National Aeronautics and Space Administration

# Global-to-Local Air Quality Forecasts using the NASA GEOS Composition Forecasting System

Steven Pawson, Christoph Keller[*], Emma Knowland[*], Michael Long[+], Carl Malings[*] Lesley Ott, Viral Shah[+], Obin Sturm[+]. Pam Wales[*], Kris Wargan[+], Callum Wayman[+], Brad Weir[*]

Global Modeling and Assimilation Office (GMAO)

Earth Sciences Division, Sciences and Exploration Directorate,

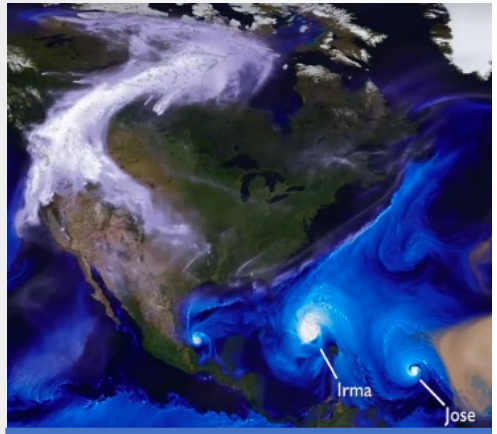
NASA Goddard Space Flight Center

*Also at GESTAR-2, Morgan State University

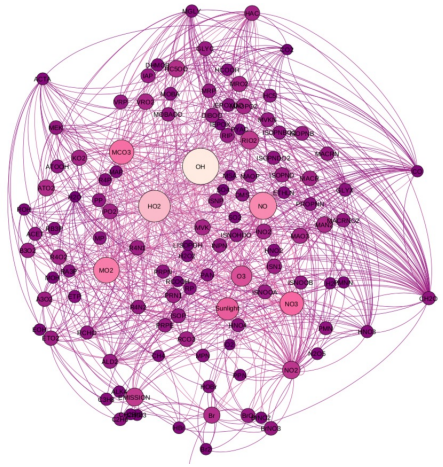
[+]Also at Science Systems and Applications, Inc. (SSAI)

# GEOS-CF produces daily global forecasts of atmospheric composition at ~0.25°/25km resolution

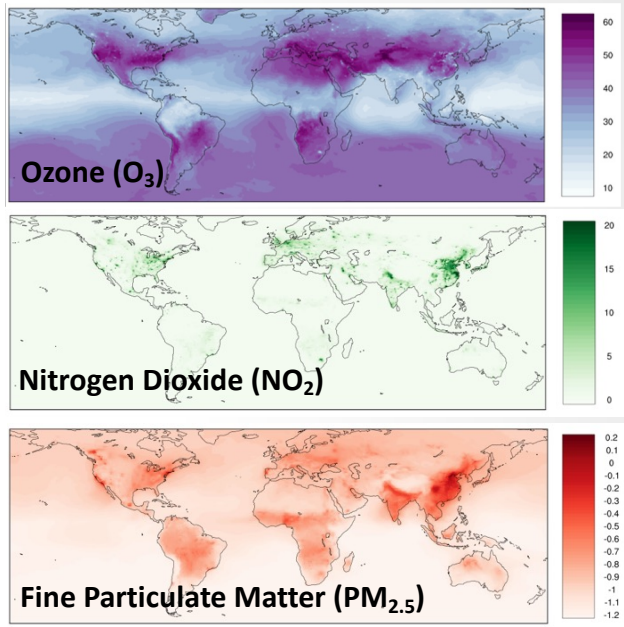





GEOS NWP



GEOS-Chem




Global replays and once daily five-day composition forecasts are produced:

- High-resolution (c360: roughly 0.25° or 25km) historical estimates for fields are available since January 2018
- Products are generated and released in near-real-time
- Forecast visualizations and links to data available at fluid.nccs.nasa.gov/cf and /cf_map

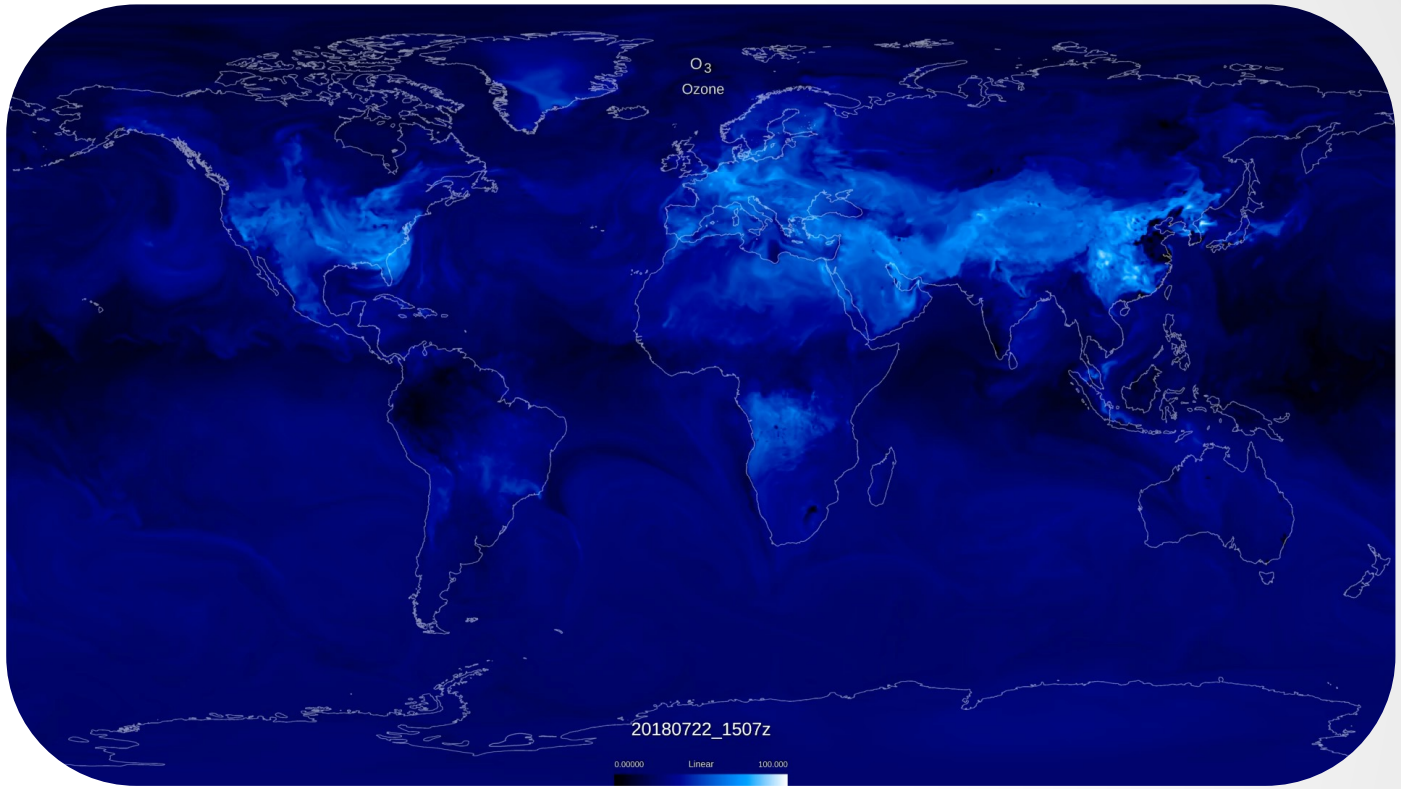
Knowland, K. E., Keller, C. A., and Lucchesi, R. 2022. "File Specification for GEOS-CF Products." *GMAO Office Note No. 17 (Version 1.3), available from http://gmao.gsfc.nasa.gov/pubs/office_notes*

# Rationale for GEOS-CF

National Aeronautics and Space Administration

Context of NASA's Earth Science Mission:

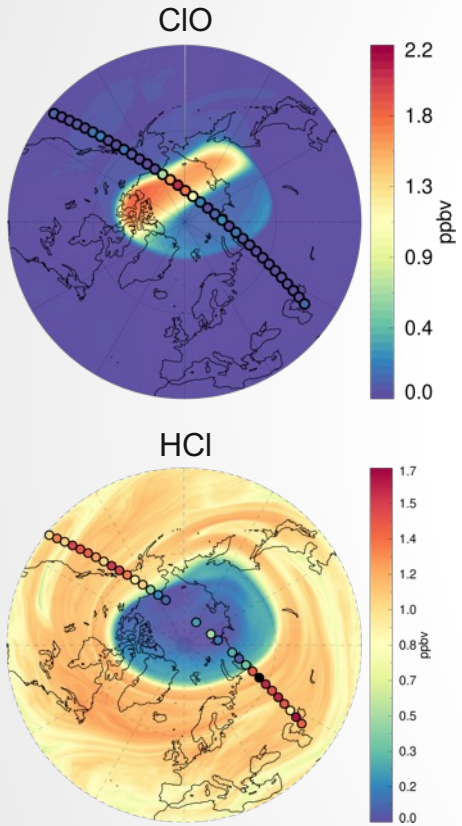
- EOS mission provides a more-than two-decade record of atmospheric composition
- Assimilated "weather" and complex chemistry module (GEOS-Chem) facilitates generation of this 3D gridded, continuous dataset for research and applications
- Real-time availability is suited for support of suborbital missions and in-situ networks
- Support of TEMPO and other space missions
- Complexity of the chemical mechanism makes GEOS-CF a baseline for more viable "operational" products



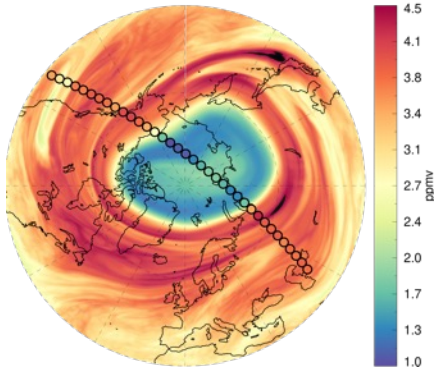

Keller, C. A., Knowland, K. E., et al. (2021). **Description of the NASA GEOS composition forecast modeling system GEOS-CF v1.0**. *Journal of Advances in Modeling Earth Systems (JAMES)*, 13, e2020MS002413. https://doi.org/10.1029/2020MS002413

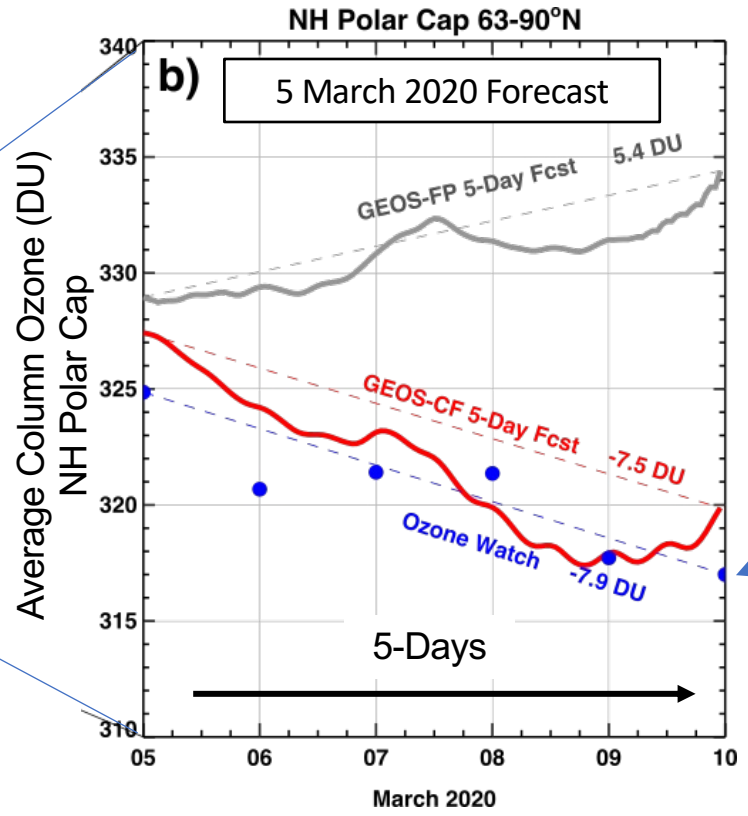
Knowland, K. E., Keller, C. A., et al. (2022). **NASA GEOS Composition Forecast Modeling System GEOS-CF v1.0: Stratospheric Composition.** *JAMES* https://doi.org/10.1029/2021MS002852

# Inclusion of Stratospheric Chemistry in GEOS-CF Provides GMAO Provides GMAO the capability of Realistic Ozone Forecasting

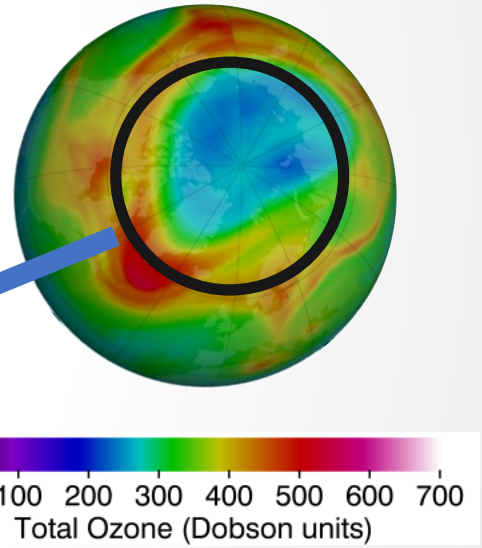



March 5, 2020
GEOS-CF




March 10, 2020
Ozonewatch





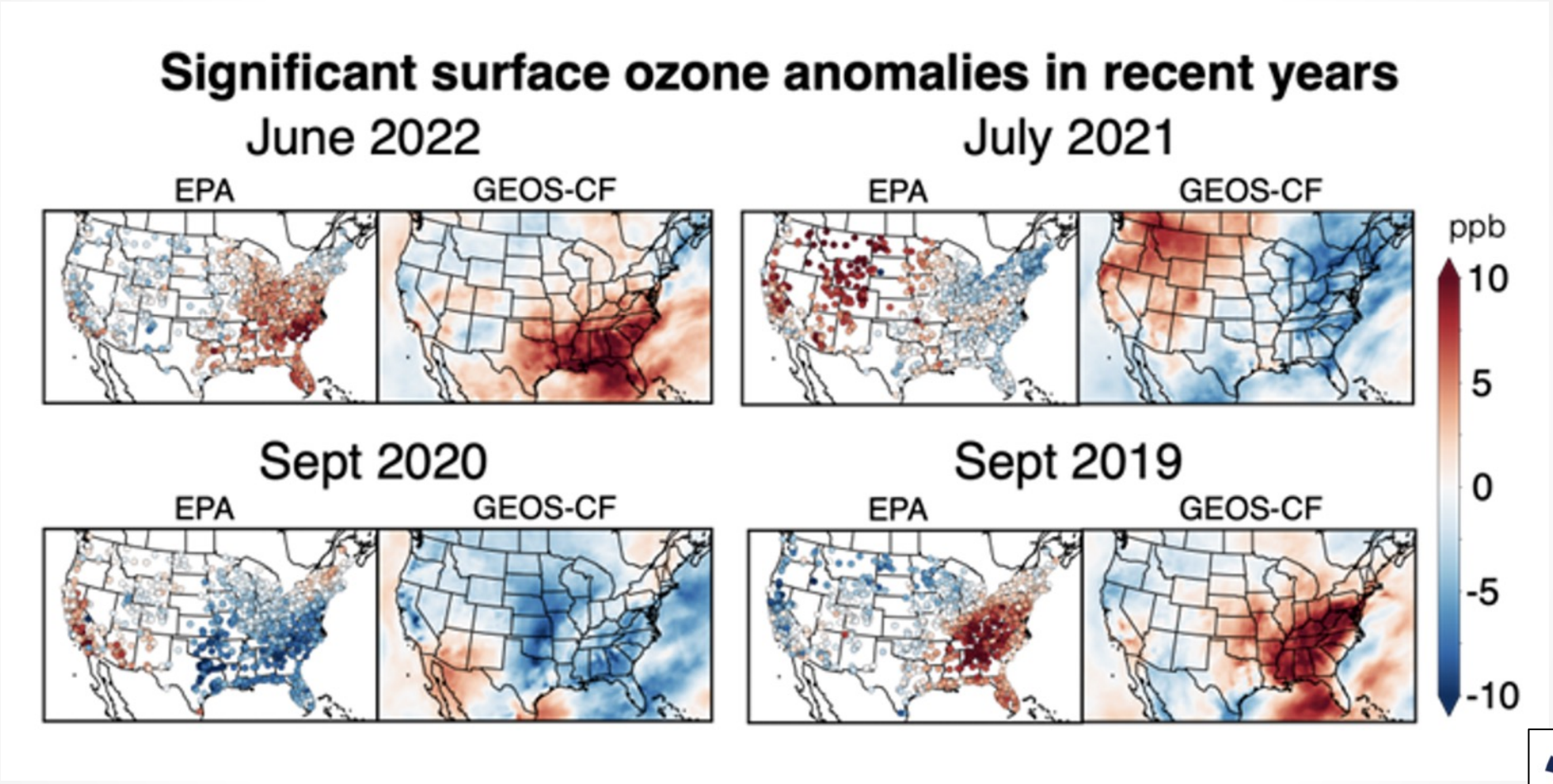

Ozonewatch.gsfc.nasa.gov

Emma Knowland

Knowland et al., JAMES, 2022, https://doi.org/10.1029/2021MS002852

National Aeronautics and Space Administration

# Linking Surface Ozone Extremes to Weather Pattern Anomalies




https://gmao.gsfc.nasa.gov/research/science_snapshots/2023/ozone-2023.php

Viral Shah

# Ongoing Efforts to Expand Data Access – Demand & Opportunity

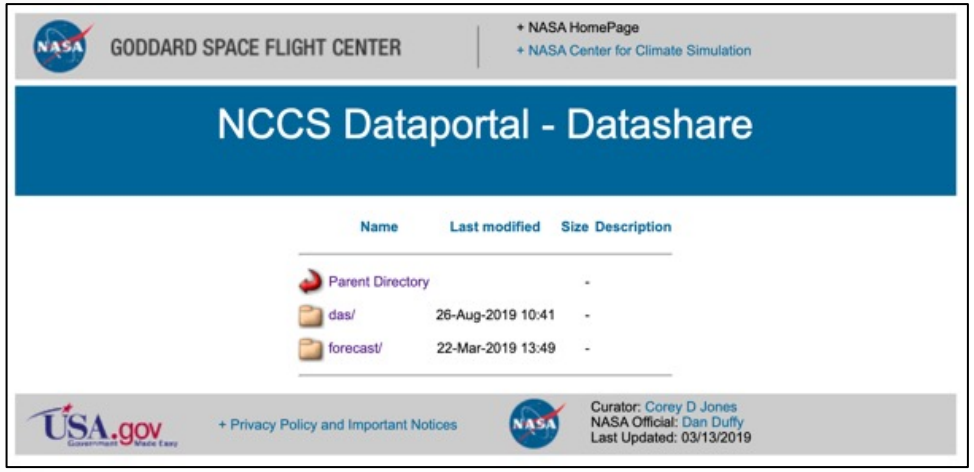
COG

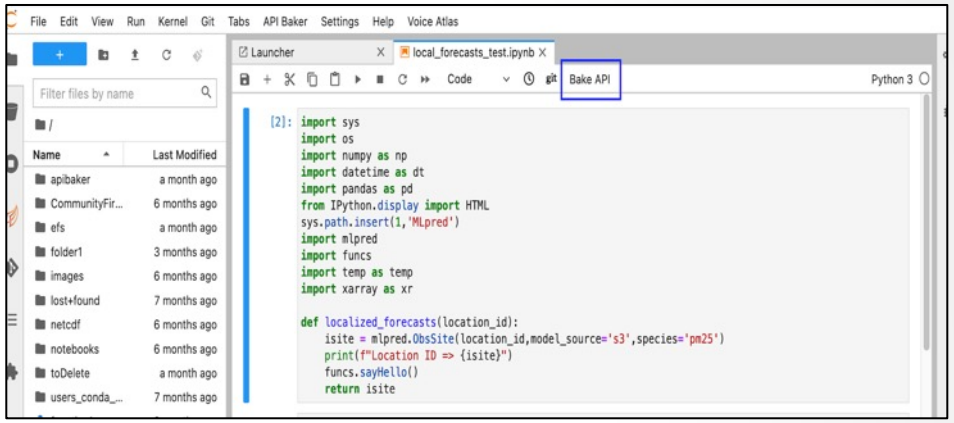
Zarr

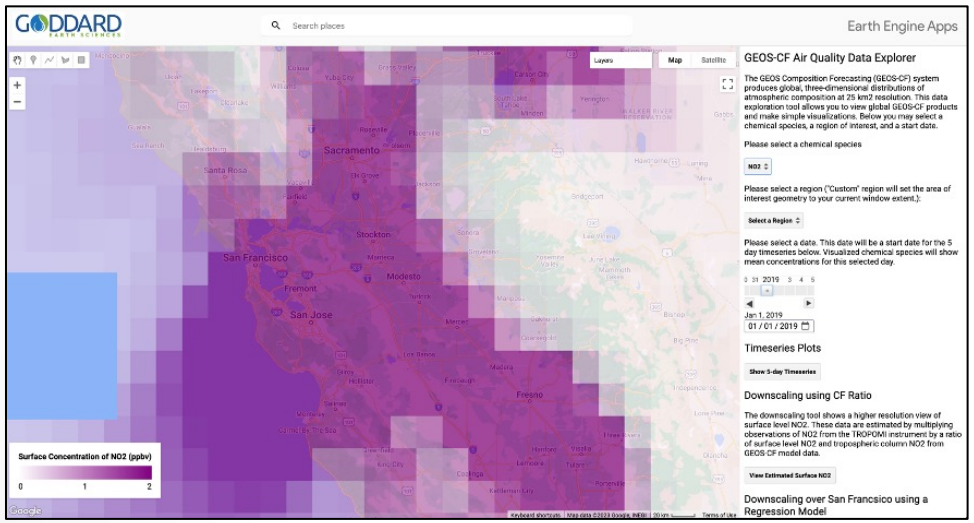
jupyter

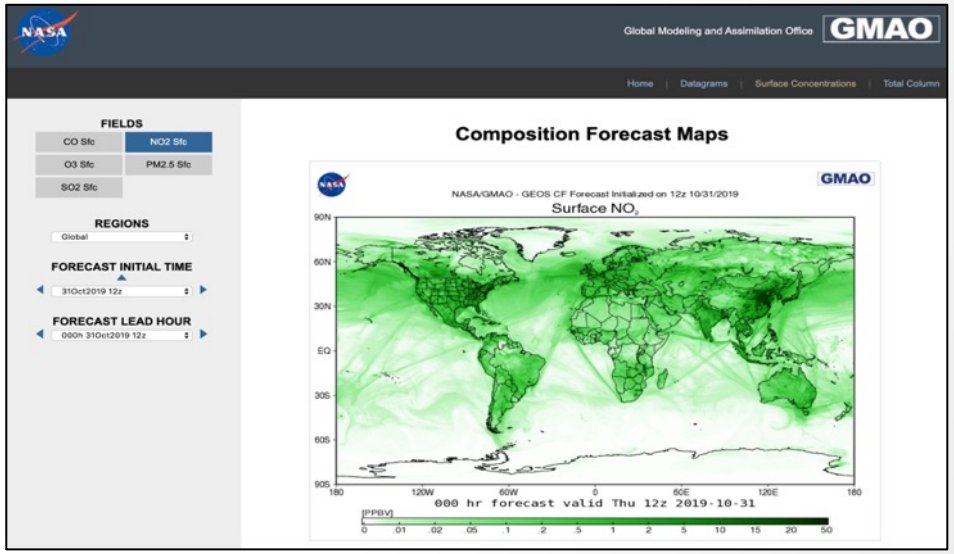
aws

Google Earth Engine



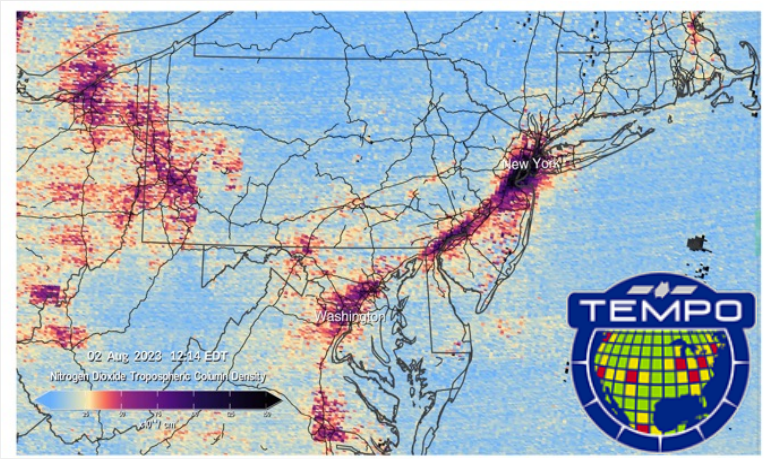



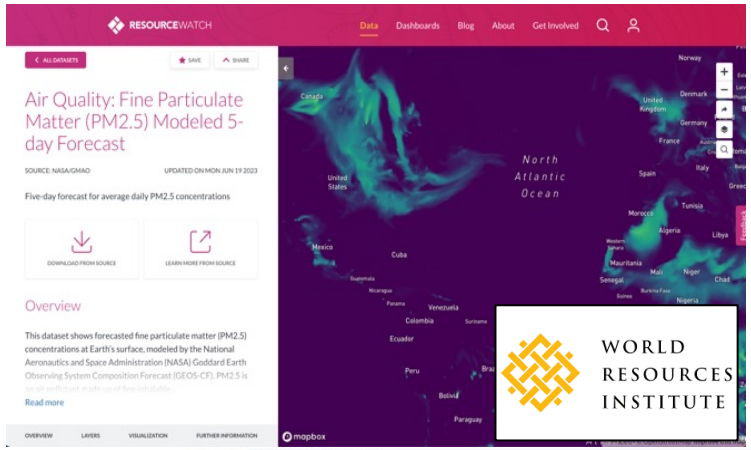



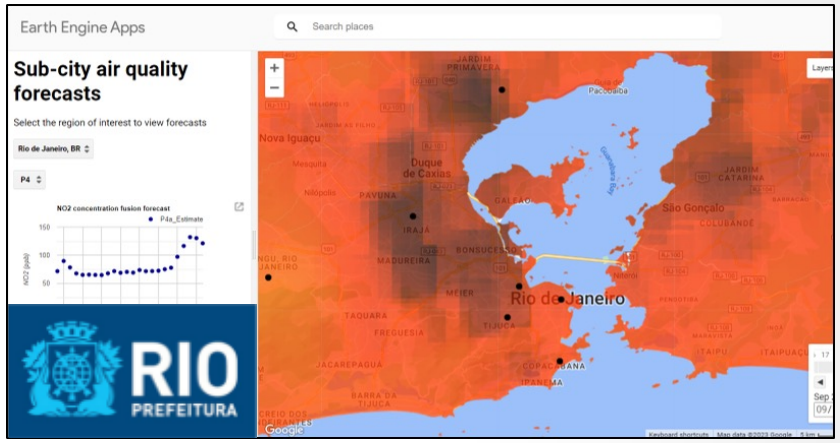



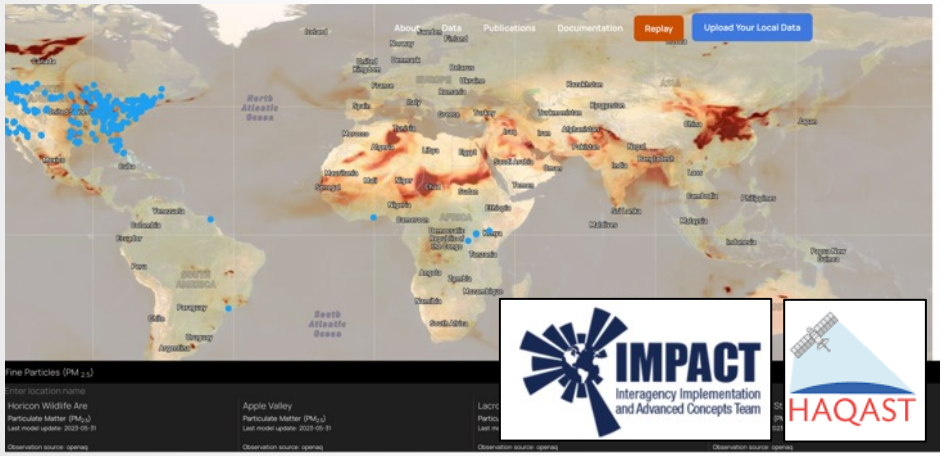

Callum Wayman

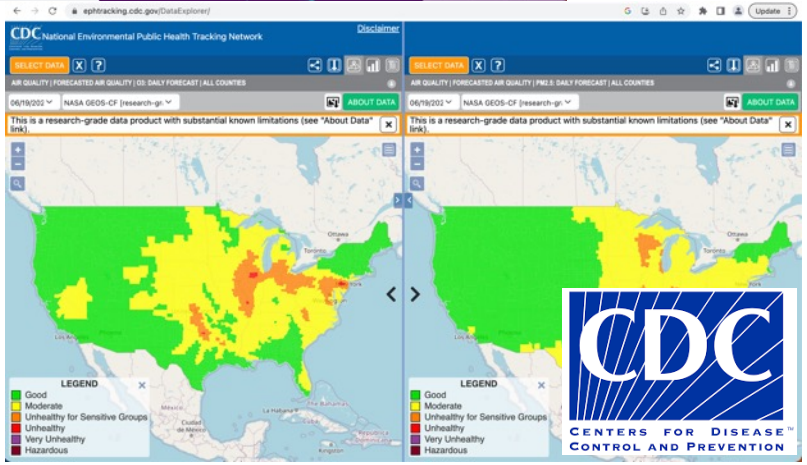
# Actively Working With End Users to Meet Their Needs

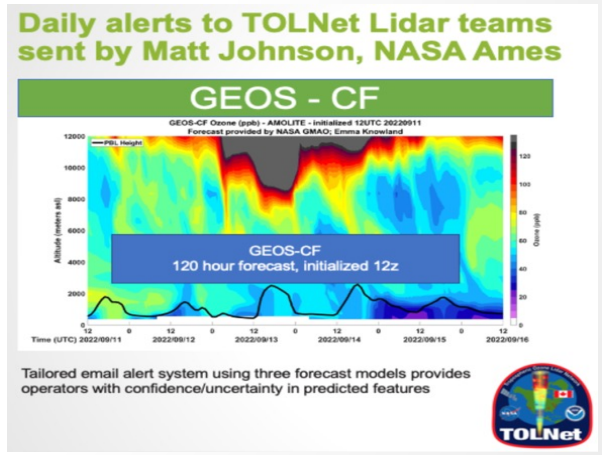


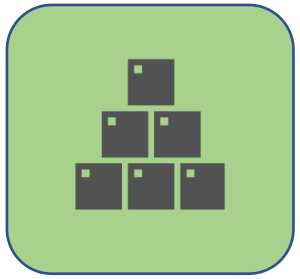
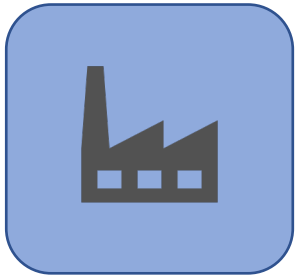
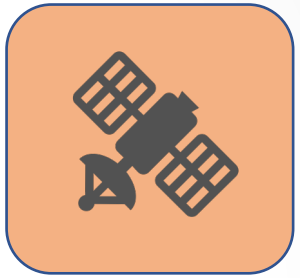



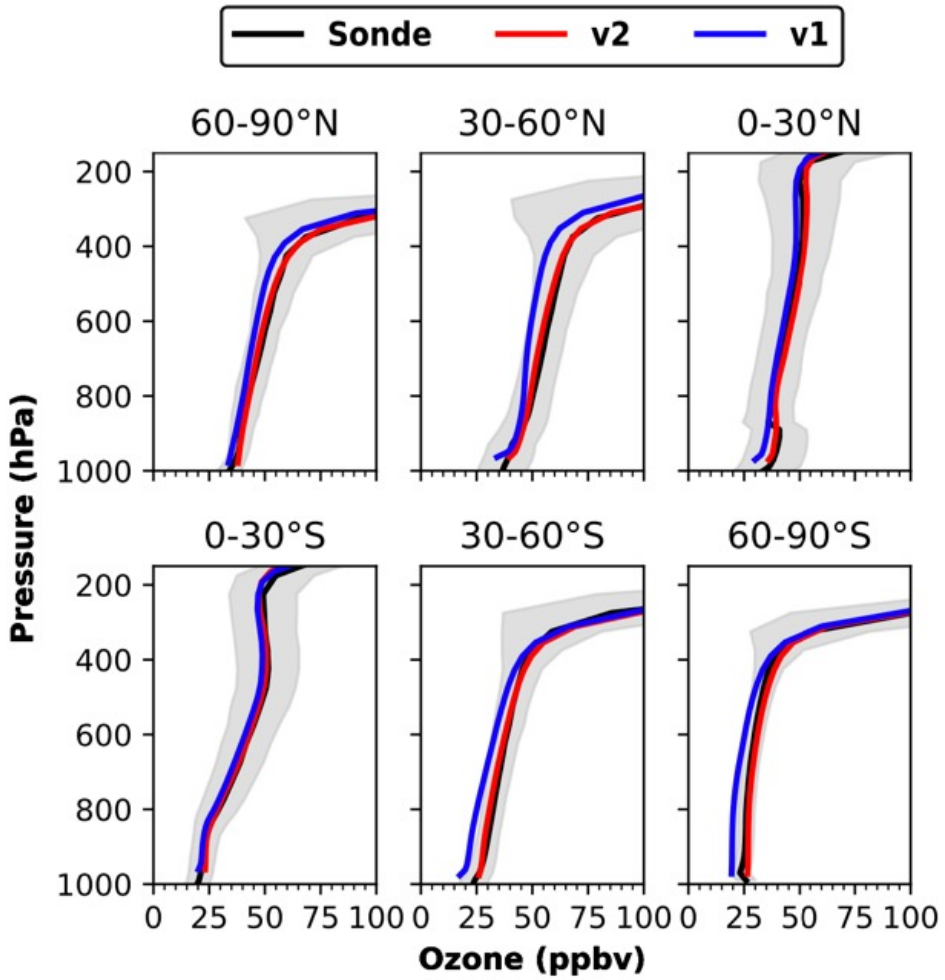



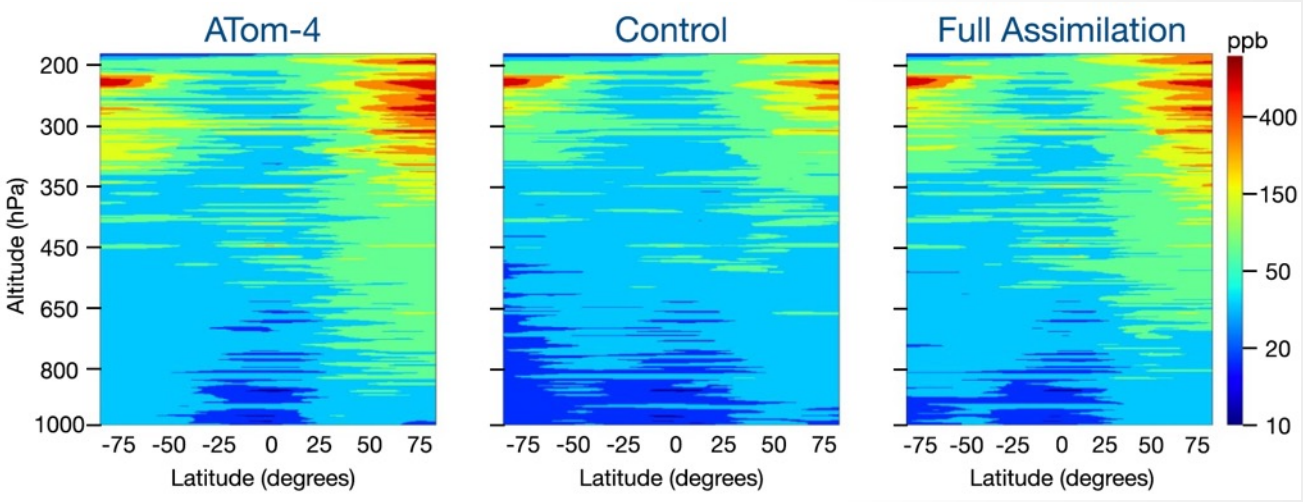
# Upgrade to GEOS-CF Version 2

| | Model Components | Emissions | Observations |
|---|---|---|---|
| |  |  |  |
| Version 2 (spinning up) | **GEOS as of 2023:**<br>- GEOSgcm v10.23.0<br>- Online tracer convection<br>- GEOS-Chem v14 | - CEDS inventory (up to 2019)<br>- Updated fire emission factors<br>- Redistributed lightning | Direct assimilation of $O_3$, $NO_2$, $SO_2$ (3D-Var) using CoDAS |
| Version 1 (current system) | **GEOS as of 2017:**<br>- Icarus-1_0<br>- GEOS-Chem v12.0.1 | HTAP v2.2 (base year 2010) | Nudge stratospheric ozone to GEOS-FP |

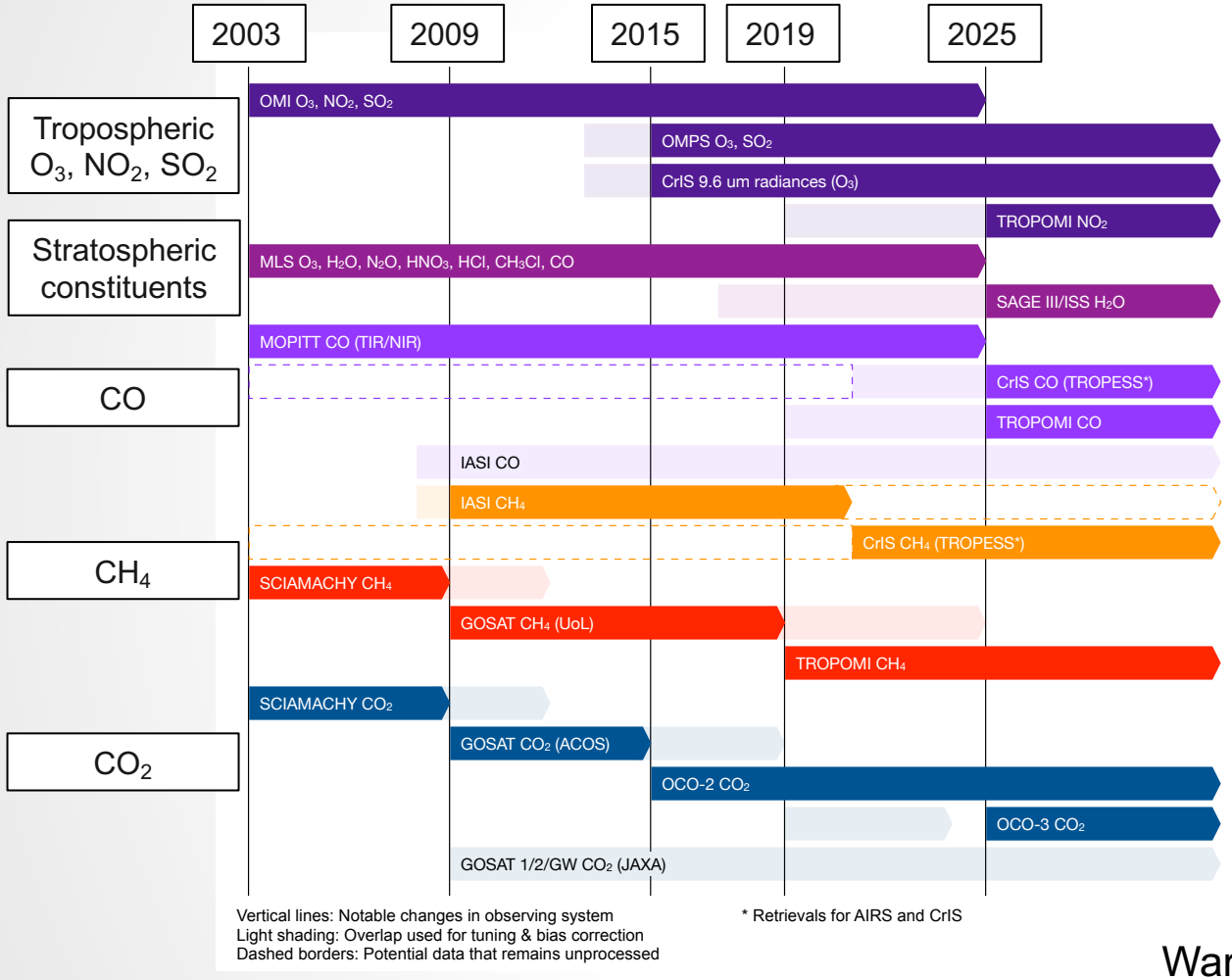
This is costly and compute-resource limited, partly because of the need to run for at least a few years

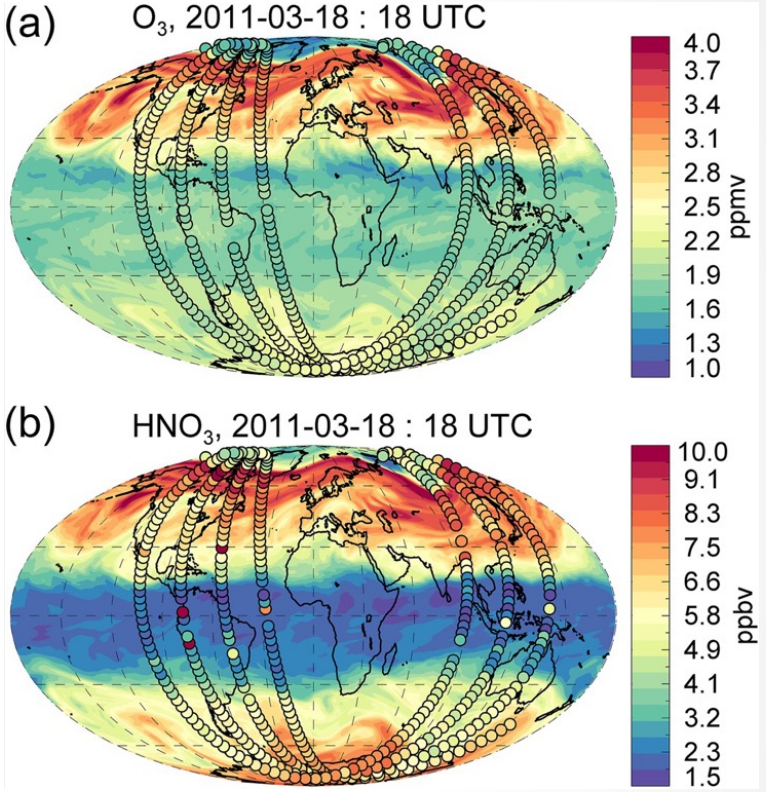
# Ozone in V2 is Improved Because of Direct Assimilation



# A Composition Reanalysis for ~2000-2025, Based on V2




GSI-based Constituent Data Assimilation System (CoDAS) forms the backbone to constituent assimilation products

Wargan et al., JAMES, 2023, https://doi.org/10.1029/2022EA002632

# Summary and Long-Term Perspective

GEOS-CF has been an exciting project!

- Version 1 grew from ROSES funding and has expanded GMAO's role in global composition forecasting
  - New capabilities (stratospheric prediction, surface ozone anomalies, …)
  - Support of additional NASA science teams (including early adoption of TEMPO)
  - Rapid growth in users from the Applications (especially health) perspective
- Version 2 introduces assimilation and other improvements (model transport, emissions)
  - Basis for GMAO's constituent reanalysis
  - Explore web-based distribution and more open-source analysis tools
- Also excited about …
  - Regional grid refinements
  - Opening opportunities for data assimilation with JEDI (a community effort across agencies)