

New Deep Blue Aerosol Products from LEO and GEO Satellites



*Photo taken from Space Shuttle:
Fierce dust front over Libya*

N. Christina Hsu (PI), Jaehwa Lee, Andrew Sayer, Vincent Kim

Climate and Radiation Laboratory

NASA Goddard Space Flight Center, Greenbelt, Maryland USA



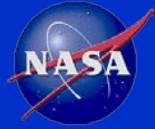
LEO Multi-Sensor Deep Blue Aerosol Products

➤ ***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***

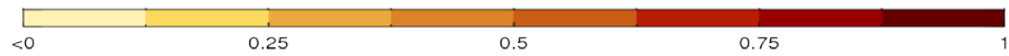
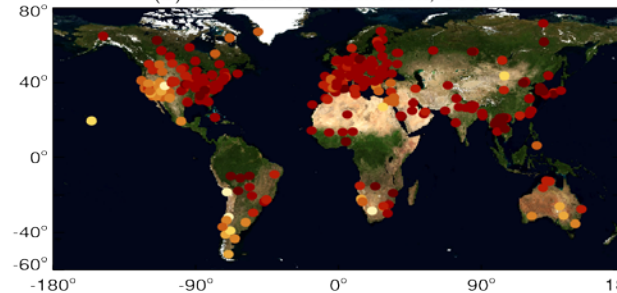
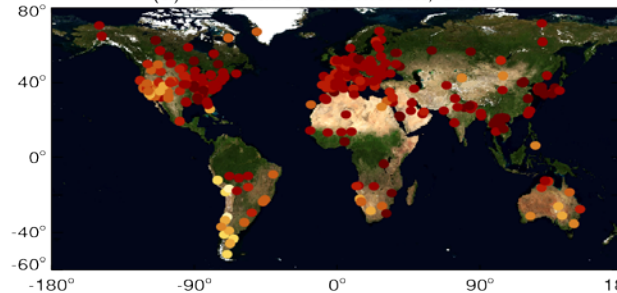
Site-by-Site Comparisons of VIIRS and MODIS/Aqua over-land products with AERONET

VIIRS (S-NPP) Deep Blue V1

MODIS (Aqua) Deep Blue C6.1

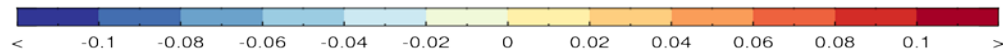
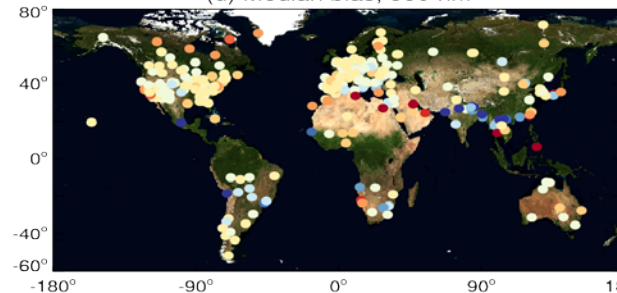
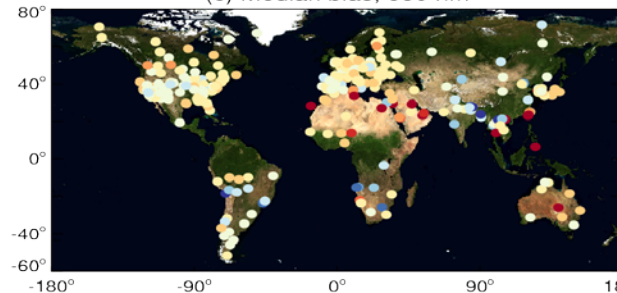
(a) Correlation coefficient, 550 nm

(b) Correlation coefficient, 550 nm



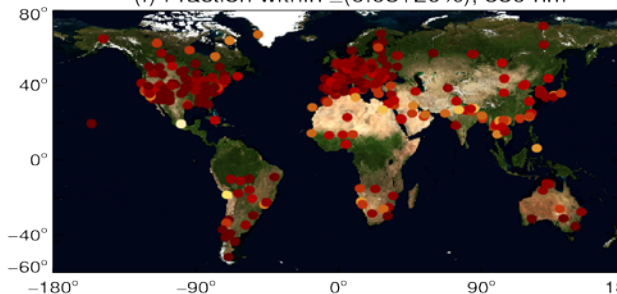
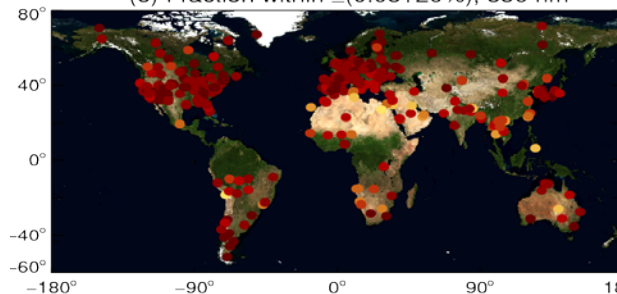
(c) Median bias, 550 nm

(d) Median bias, 550 nm



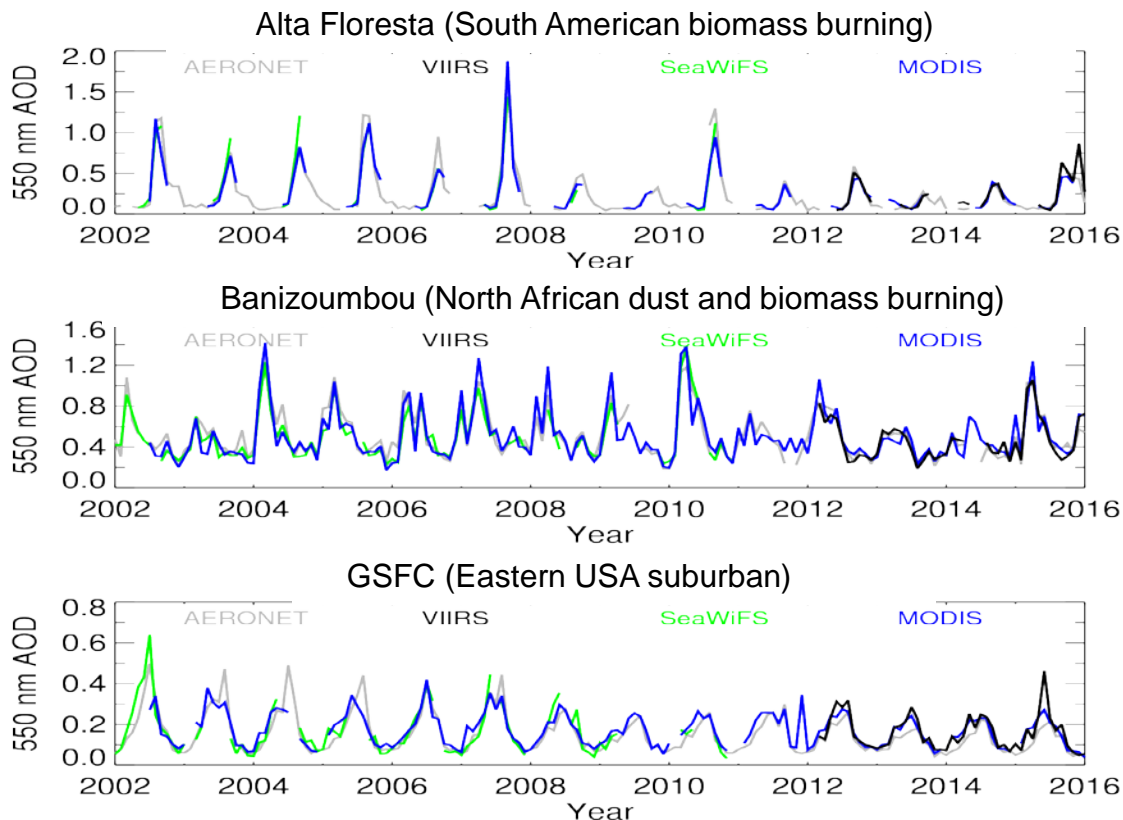
(e) Fraction within $\pm(0.05+20\%)$, 550 nm

(f) Fraction within $\pm(0.05+20\%)$, 550 nm





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



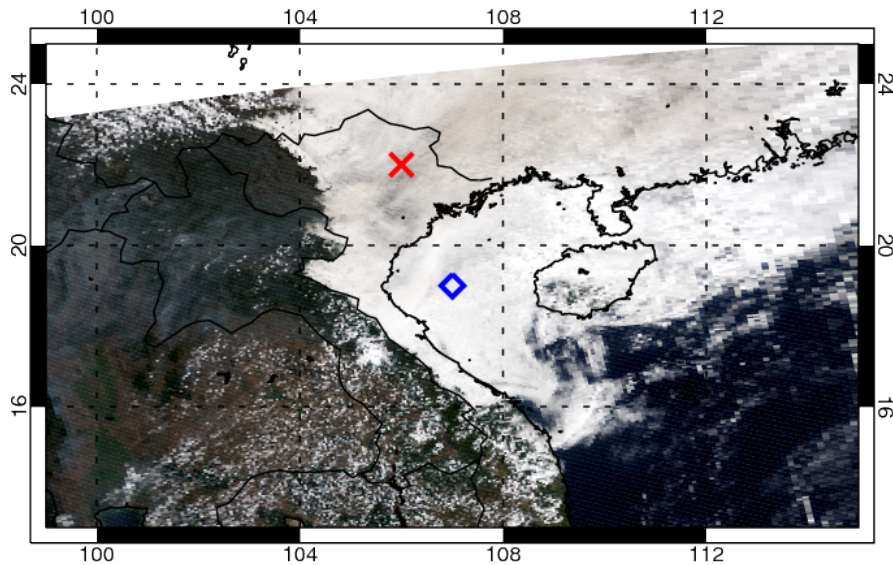
This comparison shows multi-year (2002-2015) quantitative consistency of the VIIRS AOD in comparison with our heritage MODIS and SeaWiFS results, as well as AERONET validation data.

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.

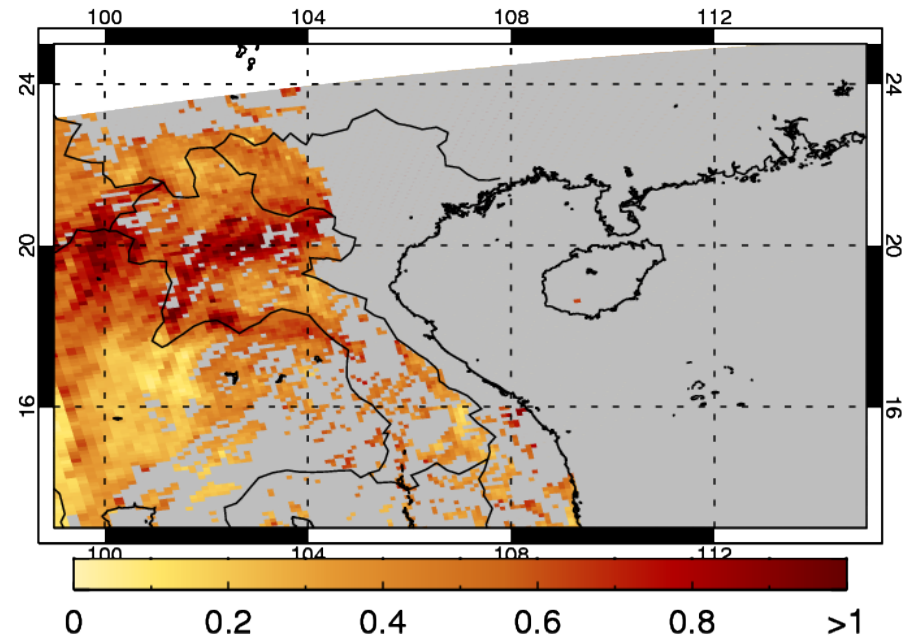
**Extend *Deep Blue* Aerosol Products from
Cloud-free to Cloudy regions**

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

MODIS Aqua, 06:25 Mar 06 2009



Clear-sky Clear-sky AOD Cloud AOD

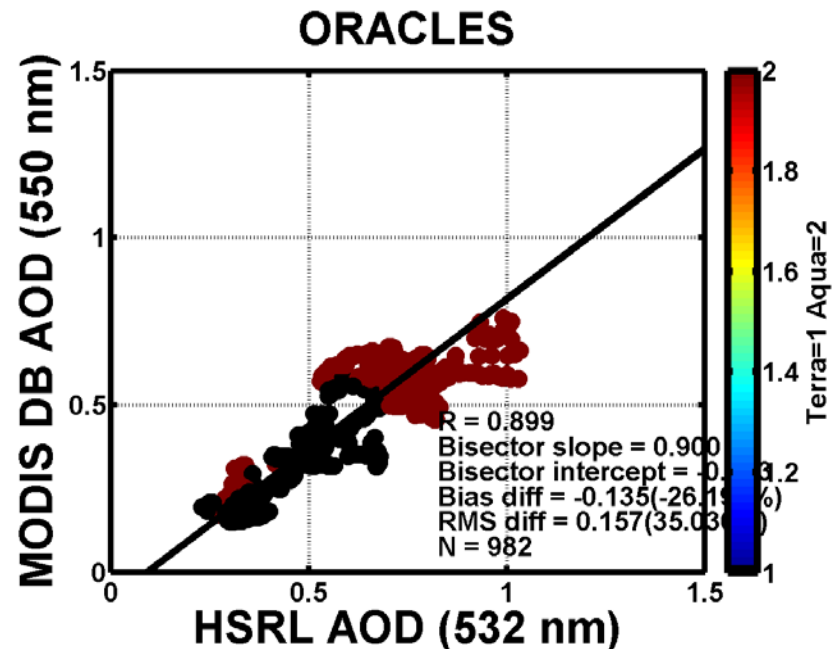
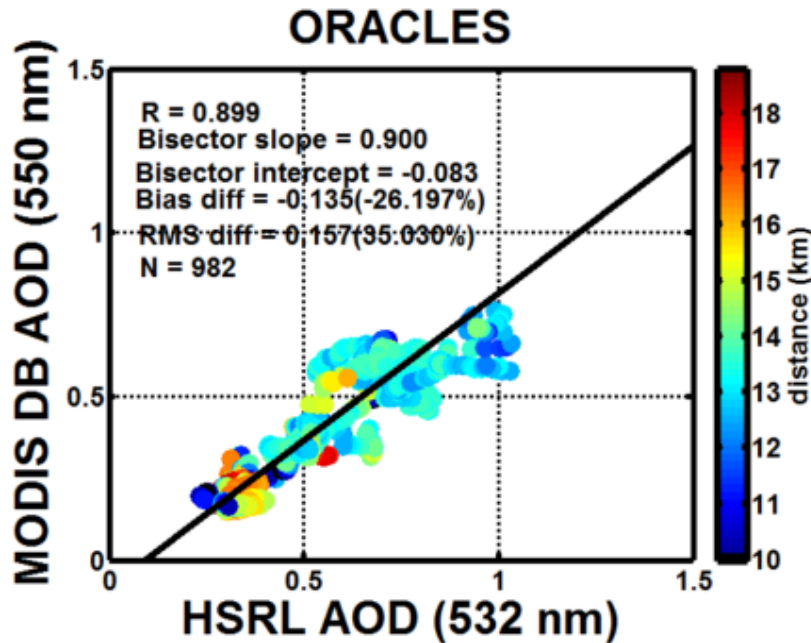


AACs **darken** clouds, and **change the spectral shape** of TOA reflectance

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 $SZA < 84^\circ$ and $VZA < 76^\circ$
- ➔ Using consistent aerosol models as in MODIS and VIIRS DB algorithms

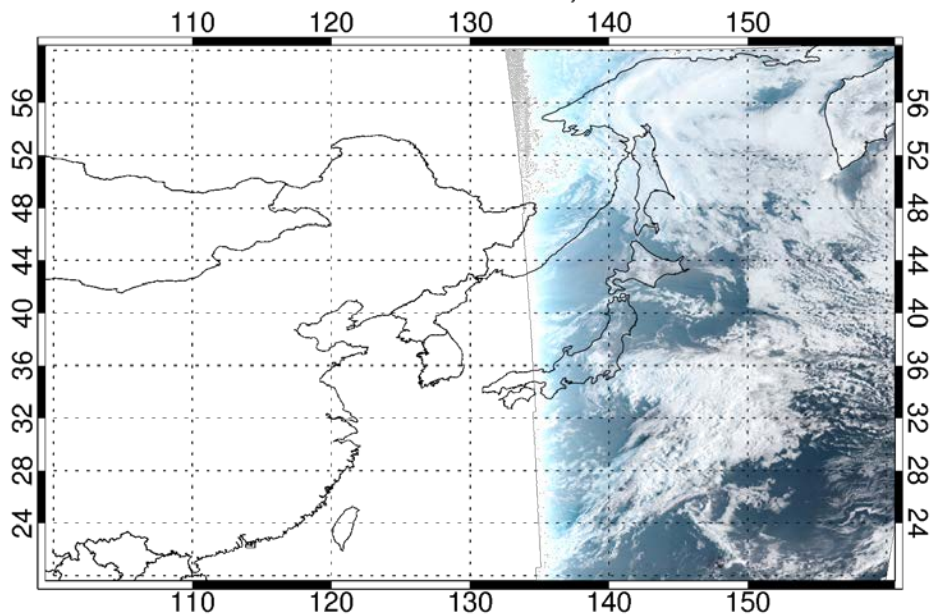
Products:

- ➔ 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)

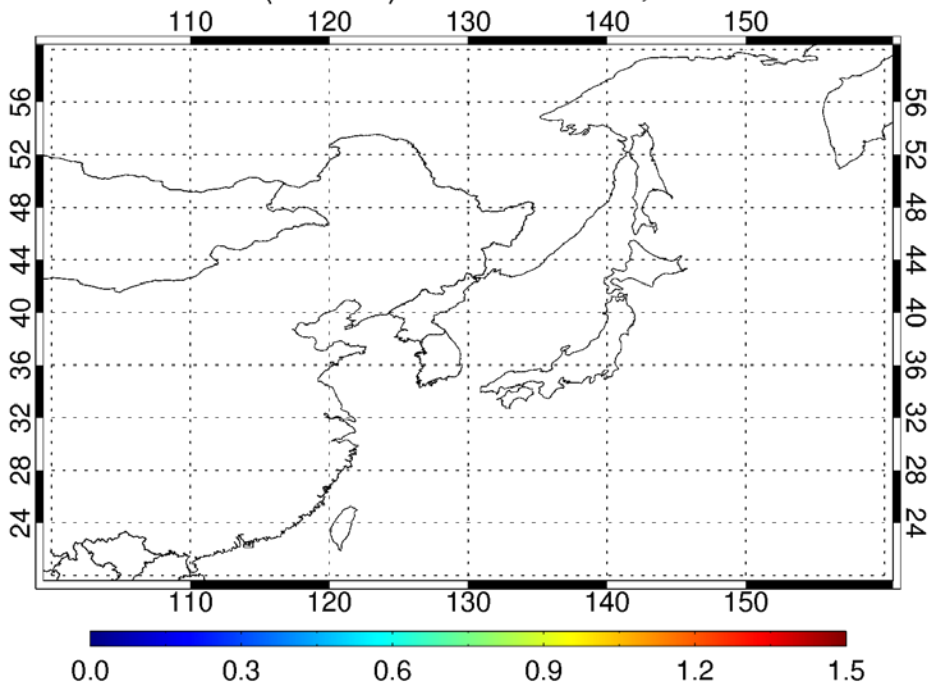
Biomass Burning Smoke over Korean Peninsula and Fine-Mode Aerosol Plumes over E. Asia

Himawari-8: 10-minute interval

AHI RGB - 26 MAR 2016, 21:00 UTC



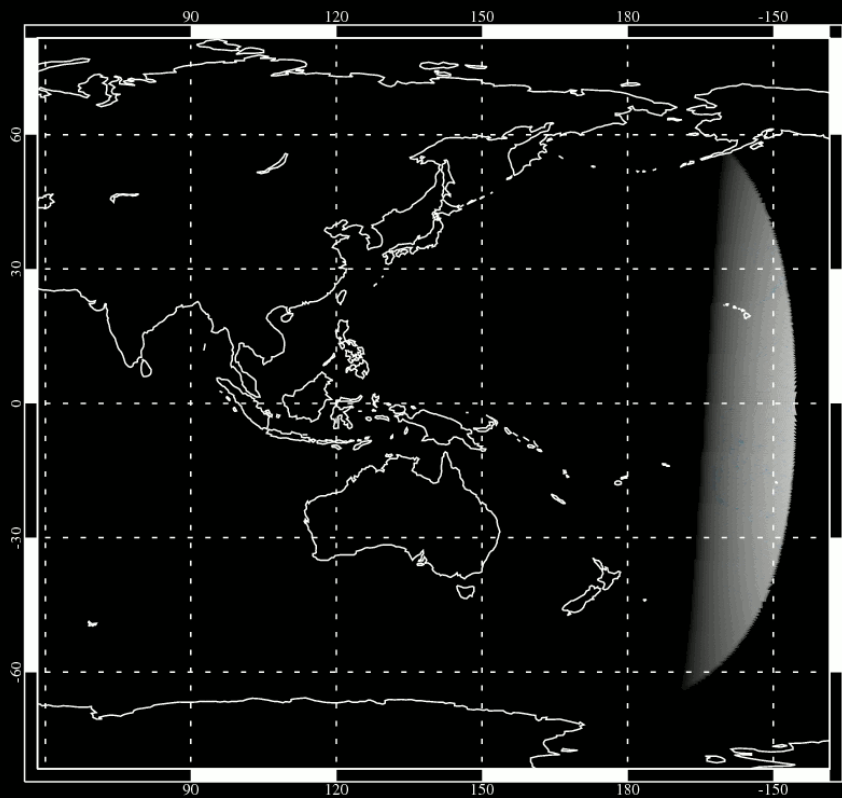
AHI AOD (550 nm) - 26 MAR 2016, 21:10 UTC



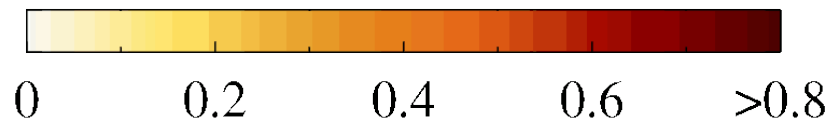
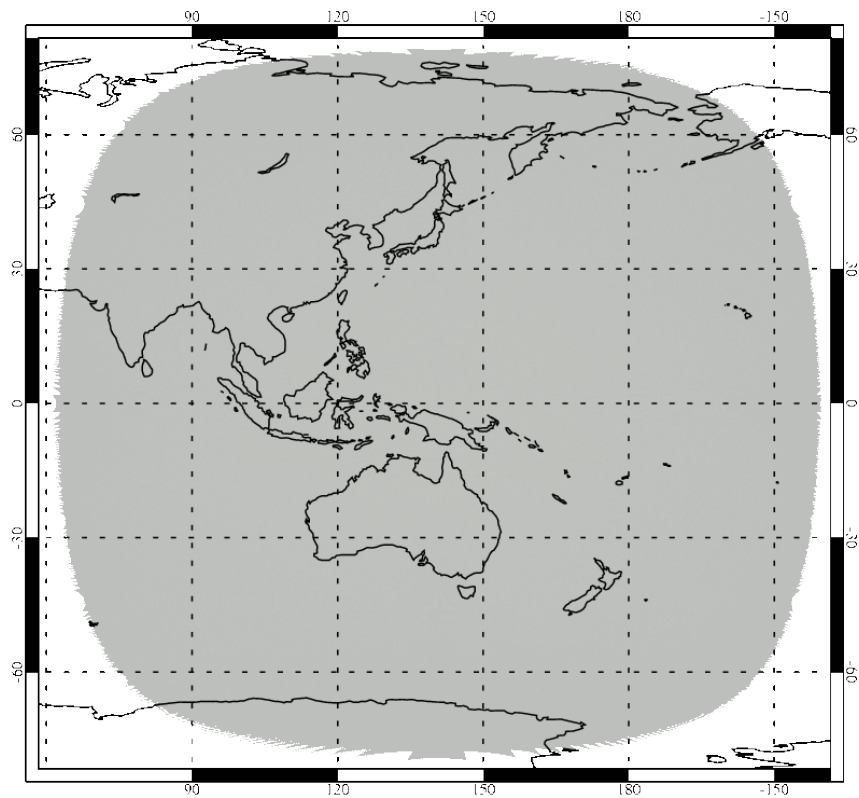
Dust Outbreak over northern China and Biomass Burning Smoke over SE Asia

Himawari-8: 10-minute interval

20160316, 1700 UTC

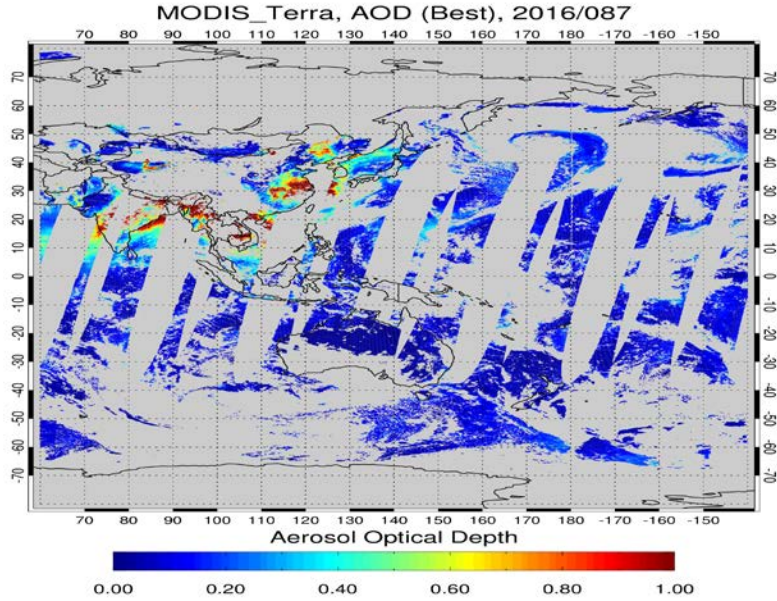


550 nm AOD

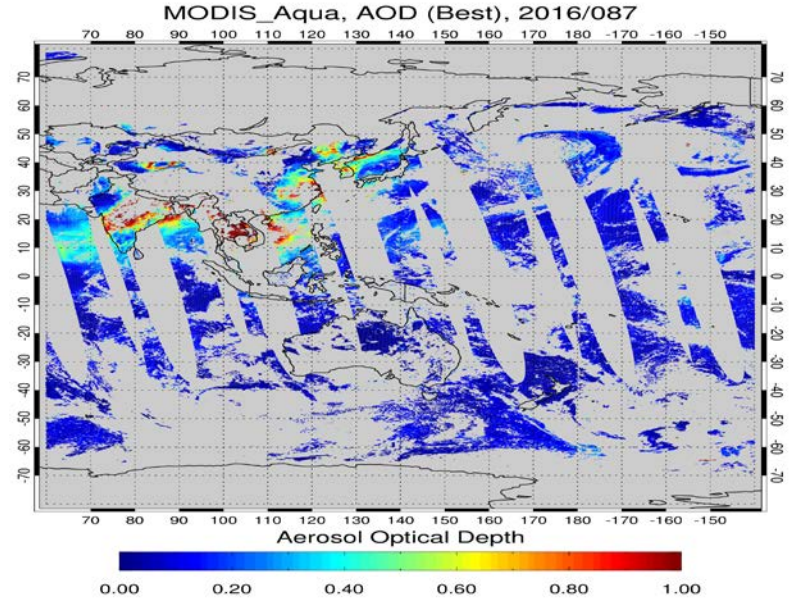


Comparisons between Terra/Aqua MODIS, VIIRS and AHI

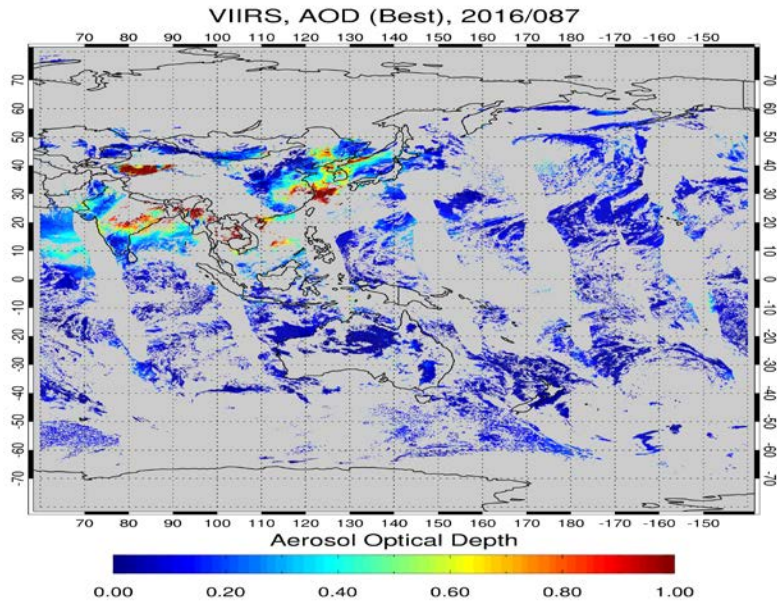
03/26/2016 20:10UTC → 03/27/2016 06:50UTC



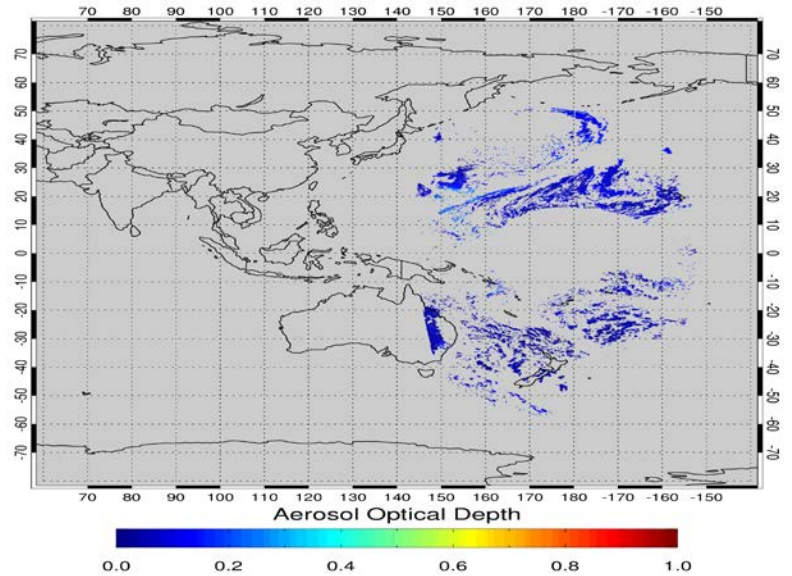
03/26/2016 23:10UTC → 03/27/2016 09:45UTC



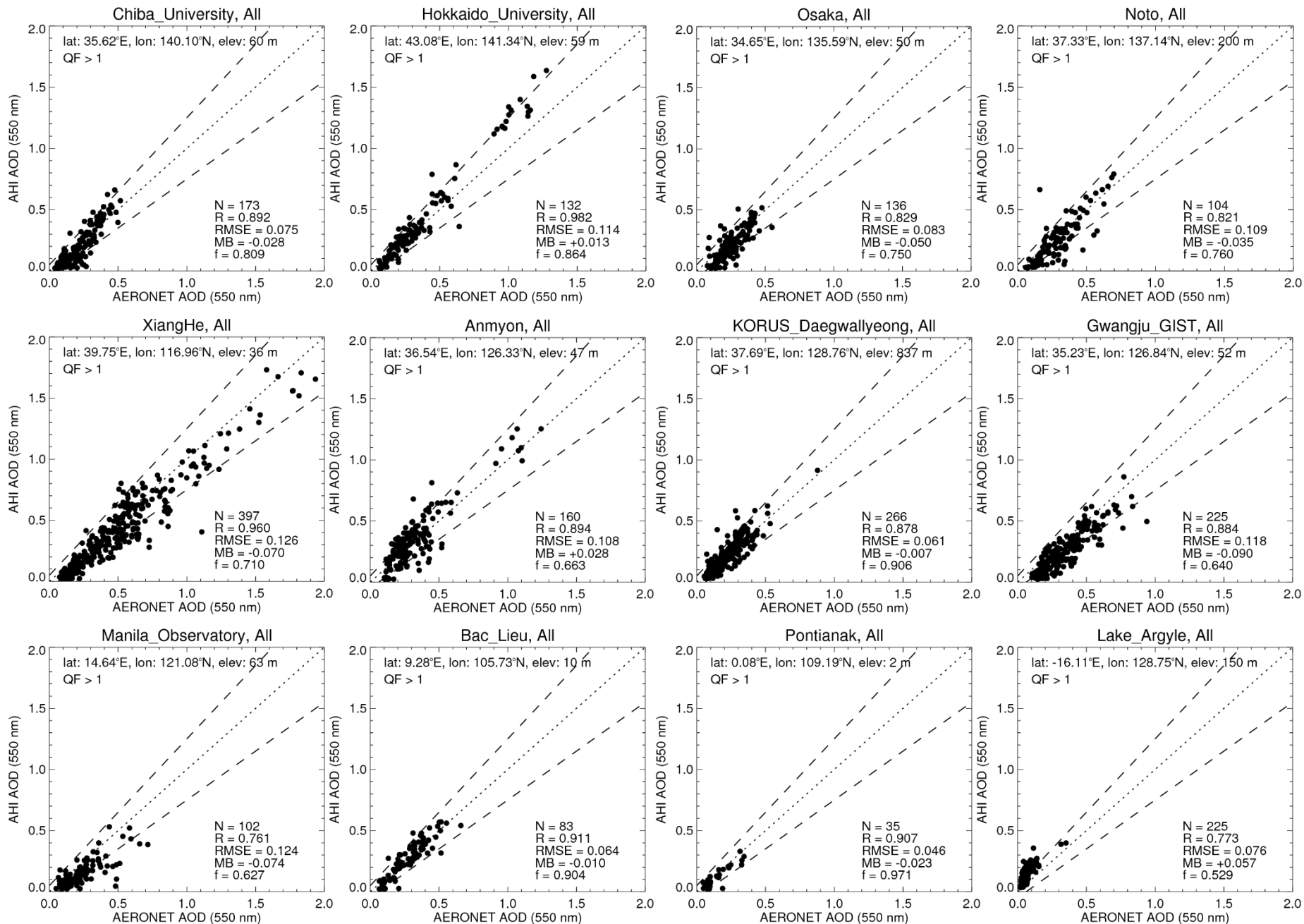
03/26/2016 21:30UTC → 03/27/2016 08:30UTC



AHI, AOD, 2016/086 2100UTC



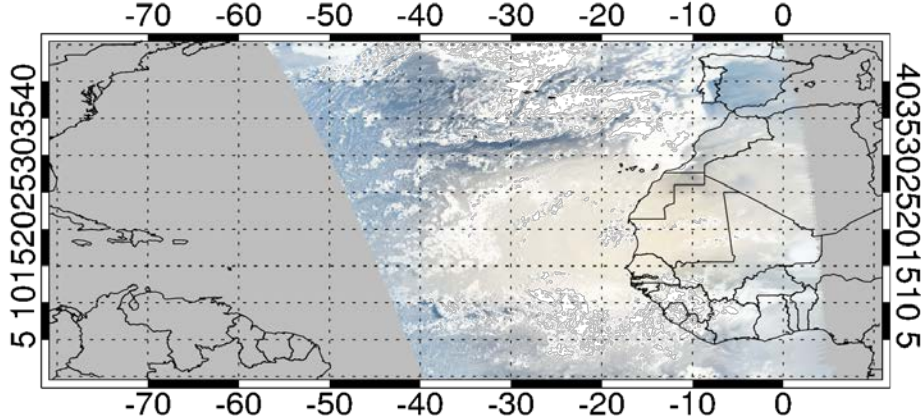
Comparisons of Himawari-8 DB AOD vs. AERONET (Entire Diurnal Cycles)



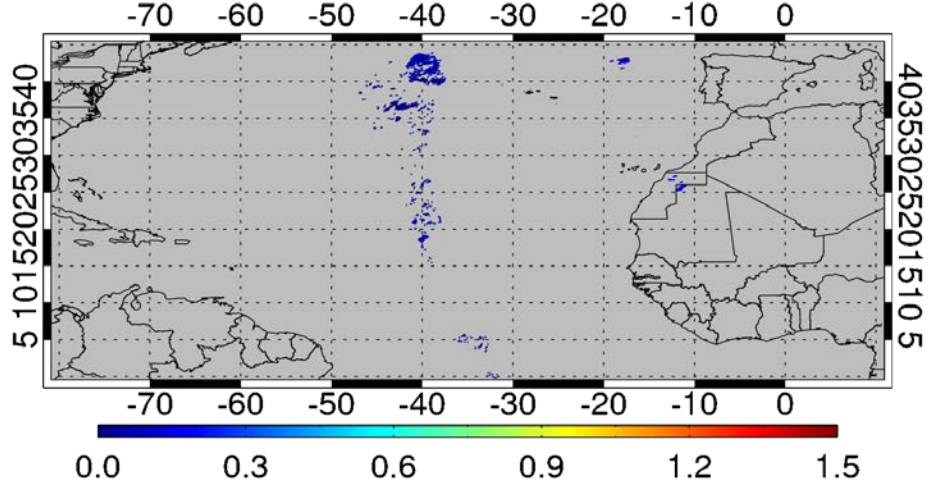
The Saharan Dust transported from N. Africa to the Atlantic Ocean

GOES-16: 15-minute interval

ABI/GOES-16 RGB - 31 JUL 2018, 09:00 UTC



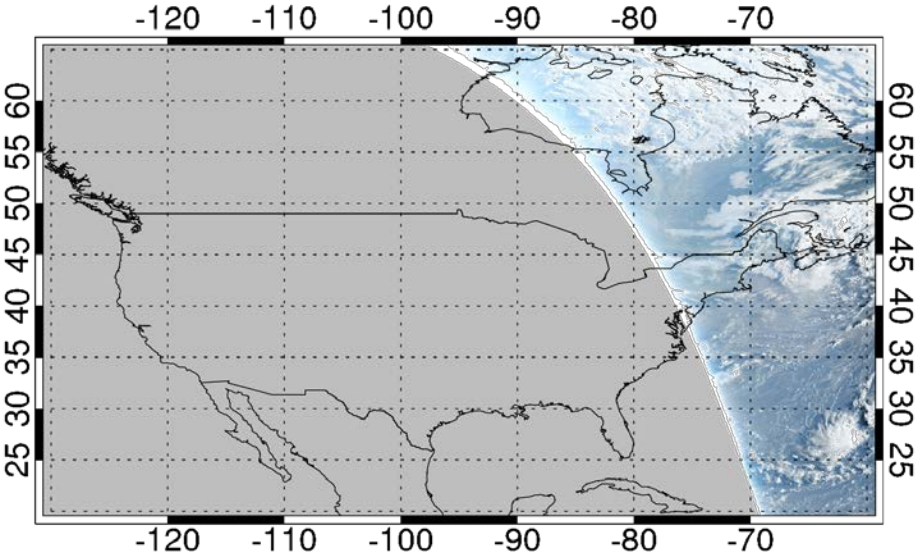
ABI AOD (550 nm) - 31 JUL 2018, 09:00 UTC



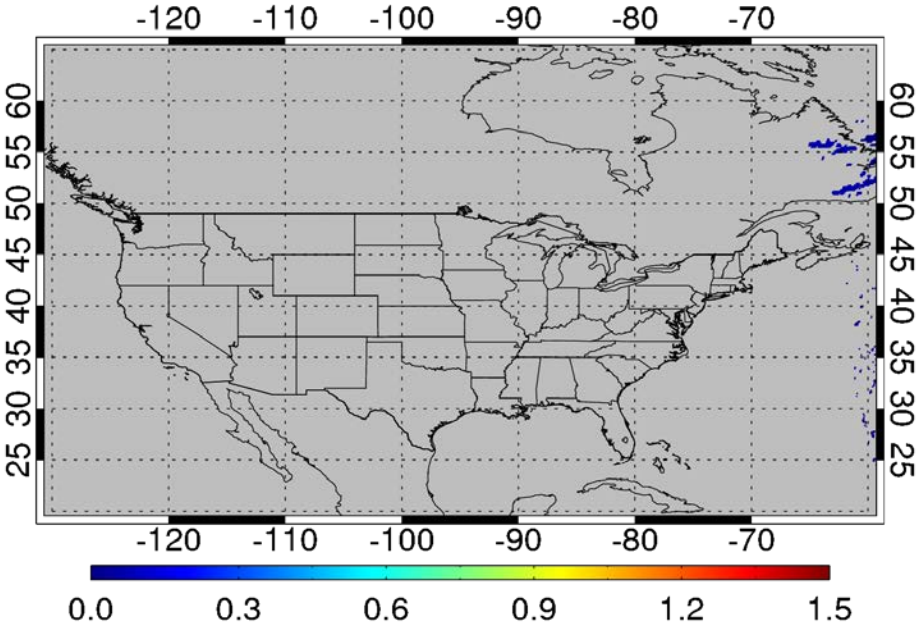
Large-Scale Biomass Burning Smoke Plumes over N. America

GOES-16: 15-minute interval

ABI/GOES-16 RGB - 16 AUG 2018, 10:15 UTC



ABI AOD (550 nm) - 16 AUG 2018, 10:15 UTC





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 $0.05 \pm 20\%$ over land and $0.03 \pm 10\%$ 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.**