NATIONAL WEATHER SERVICE

# NWS Trace Gas Observations - Assimilation and Verification

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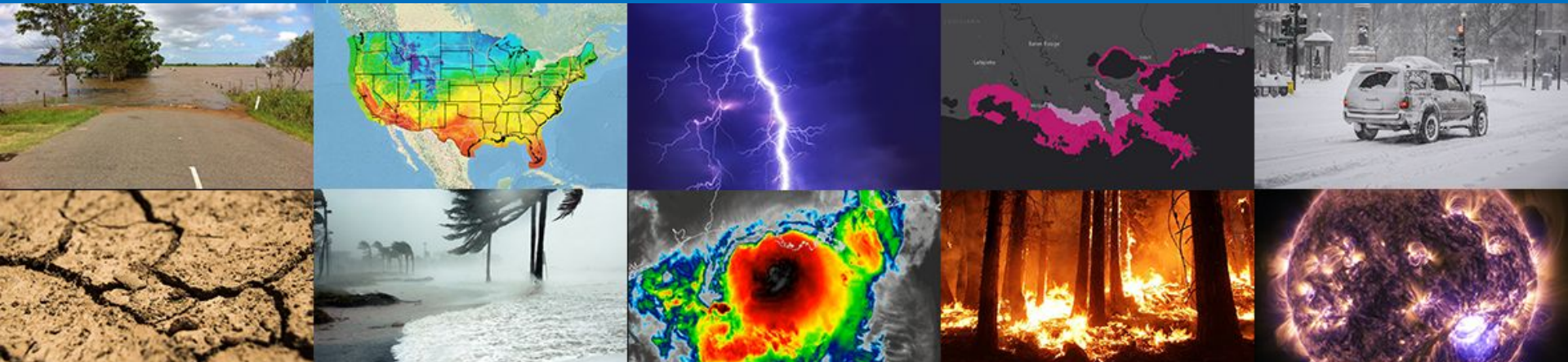
Cory Martin[1], Alicia Bentley[1], Jianping Huang[1], Jeff McQueen[1], Daryl Kleist[1], Ivanka Stajner[1], Partha Bhattacharjee[2], Hyundeok Choi[2], Ho-Chun Huang[3], Andrew Tangborn[2], Yaping Wang[2], Hongli Wang[4], Ruifang Li[4]

[1]NOAA NWS NCEP EMC | [2]SAIC @ NOAA NWS NCEP EMC | [3]Lynker @ NOAA NWS NCEP EMC | [4]CIRES @ NOAA GSL



# Current and Planned Operational Systems

Operational:

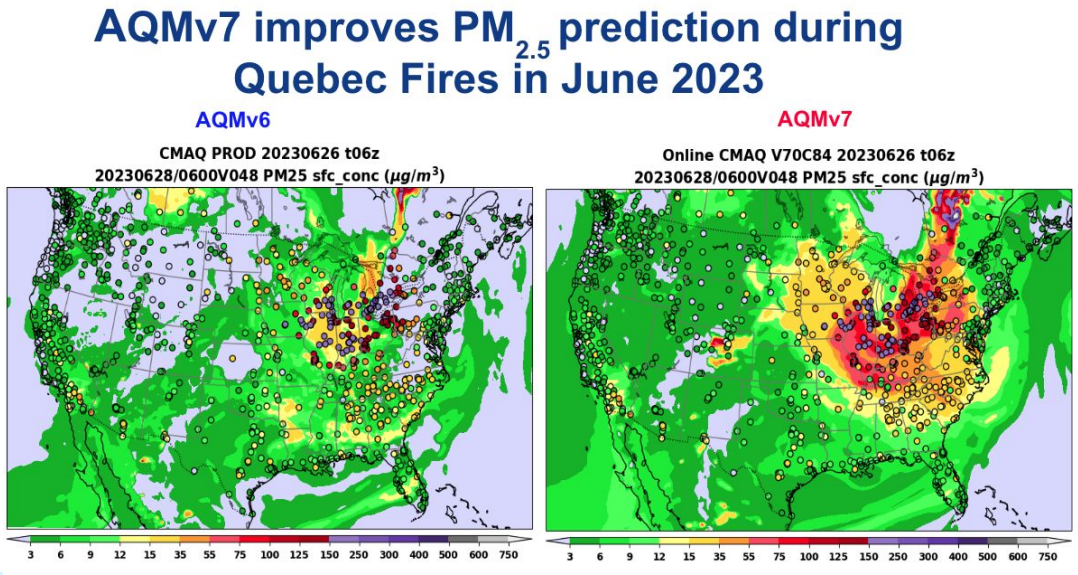
- GEFSv12 - single aerosol member out to 5 days
- AQMv7 - regional AQ model (operational implementation is imminent)
- HRRR-Smoke

Planned:

- GEFSv13 - aerosols with radiative feedback in all members
- GFSv17 - aerosol tracers (no rad. feedback) in DA forecast cycle only
- RRFSv1 - smoke and dust tracers in one member
- RRFSv2 - regional AQ forecast member as part of the RRFS

# AQMv7

- **Transitioning from an offline system (with GFS meteorology) to an online system with coupled FV3 and CMAQ**
  - 13km resolution, 65 layers, CONUS, AK, HI all in one large domain



# Usage of Atmospheric Composition Observations

## Assimilation

- GFSv17/GEFSv13
  - VIIRS Aerosol Optical Depth assimilation
- Regional AQ Model
  - TROPOMI $NO_2$, VIIRS AOD, surface PM
  - TEMPO $NO_2$, $O_3$, AOD?
- State / Emissions Adjustment
  - Longer term plan to improve NRT emissions through coupled DA

## Validation/Verification

# Joint Effort for Data assimilation Integration (JEDI) Infrastructure for Unified Data Assimilation

**JEDI** is a project within the Joint Center for Satellite Data Assimilation (JCSDA)


JEDI provides a **software infrastructure for data assimilation** that

- ❑ is model agnostic
- ❑ is generic and portable, from toy models running on laptops to operational Earth system coupled models running in the cloud.
- ❑ enables DA on the model native grid
- ❑ does not impose one specific DA methodology or algorithm
- ❑ provides a framework for rapid uptake of new observations into operations with generic observation handling and modeling
- ❑ encourages implementation of model-independent observation operators
- ❑ provides a unified Interface for Observation Data Access (IODA)

JEDI is intended for **scientific exploration** and **operational forecasting**.

The keys to success are **separation of concerns** and **interfaces**.

# GFSv17 Aerosol DA Plans

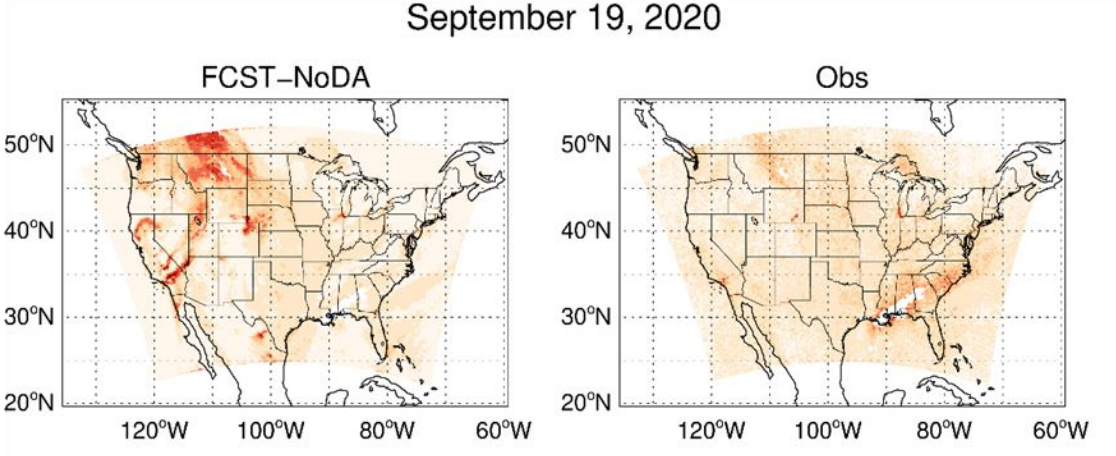
**Currently one of the few (only?) operational centers to not have aerosol DA initializing their aerosol prediction system**

- **6-hourly cycles 4x a day with early and late cycles**
  - Early cycle to initialize the GEFS long forecasts (one aerosol analysis provided, up to the ensemble forecast group to decide if/how to perturb)
  - Late cycle to initialize the high resolution GDAS forecast (without radiative feedback)
- **Analysis resolution C384L127 (~0.25 deg); background resolution C1152L127 (~9km)**
- **3DVar FGAT with 3-hourly backgrounds**
- **VIIRS EPS 550nm AOD from S-NPP, N20, N21**

# TROPOMI $NO_2$ Assimilation

In collaboration between NWS/EMC and JCSDA, a generic column retrieval forward operator has been developed in JEDI with the first application being TROPOMI $NO_2$ retrievals.

This operator has been shown to work with both total column and averaging kernel observations of constituents.

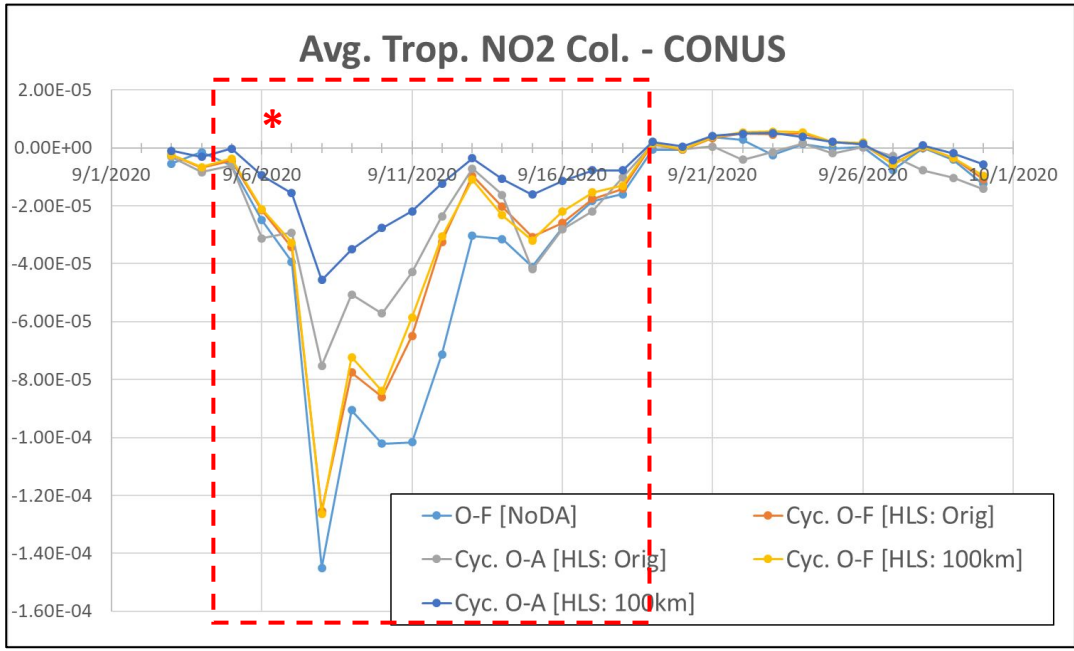



**This is the first step towards high resolution trace gas assimilation at NWS.**

# TROPOMI $NO_2$ Assimilation

Example of initial results from assimilating TROPOMI $NO_2$ retrievals in a development version of our AQM:

- Overall, DA improves $NO_2$ forecast during the fire season in September 2020.
- Initial tuning of background error and horizontal length scales is showing sensitivity to analysis performance
- * Huge negative values are related to the $NO_2$ plumes that model simulated, but observation didn't see.



# Planned TEMPO Assimilation

- **S5P only provides 1-2 observations (some overlap) per day for the coterminus US, with an overpass in the early afternoon local time**
- **For real-time air quality prediction, our forecast models will benefit greatly from geostationary observations of trace gases / aerosols for multiple reasons**
  - Higher temporal resolution (hourly; daytime only)
  - Greater chance of cloud-free retrievals
  - Data availability in the morning so that the AQ forecast can initialize early enough to provide a useful, same-day air quality prediction for the afternoon

# Assimilation of Trace Gas Obs

## Short-Term Plans

- Use TROPOMI + TEMPO to constrain ICs using $NO_2$, $O_3$, and other assimilation quality retrievals

## Future Plans

- Meteorology is an initial value problem, AQ is more sensitive to emissions (anthropogenic, biogenic, fires, etc.) and for regional, LBCs
- Using strongly coupled DA, can use retrievals + in situ obs to constrain state and adjust emissions concurrently (fire emissions already based on observations)
- Challenges:
  - Computational cost (4DVar; ensemble approaches)
  - Could AI help with either or both?

# Operational Validation Datasets

- **EVSv1 (EMC Verification System) recently went into operations (https://www.emc.ncep.noaa.gov/users/verification/)**
  - Current operational EVS is only validating with in situ surface PM2.5 and $O_3$ observations for the regional AQM
- **EVSv2 plans to include a comprehensive composition validation suite:**
  - Smoke and or dust AOD from satellites, Total AOD from satellites and AERONET
  - Surface $NO_2$ and $SO_2$
- **Future EVS implementations could include additional remotely-sensed verification datasets**
  - TEMPO: $O_3$ (tropospheric and PBL), $NO_2$, HCHO, aerosol products, $O_3$ profiles (ex: OMPS)

# Development Datasets

**Operational use of observations comes with stipulations and challenges**

- **Latency**, limited resources for ingest/storage, etc.

**But, observations from TEMPO will be useful to NWS as soon as they are publicly available**

- Verification / validation of systems under development and pre-operational implementation
- Development of future assimilation systems
- “offline” validation of currently operational systems
  - Used to define areas of focus for model upgrades

# Summary

- No operational assimilation of aerosol / trace gas observations (yet)
  - JPSS VIIRS AOD coming soon, TROPOMI/TEMPO trace gas shortly after
- Observations are/can be used to validate operational model performance
- Long term plans include simultaneous state and emissions adjustment through strongly coupled DA

Questions: cory.r.martin@noaa.gov