

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

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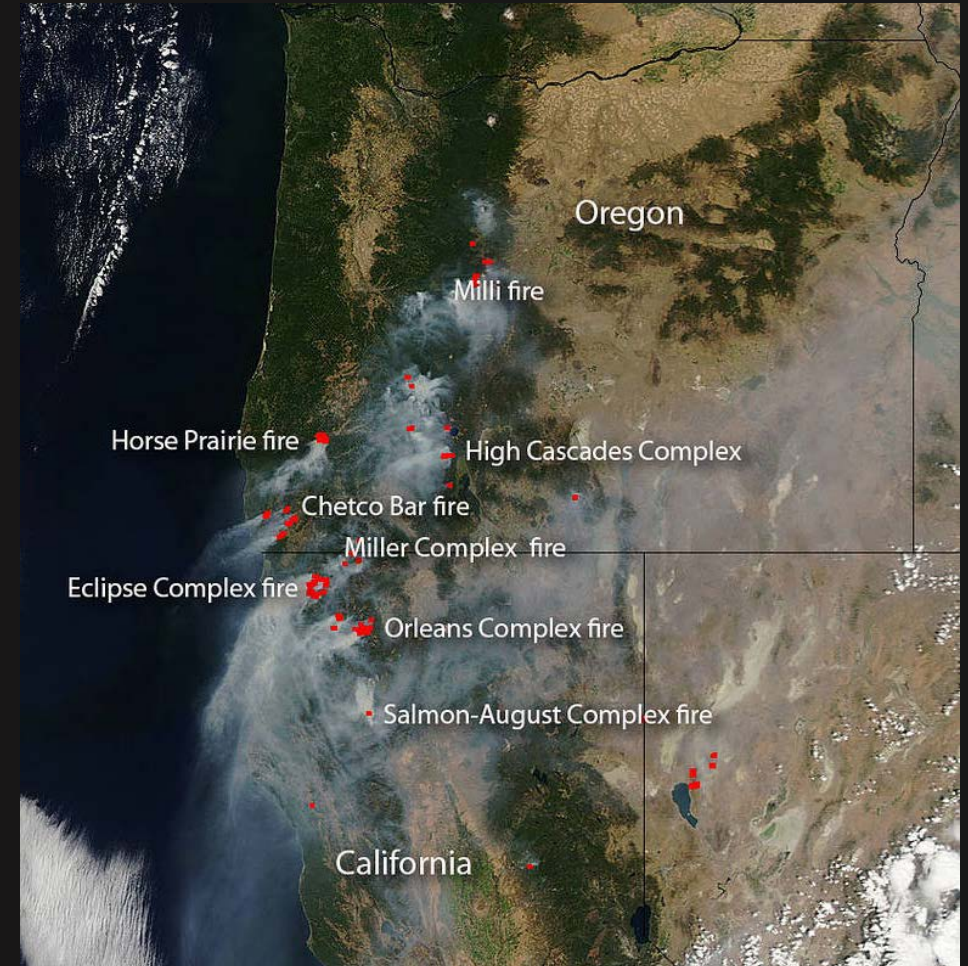
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AGU Fall Meeting 2018

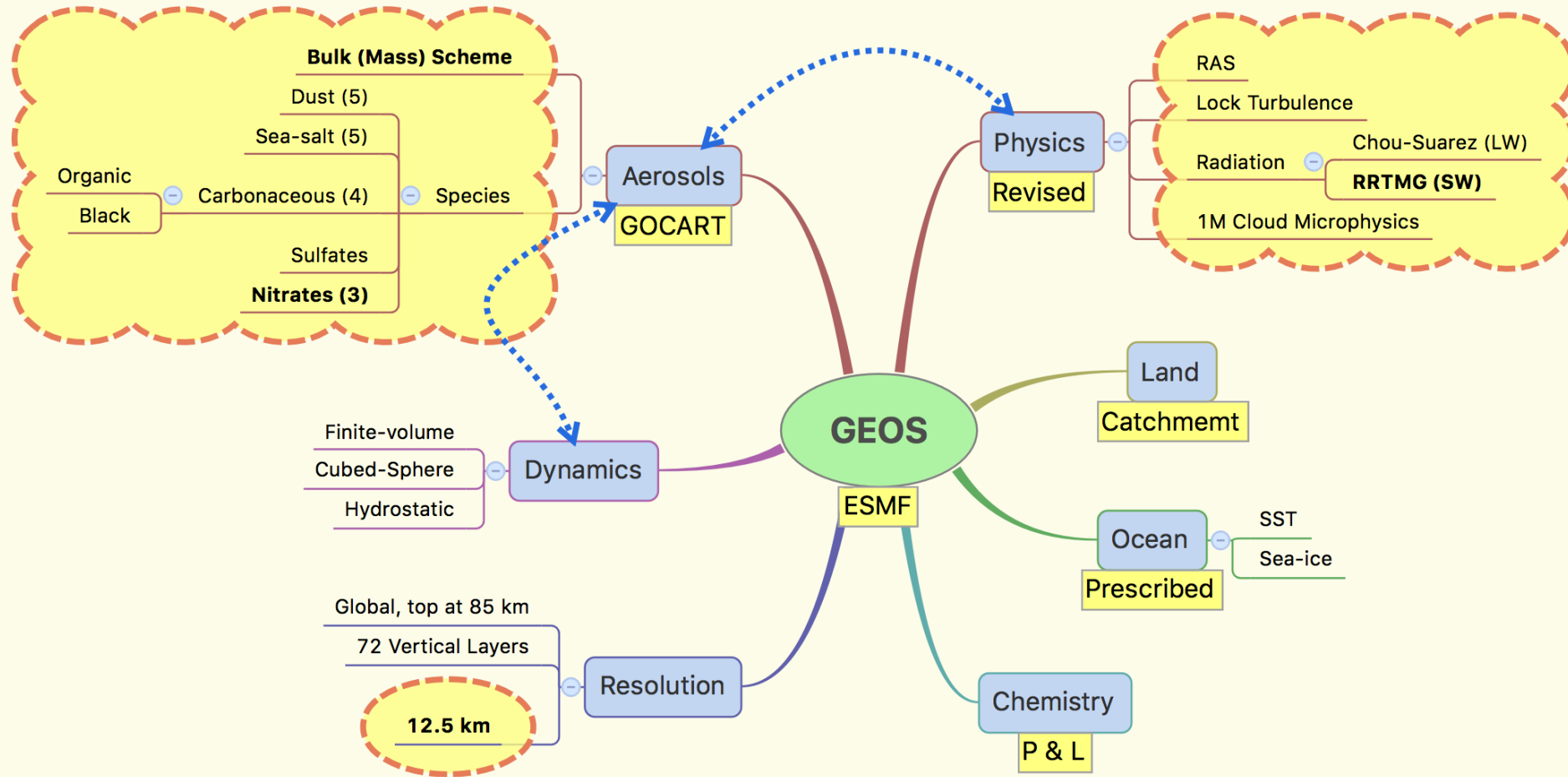
Washington, DC , 13 December 2018

Outline

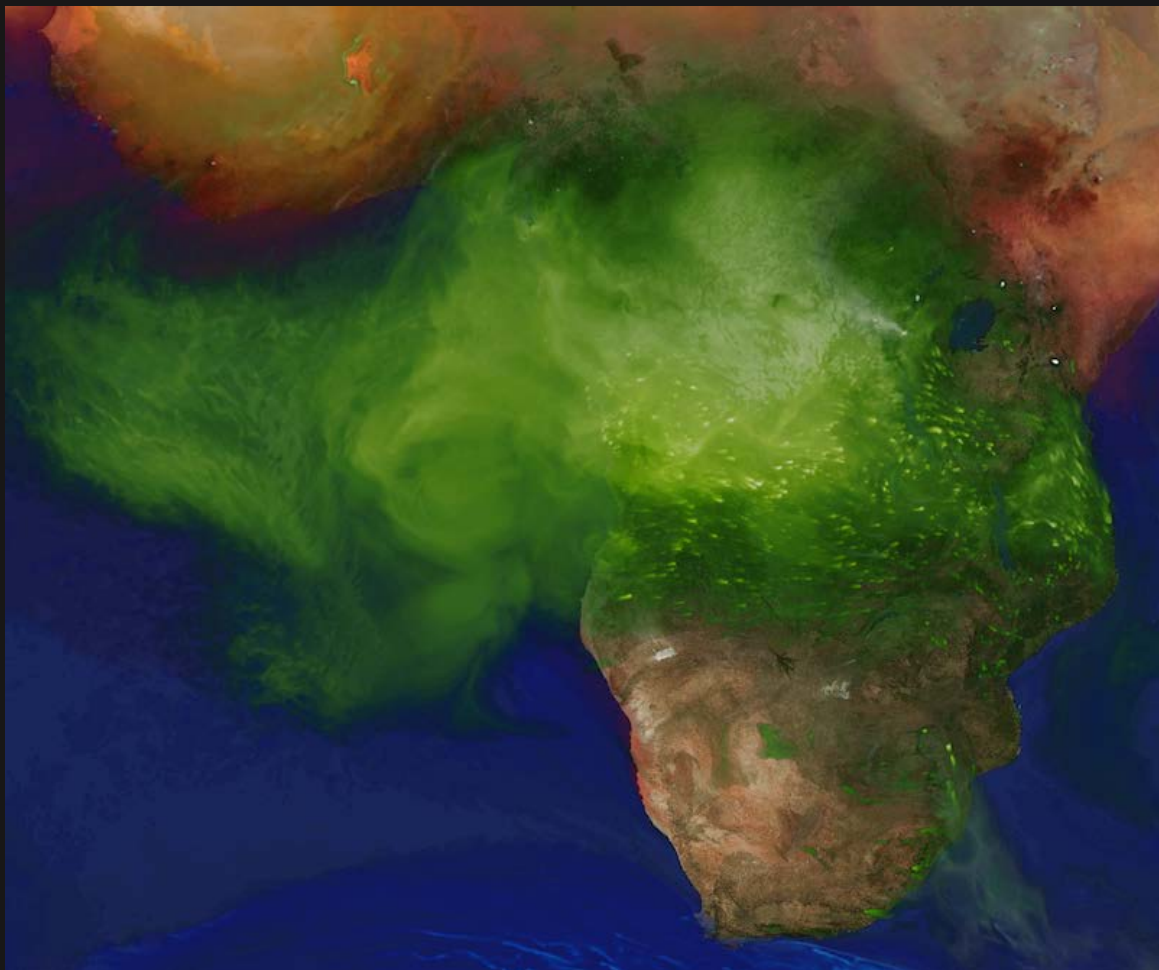
- ❑ **Aerosols in the GEOS Earth System Model**
 - GOCART Aerosols in GEOS-FP
 - QFED: GMAO's NRT biomass burning emission
- ❑ **Aerosol Data Assimilation**
 - Homogenizing the aerosol observing system
 - AOD assimilation with Local Displacement Ensembles
- ❑ **Geostationary Aerosol Retrievals from ABI**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



GEOS FP Configuration



Biomass Burning Emissions



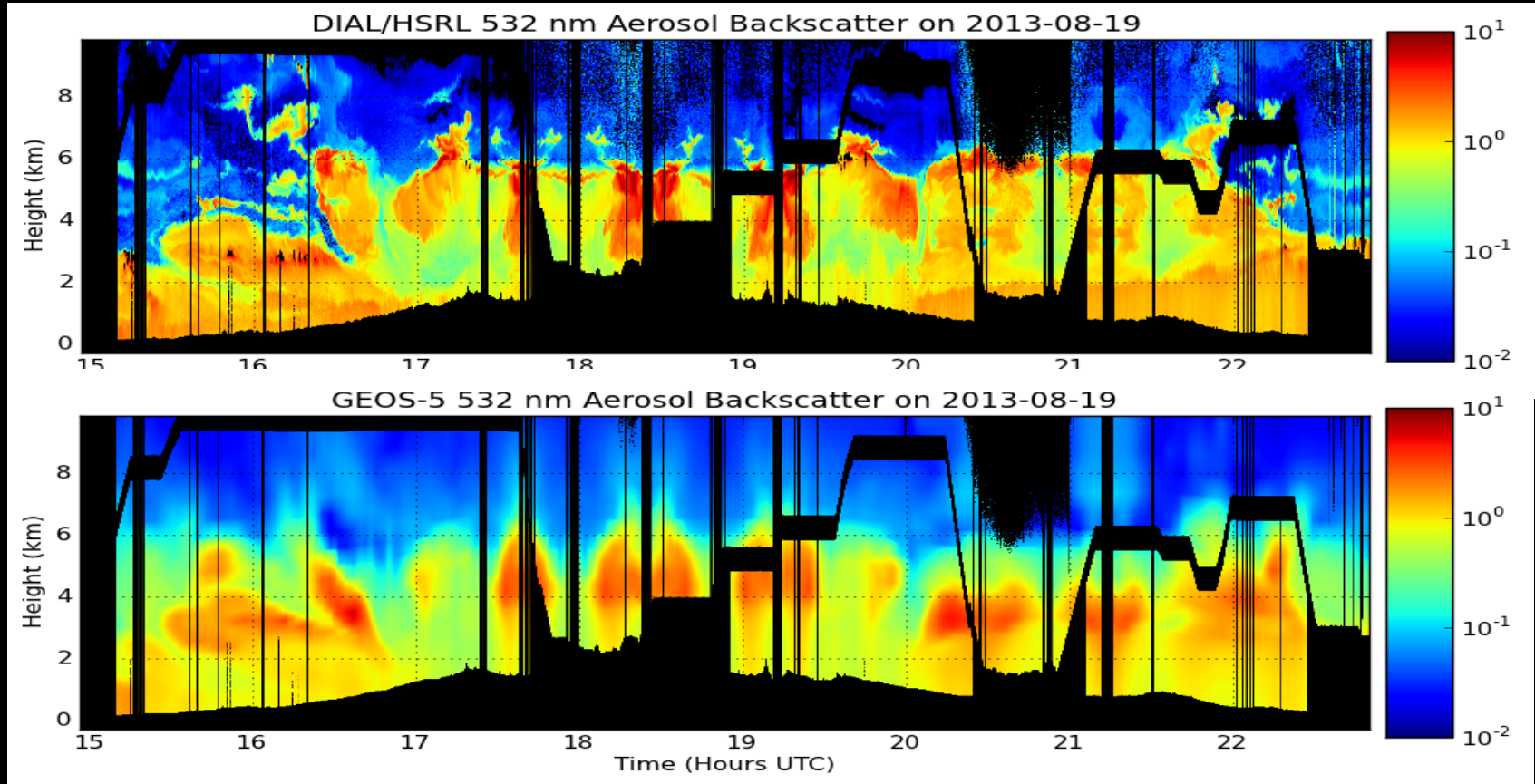
QFED: Quick Fire Emission Dataset

- ❑ 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:

$$\begin{aligned}\tau^a &\equiv Hq^a = H(q^b + \delta q^a) \\ &= \tau^b + \delta\tau^a\end{aligned}$$

GOING TO 3D CONCENTRATIONS

- Based on error covariances:

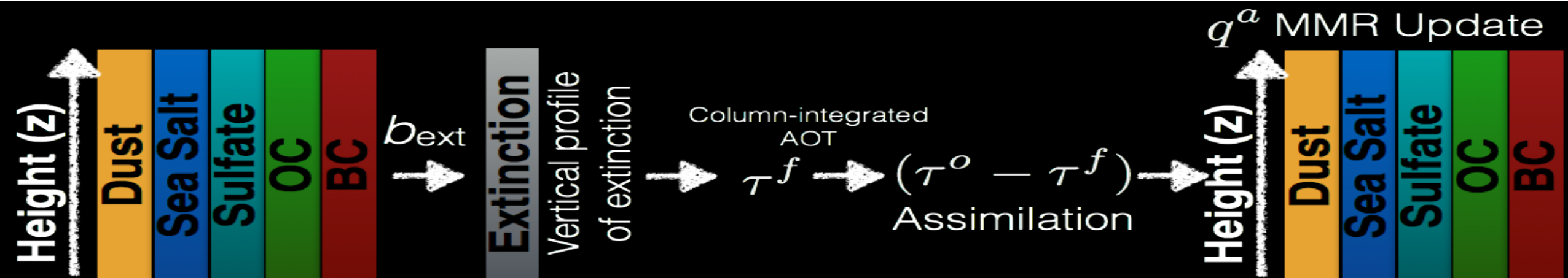
$$\delta q^a = BH^T (HBH^T)^{-1} \delta\tau^a$$

- Using ensemble perturbations,

$$\delta q^a = XY^T (YY^T)^{-1} \delta\tau^a$$

- Current GEOS uses Local Displacement Ensembles (LDE), in 1D

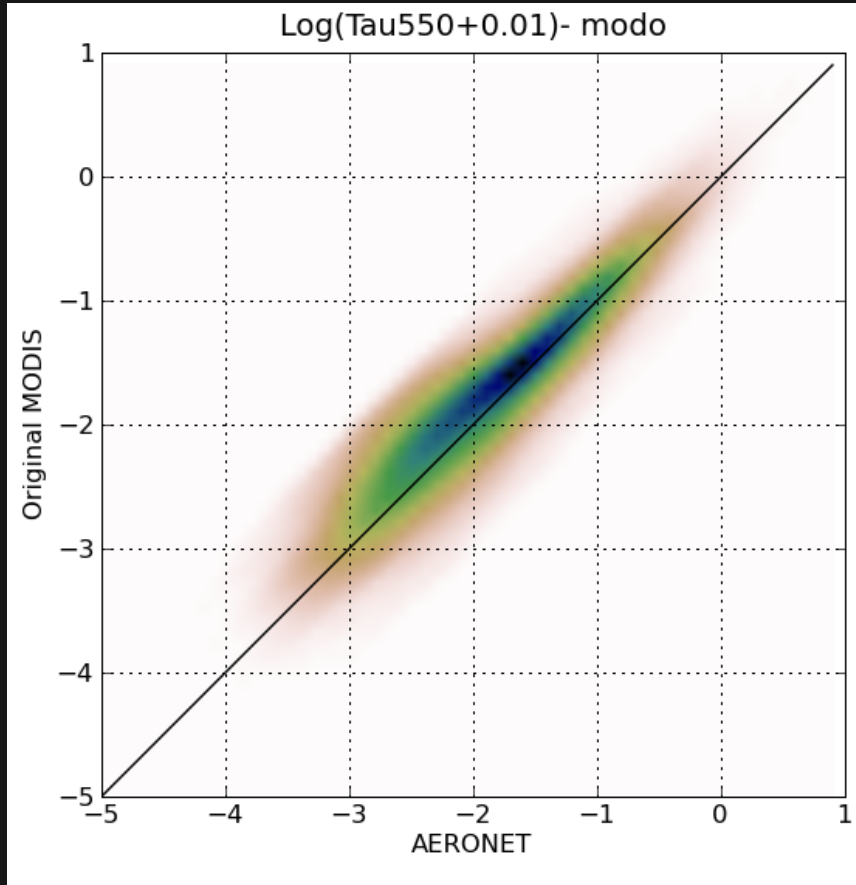
- (Could also use actual aerosol ensembles)



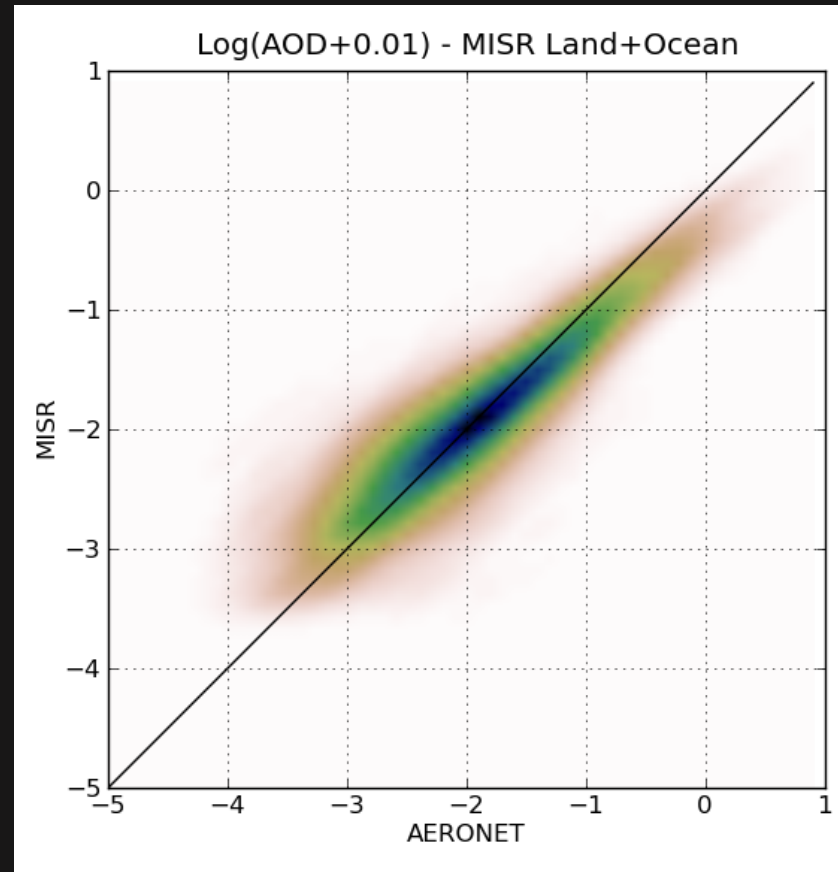
MODIS/MISR vs. AERONET

$$\eta = \log(\text{AOD}_{550} + 0.01)$$


C5 MODIS-Terra (Ocean)



MISR (Ocean+Land)



Neural Net for AOD₅₅₀ 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

- $\eta = \log(\text{AOD} + 0.01)$

□ 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

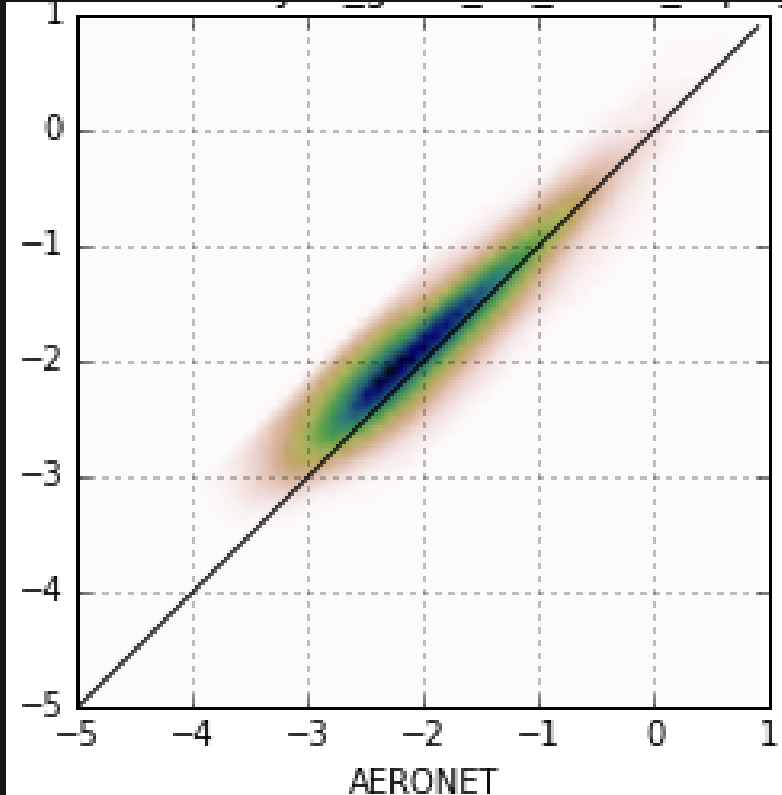
- $\eta = \log(\text{AOD} + 0.01)$



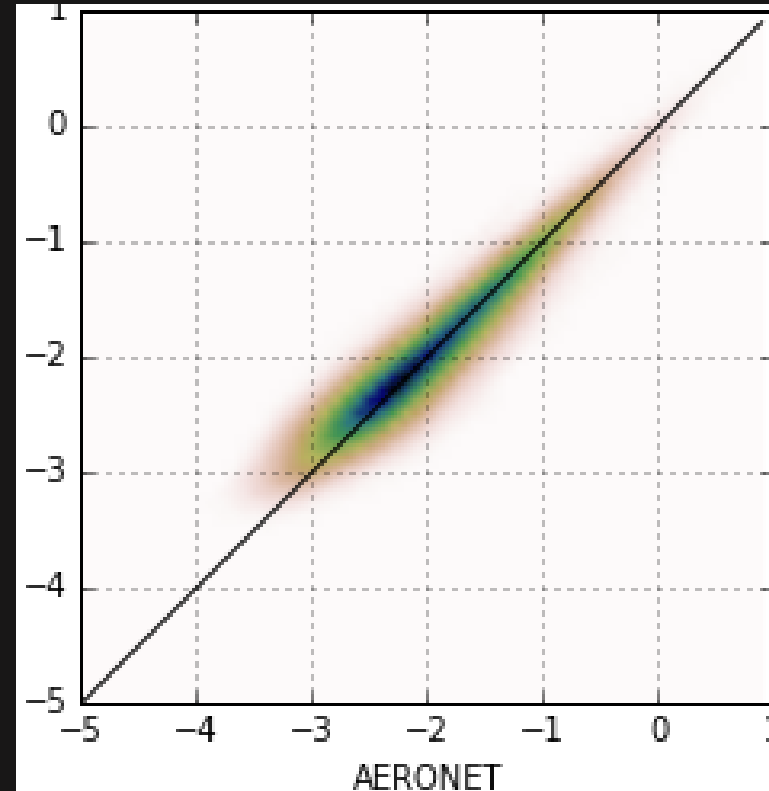
Observational Bias

$$\eta = \log(\text{AOD}_{550} + 0.01)$$

MODIS-AQUA C6 OCEAN AOD₅₅₀



BIAS CORRECTED NNR AOD₅₅₀



MODIS Neural Net AOD₅₅₀ Retrievals trained on AERONET

Dark Target (DT) ABI Aerosol Retrievals

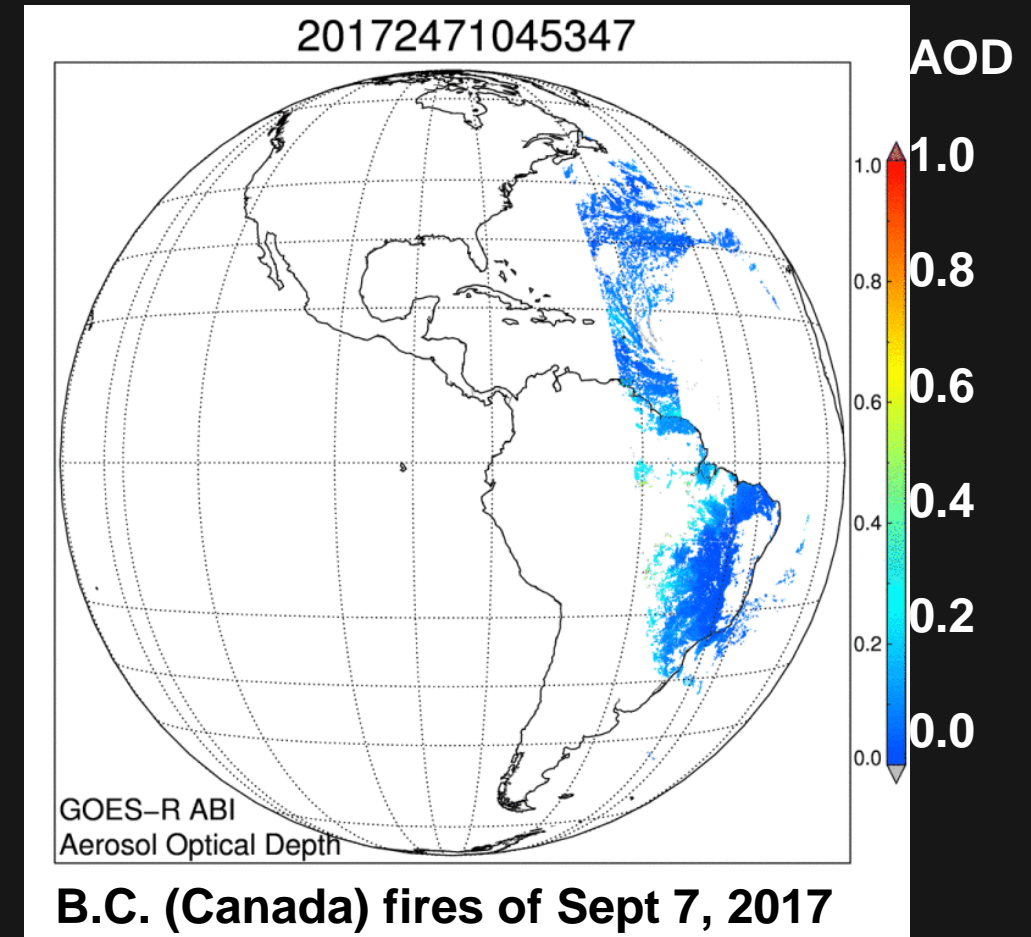
- ❑ Algorithm is adapted from MODIS-DT and VIIRS-DT
 - Uses wavelengths in VIS, NIR and SWIR for aerosol retrieval and TIR for cloud masking.
 - Accounts for wavelength shifts and gas absorptions
 - Retrieves on NxN boxes of native-resolution pixels → product is ~10 km resolution.
 - Like MODIS-DT, retrieves
 - ✓ 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

Dark Target (DT) ABI Aerosol Retrievals

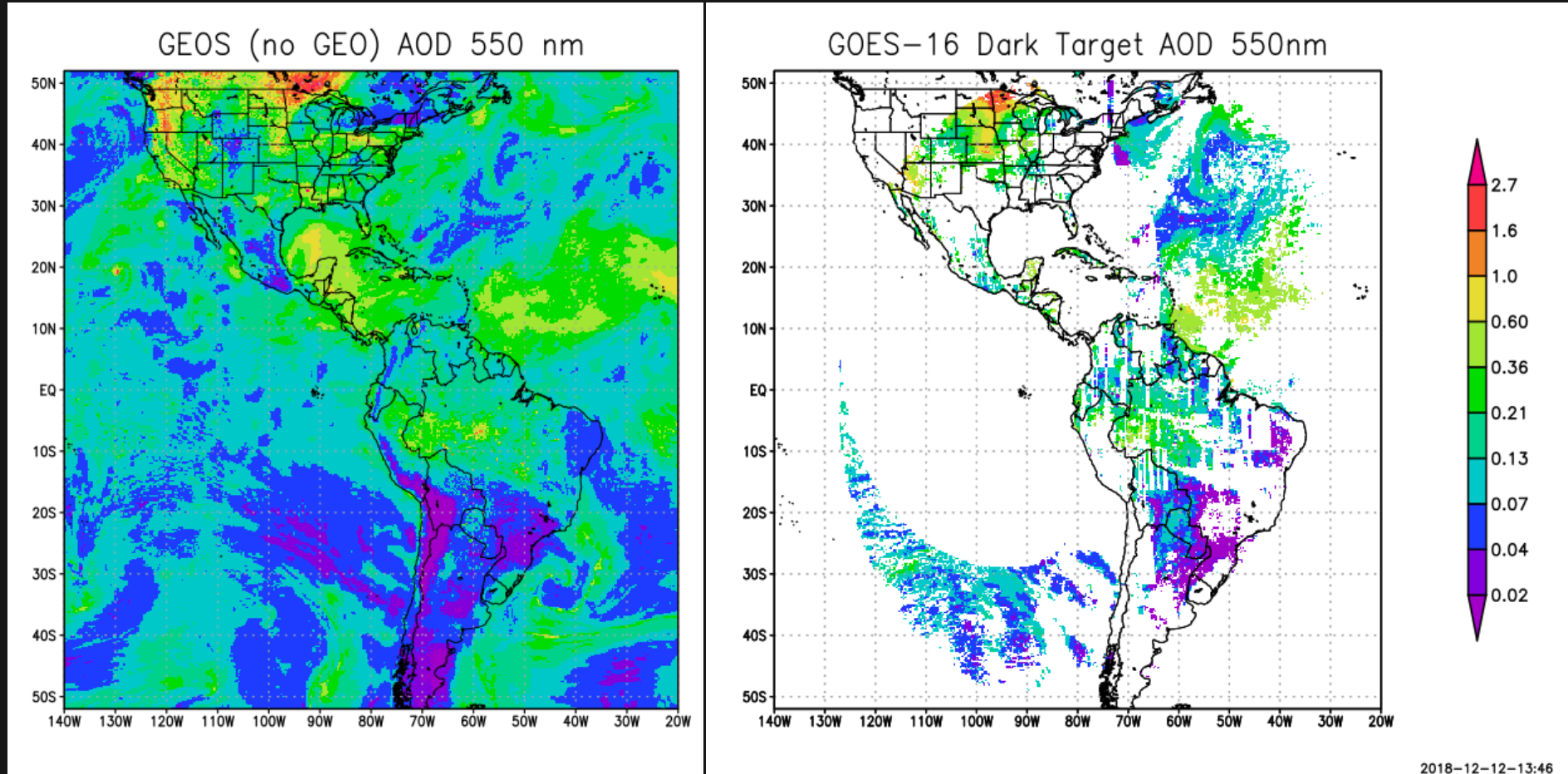
- ❑ DT relevant for GEOS assimilation effort:
 - Provides “cloud cleared” reflectance values used for the retrieval (at ~10 km product resolution)
 - Variable names are same as MODIS
 - Product files are NetCDF format
- ❑ Currently processing ABI on GOES-16, and AHI on Himawari-8. Plan is to eventually process entire 5+ years of AHI8, 2+ years of ABI16, and also work with ABI17.
- ❑ Observations of diurnal aerosol!



Additional ABI Data Screening for DA

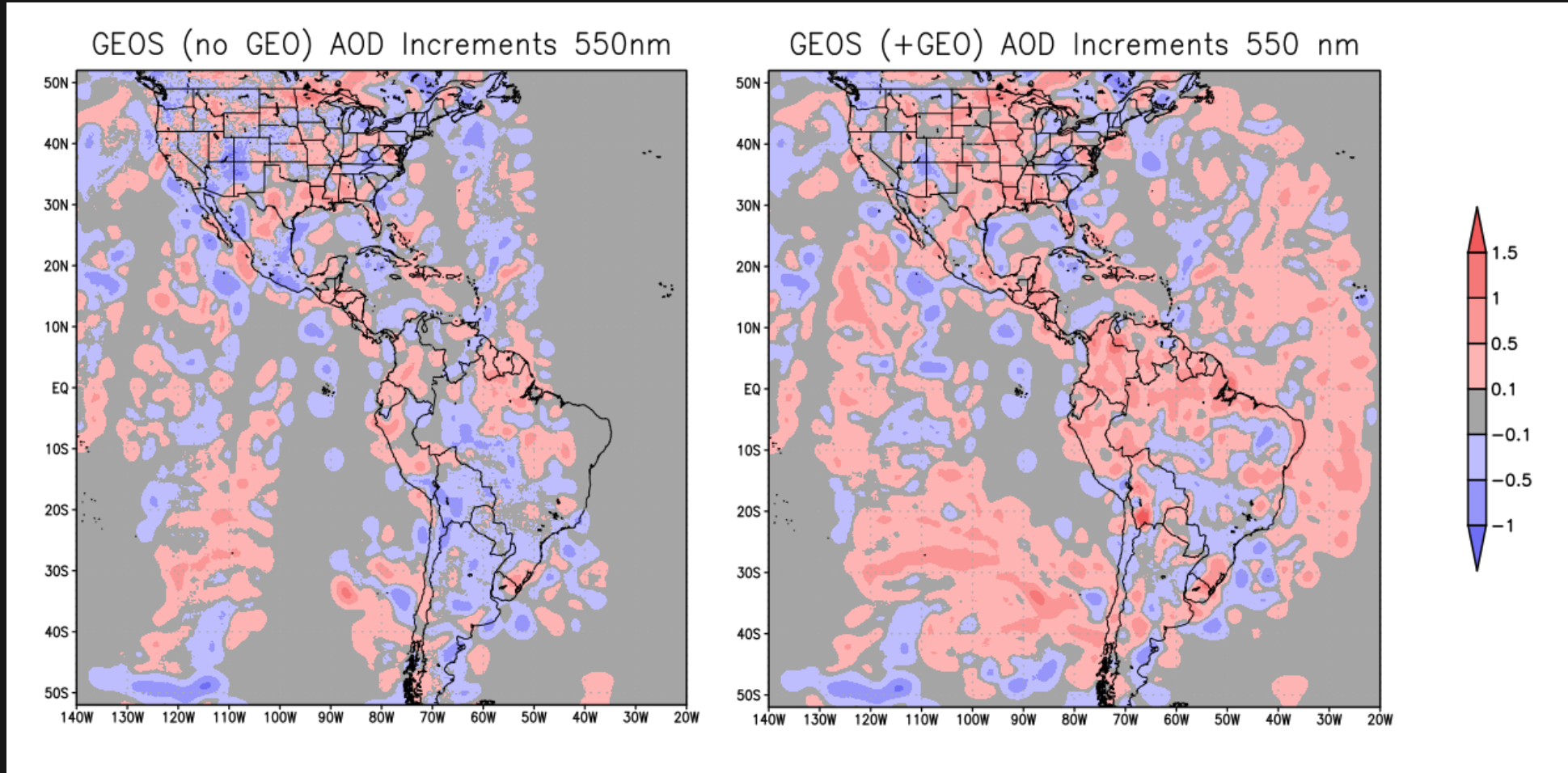
- ❑ Cloud Screening:
 - Cloud fraction < 0.7 for $AOD < 2$
 - Cloud fraction < 0.25 for $AOD > 2$
- ❑ Sensor Zenith angle < 60 degrees
- ❑ Over land:
 - Only retrievals with BEST quality mark were included
- ❑ Over ocean:
 - All retrievals with non-zero quality marks were included
 - Glint angle > 75 deg
 - Scattering angle < 170 deg

The Before Picture



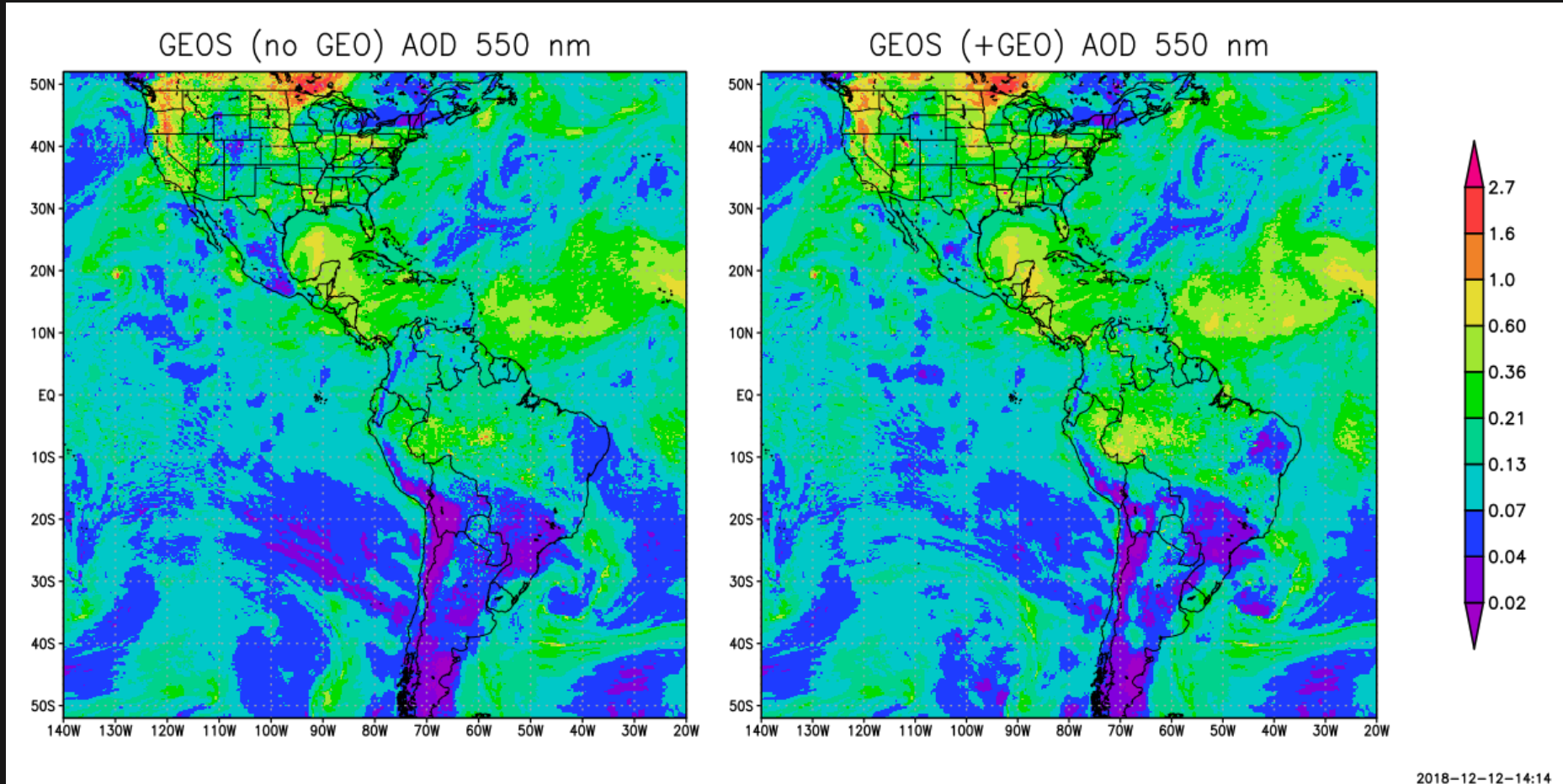
Snapshot 18Z 10Aug2018

AOD Analysis Increments: Impact of ABI



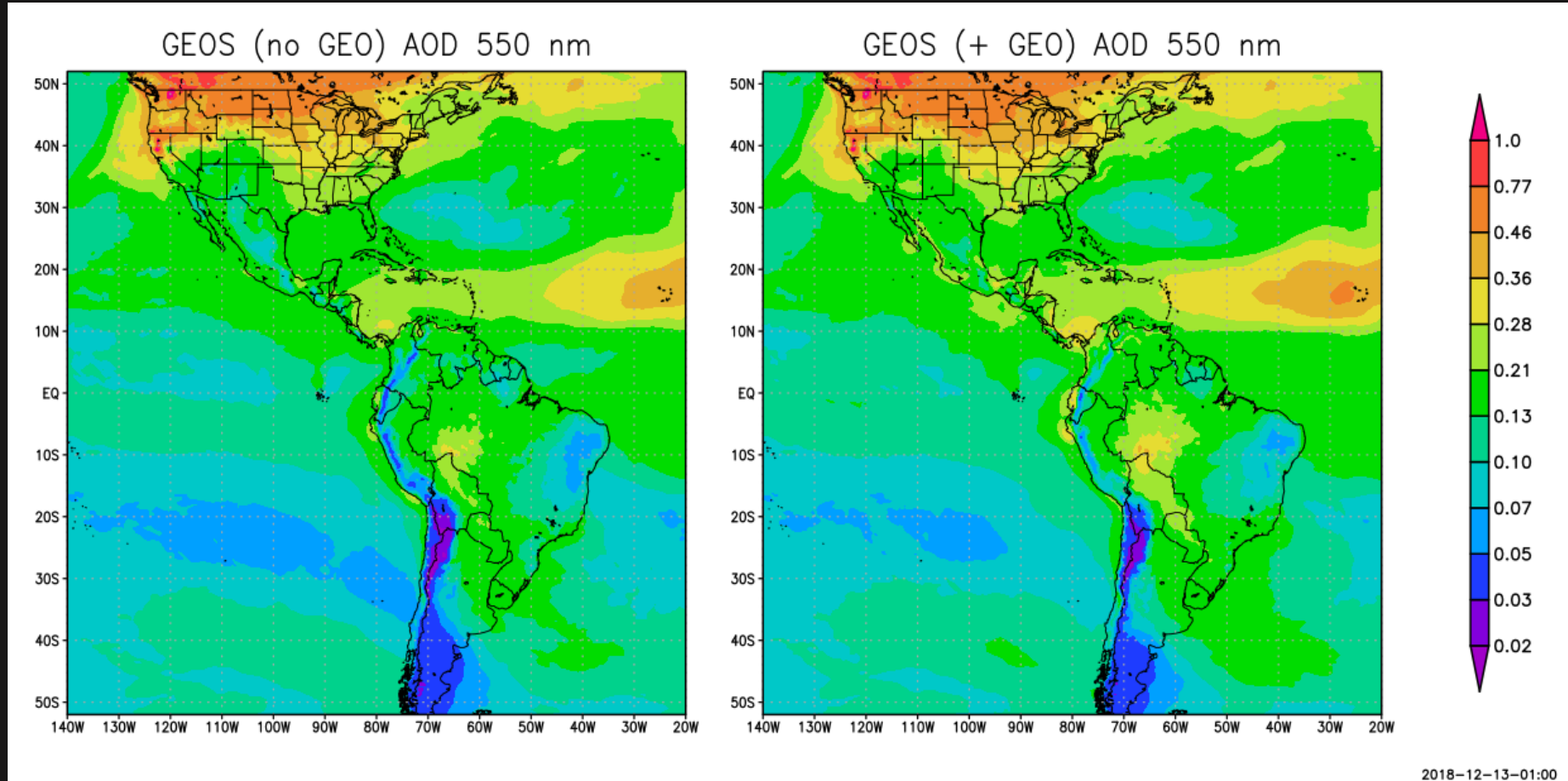
Snapshot 18Z 10Aug2018

AOD Analysis: Impact of ABI



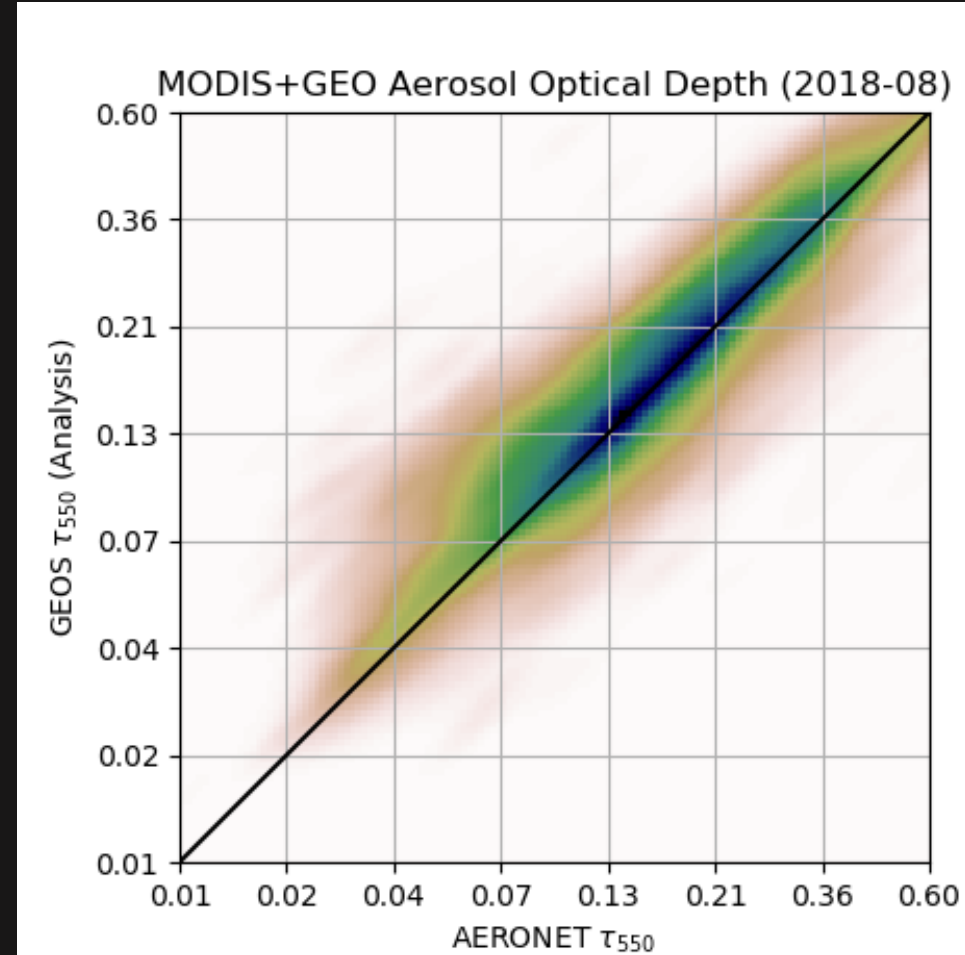
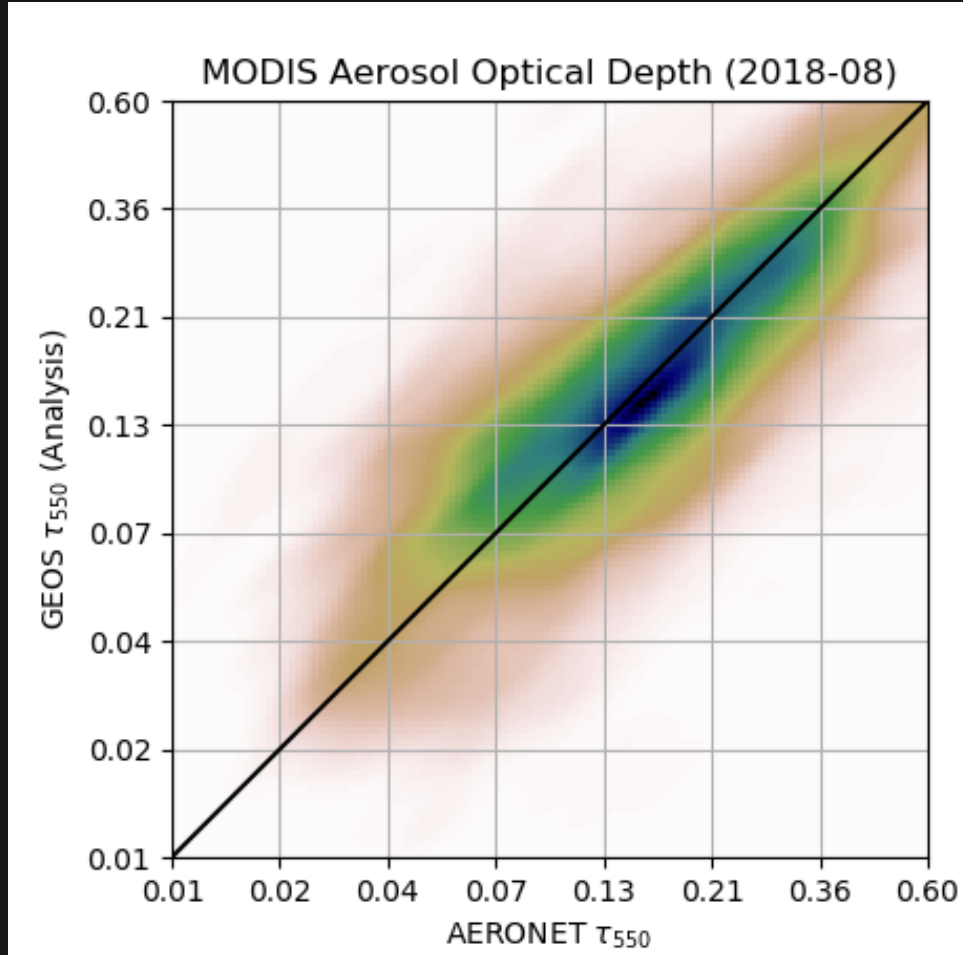
Snapshot 18Z 10Aug2018

AOD Analysis: Impact of ABI



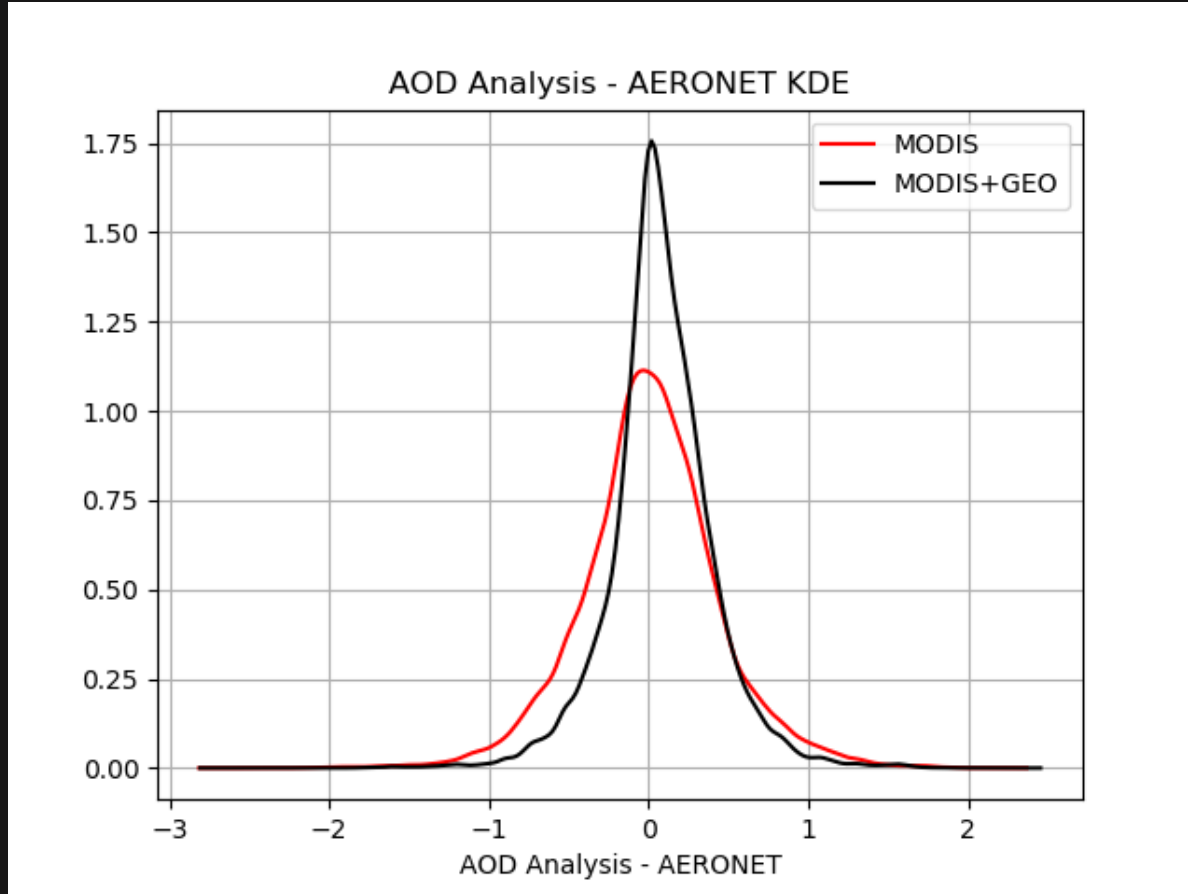
Monthly Means: Aug 2018

AERONET Verification



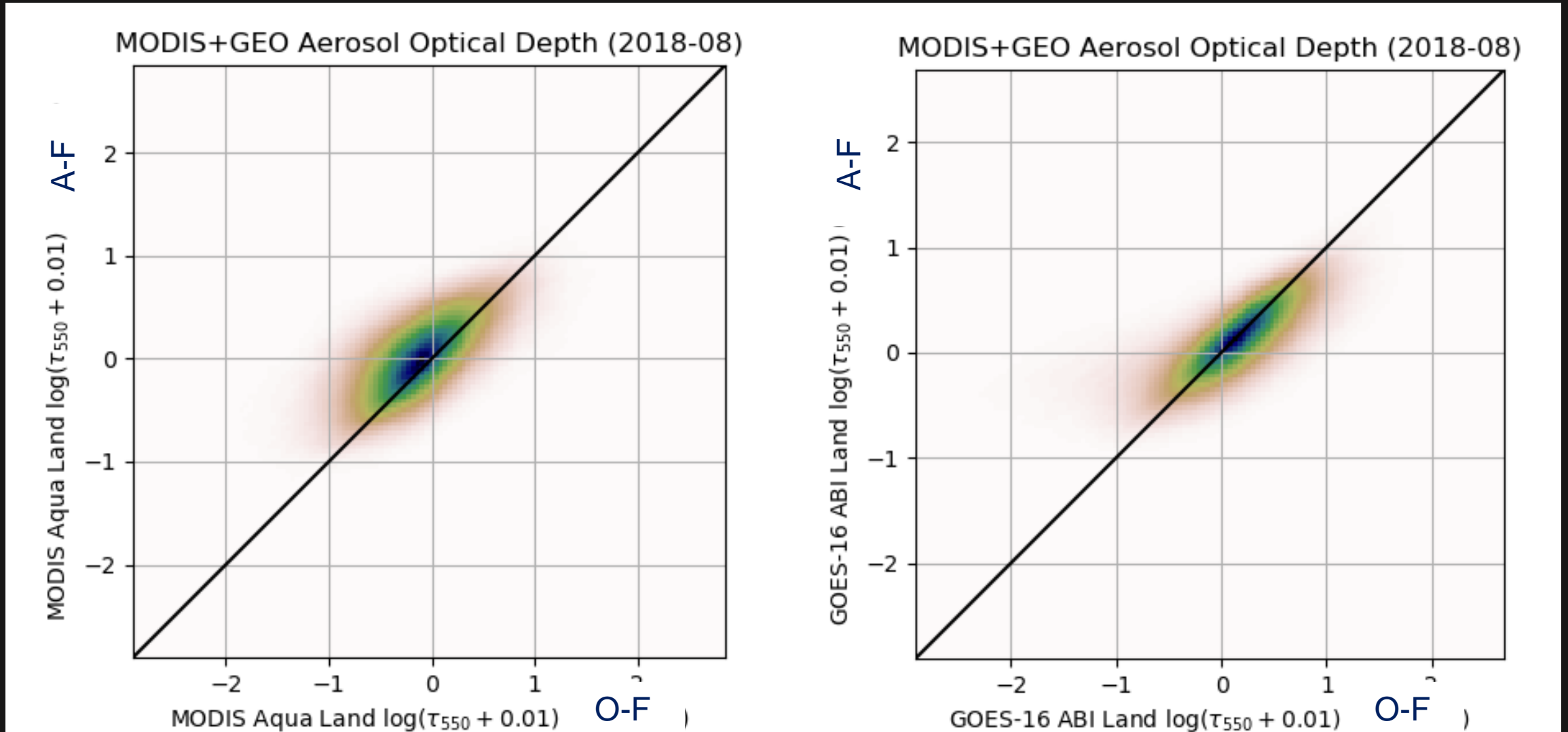
August 2018

AERONET Verification



August 2018

Contextual Biases



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