The CESM Chemical Forecast System – Summary & Coming Changes

CESM Workshop

10 June, 2025

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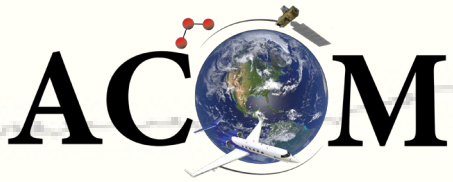
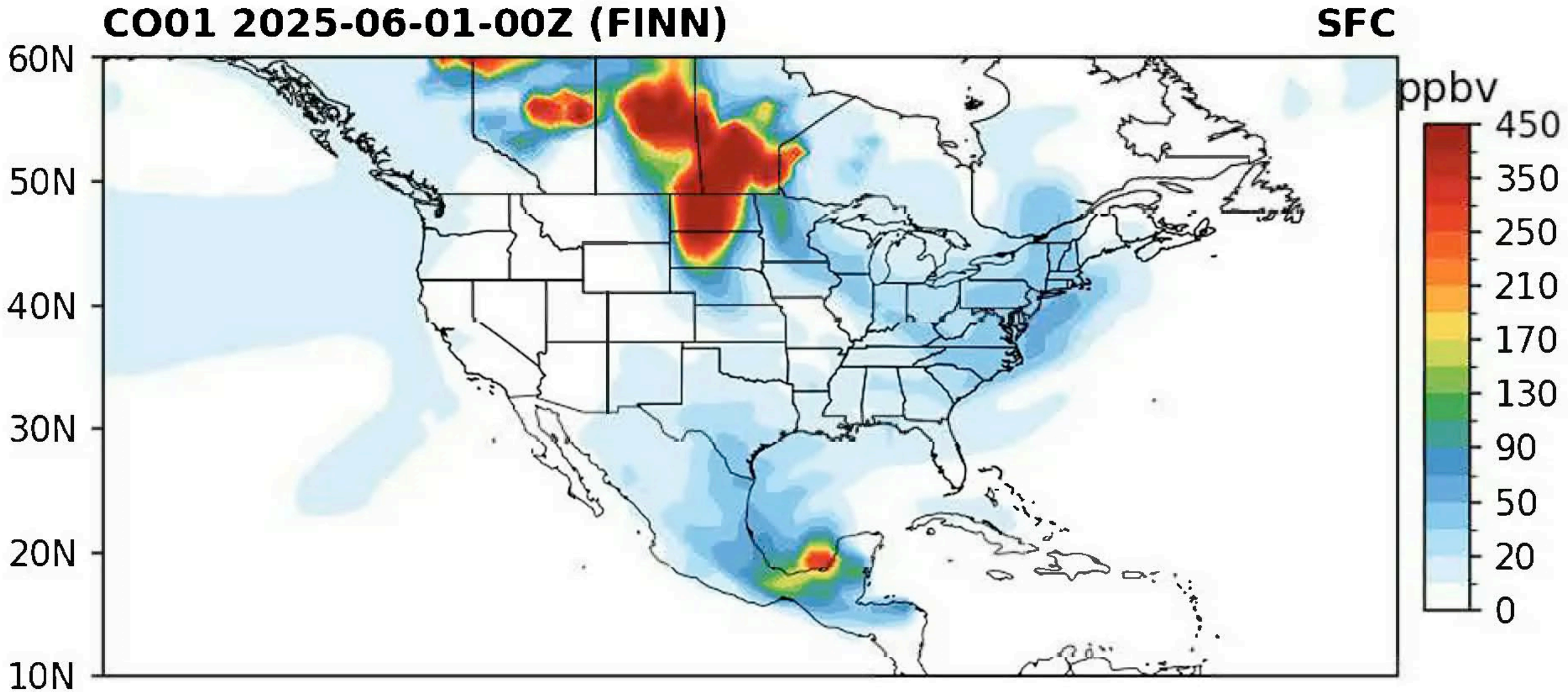


Current Chemical Forecast System

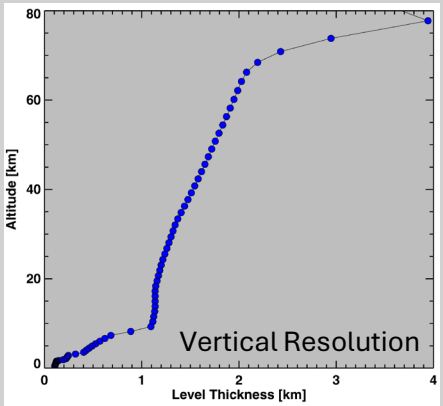
Loop: Canadian Fires from beginning of June, 2025



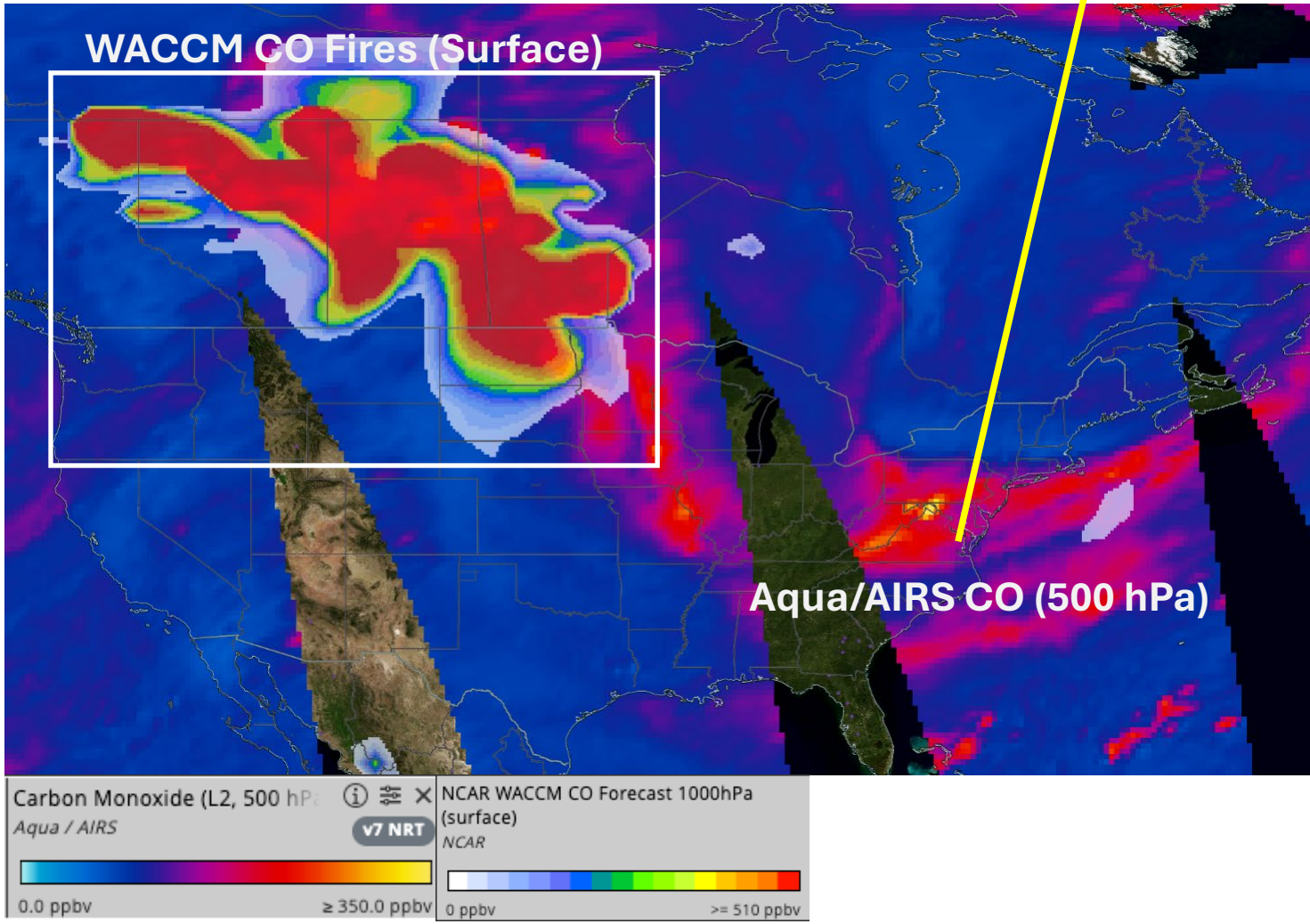
Current Chemical Forecast System

Chemical Forecasts - daily runs since 2019

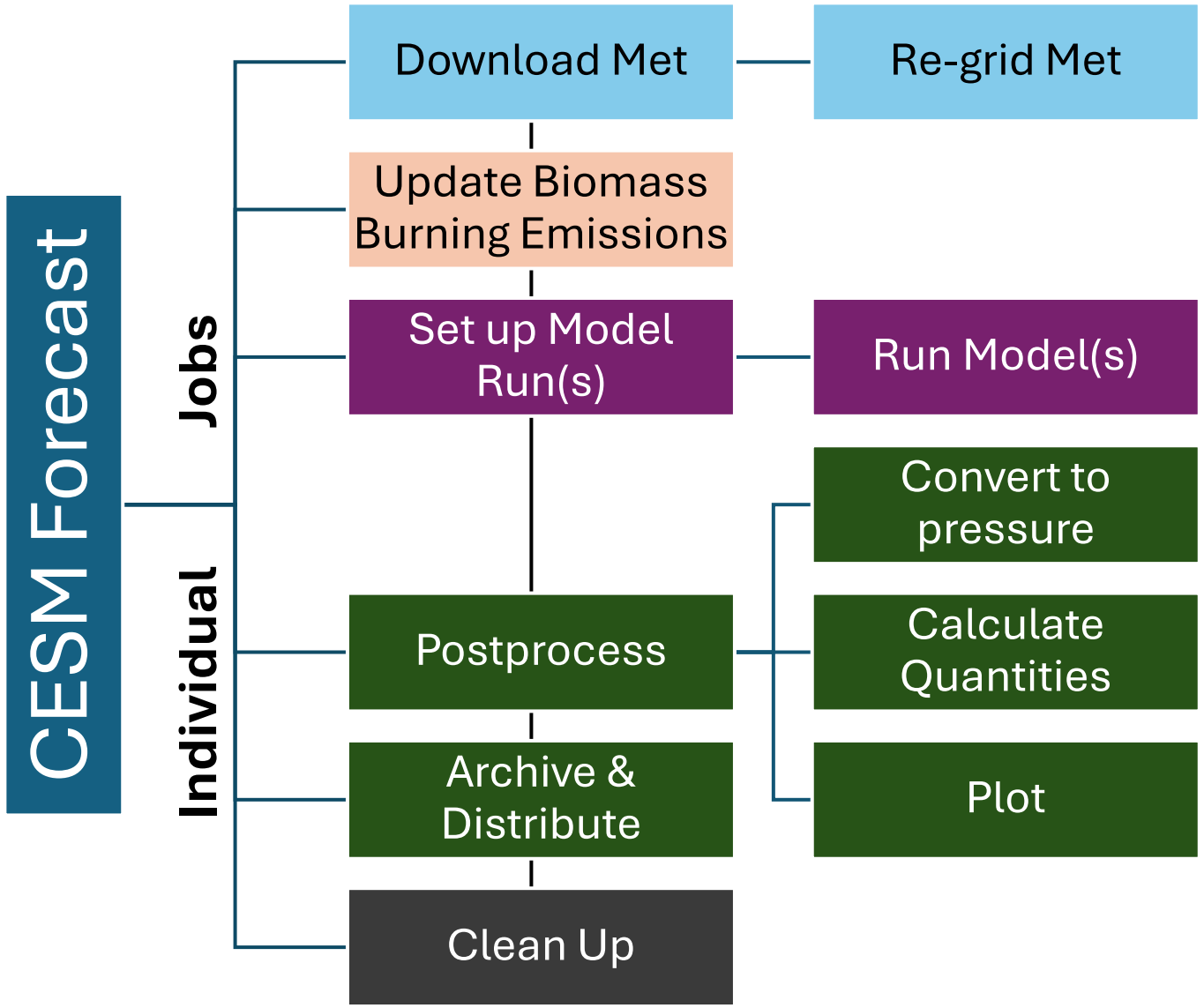
- CESM 2.2.2 – Latest Supported Dev. Release
- WACCM Specified Dynamics (FWSD)
- 10 Day 0Z Forecasts
- Two parallel runs
  - Biomass Burning
    - FINN
    - QFED
- 0.9x1.25 (f09) Horizontal Resolution
- 88 Vertical Levels
  - Surface to Thermosphere
  - 1.2 km UTLS
  - 1.2-1.5 km Middle Atmosphere
- Meteorology: NASA GEOS-FP (T, U, V)
- Anthropogenic Emissions: CAMS V5.1



Canadian Fires 1 June, 2025 – WACCM Worldview



Chemical Forecast System Breakdown



- Jobs chained via PBS Pro.
  - Predetermined resource allocations
  - Efficiency with Job Chaining
- Model(s): Derecho
- Other Jobs: Casper
- Called via Terminal or Cron
  - Allows for automation

CESM Chemical Forecast System – Challenges

- Meteorology Downloads (0Z GEOS-FP)
  - 10 Day Forecasts – 818 files
  - 243 Gb.
  - Server Slowdowns Common.

- Computer Resources
  - Core Hours: 20k /week
  - Shared resources
  - End of Fiscal Year woes.

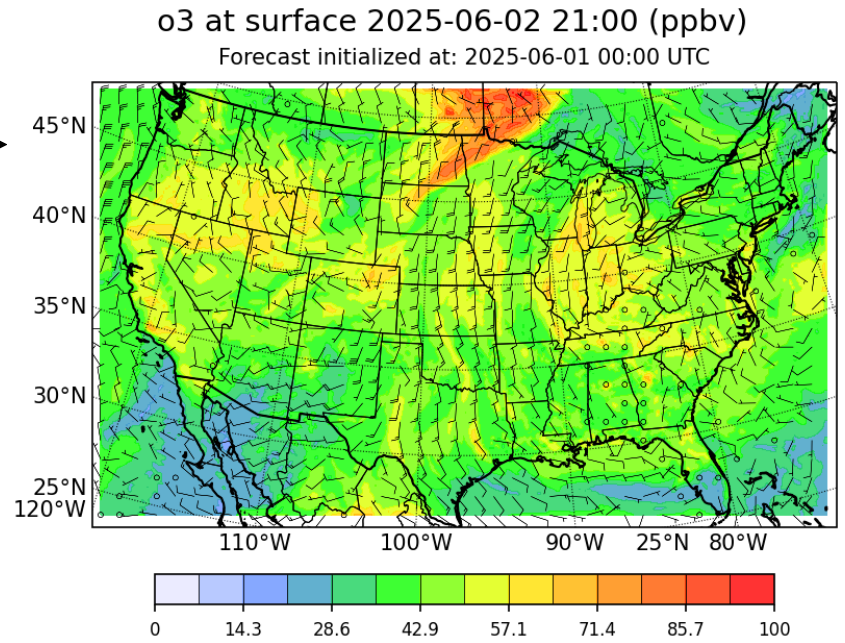
- Time Constraints
  - Needs to finish in timely manner
  - Complex runs (i.e. MUSICA) can take much longer.

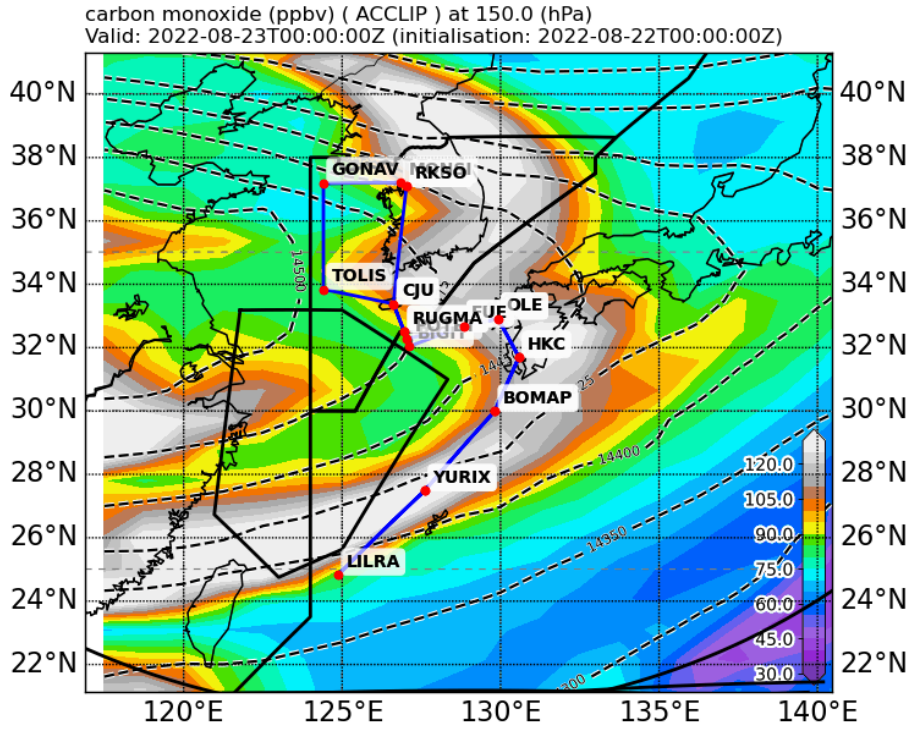
- Keeping up with inventories (i.e. emissions)

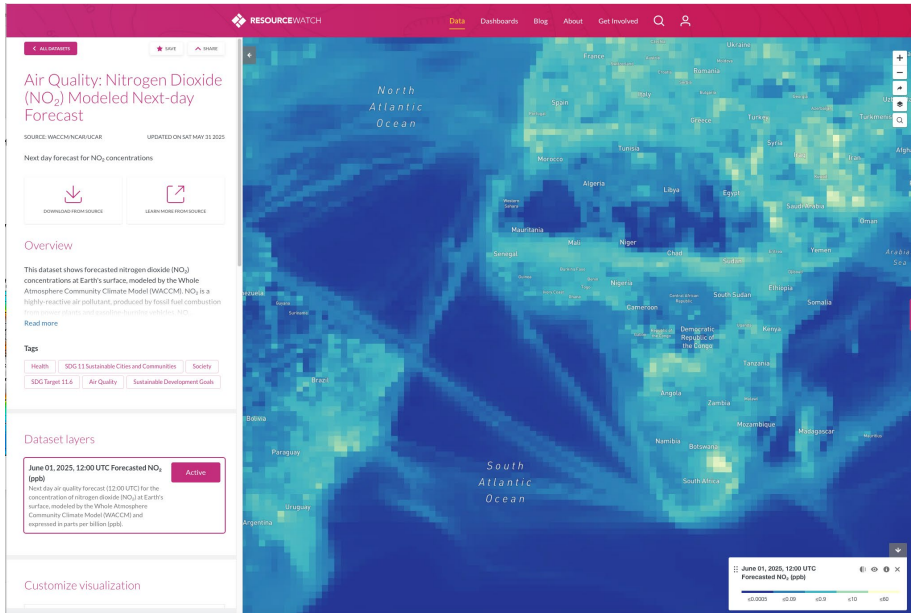
- Hardware/Software Changes & Downtime

Usage

- Boundary Conditions for regional runs
  - ACOM WRF-Chem Forecasts
  - Other WRF-Chem runs
- Field Campaign Flight Planning – Mission Support System (MSS)
  - CONTRAST
  - ACCLIP
  - TI3GER
  - CAESAR
- Air Quality
  - Resource Watch
- Other Uses
  - Comparisons
  - Model Studies
  - Etc.



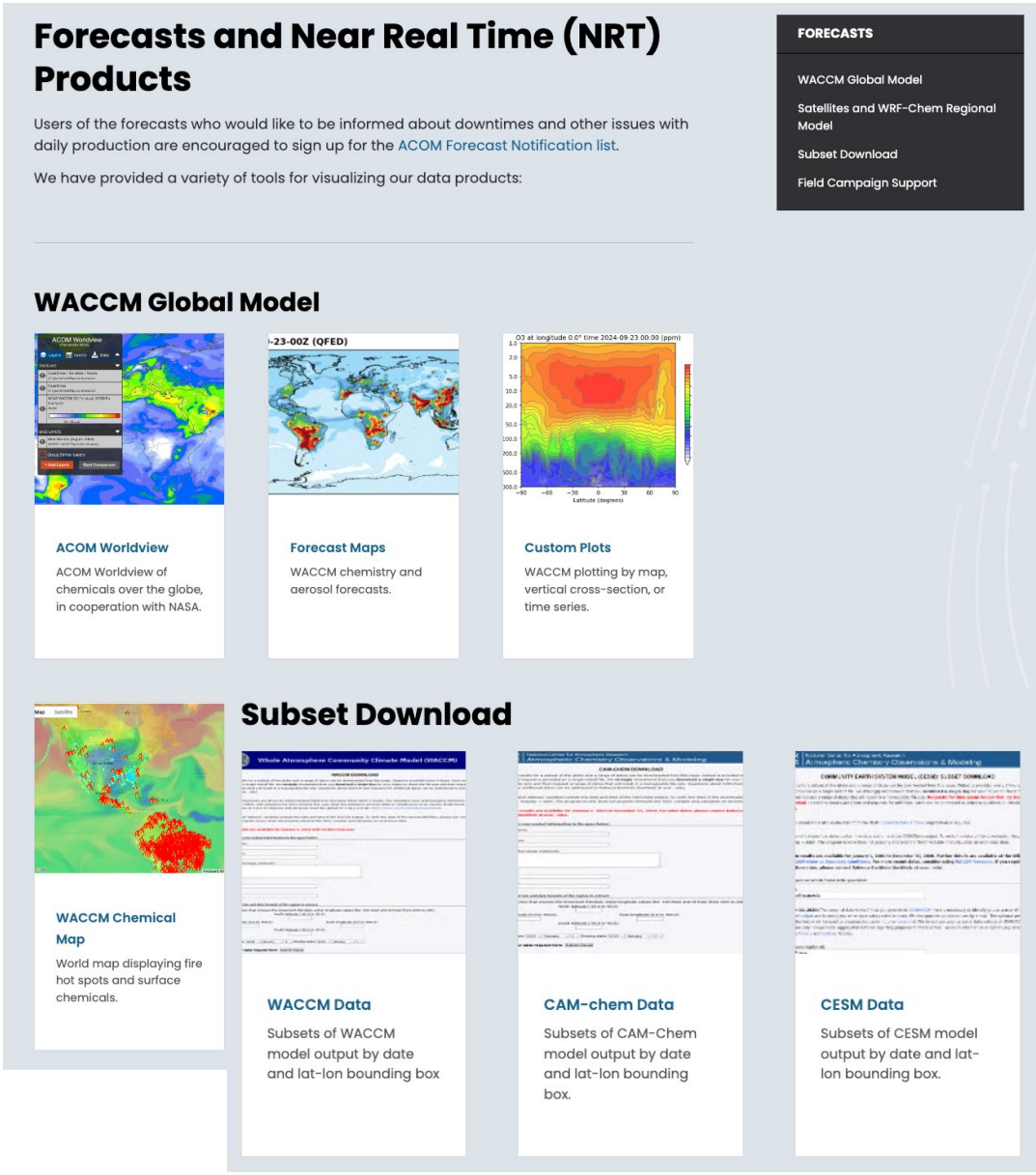




Outputs

1. NCAR Research Data Archive (RDA)
   - D313006
   - https://rda.ucar.edu/datasets/d313006/#
   - DOI assignments allow for publication tracking
   - Analyses only
   - A couple of weeks behind real time.

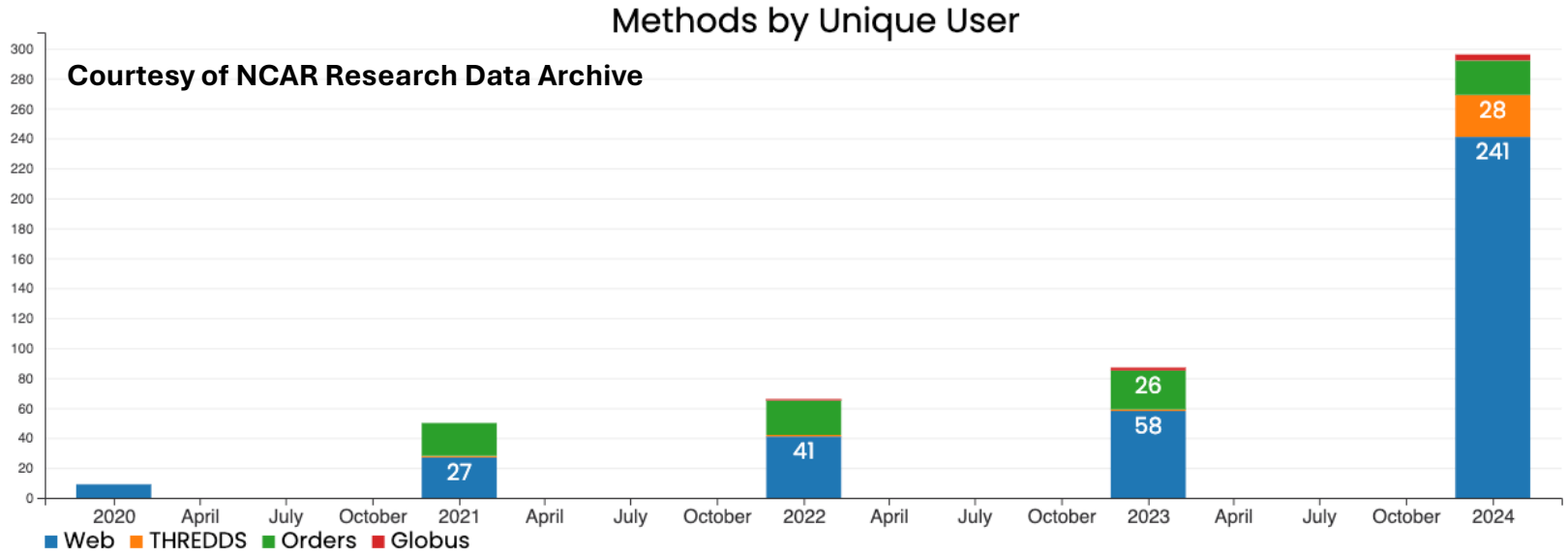
2. ACOM Forecast Page (WACCM & WRF-Chem)
   - https://www2.acom.ucar.edu/acresp/forecasts-and-near-real-time-nrt-products
   - ACOM Worldview
   - Pre-plotted Forecast Maps
   - Custom Plotting
   - WACCM Interactive Chemical Maps
   - Latest 1 year of WACCM analyses and latest forecast outputs
     - Download full files
     - Subset Downloads



Usage Statistics

On the ACOM Server:

- Over 17,000 direct downloads since 2018.
  - Over 900 unique addresses
- Over 1500 User registrations
- Over 1000 unique addresses for subset requests



Citation Statistics for this Dataset:

This dataset has been cited **12** times.

PUBLISHED WORKS THAT HAVE CITED THIS DATASET:

2025

Seo, S., S. Kim, K. Kim, A. Richter, K. Lange, J. P. Burrows, J. Park, H. Hong, H. Lee, U. Jeong, J. Woo, and J. Kim, 2025: Diurnal variations of NO_2 tropospheric vertical column density over the Seoul metropolitan area from the Geostationary Environment Monitoring Spectrometer (GEMS): seasonal differences and the influence of the a priori NO_2 profile. *Atmospheric Measurement Techniques*, **18(1)**, 115-128, https://doi.org/10.5194/amt-18-115-2025

2024

Chantaraprachoom, N., H. Shimadera, K. Uranishi, L. V. Mui, T. Matsuo, and A. Kondo, 2024: A Nation-by-Nation Assessment of the Contribution of Southeast Asian Open Biomass Burning to $PM_{2.5}$ in Thailand Using the Community Multiscale Air Quality-Integrated Source Apportionment Method Model. *Atmosphere*, **15(11)**, https://doi.org/10.3390/atmos15111358

Chou, Y., and P. K. Wang, 2024: Convective Gravity Waves in the Stratosphere and the Mesosphere: A Case Study of Airglow Over West Africa Using the Weather Research and Forecasting Model. *Journal of Geophysical Research: Atmospheres*, **129(23)**, https://doi.org/10.1029/2024JD041725

Dutta, R., S. Sridharan, and P. R. Sinha, 2024: Signature of Sudden Stratospheric Warming in the Pole and Its Antipode. *Journal of Geophysical Research: Space Physics*, **129(3)**, https://doi.org/10.1029/2023JA032285

Fernandez, R. P., L. Berna, O. G. Tomazzeli, A. S. Mahajan, Q. Li, D. E. Kinnison, S. Wang, J. Lamarque, S. Tilmes, H. Skov, C. A. Cuevas, and A. Saiz-Lopez, 2024: Arctic halogens reduce ozone in the northern mid-latitudes. *Proceedings of the National Academy of Sciences of the United States of America*, **121(39)**, https://doi.org/10.1073/pnas.2401975121

Letournel, P., C. Listowski, M. Bocquet, A. Le Pichon, and A. Farchi, 2024: Evaluating Numerical Weather Prediction Models in the Middle Atmosphere Using Coherent Oceanic Acoustic Noise Observations. *Journal of Geophysical Research: Atmospheres*, **129(23)**, https://doi.org/10.1029/2024JD042034

2023

Gao, J., Y. Huang, Y. Peng, and J. S. Wright, 2023: Aerosol Effects on Clear-Sky Shortwave Heating in the Asian Monsoon Tropopause Layer. *Journal of Geophysical Research: Atmospheres*, **128(4)**, https://doi.org/10.1029/2022jd036956

Tang, W., G. G. Pfister, R. Kumar, M. Barth, D. P. Edwards, L. K. Emmons, and S. Tilmes, 2023: Capturing High-Resolution Air Pollution Features Using the Multi-Scale Infrastructure for Chemistry and Aerosols Version 0 (MUSCIAv0) Global Modeling System. *Journal of Geophysical Research: Atmospheres*, **128(7)**, https://doi.org/10.1029/2022JD038345

Virolainen, Y. A., D. V. Ionov, and A. V. Polyakov, 2023: Analysis of Long-Term Measurements of Tropospheric Ozone at the St. Petersburg State University Observational Site in Peterhof. *Izvestiya - Atmospheric and Ocean Physics*, **59(3)**, 287-295, https://doi.org/10.1134/S000143382303009X

Virolainen, Y. A., Y. M. Timofeyev, A. V. Polyakov, and A. V. Poberovsky, 2023: Ground-Based FTIR Measurements of Atmospheric Nitric Acid at the NDACC St. Petersburg Site. *Izvestiya - Atmospheric and Ocean Physics*, **59(2)**, 167-173, https://doi.org/10.1134/S000143382302007X

Yan, S., B. Zhu, S. Shi, W. Lu, J. Gao, H. Kang, and D. Liu, 2023: Impact of aerosol optics on vertical distribution of ozone in autumn over Yangtze River Delta. *Atmospheric Chemistry and Physics*, **23(9)**, 5177-5190, https://doi.org/10.5194/acp-23-5177-2023

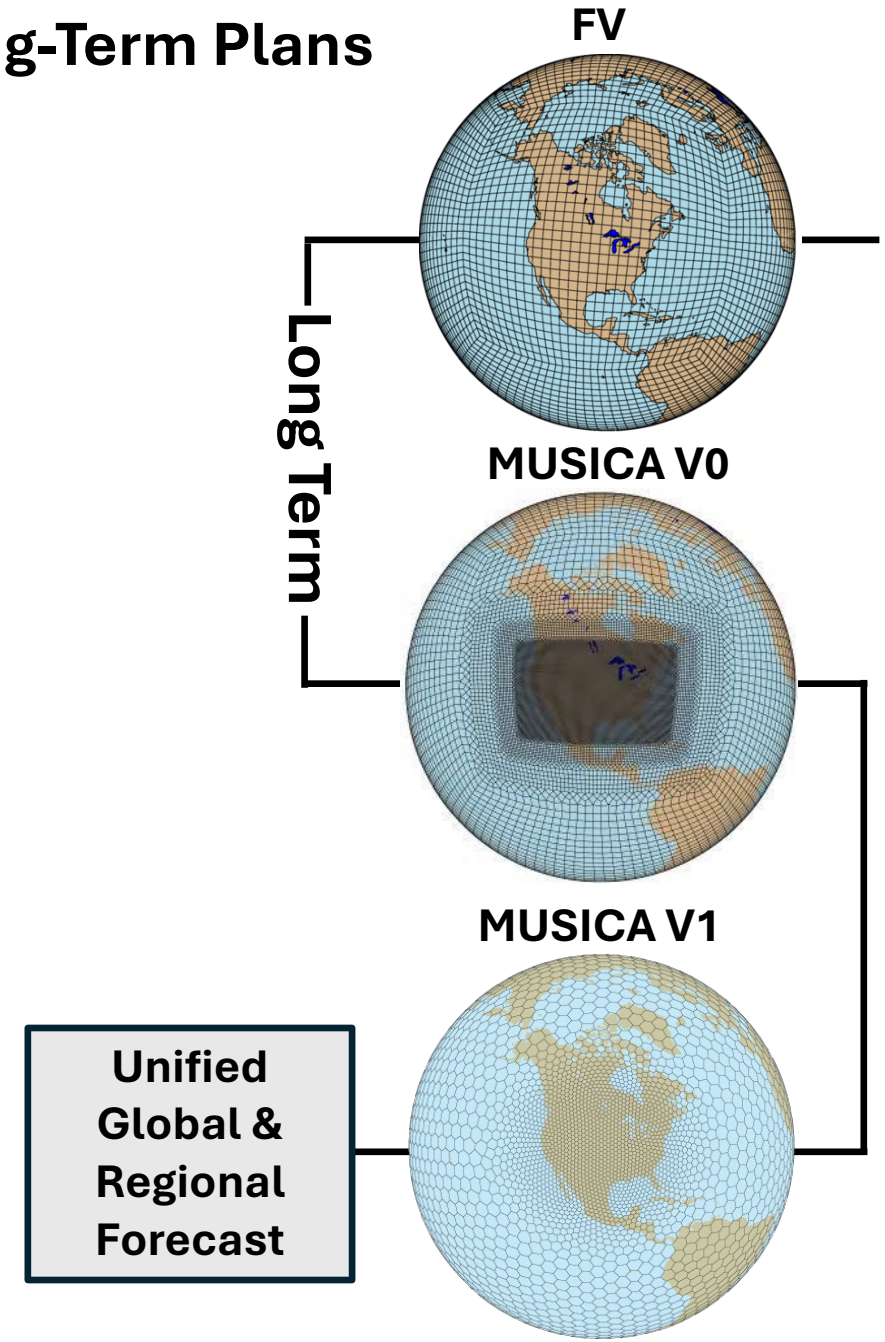
2022

Li, X., N. Bei, J. Wu, S. Liu, Q. Wang, J. Tian, L. Liu, R. Wang, and G. Li, 2022: The Heavy Particulate Matter Pollution During the COVID-19 Lockdown Period in the Guanzhong Basin, China. *Journal of Geophysical Research: Atmospheres*, **127(8)**, https://doi.org/10.1029/2021JD036191

- **RDA Usage quadrupled in 2024 vs 2023**
- **Both Analyses and Forecasts Get Used**
- **Usage continues to rise!**

Up and Coming Changes & Long-Term Plans

1. Model Version Change: CESM2.2.2 -> CESM3
2. COMPSET change: FWSD -> FWHIST
3. Vertical level change: 88L -> 70L -> 58L or 93L
4. Latest and greatest emissions
5. One model run instead of two.
6. Updated forecast code base
   - Improved meteorology downloading (GEOS-FP)
   - More Flexible
   - Cleaned up code
7. Make open source on GitHub



Up and Coming Changes & Long-Term Plans (Continued)

1. CESM2 -> CESM3
    - Improved Dust Scheme
        - Leung 2023
    - HEMCO – online emission re-gridding
    - FV -> SE dynamical core focus
    - CAM6 -> CAM7
    - Moving Mountain Gravity Wave Scheme
    - MAM4 -> MAM5
    - Many other bug fixes / code updates

2. COMPSET Change: Less restrictive vertical resolution choices
3. Vertical Level Change: Vertical resolution that best suits our needs.
4. Emissions: Current forecast is several versions behind
4. One model run instead of 2: makes way for a MUSICA forecast
6. Updated Codebase:
    - more flexible – easier integration of MUSICA
    - More user friendly.
    - Futureproof
7. GitHub: Lets others freely use the code.

<u>Another Wishlist item</u>: Forecast Diagnostics, Skill, & Evaluation

- ADF [Atmosphere Model Working Group (AMWG) Diagnostics Framework]
- MELODIES [Model EvaLuation using Observations, Diagnostics and Experiments Software] MONET

Thanks!