

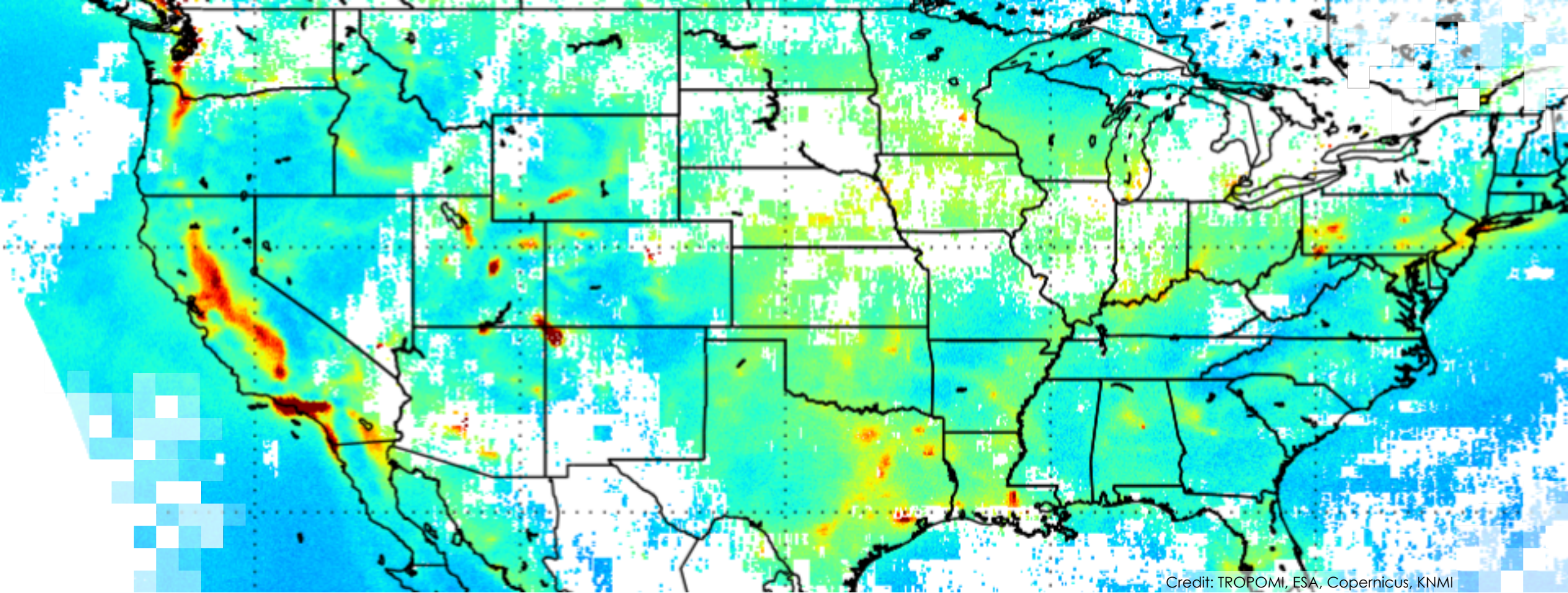
Credit: TROPOMI, ESA, Copernicus, KNMI



NASA Air Quality Forecasts

Melanie Follette-Cook and Pawan Gupta

Application of Satellite Observations for Air Quality and Health Exposure, Oct 9 and 11, 2019

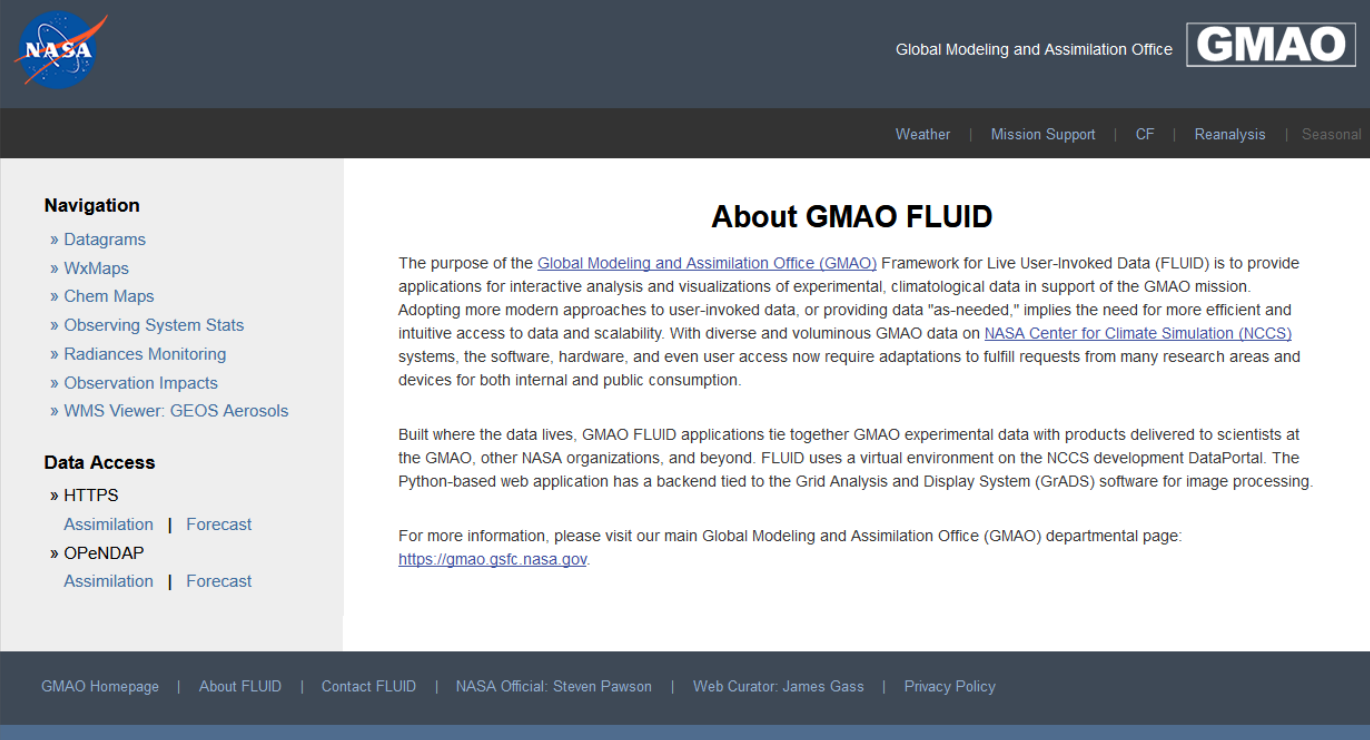


NASA GEOS Forecasts

NASA Weather and Composition Forecasts

<https://fluid.nccs.nasa.gov/about/>

- NASA's global weather and atmospheric composition forecasts
 - Weather: includes aerosols and CO
 - CF (Composition Forecast): includes trace gases like ozone and NO₂, as well as PM_{2.5}



The screenshot shows the NASA Global Modeling and Assimilation Office (GMAO) website. The header includes the NASA logo and the GMAO logo. A navigation menu at the top right lists: Weather | Mission Support | CF | Reanalysis | Seasonal. The main content area is titled "About GMAO FLUID". The text describes the purpose of the GMAO Framework for Live User-Invoked Data (FLUID) and mentions the NASA Center for Climate Simulation (NCCS). It also lists data access methods: HTTPS (Assimilation | Forecast) and OPeNDAP (Assimilation | Forecast). A footer at the bottom contains links: GMAO Homepage | About FLUID | Contact FLUID | NASA Official: Steven Pawson | Web Curator: James Gass | Privacy Policy.



NASA Forecasts: Datagrams



Home | Datagrams | WxMaps | Chem Maps | Obs Sys Stats | Radiances | Obs Impacts

METEGRAMS
Relative Humidity

AEROSOLS
Organic Carbon
Black Carbon
Sea Salt
Dust
Sulfate
Nitrate
TOTAL

Carbon Species
CO
CO₂

NATIONAL
Washington DC

WORLD
Select a Station

AERONET
Select a Station

MEGACITIES

GMAO GEOS FP Meteograms

Relative Humidity at Washington DC (38.90, -77.00)

Relative Humidity

Clouds (%)
High
Mid
Low

Relative Humidity (%)
Wind Barbs (knots)

SLP (hPa)
T2M (F)

Total Rain (mm)
Snow (mm)
Convective (mm)

2m w. spd (knots)

00z 12z 00z 12z 00z 12z 00z 12z 00z 12z 00z 12z 00z 12z 00z

Tue 1 Oct 2019 Wed 2 Oct Thu 3 Oct Fri 4 Oct Sat 5 Oct Sun 6 Oct

Lat = 38.90, Lon = -77.00, Location = Washington_DC, Fcst_Init = 2019-10-01 00:00:00

View plots for select cities, AERONET locations, and NASA field campaigns



NASA Forecasts: Chem Maps

Select a variable

Select a map region

Select a forecast

Home | Datagrams | WxMaps | Chem Maps | Obs Sys Stats | Radiances | Obs Impacts

FIELDS
Dust AOT

REGIONS

Atlantic	Australia
Global	Mid Atlantic
North America	N Polar
Pacific	Seven Seas
S Polar	

FORECAST INITIAL TIME
01Oct2019 00z

FORECAST LEAD HOUR
000h 01Oct2019 00z

Atmospheric Composition (2D) Maps

NASA GEOS Analysis
NASA - Global Modeling and Assimilation Office (GMAO)

Initial: 10/01/2019 00Z Hour: 000 Valid: 10/01/2019 00Z

Dust Aerosol Optical Thickness

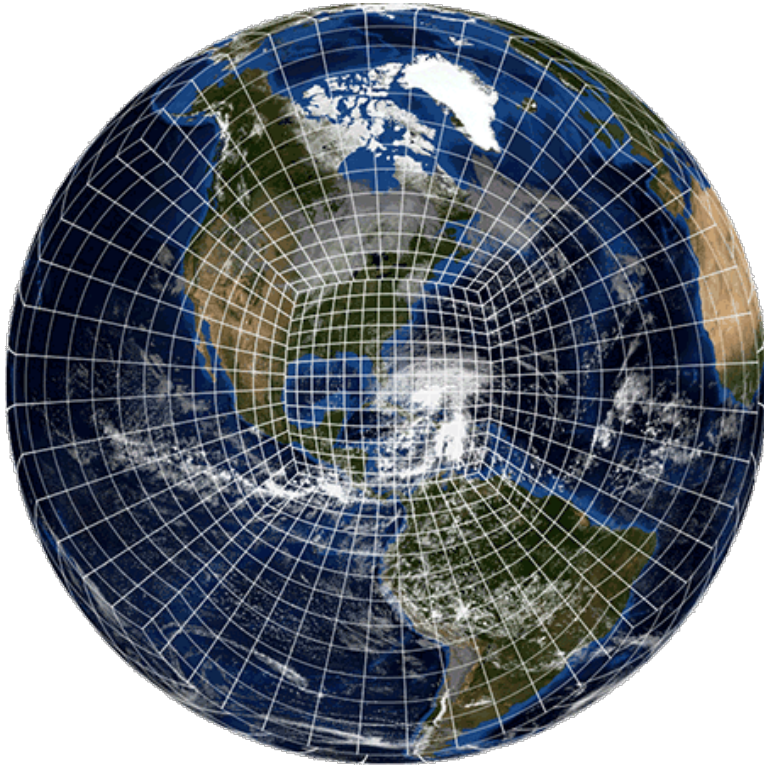
0.005 0.009 0.013 0.017 0.021 0.025 0.029 0.033 0.037 0.041 0.046 0.051 0.055

ANIMATE DOWNLOAD MOVIE

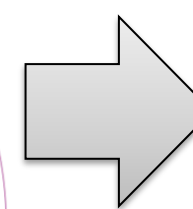
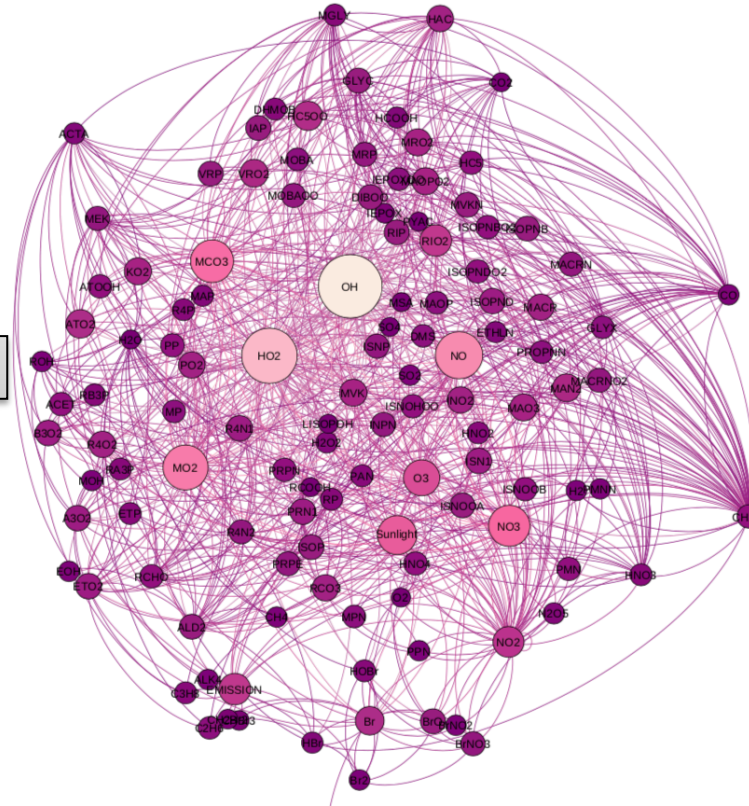
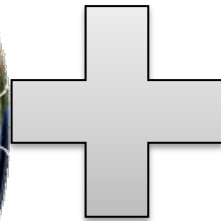
Animate the map

NASA Composition Forecasts (GEOS-CF)

GEOS
Meteorology



GEOS-Chem
Chemistry

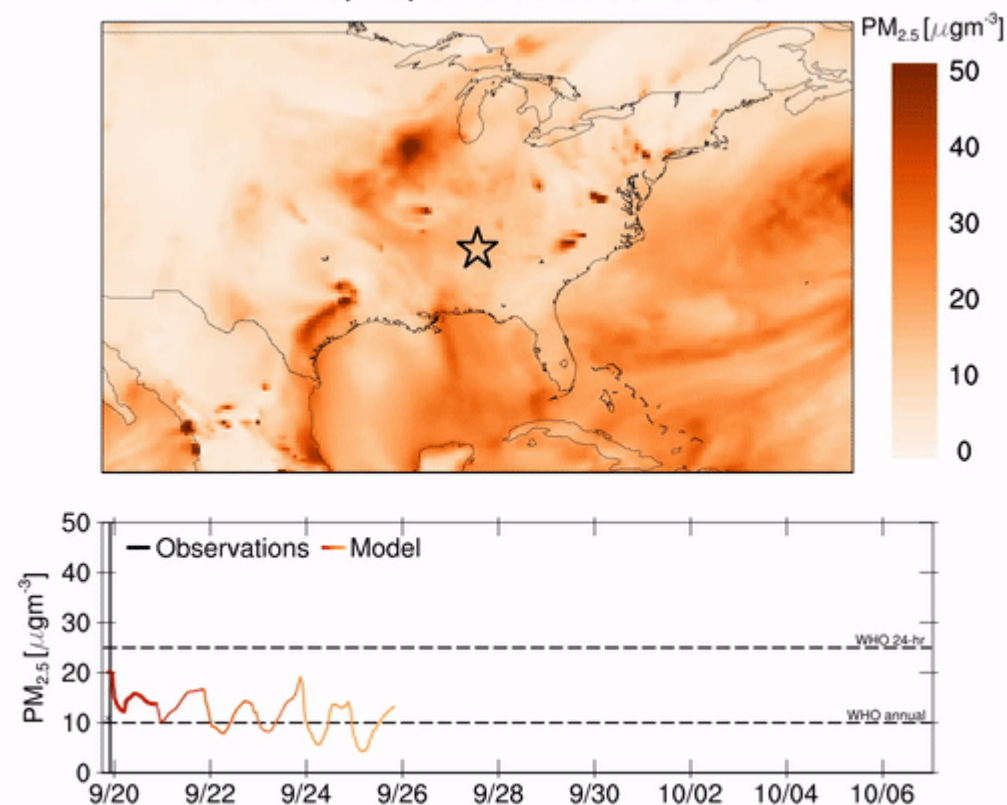


GEOS-CF

NASA GEOS-CF

- One 5-day forecast per day
- ~25x25km² resolution
- O₃, NO₂, VOCs, PM ...
- 15 minute output for the surface
- One-hour average and instantaneous 2D and 3D fields
- Available since Jan 2018

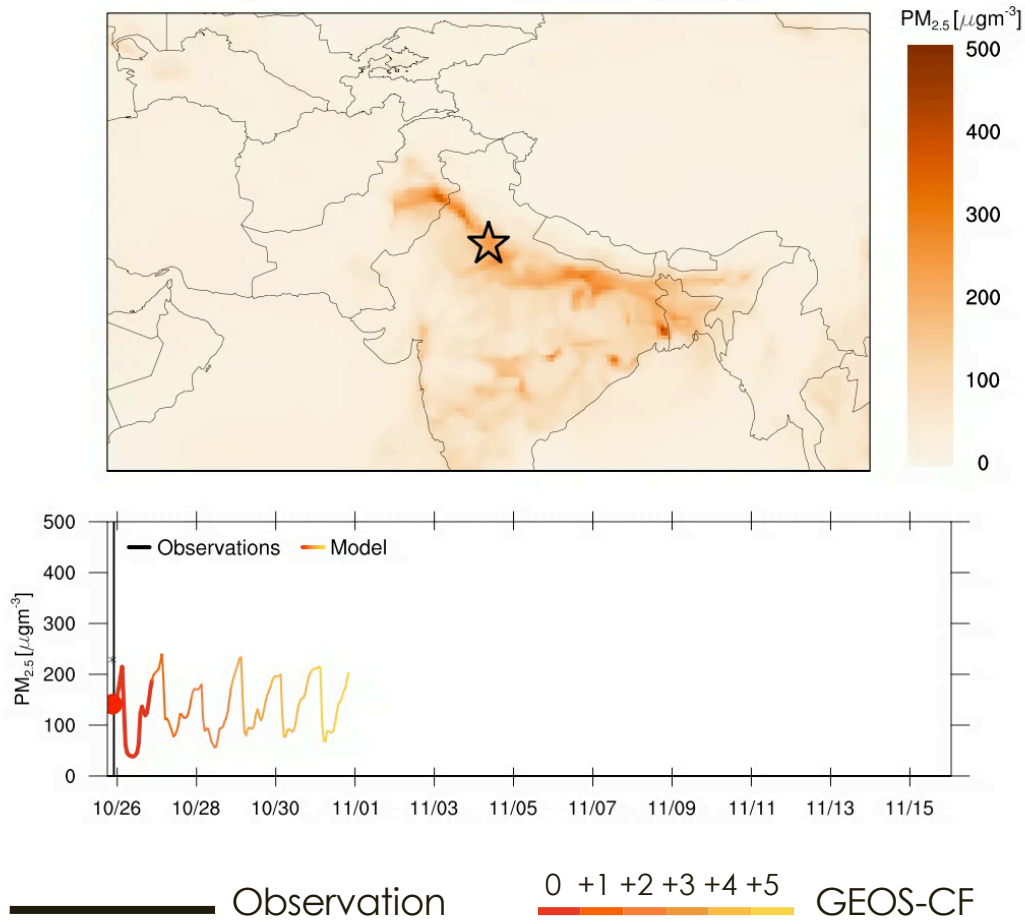
Huntsville, AL, 2019-09-20 00:45 UTC



Christoph Keller, NASA GMAO

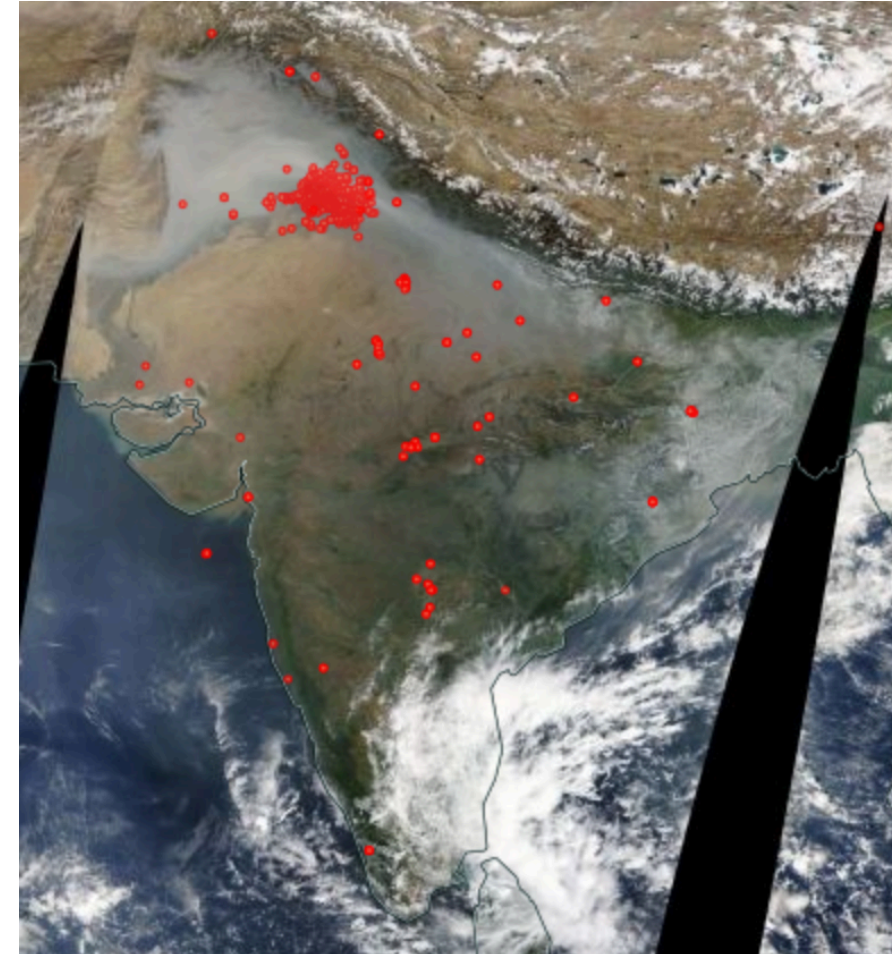
Case Study: Agricultural Fires in India

Delhi, India, 2017-10-26 00:00 UTC



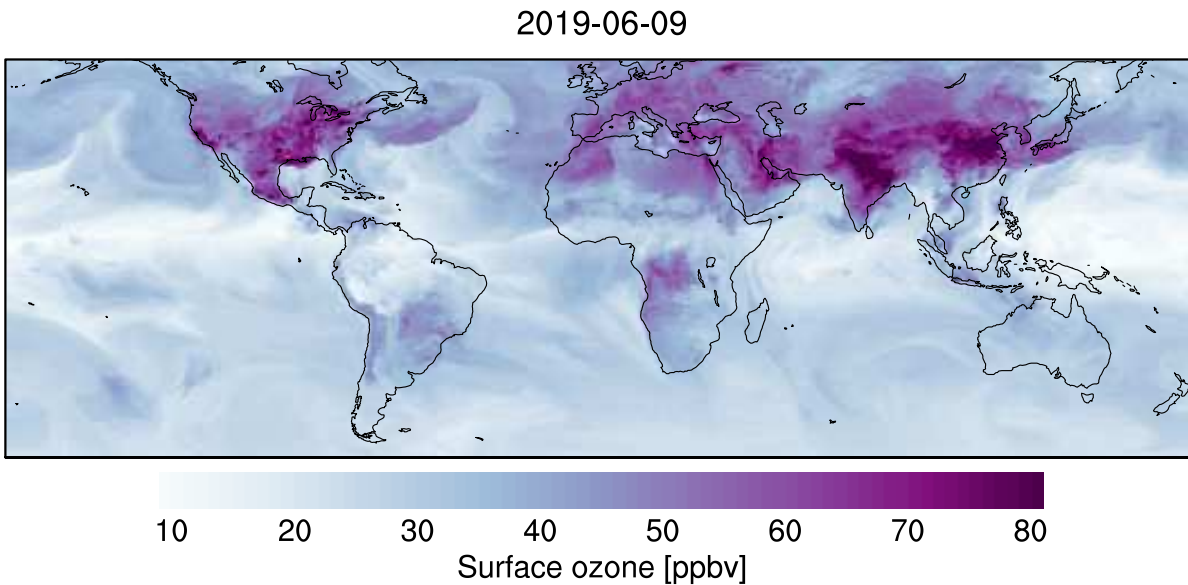
Christoph Keller, NASA GMAO

MODIS Fires Nov 1, 2017



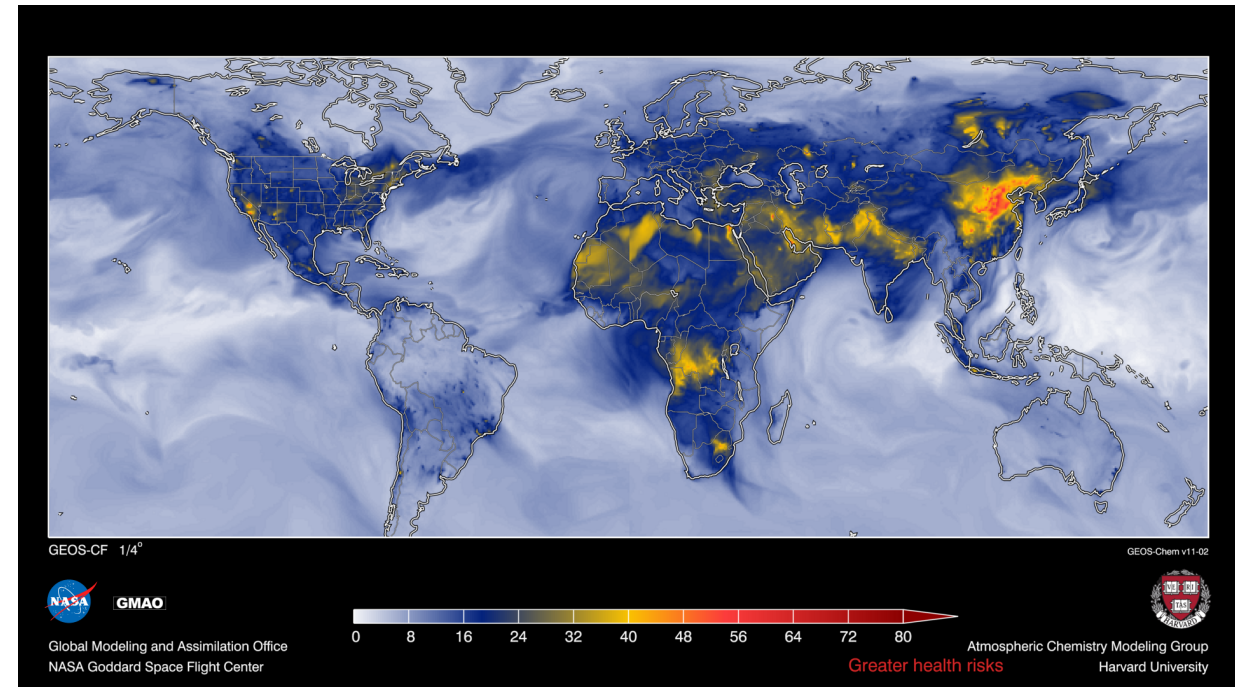
Air Quality and Health Applications

Optimize model predictions



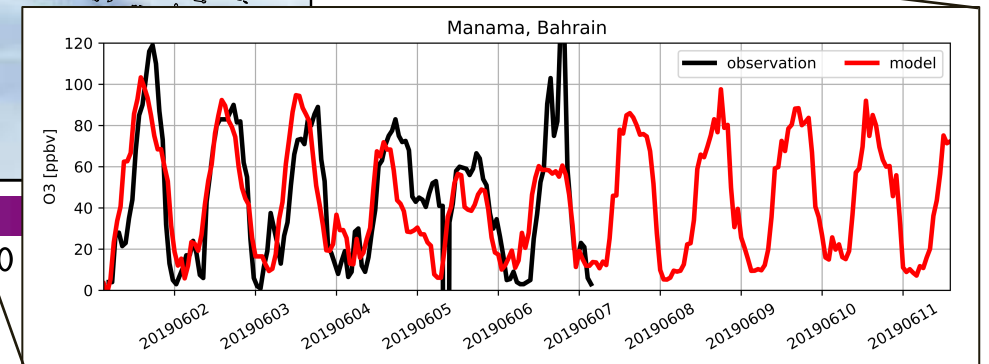
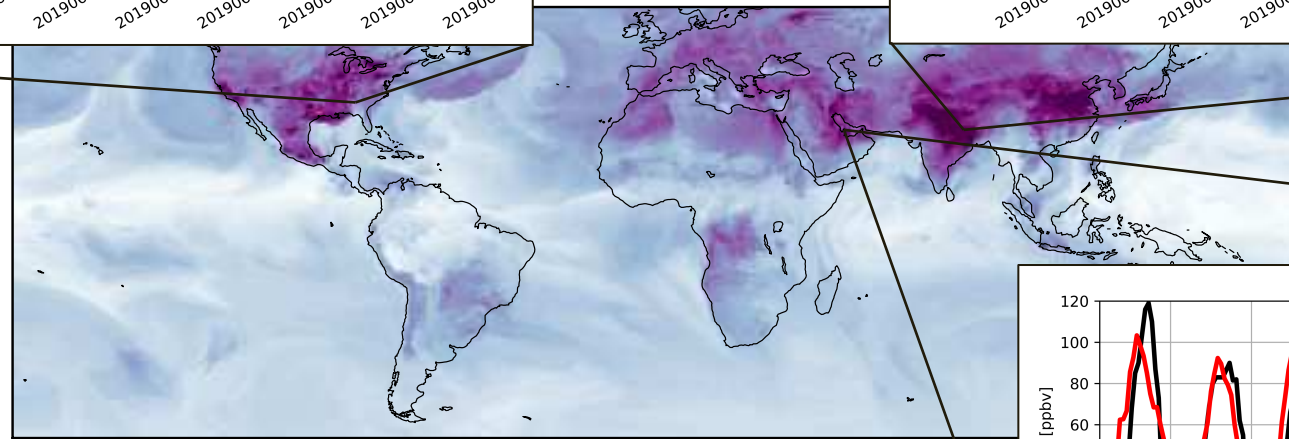
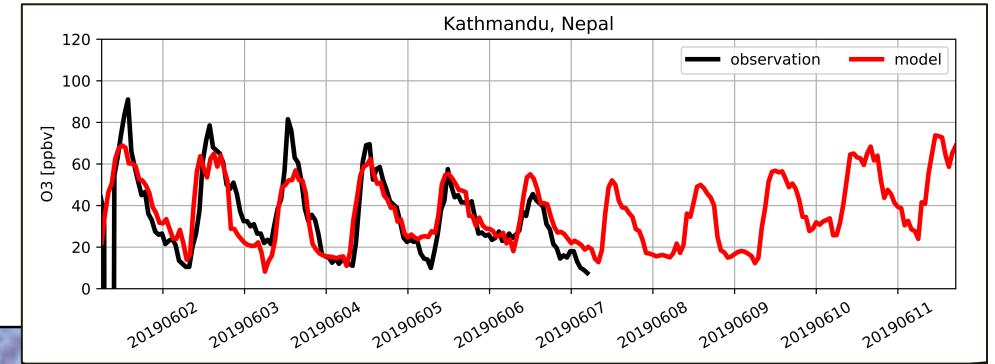
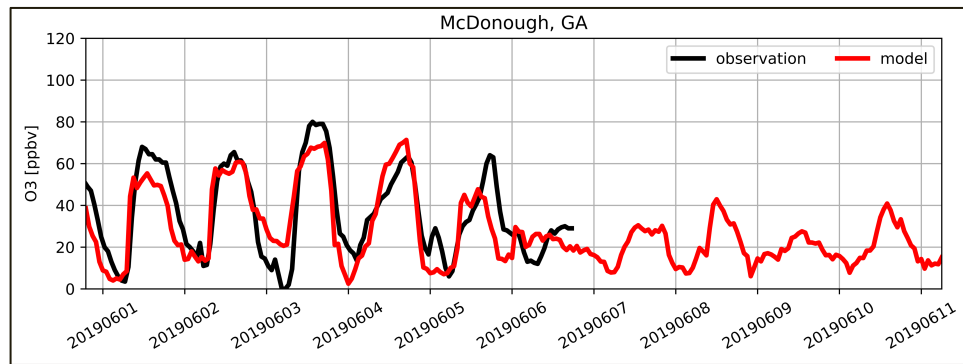
- How good is the model?

Global exposure assessment

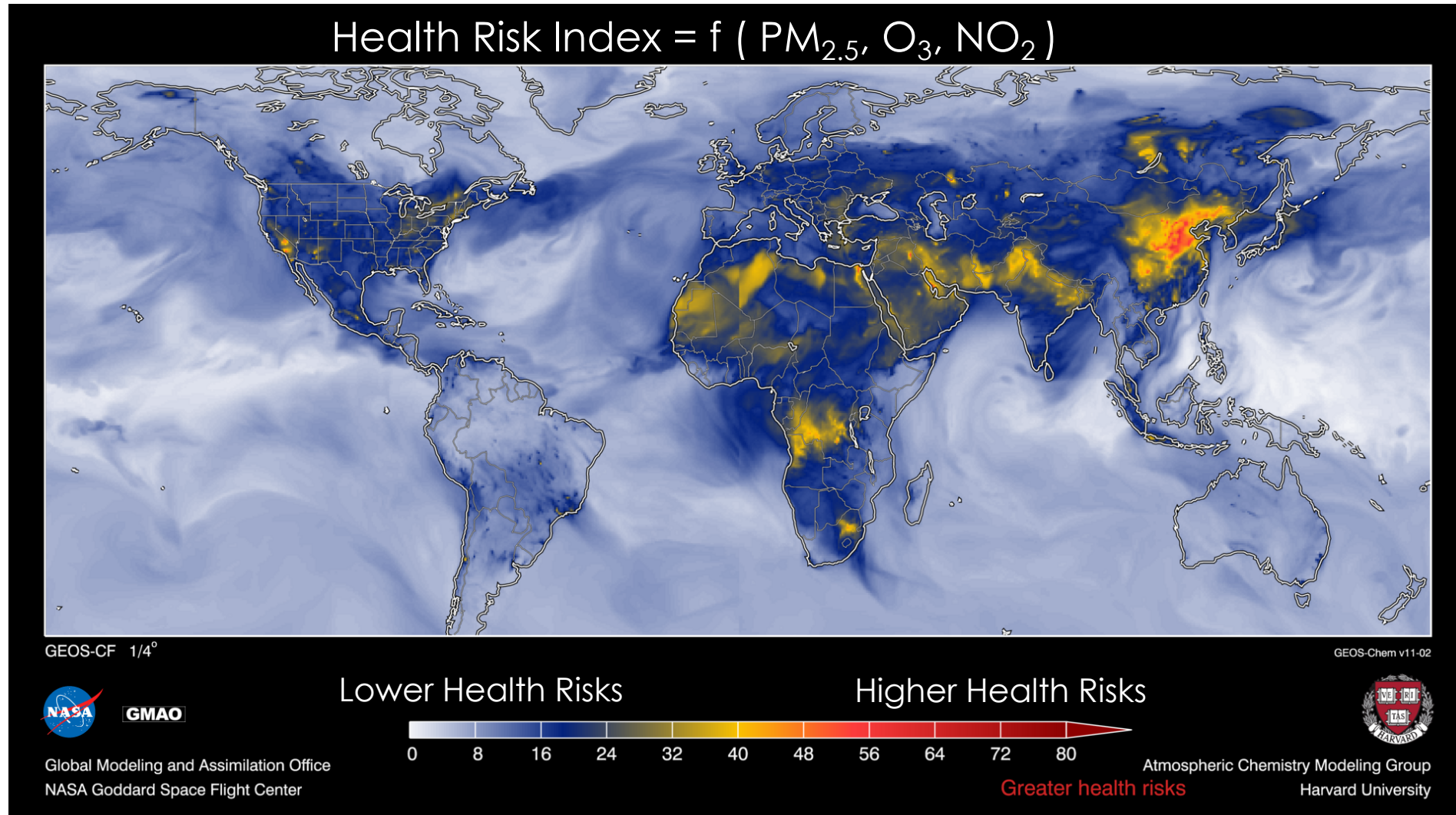


- How bad is the air pollution?

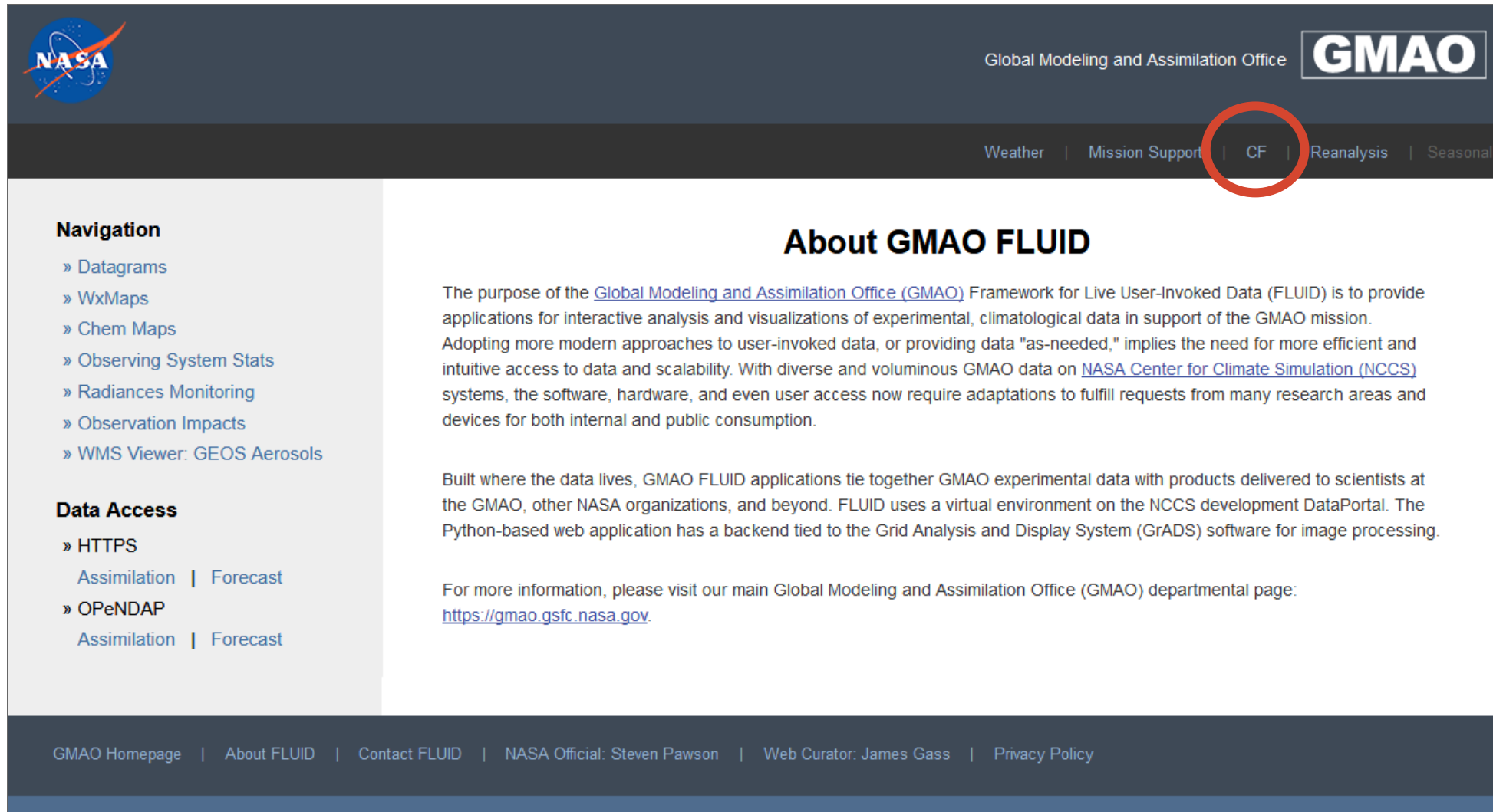
Observe Ozone Levels Around the World



Translate Pollutant Concentrations into a Health Index



Where to Find GEOS-CF Forecasts



The screenshot shows the NASA Global Modeling and Assimilation Office (GMAO) website. The NASA logo is in the top left, and the GMAO logo is in the top right. A navigation menu below the GMAO logo includes links for Weather, Mission Support, CF (circled in red), Reanalysis, and Seasonal. The main content area is titled "About GMAO FLUID" and contains text describing the FLUID framework and its purpose. A sidebar on the left lists navigation and data access options.

Navigation

- » Datagrams
- » WxMaps
- » Chem Maps
- » Observing System Stats
- » Radiances Monitoring
- » Observation Impacts
- » WMS Viewer: GEOS Aerosols

Data Access

- » HTTPS
 - Assimilation | Forecast
- » OPeNDAP
 - Assimilation | Forecast

About GMAO FLUID

The purpose of the [Global Modeling and Assimilation Office \(GMAO\)](#) Framework for Live User-Invoked Data (FLUID) is to provide applications for interactive analysis and visualizations of experimental, climatological data in support of the GMAO mission. Adopting more modern approaches to user-invoked data, or providing data "as-needed," implies the need for more efficient and intuitive access to data and scalability. With diverse and voluminous GMAO data on [NASA Center for Climate Simulation \(NCCS\)](#) systems, the software, hardware, and even user access now require adaptations to fulfill requests from many research areas and devices for both internal and public consumption.

Built where the data lives, GMAO FLUID applications tie together GMAO experimental data with products delivered to scientists at the GMAO, other NASA organizations, and beyond. FLUID uses a virtual environment on the NCCS development DataPortal. The Python-based web application has a backend tied to the Grid Analysis and Display System (GrADS) software for image processing.

For more information, please visit our main Global Modeling and Assimilation Office (GMAO) departmental page: <https://gmao.gsfc.nasa.gov>.

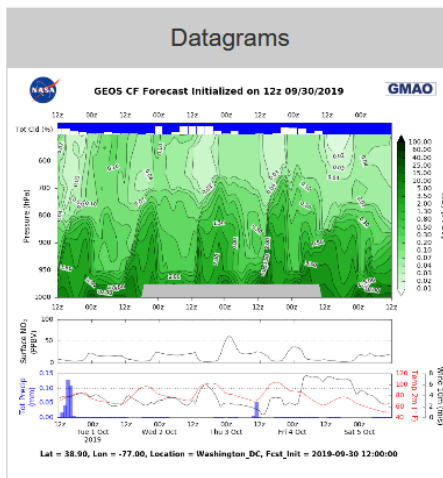
GMAO Homepage | About FLUID | Contact FLUID | NASA Official: Steven Pawson | Web Curator: James Gass | Privacy Policy



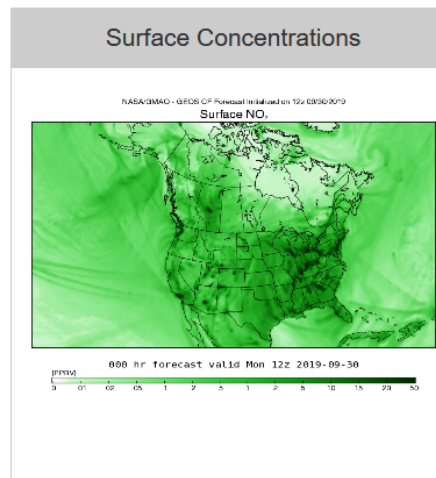
Datagrams
Surface Maps
Total Column Maps

GMAO Composition Forecast Products

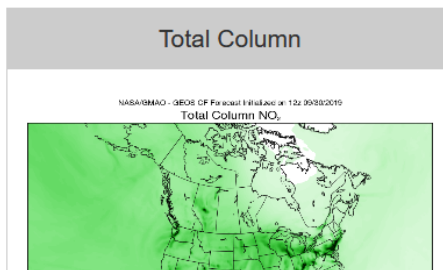
Datagrams



Surface Concentrations



Total Column

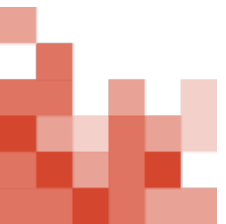


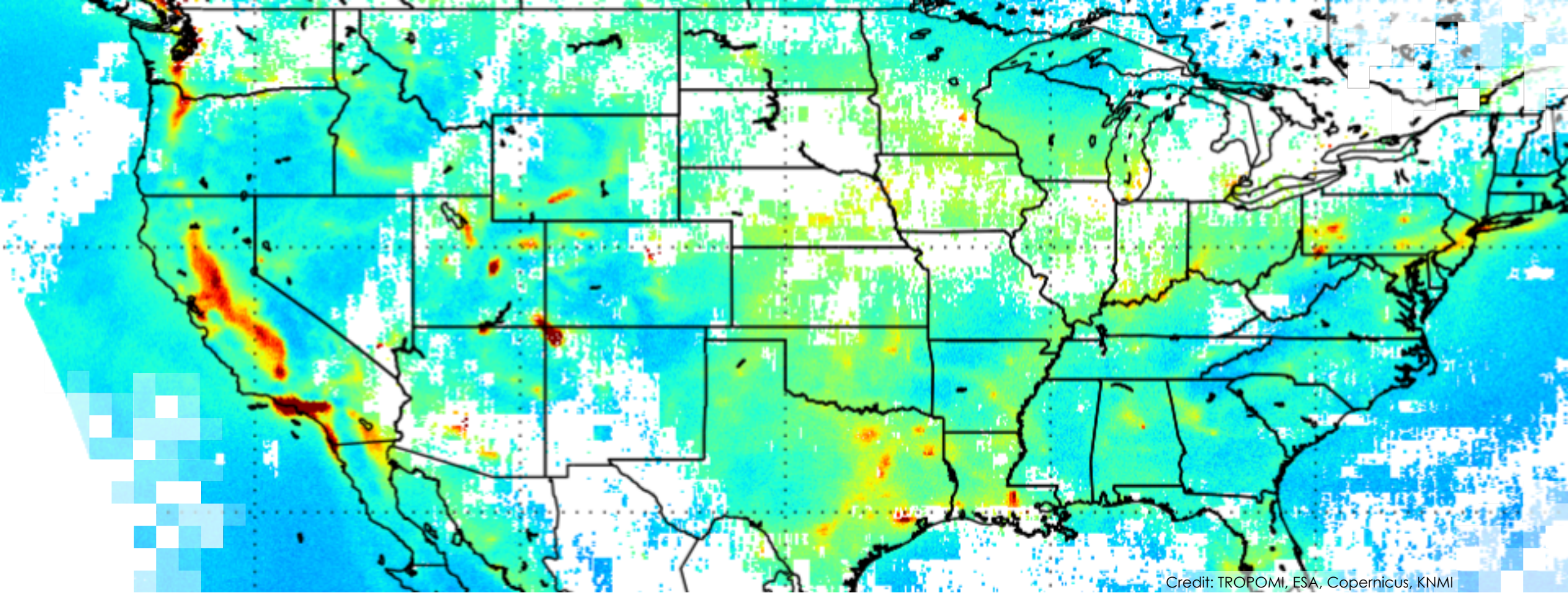


Questions and/or suggestions about the GEOS-CF should be directed to:

Christoph Keller: christoph.a.keller@nasa.gov

Emma Knowland: k.e.knowland@nasa.gov

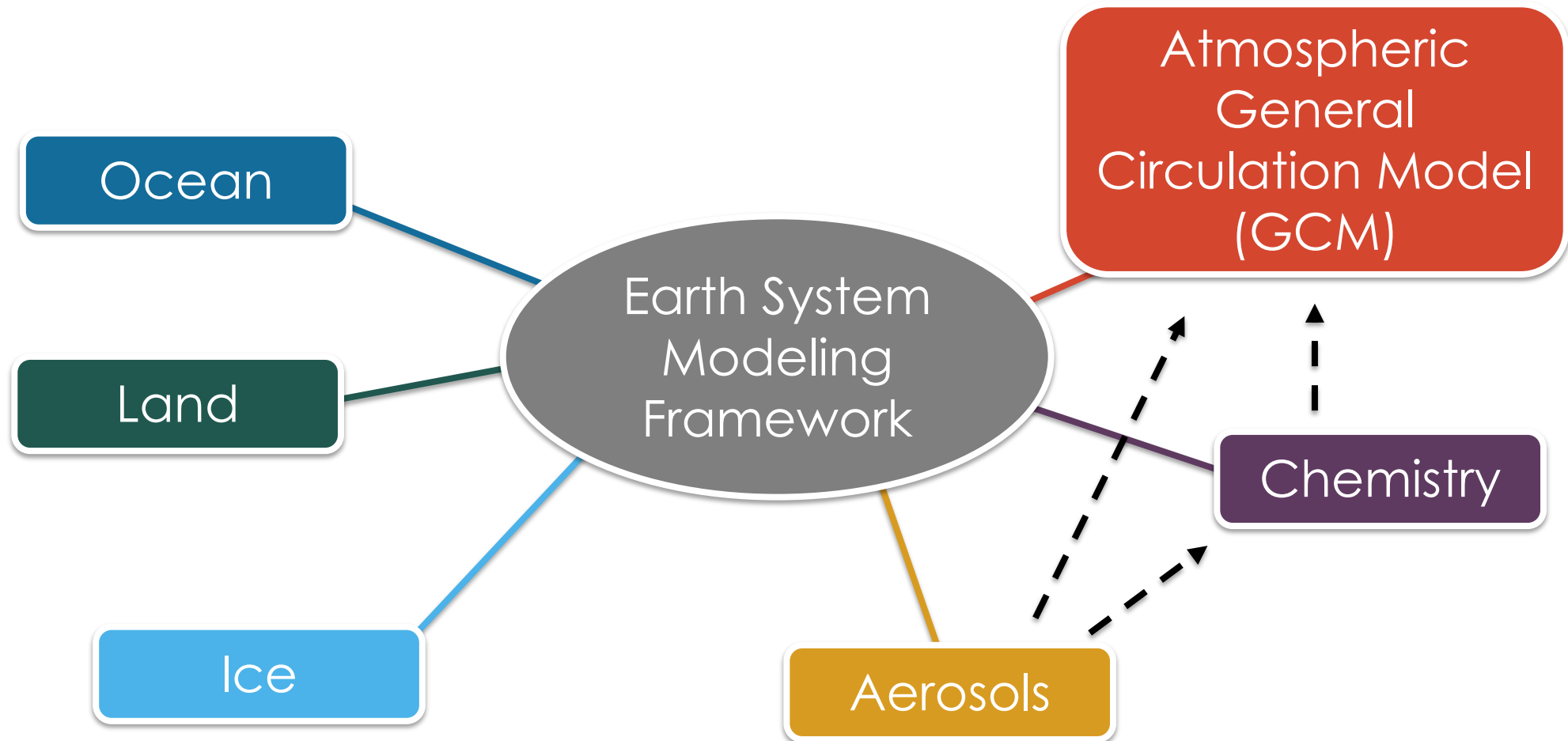




Credit: TROPOMI, ESA, Copernicus, KNMI

MERRA-2 Reanalysis

NASA GEOS Earth System Model



Why data assimilation?

- Models are useful but have difficulty specifying emissions, resolving microphysical processes, and transport, leading to large uncertainties
- While there are a large number of aerosol sensors, there are still blind spots:
 - Measurements are usually vertically integrated
 - Diurnal cycle is not represented by polar orbiters
- Data assimilation can act as an integrator of model and observational information and a conveyor of past observations

What is reanalysis, and why do we do it?

What

- A consistent reprocessing of Earth system observations using a modern, unchanging data assimilation system
- Relies on models to interpret, relate, and combine different observations from multiple sources
- A successful reanalysis **requires** a good forecast model combined with bias-corrected and quality controlled observations

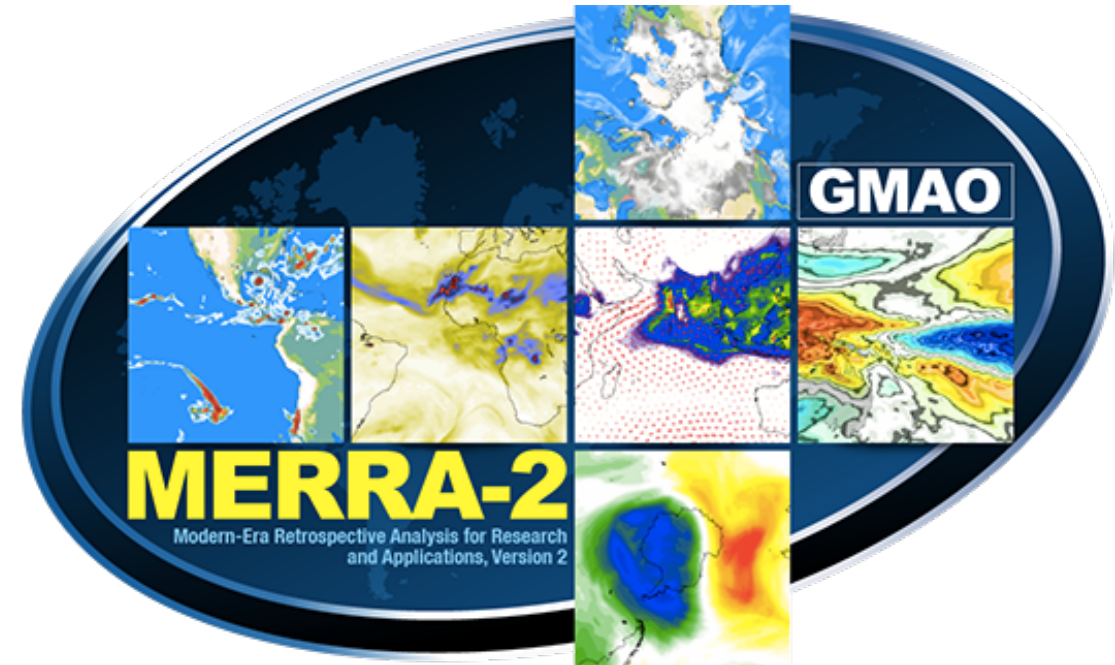
Why

- Produces multi-decadal, gridded datasets that estimate a large variety of Earth system variables, including ones that are not directly observed
- Has become fundamental to research and education in the Earth sciences

MERRA-2 Reanalysis

<https://gmao.gsfc.nasa.gov/reanalysis/MERRA-2/>

- Long-term, model-based analyses of multiple datasets using a fixed assimilation system
 - GEOS (Goddard Earth Observing System Model)
- The **M**odern-**E**ra **R**etrospective analysis for **R**esearch and **A**pplications version 2 (MERRA-2) provides data beginning in 1980 and runs a few weeks behind real-time
- MERRA-2 includes meteorology, stratospheric ozone, and aerosols at a spatial resolution of a $0.5^\circ \times 0.66^\circ$ grid



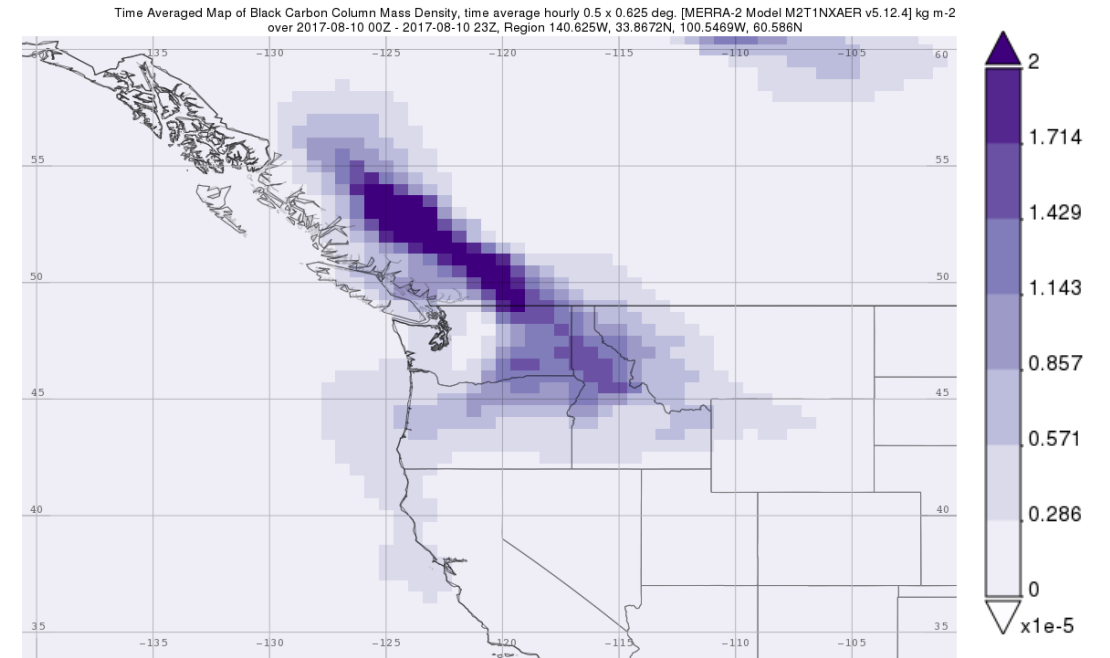
Source: <https://gmao.gsfc.nasa.gov/reanalysis/>

MERRA-2 Reanalysis Example – August 10, 2017



MODIS – Terra

MERRA-2 – Black Carbon

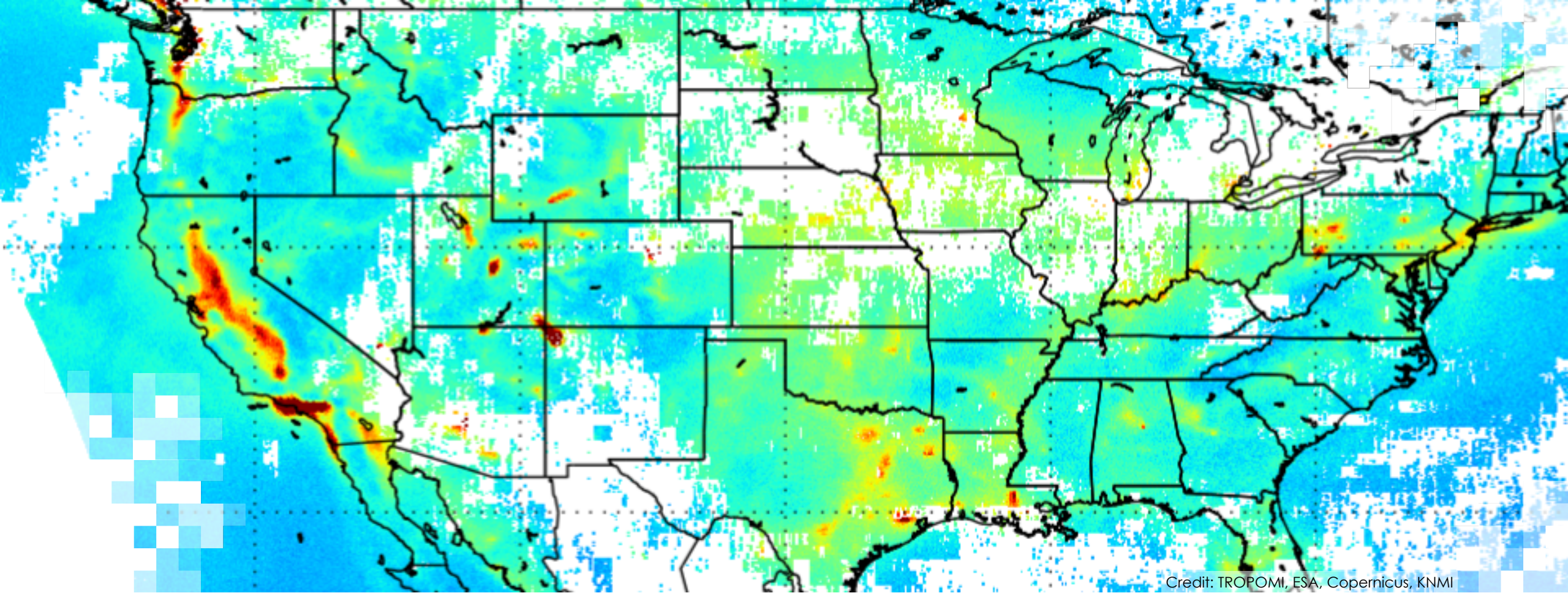


MERRA-2 Webpage Tour

<https://gmao.gsfc.nasa.gov/reanalysis/MERRA-2/>

The screenshot shows the MERRA-2 webpage layout. At the top left is the NASA logo. To its right is the text "National Aeronautics and Space Administration" and "Goddard Space Flight Center". Further right is a search bar with a "GO" button and the text "Earth Sciences Division | Sciences and Exploration". Below this is a blue banner with the text "Global Modeling and Assimilation Office" and a "Home" link. A navigation menu below the banner includes: "GMAO MISSION", "WEATHER ANALYSIS & PREDICTION", "SEASONAL-DECADAL ANALYSIS & PREDICTION", "REANALYSIS", "GLOBAL MESOSCALE MODELING", and "OBSERVING SYSTEM SCIENCE". The "REANALYSIS" menu item is highlighted. On the left side, there is a vertical list of links: "MERRA-2 Project", "Data Access", "Documentation", "Highlights", "Images", "Videos", "FAQ", "Publications", "Mailing List", "User Metrics", and "Diagnostic Feedback". The main content area features the title "Modern-Era Retrospective analysis for Research and Applications, Version 2" and a "Project Overview" section. The overview text states: "The Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2) provides data beginning in 1980. It was introduced to replace the original MERRA dataset because of the advances made in the assimilation system that enable assimilation of modern hyperspectral radiance and microwave observations, along with GPS-Radio Occultation datasets. It also uses NASA ozone observations after 2005. Additional advances in both the GEOS-5 model and the GSI assimilation system are included in MERRA-2. Spatial resolution remains about the same (about 50 km in the latitudinal direction) as in MERRA. Along with the enhancements in the meteorological assimilation, MERRA-2 takes some significant steps towards GMAO's target of an Earth System reanalysis. MERRA-2 is the first long-term global reanalysis to assimilate space-based observations of aerosols and represent their interactions with other physical processes in the climate system. MERRA-2 includes a representation of ice sheets over (say) Greenland and Antarctica." Below the text is a large graphic with the "GMAO" logo and the "MERRA-2" logo, which includes the text "Modern-Era Retrospective Analysis for Research and Applications, Version 2". The graphic also contains several small maps showing atmospheric data.





Evaluation & Inter-comparisons

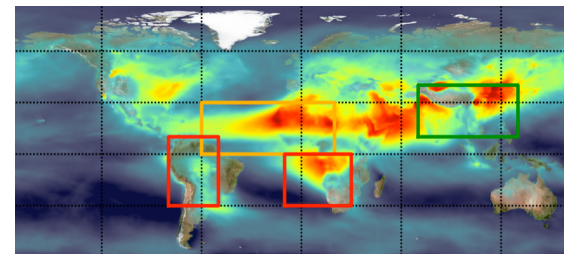
MERRA-2 Aerosol Evaluation Highlights

Using Independent Observations

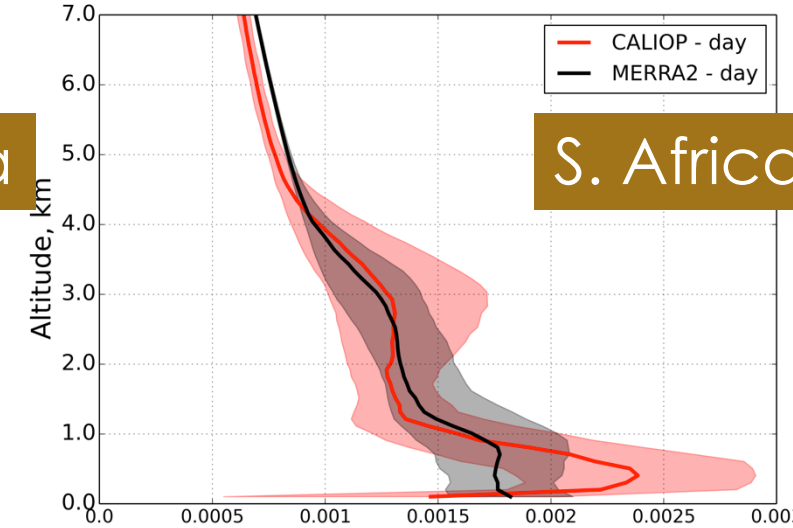
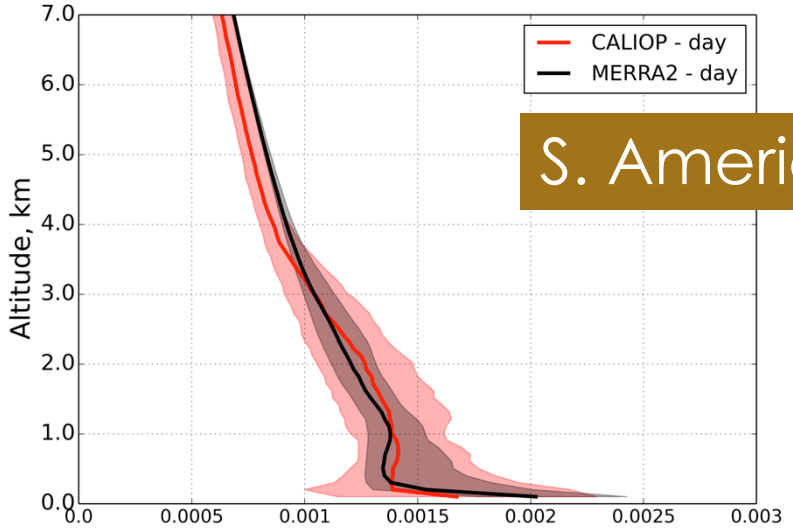
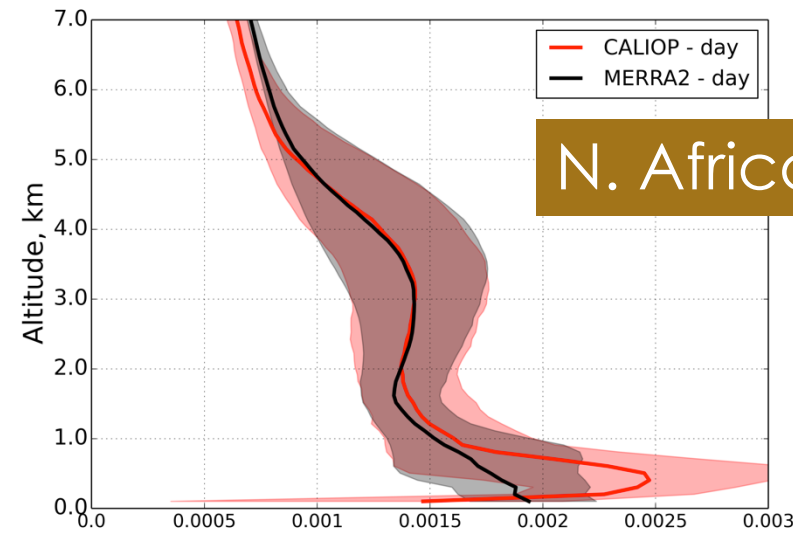
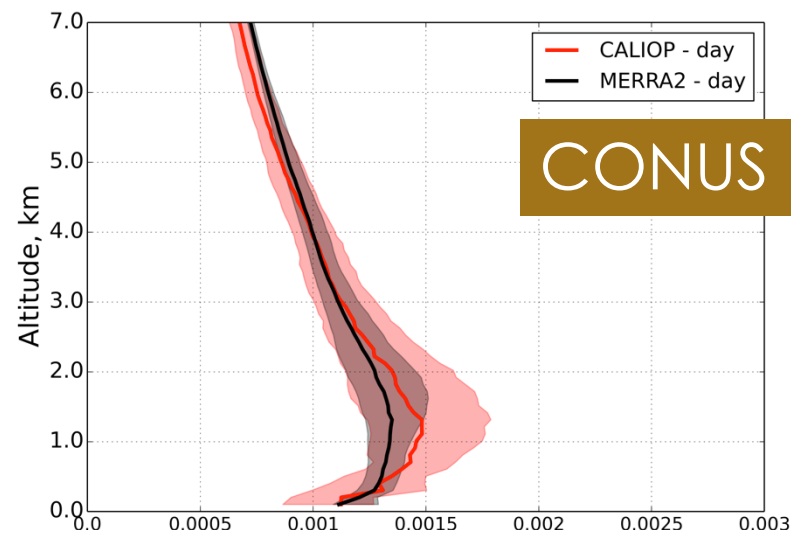


Vertical Structure

Comparison to CALIOP

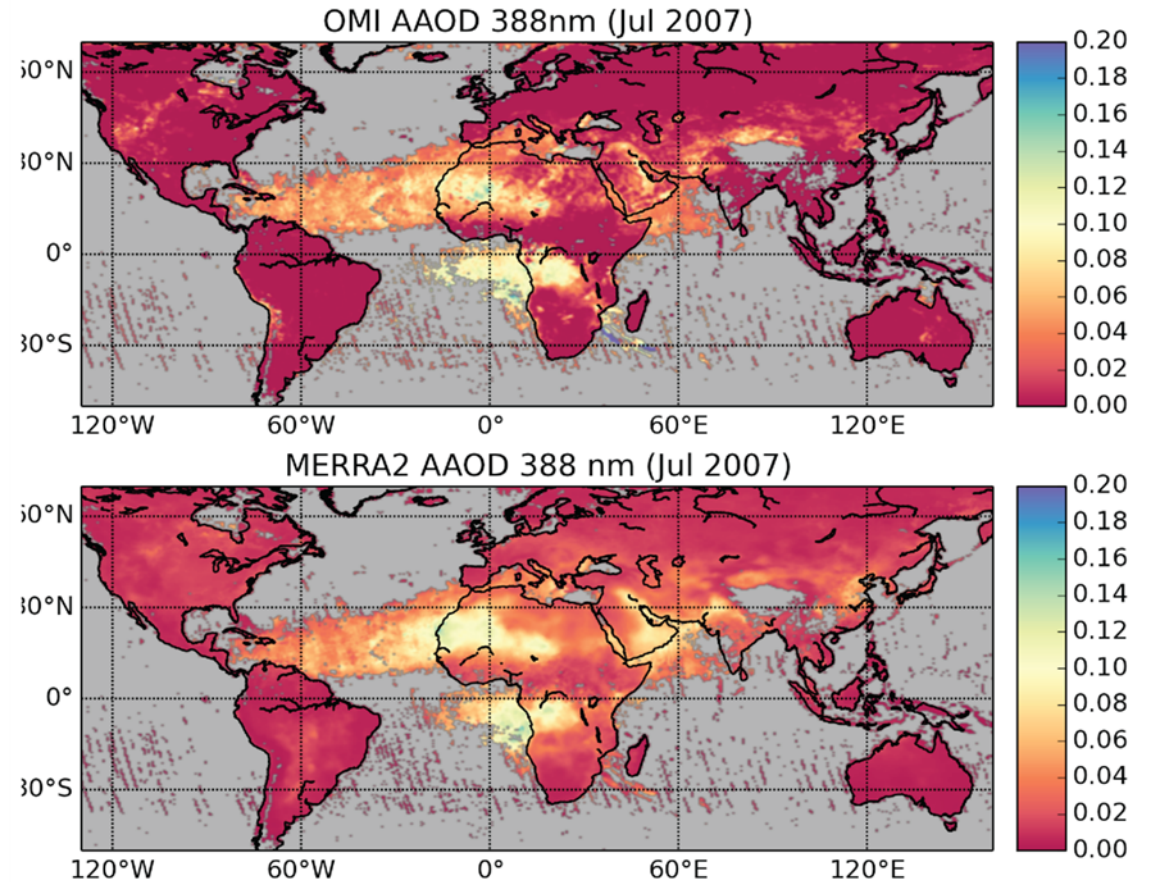


Attenuated Backscatter $\text{km}^{-1} \text{sr}^{-1}$

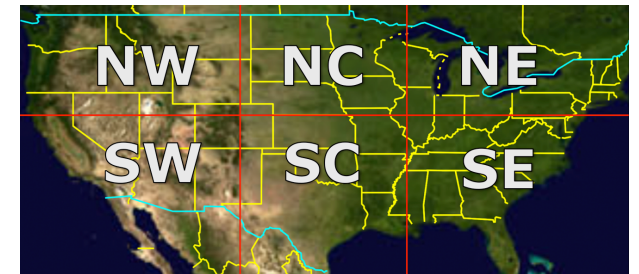
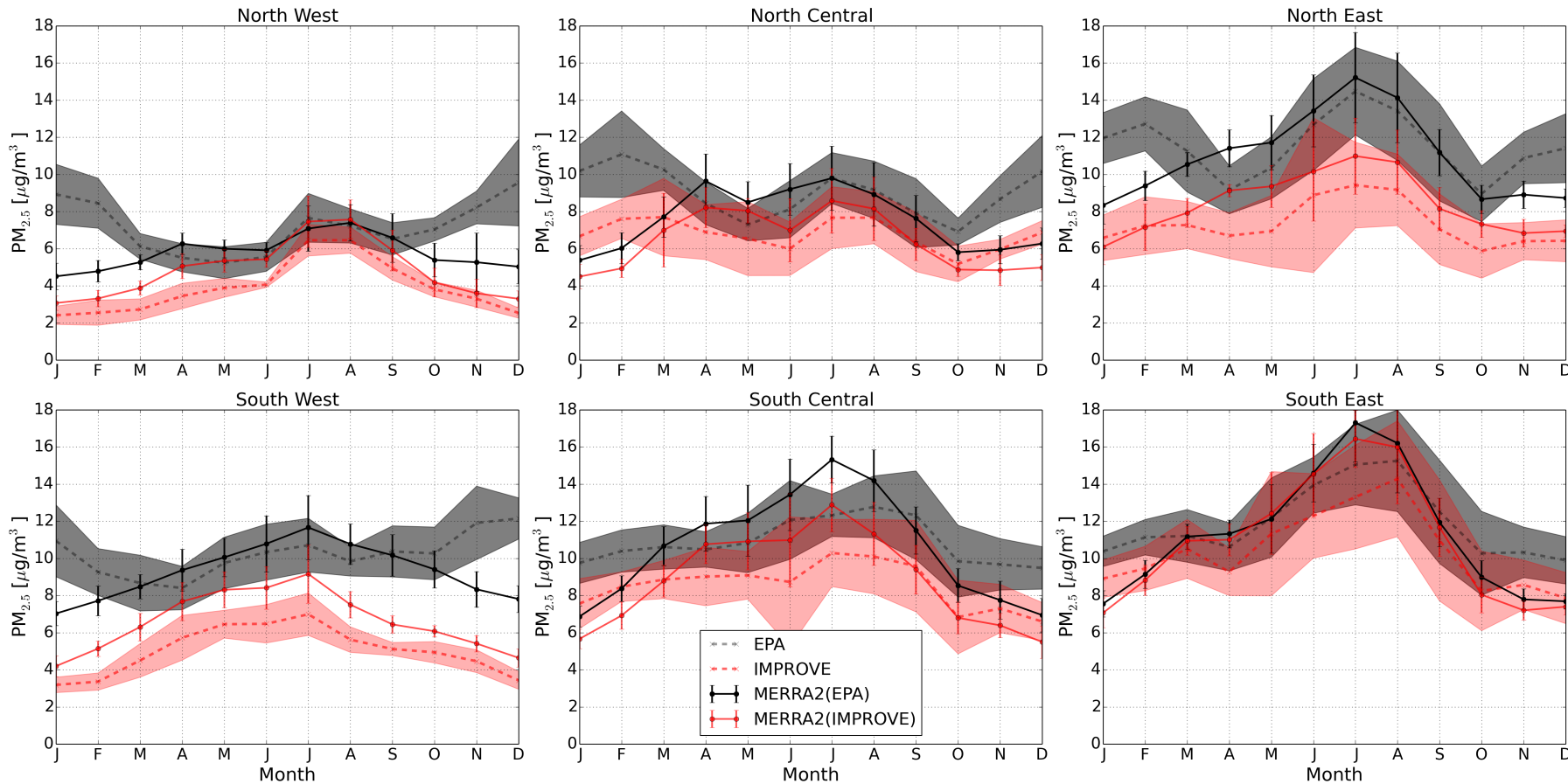


Aerosol Absorption

- Comparison of MERRA-2 Absorption Optical Depth (AAOD) with OMI retrievals
- Good agreement for African dust and smoke
- North American biomass burning underestimated according to OMI



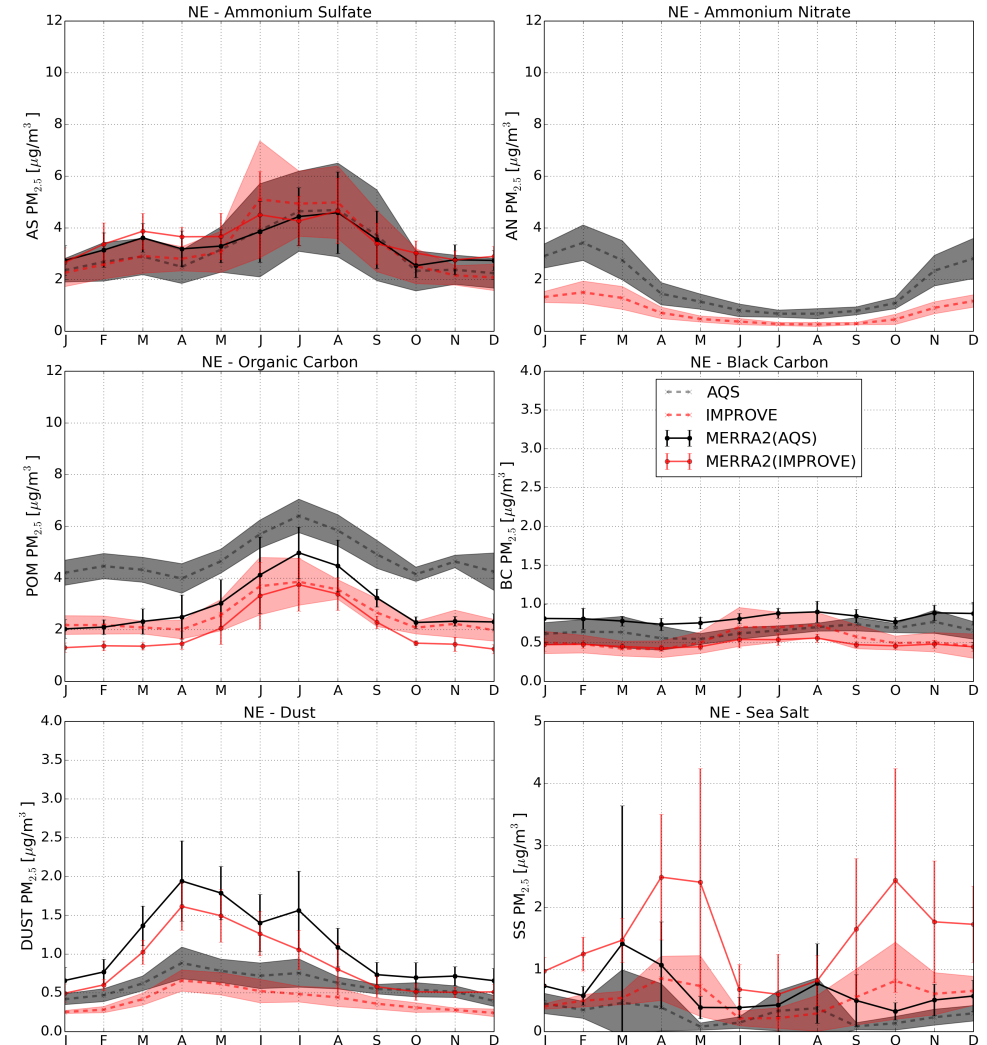
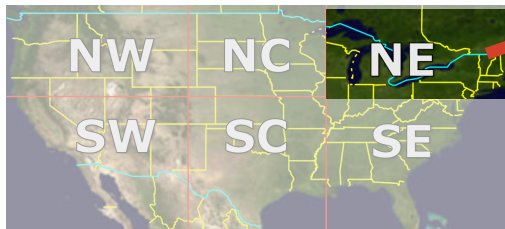
PM_{2.5} (Total) Regional Climatology



Comparison with in-situ measurements

PM_{2.5} by Species in the Northeast

- Relatively good agreement for **sulfates**
- MERRA-2 lacks **nitrates** altogether
- Underestimation of **carbonaceous** near-urban areas
- Too much **dust**
- Too much **sea salt** at coastal stations



MERRA-2 Status

- MERRA-2 has officially been released. Data access through the GES DISC:
 - <http://disc.sci.gsfc.nasa.gov/daac-bin/FTPSubset2.pl>
 - <https://disc.gsfc.nasa.gov/datasets?keywords=merra-2&page=1>
- The MERRA-2 file specification document is available at:
 - <http://gmao.gsfc.nasa.gov/pubs/> under the tab *Office Notes (GMAO Office Note No. 9)*
- NASA tech memos documenting the MERRA-2 meteorological and aerosol validation are available at:
 - <https://gmao.gsfc.nasa.gov/reanalysis/MERRA-2/docs/>
- MERRA-2 Aerosol publications:
 - Randles et al., Journal of Climate, 2017, DOI: 10.1175/JCLI-D-16-0609.1
 - Buchard et al., Journal of Climate, 2017, DOI: 10.1175/JCLI-D-16-0613.1