National Aeronautics and Space Administration

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

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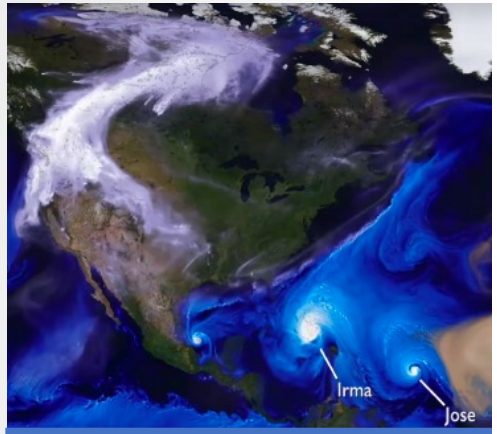
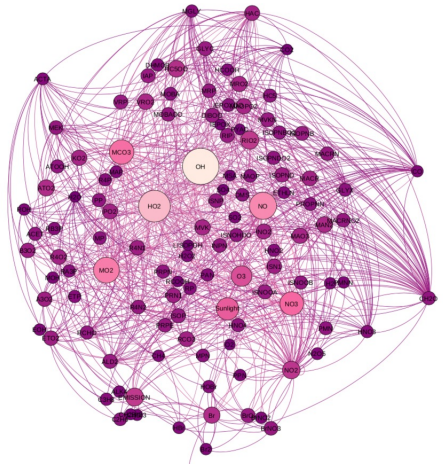
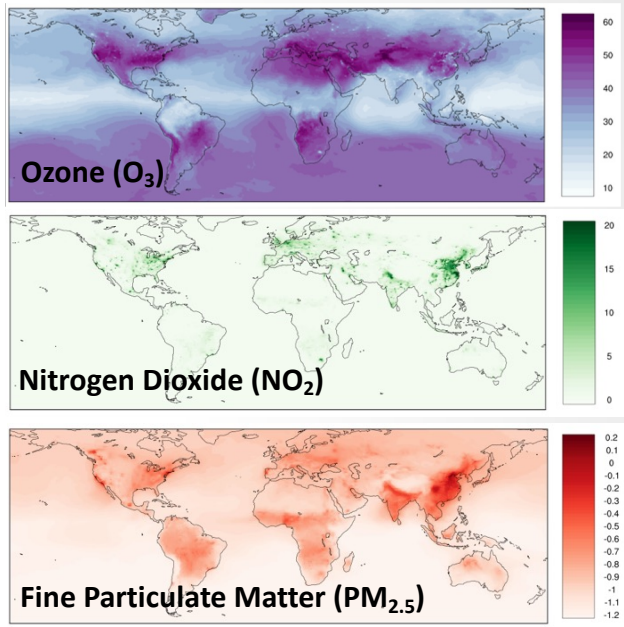
GEOS-CF produces daily global forecasts of atmospheric composition at ~0.25°/25km resolution



GEOS NWP



GEOS-Chem



Global daily estimates and five-day composition forecasts are produced:

- High-resolution (c360: roughly 0.25° or 25 km) 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

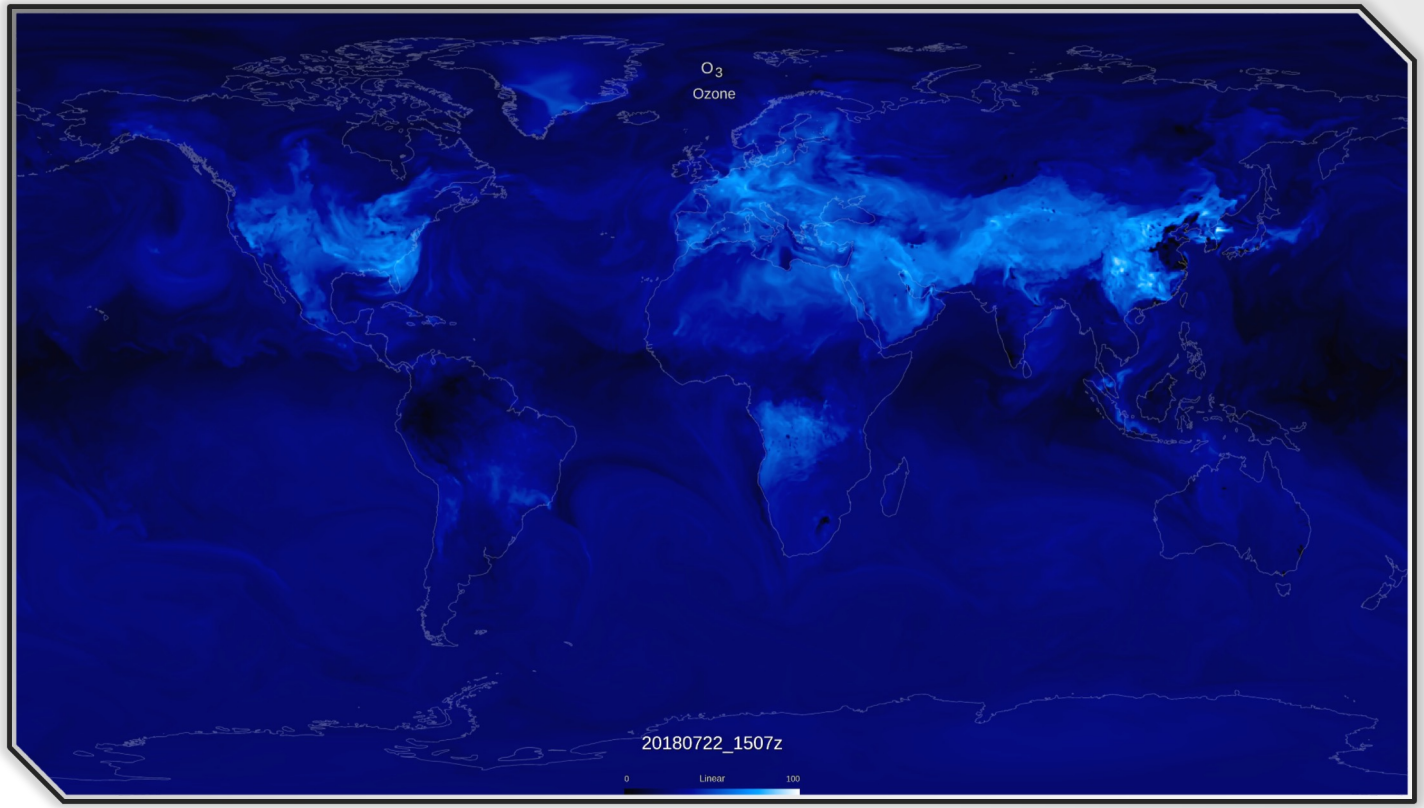
Knowland, K. E., Keller, C. A., and Lucchesi, R. 2022. "File Specification for GEOS-CF Products." *GMAO Office Note No. 17 (Version 1.3), available from http://gmao.gsfc.nasa.gov/pubs/office_notes*

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

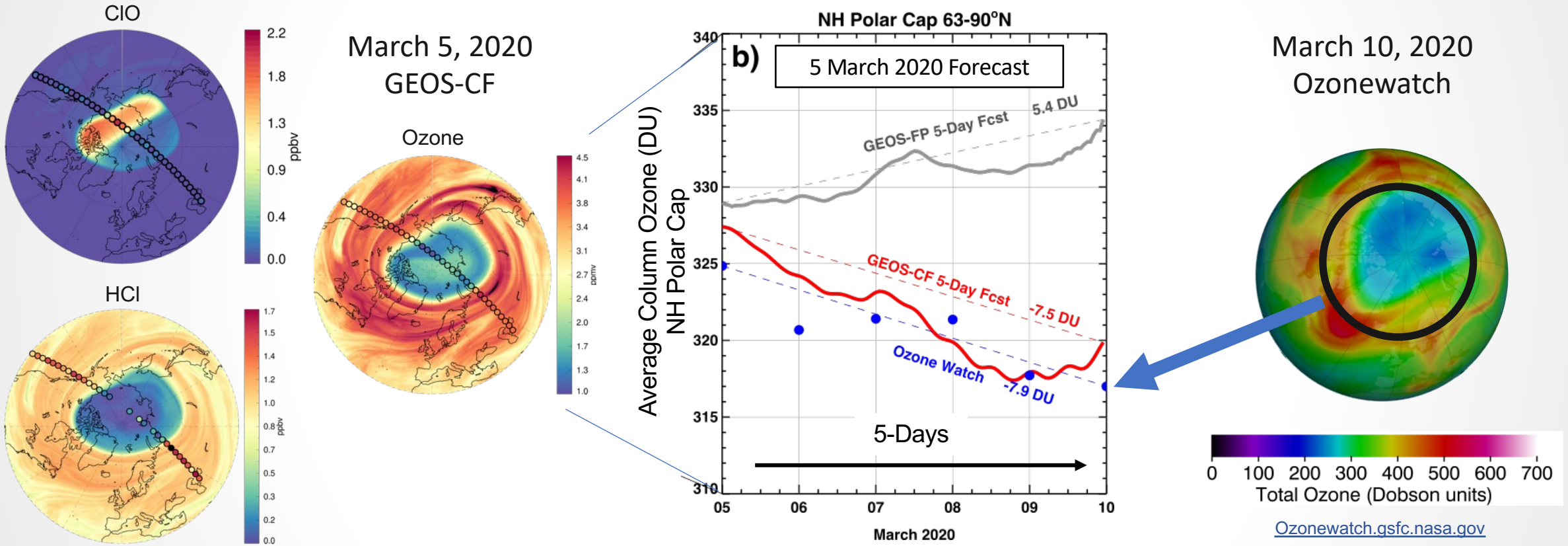


https://svs.gsfc.nasa.gov/4754

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

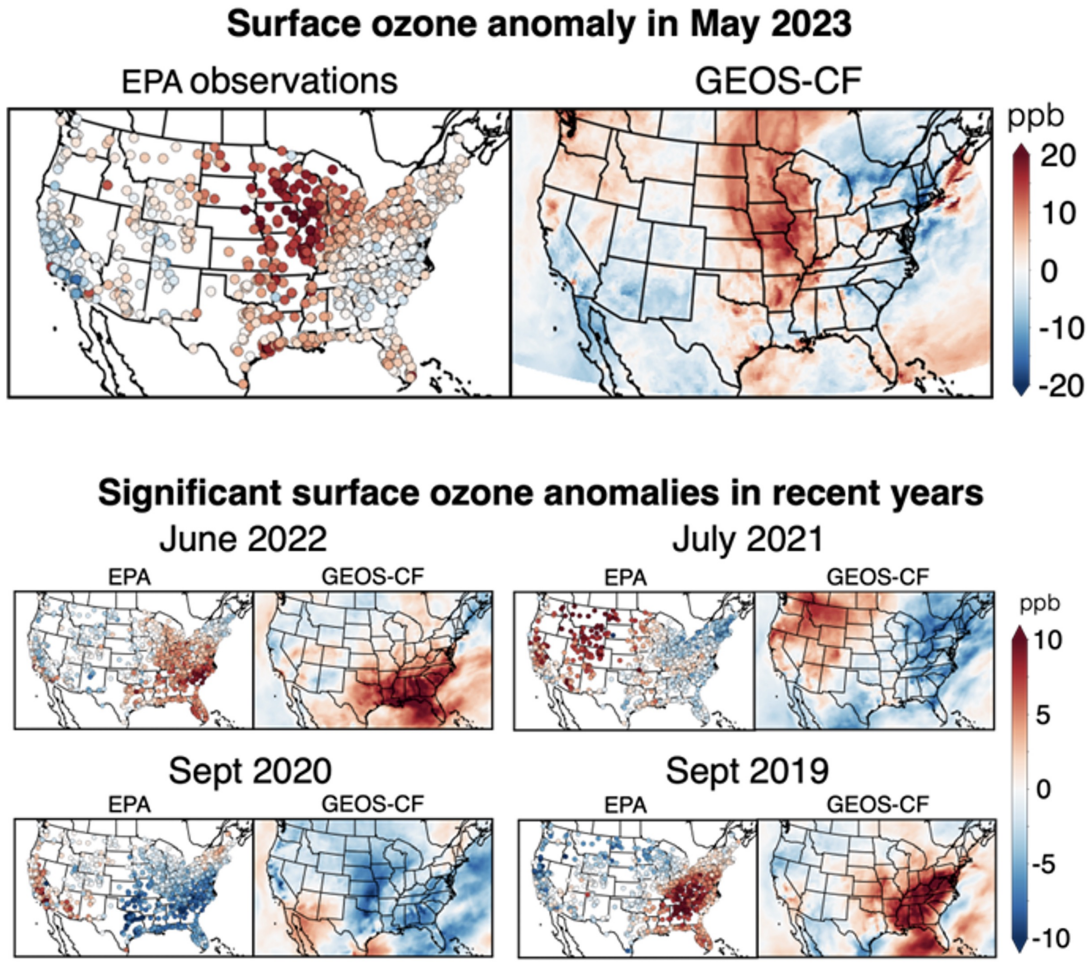


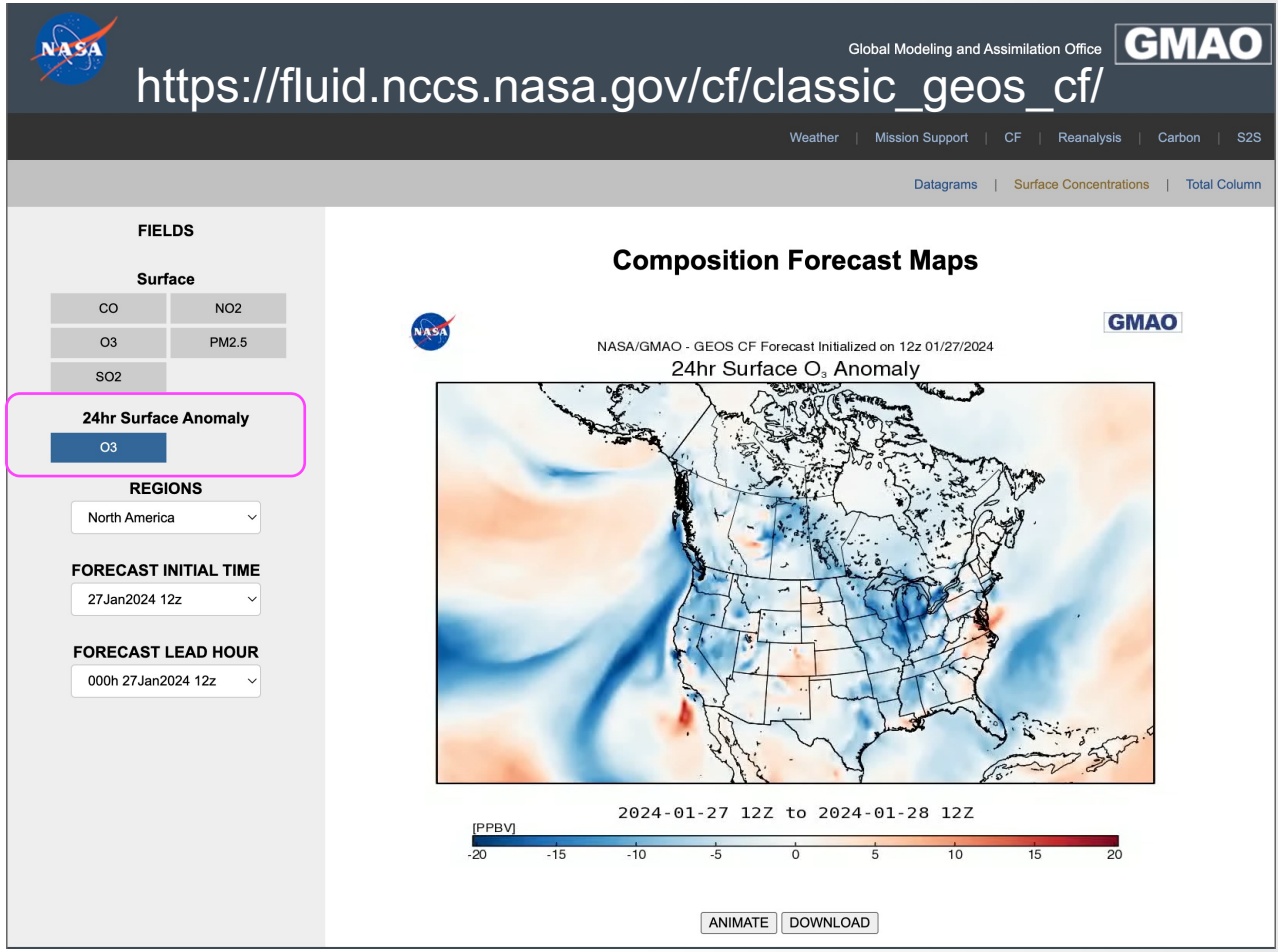
Knowland et al., JAMES, 2022, https://doi.org/10.1029/2021MS002852

Emma Knowland

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

Linking Surface Ozone Extremes to Weather Pattern Anomalies





Viral Shah

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

Ongoing Efforts to Expand Data Access – Demand & Opportunity

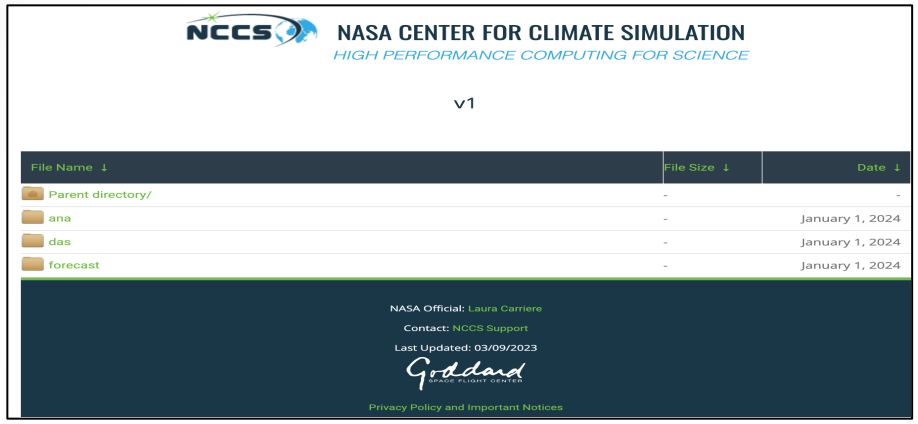
COG

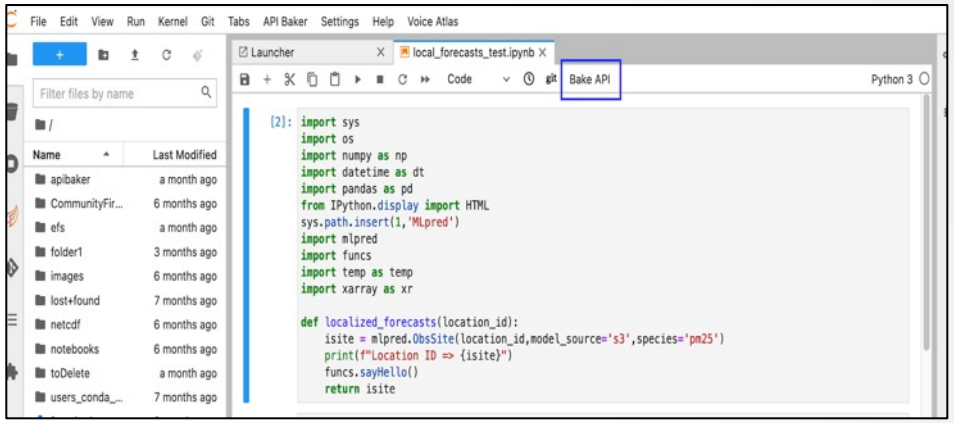
Zarr

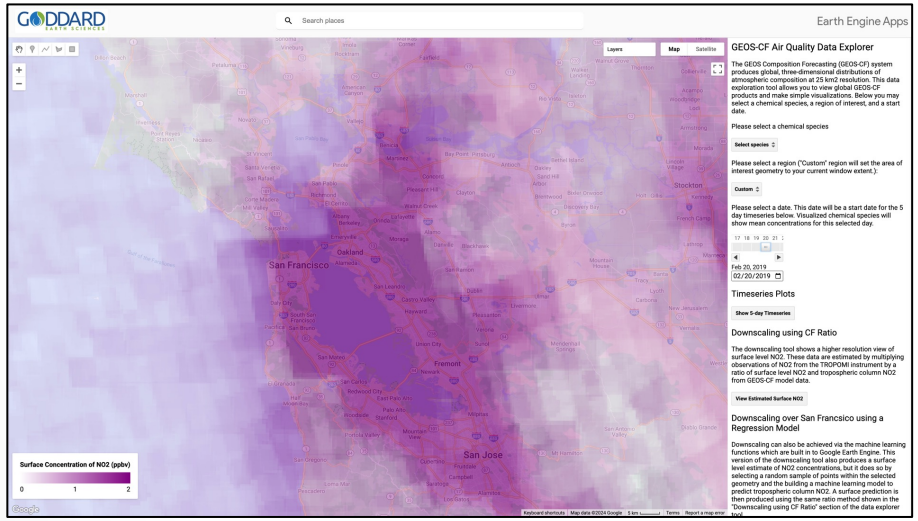
jupyter

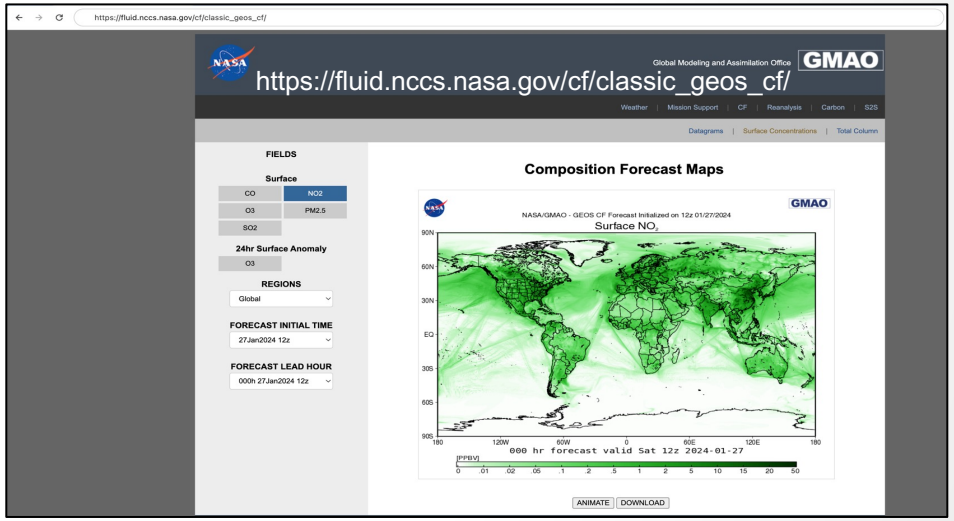
aws

Google Earth Engine





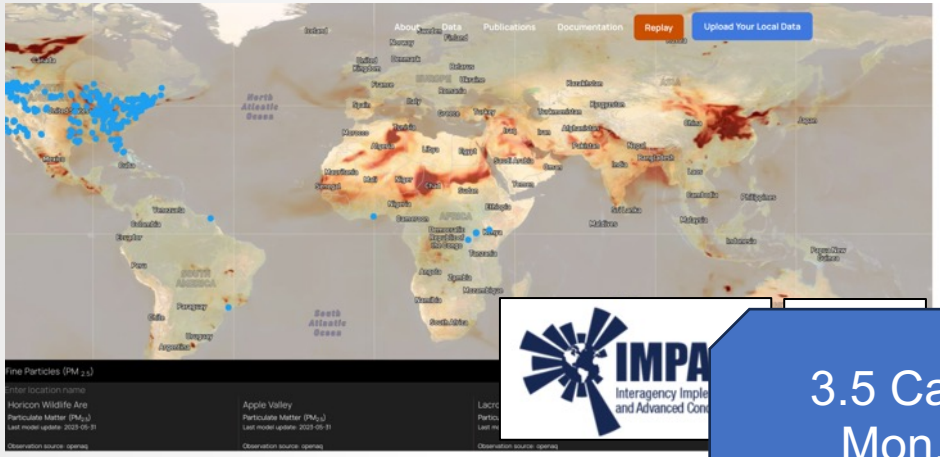


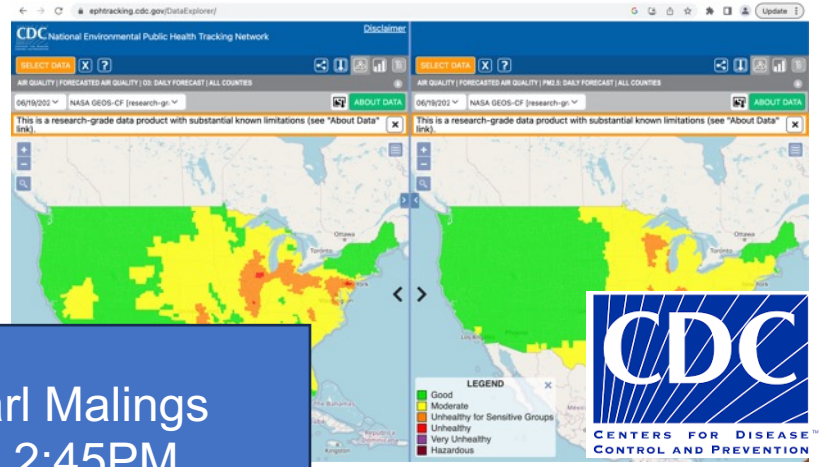


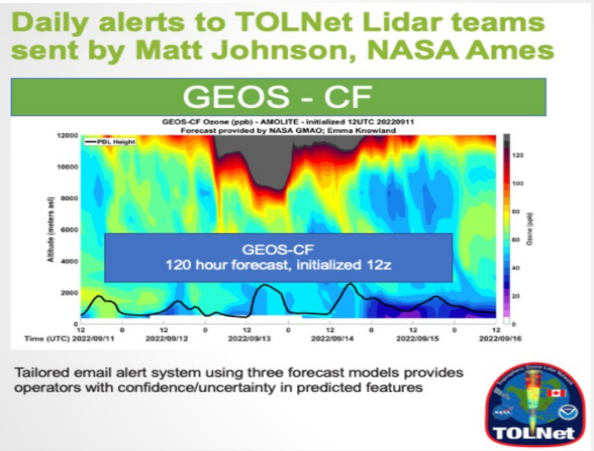
Callum Wayman

https://gmao.gsfc.nasa.gov/research/science_snapshots/2023/new-generation-gmao-apps.php

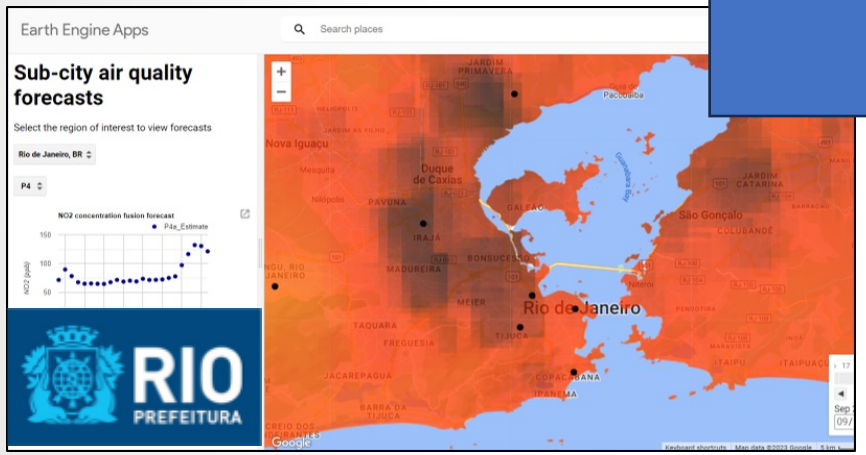
Actively Working With End Users to Meet Their Needs

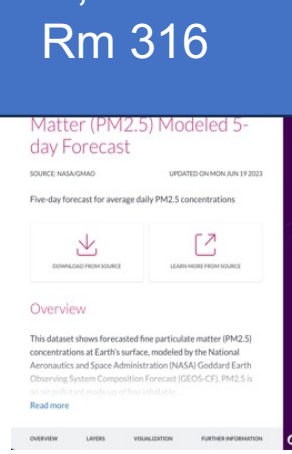




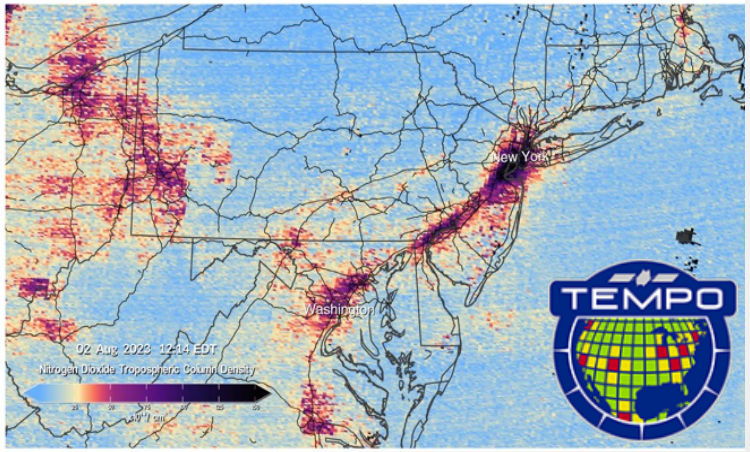


3.5 Carl Malings
Mon, 2:45PM
Rm 316



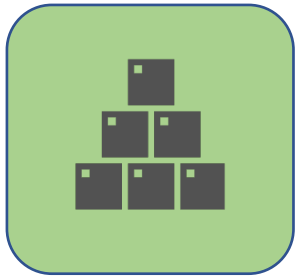
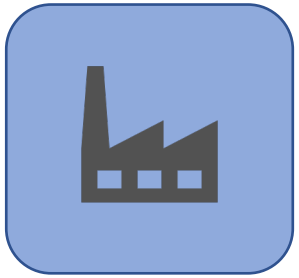
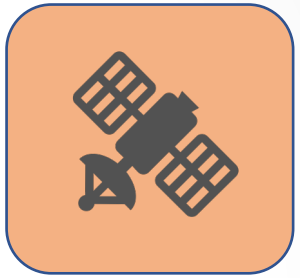






Carl Malings https://gmao.gsfc.nasa.gov/research/science_snapshots/2023/air_quality_data_fusion.php

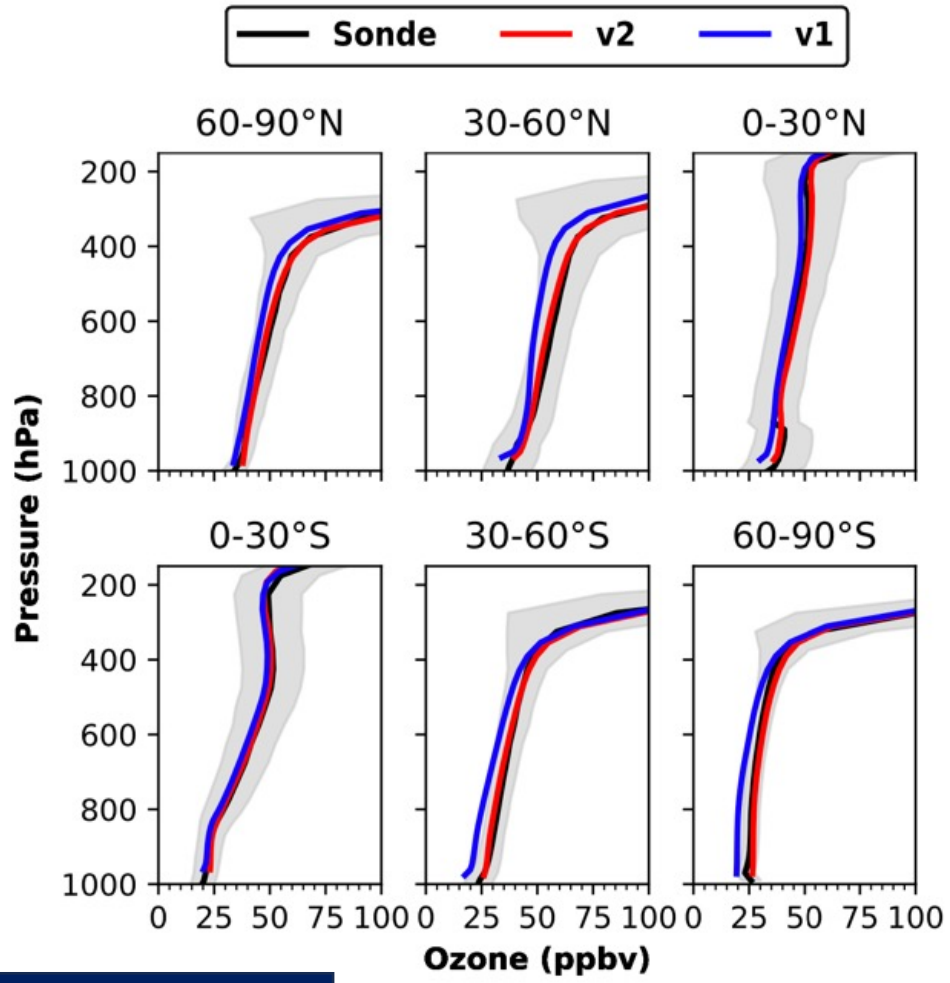
Upgrade to GEOS-CF Version 2

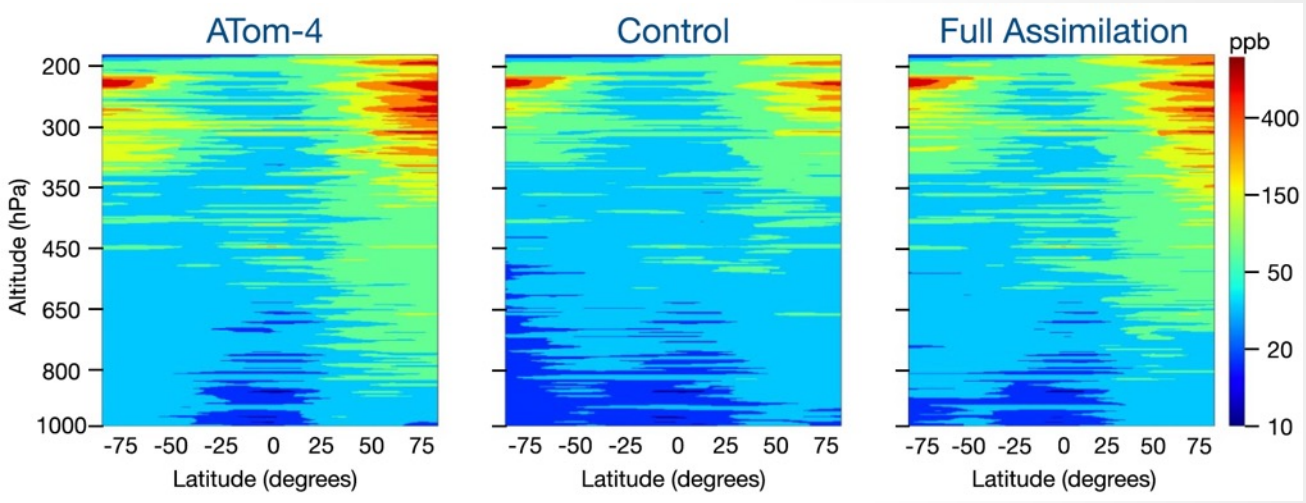
	Model Components	Emissions	Observations
			
Version 2 (spinning up)	**GEOS as of 2023:** - GEOSgcm v10.23.0 - Online tracer convection - GEOS-Chem v14	- CEDS inventory (up to 2019) - Updated fire emission factors - Redistributed lightning	Direct assimilation of O_3, NO_2, SO_2 (3D-Var) using CoDAS
Version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

Transition from v1 to v2 is costly and compute-resource limited, partly because of the need to run for at least a couple of years at high spatial resolution at the same time GEOS-CF v1 is still running

Christoph Keller

Tropospheric Ozone in V2 is Improved Because of Direct Assimilation





Kelp et al., *Environ. Res. Lett.*, 2023, https://doi.org/10.1088/1748-9326/acf0b7

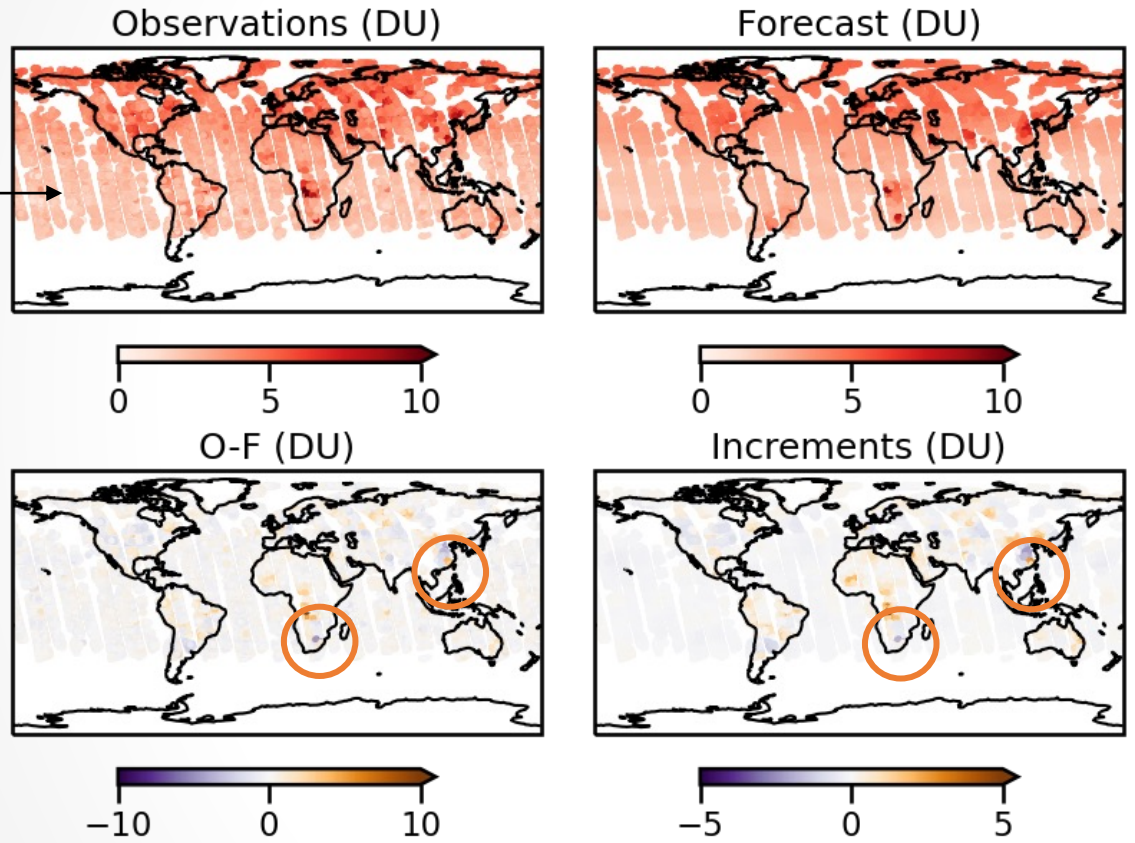
Ozone assimilation drastically **improves the representation of ozone in the remote atmosphere** according to this comparison to ATom-4 measurements and a version of the GEOS-CF v2 system used in testing.

Viral Shah

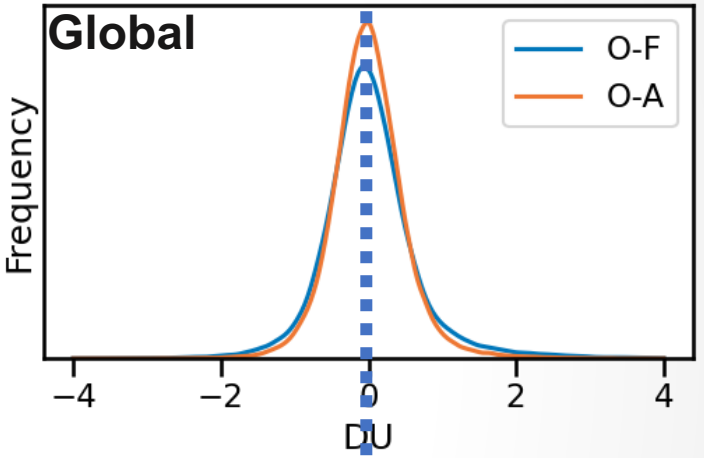
NO_2 assimilation in GEOS-CF v2 improves NO_2 in polluted areas

Assimilating OMI NO_2 total slant columns

Mostly Strat NO_2 in remote atmosphere



Frequency distributions of O-F and O-A

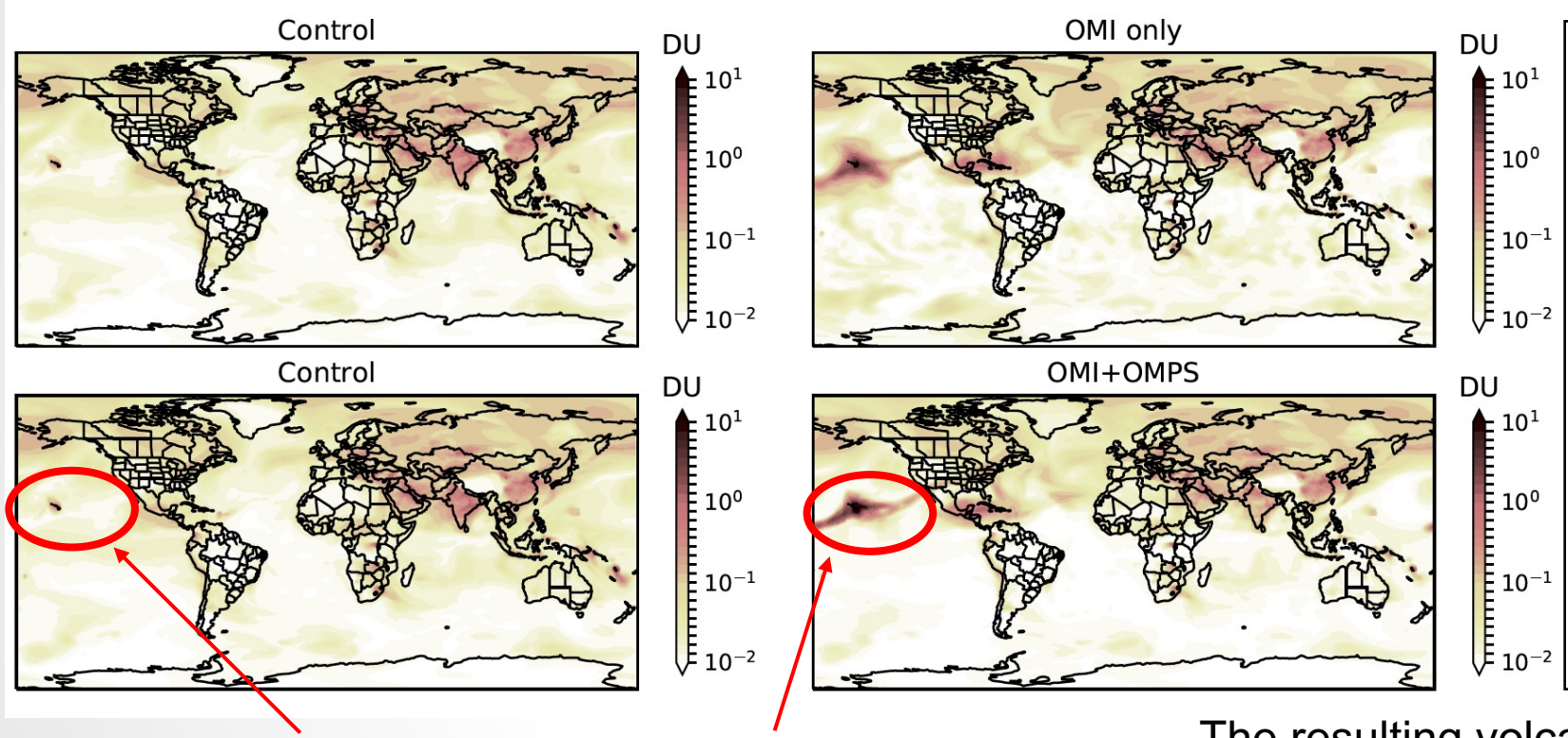


Increments smaller than O-F's reflects the ratio of observation to background errors

Viral Shah

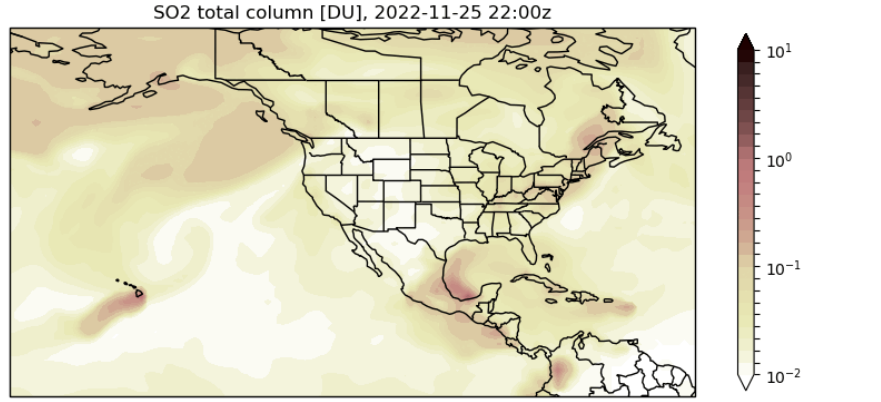
SO_2 assimilation: Mauna Loa's smoking gun

Simulated SO_2 total column [DU] for Dec 6, 2022



Mauna Loa eruption only captured in runs with assimilation

Evolution of assimilated SO_2 from the Mauna Loa eruption in November 2022



The resulting volcanic plume of sulfur dioxide (SO_2) can be seen from space with satellite instruments such as NASA's Ozone Monitoring Instrument (OMI).

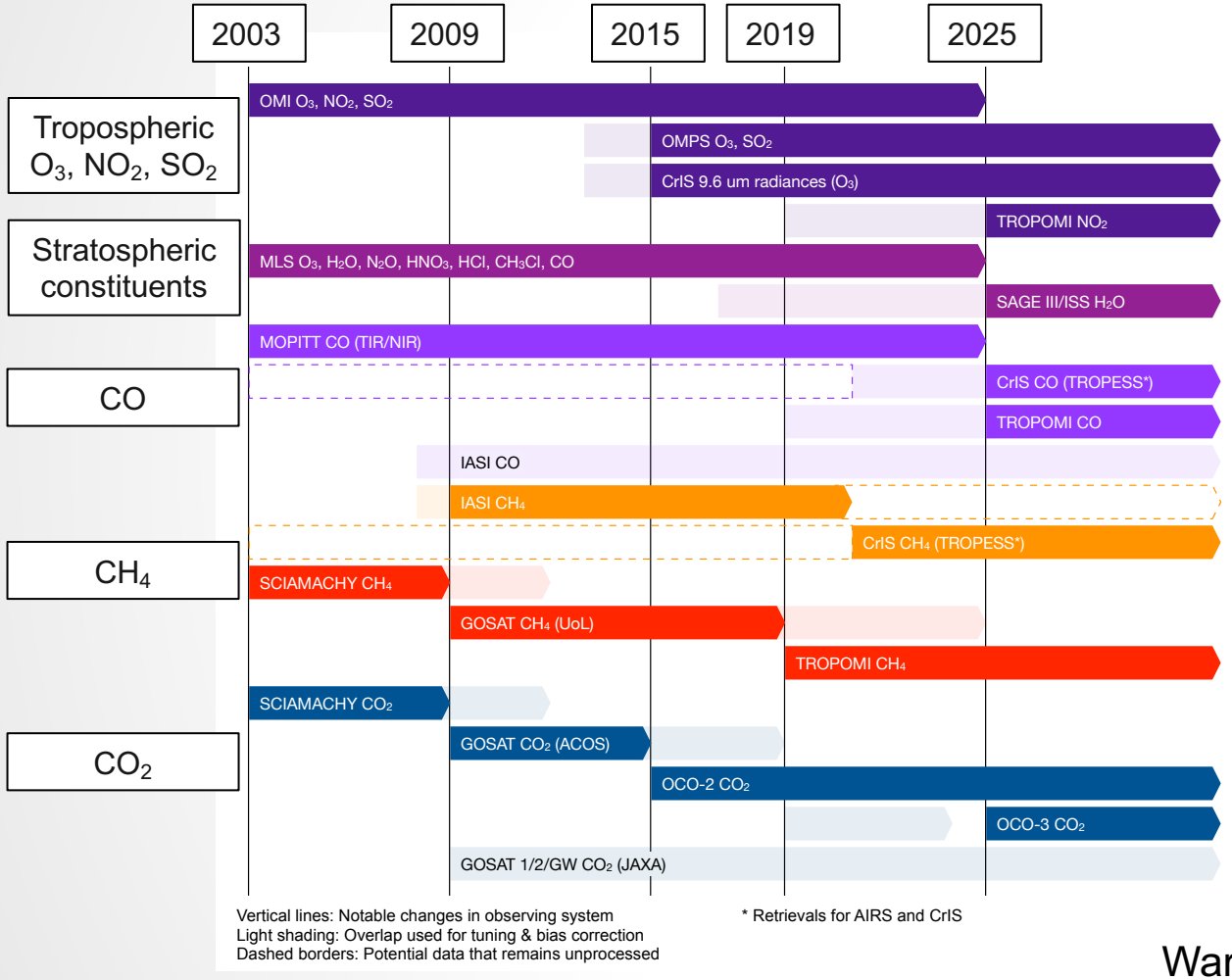
Christoph Keller

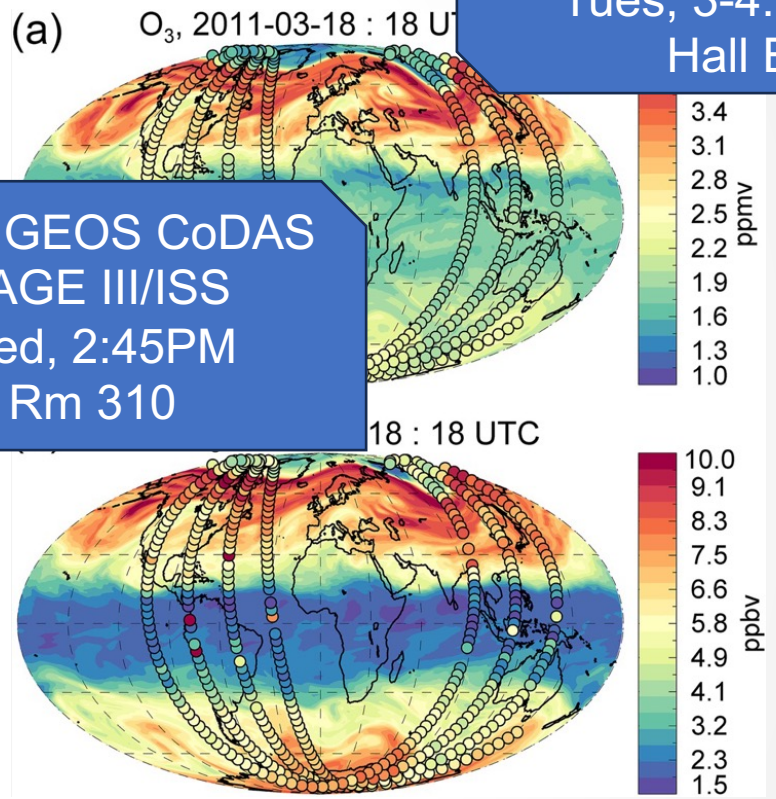
https://gmao.gsfc.nasa.gov/research/science_snapshots/2022/mauna-loa.php

Next: A GEOS Composition Reanalysis for ~2000-2025, Based on GEOS-CF V2, M2-SCREAM, and GEOS-GHG

352 S-RIP Phase 2 Poster
Tues, 3-4:30PM
Hall E

11A.5 GEOS CoDAS SAGE III/ISS
Wed, 2:45PM
Rm 310





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 (providing a priori for TEMPO trace gas retrievals, field campaigns, …)
  - 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 (GEE, AWS,…)
- Also excited about …
  - Opening opportunities for data assimilation with JEDI (a community effort across agencies)
  - Regional grid refinements

Questions about GEOS-CF may be submitted to our email List, geos-cf@lists.nasa.gov.

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• To subscribe to "geos-cf-users@lists.nasa.gov":
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