

Evolving GEOS Systems: Snapshots and Timelines

Steven Pawson
With input from many colleagues

IGC10, St Louis, Missouri
June 7, 2022



GMAO's Core Mission and its Manifestation

To enhance the value of NASA's observations to understand, analyze and predict changes in the physics, chemistry and biology of the Earth system

Products support NASA

- Space and field missions
- Modeling and analysis
- Competed research
- Community applications
- Inter-Agency collaborations

Collaborations

- Sharing expertise/experience
- Expanded footprint
- External users run big system
- Evolving open-source code
- Develop new missions

Research

- Model processes
- Complexity
- Coupling mechanisms
- Impactful observations
- Coupled assimilation

Example: Ozone in the UTLS

Wargan et al. (2018) established that the MERRA-2 climate analysis captures a realistic post-1998 trend in ozone with a transport signal imposed upon “Montreal-protocol recovery”

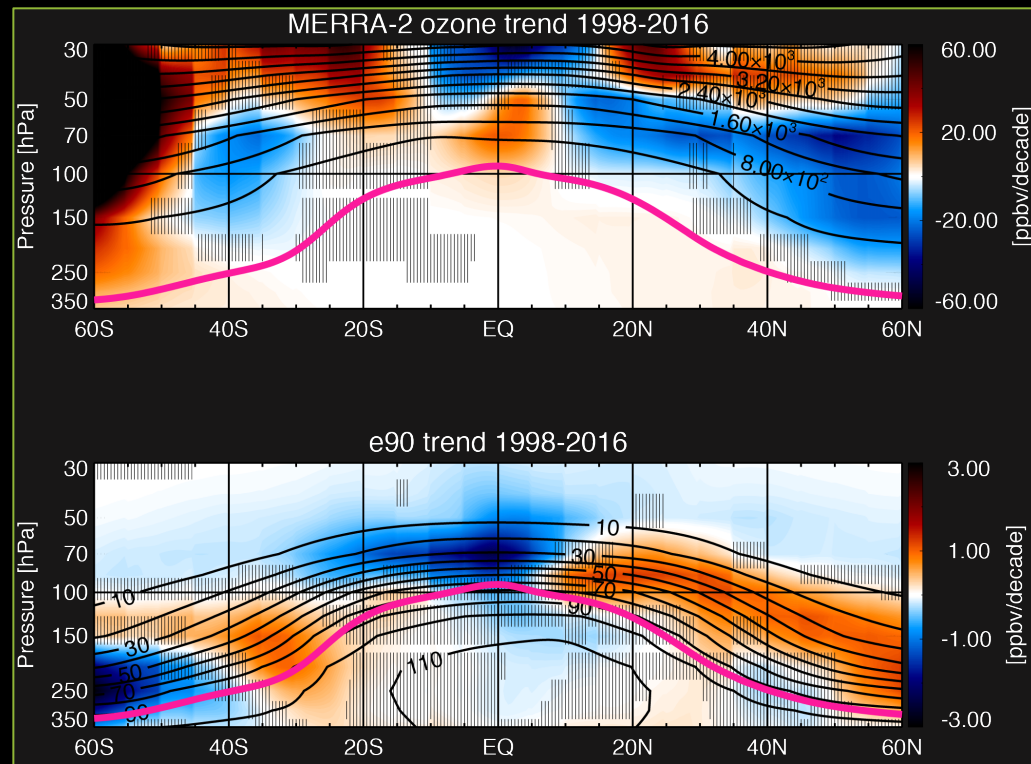


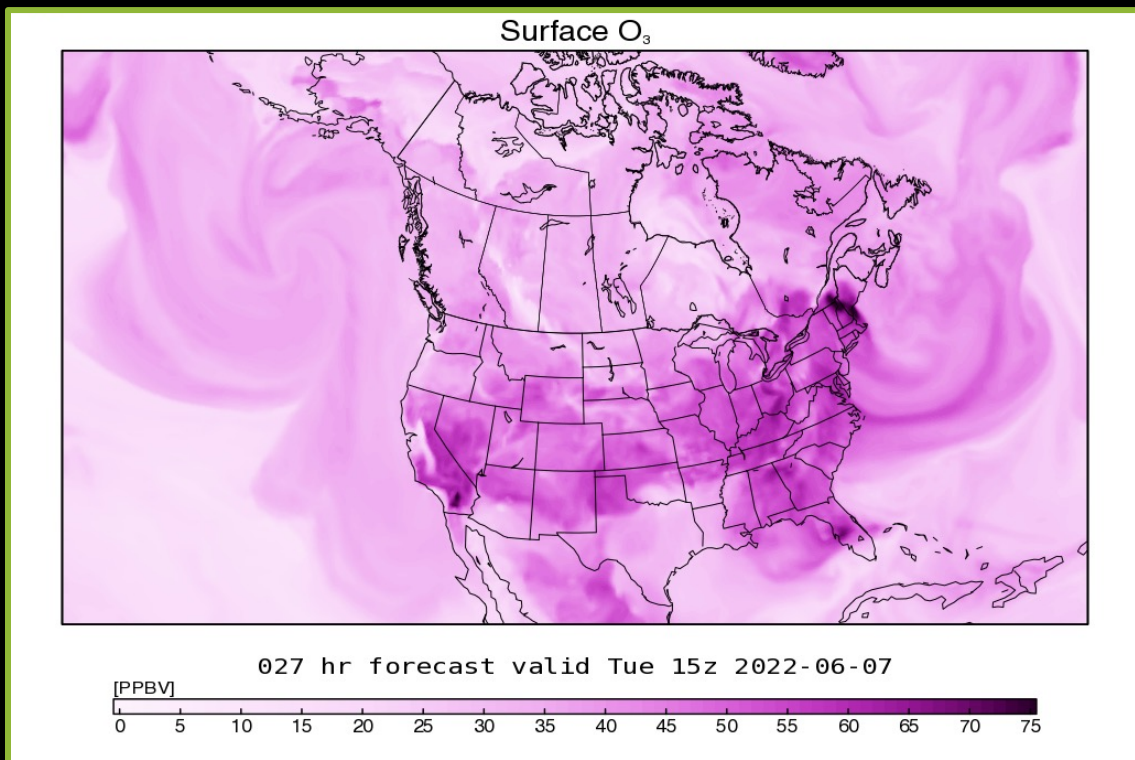
Image from Wargan et al. (2018)

Future reanalyses (GEOS-R21C) build on this:

- Extend the MLS data record assimilated in MERRA-2 by adding OMPS-LP (Wargan et al., 2020)
- Further constraining upper tropospheric ozone by adding infrared radiances (Karpowicz et al., 2021)
- Replace simple stratospheric chemistry with GEOS-Chem (Keller et al., 2021; Knowland et al., 2022)
- Assimilate ozone precursors to help improve near-surface ozone (in progress)
- **Objective is a surface-stratosphere ozone record in the early 21st Century**

GMAO – GEOS-Chem Collaboration Exemplifies Open Science

A long-standing partnership has developed shared (open) repositories that allow an identical code base to be used by international researchers and for GMAO's GEOS-CF products



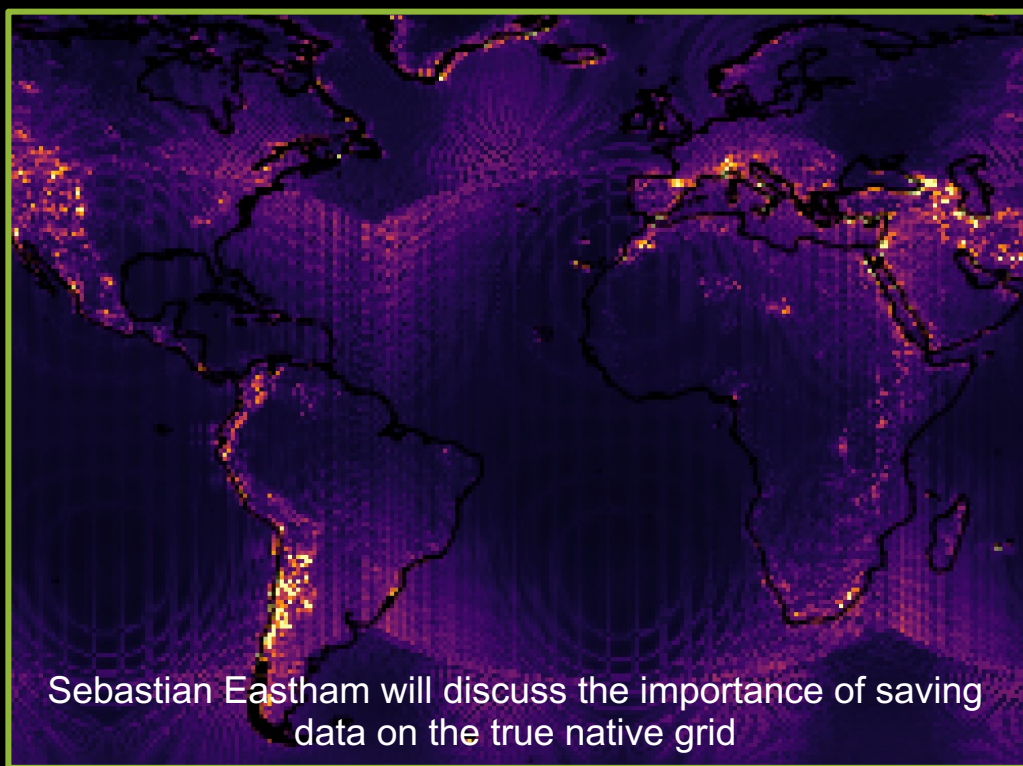
FLUID image from GMAO's web site (6/6/2022) predicted surface ozone at 15Z on 6/7/2022

An evolving relationship:

- ROSES-funded research delivered the grid-independent GEOS-Chem code (Long et al., 2015)
- Implementation in free-running, on-line GEOS GCM simulations, shown at earlier IGC meetings
- GEOS-CF system first released in 2018 and is being adopted by multiple users (missions, research)
- GEOS-CF has opened connections to the applications community and for emerging open data services
- As of 2022, resources for GEOS-CF are part of the GMAO's core budget

Foundation: the Validated and Monitored GEOS Products

GMAO's core effort is focused largely on advanced system development, including rigorous science-based development, careful evaluation, production and systematic monitoring



Excerpt from an image of vertical mass flux differences provided by Sebastian Eastham

GEOS-FP meteorology underpins this:

- Version 5.29 includes forefront data, especially all-sky microwave radiances, GPS-RO, etc.
- This hybrid 4D-ensemble-variational approach will be used for the 21st Century reanalysis, GEOS-R21C
- For accuracy and efficiency, native-grid products are transitioning to the cubed-sphere grid
- Transition to the GEOS-6 series includes a 181-layer model with fully revamped physics
- **GEOS products are tailored to community needs and are well validated and documented**

Timeline for GEOS Systems



2015

2017

2019

2021

2023

2025

2027

NASA investments in GEOS modeling and assimilation have advanced elements of Earth system analysis and prediction through the EOS and post-EOS data era

MERRA-2
Climate, aerosol

GEOS-FP
All-sky radiances

GEOS-CF
Full chemistry

GEOS-R21C
Modern obs

M2-Ocean
Altimetry, salinity

GEOS-FP
JEDI based

MERRA-3
Earth system

Prepare for
ESO data

GEOS-S2S
Unified model

Adopting JCSDA/JEDI assimilation software with the GEOS coupled model opens new horizons for NASA's analysis and prediction as we move to the ESO era

Atmospheric Assimilation
Weather/composition prediction

Ocean-Cryosphere Assimilation
Coupled prediction (S2S)



Final Summary

- GMAO's GEOS-CF project has transitioned from “competed project” to “core” support
 - Sustained pathway for system development, monitoring and evaluation
 - Constituent assimilation and forecasting is a key part of GMAO's Earth system science
 - Expect tighter coupling between GEOS-Chem and GOCART aerosols
- The GEOS-Chem modules used in GEOS-CF are validated community modules
 - GEOS-CF analyses and forecasts are a part of the GEOS-Chem ecosystem of products
 - Opening new pathways for applications, especially in the air-quality domain
 - Investing in constituents in “Joint Effort for Data assimilation Innovation” (JEDI) framework
- Opportunities abound, such as
 - Process-oriented “budget” studies with GEOS-Chem code in simulation and analysis
 - Emerging “fast chemistry” approximations to enable timely forecasts