Validating and Improving GOES-16/-17 Operational Aerosol Optical Depth Product

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1. Introduction

The aerosol optical depth (AOD) product from the Advanced Baseline Imager have been made available to the public starting 07/25/2018 for GOES-16 and 01/01/2019 for GOES-17. The evaluation with near real-time AERONET measurements indicates good agreement in terms of mean bias and standard deviation.

The high temporal resolution of geostationary satellite observations provides an opportunity to characterize the aerosol diurnal cycle. The spectral land surface relationship plays an important role in the accuracy of retrieved AOD, and thus the accuracy of diurnal cycle. We show how better accounting for angular effects in the surface reflection improves retrieval of AOD at different times of the day, which is crucial for monitoring evolution of pollution (smoke and dust) events.
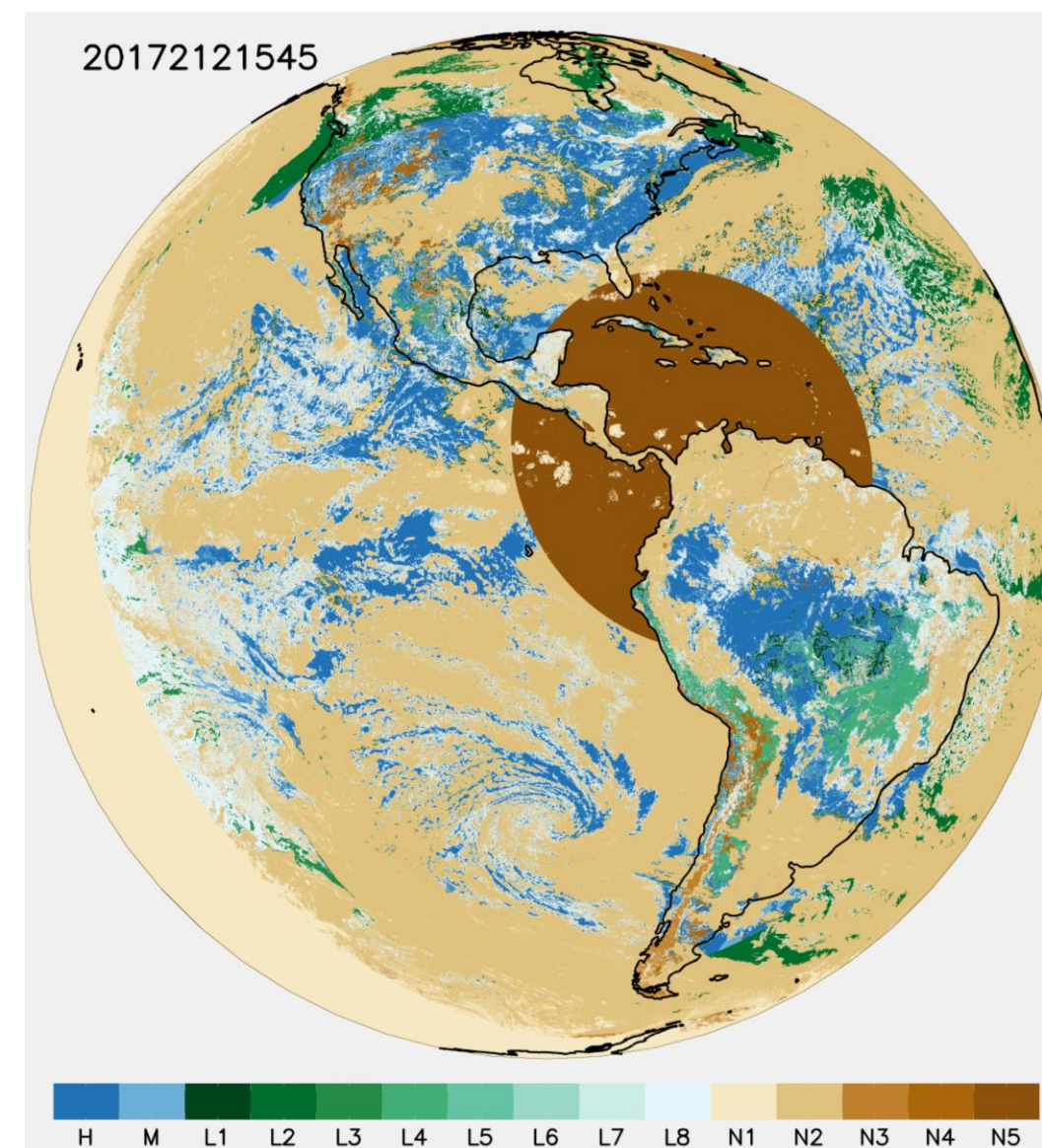
2. Algorithm and Product Overview

ABI AOD Product

Nominal Spatial Resolution	2 km
Domains	CONUS: 5 mins Full Disk: 15 mins (M3); 10 mins (M6)
AOD at 550-nm	Range [-0.05, 5]
Quality flag	0=high; 1=medium; 2=low; 3=not produced
Meta data	Mean, max, min and standard deviation of 550-nm AOD (and in 10-degree latitude zones) over land/water
Access	NOAA CLASS (https://www.class.noaa.gov)

- Based on MODIS Dark-target and NOAA VIIRS heritages;
- Pixel level AOD is the best fit from multispectral, single-look, unpolarized reflectances;
- Separate scheme over land and water;
- Selects AOD and aerosol model simultaneously;
- No retrieval over bright surface.

Detailed Quality Flag Example

Quality Level		Condition	Applies to		Detected by	
			Land	Ocean	External Mask	Internal Tests
N (No Retrievals)	N1	Invalid input data	X	X		X
	N2	Cloud	X	X	X	X
	N3	Snow/Ice	X	X	X	X
	N4	Bright Land Surface		X		X
	N5	Sun Glint	X			X
L (Low)	L1	E & l cloud tests contradict	X	X	X	X
	L2	Low Satellite (satzen > 60°)	X	X		X
	L3	Low Sun (solzen > 80°)	X	X		X
	L4	AOD out of range	X	X		X
	L5	Coastal		X	X	
	L6	Shallow Inland Water	X			X
	L7	High Residual	X	X		X
	L8	High Inhomogeneity	X	X		X
M (Medium)	M	Cloud/Snow Adjacency	X	X		X
		Shallow Ocean		X		X
		Probably Clear	X	X		X
		Medium Inhomogeneity	X	X		X
		Medium Residual	X	X		X
H (High)	H	Remaining	X	X		X

Over water:
  surface reflectance analytically calculated
  retrieval over ocean and inland water
 4 fine-mode and 5 coarse-mode candidate aerosol models

Over land:
  surface reflectance estimated from preset spectral relationships
  retrieval only over dark land surface
  4 candidate aerosol models: dust, smoke, urban and generic

### Current Spectral Land Surface Relationship

- Training dataset collected for 04/29/2017 – 01/15/2018 with the satellite mostly at test positon (89.5°W);
- Relationship is in the form of $\rho_{0.47|0.64} = f(\vartheta_s) \times \rho_{2.25}$ for 4 separate NDVI ranges, where $NDVI = (\rho_{0.86} - \rho_{0.64})/(\rho_{0.86} + \rho_{0.64})$
- Use only AERONET AOD (0.55 μm) < 0.2, dust model for AERONET (0.48 – 0.67μm) AE < 0.6 and generic model for AE > 1.6.

3. Validation with AERONET

Full Disk AOD Image Example

Low+Medium+High Quality   High Quality

08/21/2019 17:00UTC
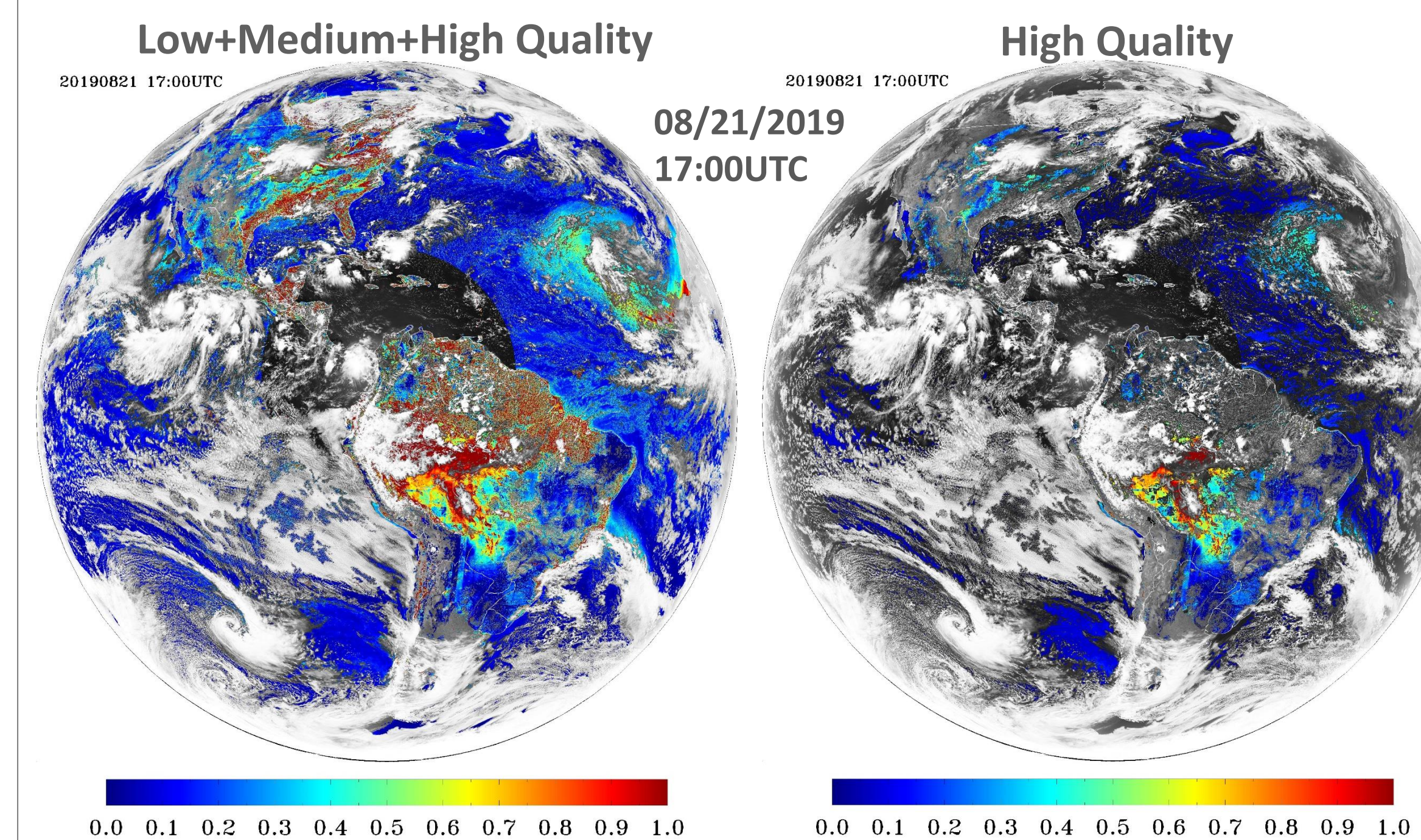
High quality retrievals are recommended for quantitative applications; however, lower quality retrievals can be considered for qualitative use due to their greater spatial coverage.
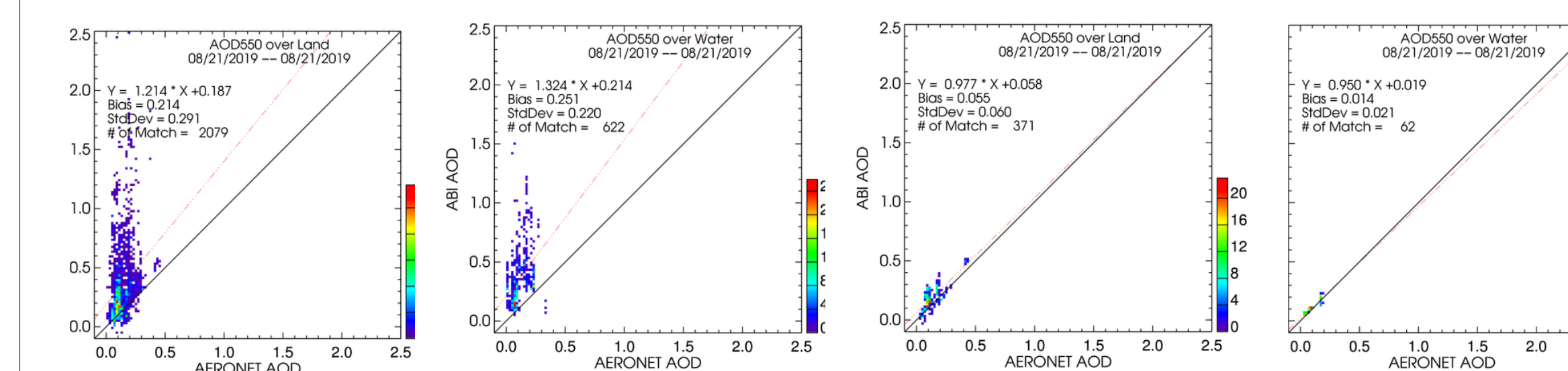
High Quality ABI AOD Validation

- High QC GOES-16/ABI vs. Version 3 Level 1.5 near real-time AERONET AOD for 07/25/2018 – 12/31/2019;
- ± 30 min time window, and a circle of 27.5 km in radius for spatial domain, require ~20% /10% over land/water ABI data points for a valid match-up;
- Majority AODs are around 1:1 line.
- STD over land is about twice as large as that over water.
- A small mean positive bias over land and over water.

Over Land

Over Water

Can this be improved?
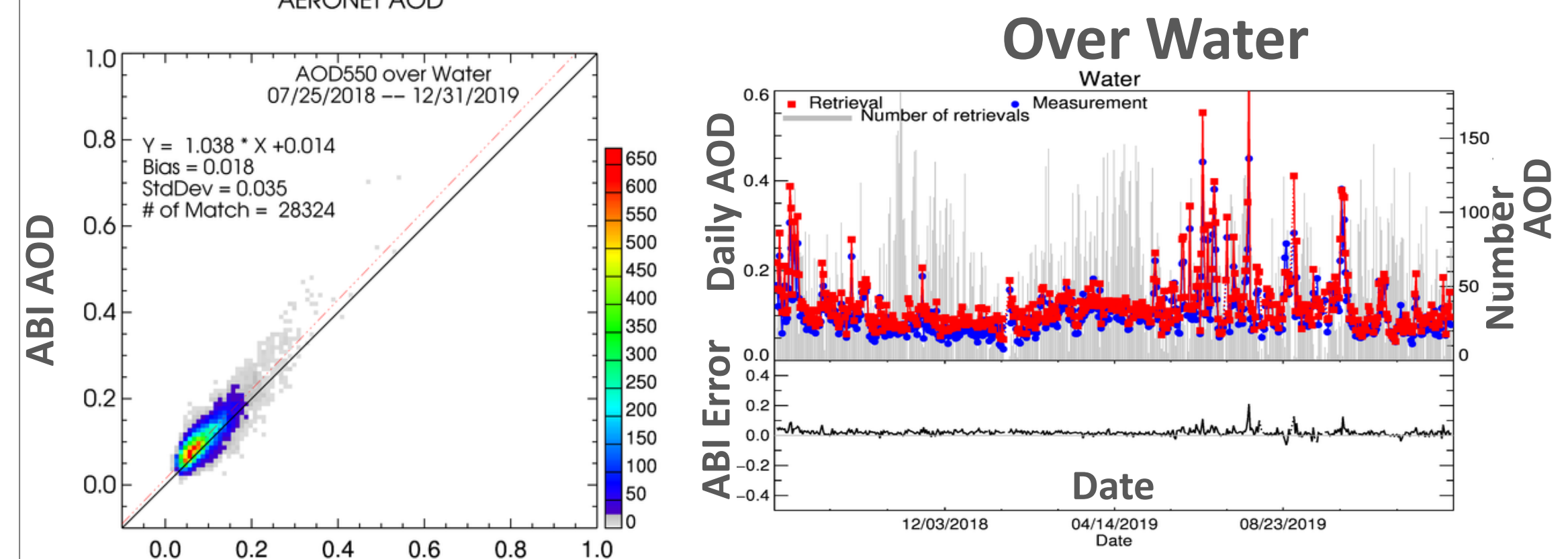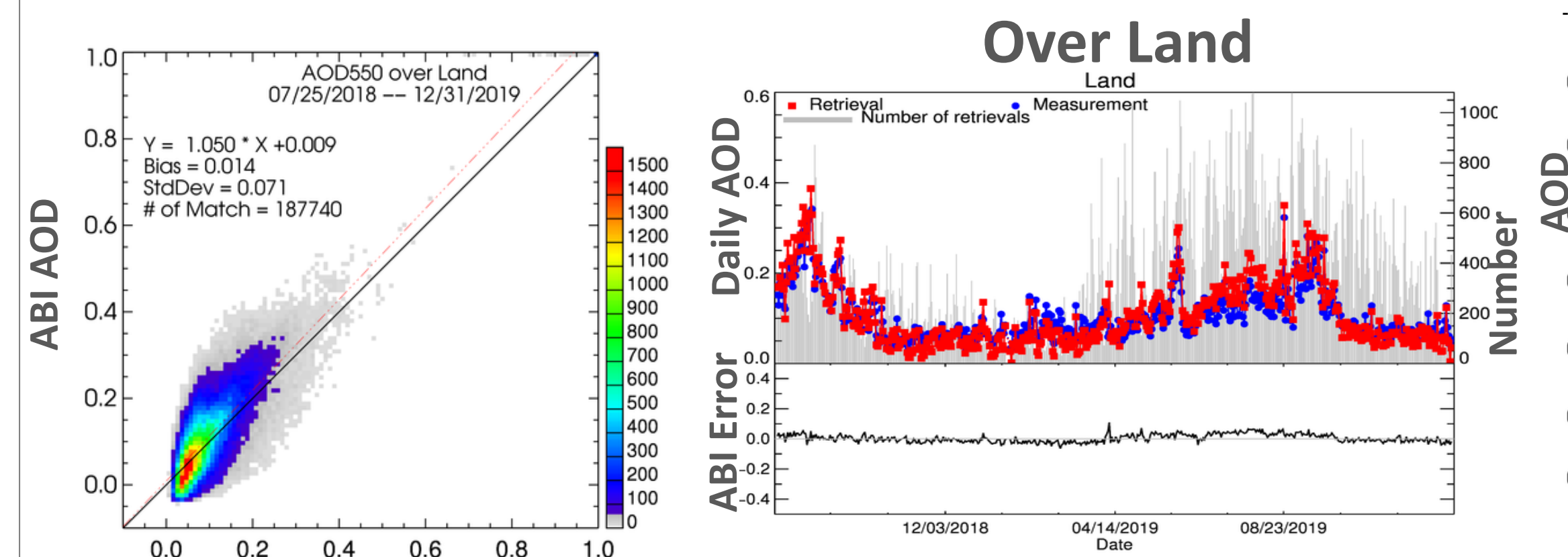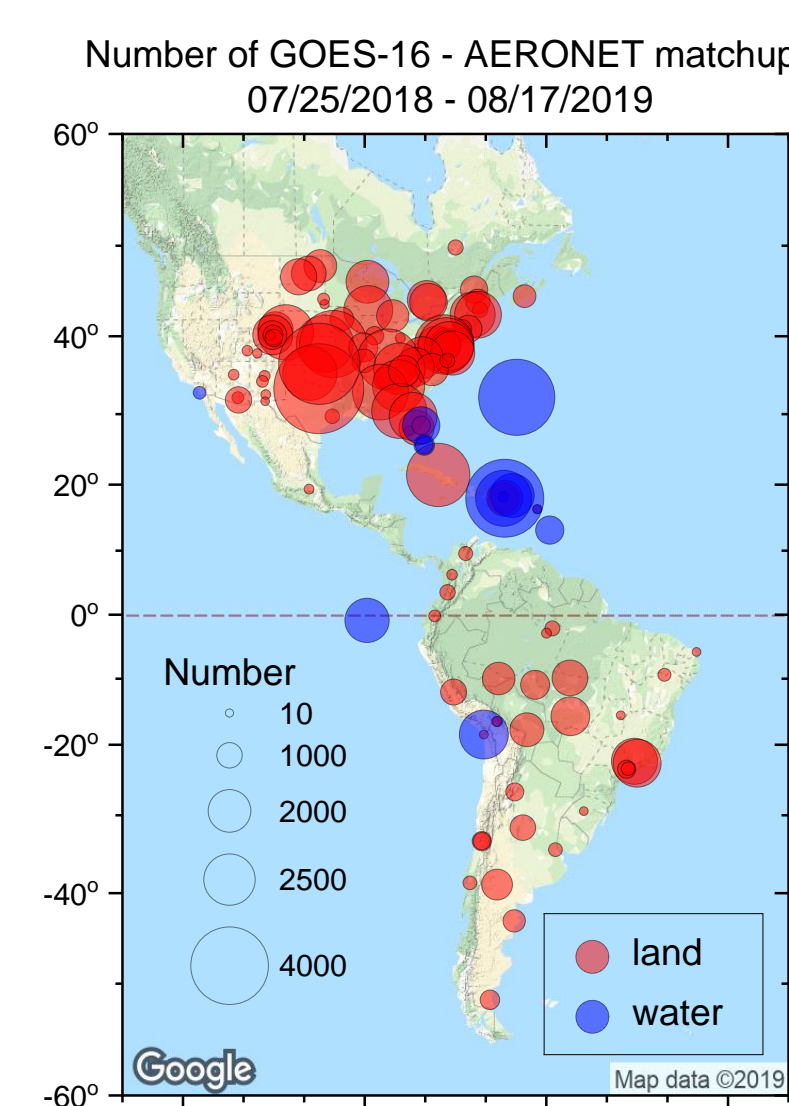
4. Updated Spectral Land Surface Relationship

- Training dataset from GOES-16 at operational positon (75°W);
- Land surface relationship is in the form $\rho_{0.47|0.64} = f(\vartheta_s, \Theta, \vartheta_v) \times \rho_{2.25}$ separately for solar azimuth angle ≤ or > 50°;
- Expanded training dataset: relaxed AERONET AE > 1.0 for generic model; extended range of allowed AERONET AOD < 0.6.

Improved Diurnal Cycle and Angular Dependence over Land

- Updated land surface relationship improves GOES-16 AOD diurnal cycle and angular dependence;
- Relatively large error in bins with small number of matchups.
- For the diurnal cycle, SZA ≤ 70°
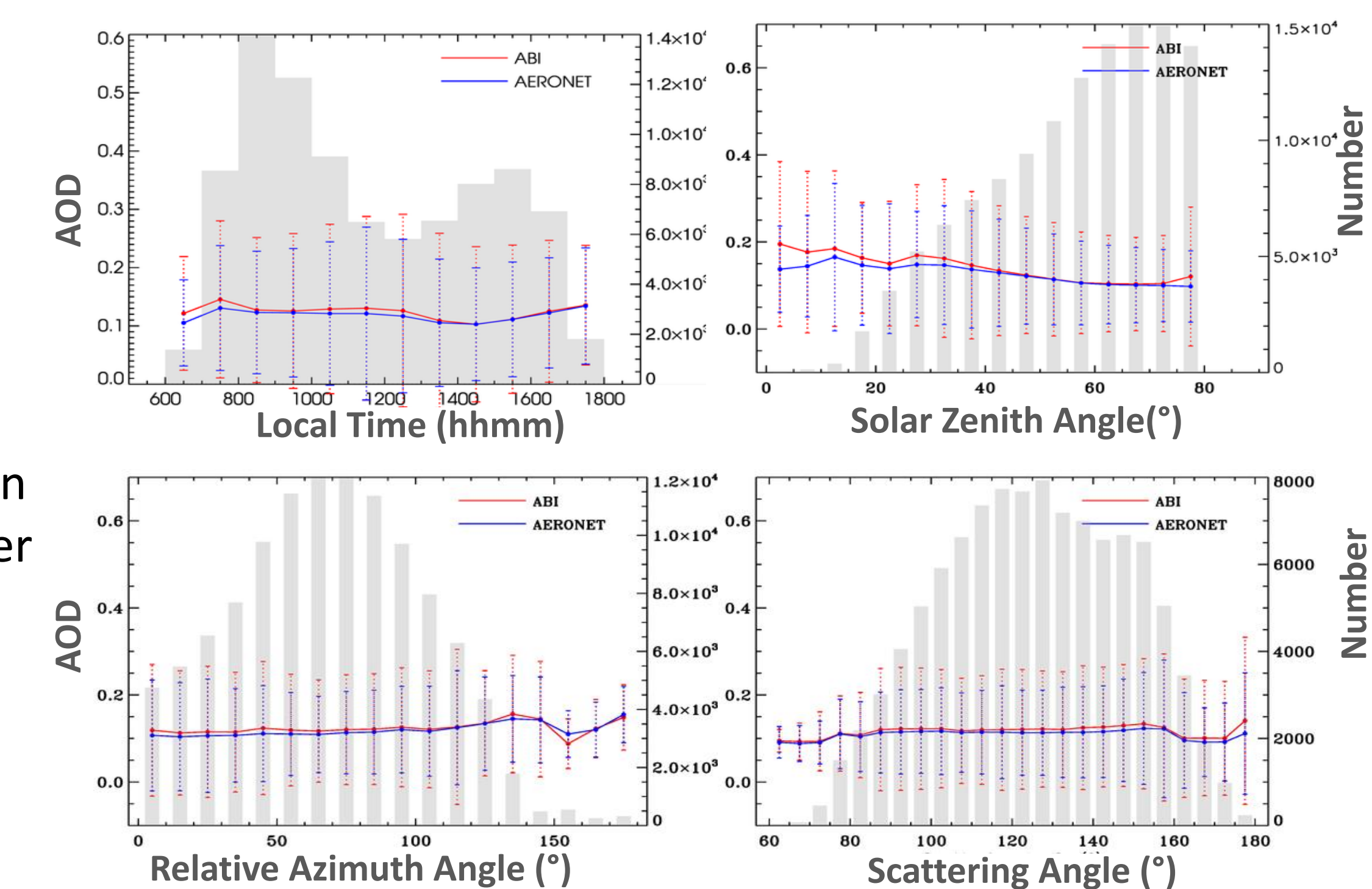
Diurnal Variation at Individual Sites During Aerosol Events

East US

West US

South America
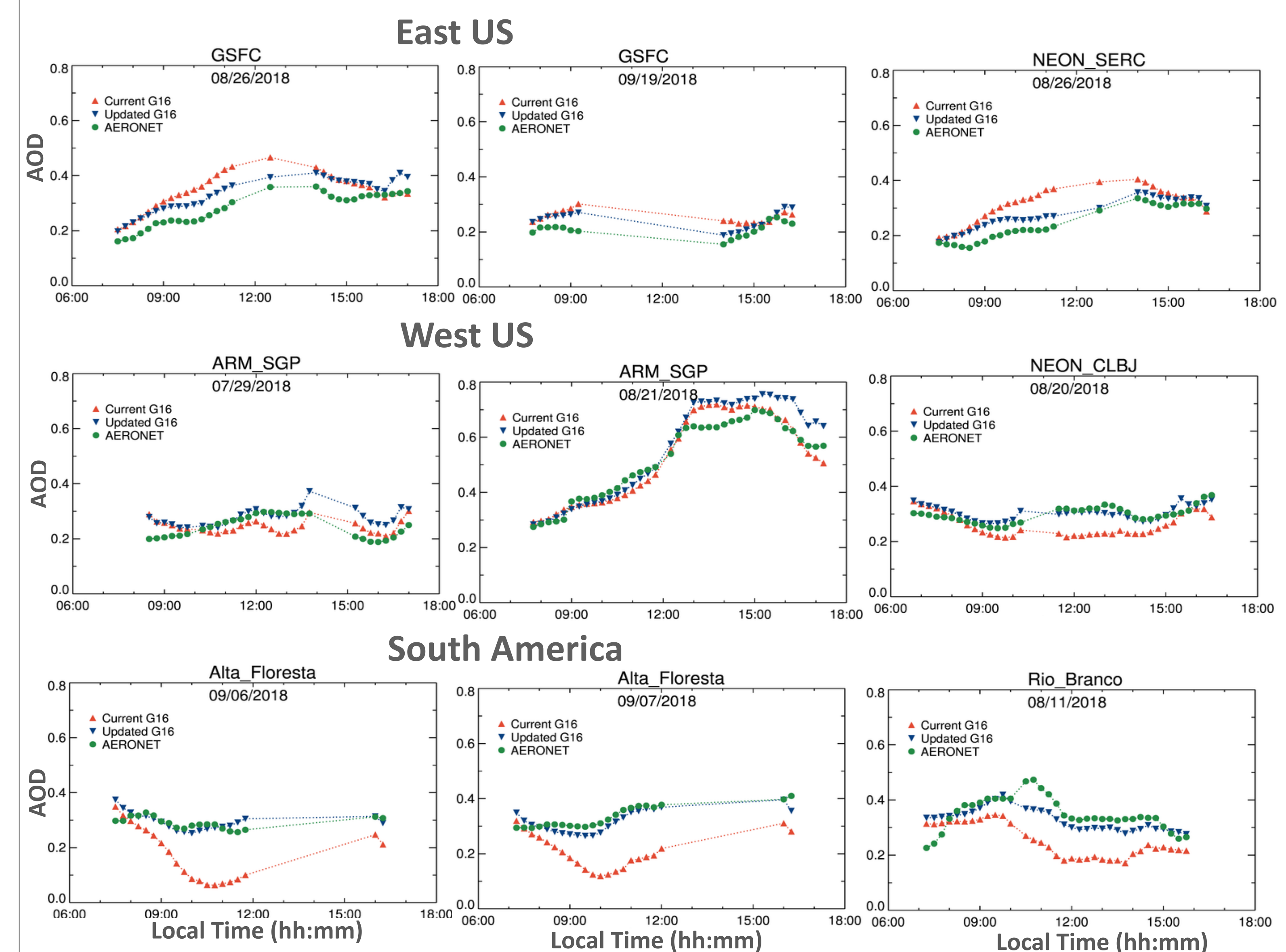
- Diurnal cycles examined at individual sites with the largest number of ABI-AERONET matchups for several months have similar performance as shown above;
- With the update, diurnal variation of G16 AOD is generally improved, and better tracks the change in AERONET AOD during high AOD events;
- Despite the good agreement in overall diurnal cycle, improving the AOD diurnal cycle at individual sites with a general surface relationship remains challenging.

5. Summary

- AOD products starting 07/25/2018 for GOES-16 and 01/01/2019 for GOES-17 are recommended to be used in studies. The high quality retrievals can be used for quantitative analysis; lower quality retrievals may be used for qualitative applications.
- Evaluated with AERONET, overall bias is ~ 0.01/0.02 and standard deviation ~ 0.07/0.04 over land/water for GOES-16/-17 high quality AODs.
- Accounting for angular effects in surface reflection can improves GOES-16 AOD diurnal variation.
- Overall statistics and diurnal variation can be improved with the updated land spectral surface relationship for GOES-17 AOD (in working).