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

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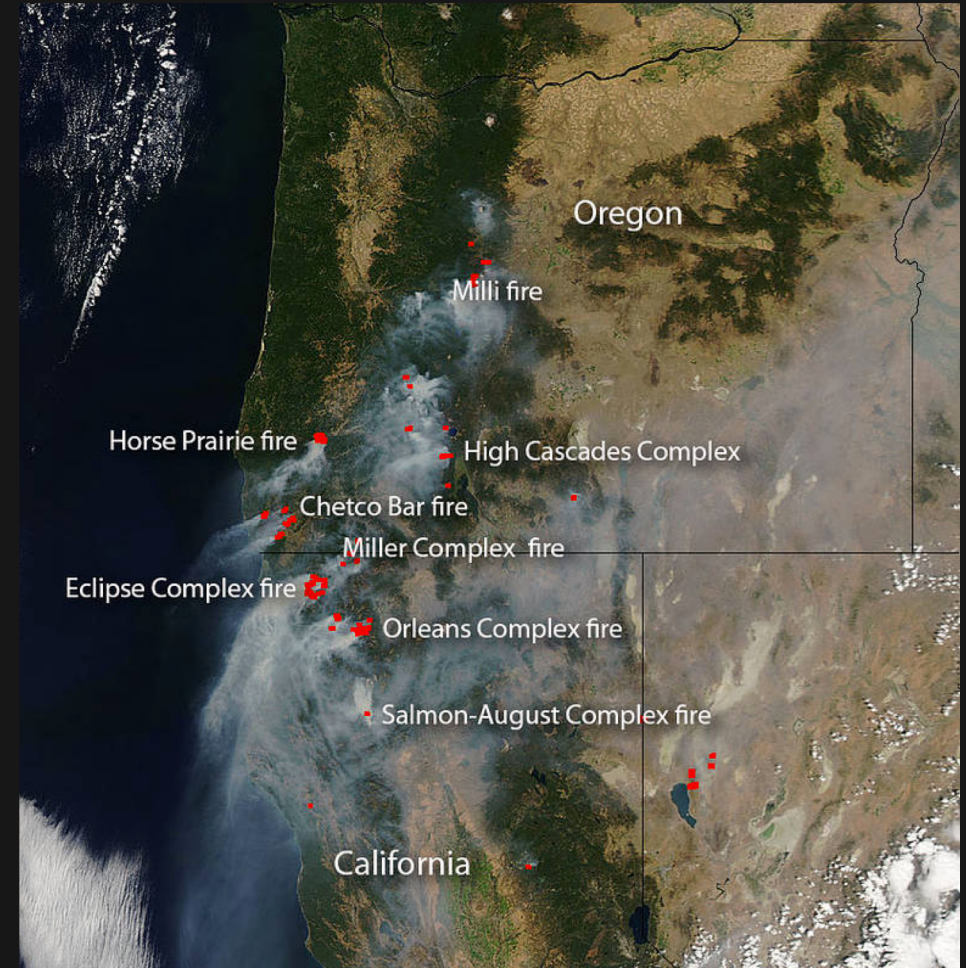GMAO and Climate and Radiation Lab

NASA/Goddard Space Flight Center

arlindo.m.dasilva@nasa.gov

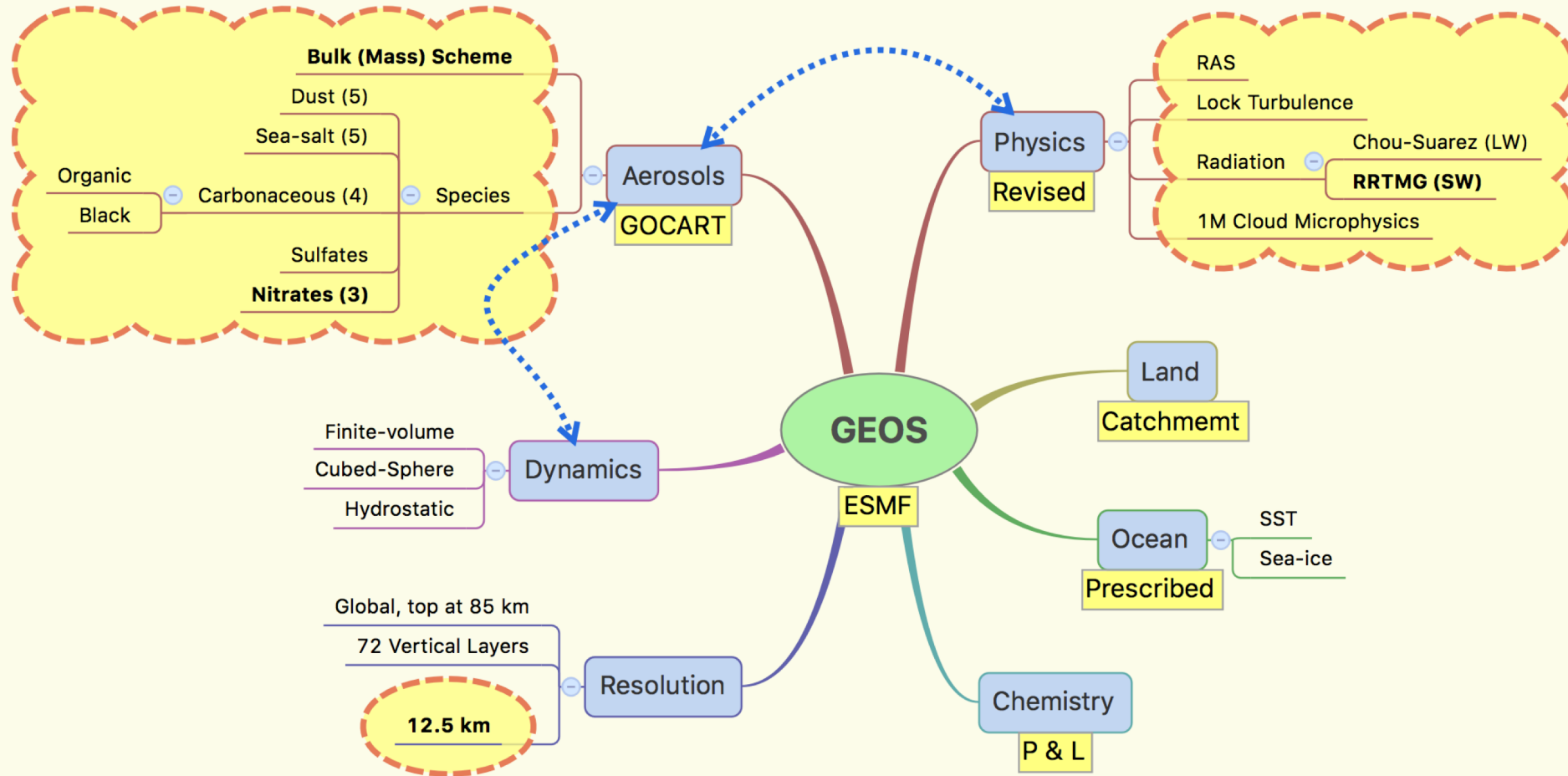*CEOS AC-VC-15 – Tokyo, Japan*

*12 June 2019*

# 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**

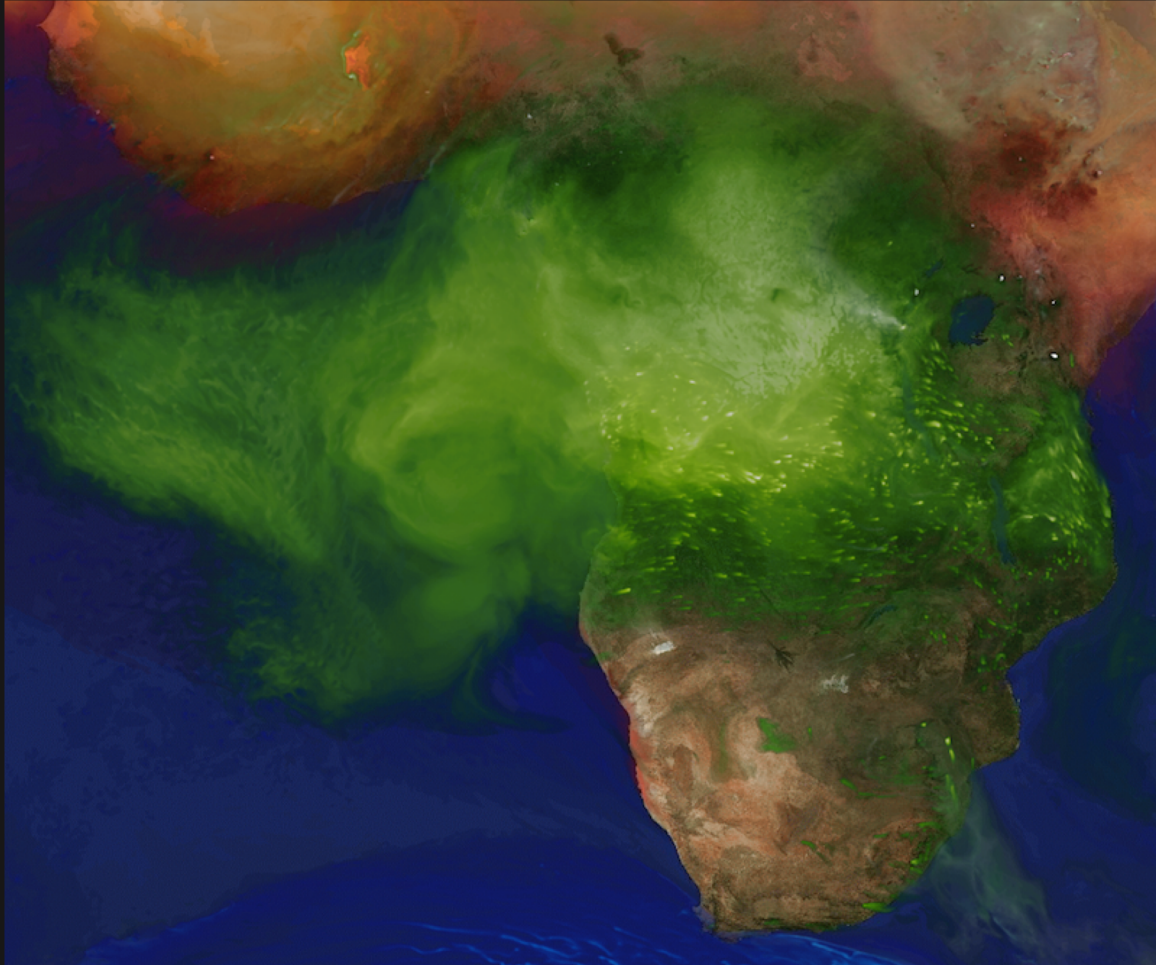- ❑ **Impact of ABI aerosol data on GEOS analysis**

- ❑ **Concluding Remarks**

# GEOS FP Configuration

# Field Campaign Support
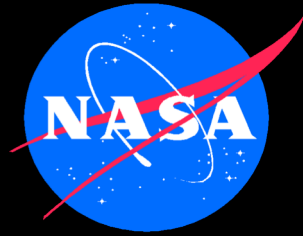


- Global 5-day chemical forecasts
  - ✓ O3, aerosols, CO, CO2, SO2
  - ✓ Nominally 12.5 km
- Driven by real-time biomass emissions from MODIS FRP (QFED)
- Constituents transported on-line, interactively
- Since 2007 supported several field missions including TC4, ARCTAS , GloPac, ATTREX, DISCOVER-AQ, HS3 , SEAC4RS, ATom, ORACLES, etc.
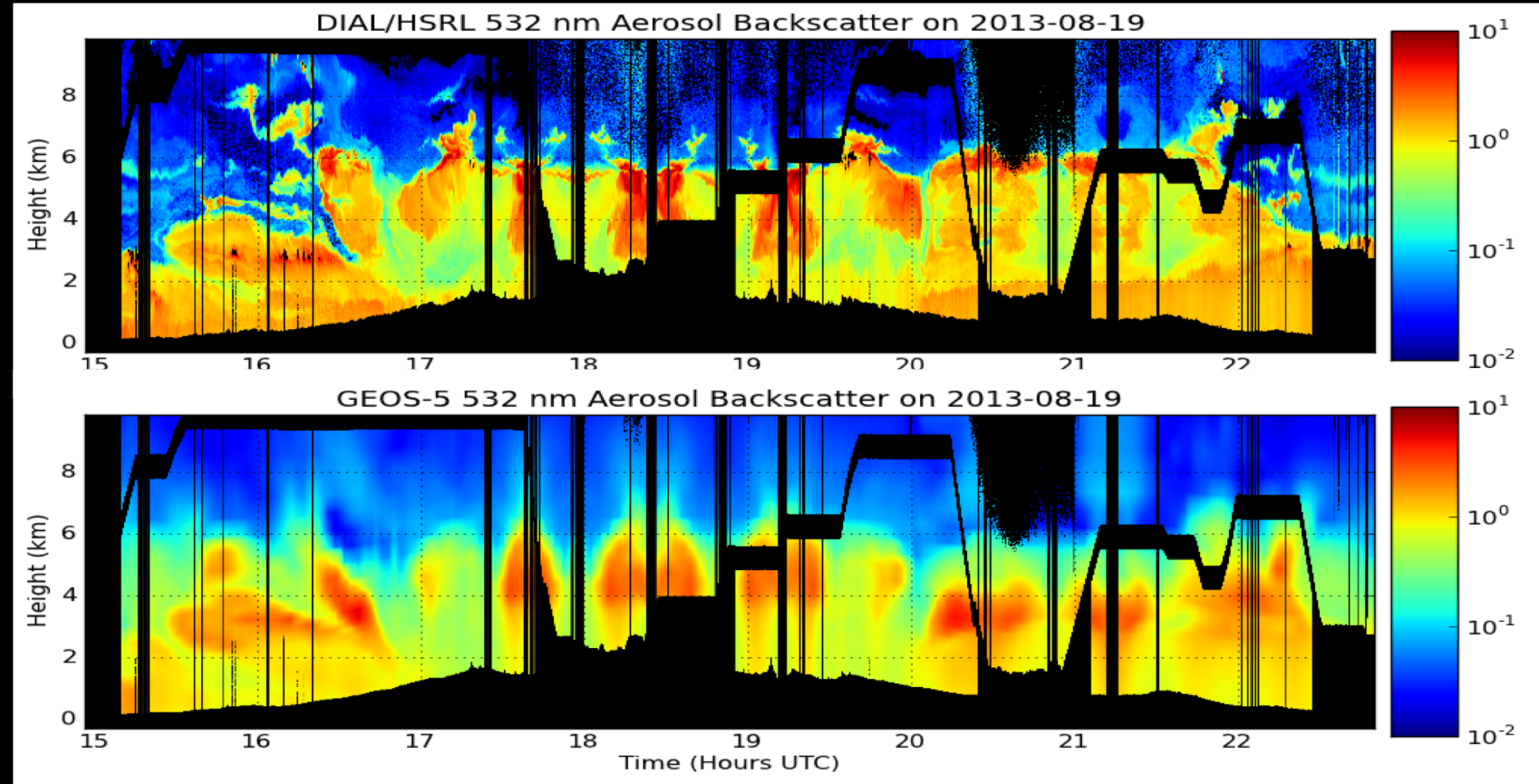


Comparison of observed (top) and simulated (bottom) aerosol backscatter for a slight during the 2013 SEAC4RS campaign.

# 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:

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

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

## GOING TO 3D CONCENTRATIONS
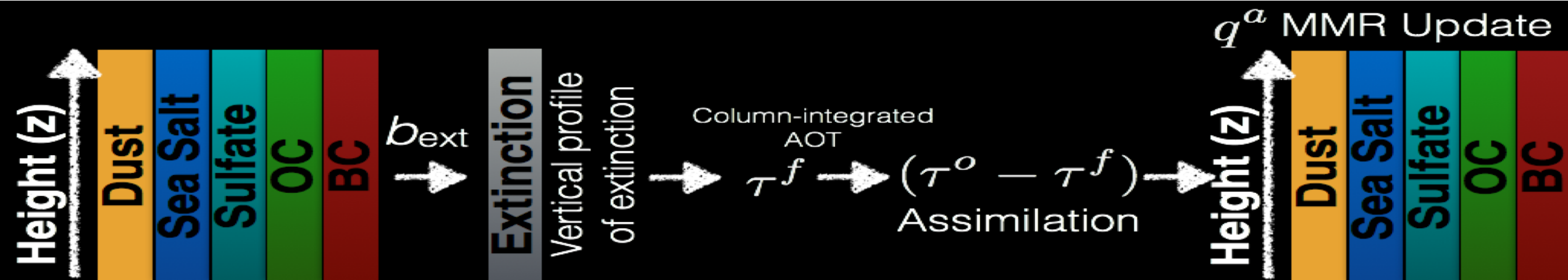
- Based on error covariances:

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

- Using ensemble perturbations,

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

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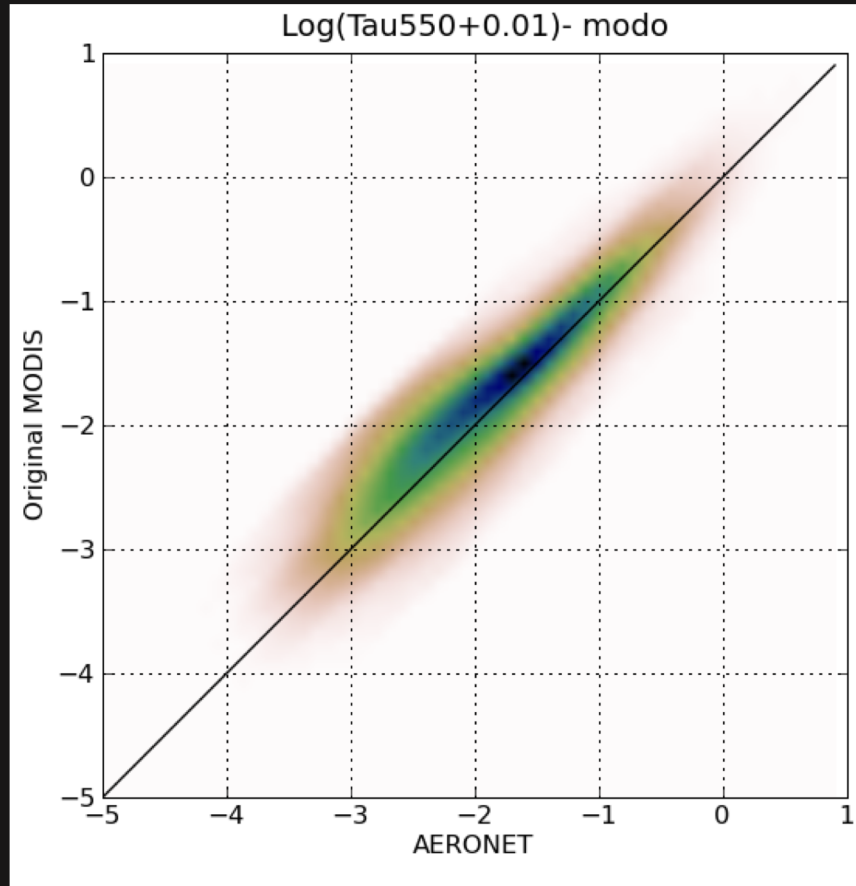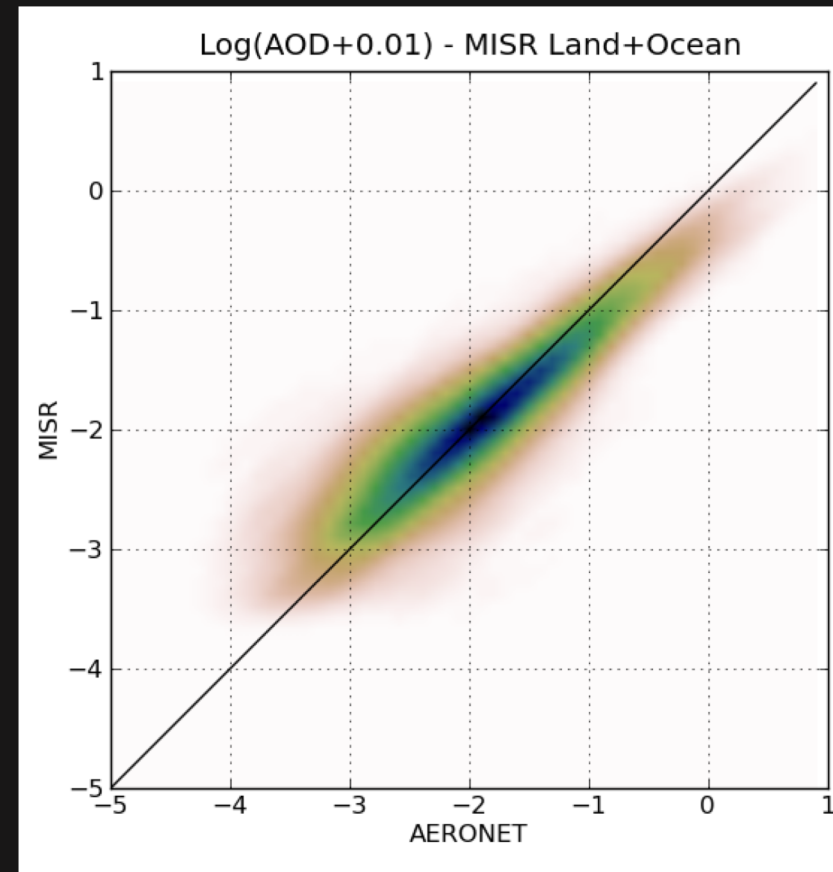- (Could also use actual aerosol ensembles)

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

## C5 MODIS-Terra (Ocean)

## MISR (Ocean+Land)



Log(Tau550+0.01)- modo



Log(AOD+0.01) - MISR Land+Ocean

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
- (Fractional AOD speciation )

## ☐ 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
- (Fractional AOD speciation)
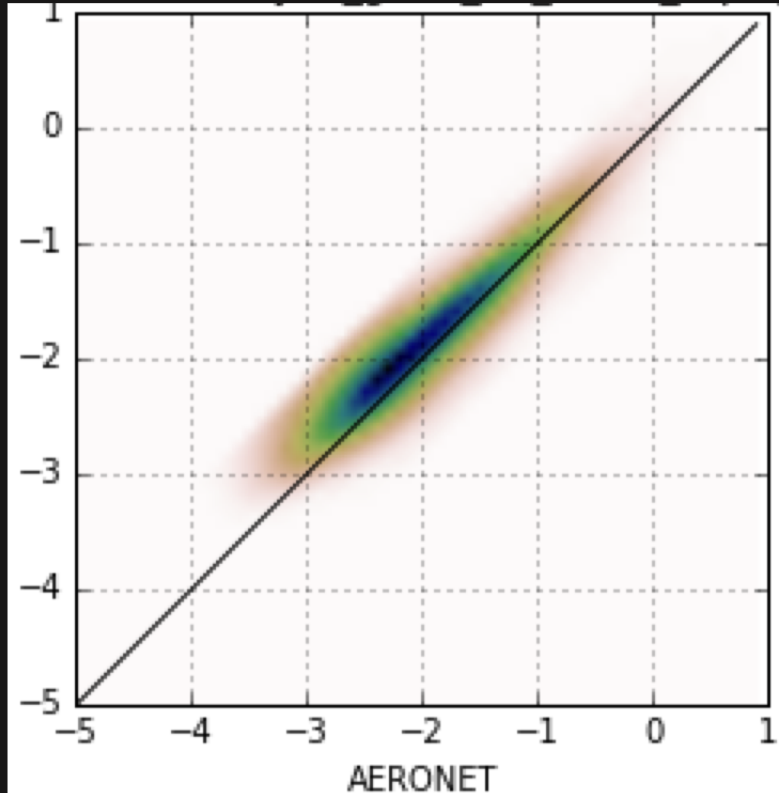
## ☐ Target: AERONET

- η = log(AOD+0.01)

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

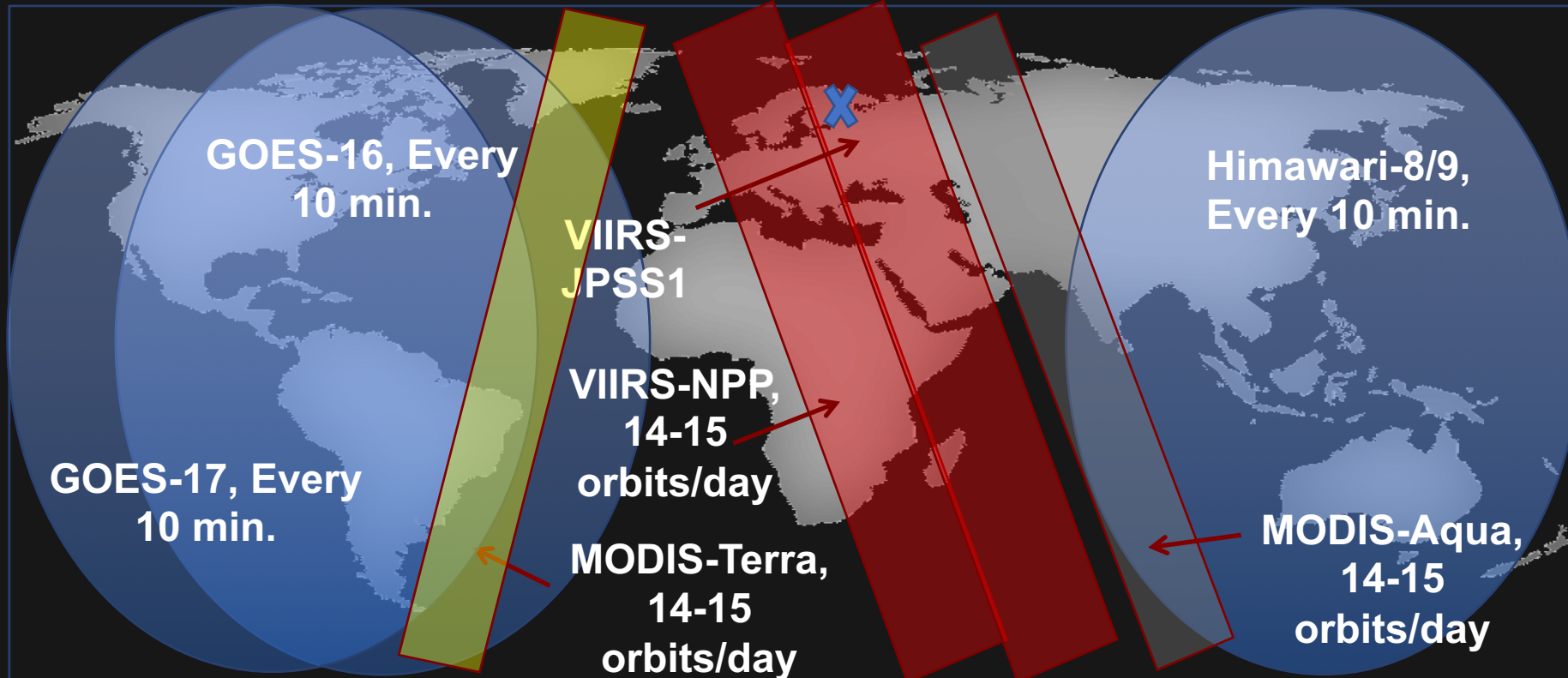**MODIS-AQUA C6 OCEAN AOD$_{550}$**

**BIAS CORRECTED NNR AOD$_{550}$**
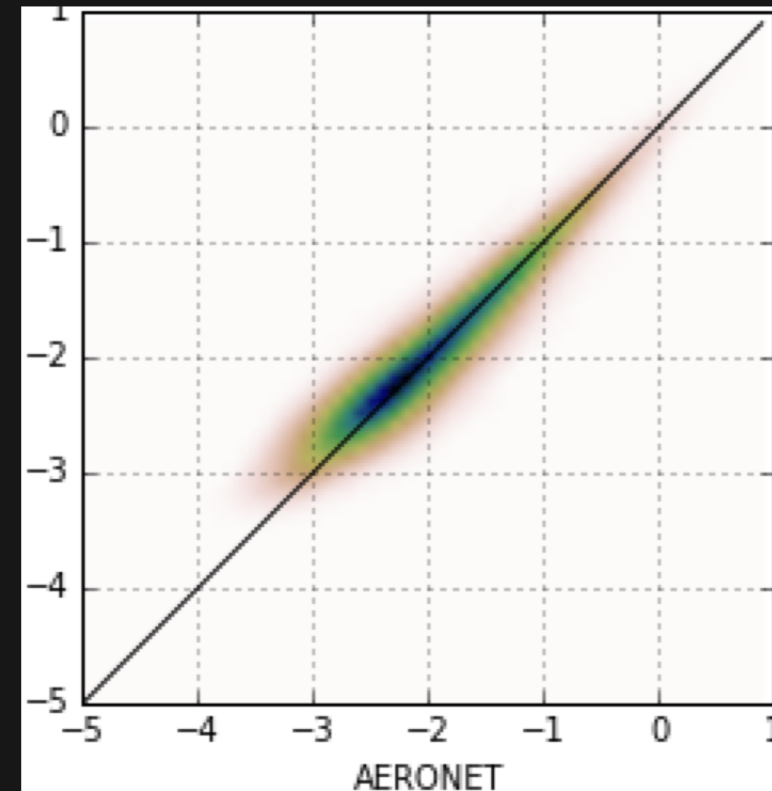


MODIS Neural Net AOD$_{550}$ Retrievals trained on AERONET

# Dark Target: Combined LEO & GEO



- DT is implemented on all 6 sensors
- Aerosol product is created for 6 sensors for one month – 12/2018
- Data integration, validation is on going

# 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!



20172471045347

GOES-R ABI
Aerosol Optical Depth

AOD

**B.C. (Canada) fires of Sept 7, 2017**
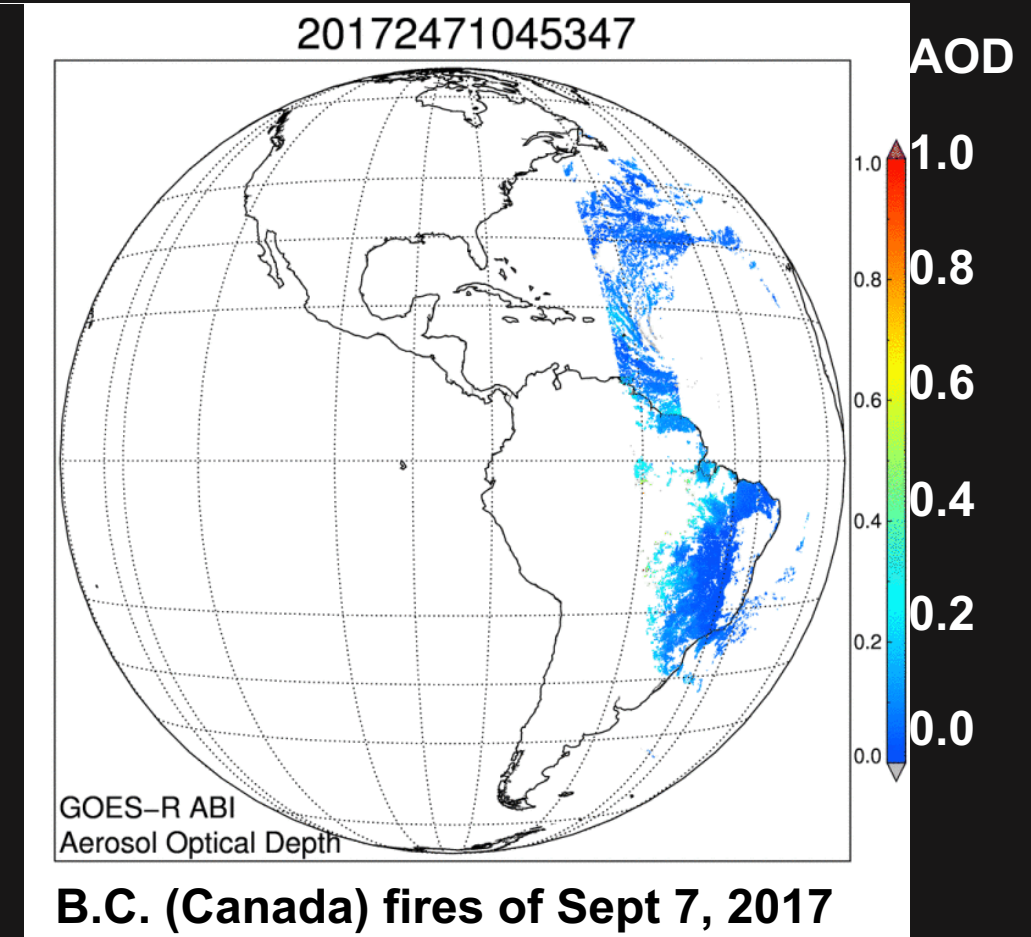
# Additional ABI Data Screening for DA

❑ Cloud Screening:
- ➢ Cloud fraction < 0.7  for AOD<2
- ➢ Cloud fraction <0.25 for AOD>2
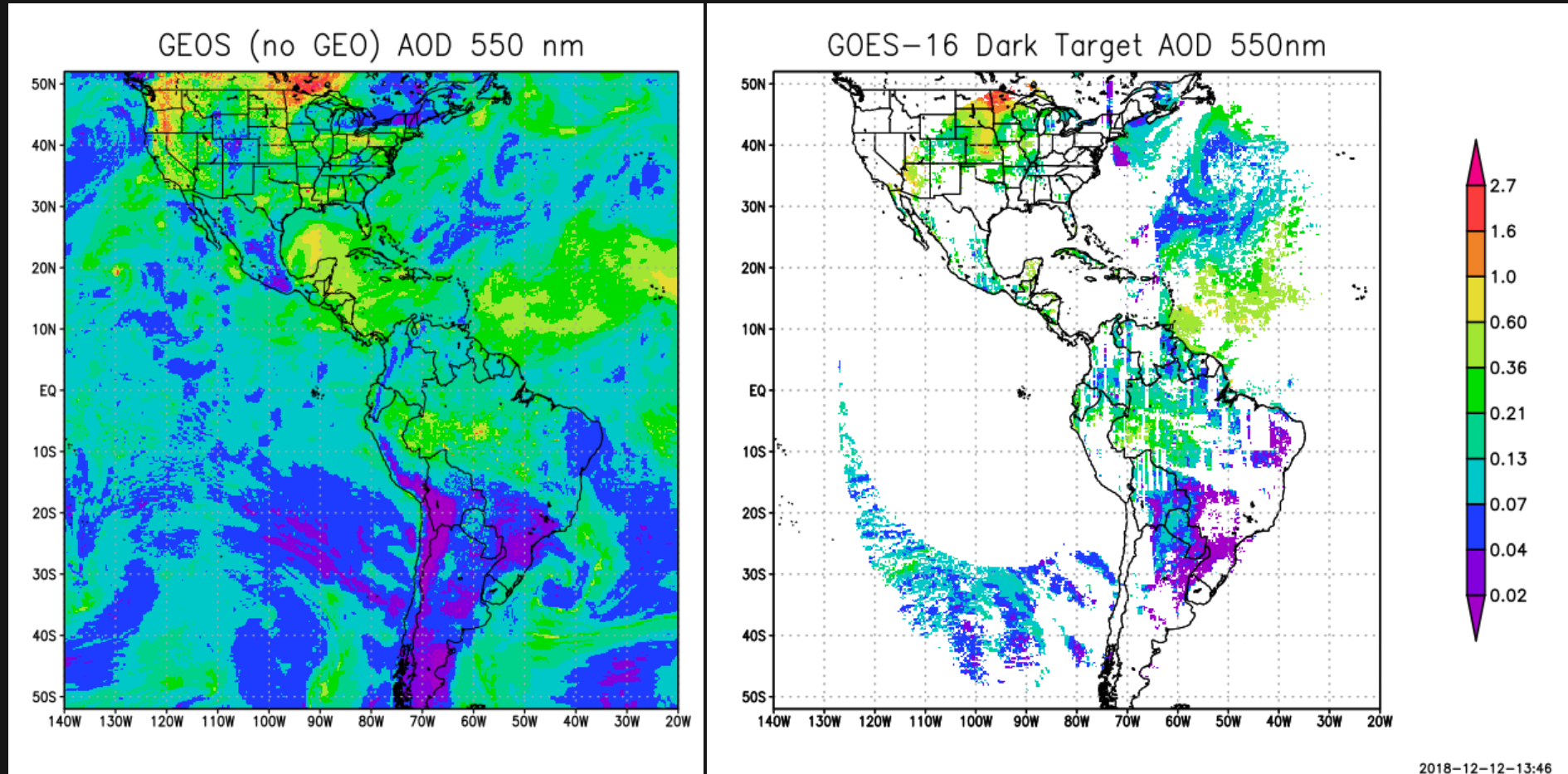
❑ Sensor Zenith angle < 60 degrees

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

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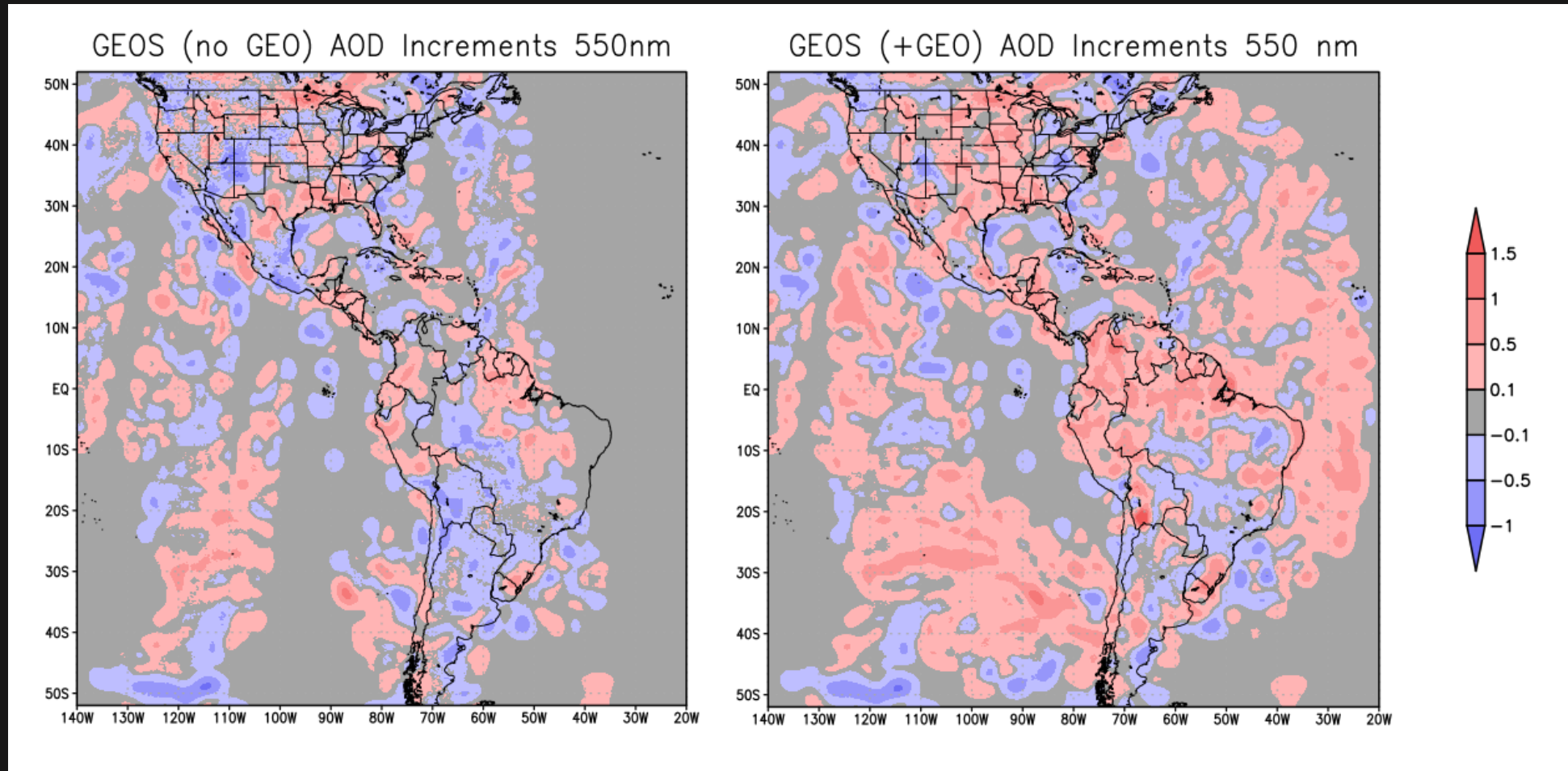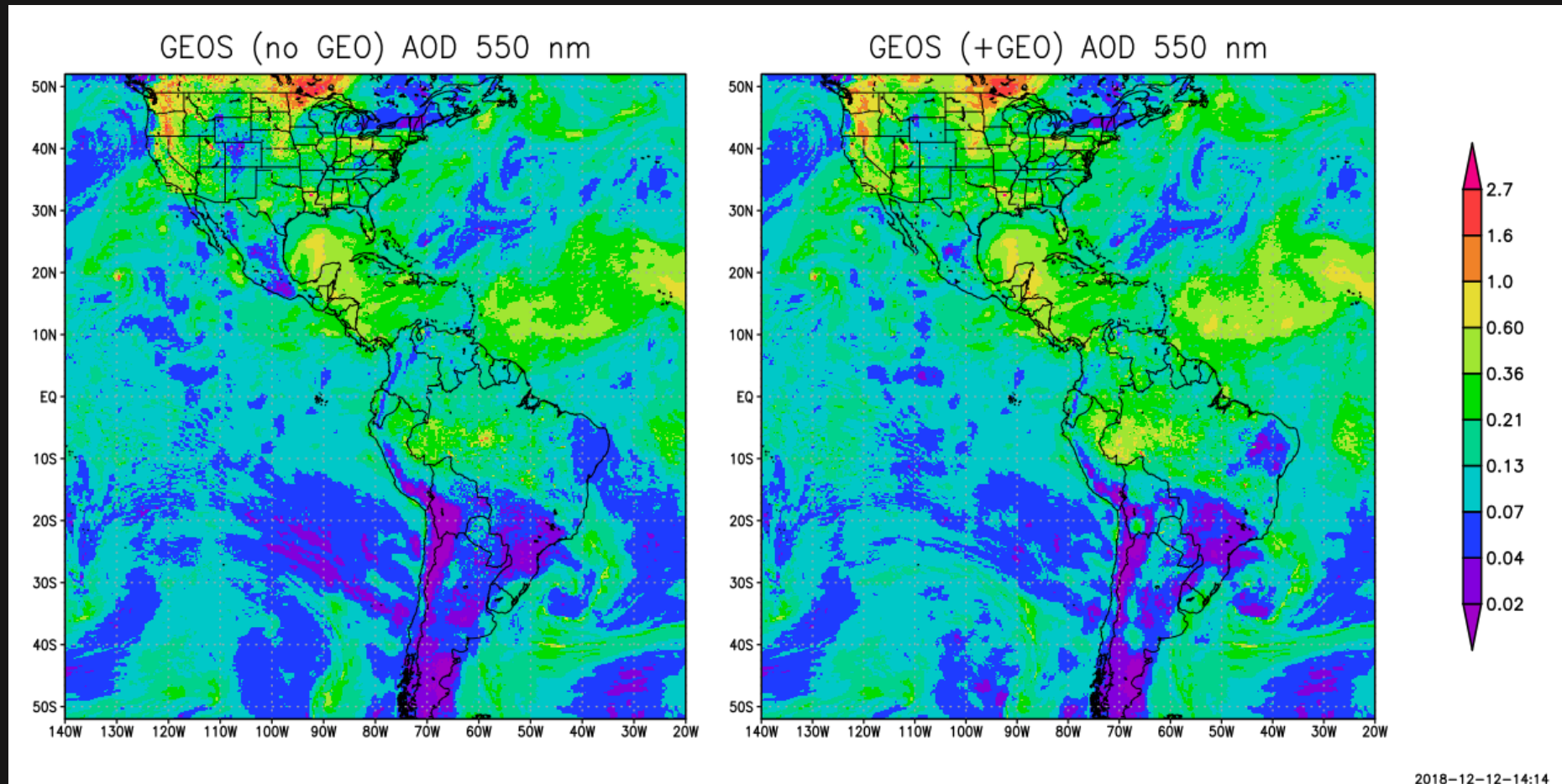- ➢ Glint angle > 75 deg
- ➢ Scattering angle < 170 deg

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# The Before Picture



GEOS (no GEO) AOD 550 nm

GOES-16 Dark Target AOD 550nm

2018-12-12-13:46

# Snapshot 18Z 10Aug2018

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# AOD Analysis Increments: Impact of ABI



GEOS (no GEO) AOD Increments 550nm

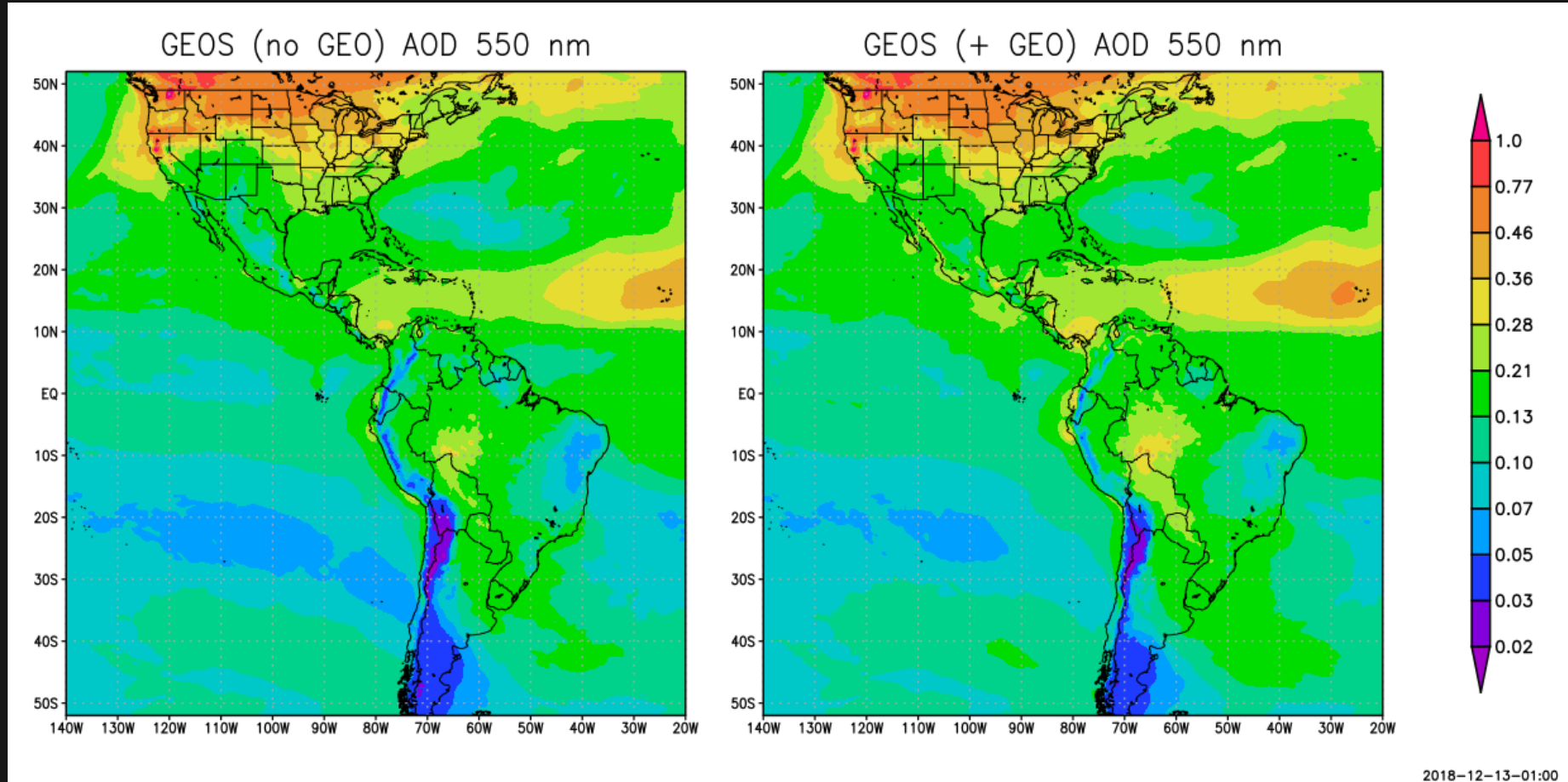GEOS (+GEO) AOD Increments 550 nm

## Snapshot 18Z 10Aug2018

# AOD Analysis: Impact of ABI



## Snapshot 18Z 10Aug2018

# AOD Analysis: Impact of ABI



GEOS (no GEO) AOD 550 nm

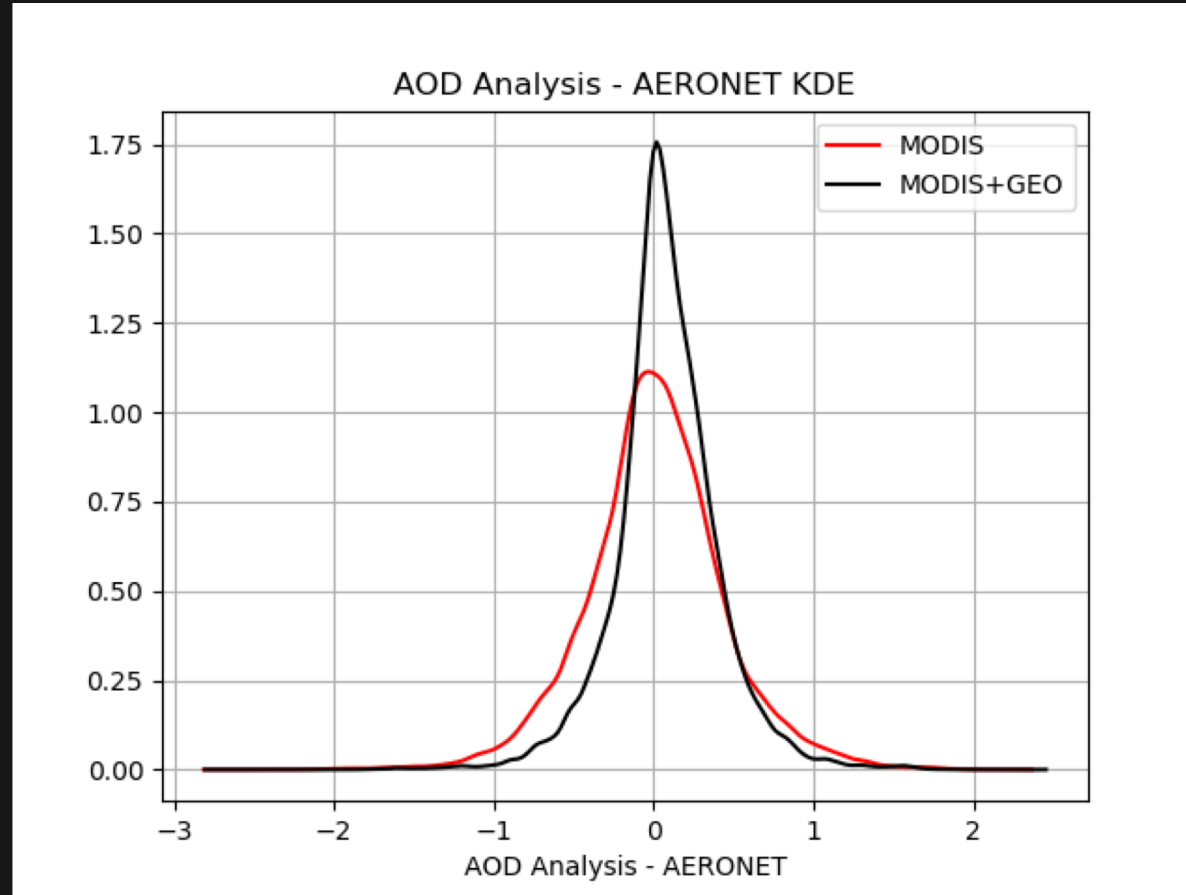GEOS (+ GEO) AOD 550 nm

2018-12-13-01:00

## Monthly Means: Aug 2018

# AERONET Verification



MODIS Aerosol Optical Depth (2018-08)

MODIS+GEO Aerosol Optical Depth (2018-08)
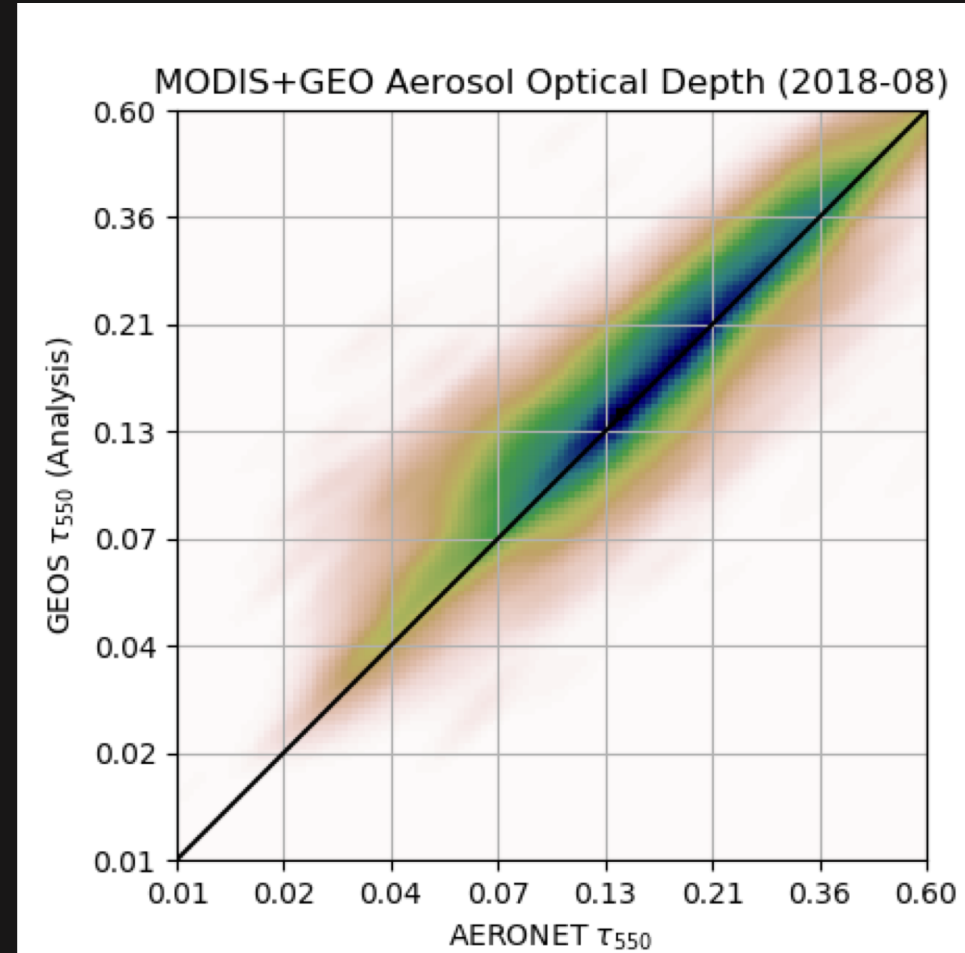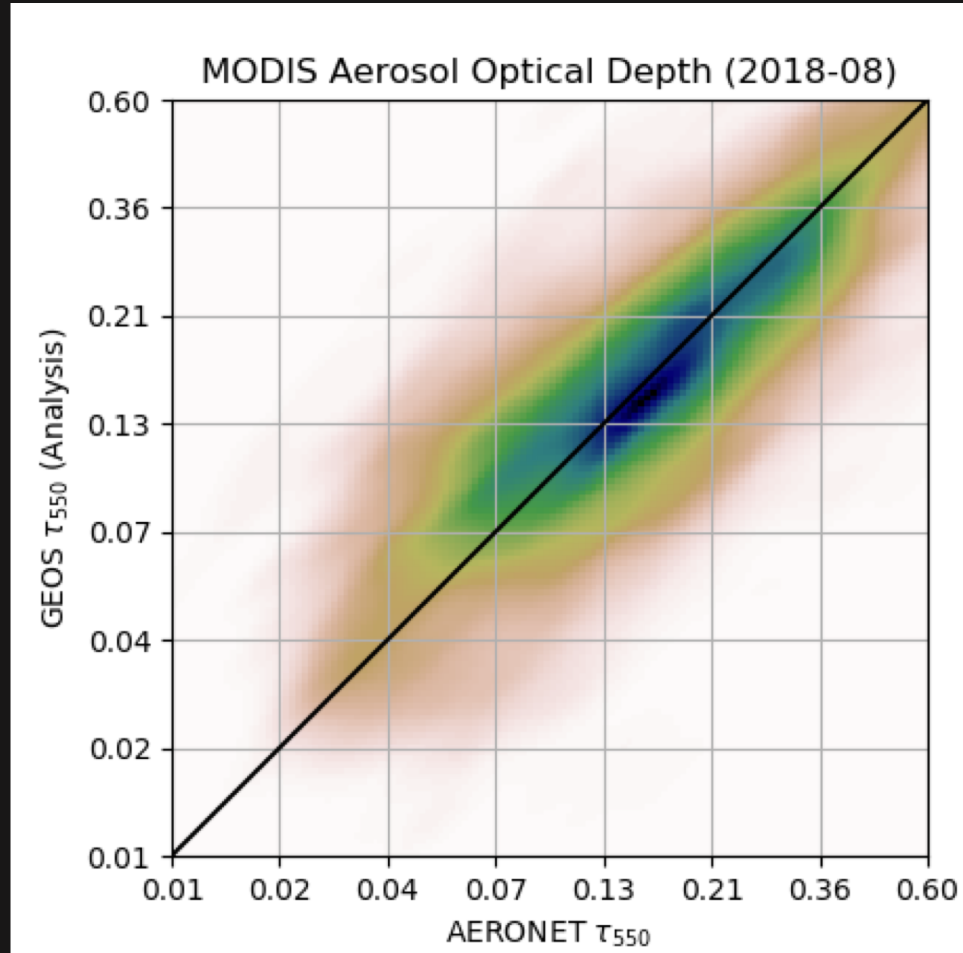
## August 2018

# AERONET Verification



## August 2018

# Contextual Biases



MODIS+GEO Aerosol Optical Depth (2018-08)

MODIS+GEO Aerosol Optical Depth (2018-08)

Bias correction is necessary
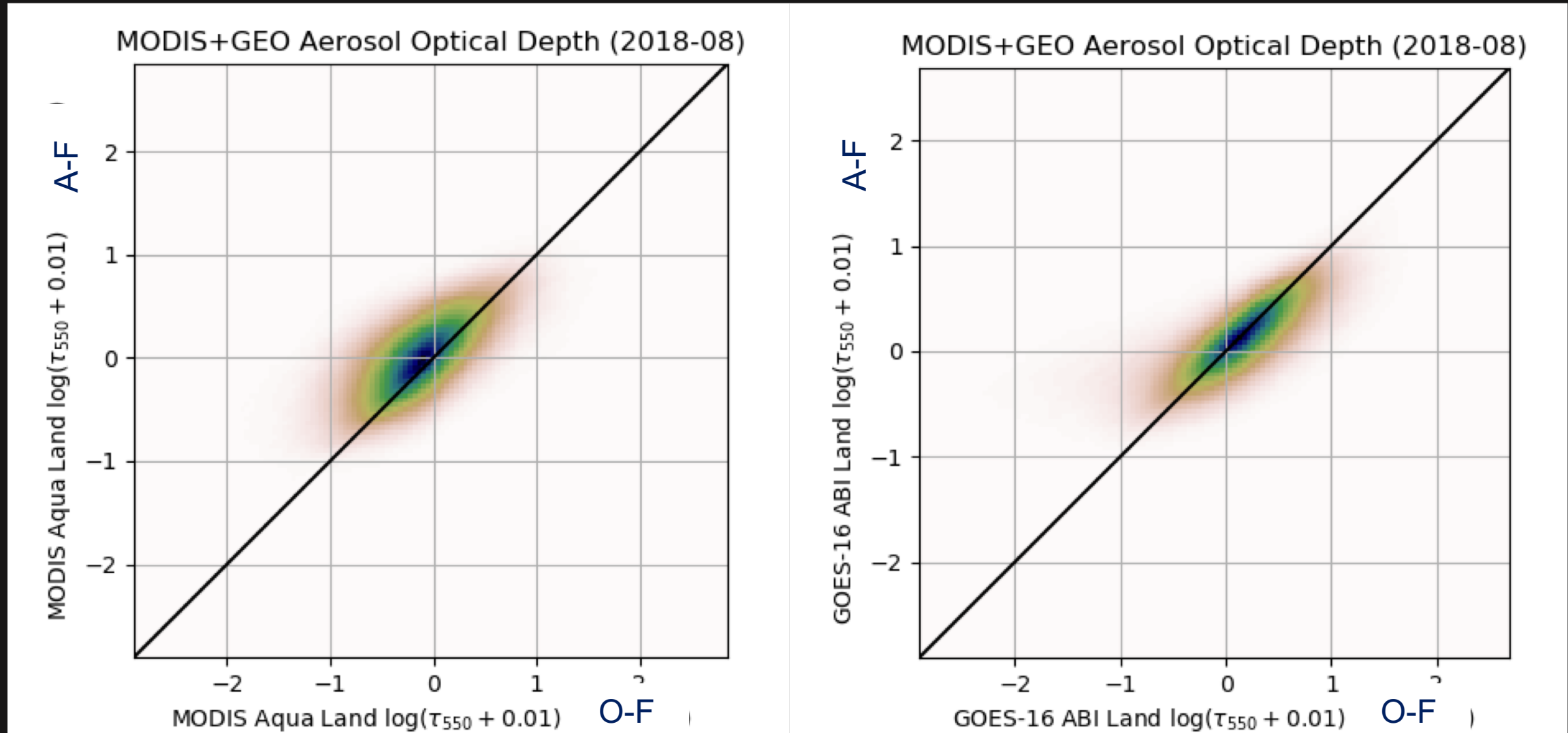
# Concluding Remarks

- ❑ **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