Updates On Deep Blue Aerosol Algorithm for LEO and GEO Satellite Measurements

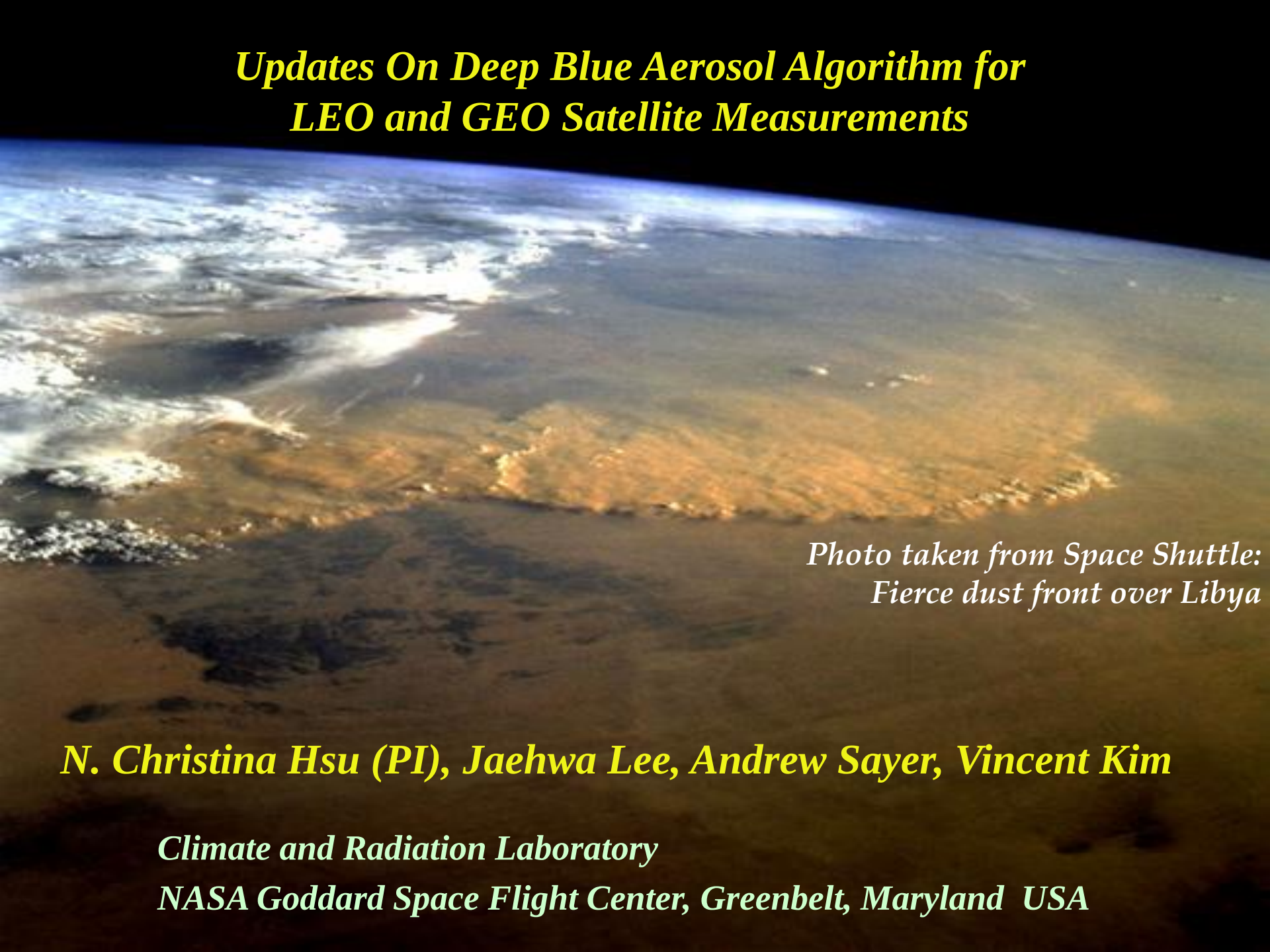

Photo taken from Space Shuttle:
Fierce dust front over Libya

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LEO Multi-Sensor Deep Blue Aerosol Products

➢ ***Science Objectives*:**

- **Our primary goal is to produce consistent long-term aerosol climate data record using multiple satellite sensor data from AVHRR (historic) to SeaWiFS and MODIS (EOS-era) to VIIRS (JPSS-era)**
- **Our new VIIRS aerosol products are generated based upon *Deep Blue* algorithm (over land) (previously applied to AVHRR, SeaWiFS and MODIS) and SOAR algorithm (over ocean) (previously applied to AVHRR and SeaWiFS)**

➢ ***Challenges*:**

✓ **Wavelength differences in key bands used in *Deep Blue* algorithm: 0.412, 0.470, 0.650, 2.13 μm (MODIS) vs. 0.412, 0.488, 0.670, 2.25 μm (VIIRS)**

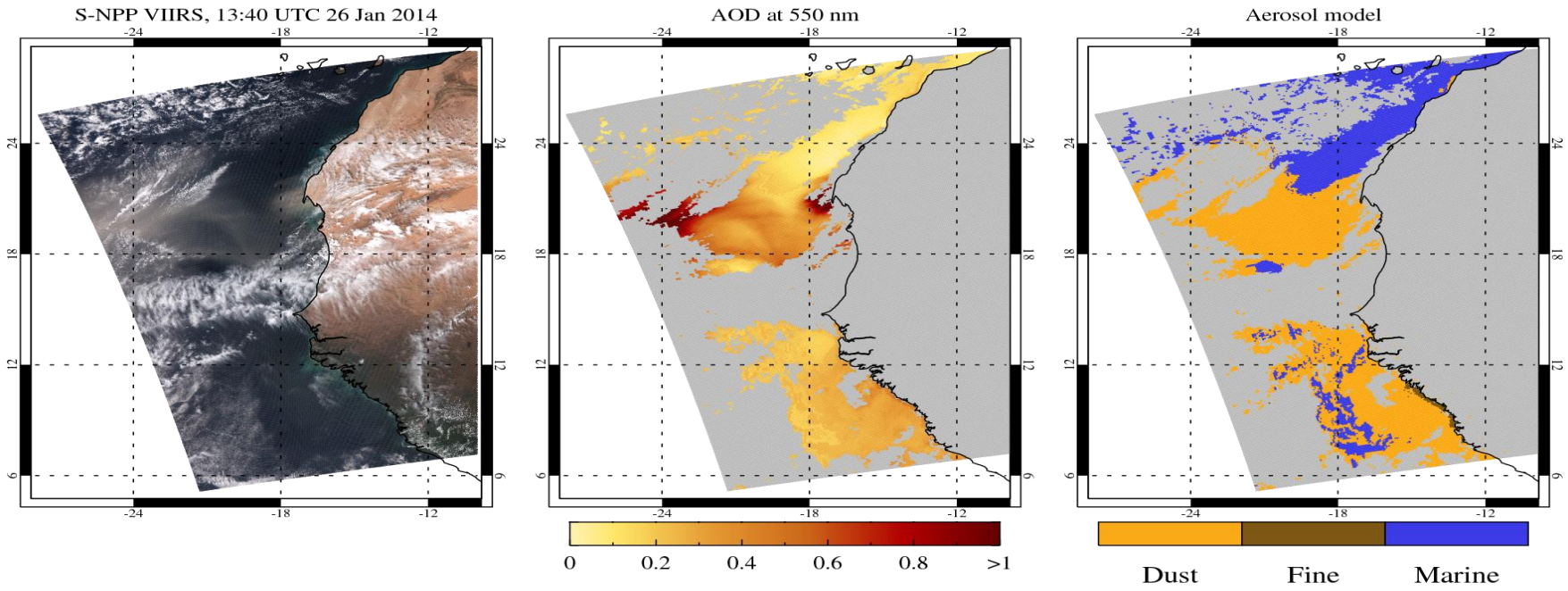
✓ **Radiometric calibration in solar reflectance channels (additional calibration correction was applied in our VIIRS algorithm to match the MODIS Aqua time series)**

✓ **Different spatial sampling (VIIRS has wider swath and more orbital overlaps than MODIS)**

Recent Progress on Deep Blue Aerosol Algorithm for VIIRS

- *Expand coverage from arid and semi-arid regions into vegetated (SeaWiFS, MODIS C6.1, and VIIRS) areas as well as oceans (SeaWiFS and VIIRS only)*
- *Develop and employ consistent non-spherical dust models for aerosol retrievals over land and ocean*
- *Utilize spectral curvature approach to distinguish smoke aerosols from urban/industrial aerosols and from clouds*
- *Produce new aerosol type products as part of the Deep Blue data suite*

VIIRS ocean retrieval algorithm



- The VIIRS ocean algorithm is an extension and improvement on our SeaWiFS algorithm
  - Similar in principle to other common approaches (e.g. MODIS) as well
- Retrieve AOD, fine mode fraction (Ångström exponent), aerosol type (from a selection of models)
  - Includes nonspherical dust model
- Cloud screening seems effective even in cases of heavy aerosol loading

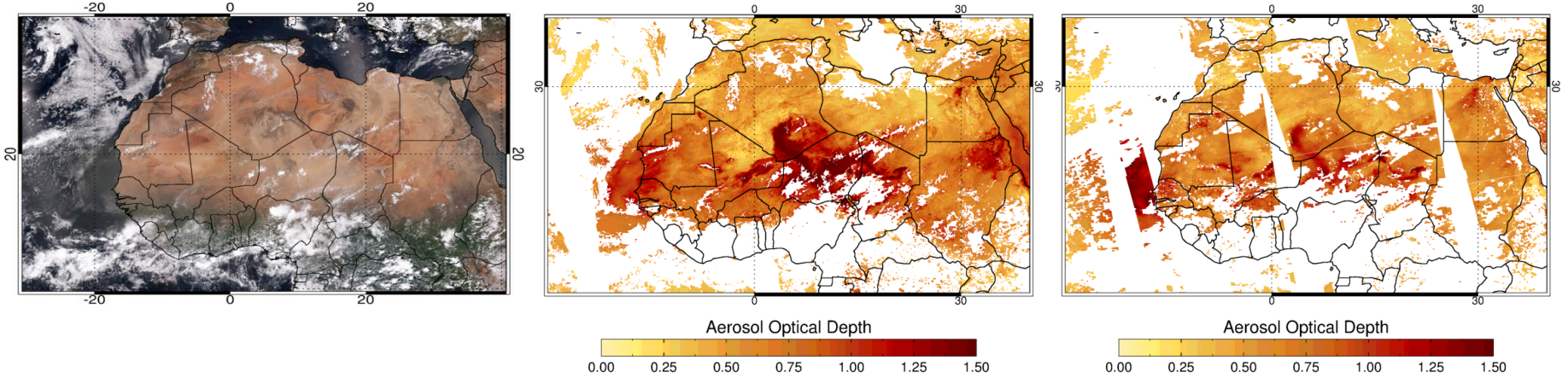
Reference: *Sayer et al*., 2017, JGR, "Satellite Ocean Aerosol Retrieval (SOAR) algorithm extension to S-NPP VIIRS as part of the `Deep Blue' aerosol project"

Effects of New Dust Optical Models on Land/Sea Discontinuity in Retrieved AOD

(a) VIIRS RGB image on June 8, 2015

(b) VIIRS AOD on June 8, 2015

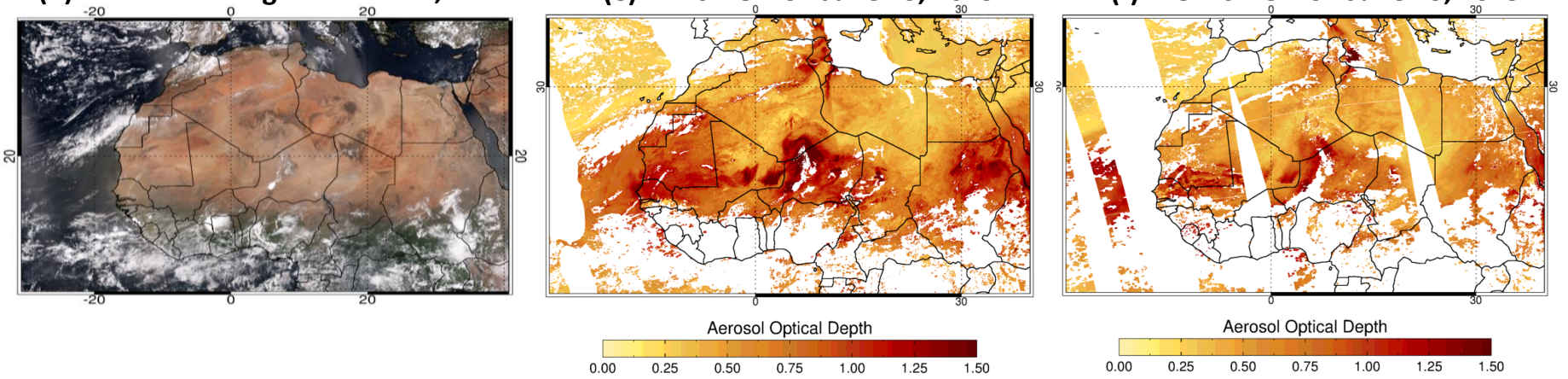
(c) MODIS AOD on June 8, 2015



(d) VIIRS RGB image on June 13, 2015

(e) VIIRS AOD on June 13, 2015

(f) MODIS AOD on June 13, 2015

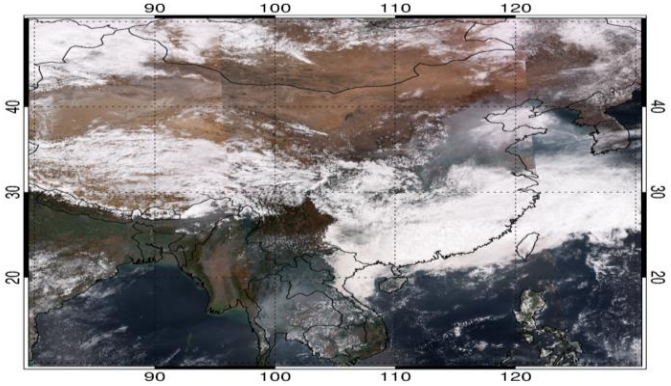


- **Implementation of consistent nonspherical dust model in both over-land and over-ocean VIIRS Deep Blue retrieval algorithms substantially improves the angular dependence of retrieved AOD bias, leading to smoother distribution of AOD across the land/sea boundary compared to MODIS**

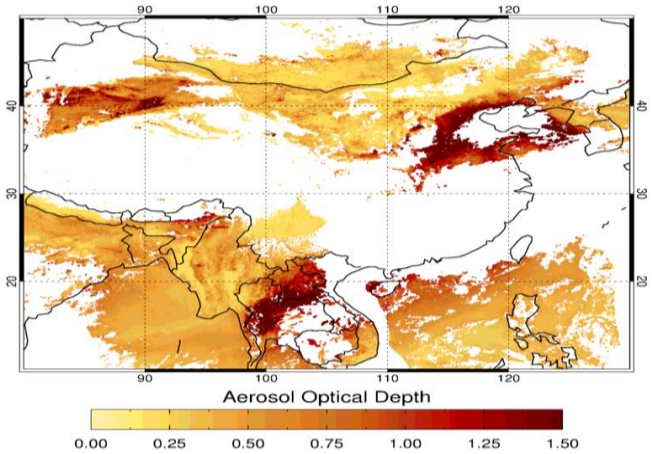
Reference: *Lee et al*., 2017, JGR, "Effects of nonspherical dust optical models on the VIIRS Deep Blue over-water aerosol product"

Adding Aerosol Type Product into the Deep Blue Data Suite

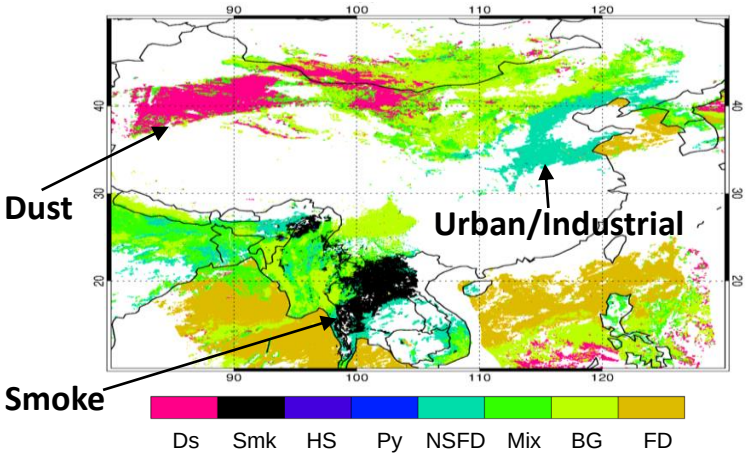
VIIRS RGB image 3/8/2014



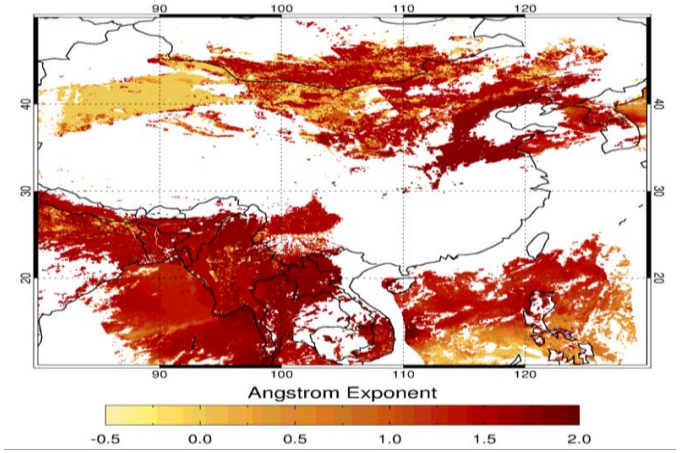
AOD at 0.550 µm



Aerosol Type

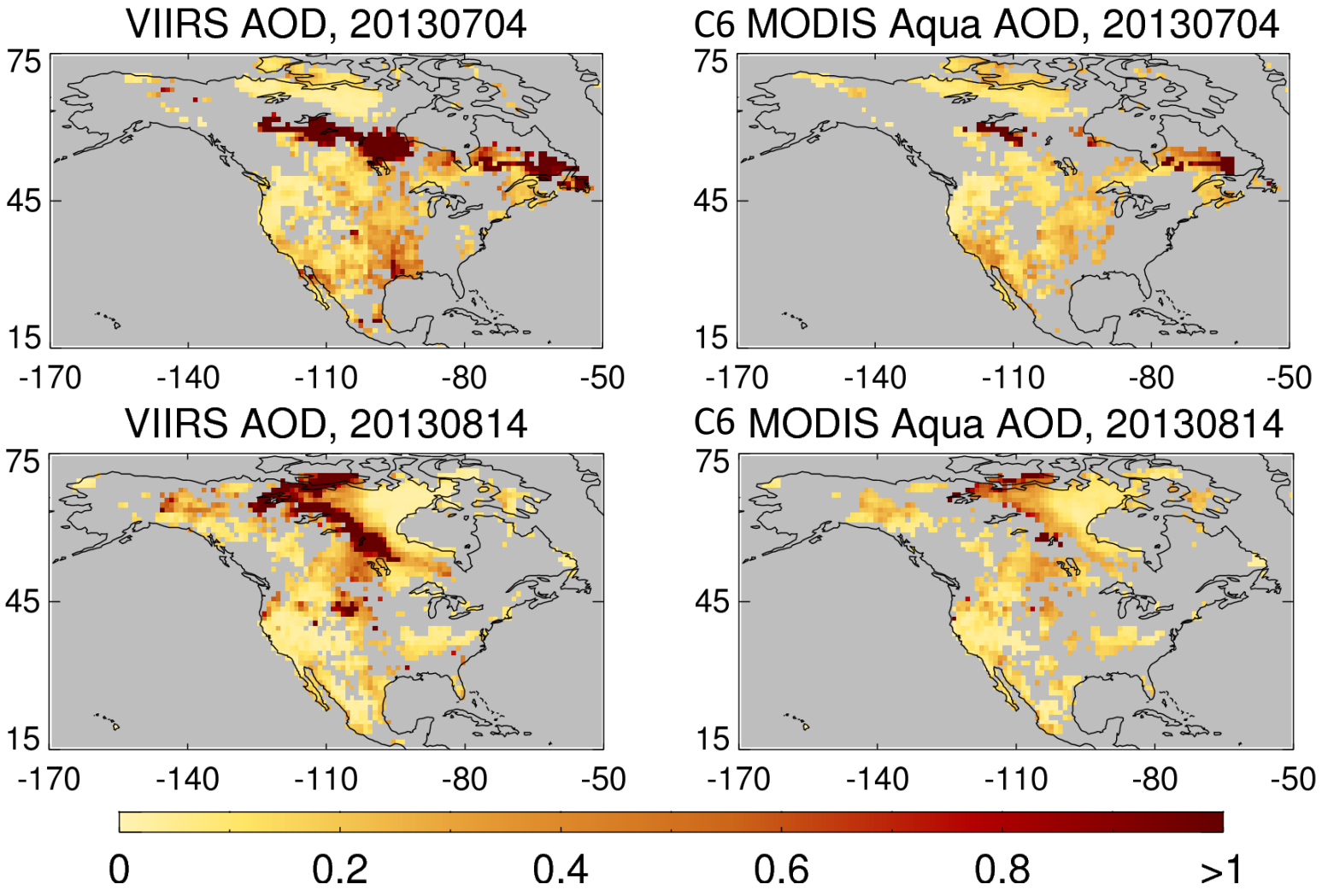


Angstrom Exponent



- By taking advantage of the spectral curvature approach due to the light absorption of biomass burning smoke aerosols at the blue wavelengths, we are able to distinguish smoke aerosols from other fine mode aerosols such as urban/industrial aerosols;
- Aerosol type information is derived by combining this smoke mask with retrieved AOD and Angstrom Exponent.

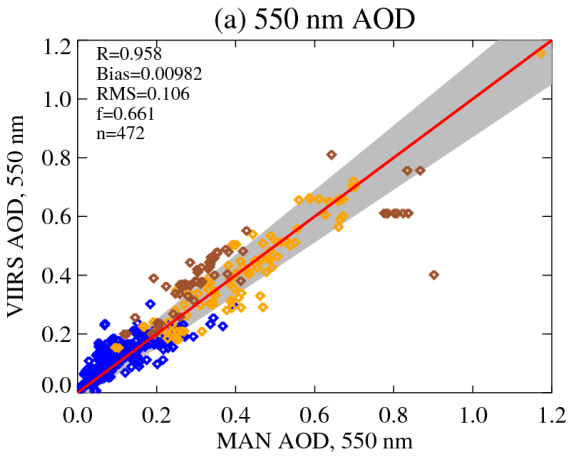
- **Improved VIIRS and MODIS C6.1 heavy smoke/cloud detection scheme significantly increases the spatial coverage of the retrieved AOD compared to MODIS C6 over major smoke plumes**

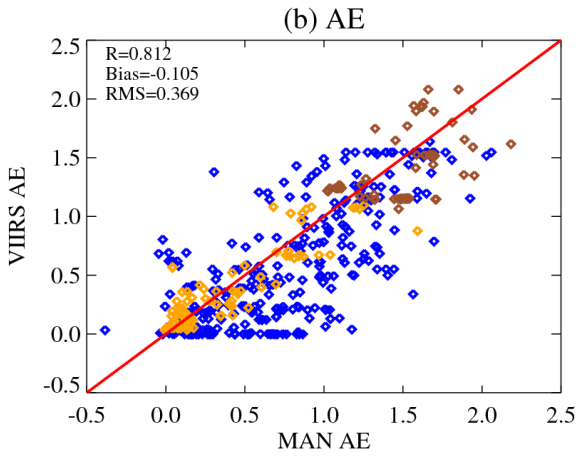


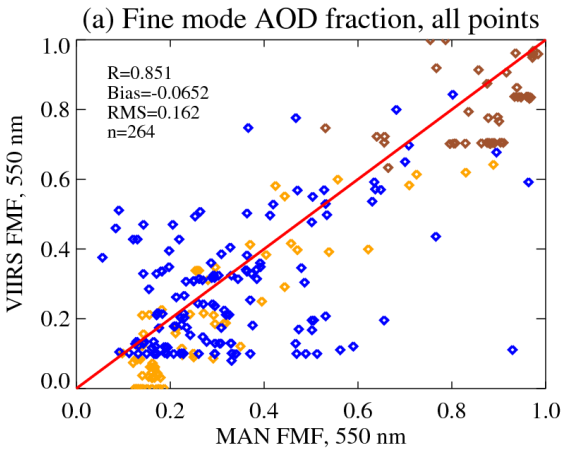
Reference: *Hsu et al.*, 2019, JGR, "VIIRS Deep Blue Aerosol Products Over Land: Extending the EOS Long - Term Aerosol Data Records"

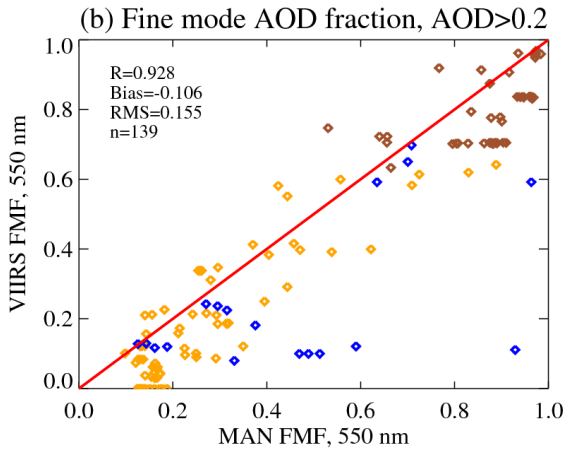
Comparisons of VIIRS over-ocean products with Maritime Aerosol Network (MAN)

- AOD retrieval quality similar to, or better than, standard MODIS product
- Ångström exponent (AE) and fine mode AOD fraction compare favorably to MAN data, even when the AOD is not high
- Colors indicate aerosol optical model: retrieved, not prescribed
  - Either **marine**, **dust**, or **fine-dominated**

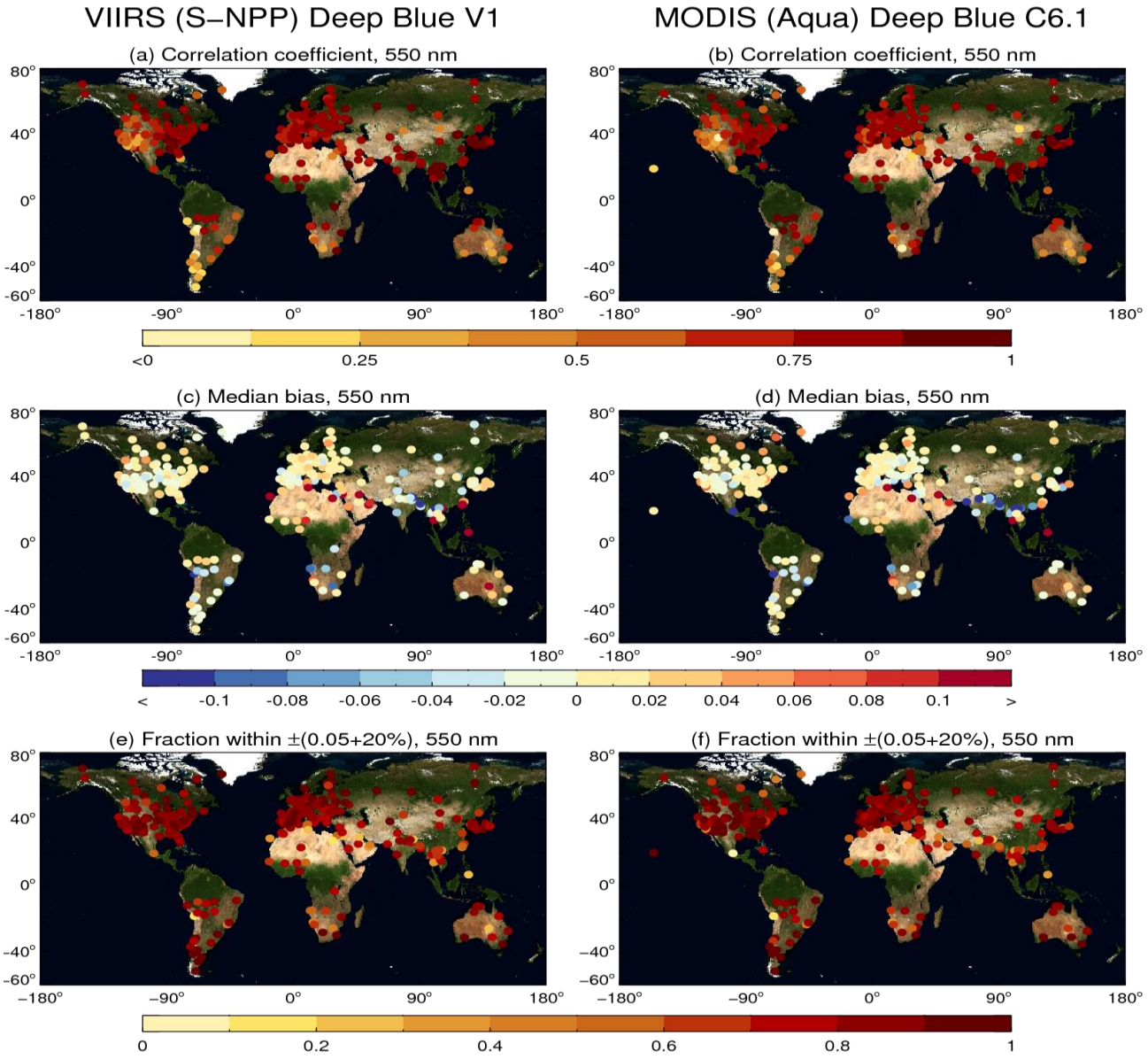




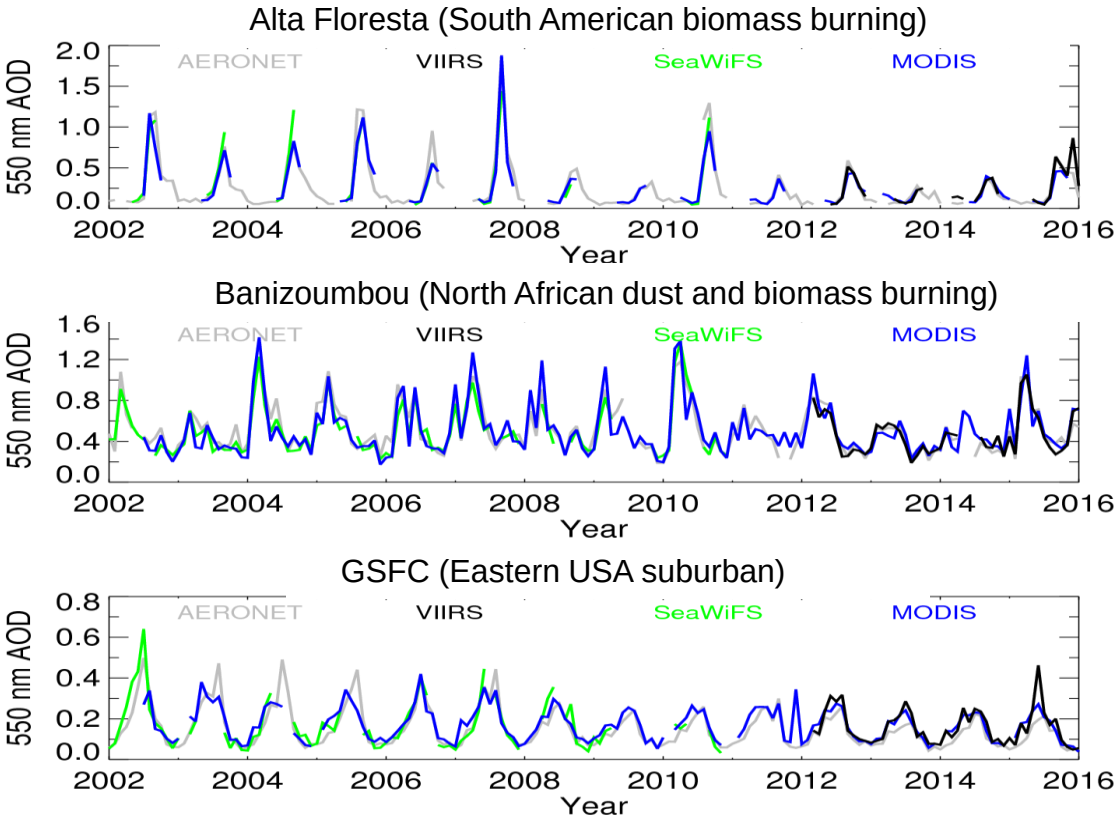




Site-by-Site Comparisons of VIIRS and MODIS/Aqua over-land products with AERONET



Time Series of Monthly Mean AOD from Multi-satellite Deep Blue data at select AERONET sites

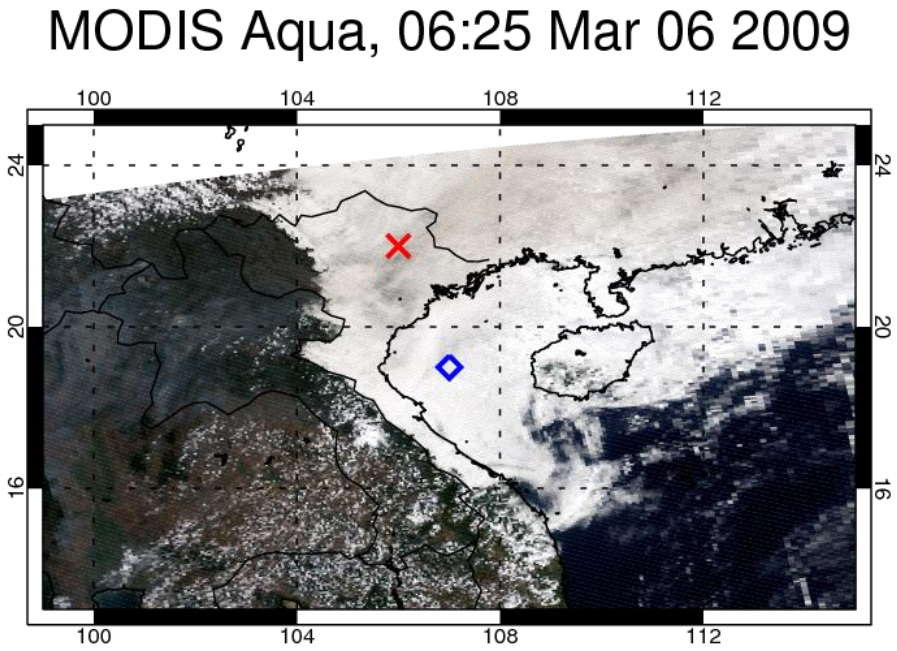


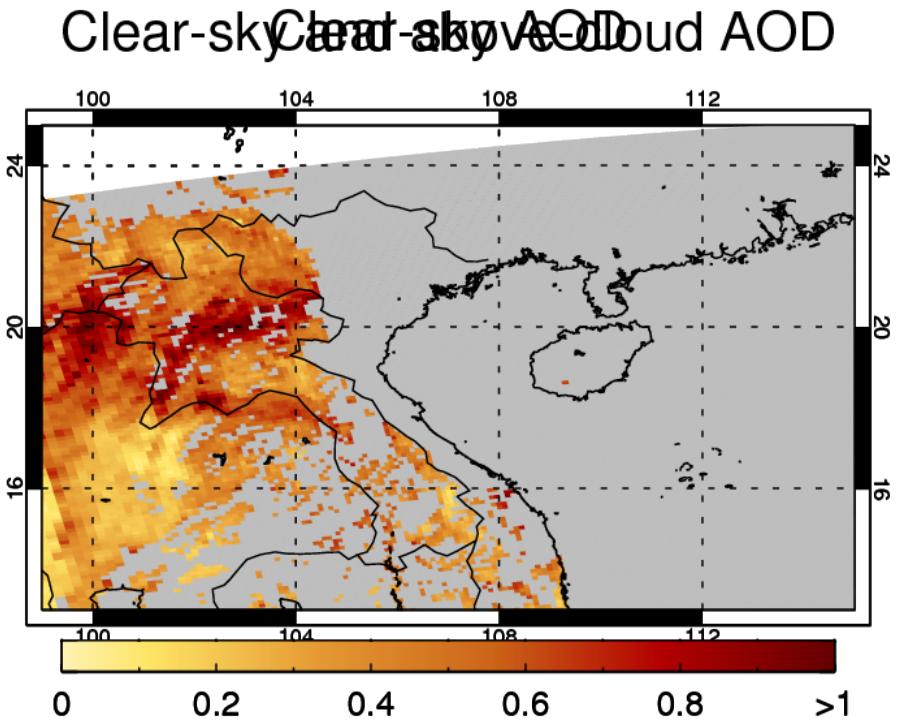
This comparison shows multi-year (2002-2015) quantitative consistency of the VIIRS AOD in comparison with our heritage MODIS and SeaWiFS results, as well as AERONET validation data.

These VIIRS AOD data are generated using corrected VIIRS L1B files after we assessed the calibration of S-NPP VIIRS against MODIS Aqua and developed a cross-calibration correction for VIIRS, which was shown to decrease the uncertainty in retrieved AOD and make VIIRS results more comparable to MODIS .

Extend *Deep Blue* Aerosol Products from Cloud-free to Cloudy regions

We can use sensors like MODIS and VIIRS to quantify absorbing aerosols above clouds (AACs)



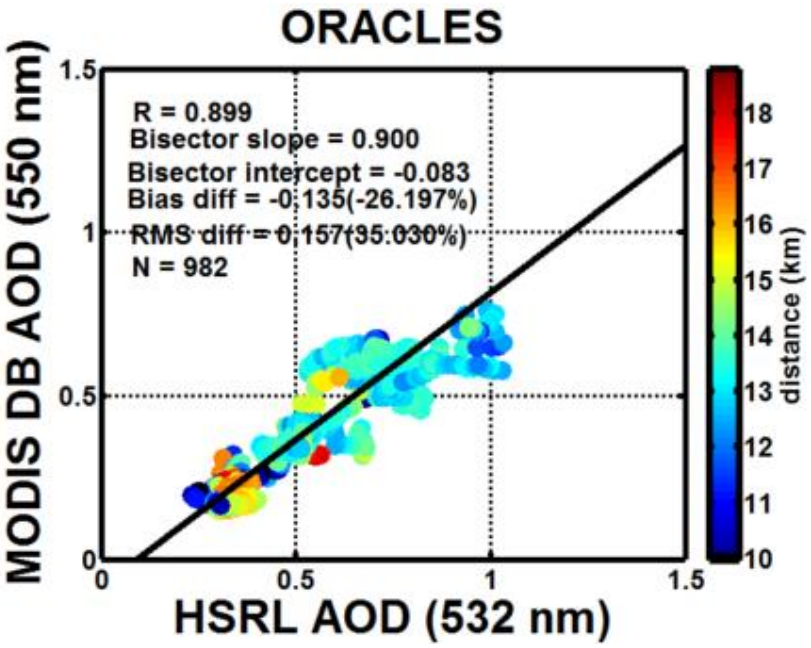


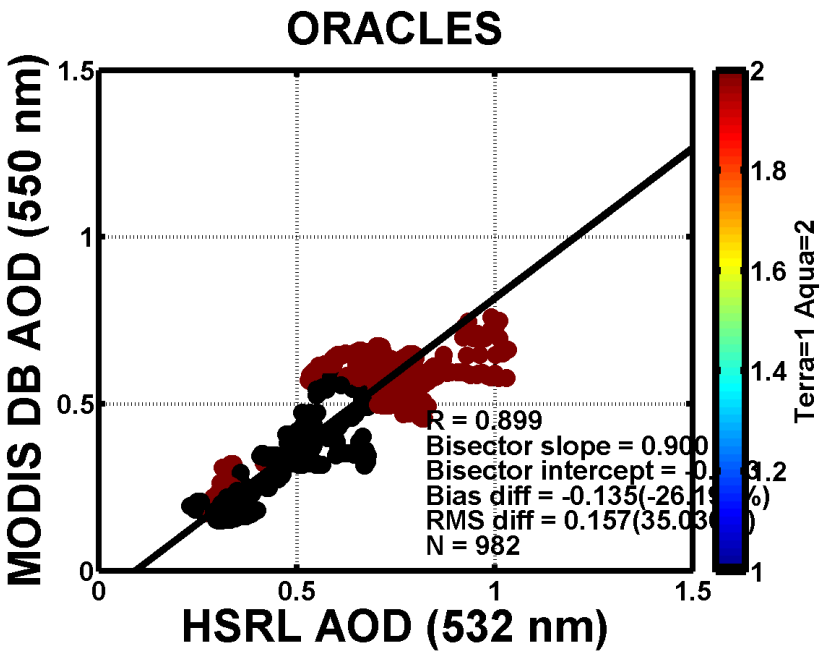
AACs **darken** clouds, and **change the spectral shape** of TOA reflectance

With some assumptions, we can retrieve the **above-cloud AOD** and an estimate of the **COD** of the underlying liquid water cloud

Reference: *Sayer et al*., 2016, JGR, "Extending "Deep Blue" aerosol retrieval coverage to cases of absorbing aerosols above clouds: Sensitivity analysis and first case studies"

ORACLES data have greatly expanded our available validation





HSRL-2 data from ORACLES 2016 (courtesy R. Ferrare and S. Burton, NASA LaRC)

Left: AOD scatter plot, colored by distance between observations
Right: AOD scatter plot, for Terra (black) and Aqua (red)
Broadly consistent with AATS comparison results; covers larger range of AOD

Reference: *Sayer et al*., 2019, AMT, "Two decades observing smoke above clouds in the south-eastern Atlantic Ocean: Deep Blue algorithm updates and validation with ORACLES field campaign data"

New Deep Blue Geostationary Aerosol Products from Himawari-8 and GOES-16

Methodology:

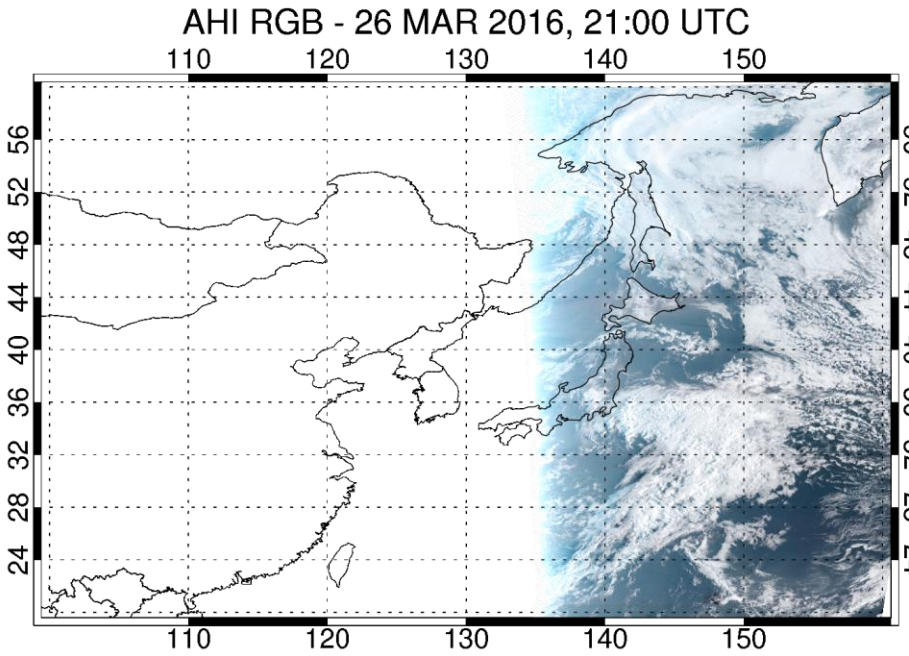
- Employing modified Deep Blue (DB) algorithm by using hourly surface database
- Aerosol retrievals only perform when SZA < 84 ° and VZA < 76°
- Using consistent aerosol models as in MODIS and VIIRS DB algorithms

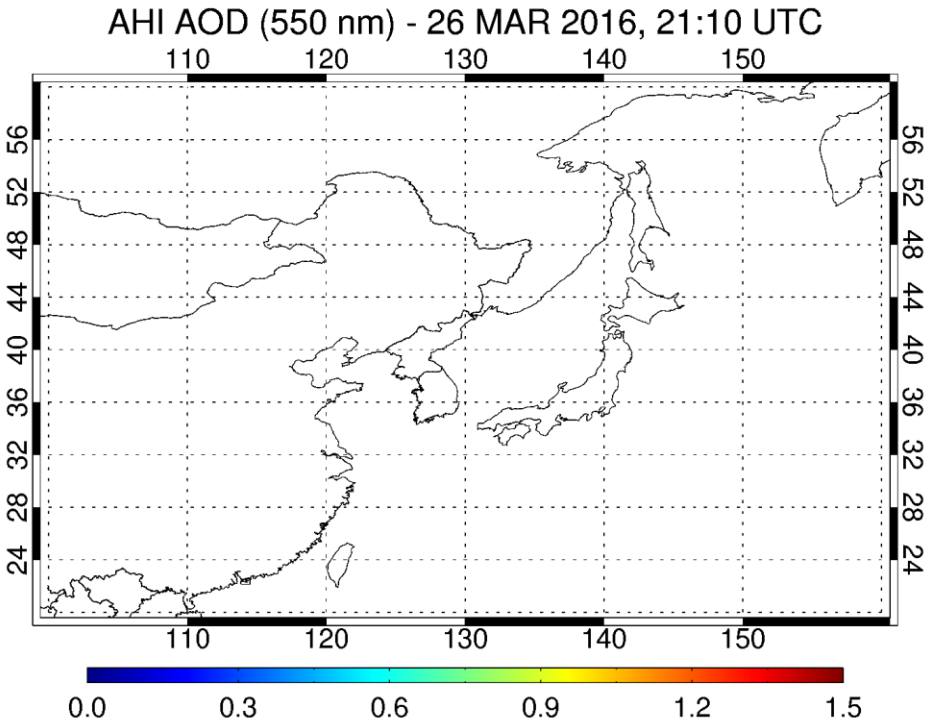
Products:

- AOD over both land and ocean, Level 2 spatial resolution: 8 km (4 x 4 aggregation of 2 km resolution data)
- Temporal coverage: every 10 minutes (AHI) and every 15 minutes (ABI) from Sunrise to Sunset (within retrieval angle ranges)

Biomass Burning Smoke over Korean Peninsula and Fine-Mode Aerosol Plumes over E. Asia

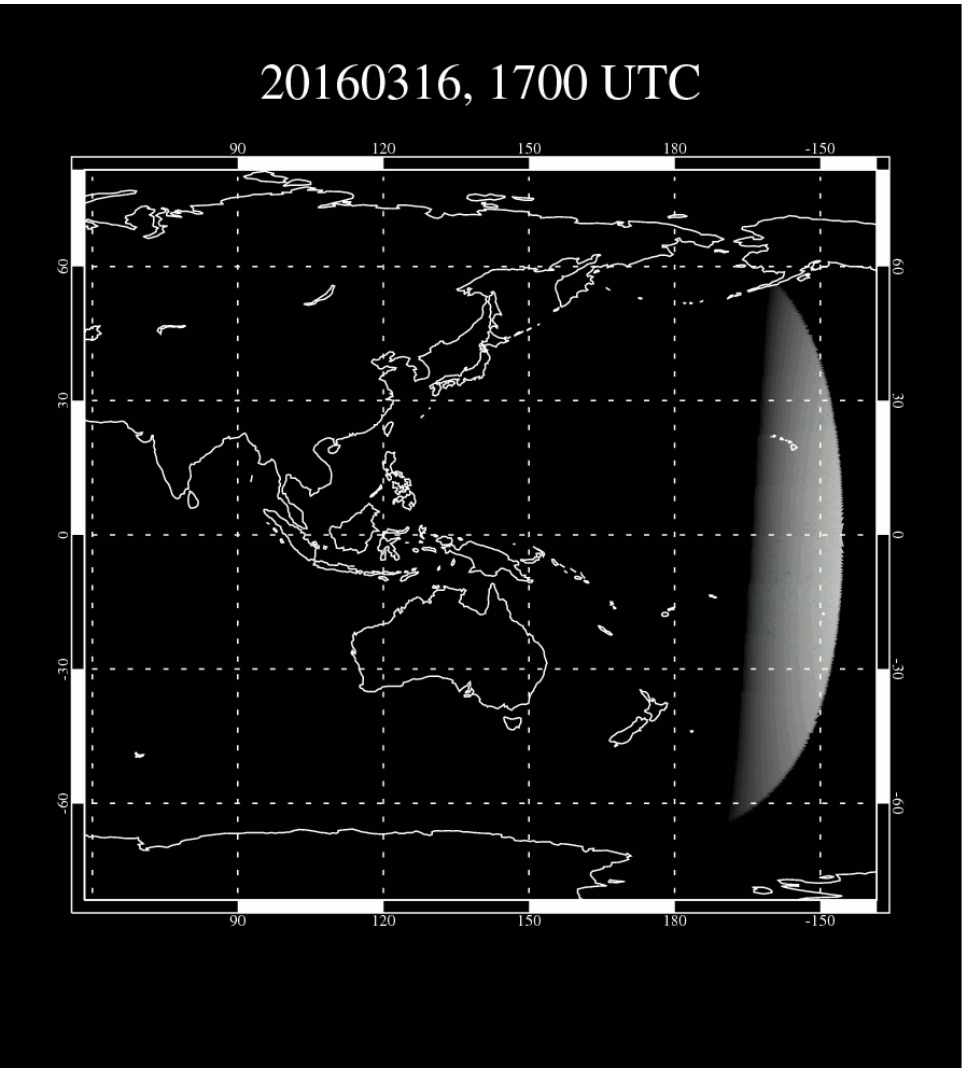
Himawari-8: 10-minute interval

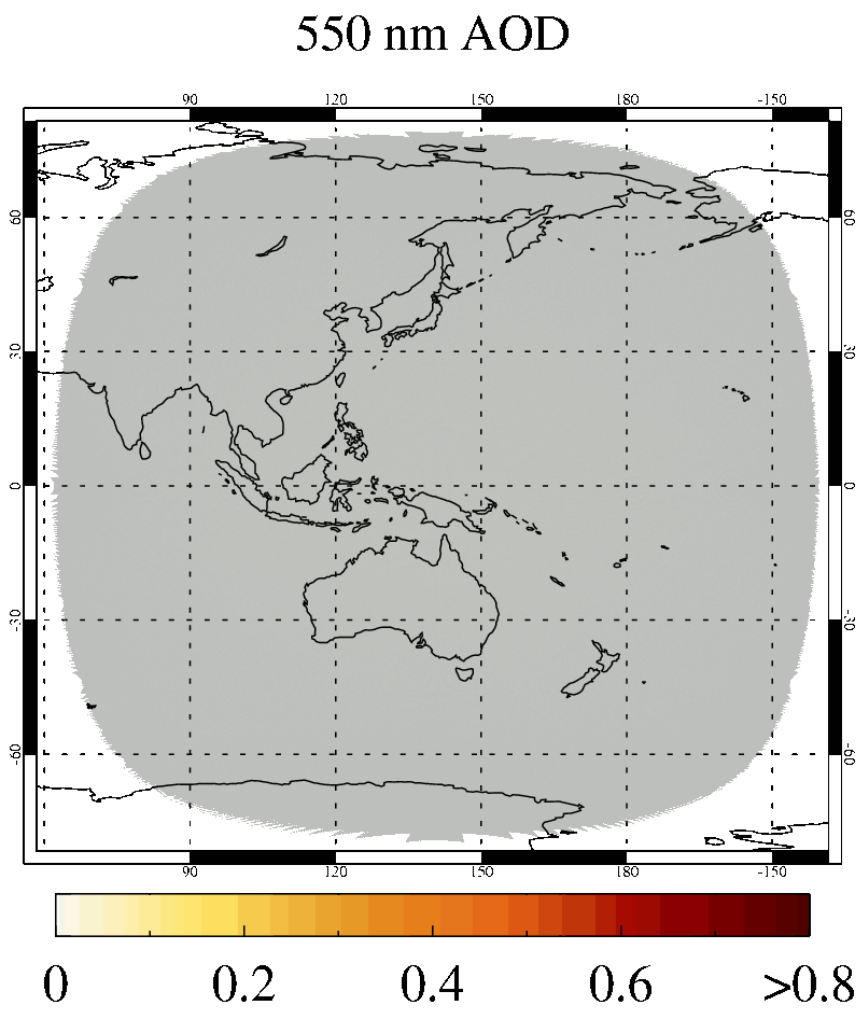




Dust Outbreak over northern China and Biomass Burning Smoke over SE Asia

Himawari-8: 10-minute interval





Comparisons between Terra/Aqua MODIS, VIIRS and AHI

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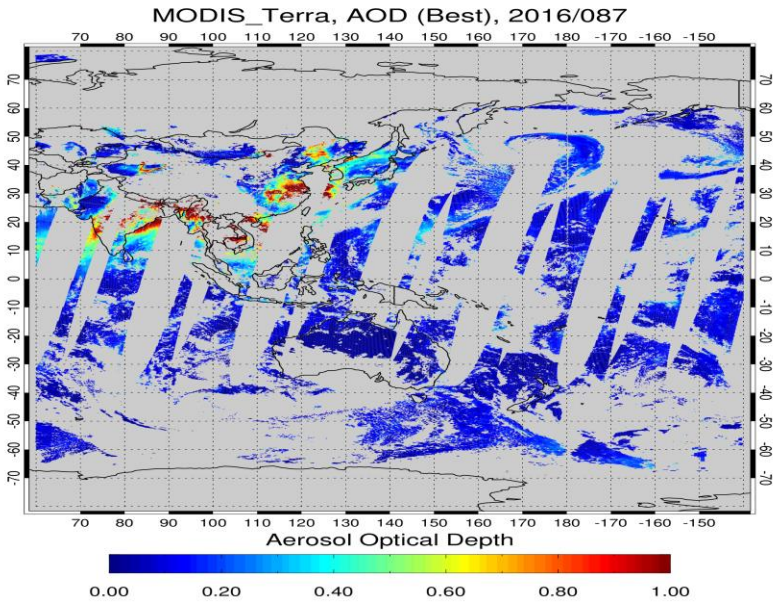

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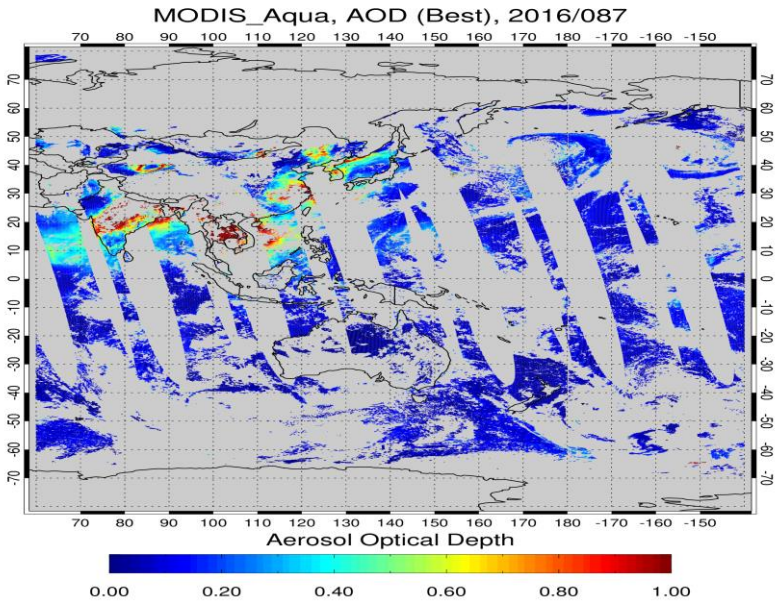

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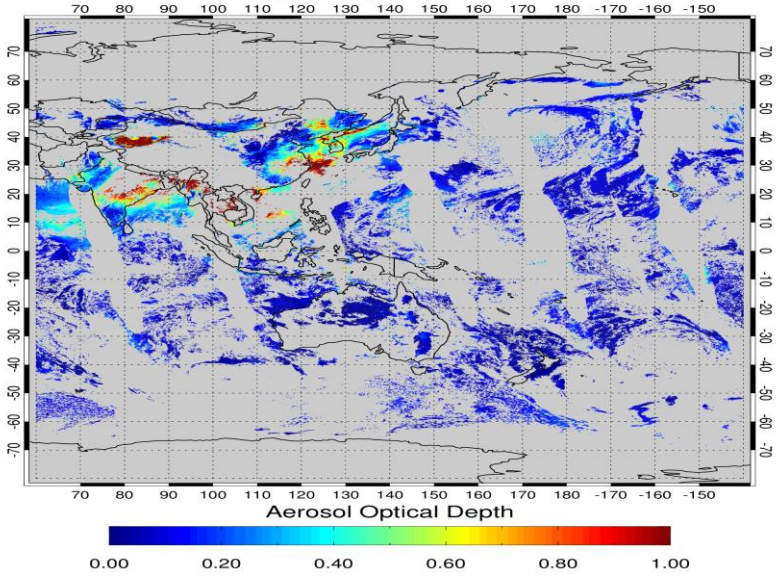
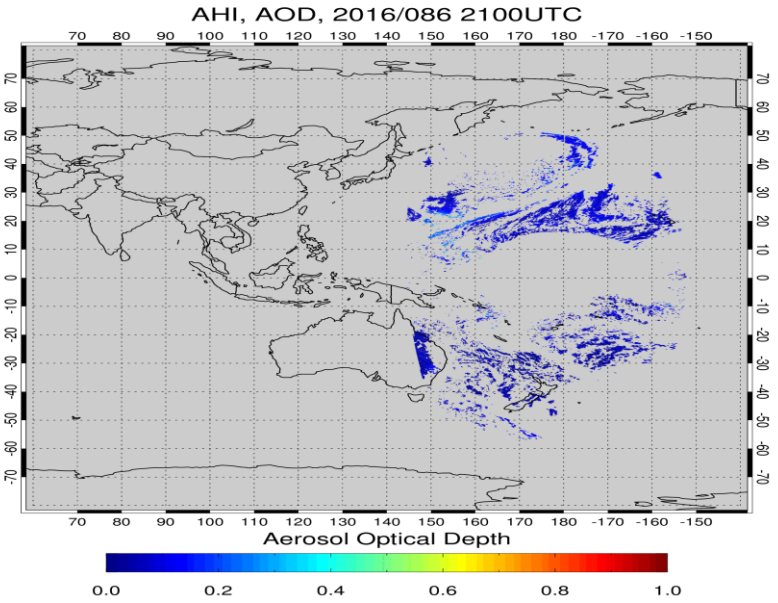
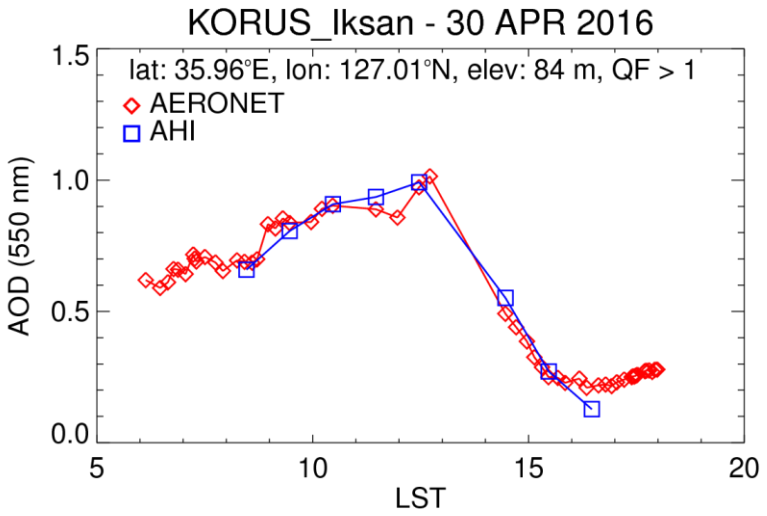
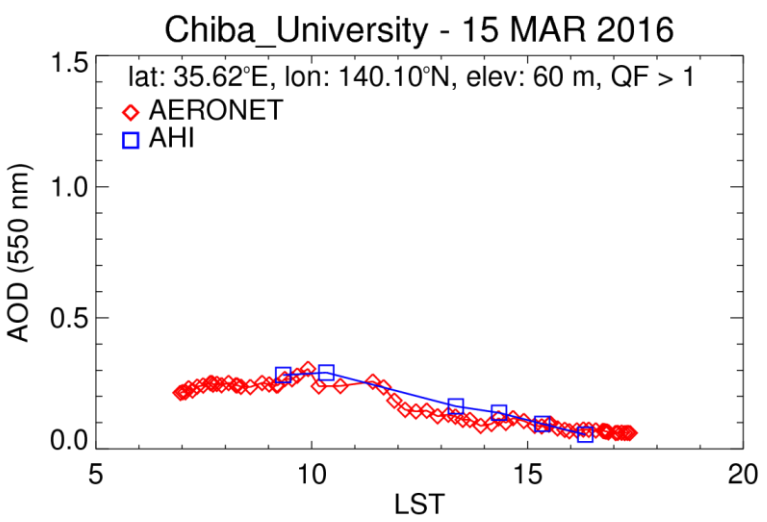
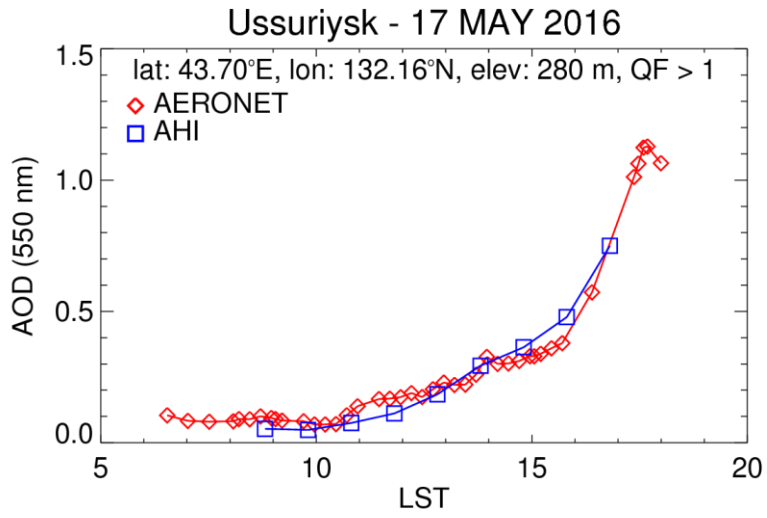


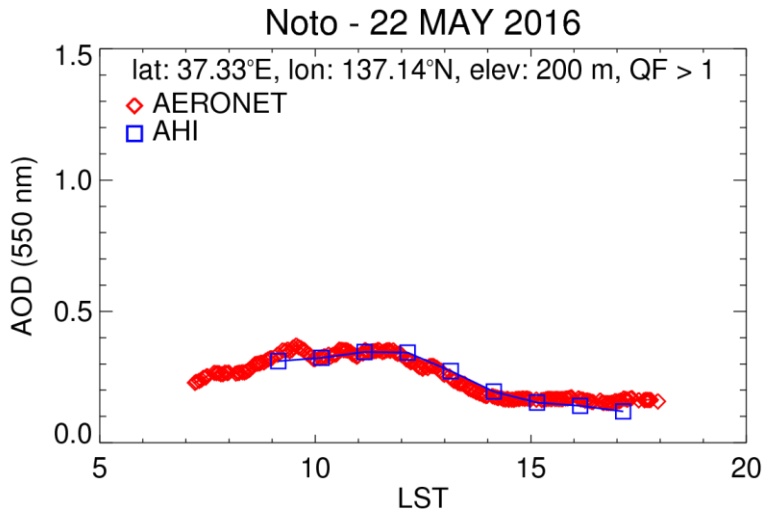


Diurnal Cycles of AOD Retrieved from AHI vs AERONET

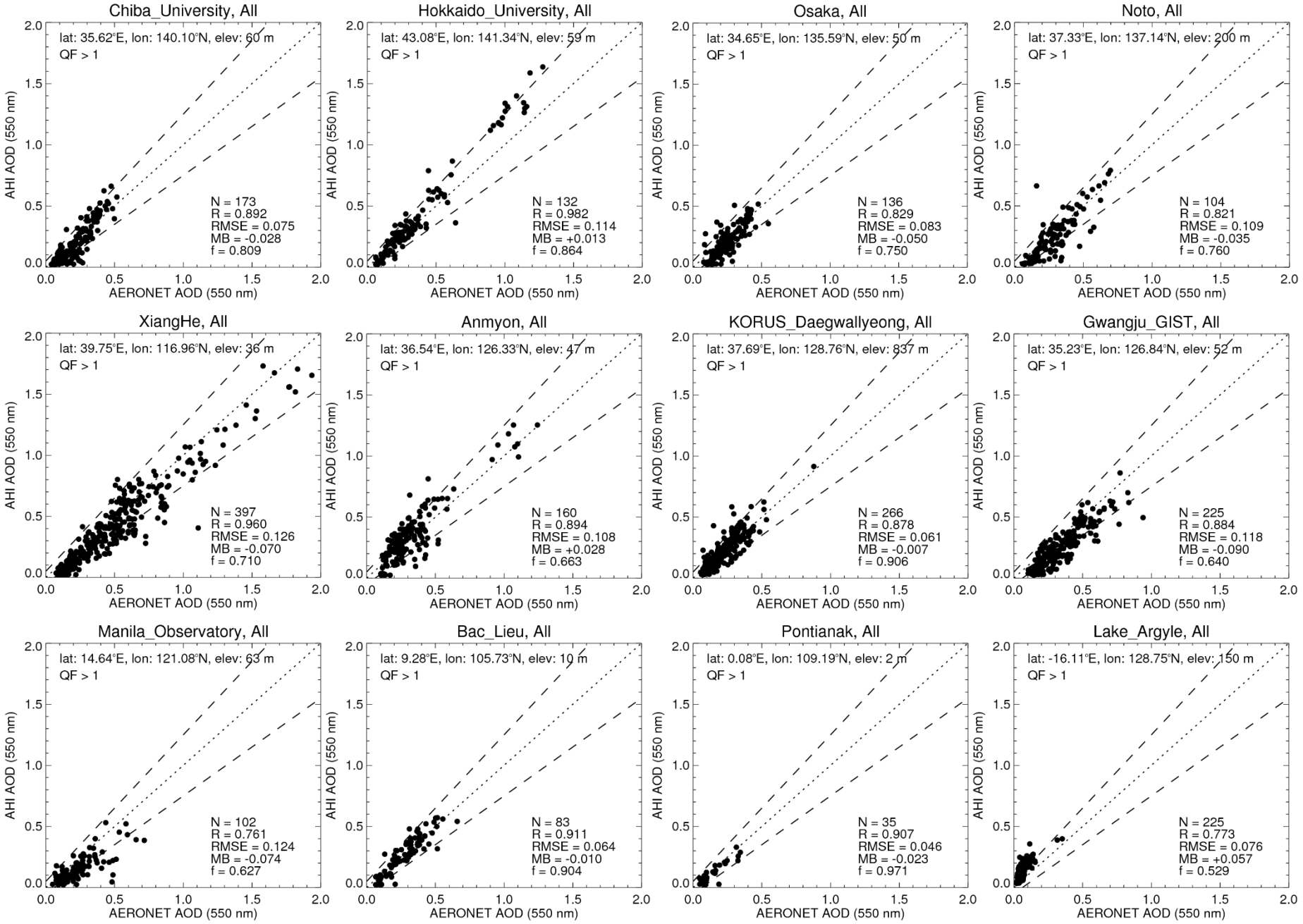






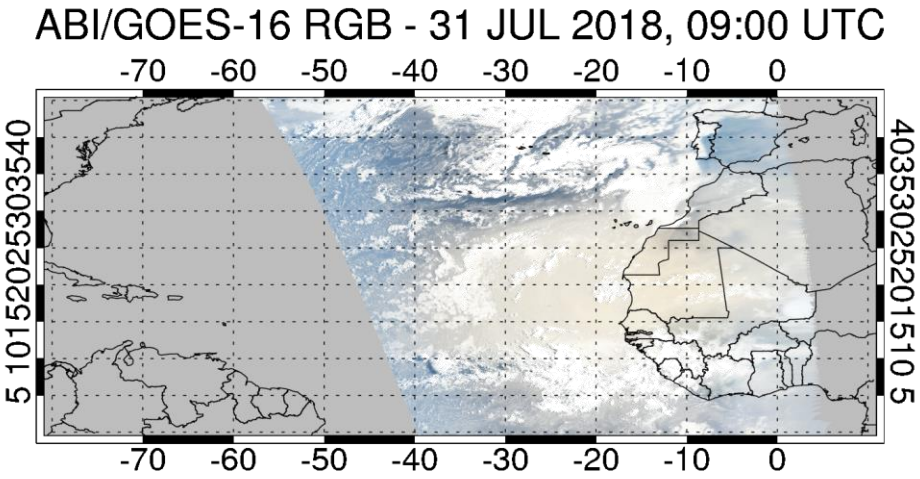


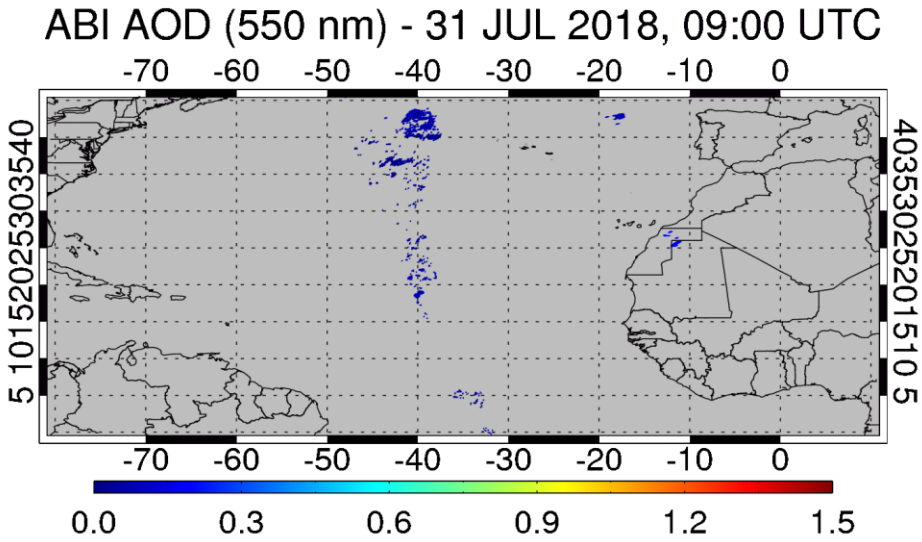
Comparisons of Himawari-8 DB AOD vs. AERONET (Entire Diurnal Cycles)



The Saharan Dust transported from N. Africa to the Atlantic Ocean

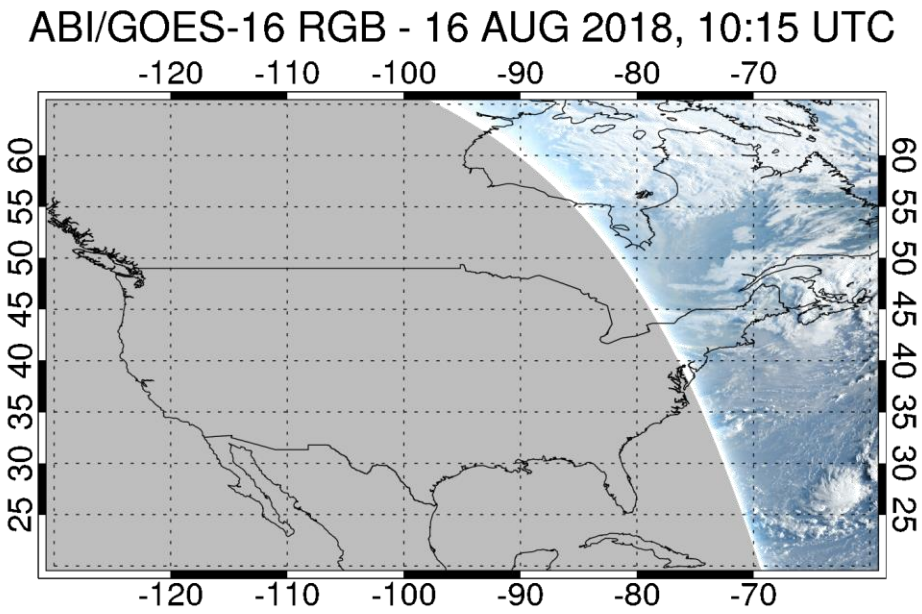
GOES-16: 15-minute interval

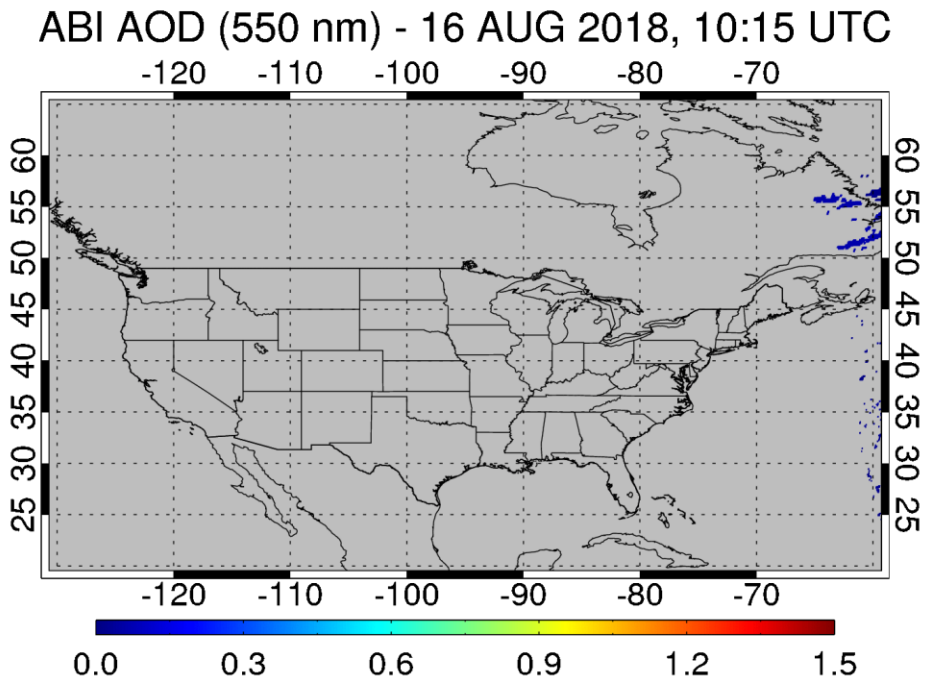




Large-Scale Biomass Burning Smoke Plumes over N. America

GOES-16: 15-minute interval





Summary

- **The Version 1 VIIRS Deep Blue aerosol products have been in operational mode since December 2018. Thanks for the support from Atmosphere SIPS and LANCE, near-real time VIIRS DB aerosol products are now also available via LANCE. The public announcement will follow soon once the Worldview imagery flow is complete.**
- **Based upon the comparisons with AERONET AOD global observations, the expected error for VIIRS DB is 0.05±20% over land and 0.03±10% over ocean, which is comparable to that for MODIS DB. The AOD time series from VIIRS and MODIS are consistent with each other. New aerosol above cloud product will be in VIIRS V2 and MODIS C7.**
- **We have successfully processed geostationary satellite data from Himawari-8 and GOES-16 using modified Deep Blue algorithm. The comparisons between our retrieved AHI AOD with the AERONET data show reasonable agreements. Derivation of additional sensor calibration is currently underway for ABI.**