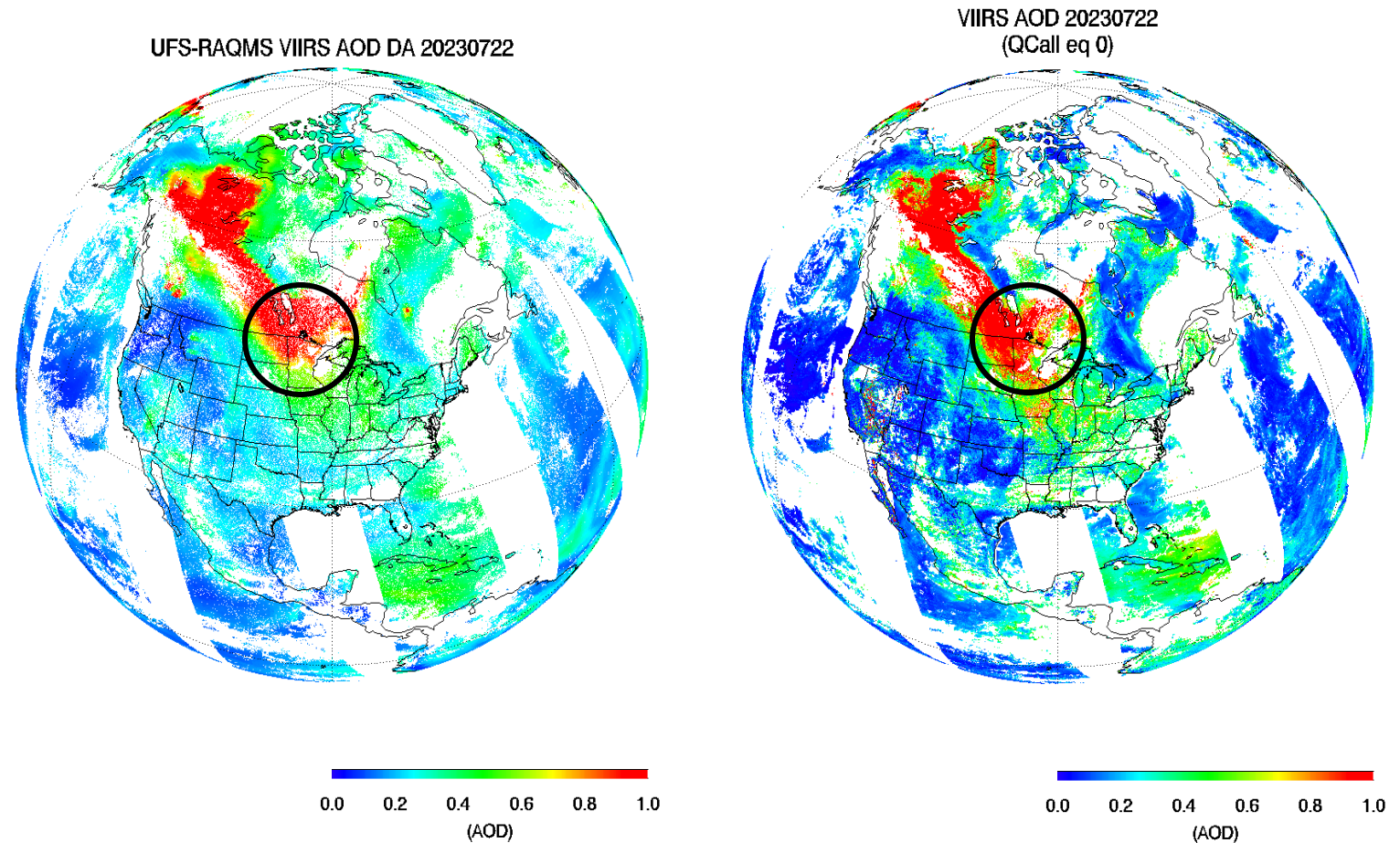
- **Real-time Air Quality Modeling System (RAQMS)** unified stratosphere/ troposphere chemical module incorporated into NOAA UFS
 - Supports **global air quality** and **Seasonal to Sub-seasonal** (S2S) forecasting
 - C192 (0.5degree) horizontal resolution
- **Community Emissions Data System (CEDS)** 2021 anthropogenic emissions
- **Blended Global Biomass Burning Emissions Product (GBBEPx)** real-time biomass burning emissions
- **NOAA Gridpoint Statistical Interpolation (GSI) 3d-Variational analysis**
 - Assimilation of JPSS **VIIRS** AOD



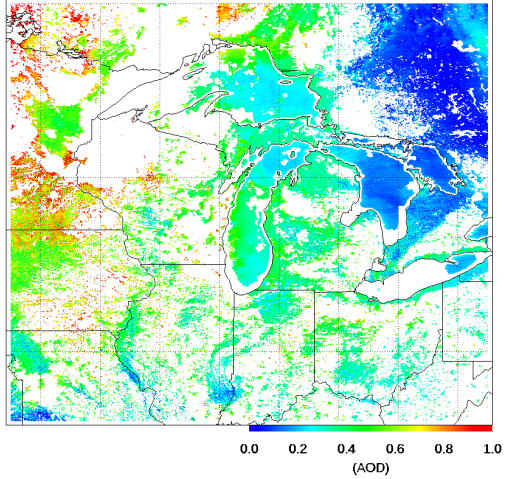
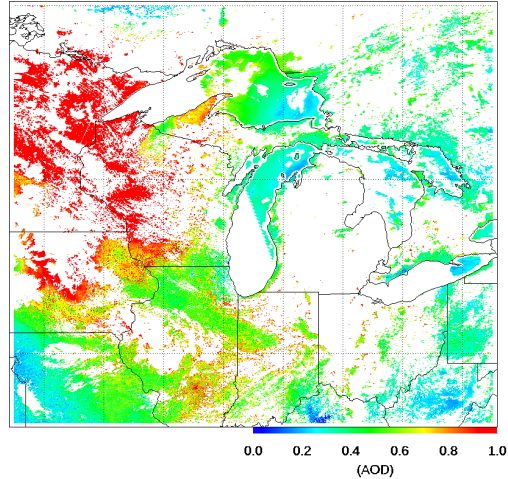
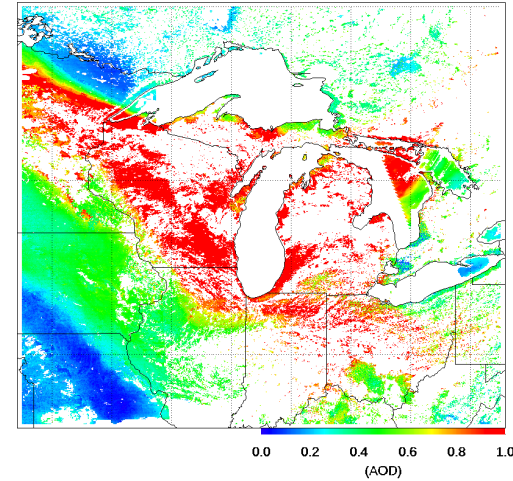
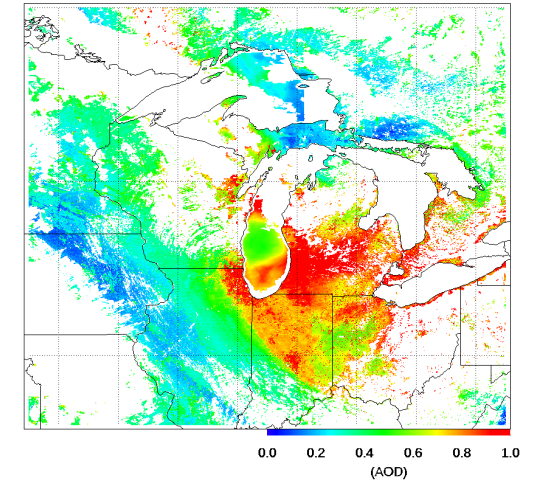
Composition Forecasting and Assimilation

Assimilation of VIIRS AOD improves long-range transport of wildfire smoke

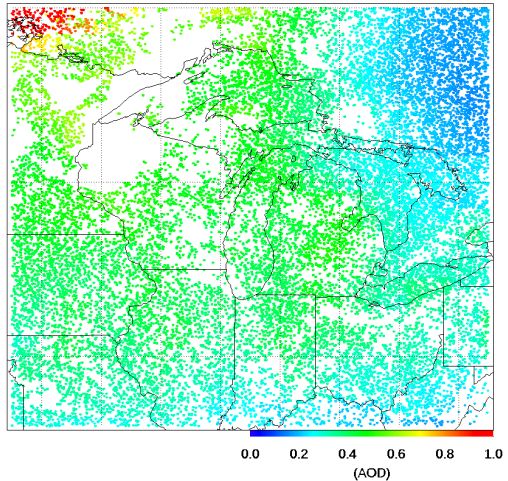
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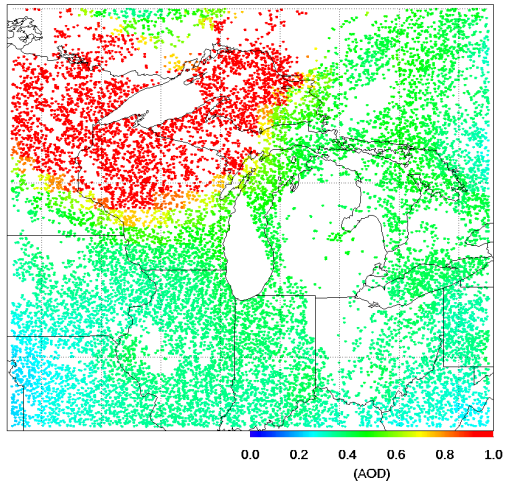
Composition Forecasting and Assimilation

VIIRS AOD 20230722
(QCall eq 0)VIIRS AOD 20230723
(QCall eq 0)VIIRS AOD 20230724
(QCall eq 0)VIIRS AOD 20230725
(QCall eq 0)

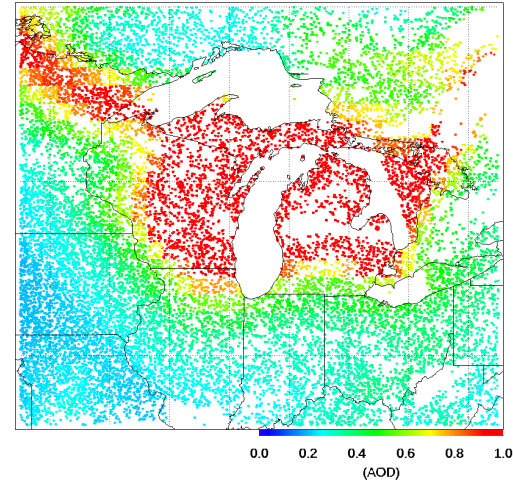
UFS-RAQMS CONTROL 20230722



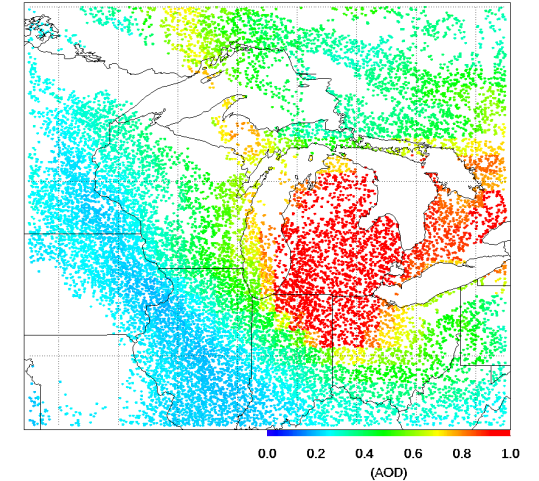
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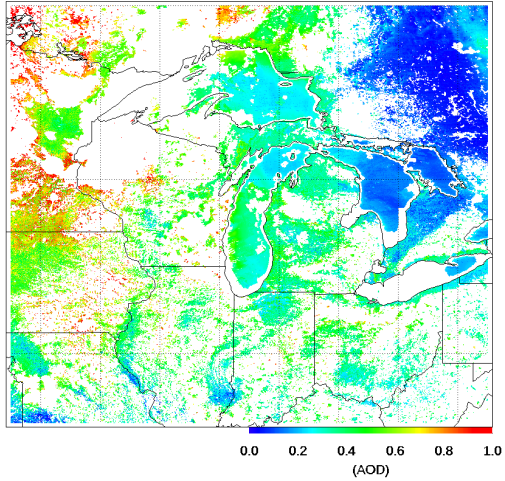
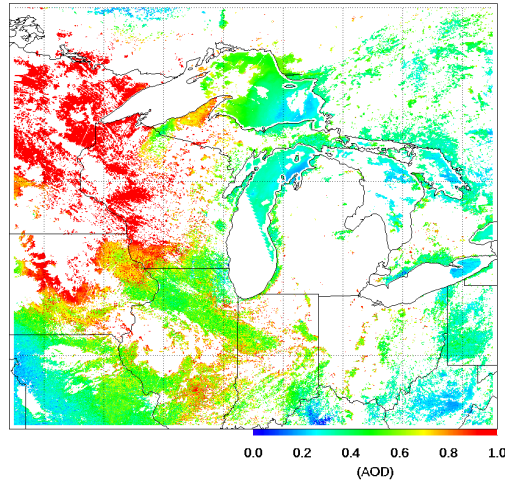
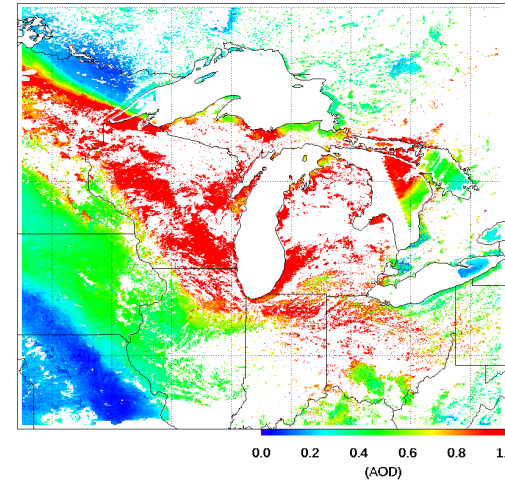
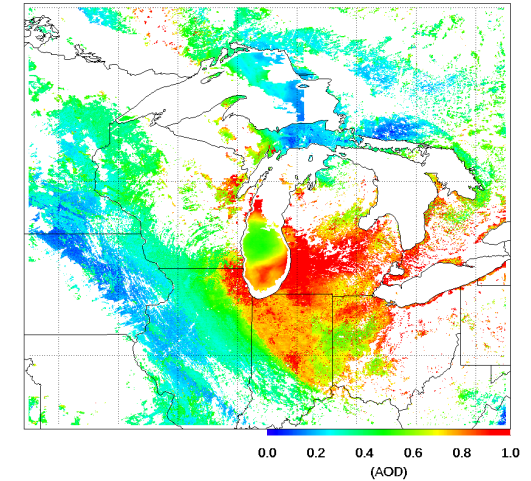
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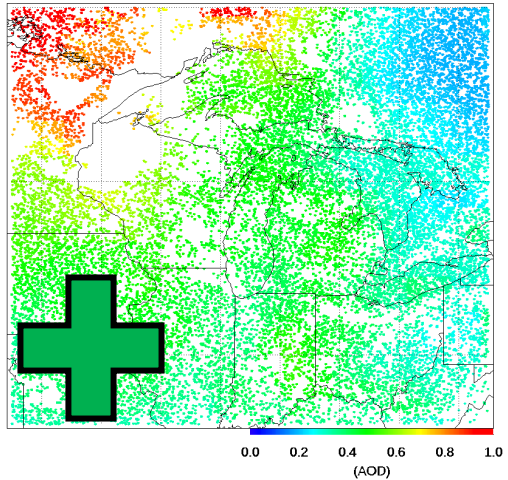
UFS-RAQMS CONTROL 20230725



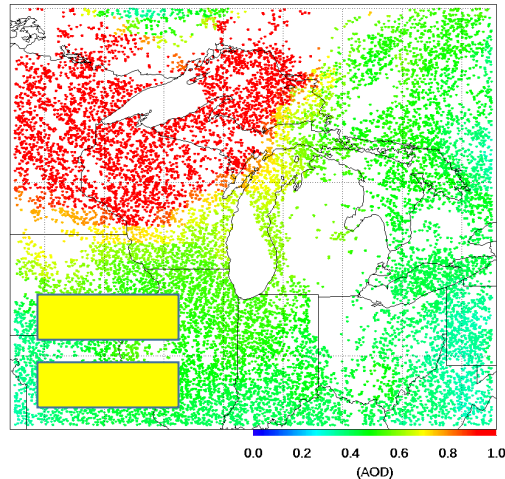
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VIIRS AOD 20230722
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(QCall eq 0)VIIRS AOD 20230724
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(QCall eq 0)

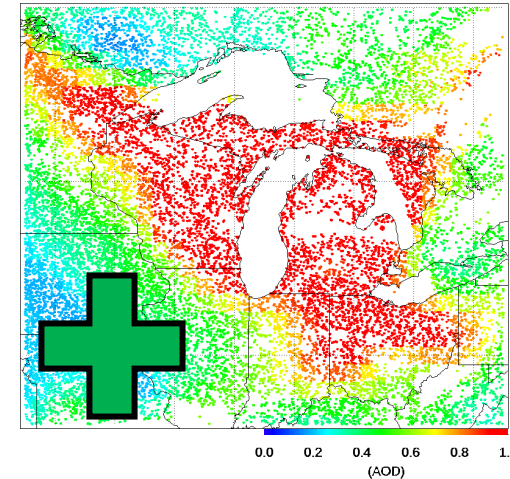
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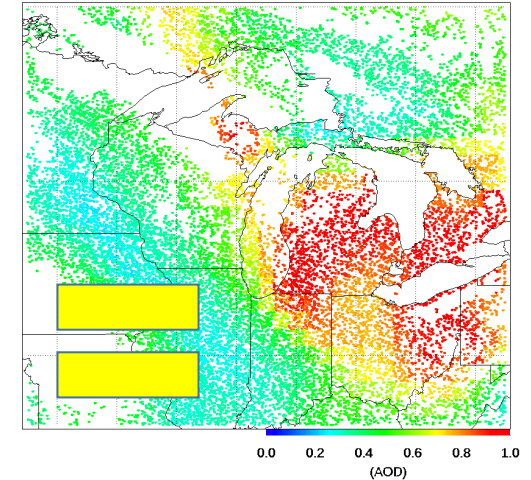
UFS-RAQMS VIIRS AOD DA 20230723



UFS-RAQMS VIIRS AOD DA 20230724



UFS-RAQMS VIIRS AOD DA 20230725



Key takeaways:

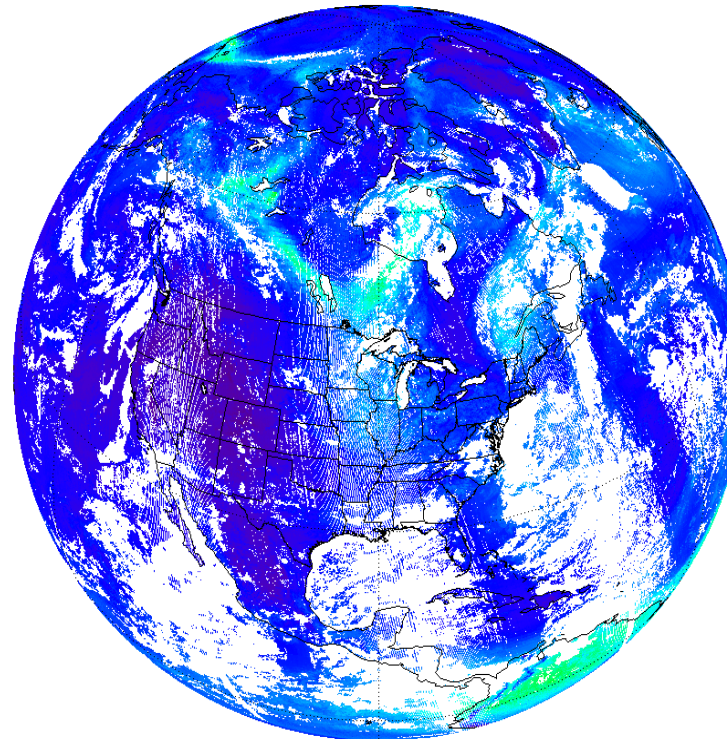
- Long-range transport of Canadian wildfire smoke had significant ($>20\mu\text{g}/\text{m}^3$, $>20\text{ppbv}$) regional impacts on surface PM_{2.5} and O₃ during July 25, 2023 exceedance event
 - The ozone exceedance along the western shore of Lake Michigan was not strongly influenced by the Canadian wildfires (small differences between experiments in this narrow coastal zone)
 - The high PM_{2.5} along the western shore of Lake Michigan was more strongly influenced by the Canadian wildfires (significant differences between experiments in this narrow coastal zone) but still underestimated PM_{2.5} observations
- Large uncertainties in wildfire emissions leads to errors in the magnitude of long-range pollution transport
 - Aerosol data assimilation can lead to improvements in the analysis of long-range transport within global air quality models and improve regional air quality predictions
- HAQAST Tiger Team is working with multiple global modeling groups and air quality management agencies to improve the availability and use of global air quality models for regional Lateral Boundary Conditions

Extra Slides

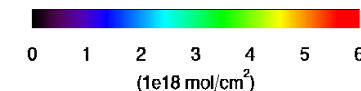
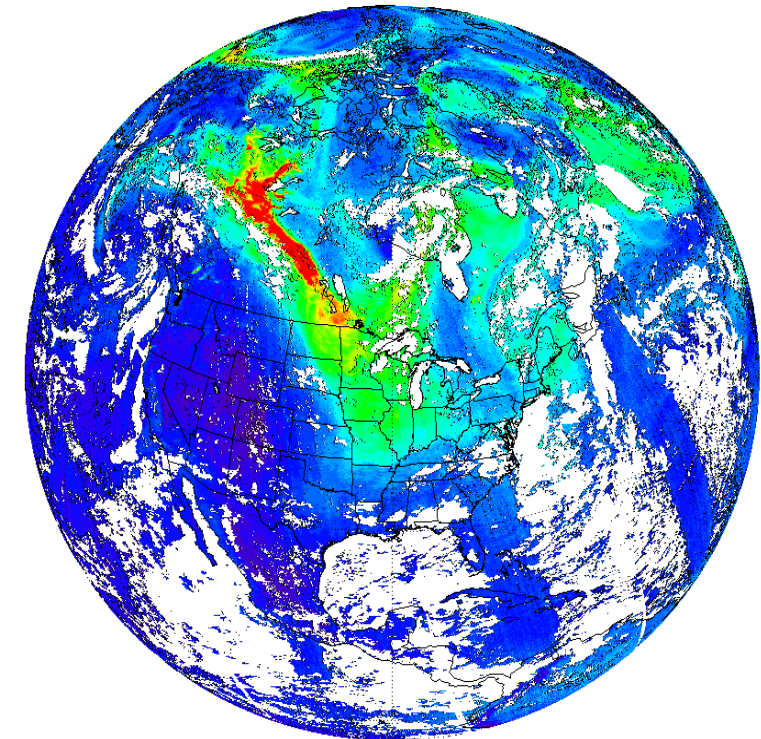
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 - Assimilation of **TROPOMI** CO columns

UFS-RAQMS CONTROL CO Column 20230722
(TropOMI AK Applied)



TropOMI Column (Corrected) Carbon Monoxide (10^{18} mol/cm²) 20230722

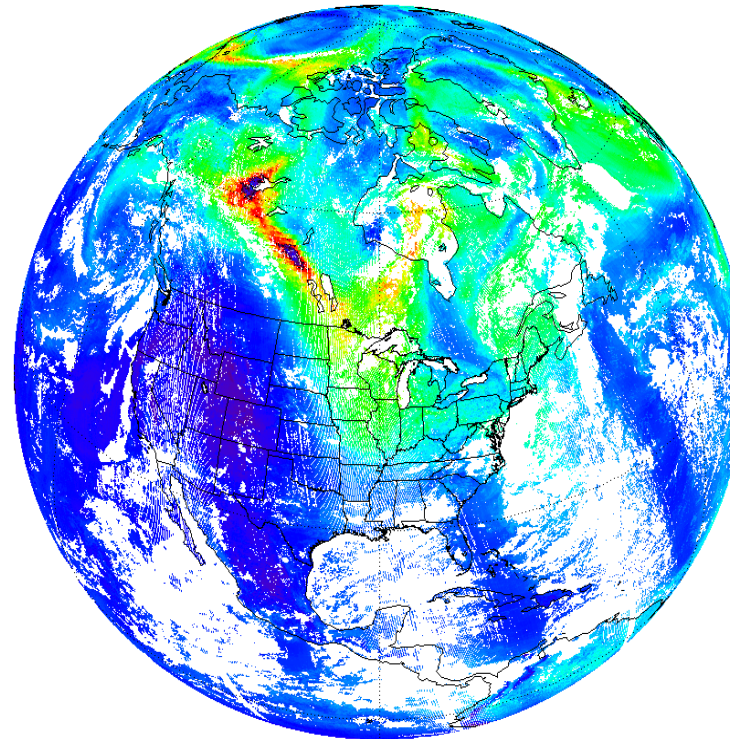


Composition Forecasting and Assimilation

Assimilation of TROPOMI CO improves long-range transport of wildfire pollutants

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UFS-RAQMS TROPOMI DA CO Column 20230722
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