



NASA GEOS Composition Forecast: Overview, TEMPO Support, and Version 2 updates

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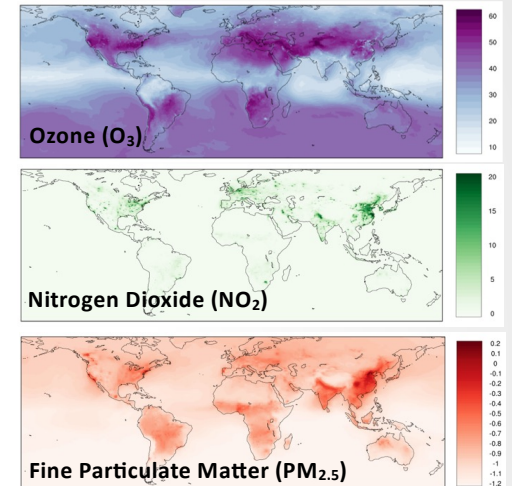
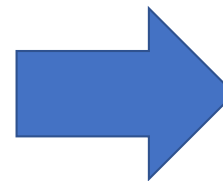
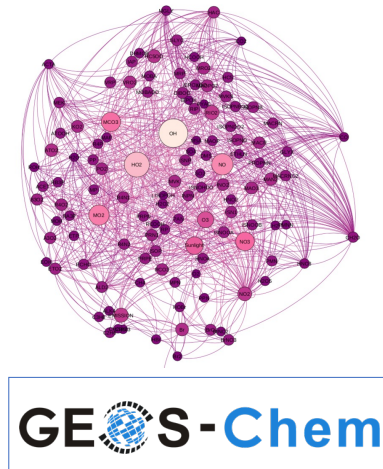
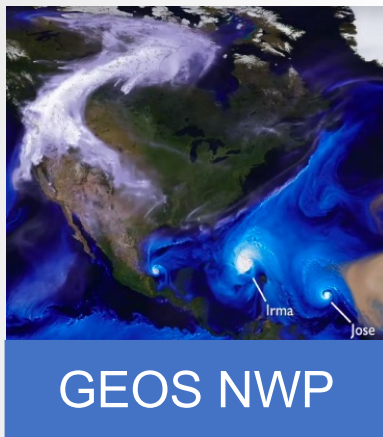


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https://gmao.gsfc.nasa.gov/weather_prediction/GEOS-CF/
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GEOS with Coupled GEOS-Chem chemistry: TEMPO support



G5NR - Chem

Hu, L., Keller, C. A., et al (2018). **Global simulation of tropospheric chemistry at 12.5 km resolution: performance and evaluation of the GEOS-Chem chemical module (v10-1) within the NASA GEOS Earth system model (GEOS-5 ESM).** *Geosci. Model Dev.*, 11, 4603–4620, <https://doi.org/10.5194/gmd-11-4603-2018>.

GEOS - CF

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*, 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>

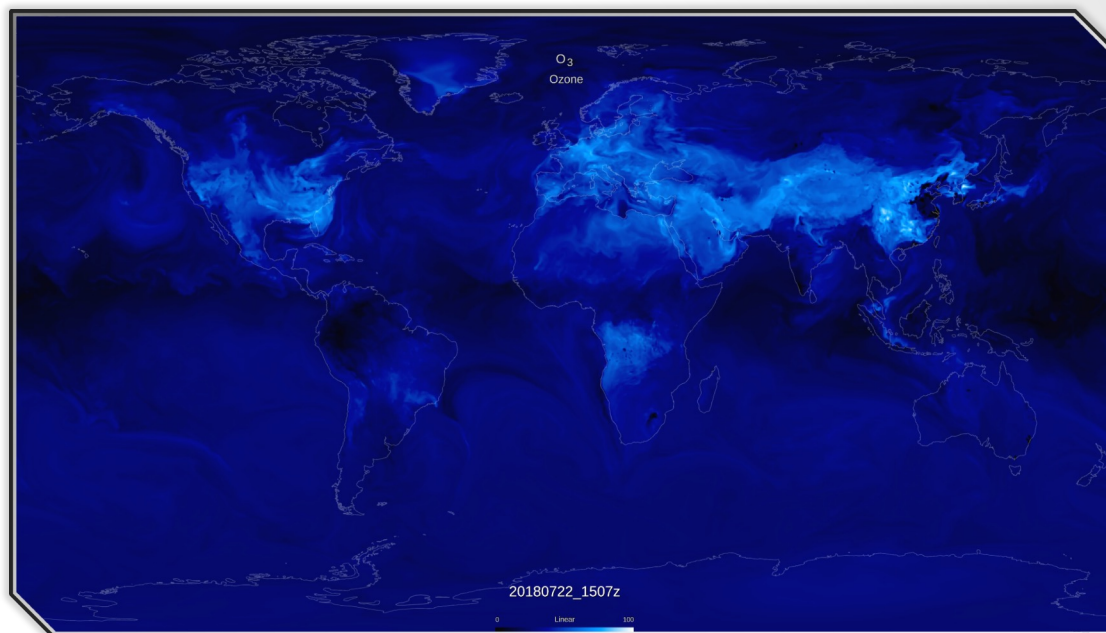




Rationale for GEOS-CF

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>

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GEOS with Coupled GEOS-Chem chemistry: TEMPO support

G5NR-Chem

1 July 2013 – 1 July 2014

- Meteorological “replay”
- GEOS-Chem v10-01 Tropospheric-only mode
- c720 (0.125 °, ~12.5 x 12.5 km²)
- 72 model layers
- Default GEOS-Chem emissions
- 1-hour, 29 species

GEOS-CF

1 January 2018 - present

- 1-day replay + 5-day forecast
- GEOS-Chem v12.0.1, with full Tropospheric & Stratospheric chem
- c360 (0.25°, ~25 x 25 km²)
- 72 model layers
- HTAP v2.2 anthropogenic emissions
- 1-hour 2D & 3D output, **including specific TEMPO file for retrievals**

Knowland et al., 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



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TEMPO specific collection: “sat_inst_1hr_r721x361_v72”

Regional Chemistry and Meteorology Diagnostics to support TEMPO satellite

Frequency: hourly instantaneous from 00:00 UTC

Spatial Grid: 3D, model-level, subset region of full horizontal resolution

Dimensions: longitude=721, latitude=361, every 0.25°

longitude: 0° to -180°

latitude: 0° to 90°

vertical level: 72 layers

Granule Size: ~258 MB per file

Start date: 00 UTC 1 January 2022

Mode: Replay only; Forecasts available based on mission requirements

Knowland et al., 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

Name	Dim	Description	Units
BrO	tzyx	Bromine monoxide (BrO, MW = 96.00 g mol ⁻¹) volume mixing ratio dry air	mol mol ⁻¹
FRSEAICE	tyx	ice covered fraction of tile	1
FRSNO	tyx	fractional area of land snowcover	1
GLYX	tzyx	Glyoxal (CHOCHO, MW = 58.00 g mol ⁻¹) volume mixing ratio dry air	mol mol ⁻¹
HCHO	tzyx	Formaldehyde (CH ₂ O, MW = 30.00 g mol ⁻¹) volume mixing ratio dry air	mol mol ⁻¹
HNO ₂	tzyx	Nitrous acid (HNO ₂ , MW = 47.00 g mol ⁻¹) volume mixing ratio dry air	mol mol ⁻¹
IO	tzyx	Iodine monoxide (IO, MW = 143.00 g mol ⁻¹) volume mixing ratio dry air	mol mol ⁻¹
NO ₂	tzyx	Nitrogen dioxide (NO ₂ , MW = 46.00 g mol ⁻¹) volume mixing ratio dry air	mol mol ⁻¹
O ₃	tzyx	Ozone (O ₃ , MW = 48.00 g mol ⁻¹) volume mixing ratio dry air	mol mol ⁻¹
OCIO	tzyx	Chlorine dioxide (OCIO, MW = 67.00 g mol ⁻¹) volume mixing ratio dry air	mol mol ⁻¹
PHIS	tyx	surface geopotential height	m+2 s ⁻²
PS	tyx	surface pressure	Pa
Q	tzyx	specific humidity	kg kg ⁻¹
SNODP	tyx	snow depth	m
SNOMAS	tyx	Total snow storage land	kg m ⁻²
SO ₂	tzyx	Sulfur dioxide (SO ₂ , MW = 64.00 g mol ⁻¹) volume mixing ratio dry air	mol mol ⁻¹
T	tzyx	air temperature	K
TROPPB	tyx	tropopause pressure based on blended estimate	Pa
U2M	tyx	2-meter eastward wind	m s ⁻¹
V2M	tyx	2-meter northward wind	m s ⁻¹
ZPBL	tyx	planetary boundary layer height	m



Upgrade to GEOS-CF Version 2

Model components



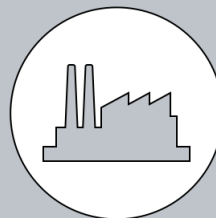
**GEOSgcm v10.23
with new model
physics**

Replay to GEOS-IT

GEOS Chem 14.0

**GEOS convective
transport**

Emissions



HTAP → CEDS

**Updated fire
emission factors**

**Redistributed
lightning**

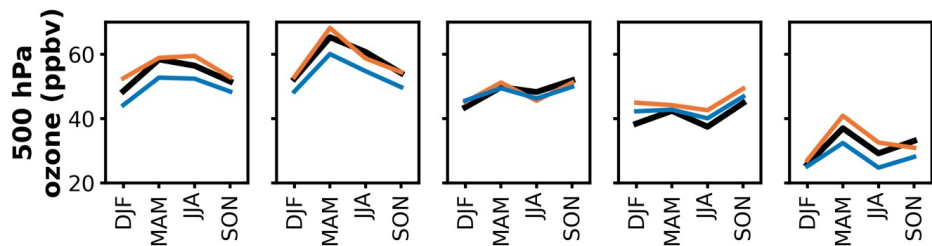
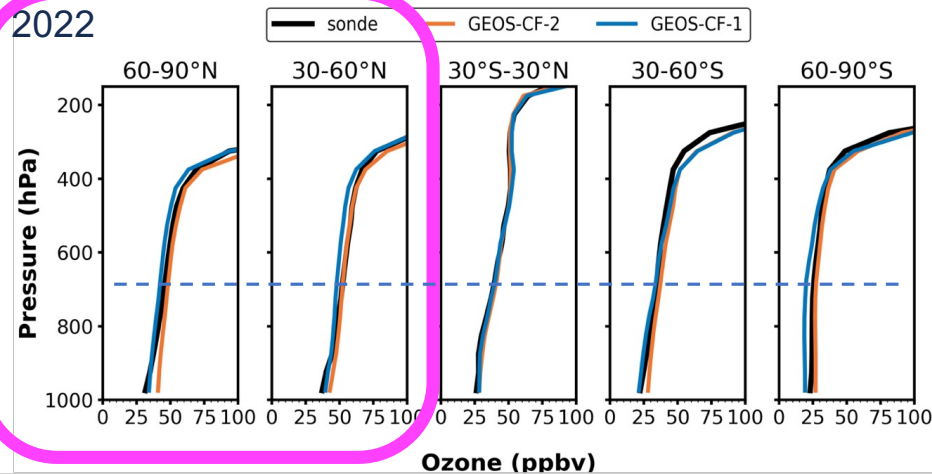
Data assimilation



**3D-Var assimilation
of ozone, NO₂ and
SO₂ satellite data**

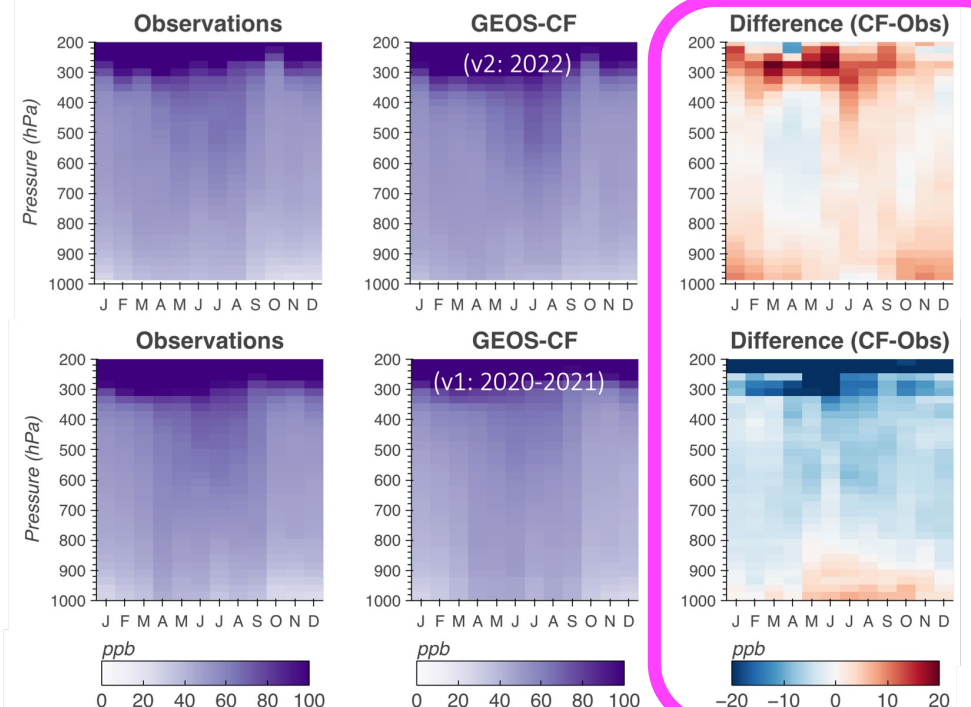


Tropospheric Ozone in V2 is Improved Because of Direct Assimilation



Version 1 Version 2

Ozone assimilation → Improved tropospheric O₃

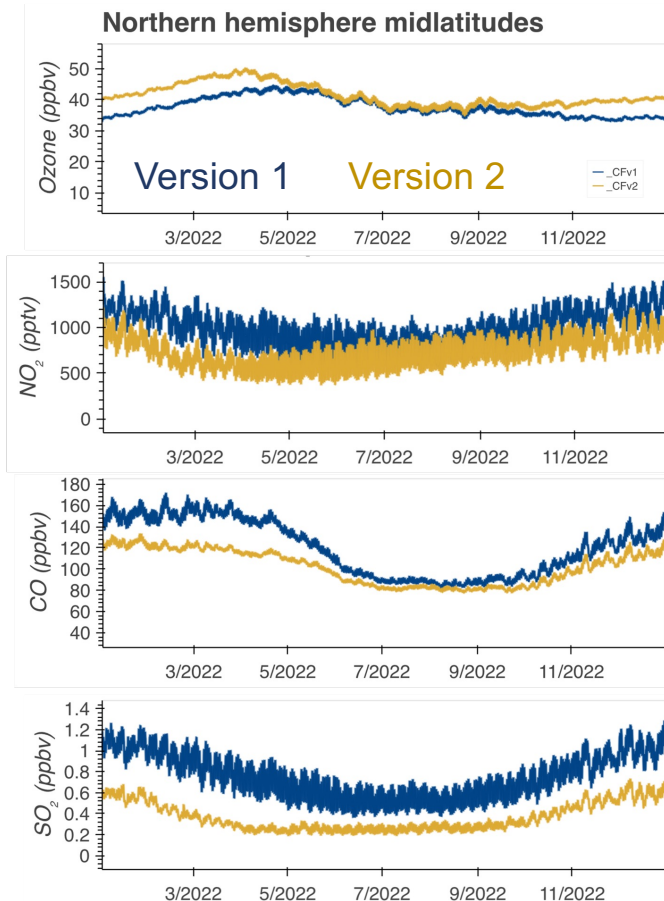


Composite of NA & European ozonesondes

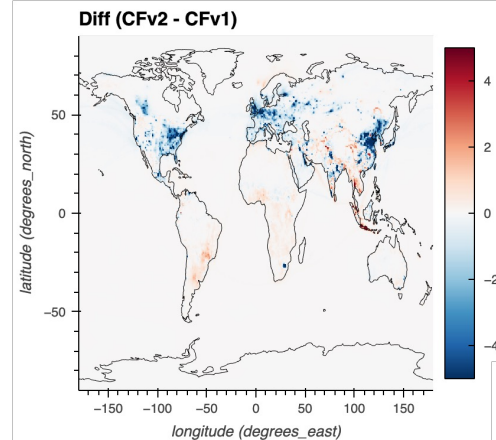
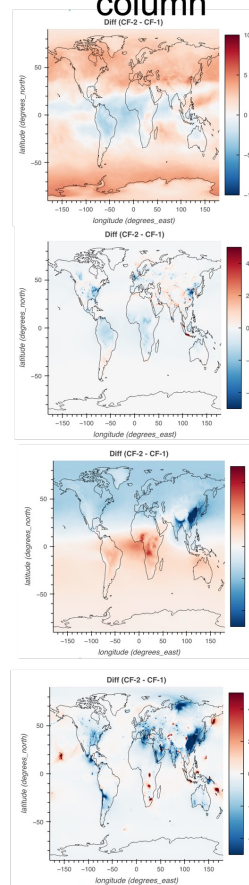


Lower NO_x emissions is leading to higher Ozone in GEOS-CF version 2

2022 Annual surface concentration
Northern hemisphere midlatitudes

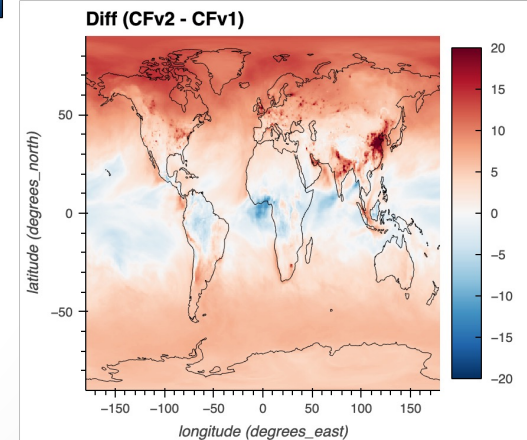


Annual tropospheric
column



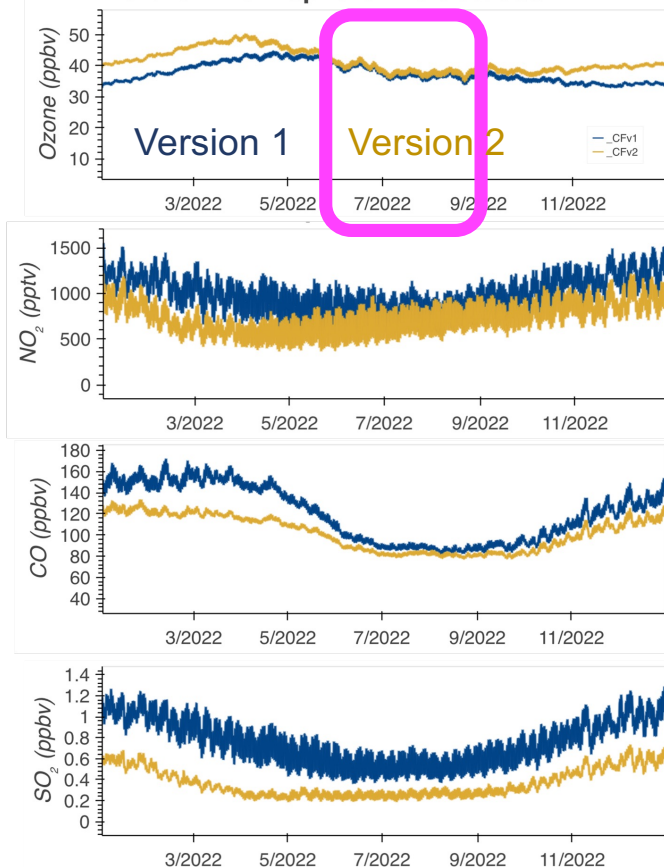
← Surface NO₂ is lower
in v2, especially in
urban areas

→ this leads to
higher surface O₃

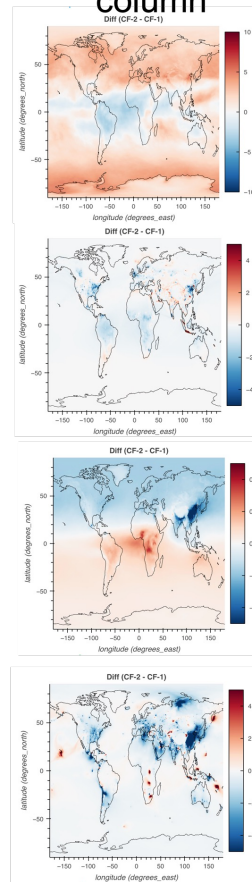


With updated GEOS met the summer O_3 bias in Southeast US is reduced

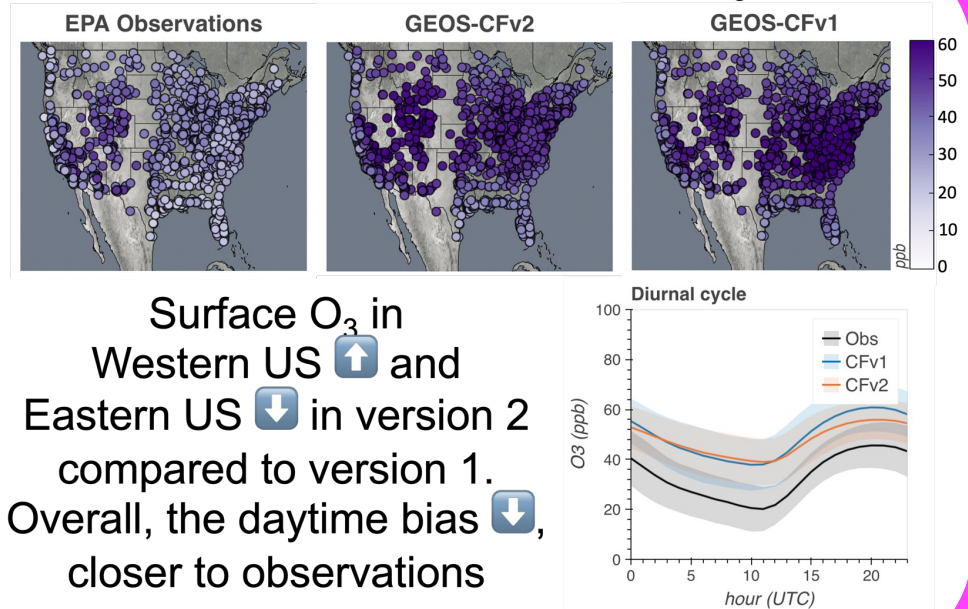
2022 Annual surface concentration
Northern hemisphere midlatitudes



Annual tropospheric
column



Summertime (JJA) surface O_3





Summary and Long-Term Perspective

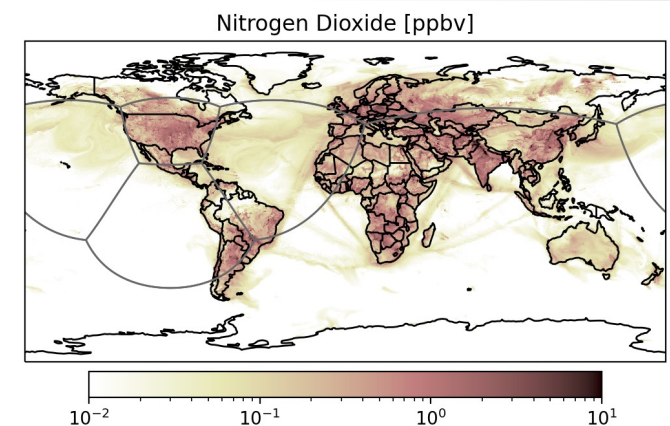
- Version 1 grew from ROSES funding and has expanded GMAO's role in global composition forecasting
 - New capabilities (stratospheric prediction, surface ozone anomalies, ...)
 - Support of additional NASA science teams (providing a priori for TEMPO trace gas retrievals, field campaigns, ...)
 - Rapid 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 and higher vertical resolution in GEOS
 - Chemistry speed-ups

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

Sign up for notifications about GEOS-CF production issues and upgrades –

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

Send an e-mail to geos-cf-users-join@lists.nasa.gov (no subject or text in the body is required).



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