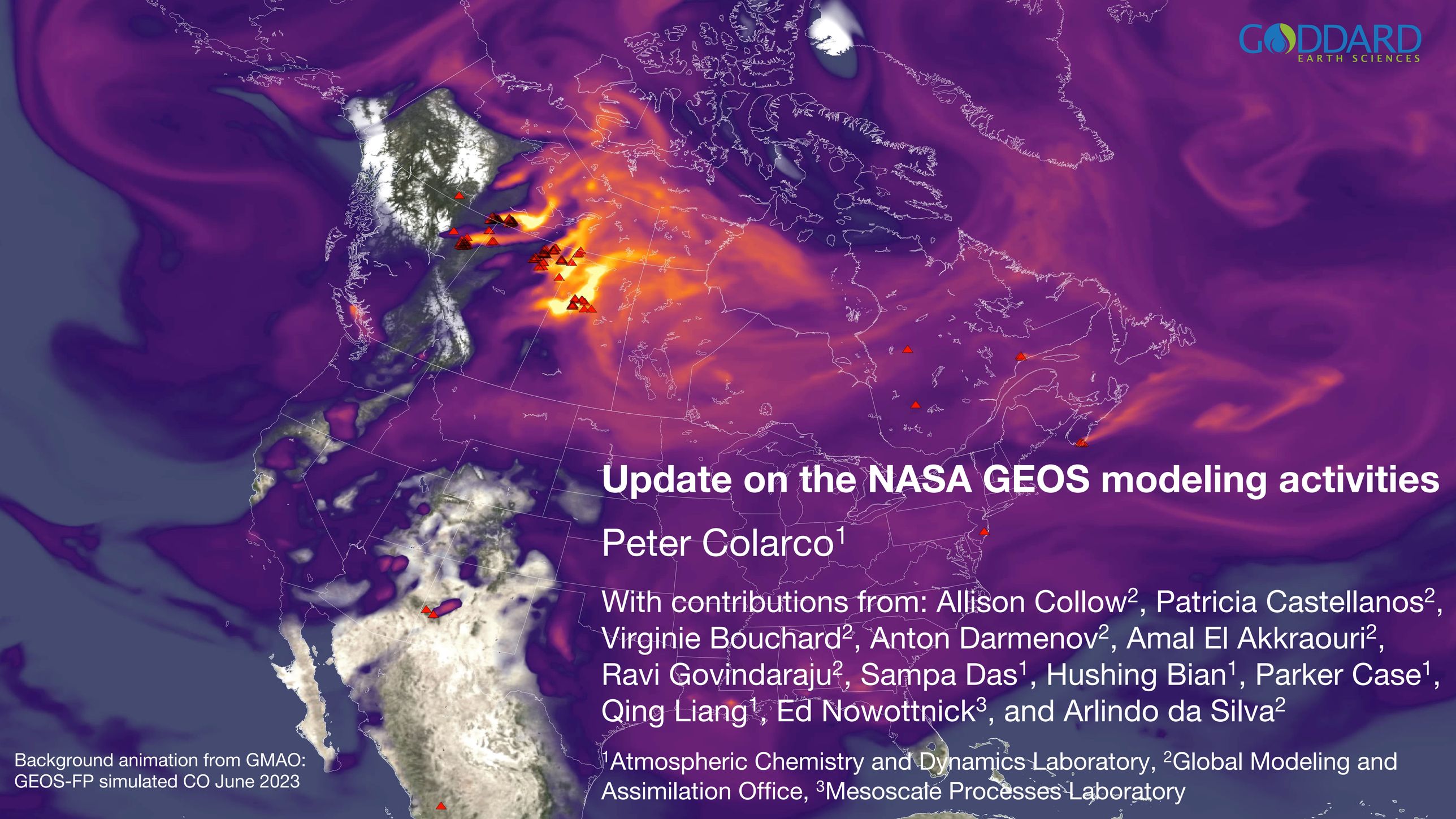


Update on the NASA GEOS modeling activities

Peter Colarco[1]

With contributions from: Allison Collow[2], Patricia Castellanos[2], Virginie Bouchard[2], Anton Darmenov[2], Amal El Akkraouri[2], Ravi Govindaraju[2], Sampa Das[1], Hushing Bian[1], Parker Case[1], Qing Liang[1], Ed Nowottnick[3], and Arlindo da Silva[2]

[1]Atmospheric Chemistry and Dynamics Laboratory, [2]Global Modeling and Assimilation Office, [3]Mesoscale Processes Laboratory

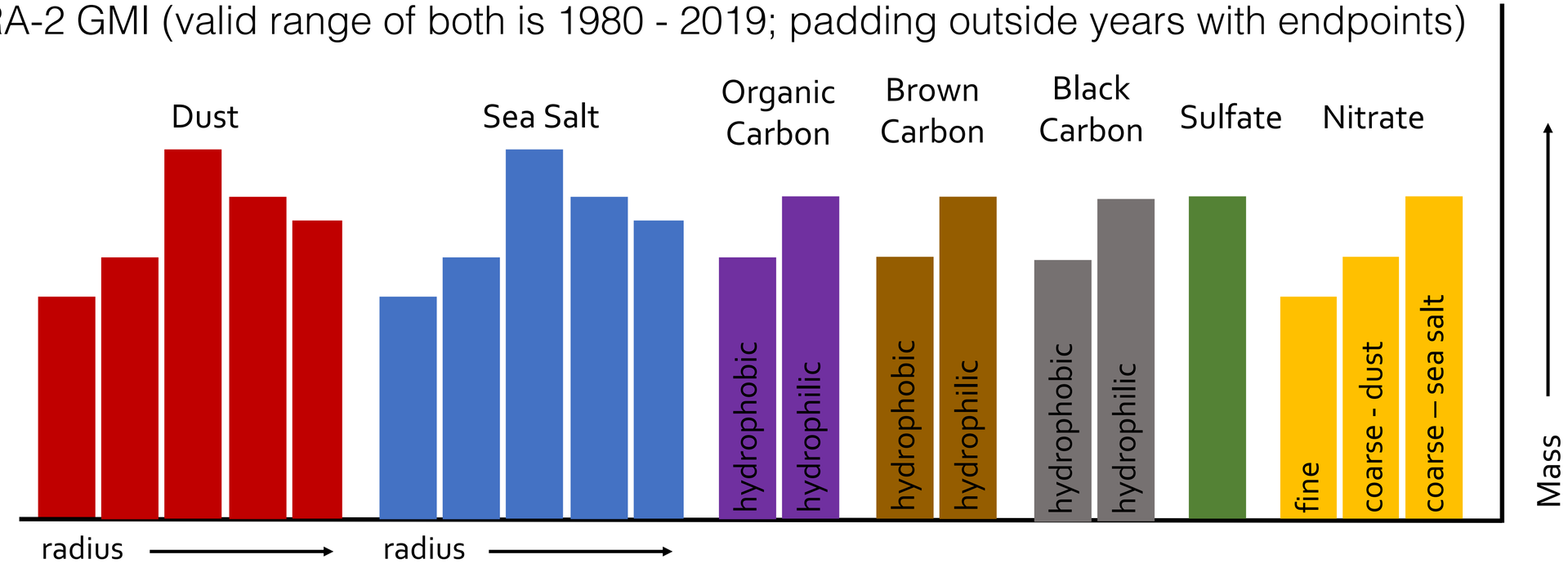
Background animation from GMAO:
GEOS-FP simulated CO June 2023

Outline

- Update on GOCART2G and model products
- Recent and planned field campaign support
- Science snapshots
- Updates on data assimilation and fire emissions
- Outlook

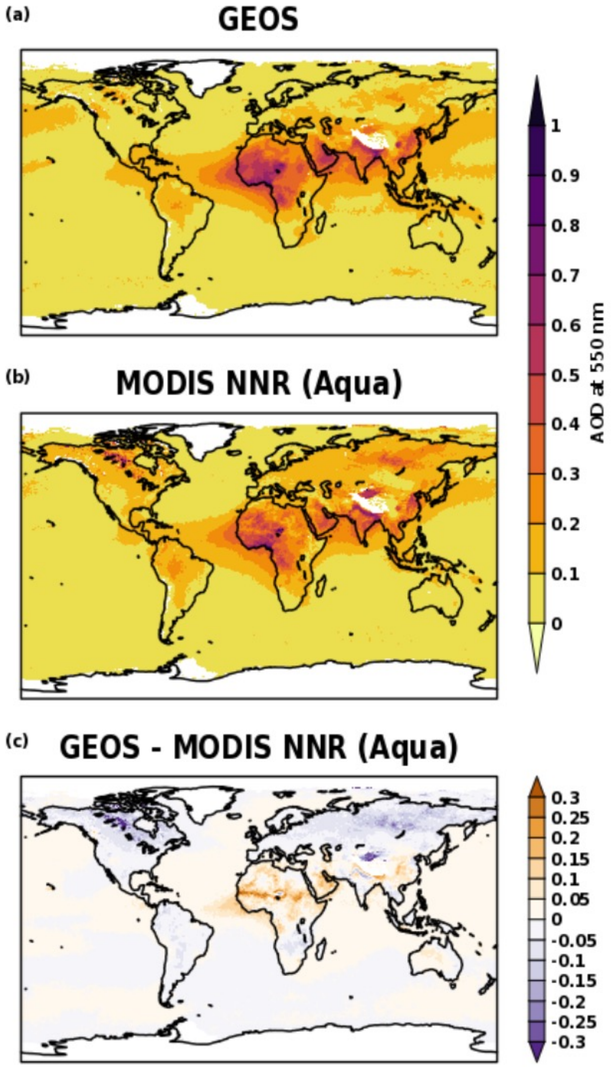
GOCART2G Configuration

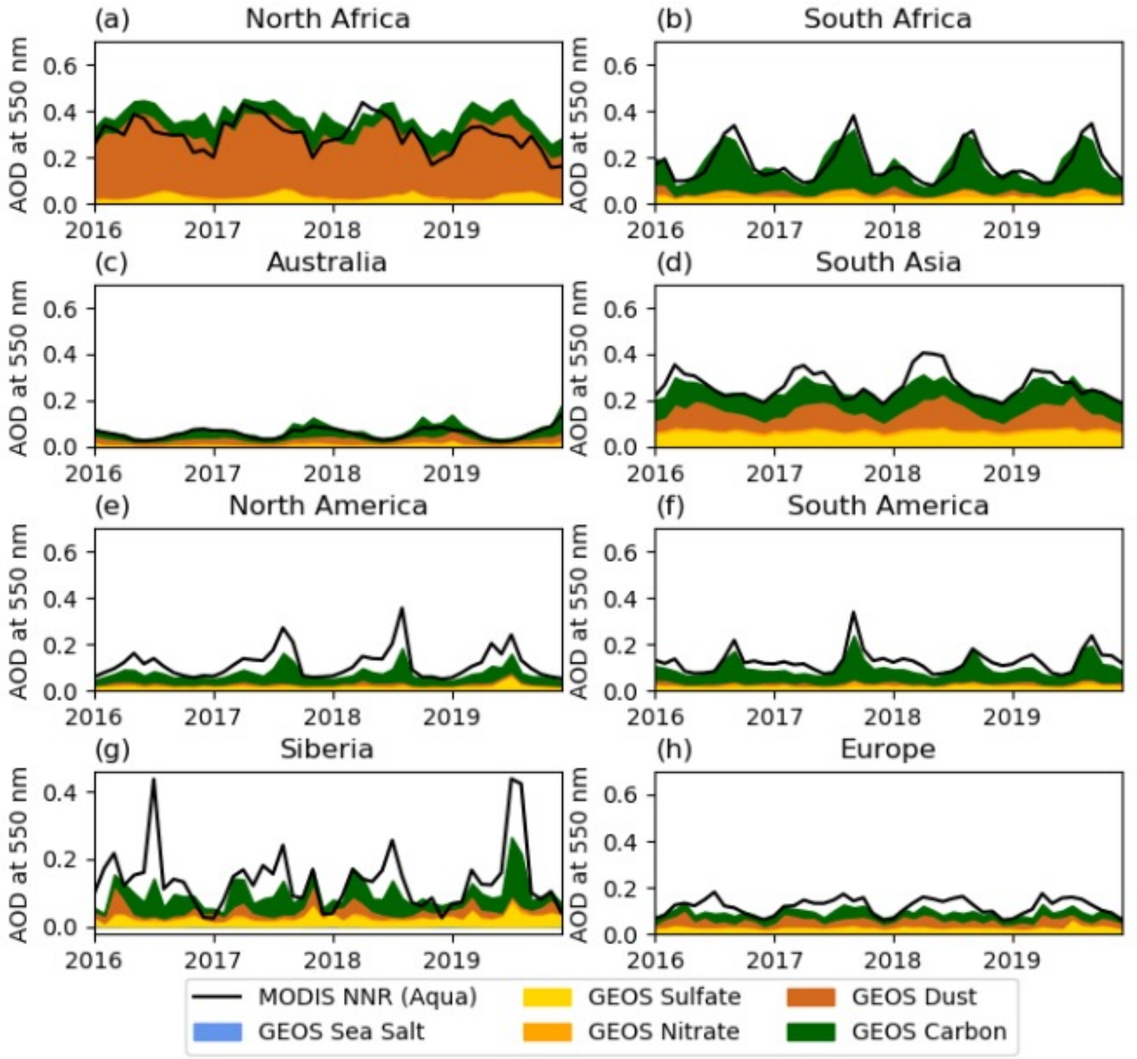
- Separation of organic aerosol into “white” (anthropogenic) and “brown” (biomass burning) components with distinct optical properties
- Increase OA:OC ratio in line with recent airborne measurements (e.g., Atom)
- Inclusion of an ACHEM-driven SOA scheme for anthropogenic and biomass burning sources
- Inclusion of a HEMCO/MEGAN-driven biogenic SOA scheme
- Introduction of “point wise” source emissions for pyroCb inputs
- Update anthropogenic emissions to downscaled-CEDS emission inventory and input oxidant fields to MERRA-2 GMI (valid range of both is 1980 - 2019; padding outside years with endpoints)



Collow, A. B., Colarco, P. R., da Silva, A. M., Buchard, V., Bian, H., Chin, M., Das, S., Govidaraju, R., Kim, D., and Aquila, V.: Benchmarking GOCART-2G in the Goddard Earth Observing System (GEOS), Geosci. Model Dev. Discuss. [preprint], https://doi.org/10.5194/gmd-2023-129, in review, 2023.

GOCART2G Validation





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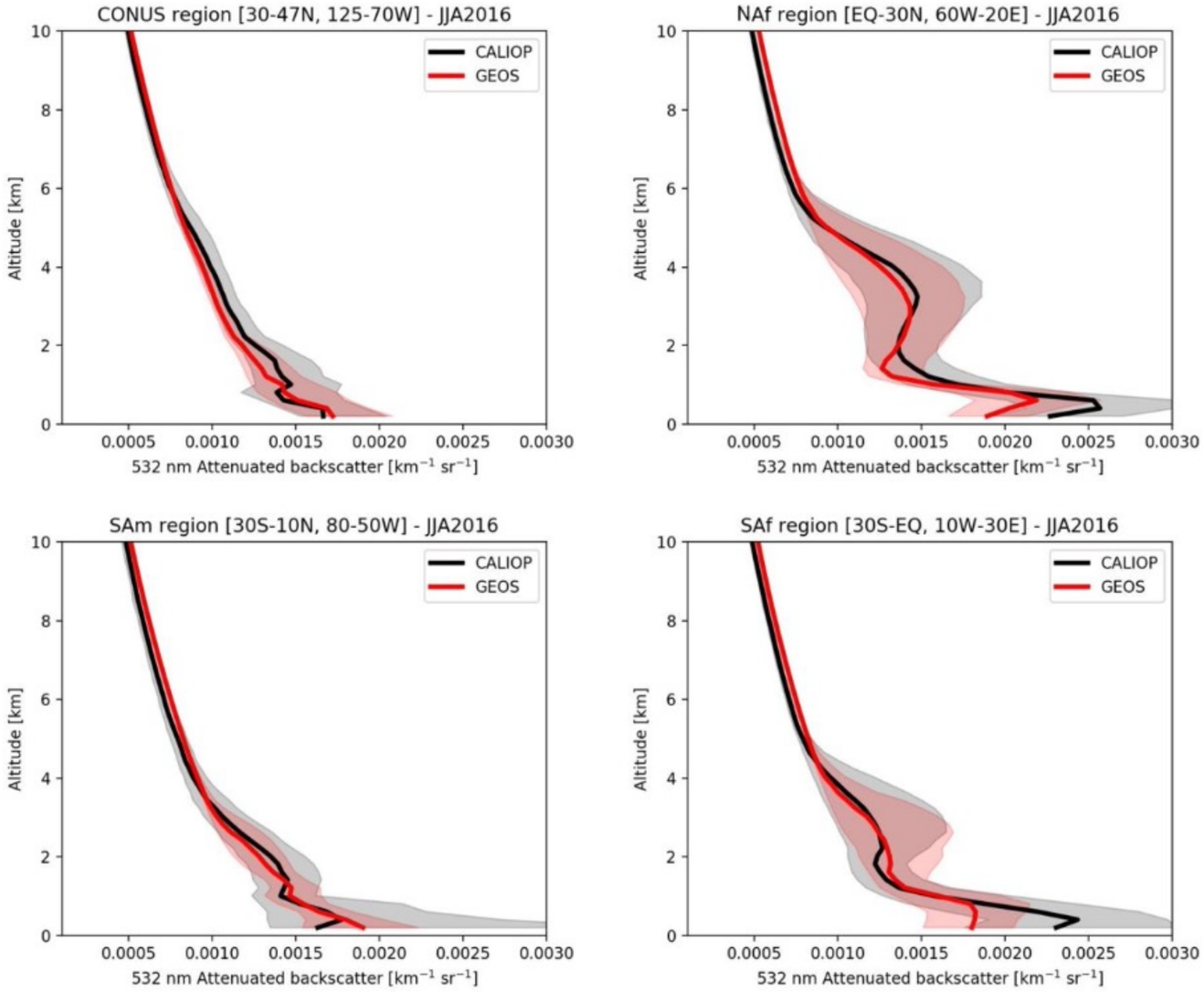
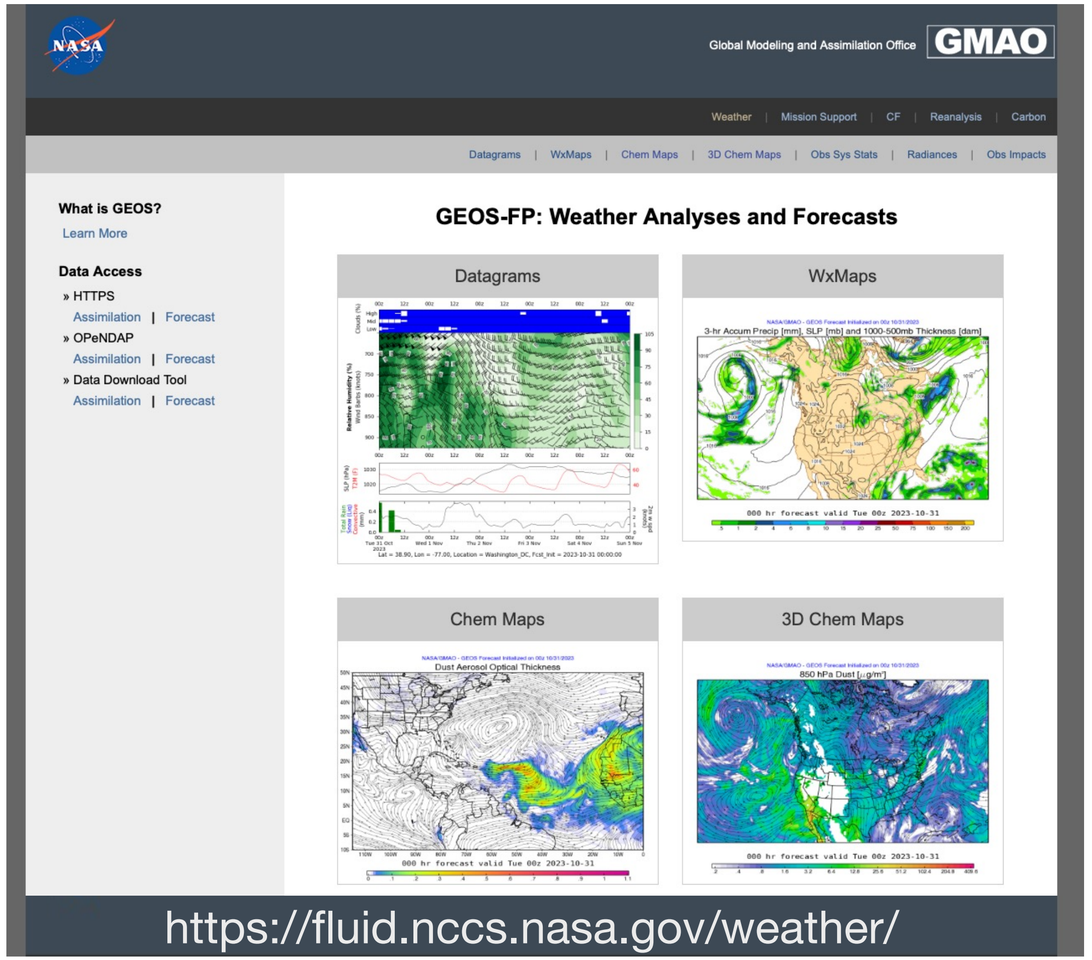


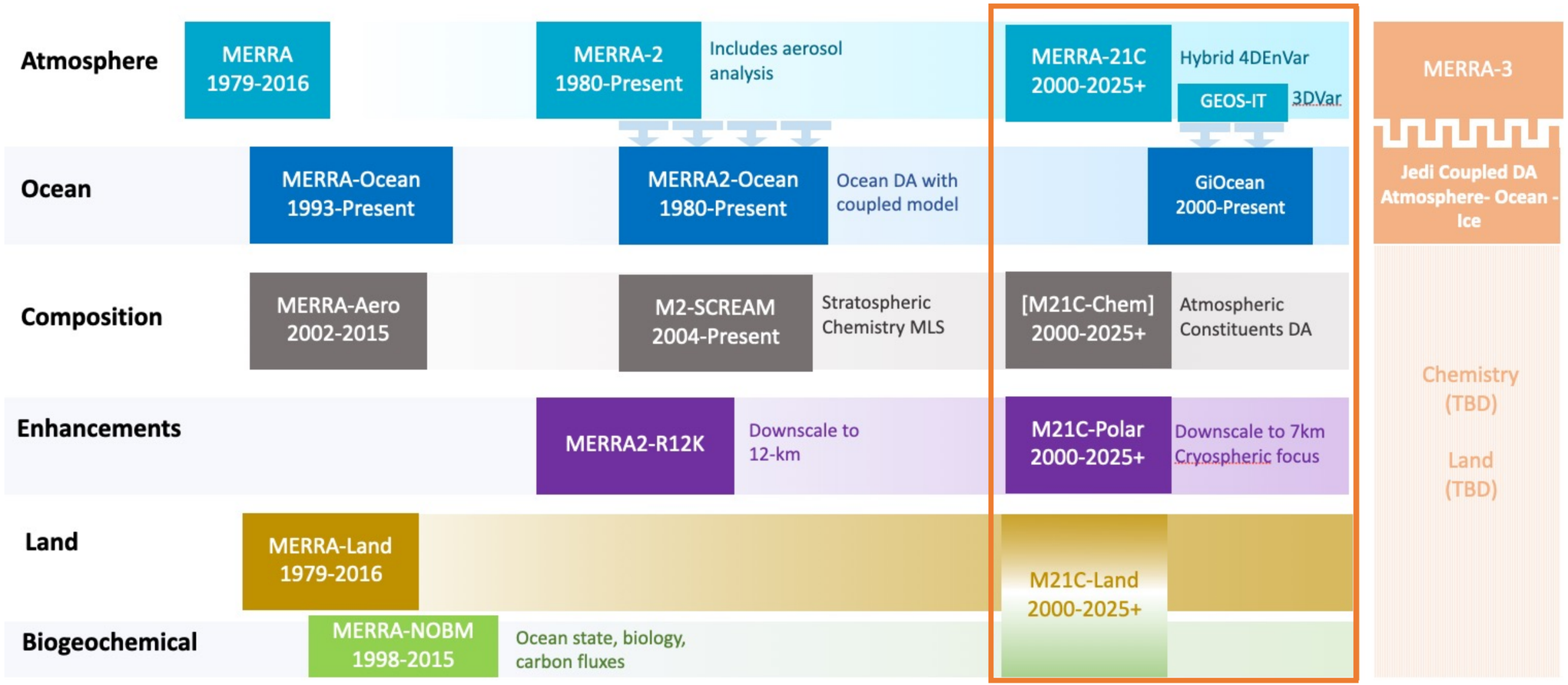
Collow, A. B., Colarco, P. R., da Silva, A. M., Buchard, V., Bian, H., Chin, M., Das, S., Govidaraju, R., Kim, D., and Aquila, V.: Benchmarking GOCART-2G in the Goddard Earth Observing System (GEOS), Geosci. Model Dev. Discuss. [preprint], https://doi.org/10.5194/gmd-2023-129, in review, 2023.

GEOS-FP

- GEOS Near-Real Time System
- Currently: Version 5.29.5
- ~12 km horizontal, 72 levels to ~80 km
- Legacy GOCART->transition to GOCART2G next year
- Aerosols are inline and radiatively interactive with meteorology
- Assimilation MODIS NNR and AERONET AOD at 550 nm
- 4x daily forecasts
- Inputs to ICAP MME



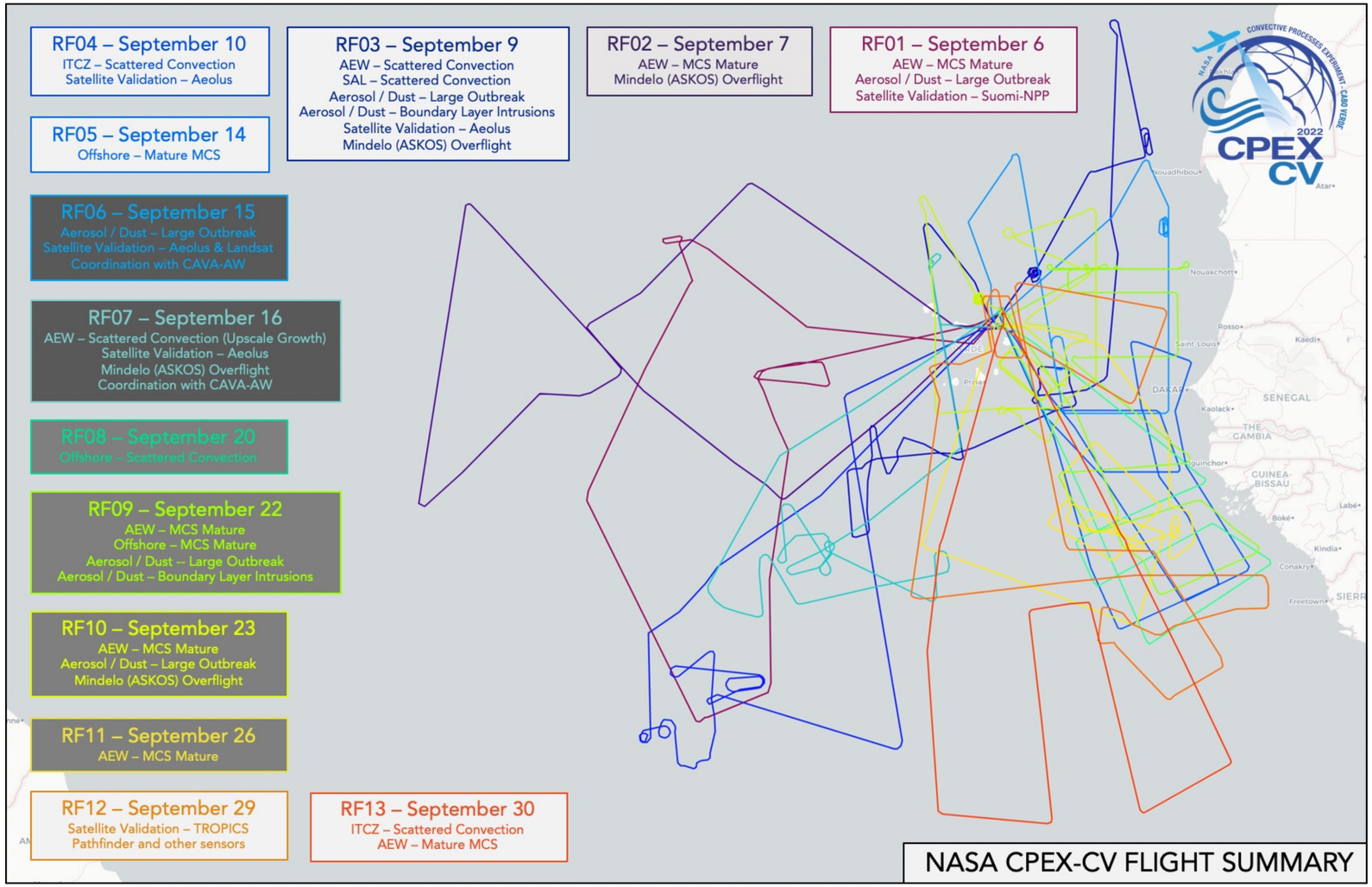
GMAO Reanalysis Products

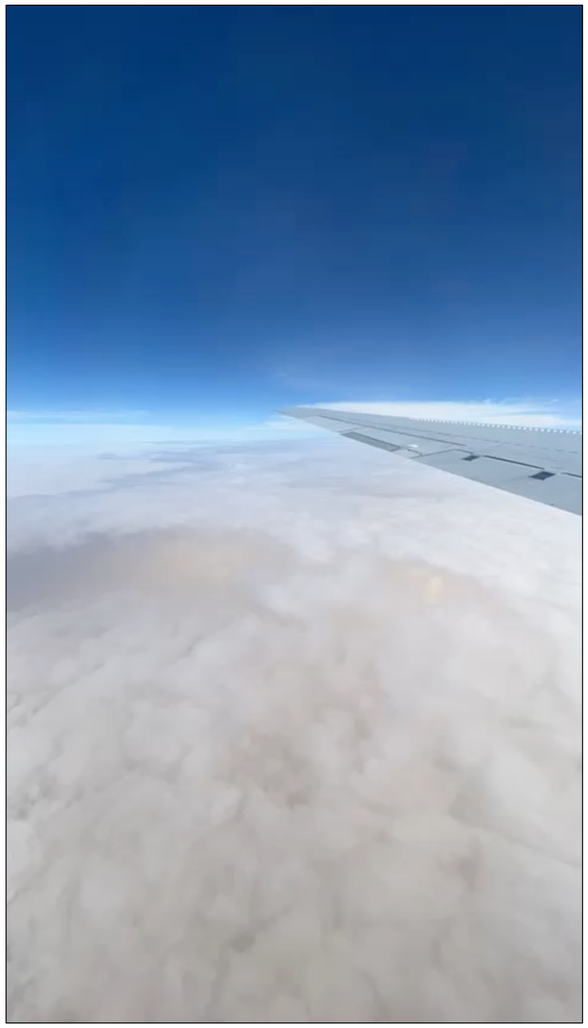


MERRA-21C, will use GOCART2G, Hybrid 4D EnVar All Sky DA
2000 - present, 25 km resolution (MERRA-2 was 50 km)
Product availability in 2024

Courtesy: Amal EL Akkraouri

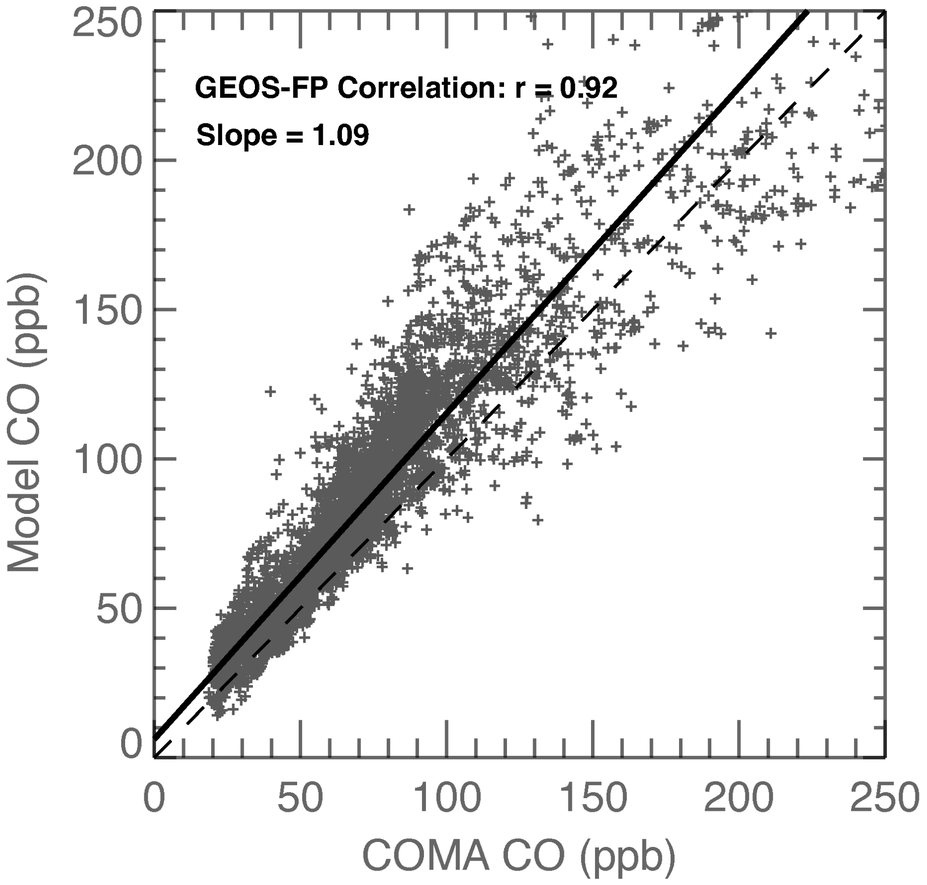
Field Campaigns Supported - CPEX-CV

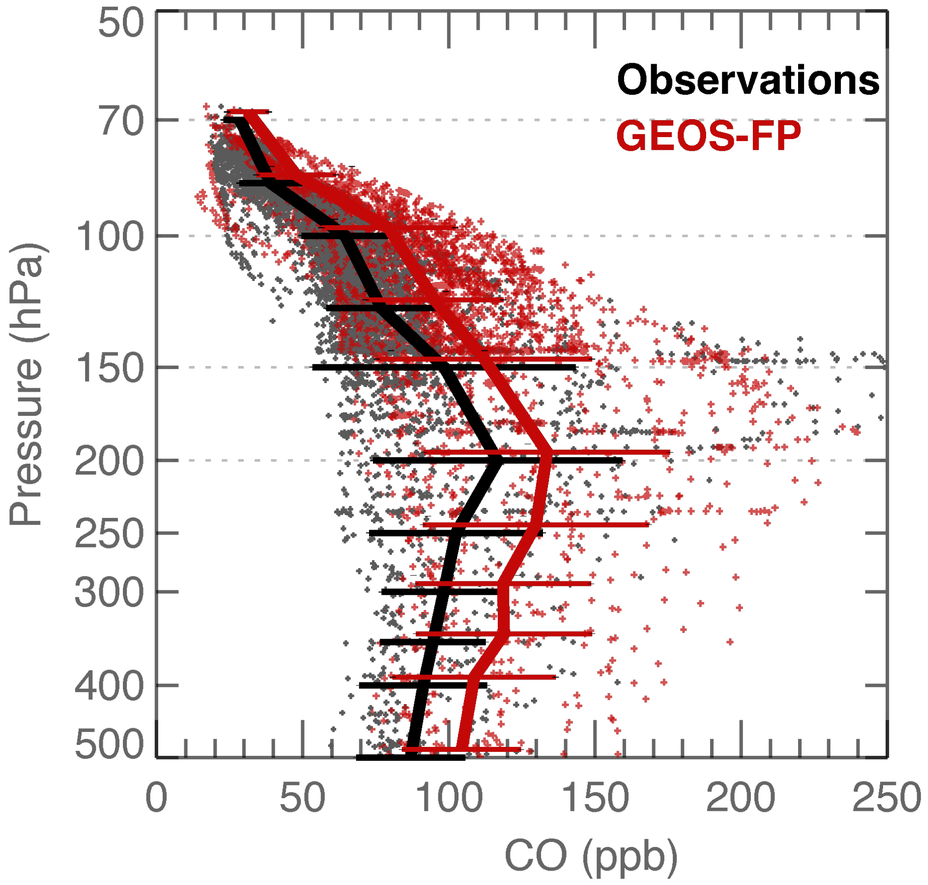




Courtesy: Ed Nowottnick

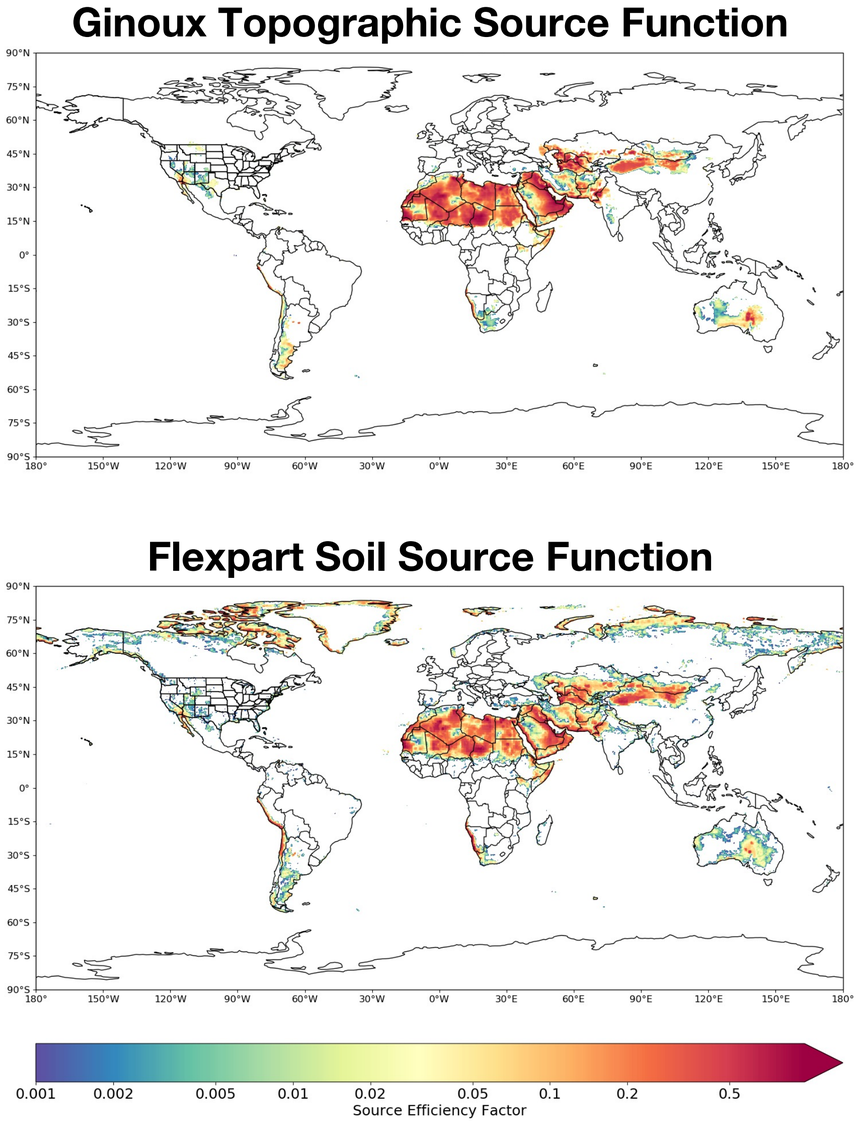
Field Campaigns Supported - ACCLIP





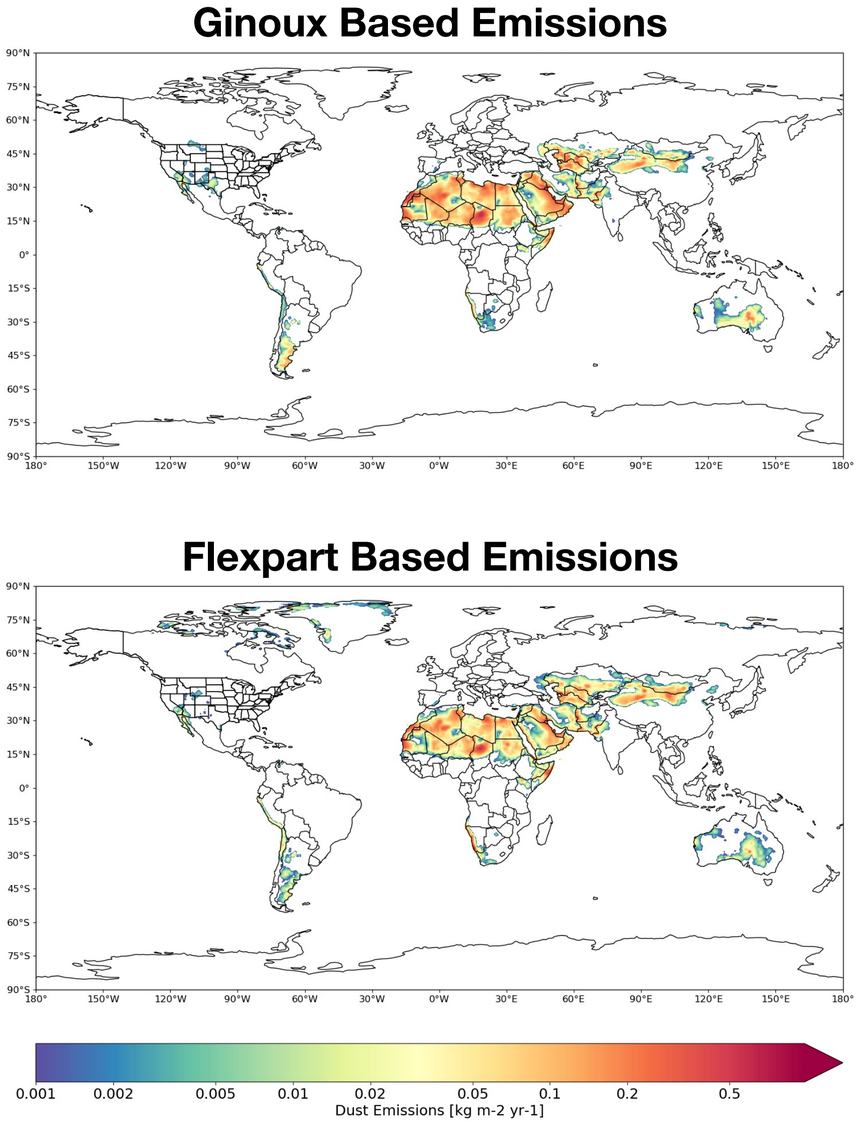
Courtesy: Qing Liang

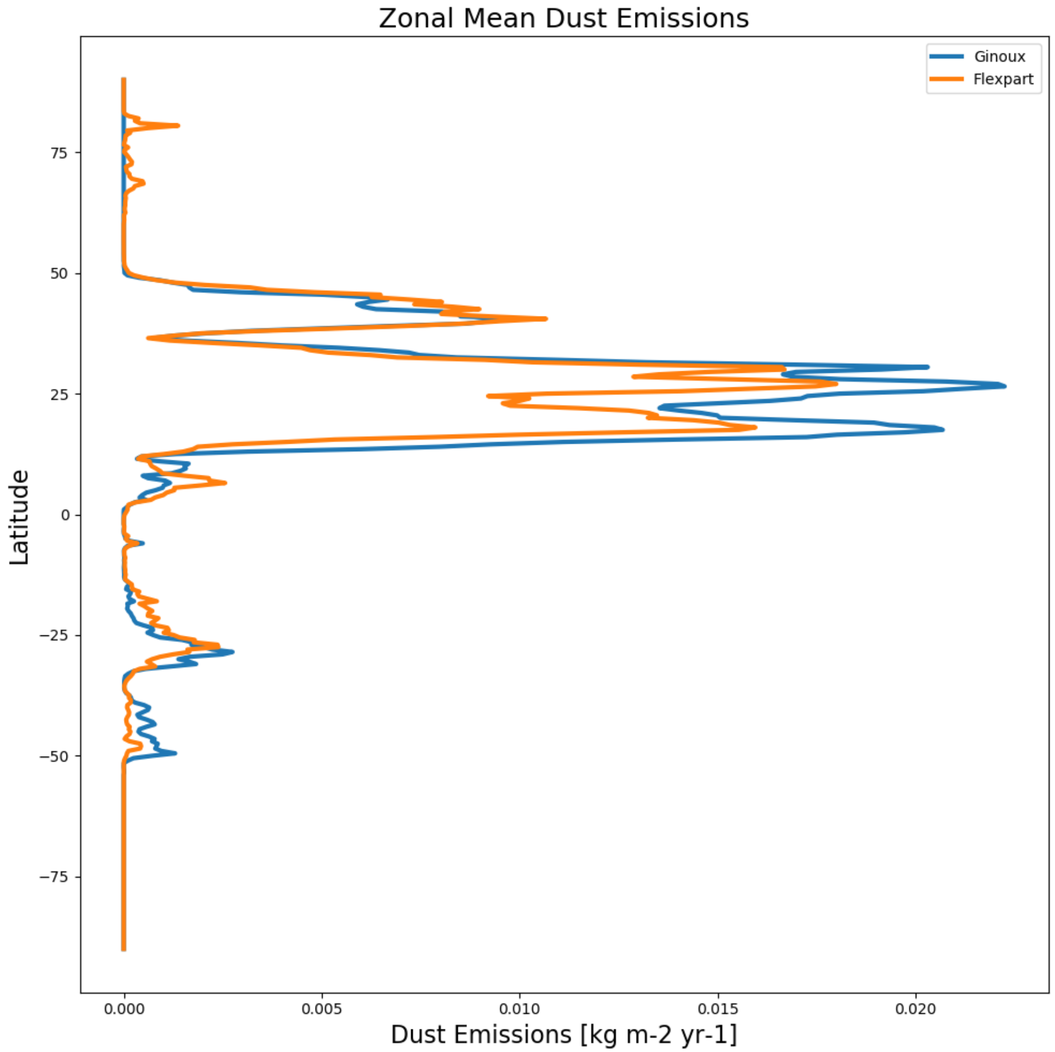
Field Campaigns Supported - NASA ARCSIX



Acknowledgement: Christine Groot Zwaaftink/NILU

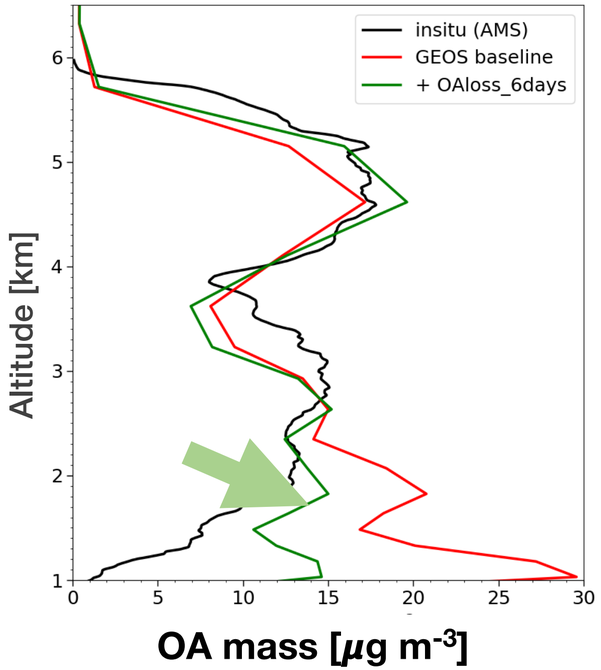
Field Campaigns Supported - NASA ARCSIX



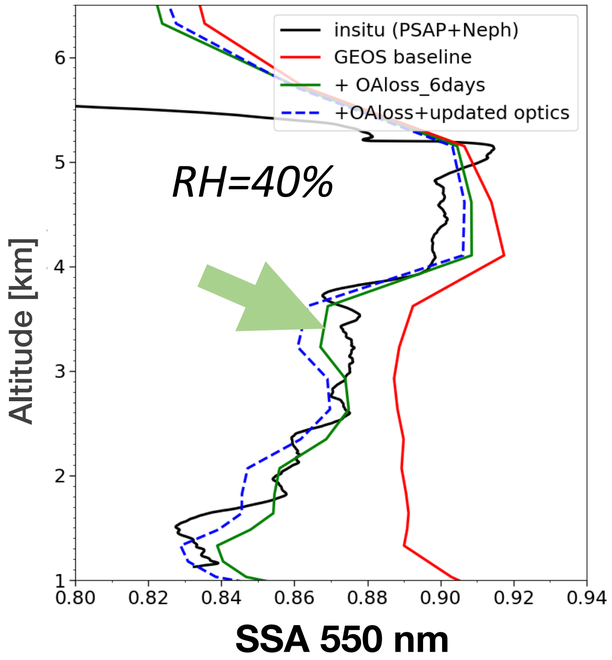


Improvements to Biomass Burning Aerosol

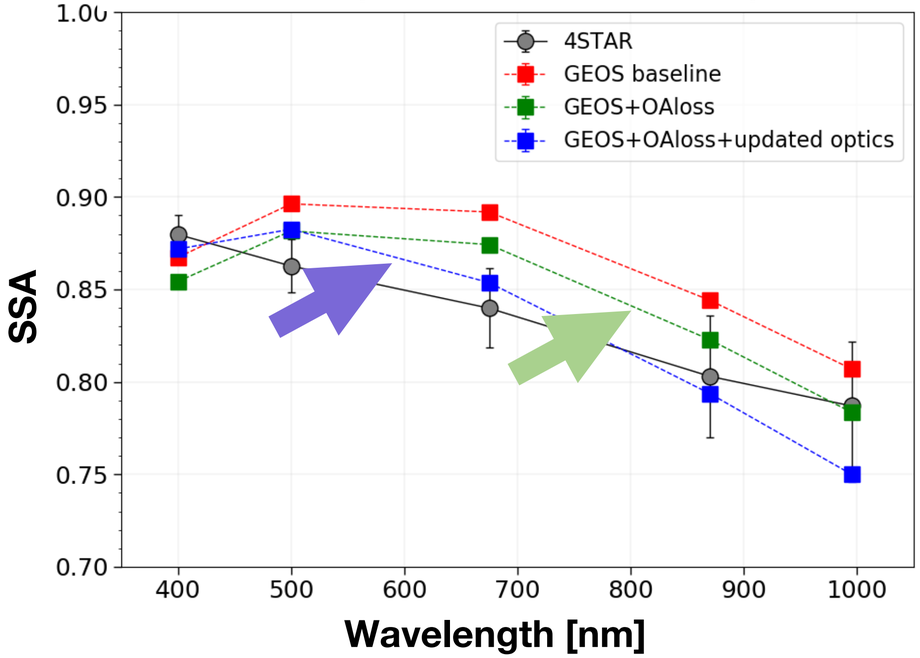
Organic Aerosol



Aerosol Absorption



Column Spectral Aerosol Absorption



NASA ORACLES airborne data shows vertical variability in biomass burning aerosol distribution and absorption not reproduced in GEOS

We hypothesize a missing loss process (e.g., photochemical destruction of organics)-> Including an ad hoc loss process and adjusting optical properties improves fidelity

Das, S., Colarco, P., Bian, H., and Gasso, S.: Improved Simulations of Biomass Burning Aerosol Optical Properties and Lifetimes in the NASA GEOS Model during the ORACLES-I Campaign, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2023-1311, 2023.

Improvements to Biomass Burning Aerosol

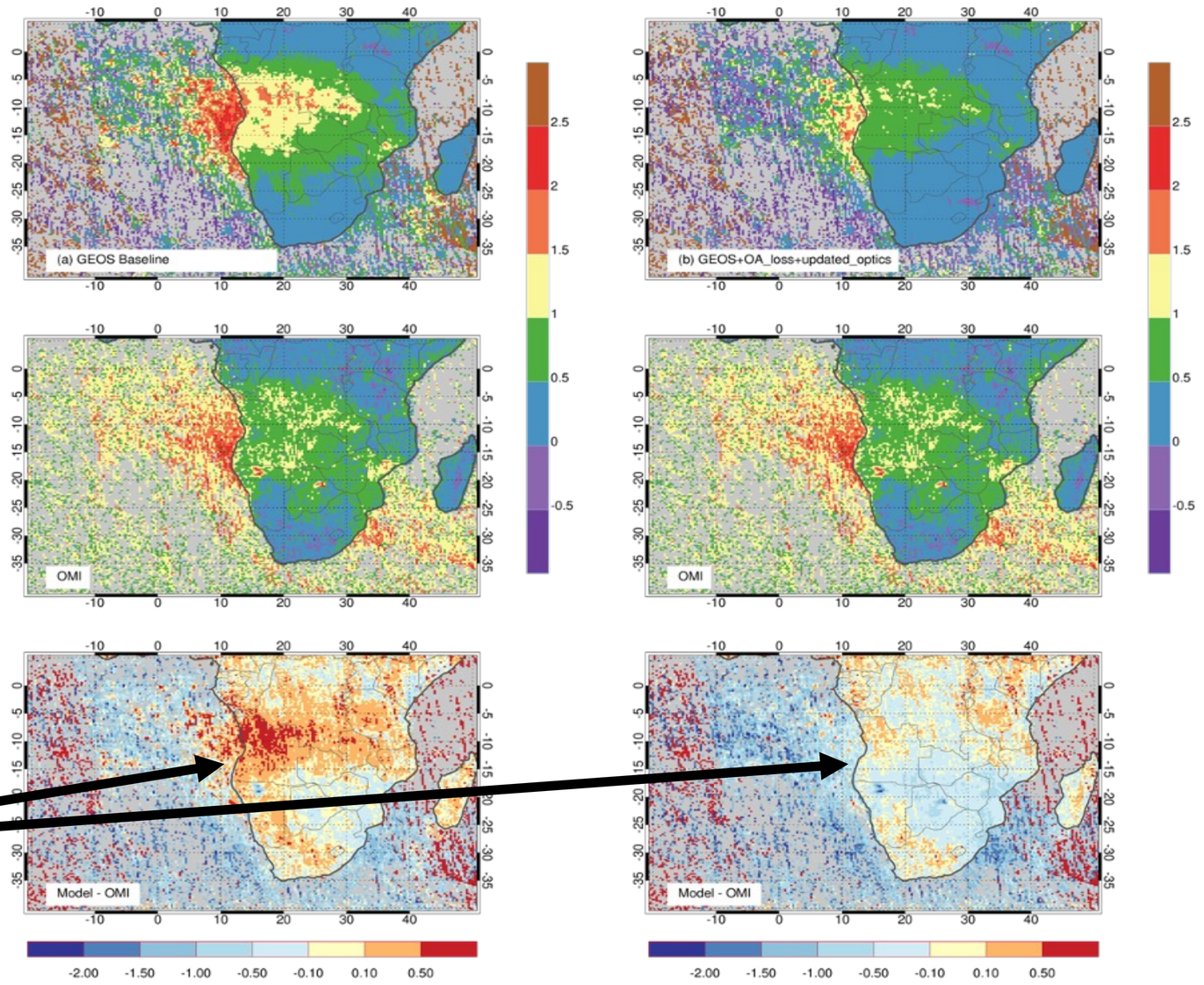
September 2016 Monthly Mean

GEOS AI calculation:

1. GEOS aerosol profiles and assumed optical properties
2. OMI observation geometry and retrieved surface reflectance

AI is sensitive to aerosol height, amount, and spectral absorption

Updated model reduces the high bias in simulated AI over southern Africa



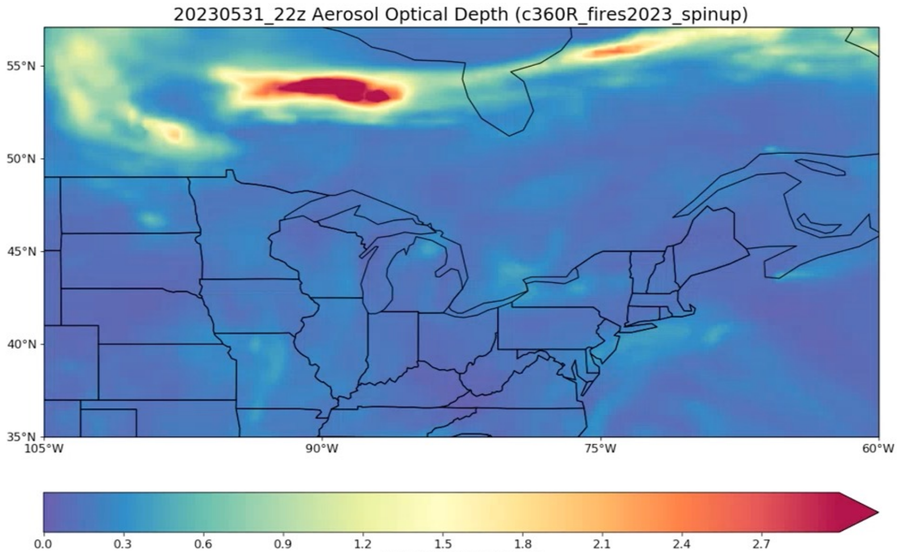
Das, S., Colarco, P., Bian, H., and Gasso, S.: Improved Simulations of Biomass Burning Aerosol Optical Properties and Lifetimes in the NASA GEOS Model during the ORACLES-I Campaign, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2023-1311, 2023.

Challenges in Simulating Smoke Episodes

Early June 2023 Canadian smoke episode impact air quality in US NE

Forecasting is a challenge

- Meteorology
- Fire location
- Emission magnitude
- Vertical placement of emissions

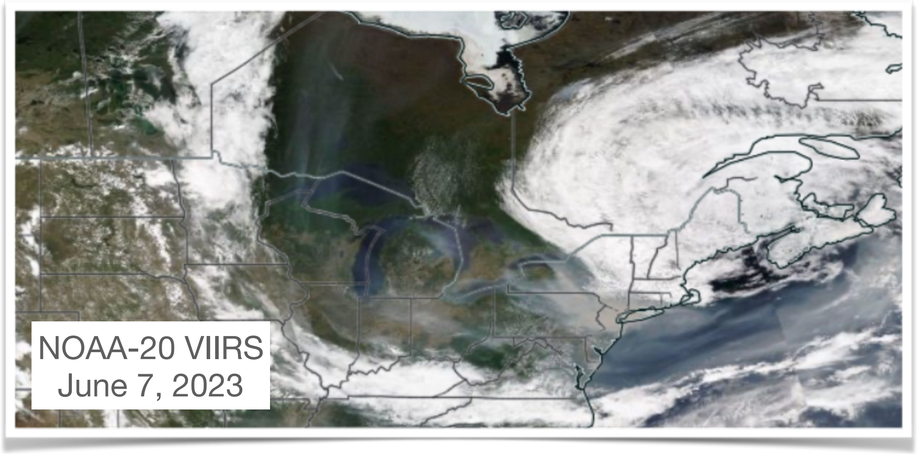


Aerosol Optical Depth

GEOS near-real time system (“GEOS-FP”) runs aerosol, CO and meteorological forecasts 4x daily at global 12 km resolution and assimilates meteorology and aerosol AOD

Research version shown here run at 25 km resolution with meteorology from GEOS-FP and assimilates aerosol AOD

Biomass burning emissions derived from near-real time MODIS fire radiative power products (QFED)

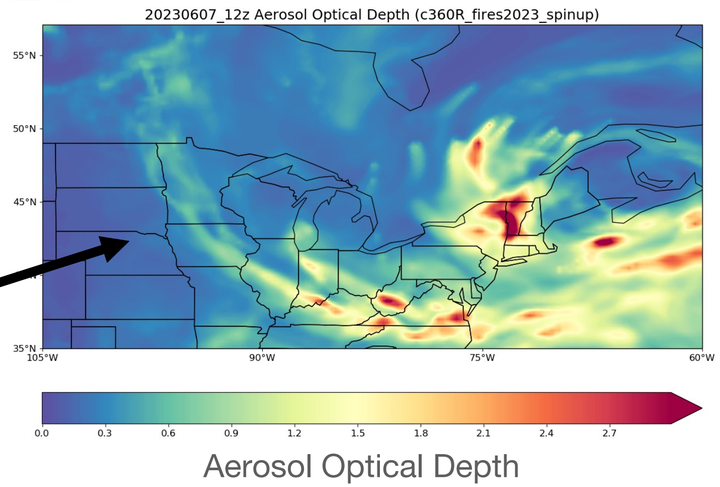


What do you know about emissions?

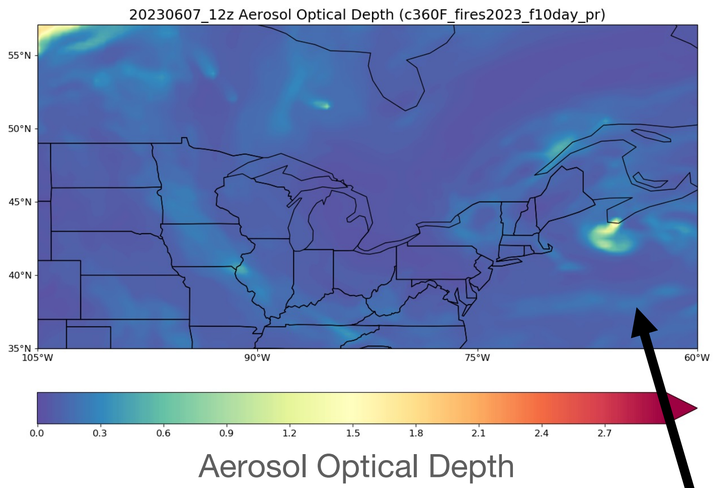
Valid: June 7, 2023

Replay to assimilated meteorology

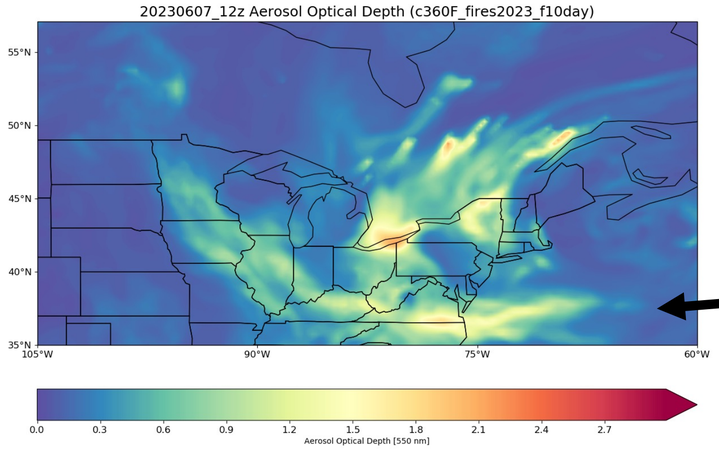
Replayed (Day-Of Emissions)



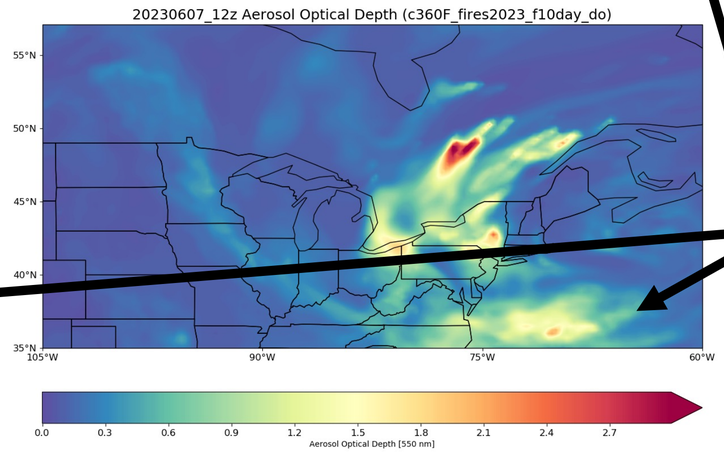
Forecast (Persisted from May 31 Emissions)



Forecast (Day-Of Emissions)



Forecast (Day-Prior Emissions)



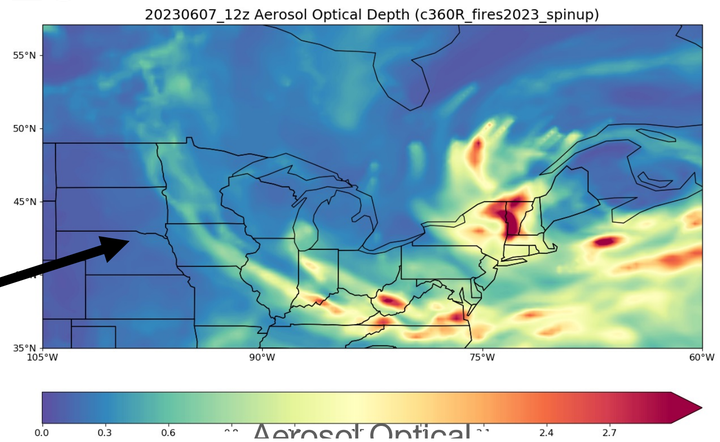
10-day forecasts

What do you know about emissions?

Valid: June 7, 2023

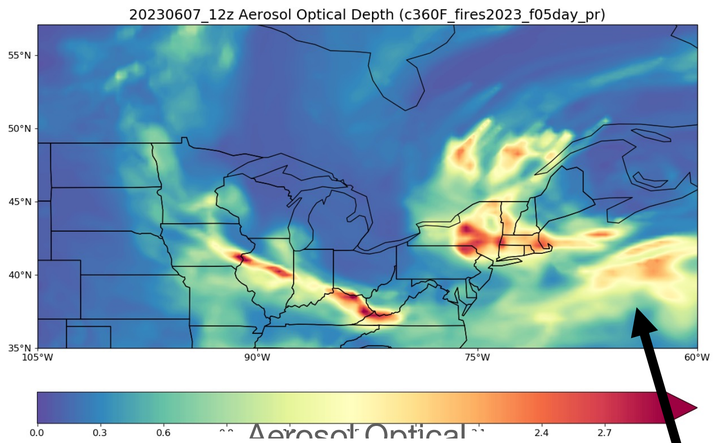
Replay to assimilated meteorology

Replayed (Day-Of Emissions)



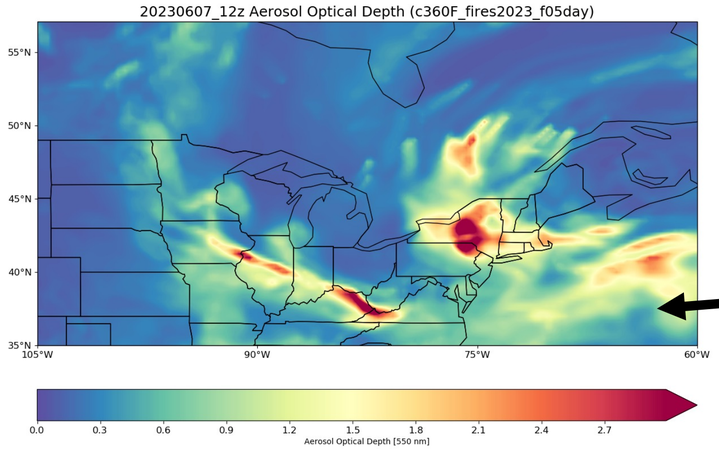
Aerosol Optical Depth

Forecast (Persisted from June 5 Emissions)



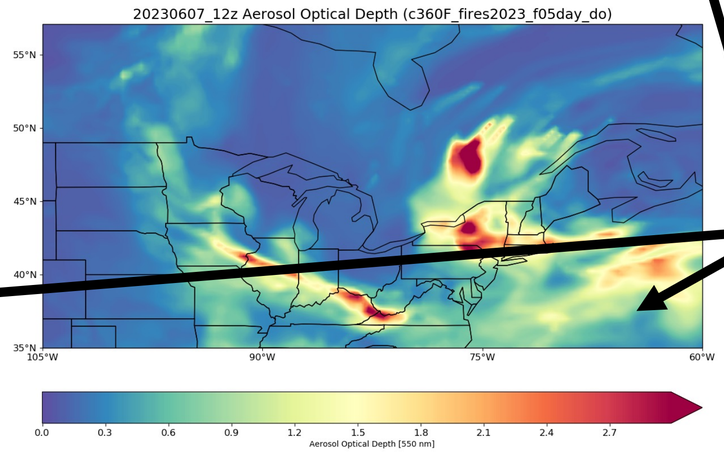
Aerosol Optical Depth

Forecast (Day-Of Emissions)



Aerosol Optical Depth

Forecast (Day-Prior Emissions)

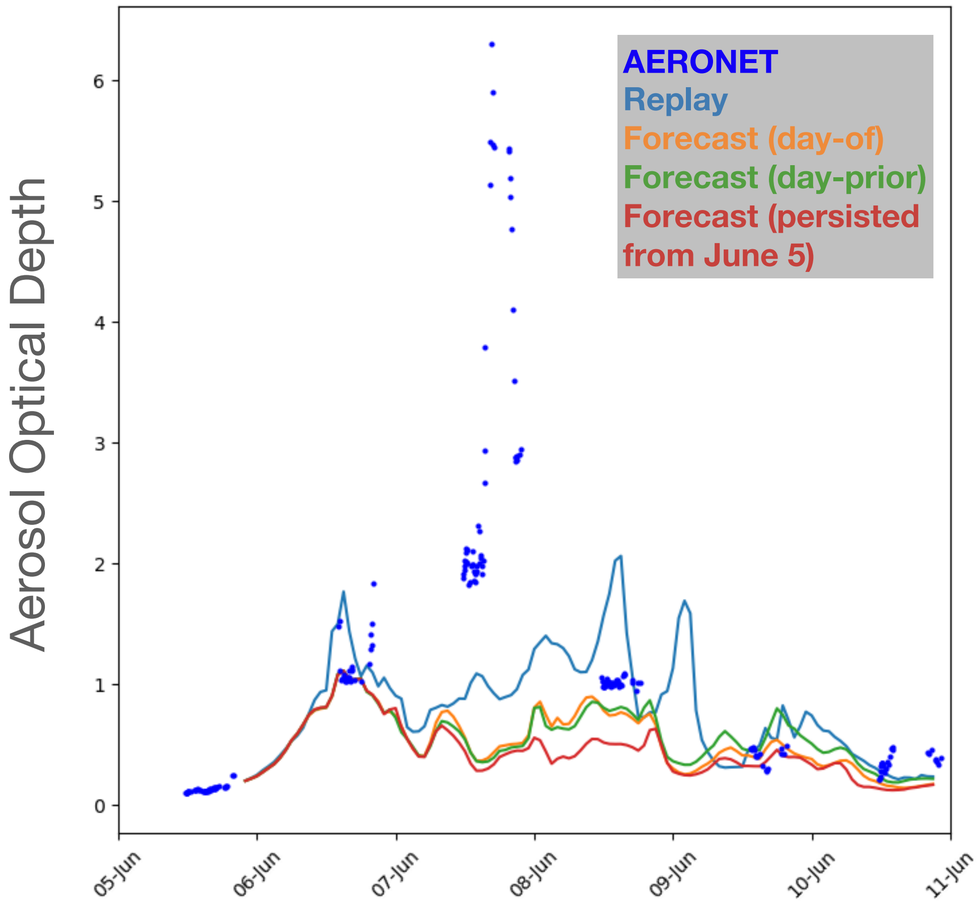


Aerosol Optical Depth

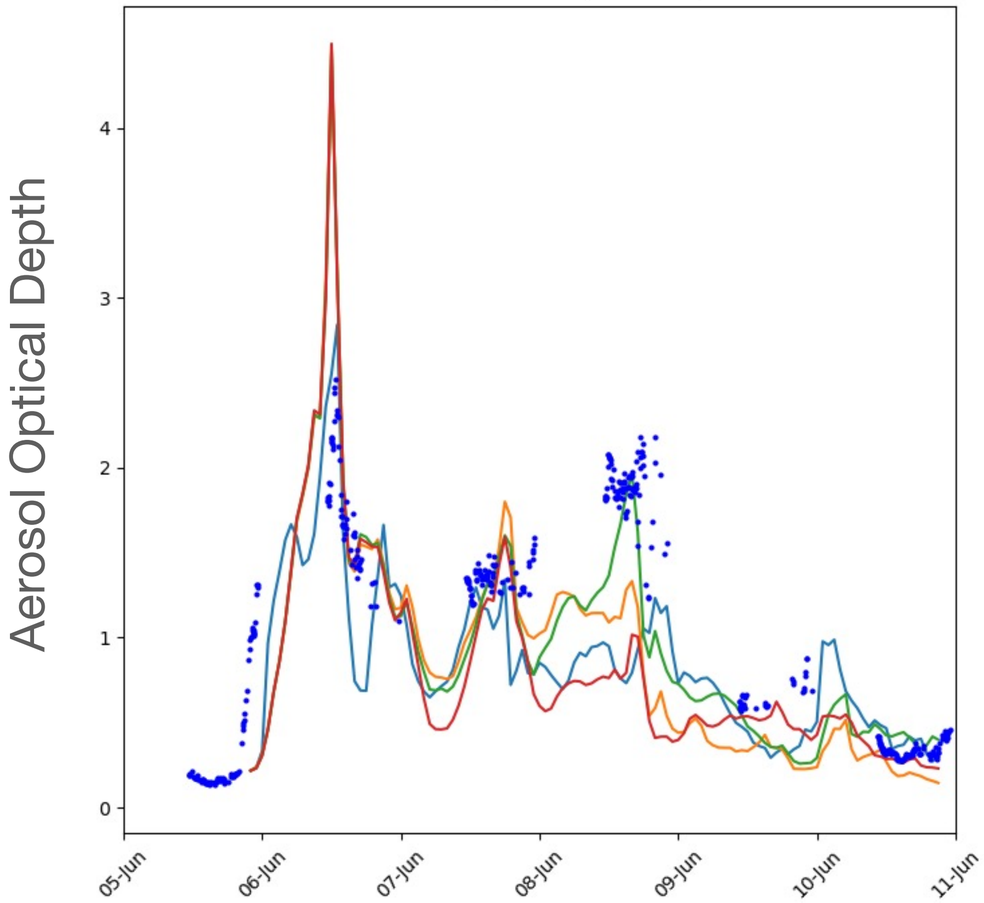
2-day forecasts

Site Comparison, June 5, 2023 Init

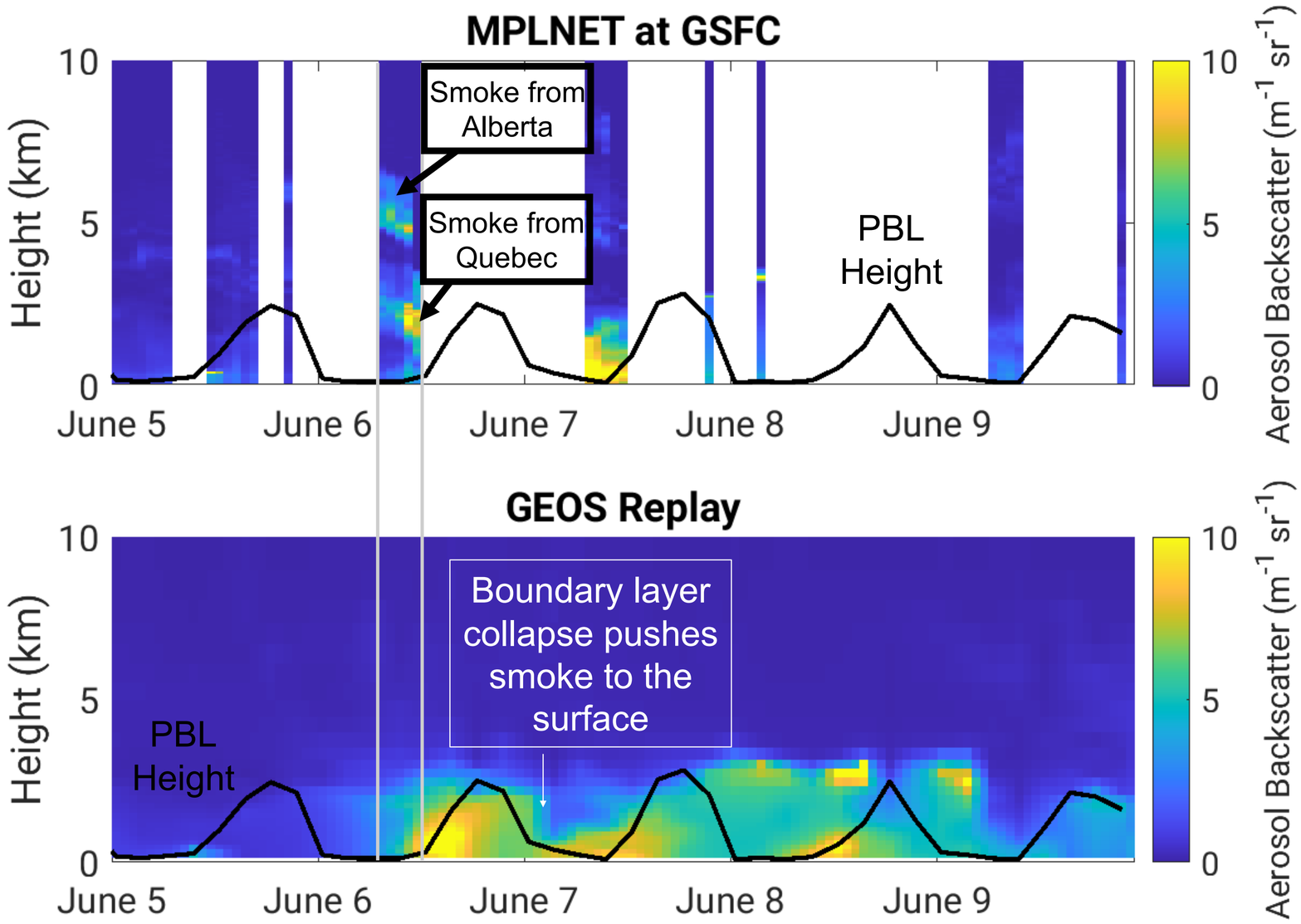
New York City

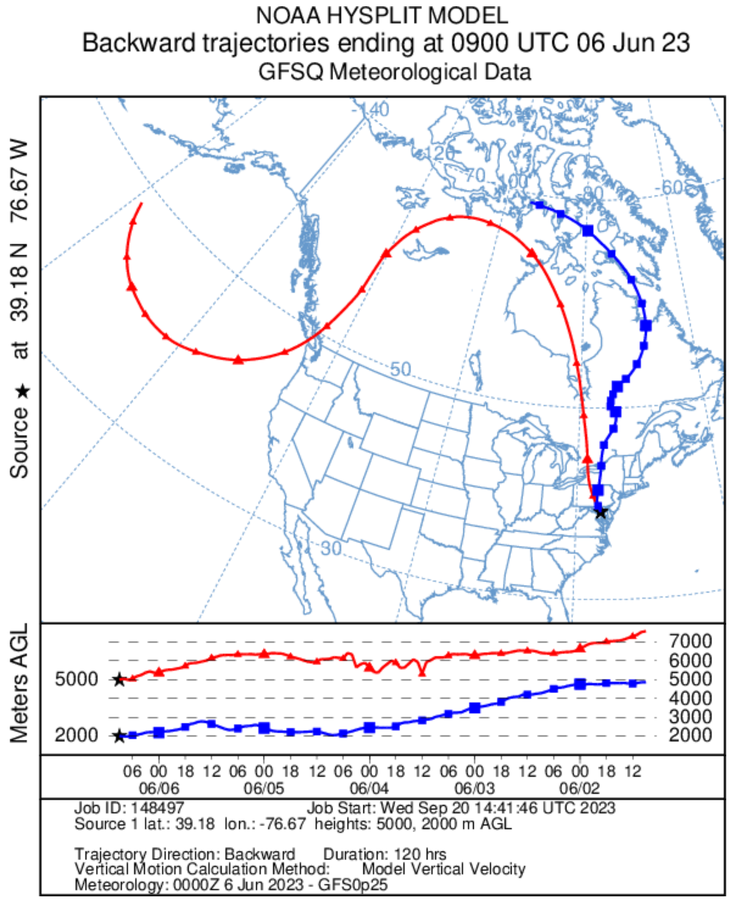


GSFC (Maryland)



Residual Uncertainty Due to Vertical Profile





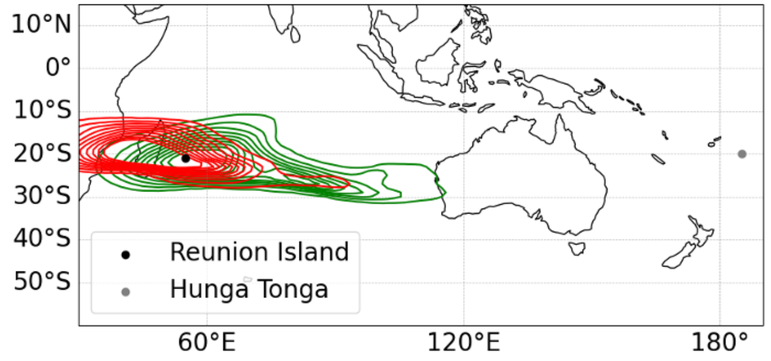
- Back trajectory indicates smoke originated above the PBL, where it was emitted in the model

Courtesy: Allie Collow

Hunga Tonga Example

January 2022 eruption of Hunga Tonga-Hunga Ha'apei injected modest amount of SO2 (0.4 Tg) into stratosphere, but enormous amount of water (150 Tg, about 10% of background)

Water seriously perturbed the chemistry, causing *very* rapid conversion of SO2 to sulfate aerosol

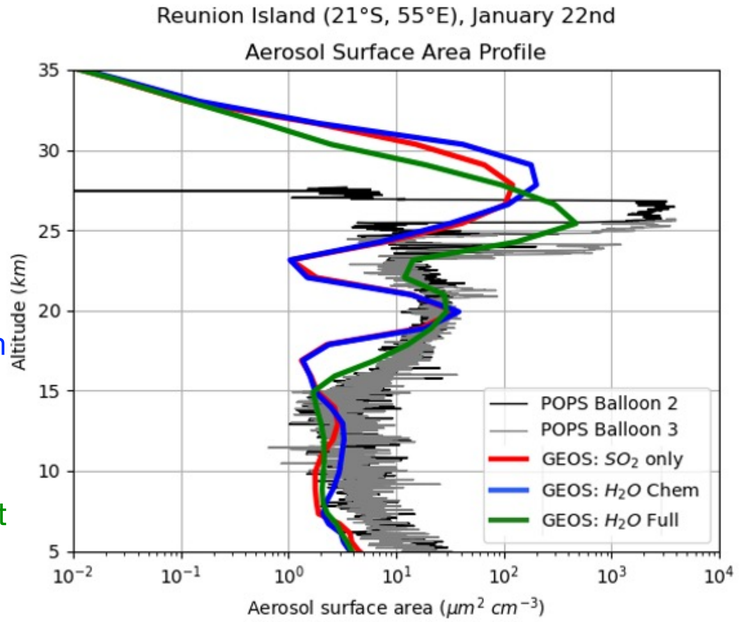


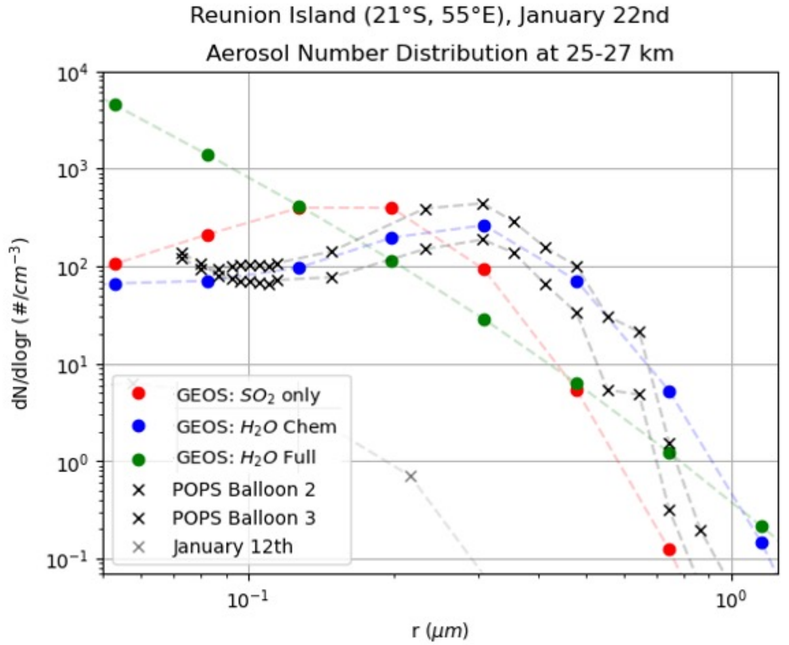
Simulations with bin microphysics used to understand impact of eruption:

Simulation with just SO2 results in too small particles at too high altitude

Simulation that includes water impact on chemistry produces better size distribution

Simulation that accounts for chemical *and* radiative impact has best height, but wrong size distribution—> too much nucleation

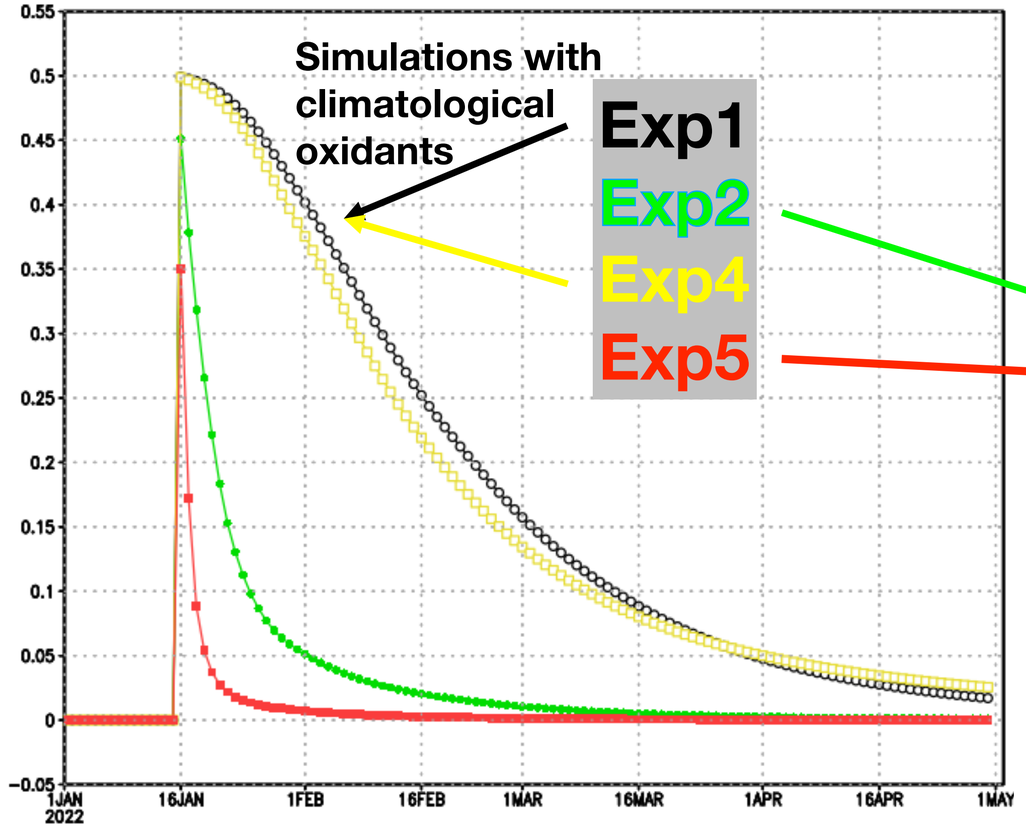




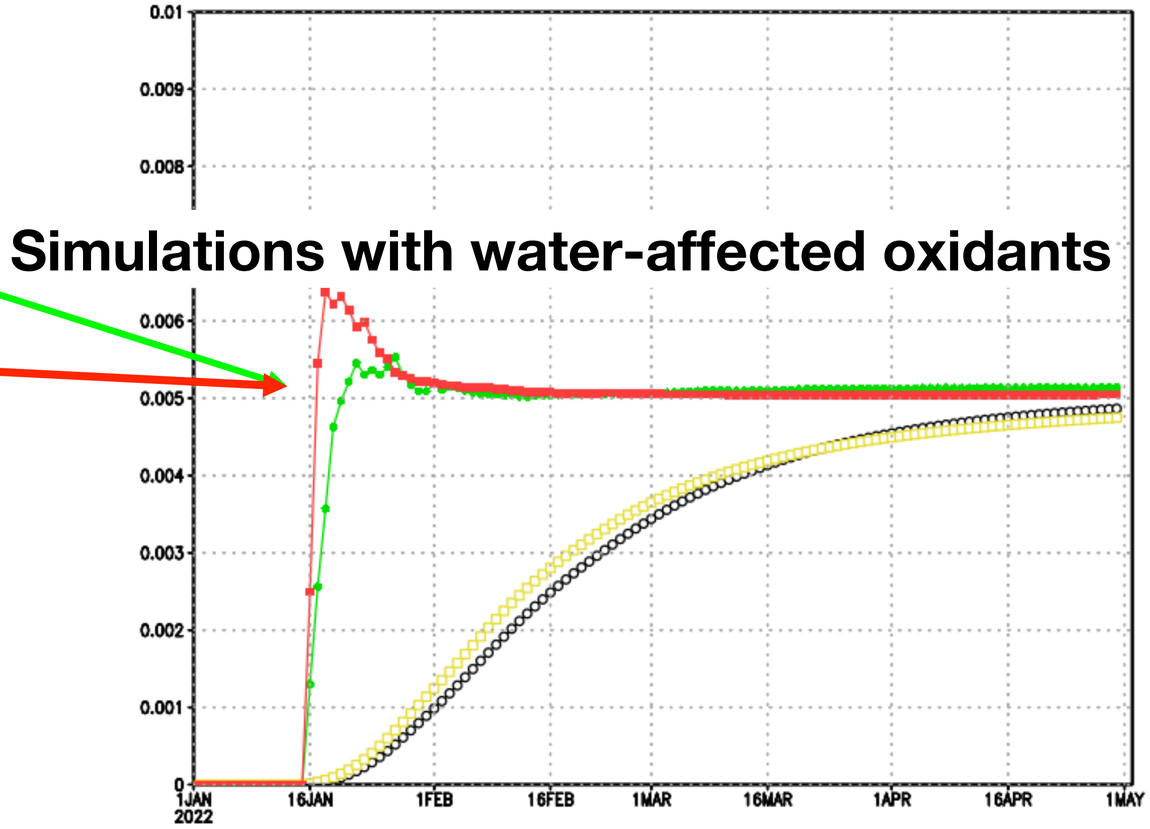
Courtesy: Parker Case

Hunga Tonga Example

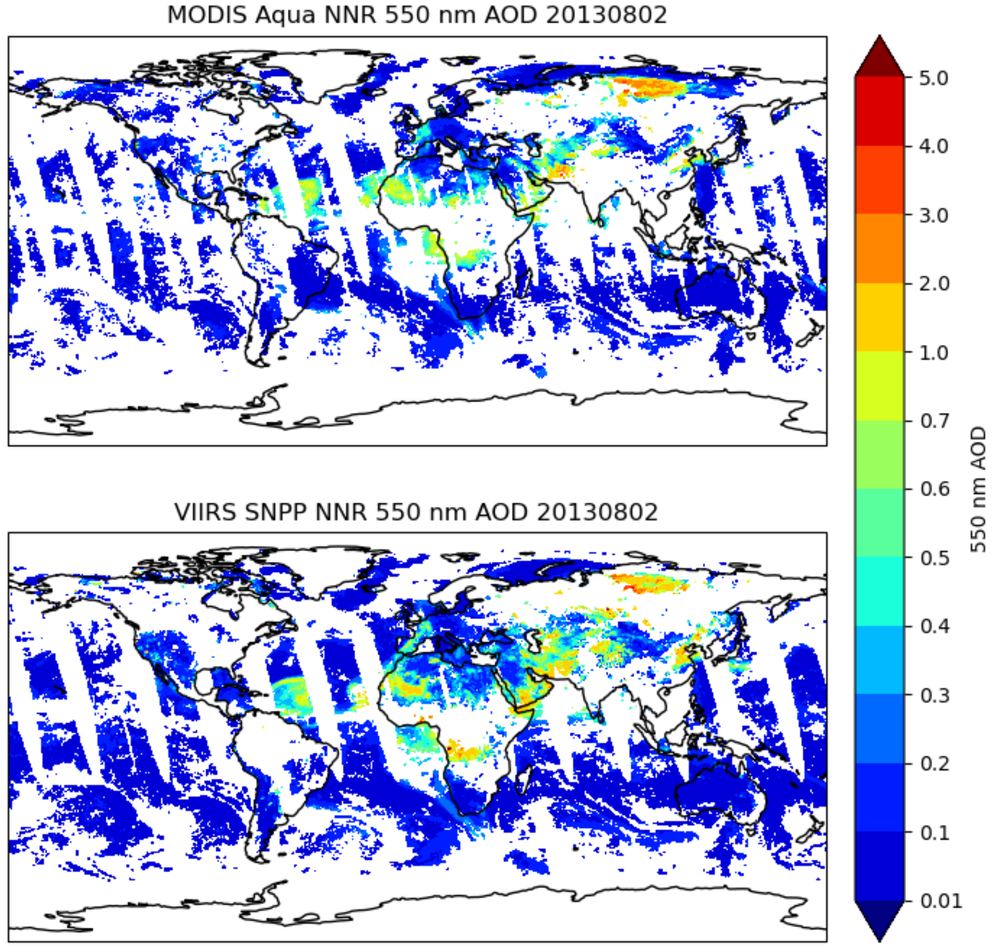
Volcanic SO2 column mass [Tg]

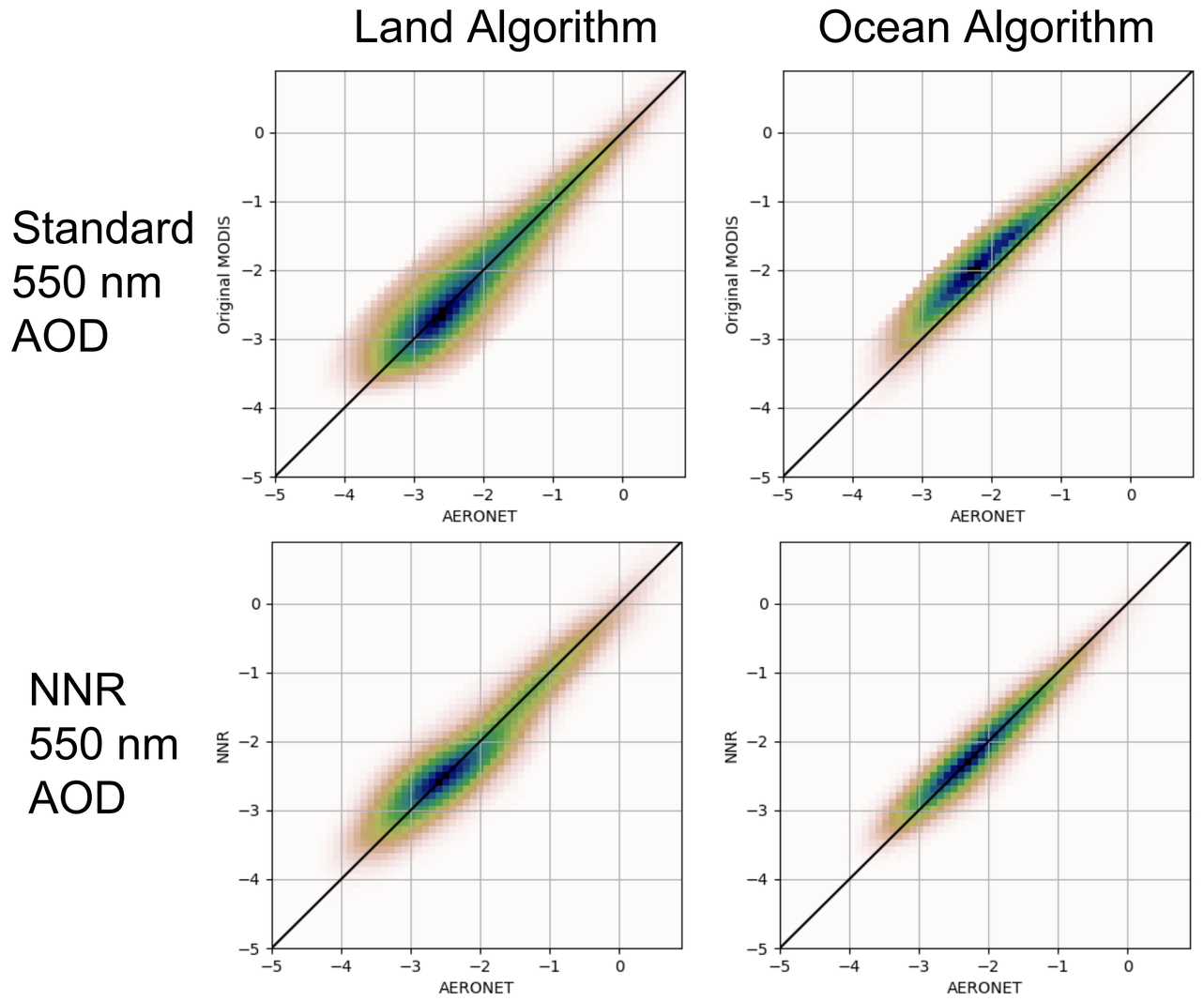


Volcanic AOD



NNR Implemented on VIIRS-SNPP

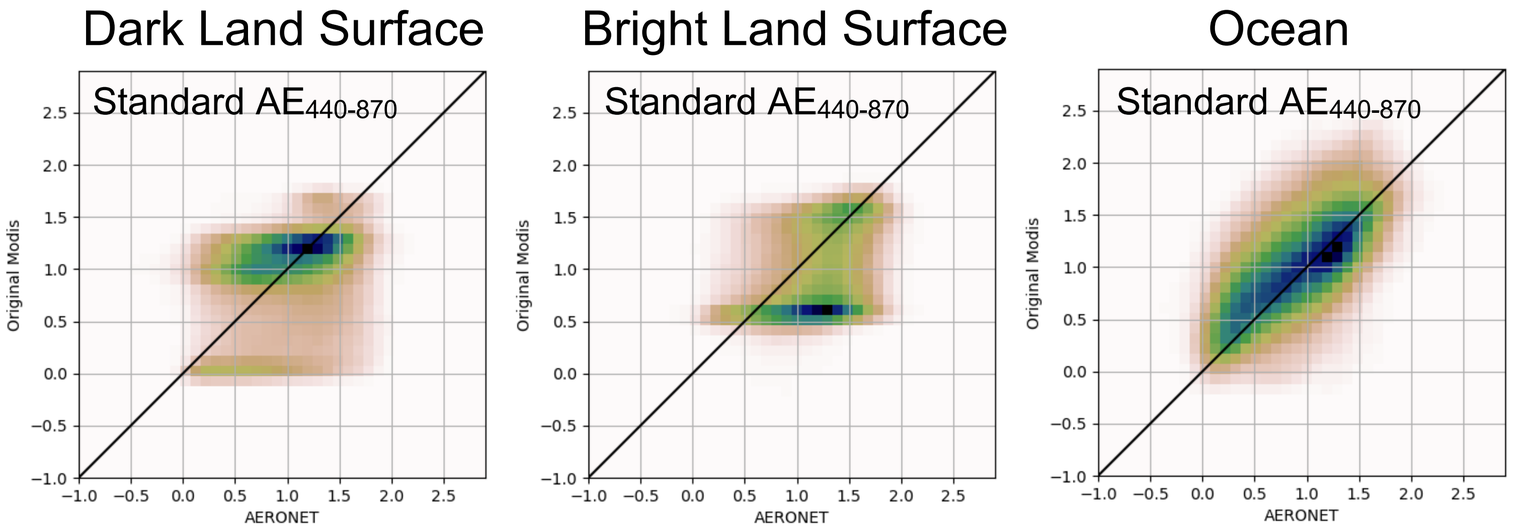


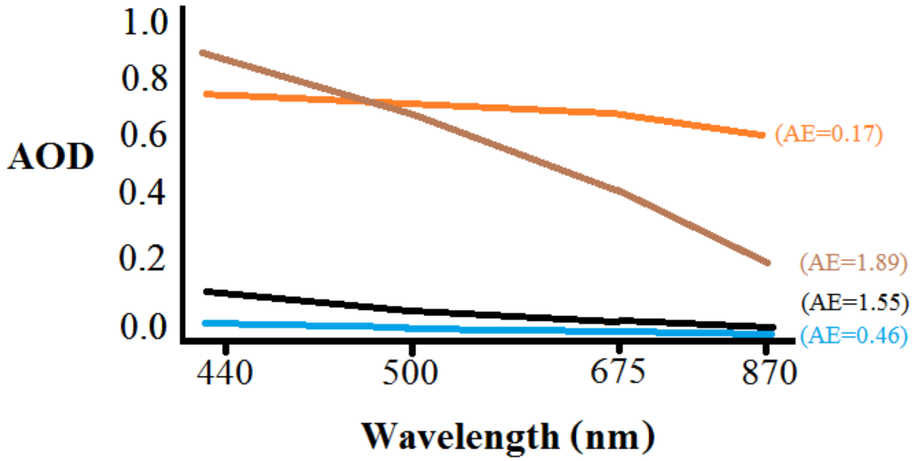


Courtesy: Patricia Castellanos, Virginie Buchard

Satellite Visible Angstrom Exponent

- Spectral AOD can help distinguish different aerosol types
- Large aerosol (dust, sea salt) have low spectral AOD variability (low AE), while fine aerosol (smoke, sulfate) have high variability



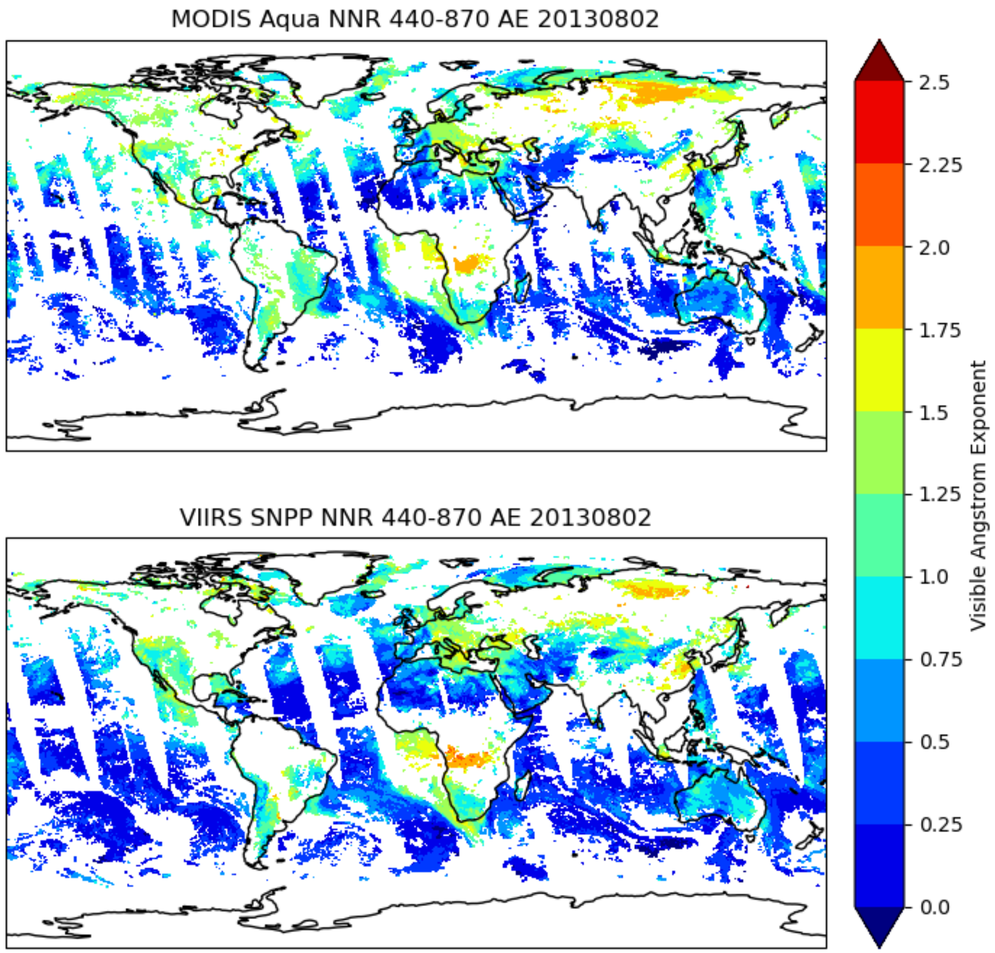


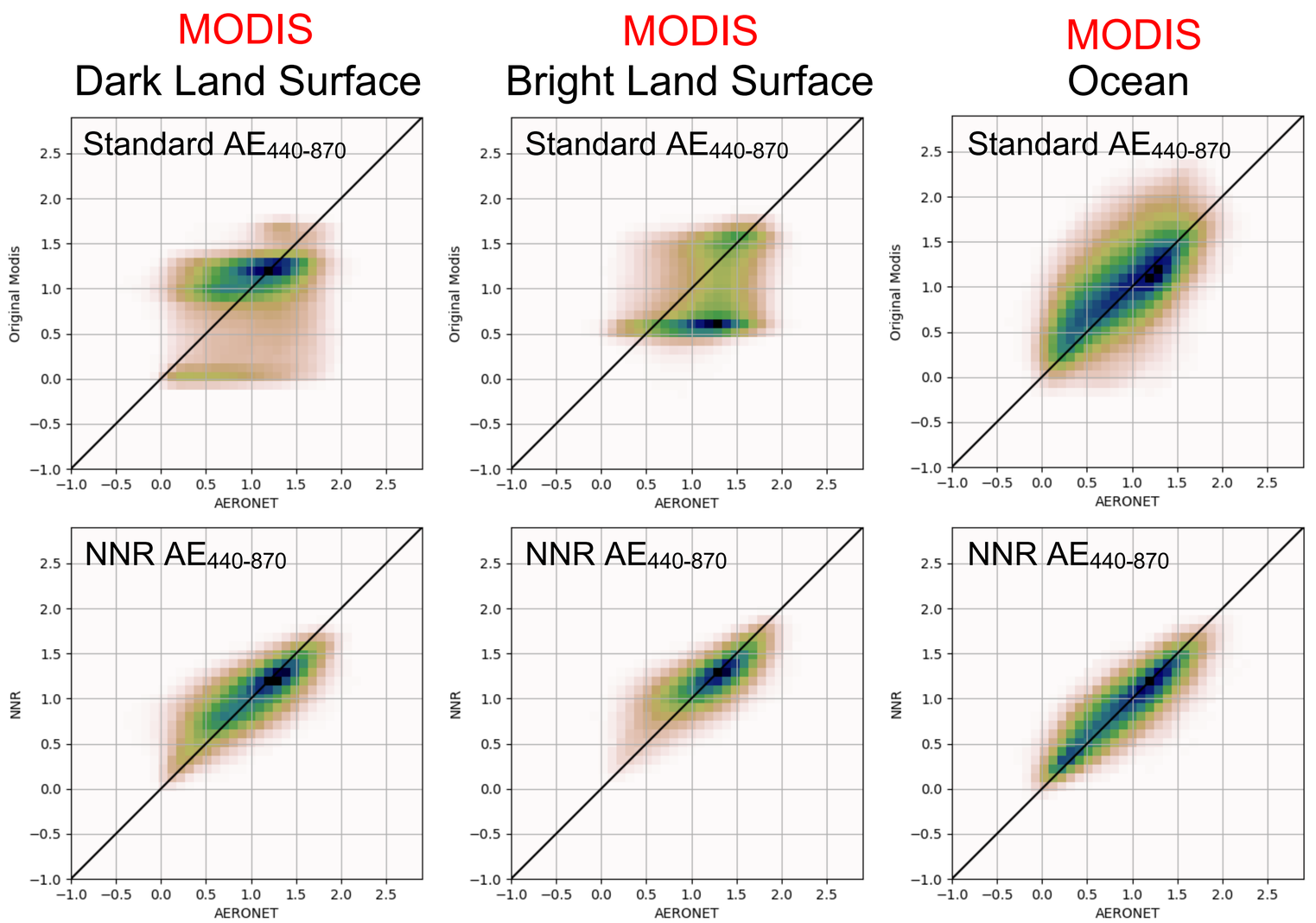
Dust
Sea Salt
Smoke
Sulfate

- Standard AOD retrievals depend on a limited number of assumed aerosol optical models
- As the NNR is based on simulated aerosol types, more variability in the aerosol optical model is possible

Courtesy: Patricia Castellanos, Virginie Buchard

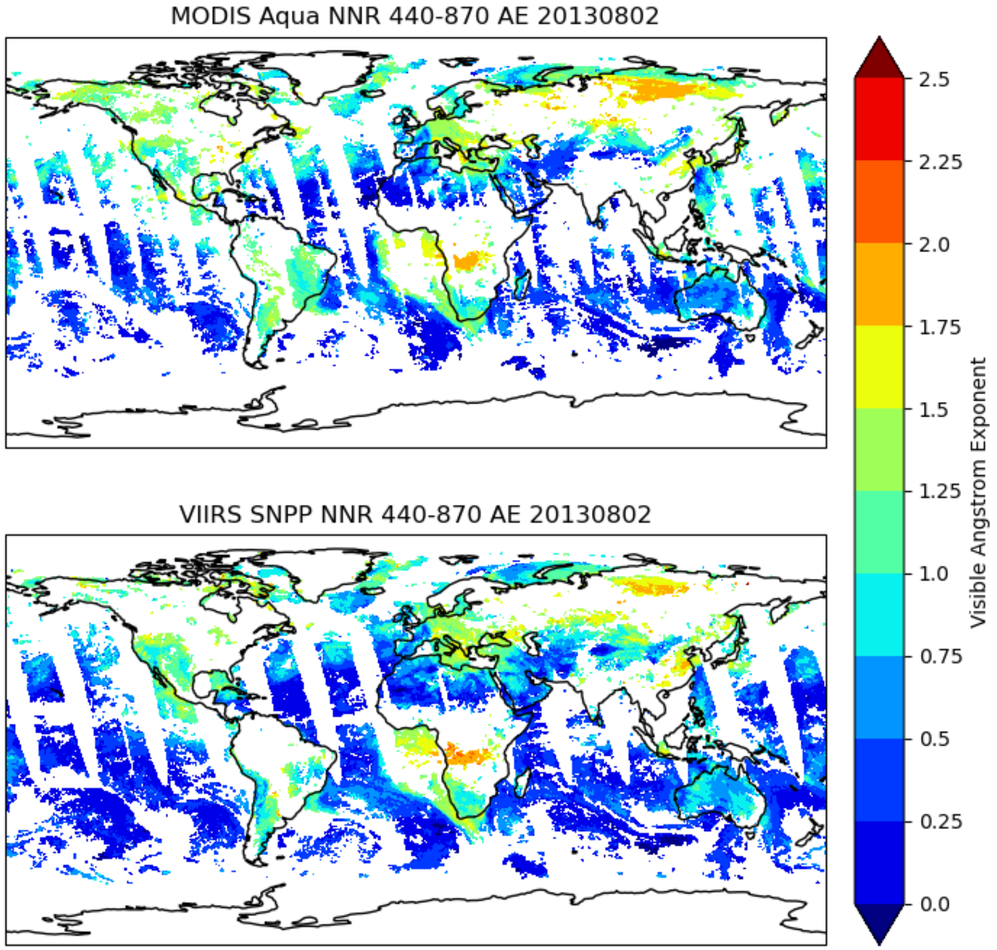
NNR Algorithm Modified to Predict Visible Angstrom Exponent



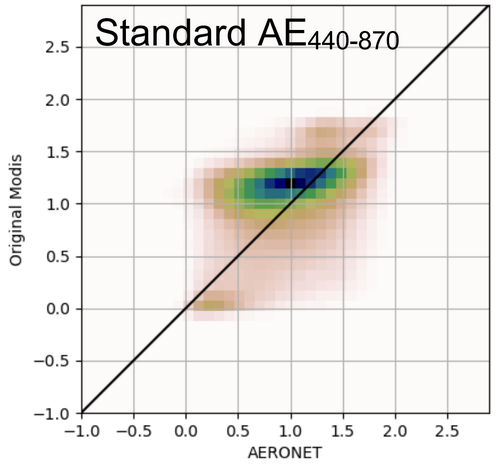


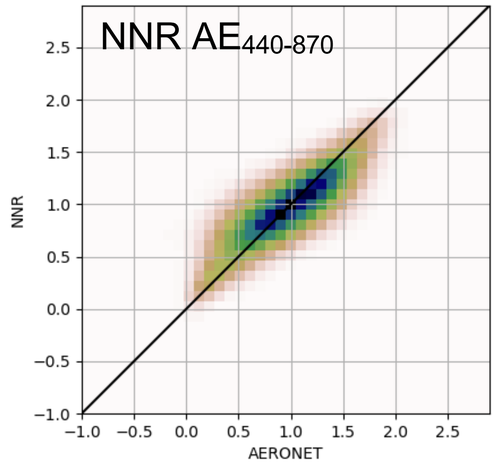
Courtesy: Patricia Castellanos, Virginie Buchard

NNR Algorithm Modified to Predict Visible Angstrom Exponent

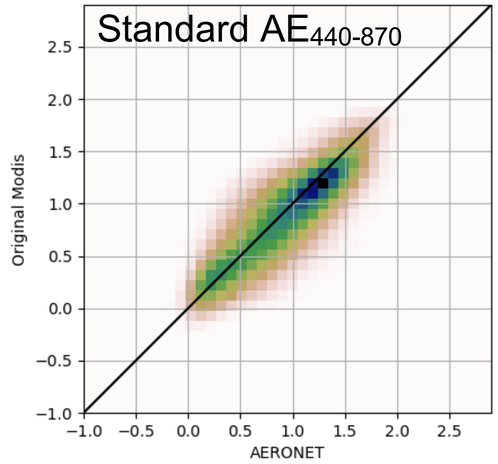


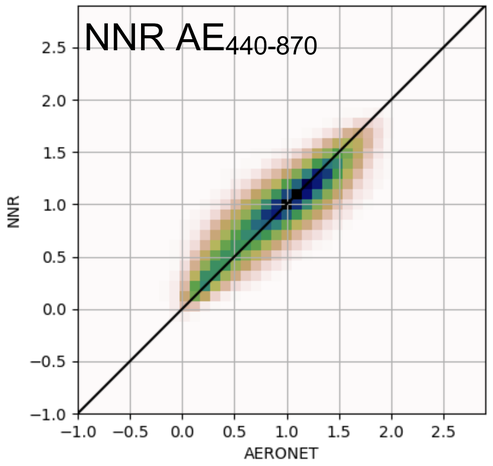
VIIRS
Land Surface





VIIRS
Ocean



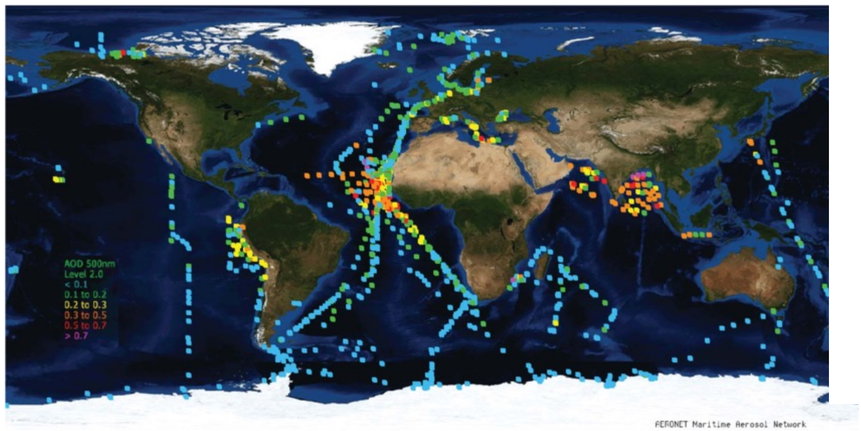


Courtesy: Patricia Castellanos, Virginie Buchard

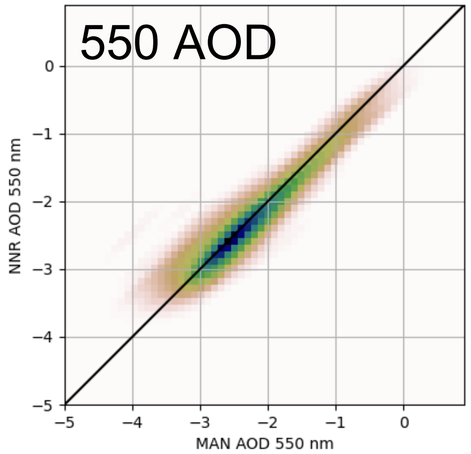
Validation: Comparison to Maritime Aerosol Network

Handheld sun photometers are deployed during research cruises

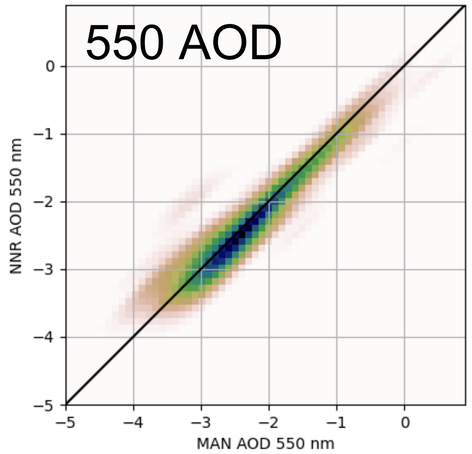
MAN Cruise Tracks



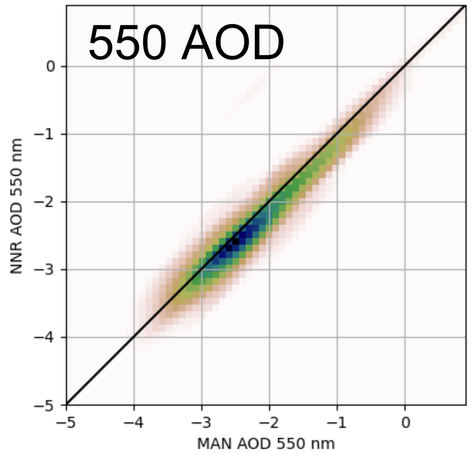
MODIS TERRA

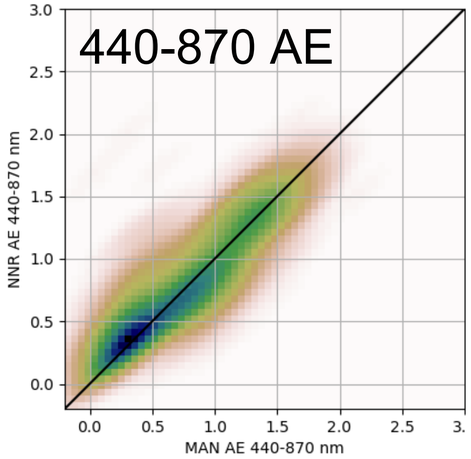


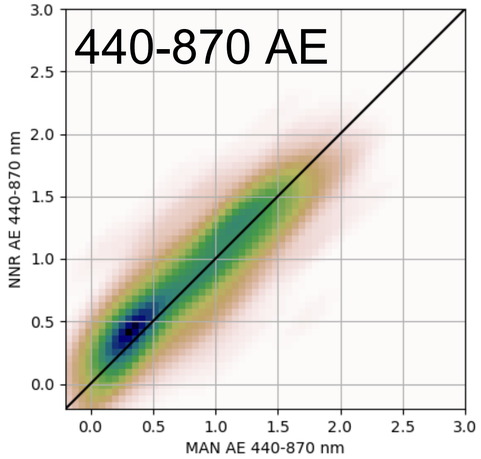
MODIS AQUA

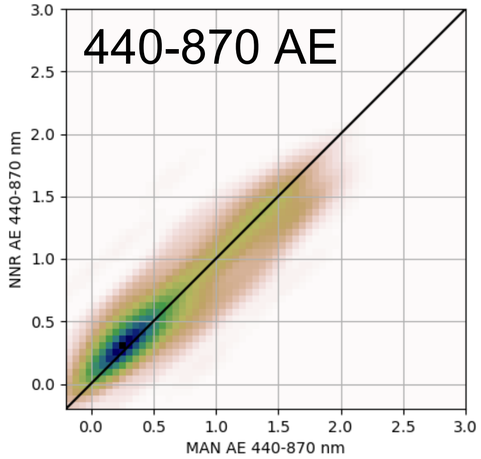


VIIRS SNPP









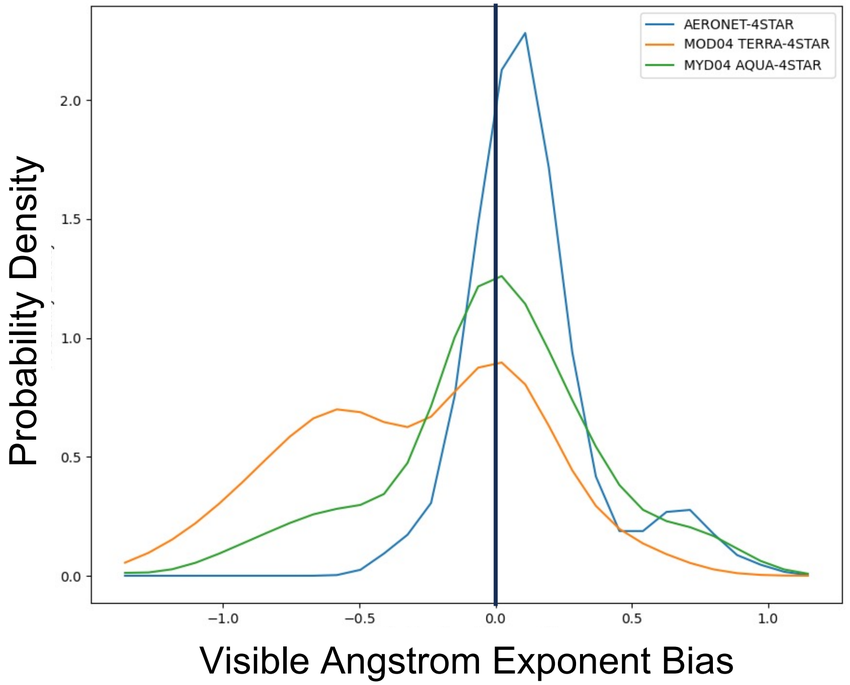
Courtesy: Patricia Castellanos, Virginie Buchard

Comparison to 4STAR Airborne Observations of AE

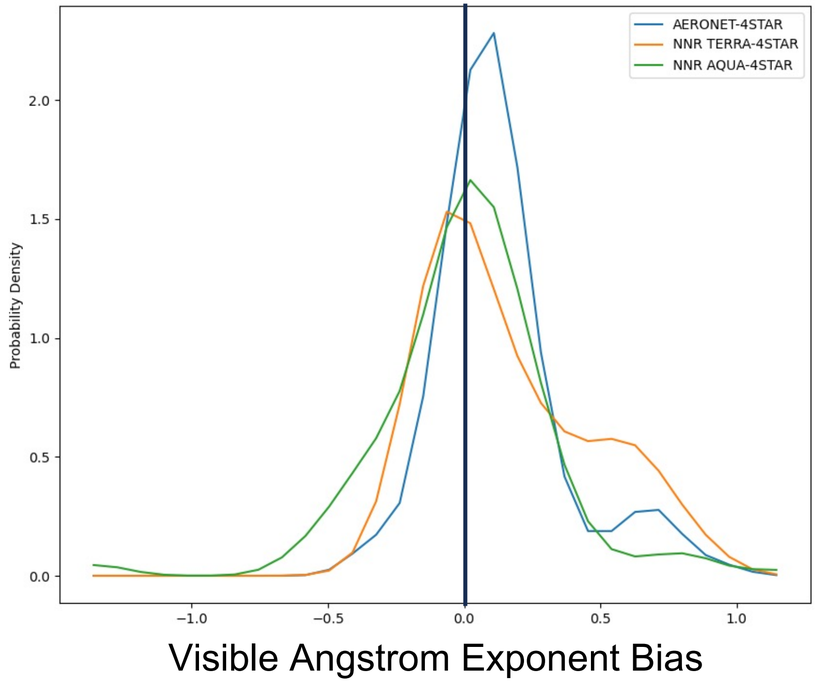
Spectrometer for Sky-Scanning, Sun-Tracking Atmospheric Research (4STAR)

- Airborne sun-sky spectrophotometer measuring direct beam transmittance
- Measures column above aircraft
  - Extensive AOD will be biased, but intensive AE is a more robust comparison
- MODIS underpasses where the aircraft was below 1000 m were considered:
  - KORUS-AQ
  - TCAP
  - NAAMES
  - SEAC4RS

Standard MODIS Retrievals



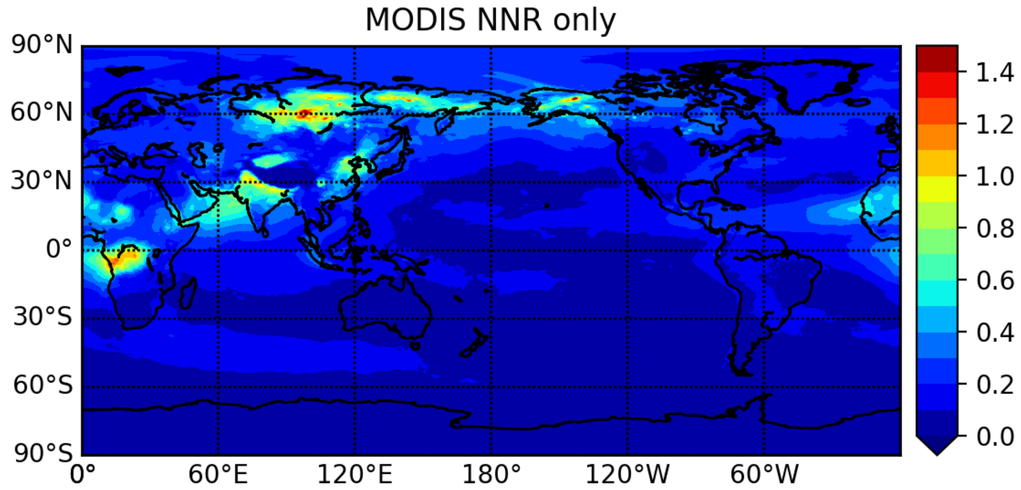
NNR

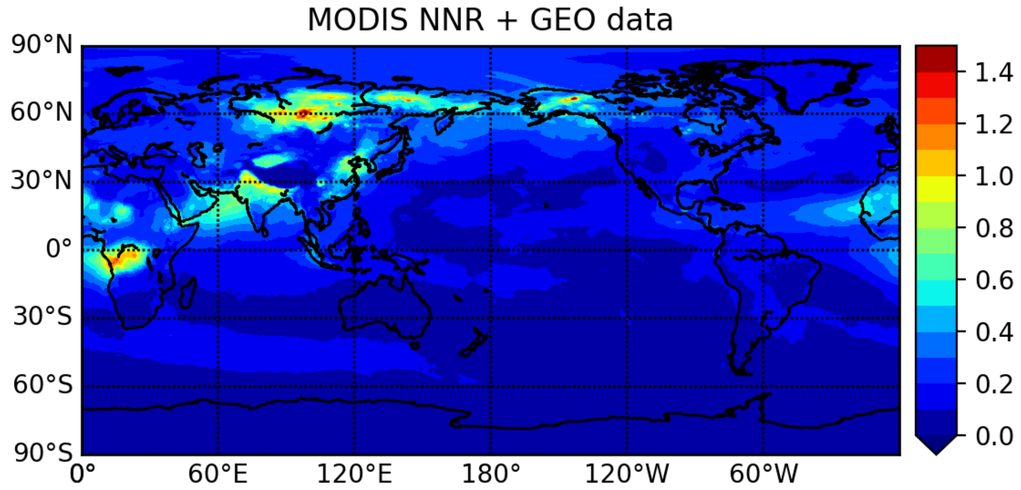


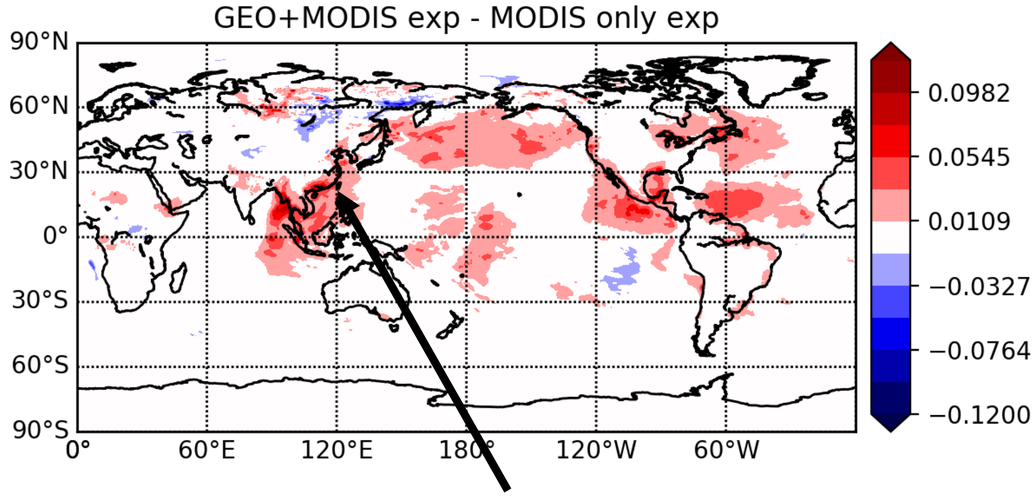
- As 4STAR measures the partial column, errors are to be expected in comparisons to total column observations
- Here we look at the contextual bias:
  - The NNR AE predictions has a similar error PDF as AERONET

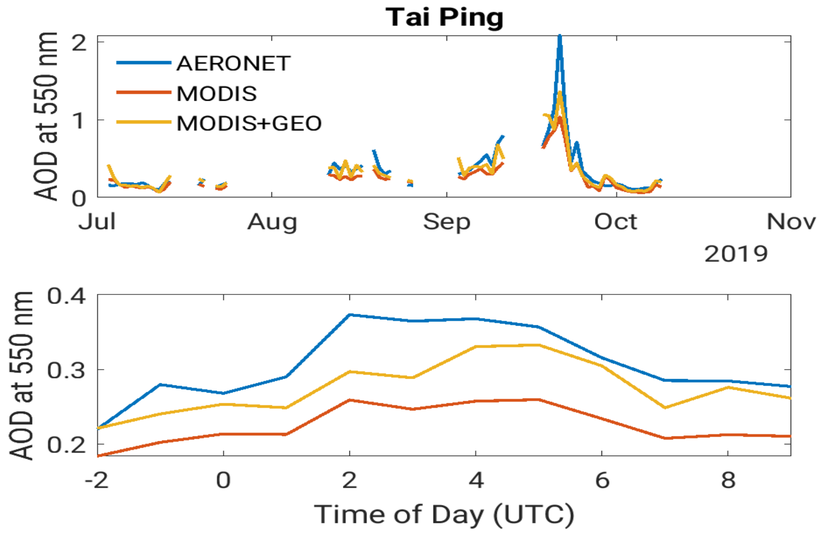
Courtesy: Patricia Castellanos, Virginie Buchard

Assimilation of GEO 550 nm AOD Over Ocean



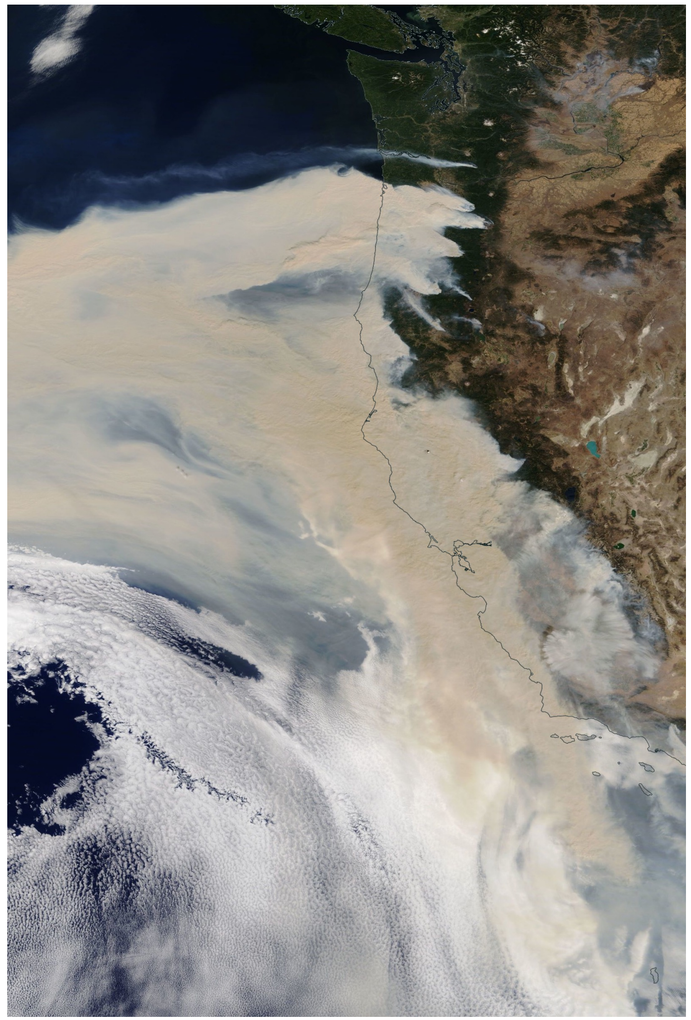






Courtesy: Patricia Castellanos, Virginie Buchard

QFED: Transitioning from MODIS to VIIRS



The Quick Fire Emissions Dataset (QFED) is the principal GMAO product used in the flagship GEOS systems and GMAO reanalyses.

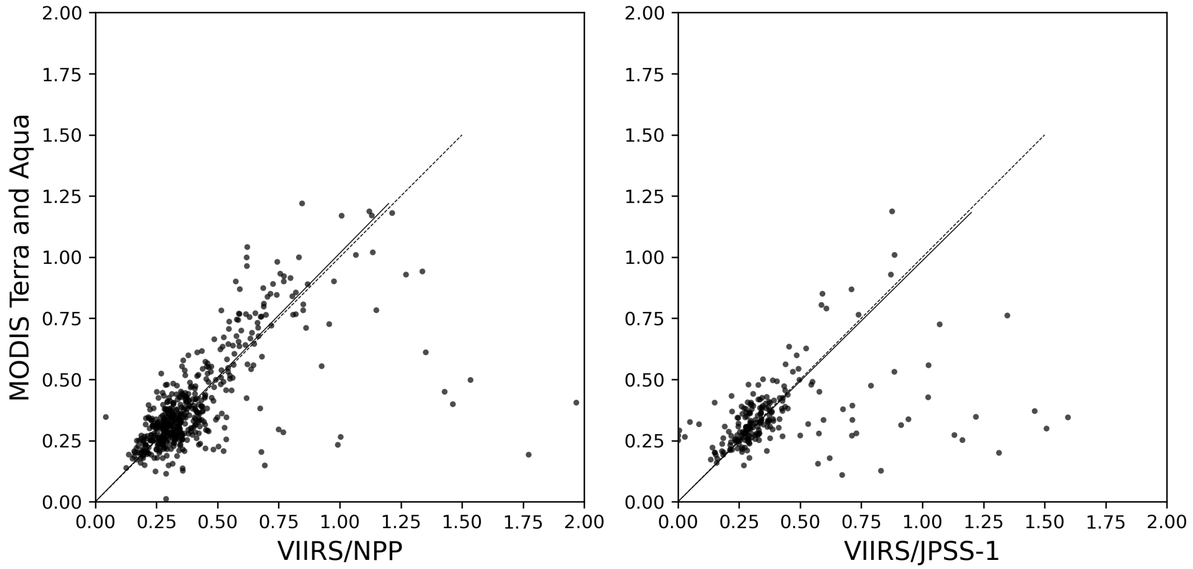
Objectives

- Integrate VIIRS NPP and VIIRS JPSS fire data into the Quick Fire Emissions Dataset (QFED; GMAO).

- Create fire emissions for R21C and the flagship configurations of GEOS with minimal discontinuity in aerosols and meteorology at the point of transition from MODIS to VIIRS.

Courtesy: Anton Darmenov

QFED: Transitioning from MODIS to VIIRS



Comparison of VIIRS/NPP and VIIRS/JPSS-1 fire emissions with MODIS. The depicted data is proportional to the daily global emissions. The target emissions are QFED(MODIS C6).

Progress

- Redesigned and modernized the QFED code to ease the integration of new fire observations, facilitate science innovation and speed up research to operations.
- Improved the workflow to efficiently handle the growth of data that needs to be processed.
- Generated and evaluated VIIRS fire emissions for the period 2021-2022.

Courtesy: Anton Darmenov

Outlook

- GOCART2G to go live in GEOS-FP system next year
- MERRA-21C getting going now, products next year
- Work on aerosol microphysics and aerosol-chemistry coupling continuing under Chemistry-Climate Modeling activities; transitions of information content to NRT systems ongoing
- Assimilation of Angstrom exponent will be part of ensemble JEDI system; sometime in next year or so