National Aeronautics and Space Administration

Impact of Geostationary Aerosol Observations on the GEOS Aerosol Forecasting System:
Preliminary Results for ABI on GOES-16

Arlindo da Silva, Patricia Castellanos, Robert Levy and Shana Mattoo

GMAO and Climate and Radiation Lab

NASA/Goddard Space Flight Center

arlindo.m.dasilva@nasa.gov

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GMAO **Global Modeling and Assimilation Office**
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Outline

- ❑ **Aerosols in the GEOS Earth System Model**
  - ➢ GOCART Aerosols in GEOS-FP
  - ➢ QFED: GMAO's NRT biomass burning emission
- ❑ **Aerosol Data Assimilation**
  - ➢ Homogenizing the aerosol observing system
  - ➢ AOD assimilation with Local Displacement Ensembles
- ❑ **Geostationary Aerosol Retrievals from ABI**
  - ➢ **Summary of DT algorithm and processing**
- ❑ **Impact of ABI aerosol data on GEOS analysis**
- ❑ **Concluding Remarks**
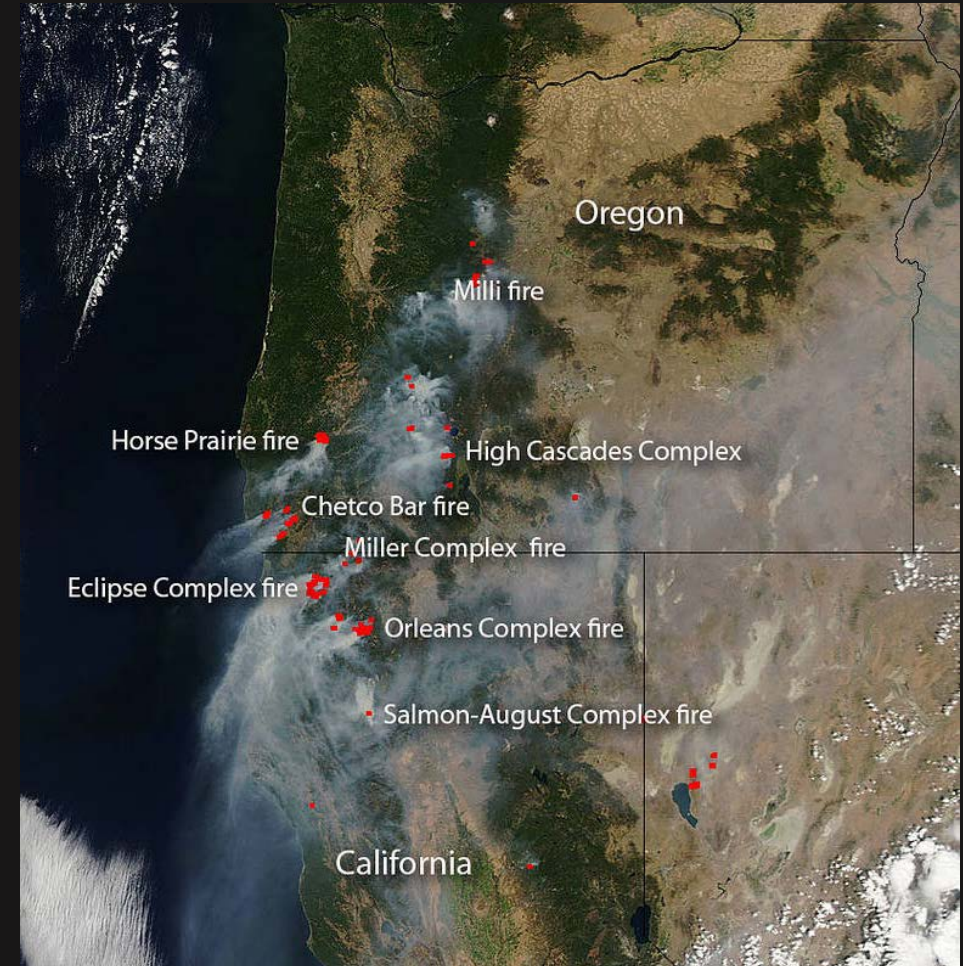
GEOS FP Configuration
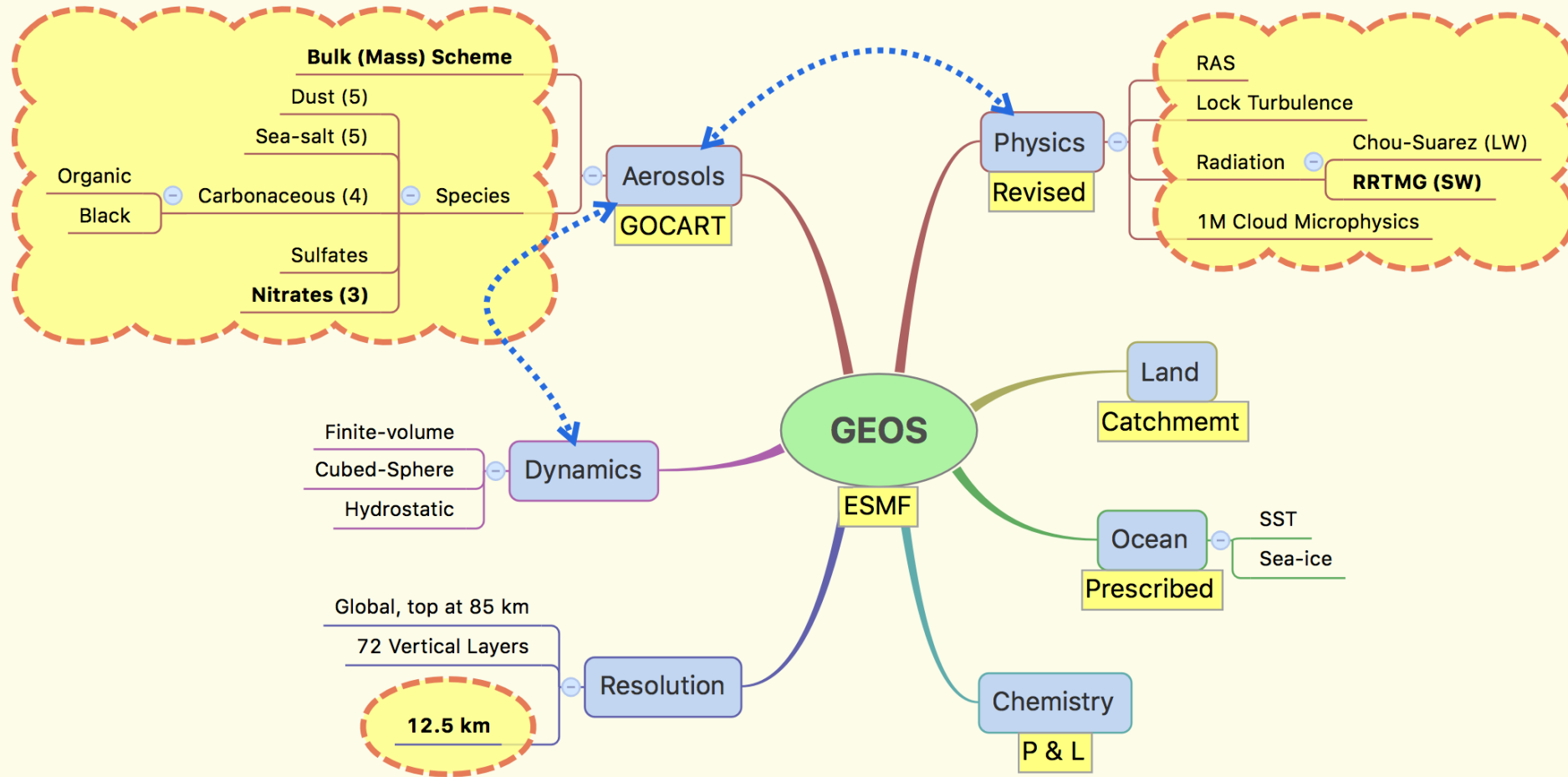
Biomass Burning Emissions
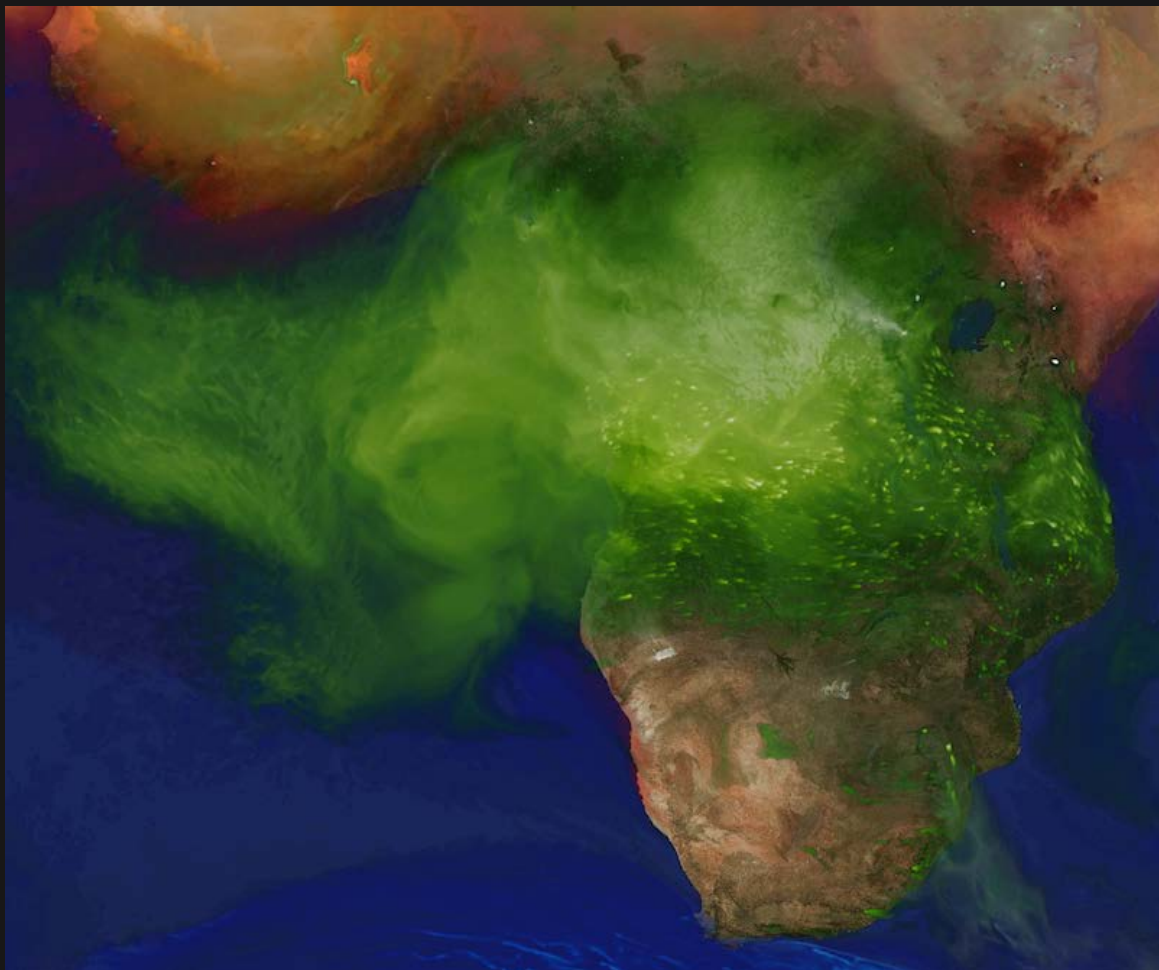
QFED: Quick Fire Emission Dataset

- ❑ 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

- ❑ In GEOS-5 BB emissions are deposited in the PBL.

Field Campaign Support
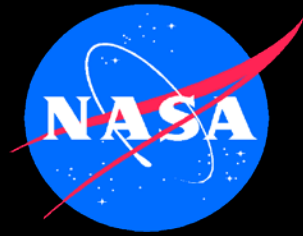
- Global 5-day chemical forecasts
  - ✓ O3, aerosols, CO, CO2, SO2
  - ✓ Nominally 12.5 km
- Driven by real-time biomass emissions from MODIS FRP (QFED)
- Constituents transported on-line, interactively
- Since 2007 supported several field missions including TC4, ARCTAS , GloPac, ATTREX, DISCOVER-AQ, HS3 , SEAC4RS, ATom, ORACLES, etc.
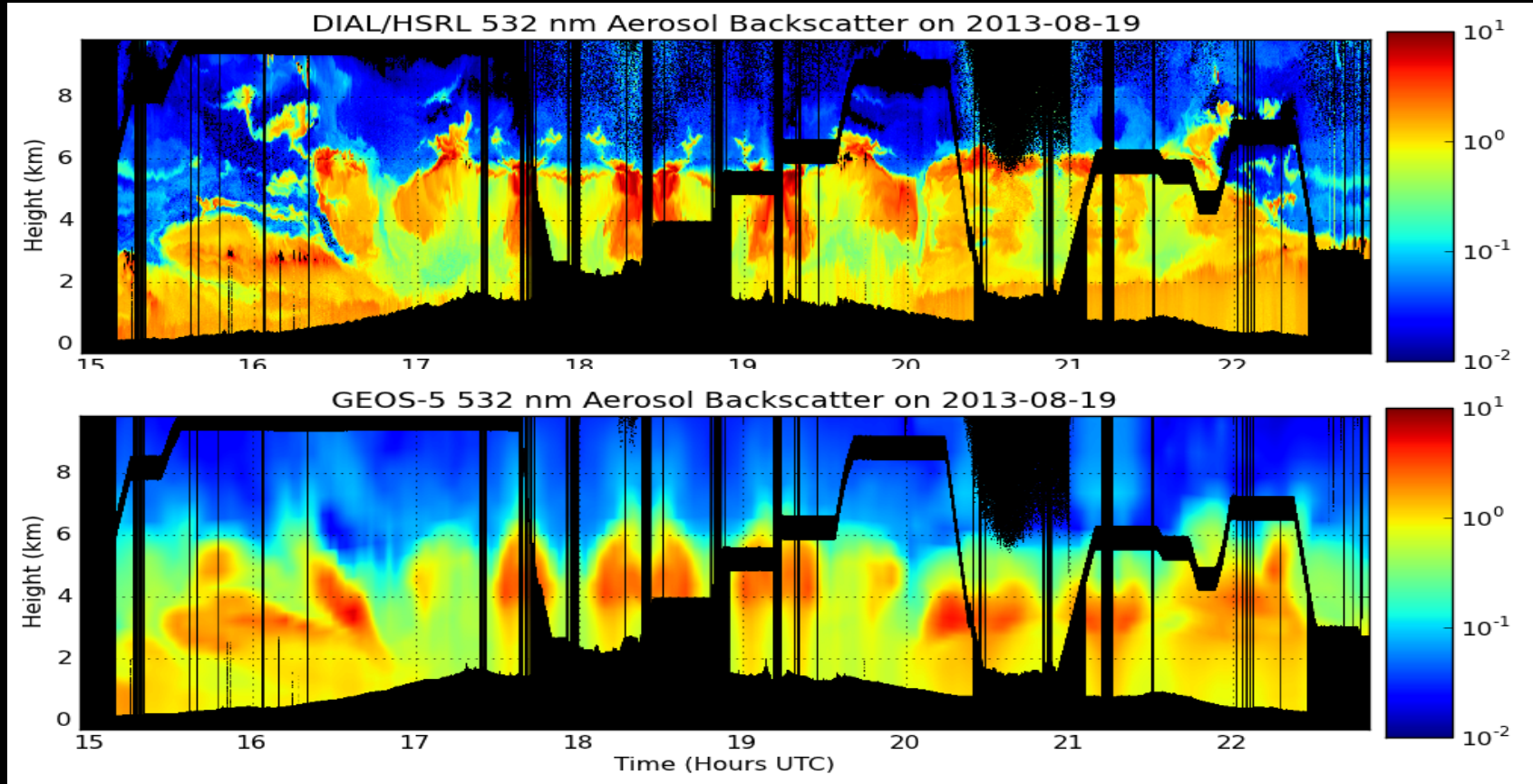
Comparison of observed (top) and simulated (bottom) aerosol backscatter for a slight during the 2013 SEAC4RS campaign.

Aerosol Analysis: Splitting

2D AOD ANALYSIS

- Observable 550 nm AOD is 2D
  - Constrains column averaged optics
  - Cannot constrain speciation or vertical distribution
- Analysis in observation space:

$$\tau^a \equiv H q^a = H \left(q^b + \delta q^a \right)$$

$$= \tau^b + \delta \tau^a$$

GOING TO 3D CONCENTRATIONS

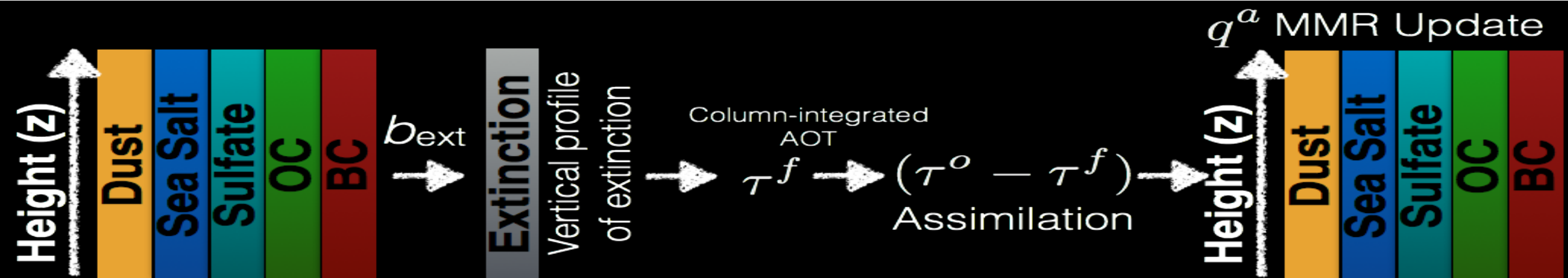- Based on error covariances:

$$\delta q^a = B H^T \left(H B H^T \right)^{-1} \delta \tau^a$$

- Using ensemble perturbations,

$$\delta q^a = X Y^T \left(Y Y^T \right)^{-1} \delta \tau^a$$

- Current GEOS uses Local Displacement Ensembles (LDE), in 1D
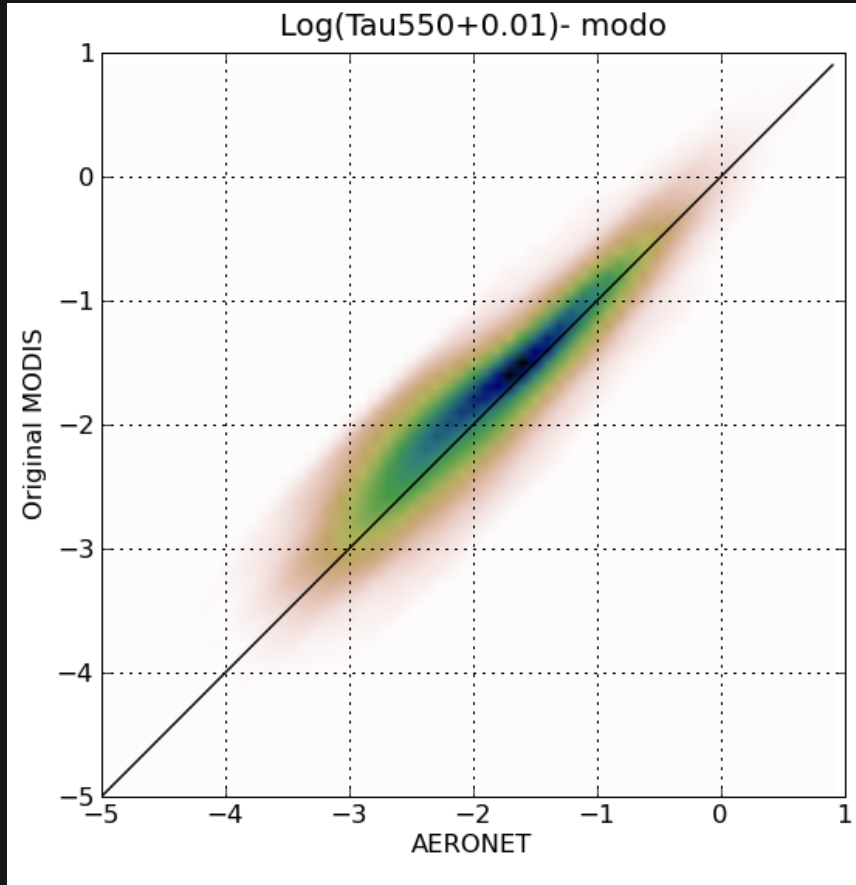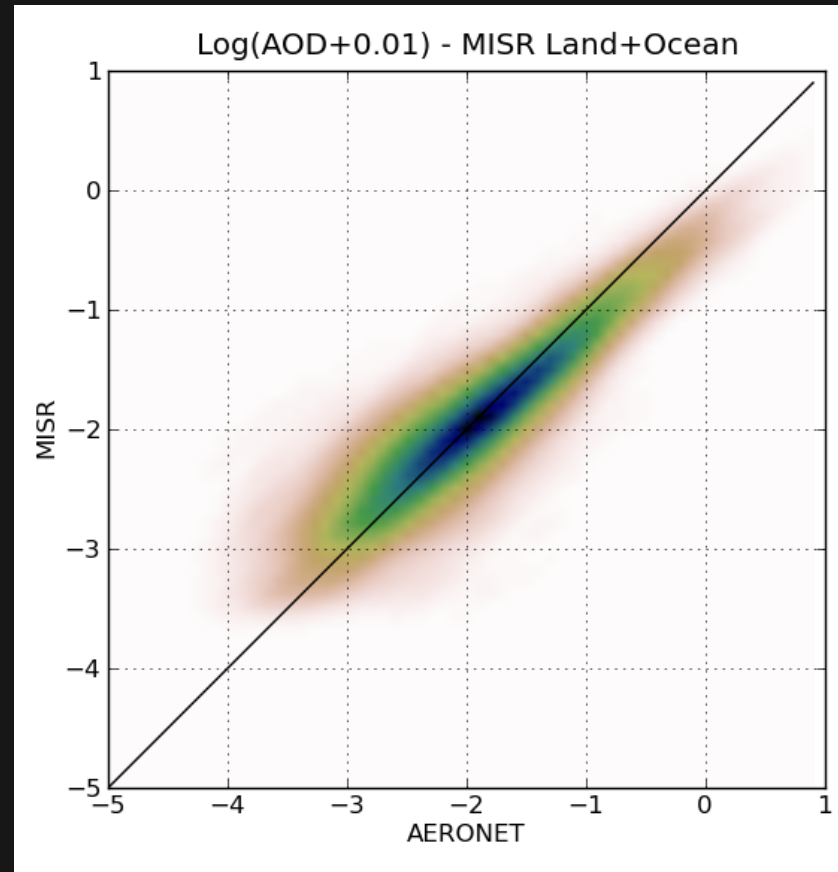- (Could also use actual aerosol ensembles)

MODIS/MISR vs. AERONET
$\eta = \log(AOD_{550}+0.01)$

C5 MODIS-Terra (Ocean)

MISR (Ocean+Land)

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Observation bias correction is necessary.

Neural Net for AOD$_{550}$ Empirical Retrievals

☐ Ocean Predictors

- ■ Multi-channel
  - ☐ ~~Operational AOD retrieval~~
  - ☐ TOA reflectances
- ■ Solar and viewing geometry:
  - ☐ Glint
  - ☐ Solar
  - ☐ Sensor
- ■ Cloud fraction (<70%)
- ■ Wind speed

☐ Target: AERONET

- ■ η = log(AOD+0.01)

☐ Land Predictors

- ■ Multi-channel
  - ■ ~~Operational AOD retrieval~~
  - ■ TOA reflectances
- ■ Solar and viewing geometry:
  - ☐ Solar
  - ☐ Sensor
- ■ Cloud fraction (<70%)
- ■ Surface Albedo or BRDF Kernels
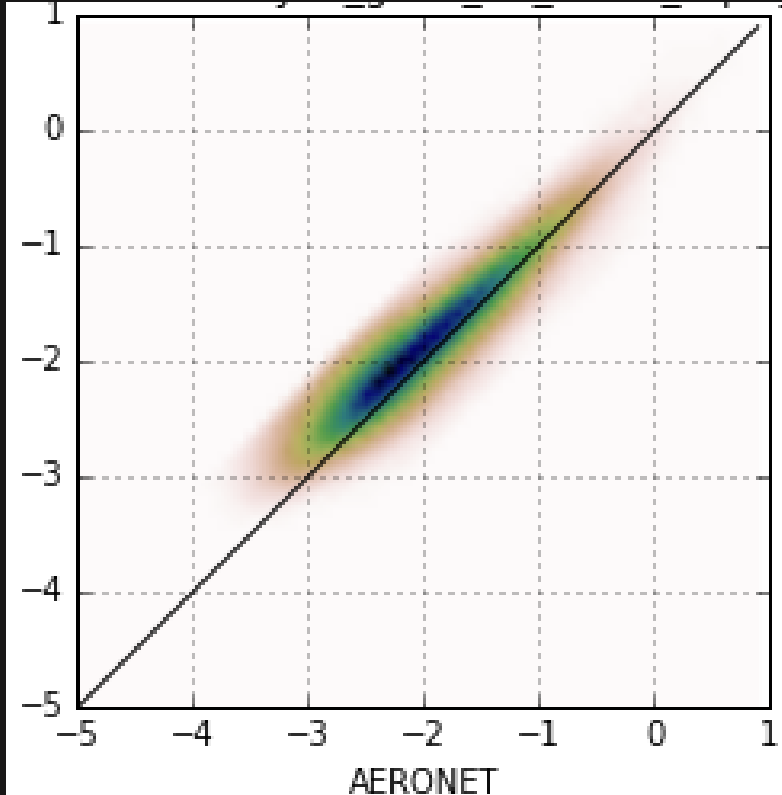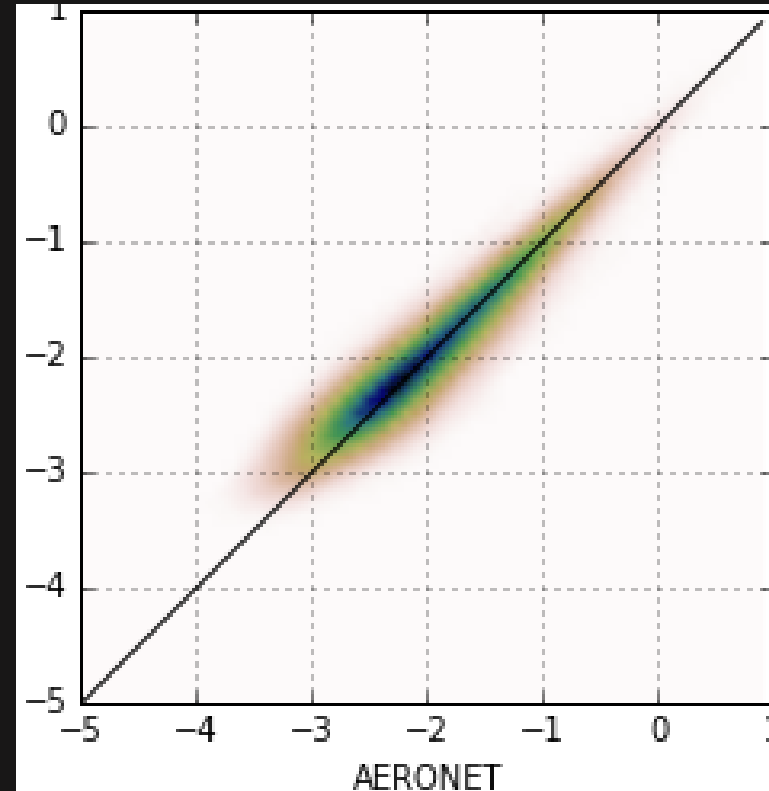
☐ Target: AERONET

- ■ η = log(AOD+0.01)

Observational Bias
$\eta = \log(AOD_{550} + 0.01)$

MODIS-AQUA C6 OCEAN AOD$_{550}$

BIAS CORRECTED NNR AOD$_{550}$

MODIS Neural Net AOD$_{550}$ Retrievals trained on AERONET

Dark Target (DT) ABI Aerosol Retrievals

❑ **Algorithm is adapted from MODIS-DT and VIIRS-DT**

➢ Uses wavelengths in VIS, NIR and SWIR for aerosol retrieval and TIR for cloud masking.

➢ Accounts for wavelength shifts and gas absorptions

➢ Retrieves on NxN boxes of native-resolution pixels → product is ~10 km resolution.

➢ Like MODIS-DT, retrieves
  ✓ AOD at 550 nm,
  ✓ spectral AOD,
  ✓ diagnostics and
  ✓ QA confidence flags

Sensor wavelengths/native pixel resolution

	MODIS	VIIRS	ABI
Blue	0.47/0.5	0.49/0.75	0.47/1.0
Green	0.55/0.5	0.55/0.75	
Red	0.66/0.25	0.67/0.75	0.64/0.5
NIR	0.86/0.25	0.86/0.75	0.86/1.0
NIR	1.24/0.5	1.24/0.75	
Cirrus	1.38/0.5	1.38/0.75	1.38/2.0
SWIR	1.61/0.5	1.61/0.75	1.61/1.0
SWIR	2.11/0.5	2.25/0.75	2.25/2.0

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Dark Target (DT) ABI Aerosol Retrievals

❑ DT relevant for GEOS assimilation effort:

➢ Provides "cloud cleared" reflectance values used for the retrieval (at ~10 km product resolution)

➢ Variable names are same as MODIS

➢ Product files are NetCDF format

❑ Currently processing ABI on GOES-16, and AHI on Himawari-8. Plan is to eventually process entire 5+ years of AHI8, 2+ years of ABI16, and also work with ABI17.

❑ Observations of diurnal aerosol!

20172471045347

AOD

GOES–R ABI
Aerosol Optical Depth

B.C. (Canada) fires of Sept 7, 2017
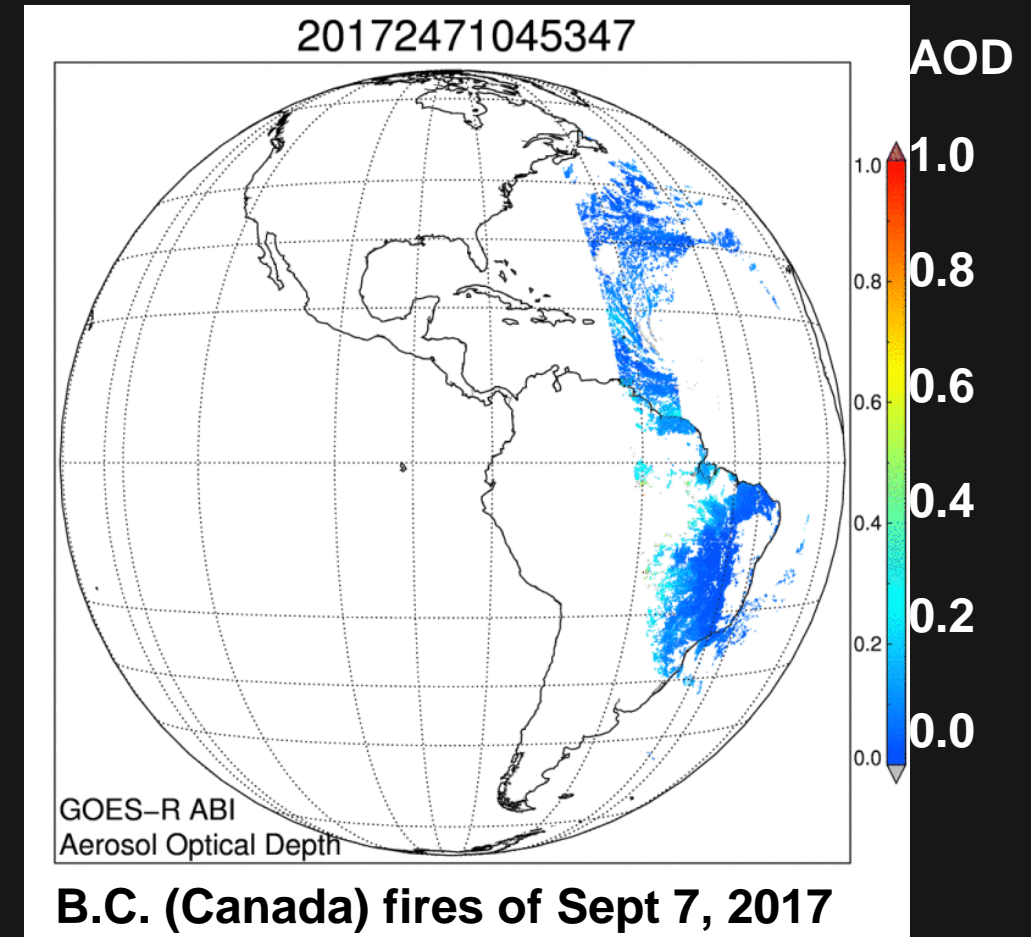
Additional ABI Data Screening for DA
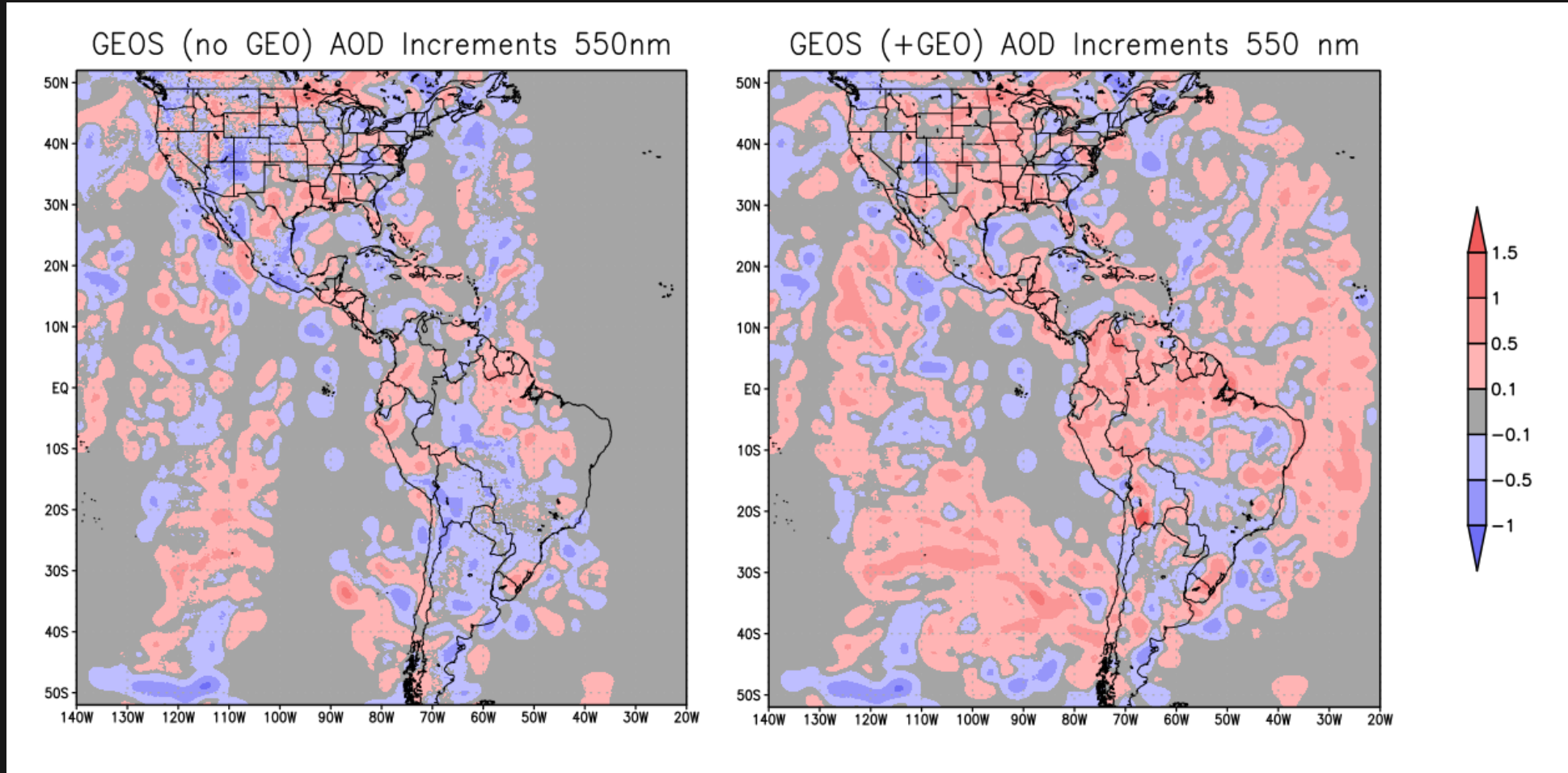
❑ Cloud Screening:
- ➤ Cloud fraction < 0.7 for AOD<2
- ➤ Cloud fraction <0.25 for AOD>2

❑ Sensor Zenith angle < 60 degrees

❑ Over land:
- ➤ Only retrievals with BEST quality mark were included

❑ Over ocean:
- ➤ All retrievals with non-zero quality marks were included
- ➤ Glint angle > 75 deg
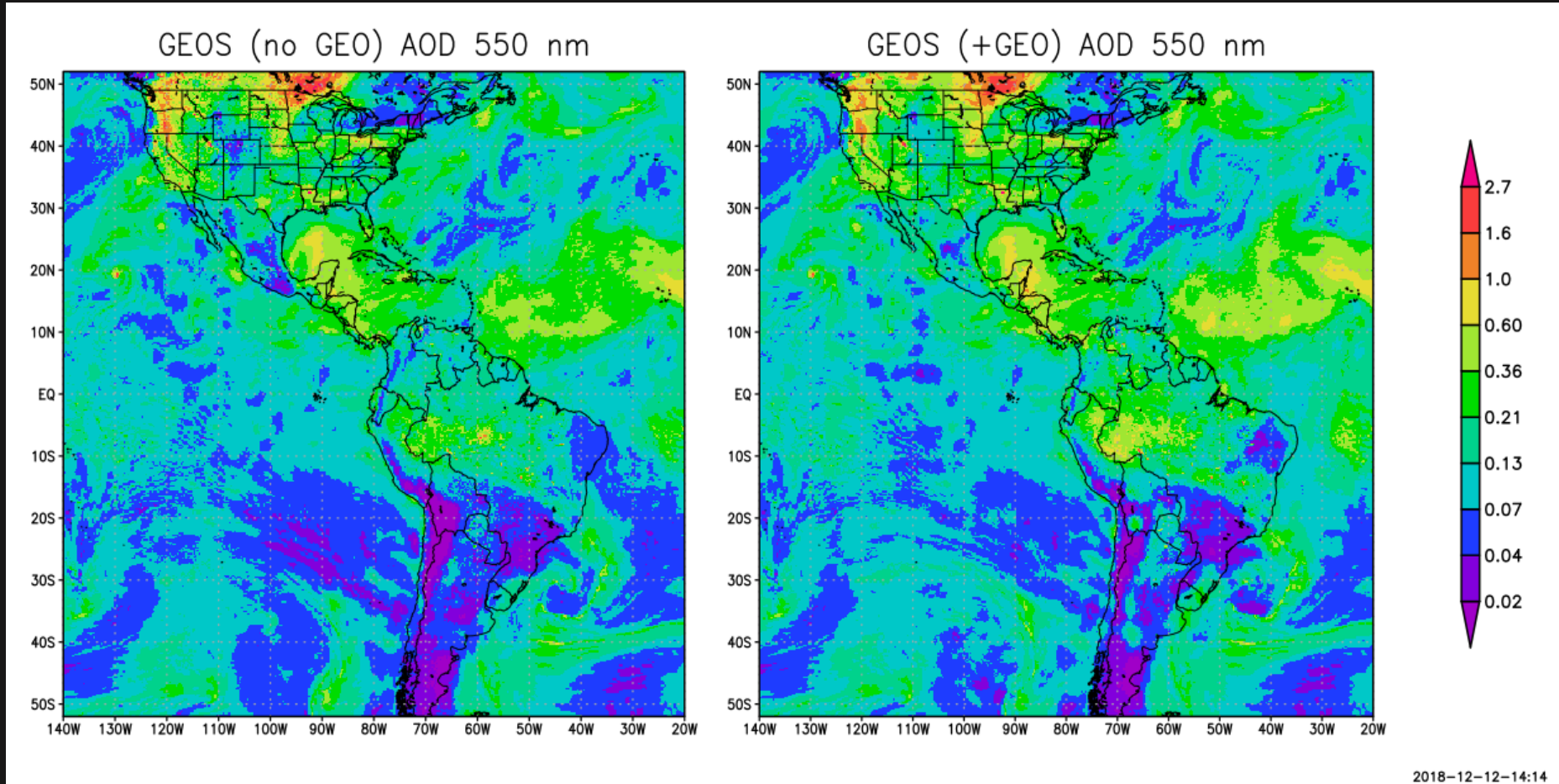- ➤ Scattering angle < 170 deg

The Before Picture
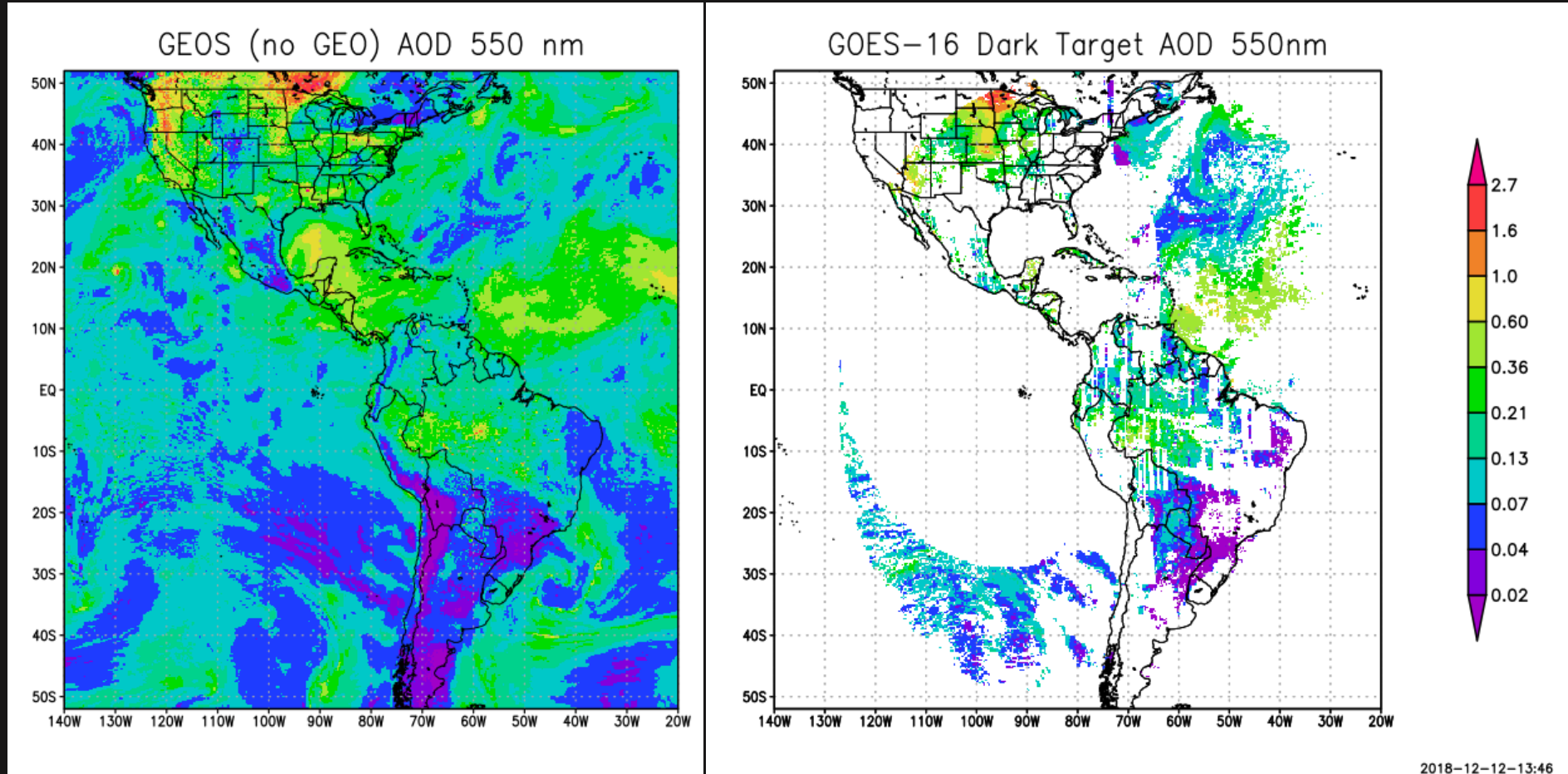
Snapshot 18Z 10Aug2018

AOD Analysis Increments: Impact of ABI

Snapshot 18Z 10Aug2018

AOD Analysis: Impact of ABI

GEOS (no GEO) AOD 550 nm

GEOS (+GEO) AOD 550 nm
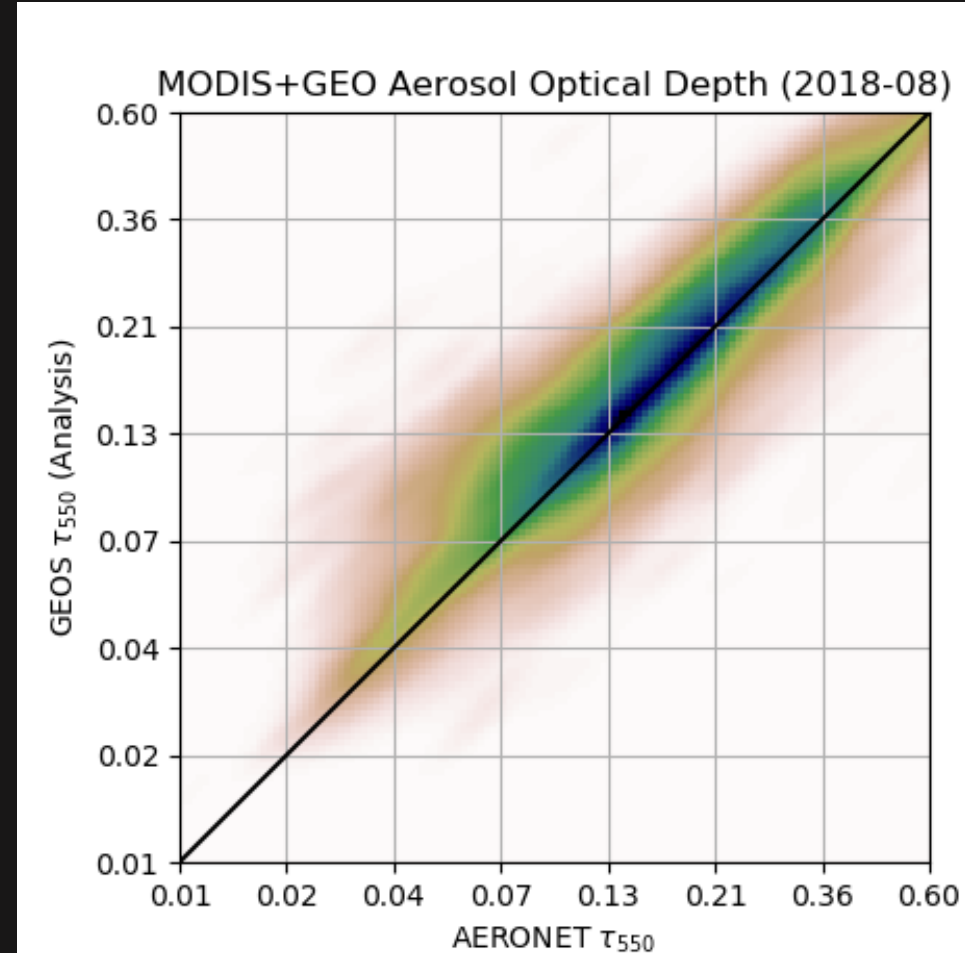
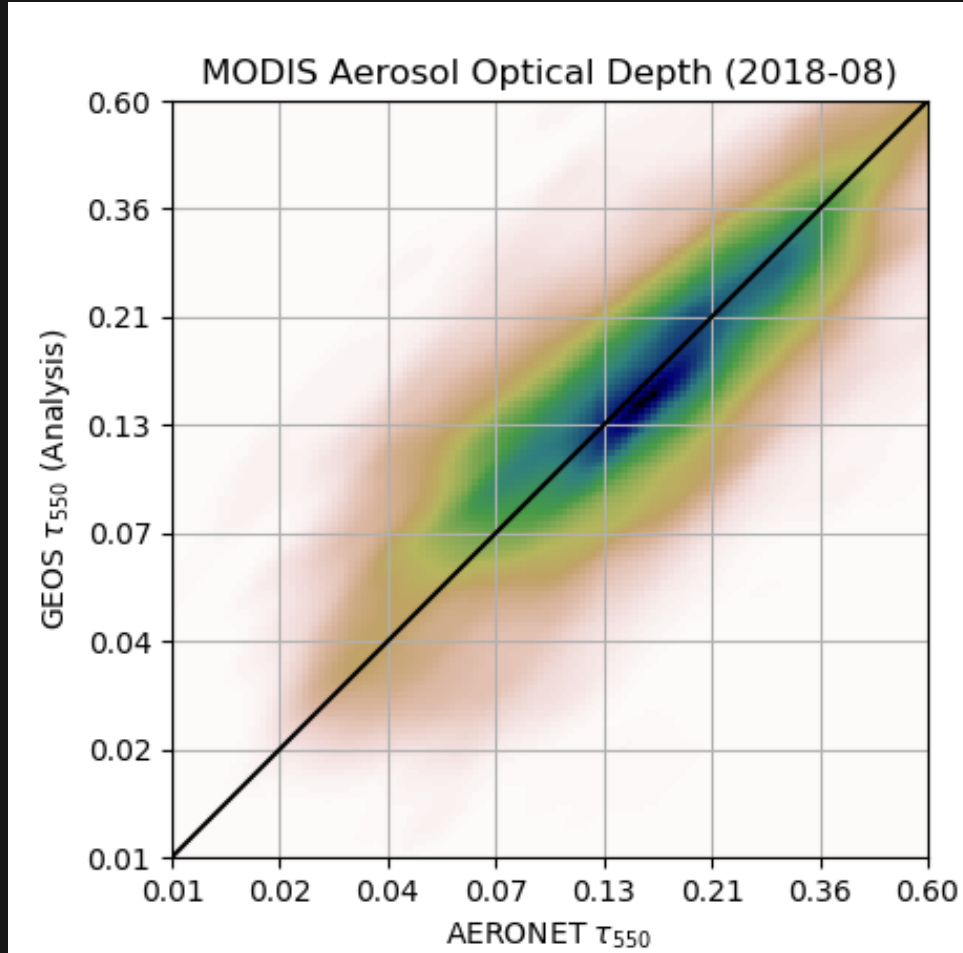2018−12−12−14:14

Snapshot 18Z 10Aug2018

AOD Analysis: Impact of ABI
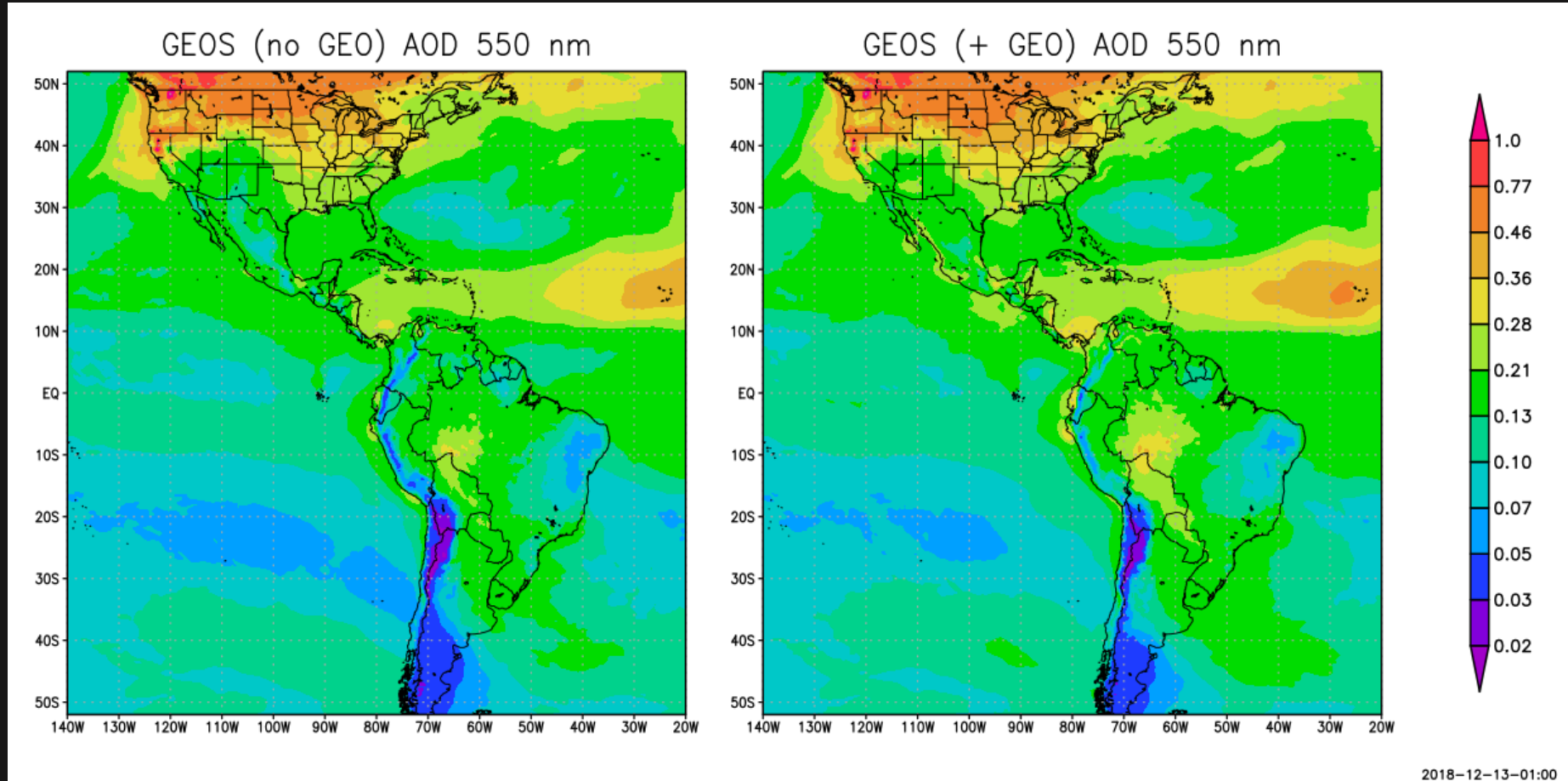
Monthly Means: Aug 2018

AERONET Verification

August 2018

AERONET Verification
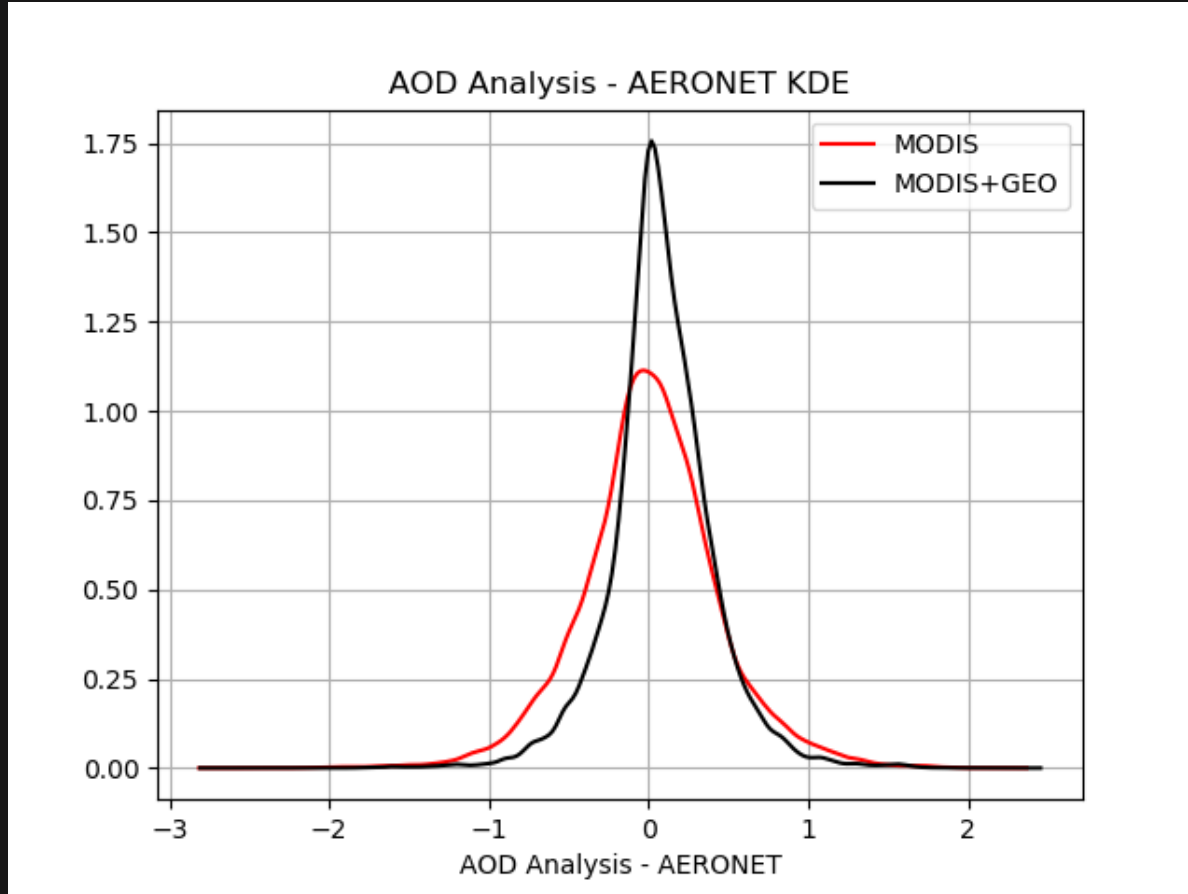
August 2018

Contextual Biases

MODIS+GEO Aerosol Optical Depth (2018-08)

MODIS+GEO Aerosol Optical Depth (2018-08)

Bias correction is necessary
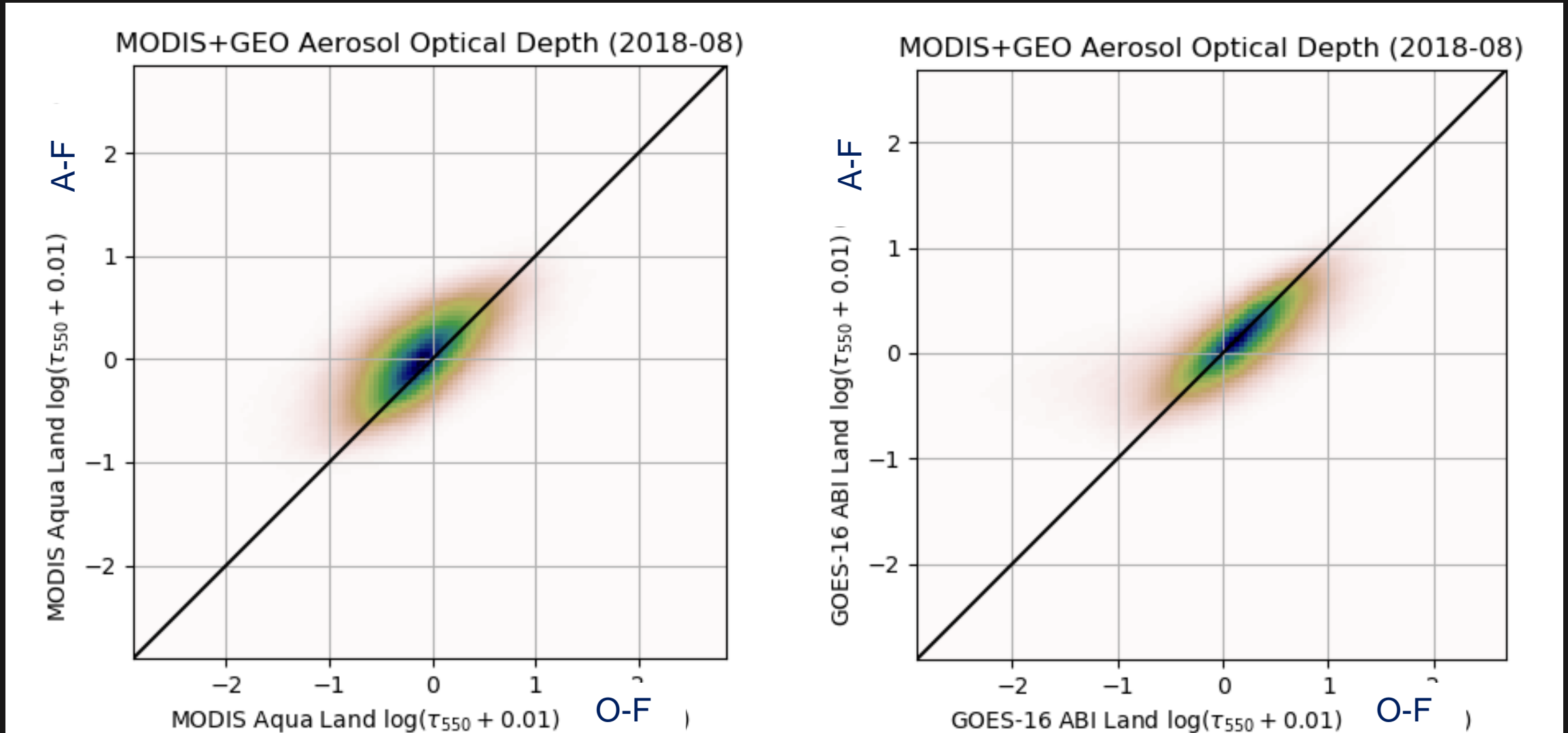
Concluding Remarks

❑ **Dark Target (DT) aerosol retrievals based on MODIS-heritage algorithms by Rob Levy's group**

  ➢ Currently processing ABI on GOES-16, and AHI on Himawari-8.

  ➢ Plan is to eventually process entire 5+ years of AHI8, 2+ years of ABI16, and also work with ABI17

❑ **We have performed a preliminary evaluation of the impact of DT ABI retrievals on the GEOS Aerosol Data Assimilation System for August 2018.**

  ➢ **DT retrievals shows high bias compared to MODIS NNR retrievals currently used in GEOS**

  ➢ **Independent AERONET verification shows clear benefits of assimilating ABI aerosol data, although bias correction may be necessary before implementation.**

  ➢ **Impact on diurnal cycle and Aerosol forecast skill being evaluated.**

❑ **Aerosol analysis migrating to an EnKF based system**

  ➢ New observables: multi-spectral AOD, attenuated backscatter

  ➢ New active/passive sensors: VIIRS, ABI, AHI, TropOMI