Unifying Atmospheric Composition in the Unified Forecasting System Through UFS-Chem Development

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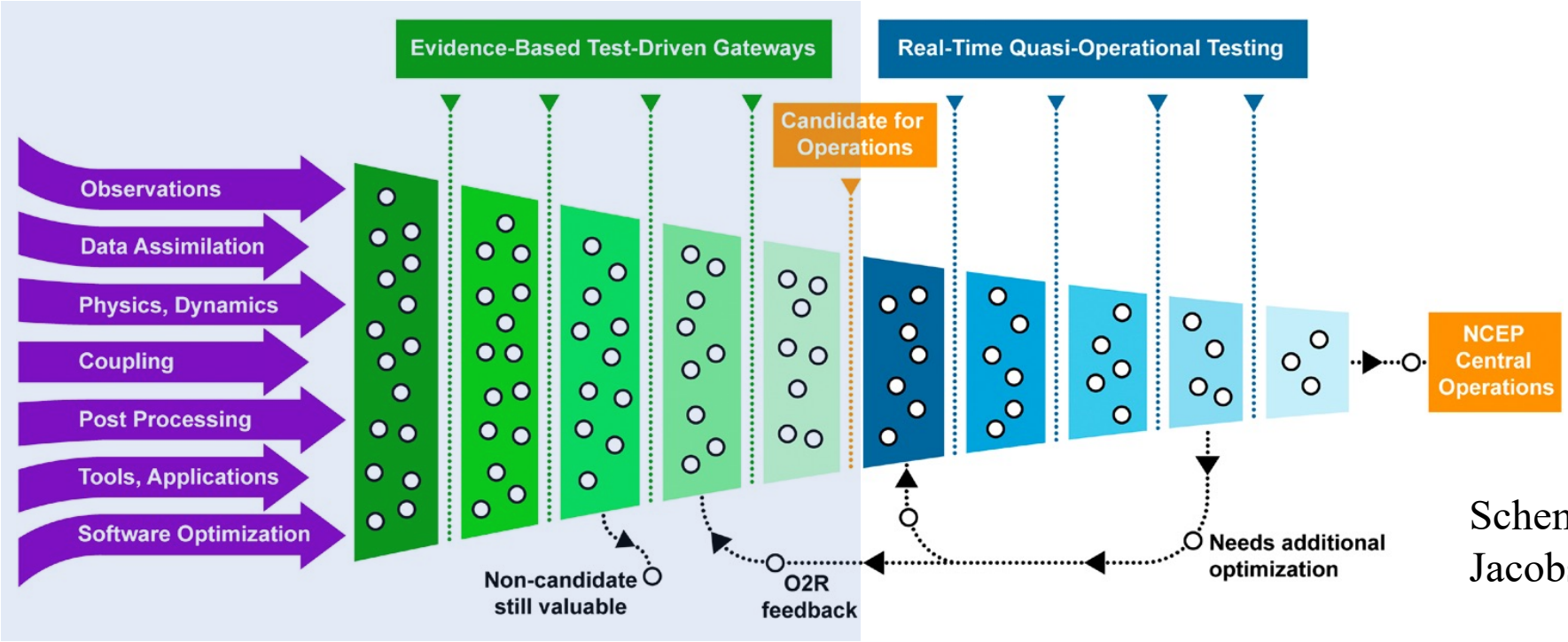
Development of UFS-Chem is a collaborative effort so far across NOAA, EPA, & NSF NCAR

We are actively growing our community. Please email Rebecca.Schwantes@noaa.gov if you would like to be more involved!

The NOAA Unified Forecasting System (UFS)

- Community-developed Earth system model for research and operations
- Goal is to improve R2O and O2R activities and community involvement
- **Problem:** Currently, chemistry related code is often duplicated in the UFS and organized based on external code packages rather than by processes
  - This non-unified framework is inefficient for code maintenance and development
  - **Adding research capabilities is not possible in such a divided infrastructure**



Schematic of UFS from Jacobs, *BAMS*, 2021

UFS Atmospheric Chemistry Science Questions

Motivation: Greater understanding of societal challenges related to weather, air quality, smoke, and climate leading to improved forecasts and ability to inform policy

Science Questions:

How well are emissions, chemical processing, and dynamics from wildfires, urban sources, oil & gas production, and their interactions represented in the UFS compared to observations for both air pollutants and GHGs?

What are the co-benefits for climate change mitigation efforts on air quality?

How can data assimilation of satellite observations be used to improve emissions especially for near real time events?

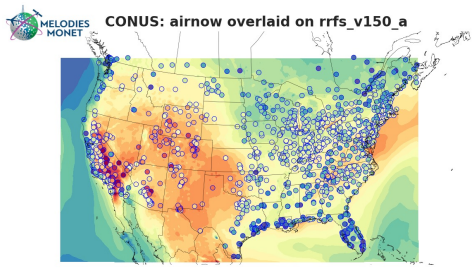
How can we improve aerosol predictions and quantify their impact on weather forecasts?

How do we incorporate algorithms that encourage collaborative development across groups with different perspectives?

These Science Questions Motivate Us To Add Innovative Research Capabilities

- Options to use gas and aerosol chemical mechanisms of varying complexity
- Options for passive tracers (e.g., long lived greenhouse gases)
- Novel parameterizations for fire weather
- Ability to easily and accurately couple different mechanisms to different physics options
- Development of a more flexible emissions processing system
- Interfacing with state-of-science atmospheric composition data assimilation capabilities
- Further investment of model evaluation tools like MELODIES MONET

Surface



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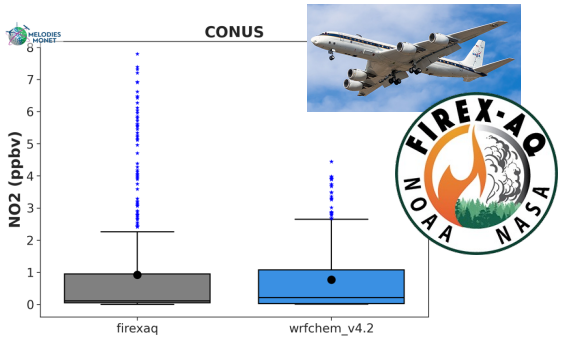
Aircraft



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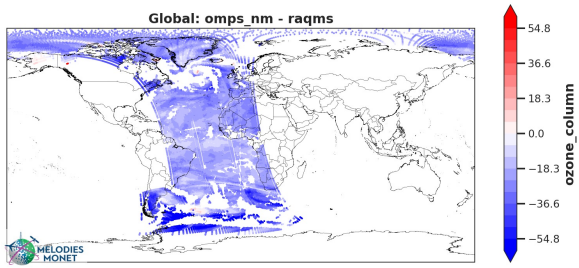
Satellites



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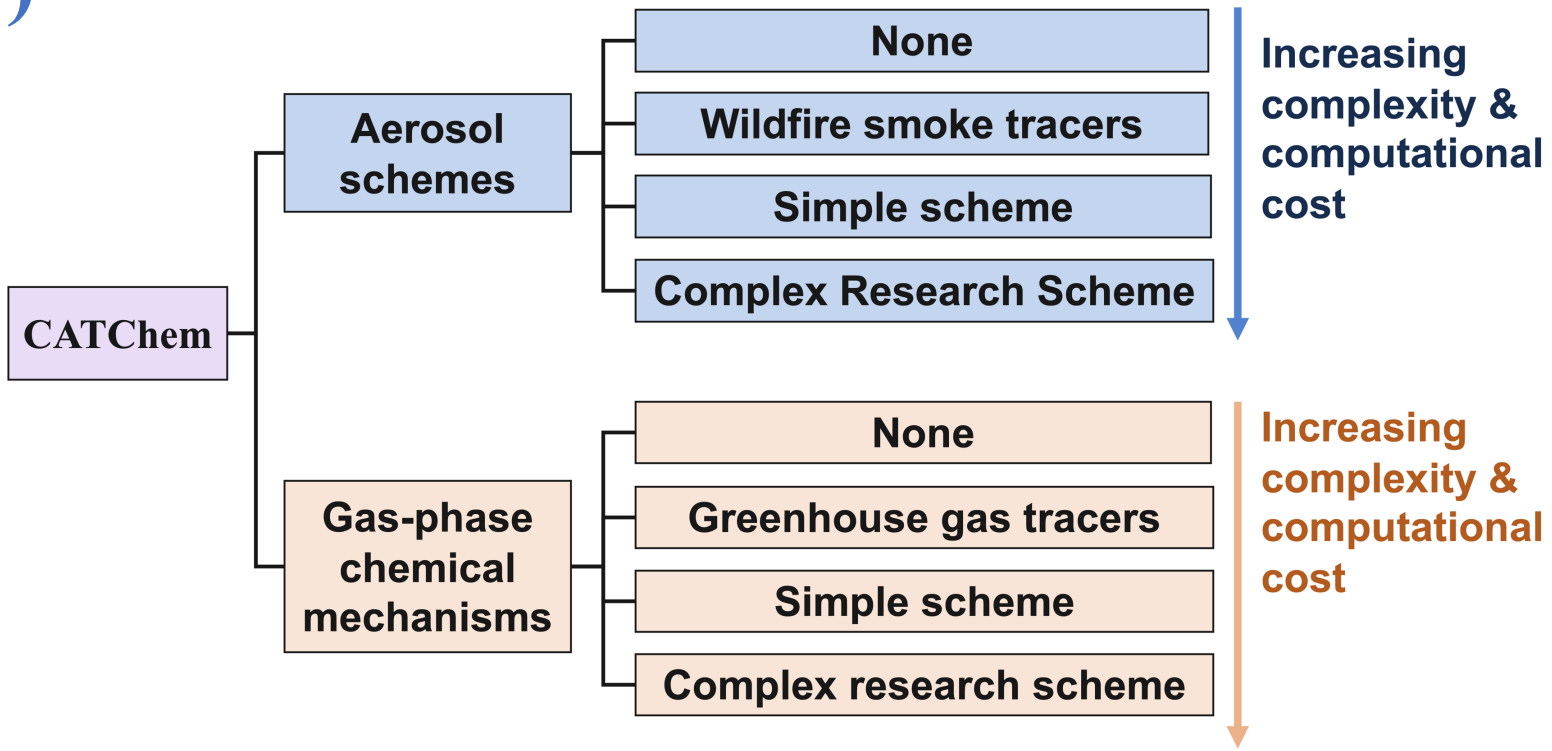
More complete understanding of model biases & accurate plans for addressing them

MELODIES MONET

https://melodies-monet.readthedocs.io

Create Chemistry Package called CATChem (Configurable ATmospheric Chemistry)

- Stores all chemistry related code in one unified location
- Will be flexible and configurable
  - For example, users can choose the aerosol scheme and the gas-phase chemical mechanism of the right complexity for their application

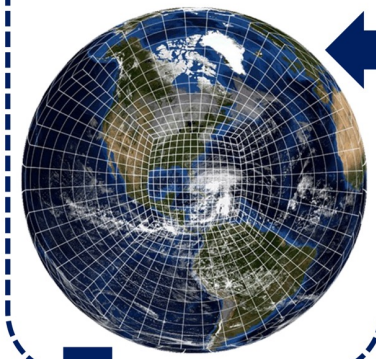


- We will still link to authoritative repositories from external collaborators, **but at a process level only**
  - Model Independent Chemistry Module (MICM) - developed by NSF NCAR/ACOM
    - Learn more about MUSICA from Gabriele Pfister: EGU24-11179 | Orals | AS3.21
  - The Community Regional Atmospheric Chemistry Multiphase Mechanism (CRACMM) - developed by US EPA, NOAA CSL, and the community

UFS-Chem

Data Assimilation
Chem-DART / JEDI

Meteorology
UFS



Chemistry
CATChem

CATChem
- Aerosol schemes
  - None
  - Wildfire smoke tracers
  - Simple scheme
  - Complex Research Scheme
  - *Increasing complexity & computational cost*
- Gas-phase chemical mechanisms
  - None
  - Greenhouse gas tracers
  - Simple scheme
  - Complex research scheme
  - *Increasing complexity & computational cost*

Evaluation
MELODIES MONET

Greater understanding of societal challenges related to weather, air quality, smoke, and climate leading to improved forecasts and ability to inform policy

Emissions

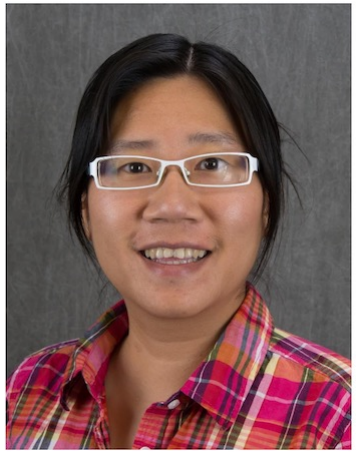
NEXUS (Emissions Processing)

GRA^{2}PES (Anthropogenic), RAVE (Fires), FENGSHA (Dust), Canopy-App (Biogenic), OASISS (Ocean)

First Global Configuration of the UFS with Full Gas-Phase Chemistry

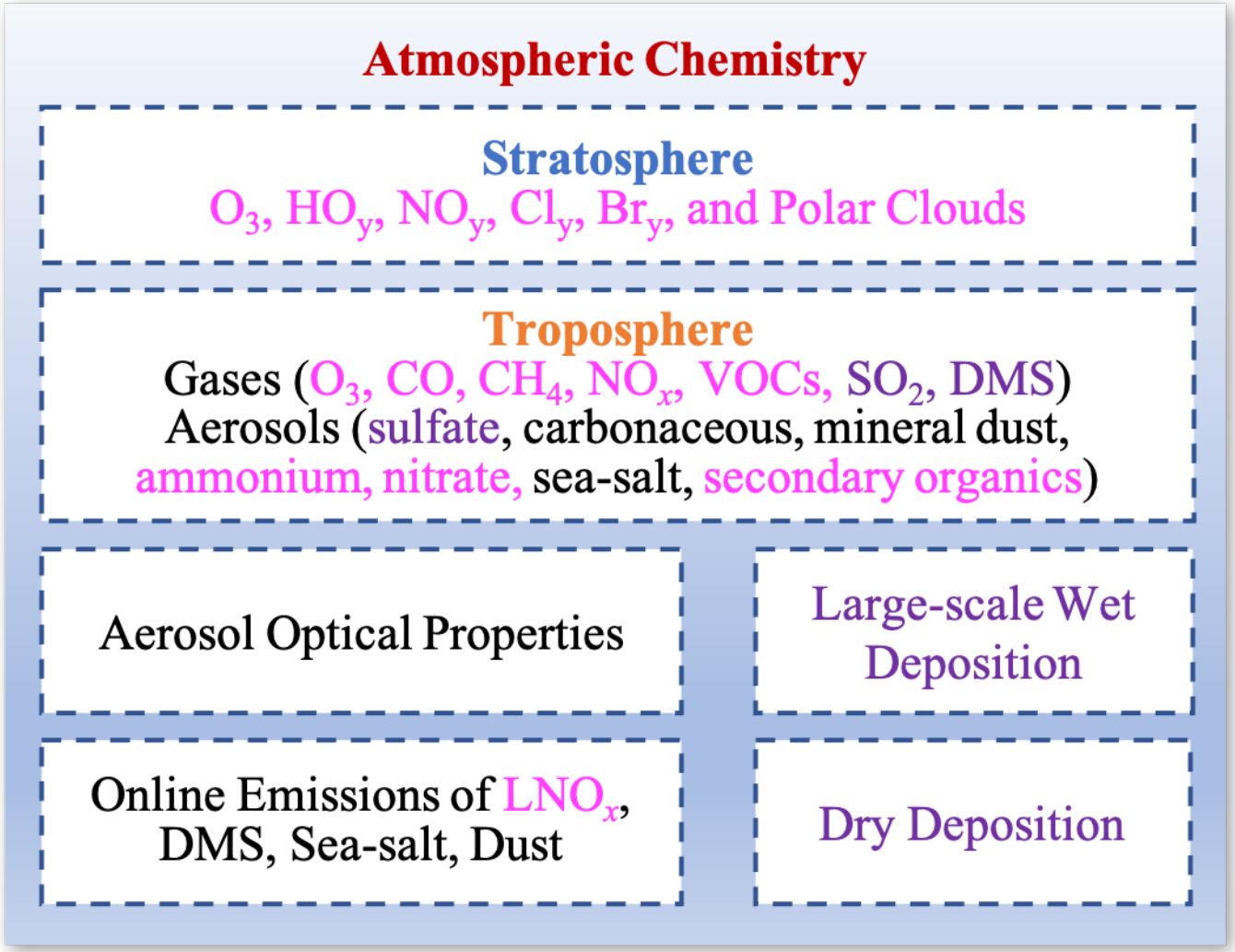
- Added full gas-phase tropospheric and stratospheric chemistry from the NOAA GFDL AM4 model into CATChem and started to link this to the UFS

Jian He,
NOAA CSL



Li (Kate) Zhang,
NOAA GSL

See poster (X5.70 | EGU24-6827 | AS3.18) for more details about UFS-Chem simple aerosol scheme and the fire aerosol predictions

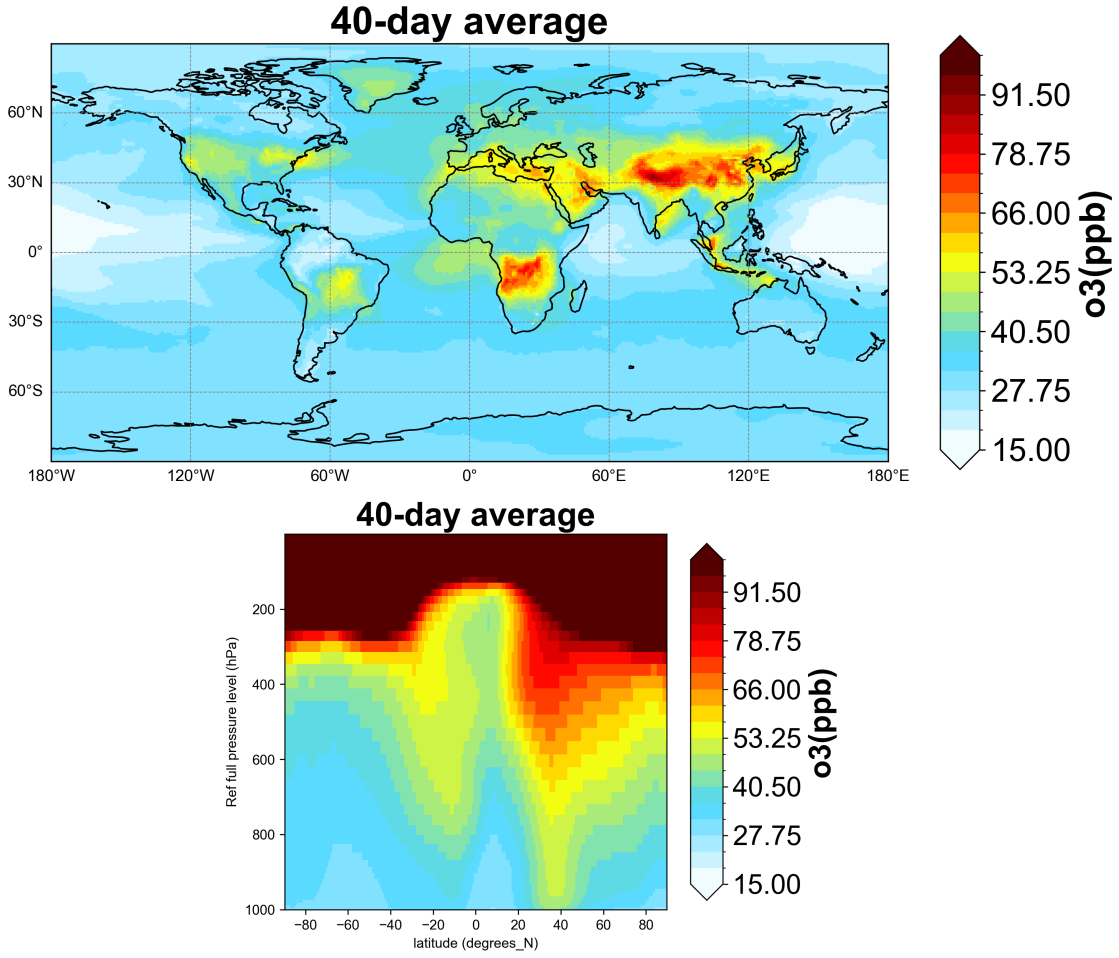


Existing processes (Zhang et al., *GMD*, GEFS-Aerosols v1, 2022)
New processes
Modified processes

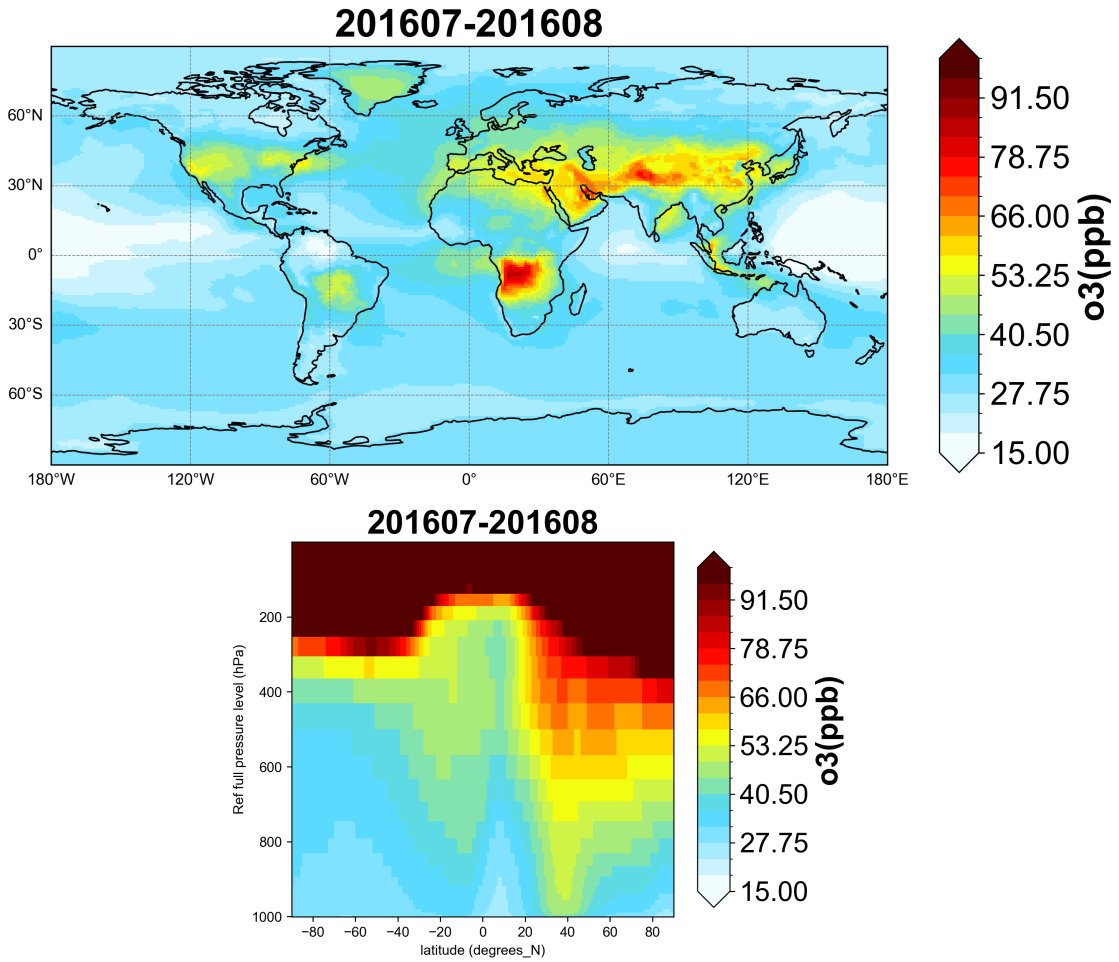
Initial Tests of UFS-Chem with AM4 Chemistry

- Initial tests demonstrate UFS-AM4 represents key new species like ozone well
- More tests for individual processes are underway including evaluation against the ATom field campaign dataset

UFS-Chem with AM4 Chemistry



NOAA GFDL AM4 Model



Conclusions

- We are unifying atmospheric chemistry and composition in the UFS through development of CATChem and UFS-Chem
- Significant scientific and programmatic motivation for UFS-Chem
  - Increase efficiency and reduce costs in code development and code maintenance
  - Reduce time and effort for transitions to operations
  - Enhance collaborations with the atmospheric chemistry and carbon cycle research communities
- If you would like to be involved with CATChem or UFS-Chem development or have suggestions, email me: Rebecca.Schwantes@noaa.gov
  - If you have a modularized atmospheric chemistry or aerosol component or are currently developing one that would be useful to add to our tool, let us know!
- Useful links to learn more
  - CATChem
    - Source Code: https://github.com/UFS-Community/CATChem
    - User Guide: https://catchem.readthedocs.io/
  - MELODIES MONET (new model evaluation tool under development)
    - Source Code: https://github.com/NOAA-CSL/MELODIES-MONET
    - User Guide: https://melodies-monet.readthedocs.io/