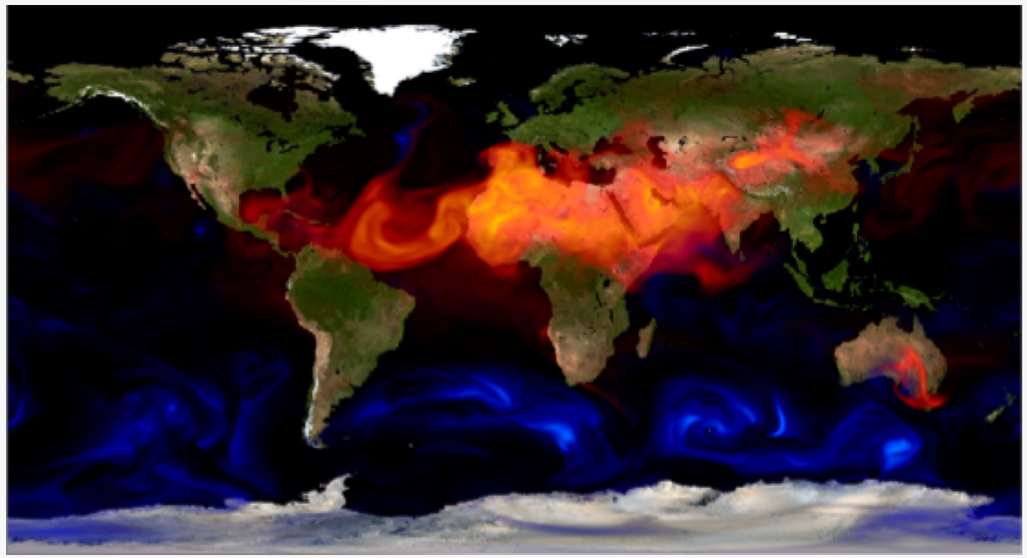
Aerosol Assimilation at NASA GMAO

Speaker: Virginie Buchard virginie.buchard@nasa.gov

Patricia Castellanos, Arlindo da Silva, Ravi Govindaraju, Allie Collow and Anton Darmenov

Outline

- GEOS Main Systems
- GEOS Aerosol Scheme: GOCART2G
- Aerosol Data Assimilation
  - Ongoing work:
    - Transition to JCSDA/JEDI
    - Aerosol Observation System
- Summary

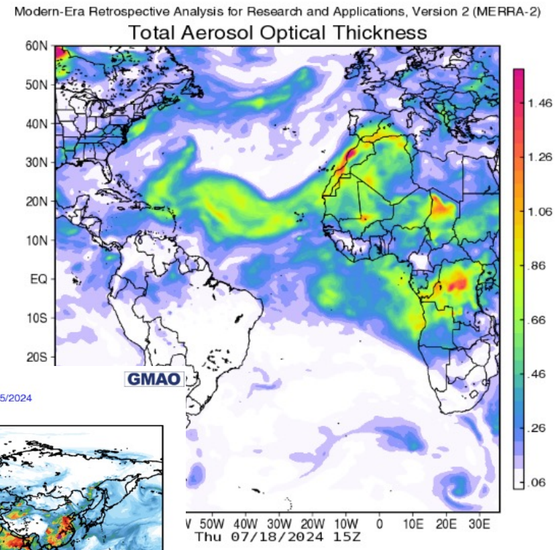


GEOS Main Systems

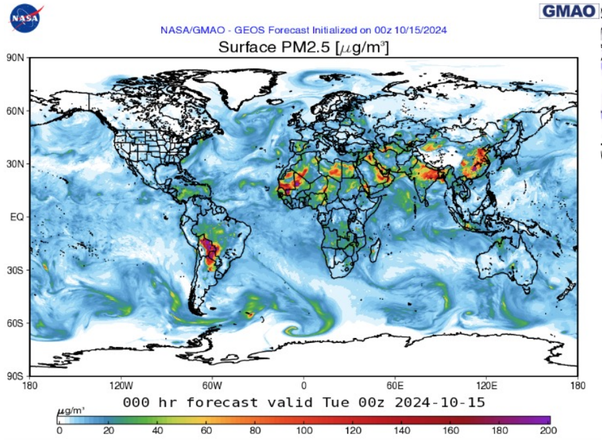
- Aerosols are an integral part of the GEOS forecasting system
- Aerosols runs interactively at the model highest resolution

GEOS products	Purpose	Nominal Res	Aerosol DA
GEOS-FP	Weather/aerosols analyses and forecasts	12 km	X
GEOS-S2S	Coupled system for S2S predictions	50 km	(X)
GEOS-CF	Composition Forecast Full reactive gas chemistry	25 km	(X)
Reanalysis			
MERRA-2	Gelaro et la, 2016, Randles et al., 2017	50 km	X
GEOS-IT	N.R.T analysis system for Instrument Teams	50 km	X
MERRA-21C	Current reanalysis on production	25 km	X

Total AOD at 550nm from MERRA-2



Surface PM2.5 form GEOS-FP



https://fluid.nccs.nasa.gov/weather/

- The prognostic model underlying the data assimilation system is based on the **GEOS earth system model radiatively coupled to GOCART aerosol Module** (recently refactored as GOCART2G (*Collow et al., 2023, GMD*) *(https://github.com/GEOS-ESM/GOCART)*

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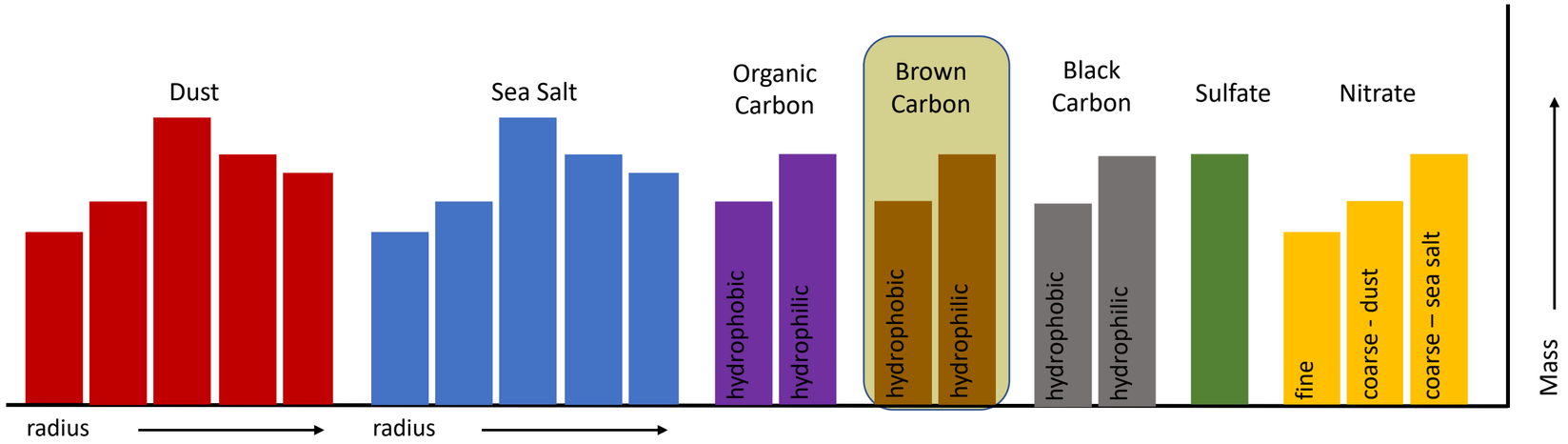
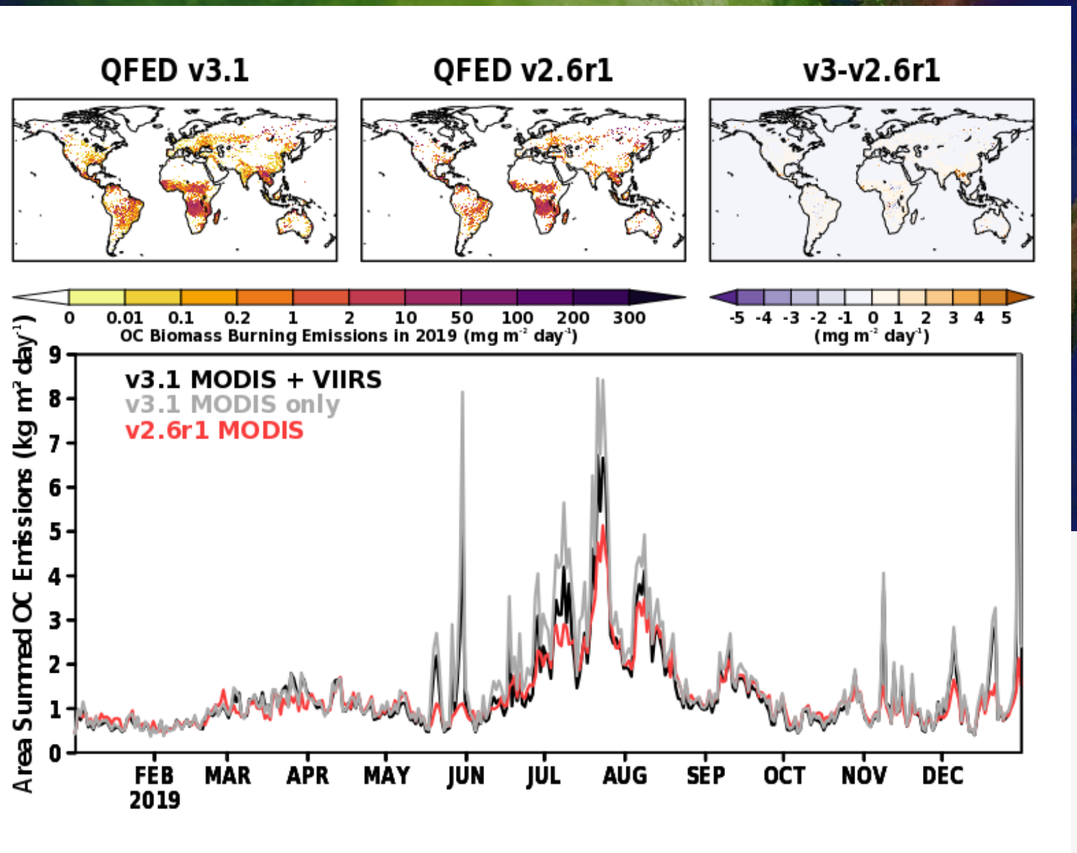
GEOS Aerosol Scheme: GOCART-2G

- 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
- 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



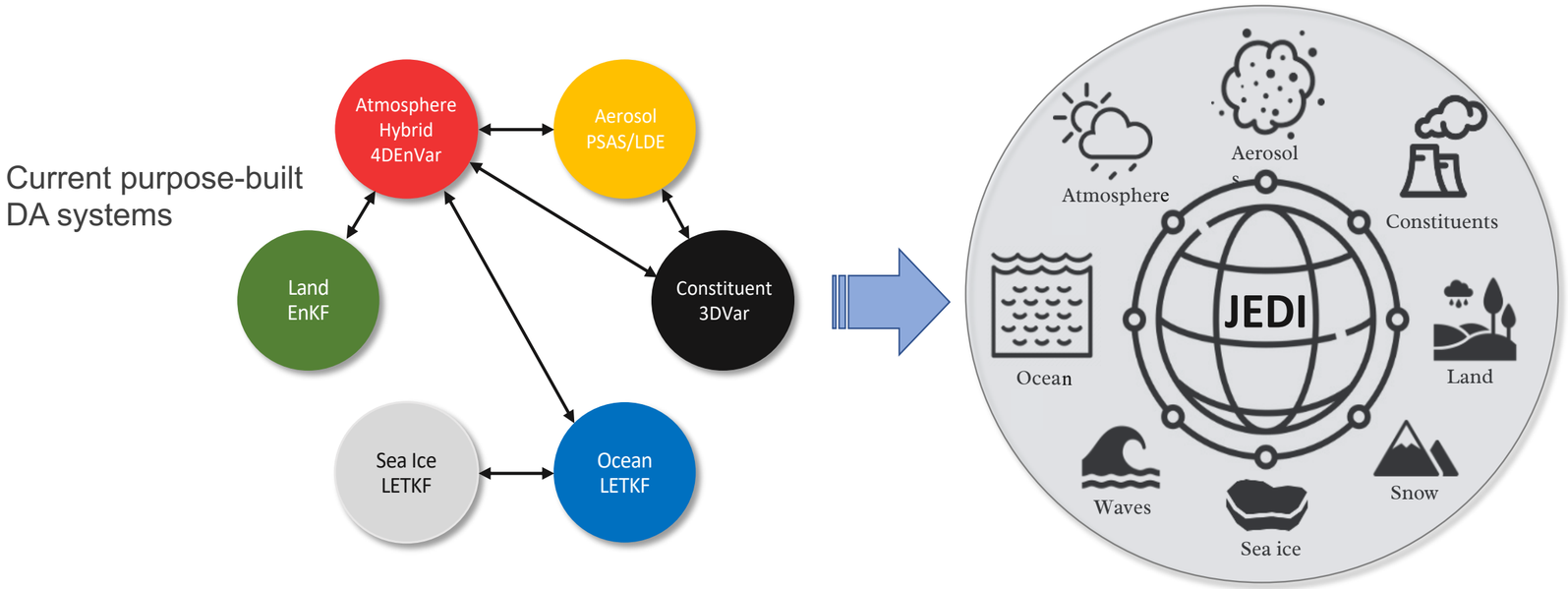
QFED: Quick Fire Emission Dataset

- Top-down algorithm based on MODIS Fire Radiative Power (AQUA/TERRA)
- FRP Emission factors tuned by means of inverse calculation based on MODIS AOD data.
- Daily mean emissions, NRT
- Prescribed diurnal cycle
- VIIRS has a different footprint that is capable of detecting more, smaller fires
- New version of QFED is under testing



The context for JEDI at GMAO

GMAO is developing a unified coupled data assimilation system based on the GEOS model and JEDI, for weather analysis and prediction, reanalysis, composition forecasting, and S2S prediction.



- Eliminate GMAO's dependence on legacy, purpose-built assimilation systems
- Use coupled models to exploit the full range NASA's diverse set of Earth-system observations
- Capitalize on JEDI's multi-agency adoption to accelerate R2O transition of NASA's observations

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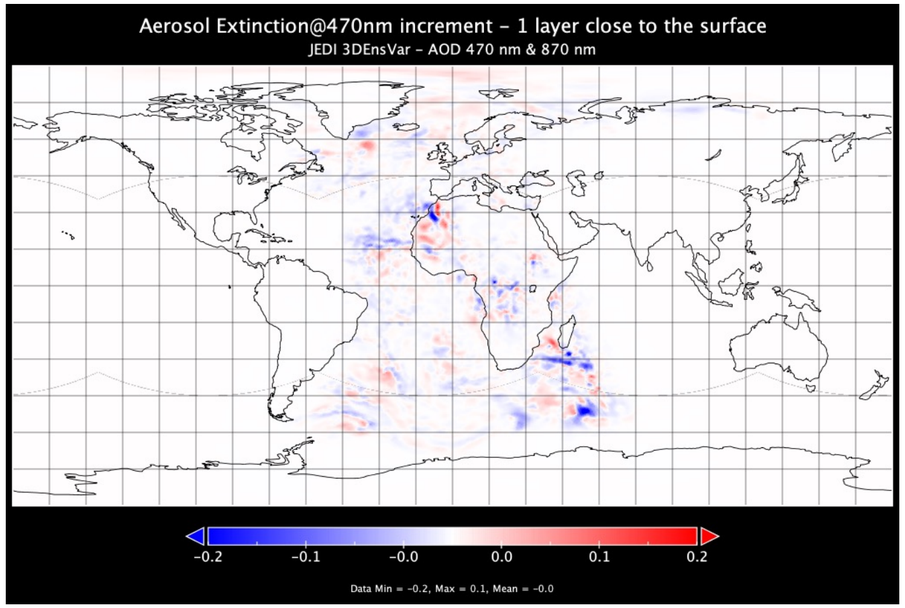
GEOS JEDI Aerosol DA

Transition from PSAS ⟶ JEDI

- **Solver:** PSAS 2D ⟶ JEDI 3D-EnVar
- **Control variable:** 2D single-λ AOD ⟶ 3D multi-λ extinction profiles
- **Observations:** single-λ NNR AOD (550 nm) ⟶ multi-λ NNR AOD
- **Background Error:** transition to a flow dependent background error using meteorological ensemble

Pathway to future observables including lidar, aerosol optical centroid height, radiances…



Aerosol extinction increments at 470 nm for near-surface model layer after one analysis cycle at C90 resolution. Observations are multi-wavelength NNR AOD at 470 & 870 nm.

GEOS JEDI Aerosol DA status

Observation operator for multi-wavelength AOD developed and merged into JEDI/UFO

- Developed using multi-wavelength extinction profiles (2 or 3) as the control variable
- Updated with log option (AOD closer to log-normal distribution)
- Updated with an option to select which observation wavelengths to simulate

IODA Python App

- **Offline:** Conversion of current aerosol observation file in ODS format to JEDI/IODA format; completed
- **Online:** Integration into current NNR codes to include model information for quality control; ongoing

Quality control of aerosol observations

- Current quality control for aerosols in GEOS-FP is not available in the JEDI framework
- Background and buddy-check codes are being written in Python and will be performed outside JEDI; ongoing

Cycling the model with the DA system

- Model extinction profile control variable
  - Multiple-λ extinction profiles available in refactored and more flexible GOCART-2G aerosol module; completed
- Updating current GAAS modules inside GEOS model
  - Transform of extinction increments into mass mixing ratio required by the model; requires development

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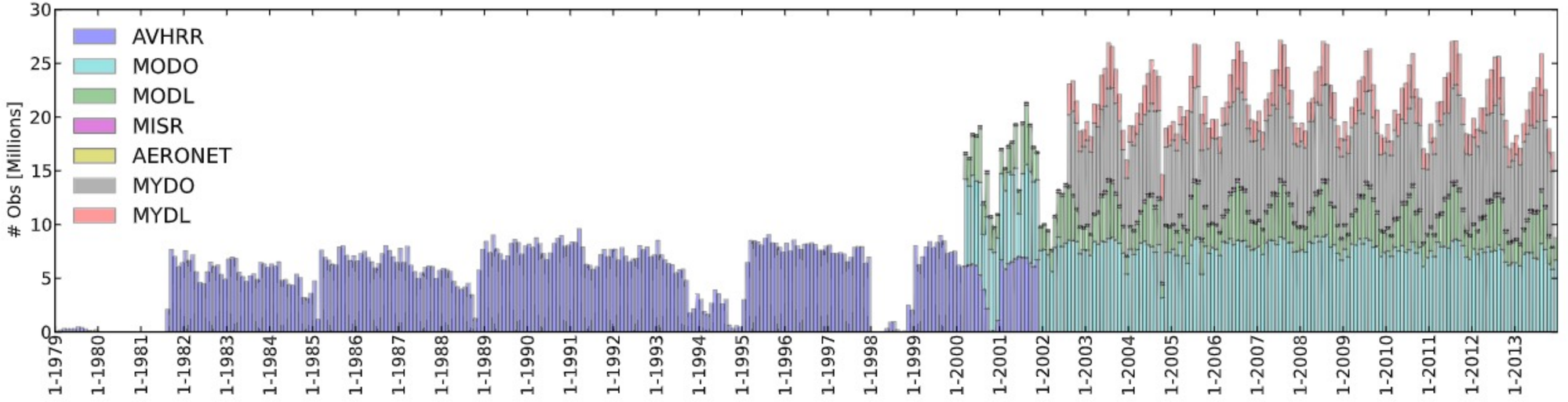
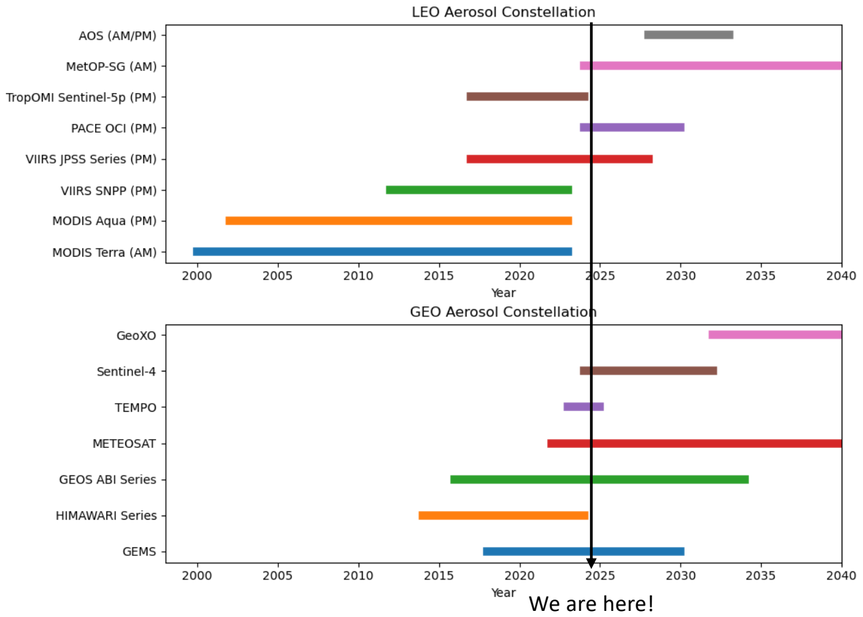
GEOS Aerosol Observing System

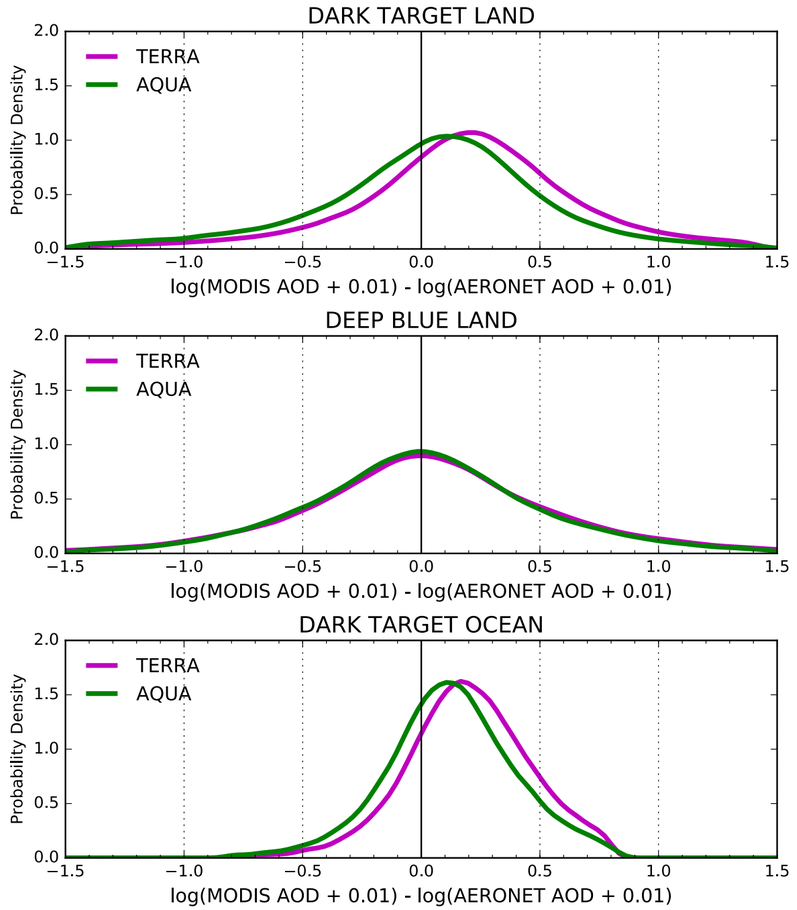


- MODIS Terra & Aqua observations of 550 nm AOD have been, by far, the main sources of aerosol observations for the GEOS aerosol DA system
- Actively working to include VIIRS NNR dataset in the GEOS system
- Will follow with the GEO dataset



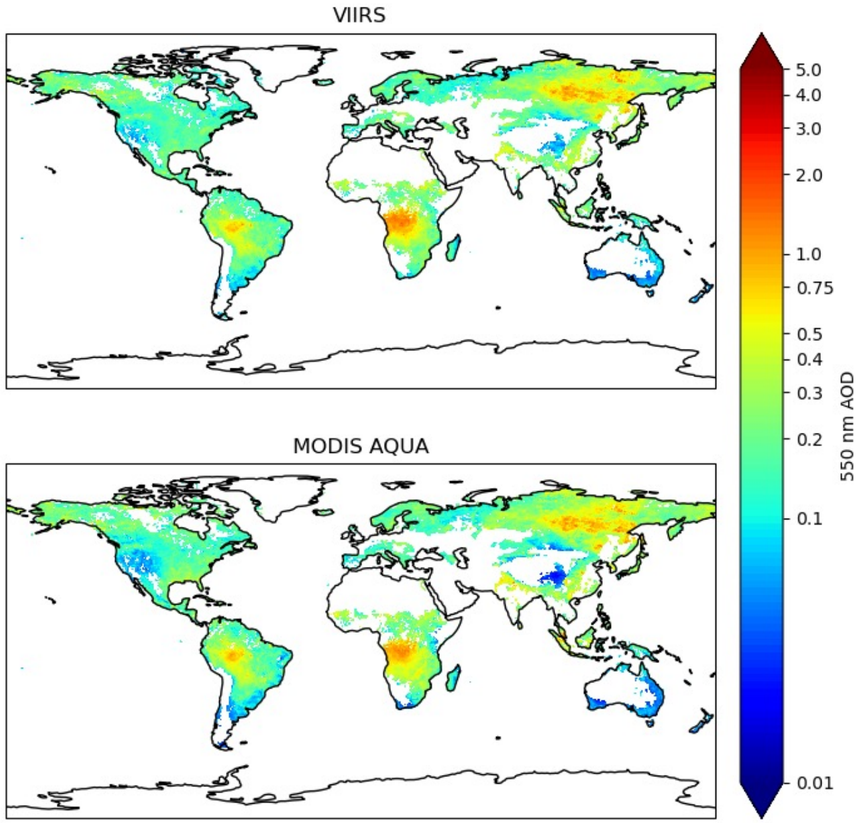
GEOS Aerosol Observing System

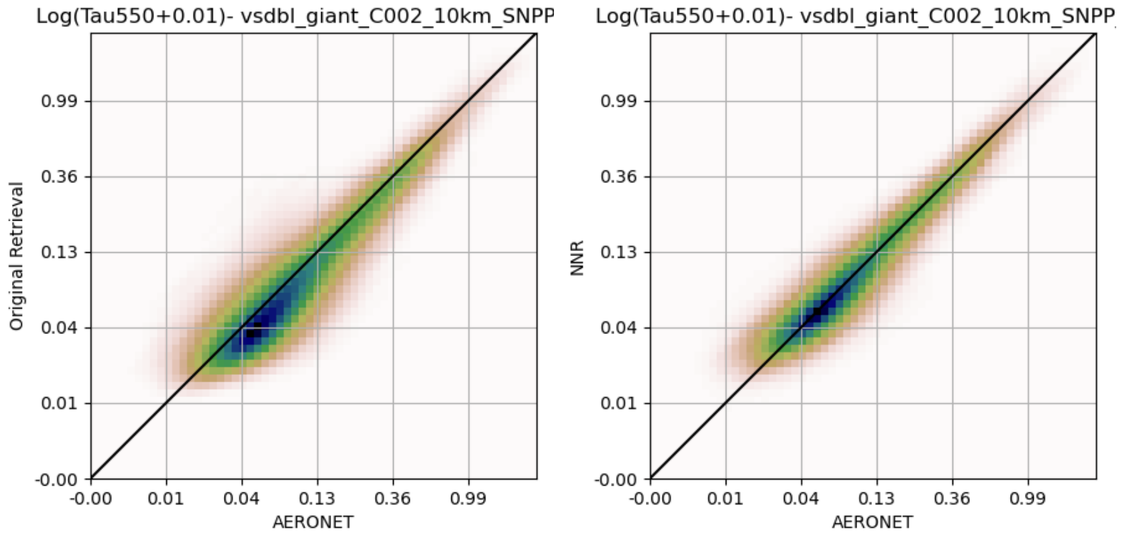
- The aerosol DA problem requires a homogenized AOD observing system across many different platforms
- Biases between datasets can propagate in the model forecast and lead to artificial variability



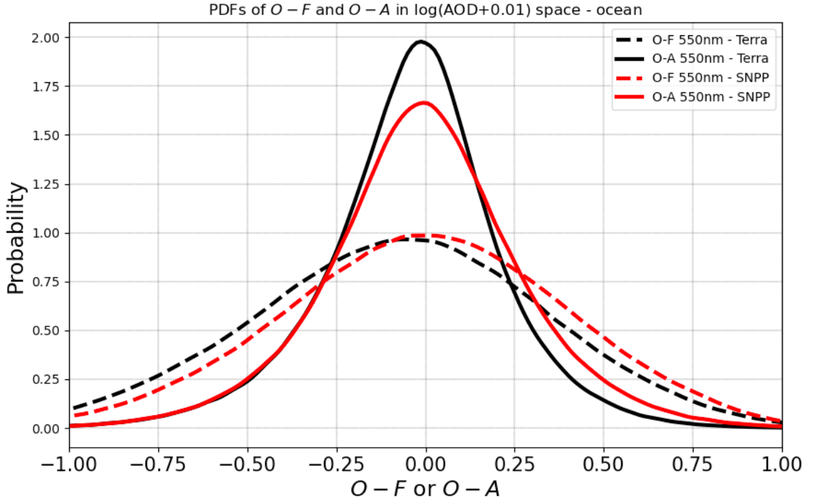
GEOS Aerosol Observing System

NNR implementation on VIIRS dataset





August 2019



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Summary & Outlook

- Aerosol DA transition to JCSDA/JEDI framework:
  - Phased implementation of JEDI Var for NWP and aerosols into the existing GEOS-FP scripting to expedite transition
  - Transition from PSAS to JEDI aerosol DA is maturing rapidly, with initial targets providing science advancements

- The Aerosol Observing System is being expanded
  - Actively testing the inclusion of VIIRS dataset into GEOS aerosol DA system
  - Without TERRA, there will no longer be a LEO morning orbit
  - The geostationary constellation provides substantial temporal and spatial coverage
    - 5 years (2019-2024) of DT & DB retrievals on GEOS and HIMAWARI will be the focus of our next developments, and we will use transfer learning techniques from the LEO sensors to propagate the AERONET calibration to GEO sensors

- Project to assimilate Aerosol Layer Height information content for absorbing aerosols from TROPOMI into the system -> constrain of the aerosol profile -> may improve the surface PM2.5 concentration. (Proposal submitted in collaboration with University of IOWA)