

Introducing MODIS Collection 7 Deep Blue Aerosol Products

Deep Blue Aerosol Project team:

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Status of Deep Blue Aerosol Products

MODIS Collection 7

- Algorithm based on VIIRS Version 2 production code, with major upgrades relative to Collection 6.1
- Standalone source code integrated into the production system, tested, and currently in production
- Level 2 production completed for the “Tier 1” period (2008 – 2018) for both Terra and Aqua; Level 3 in test production
- Additional refinements beyond VIIRS Version 2 to be incorporated into the VIIRS Version 3
- Performance improvements vs. C6.1:
 - Over high-elevation regions
 - Over bright and heterogeneous surfaces
 - For mineral dust and fine-dominated aerosol cases
 - Overall improvements due to calibration updates

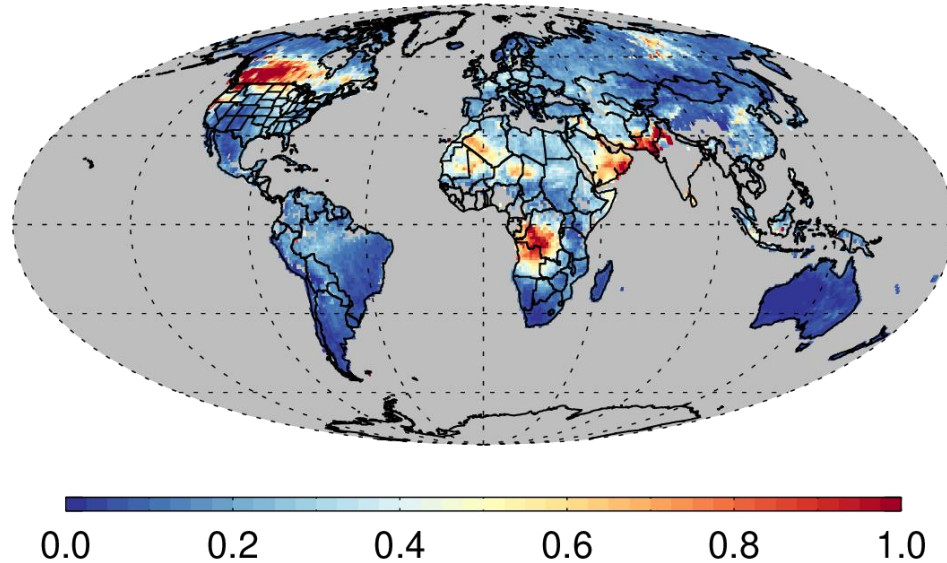
VIIRS Version 2.1

- Expanded to include NOAA-21 VIIRS, in addition to SNPP and NOAA-20
- Data sets produced at A-SIPS and approved by LAADS
- Partial implementation of MODIS C7 updates to improve data continuity
- Full algorithm consistency with MODIS C7 planned for Version 3

MODIS C7 Aerosol Product

MODIS C6.1

Aqua MODIS DB AOD (550 nm, AUG 2018)

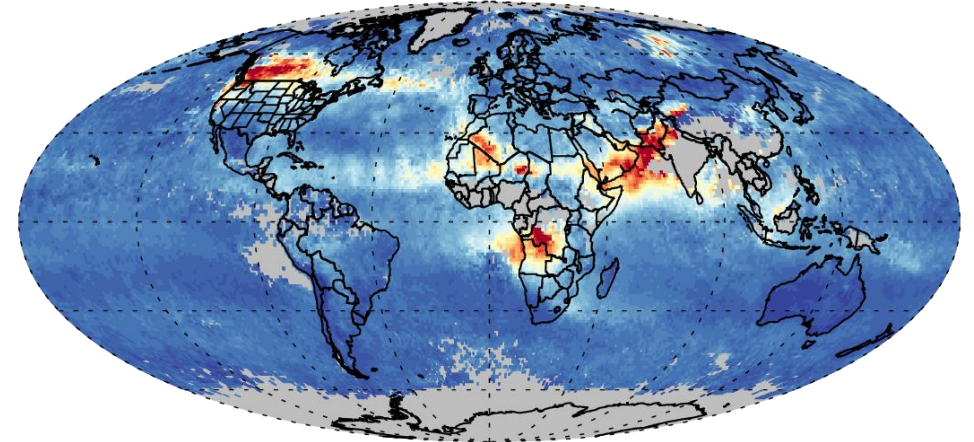


MODIS C7 algorithm

- Based on VIIRS V2 algorithm
- New over-water retrievals using DB/SOAR algorithm
- Better consistency with VIIRS V2 data sets
- C7 updates have been partially transferred to VIIRS V2.1 and will be fully implemented in V3

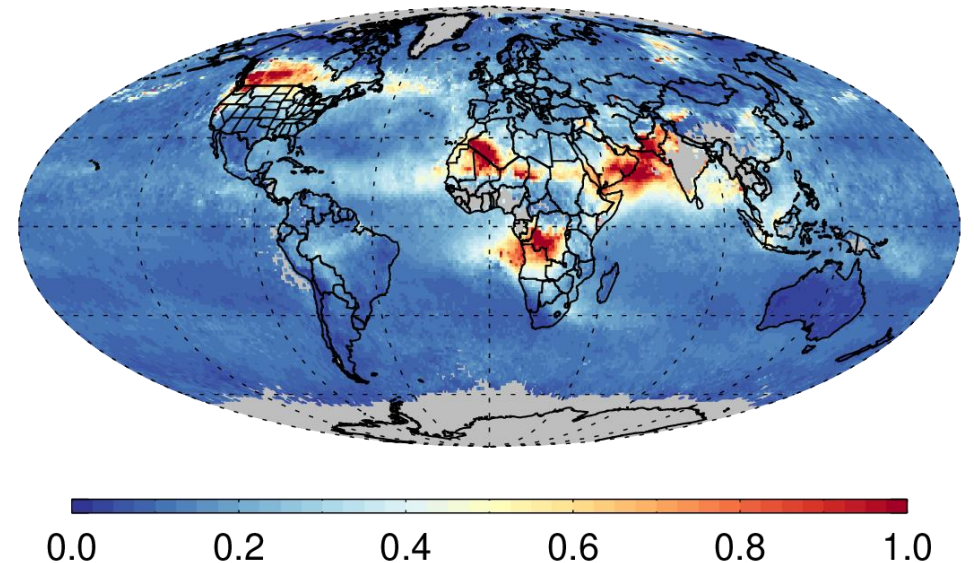
MODIS C7

Aqua MODIS DB AOD (550 nm, AUG 2018)



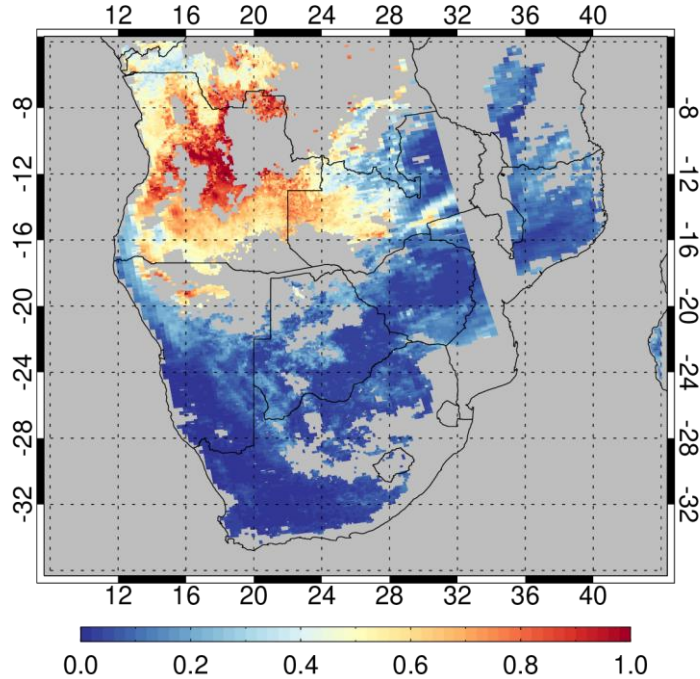
VIIRS V2

SNPP VIIRS DB AOD (550 nm, AUG 2018)

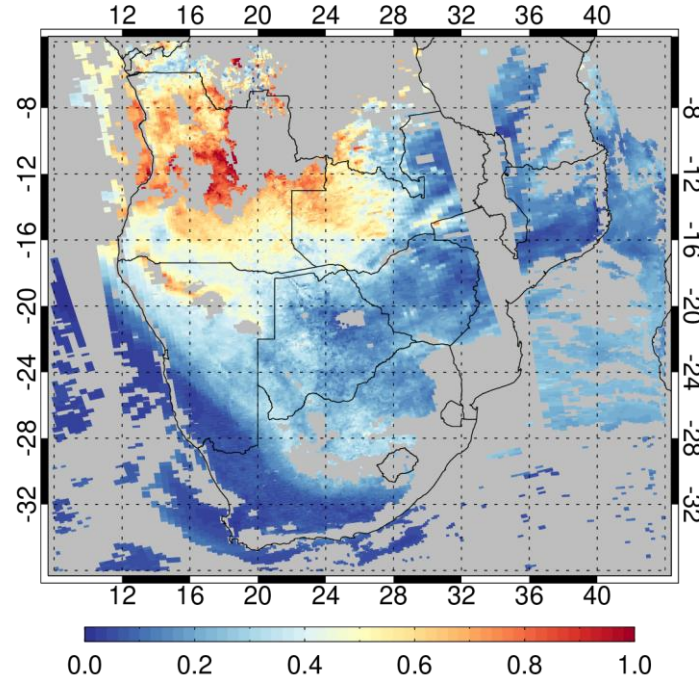


Southern Africa (high-elevation terrain)

C6.1 MODIS DB AOD (550 nm) - 03 AUG 2018

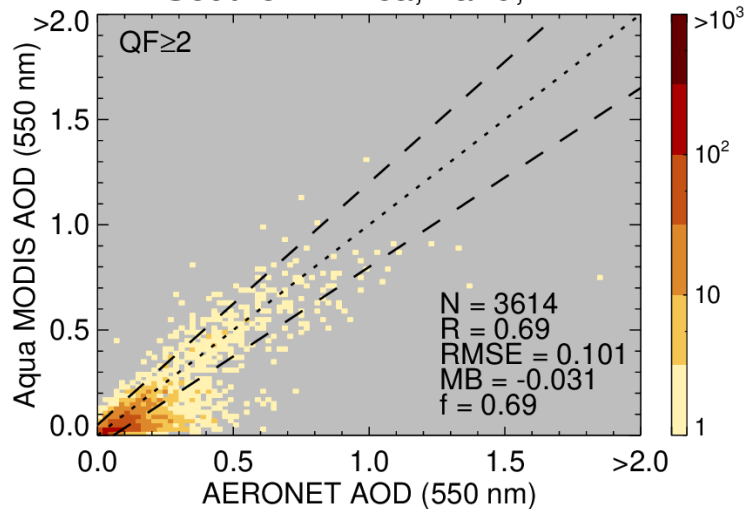


C7 MODIS DB AOD (550 nm) - 03 AUG 2018

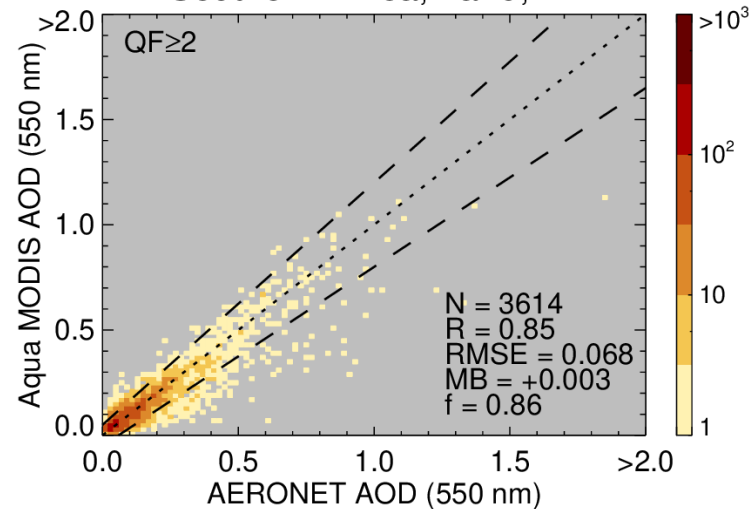


- Improved AOD retrievals over high-elevation regions
- Accounting for surface pressure over both land and ocean
- Mitigated a significant negative bias over high-elevation terrain
- Increased spatial coverage
- Improved land-ocean continuity
- Significantly improved validation statistics

Southern Africa, Land, All

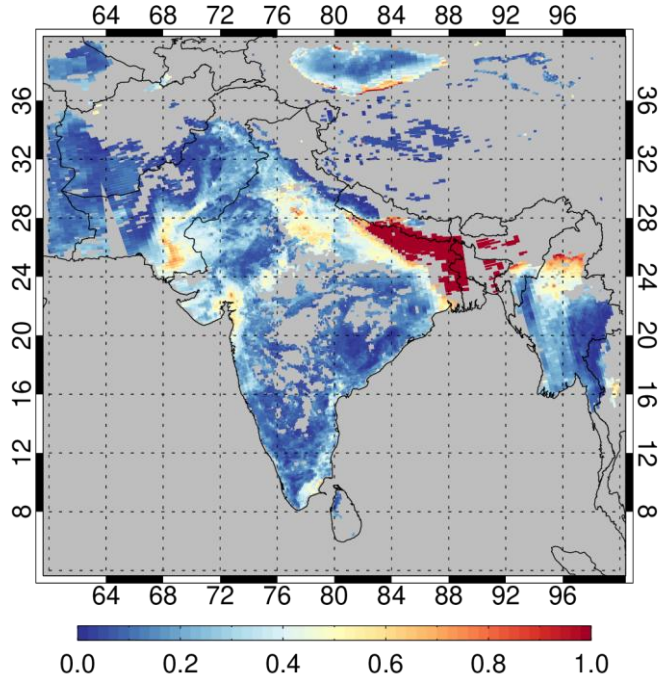


Southern Africa, Land, All



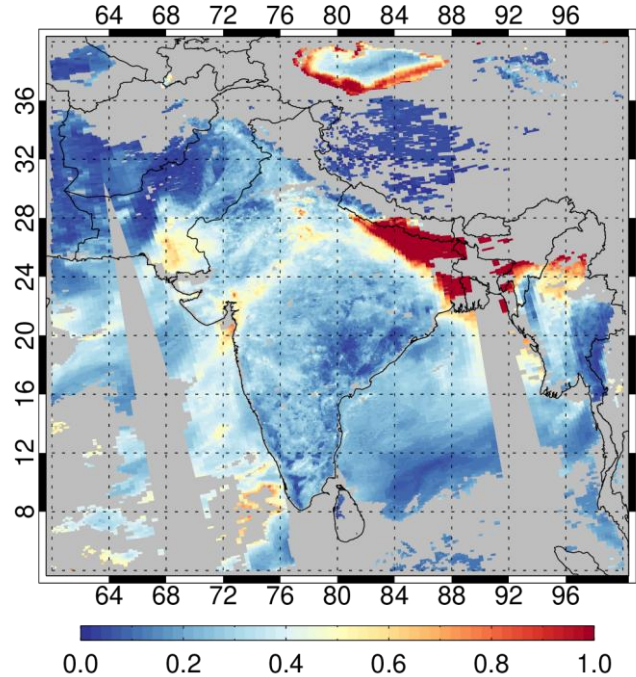
India (inhomogeneous surface + fine-dominated aerosols)

C6.1 MODIS DB AOD (550 nm) - 02 FEB 2018

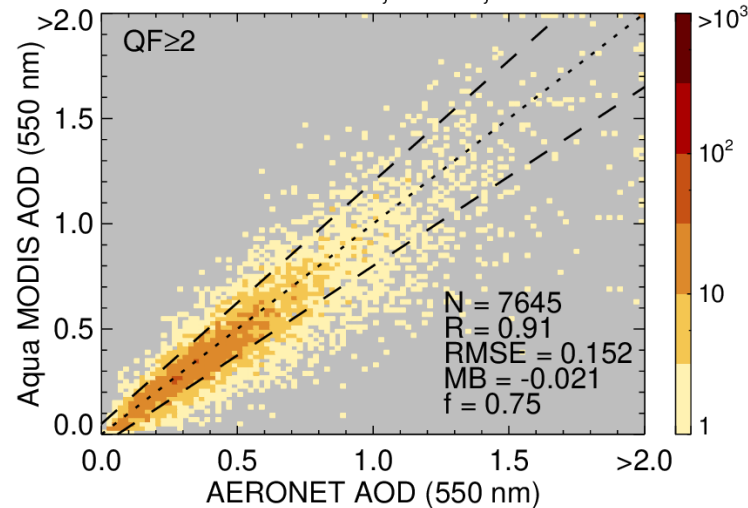
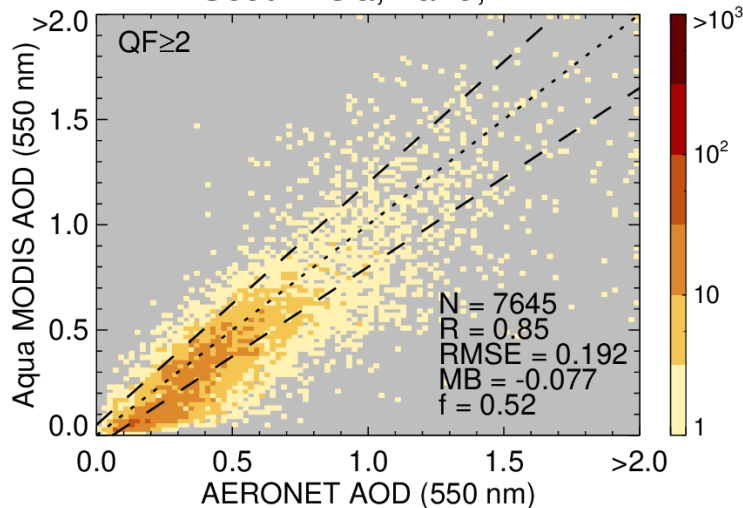


South Asia, Land, All

C7 MODIS DB AOD (550 nm) - 02 FEB 2018



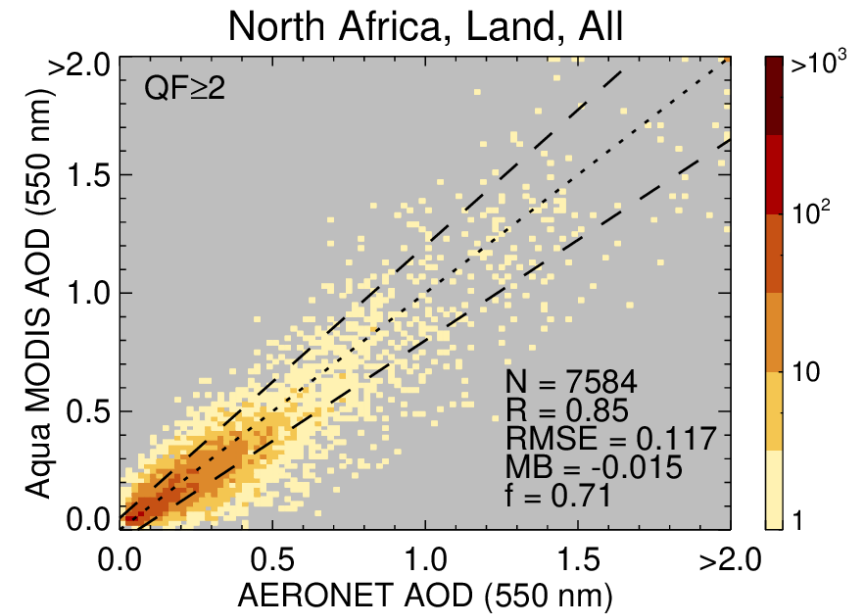
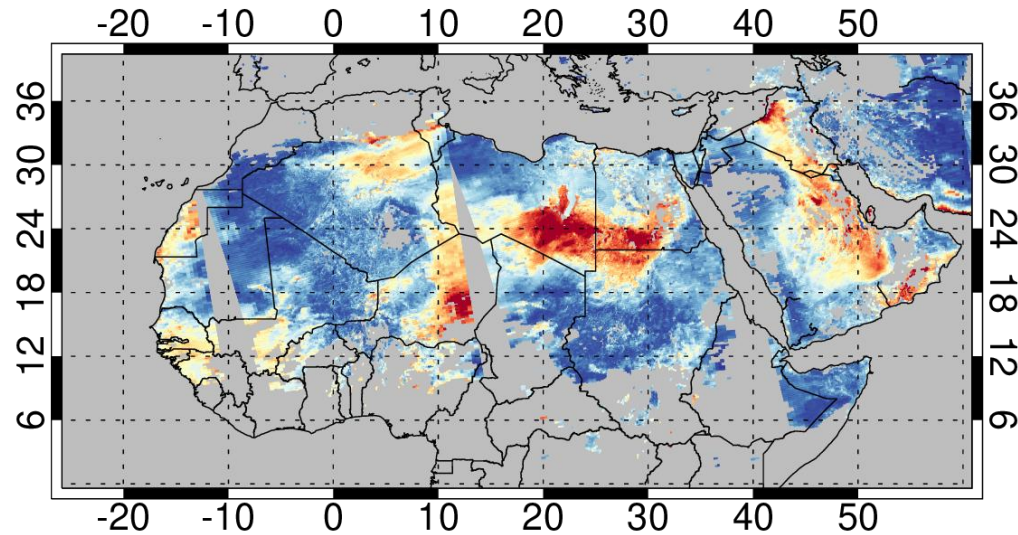
South Asia, Land, All



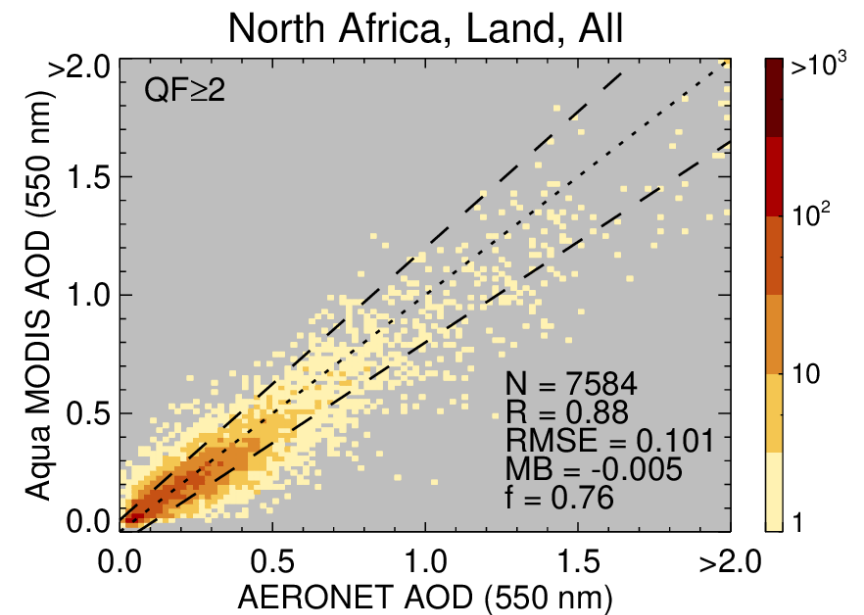
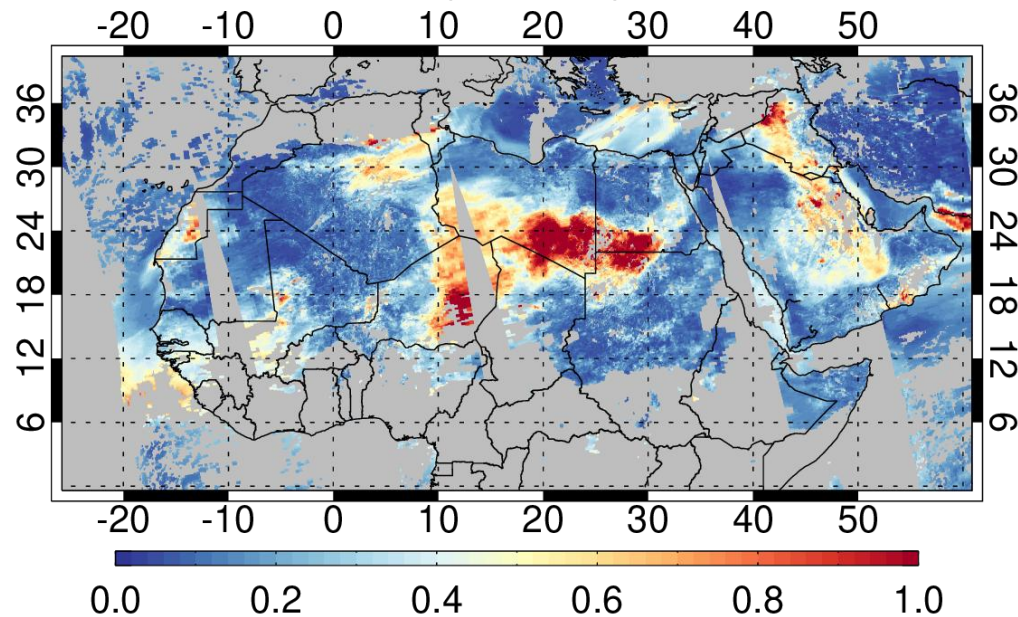
- Improved AOD retrievals over heterogeneous surfaces (croplands)
- Improved surface reflectance characterization
- Implemented a fine-dominated anthropogenic aerosol optical model with a bimodal lognormal size distribution
- Increased spatial coverage
- Improved land-ocean continuity
- Significantly improved validation statistics

North Africa (bright surface + nonspherical dust)

C6.1 MODIS DB AOD (550 nm) - 20 MAR 2018



C7 MODIS DB AOD (550 nm) - 20 MAR 2018



Cross-Calibration Across Sensors

Terra against Aqua MODIS

Calibration gain factors for Terra	410 nm	470 nm	550 nm	650 nm	860 nm	1240 nm	1610 nm	2130 nm
Angal et al. (2020)	N/A	0.979	0.992	0.997	0.983	0.956	N/A	0.969

NOAA-20 and 21 against SNPP over land

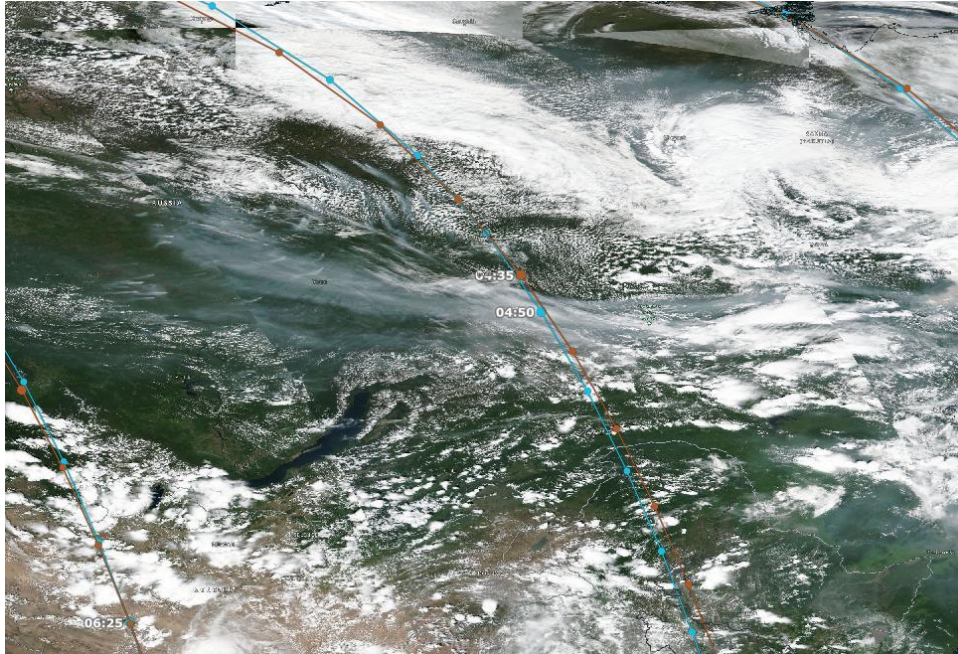
Calibration gain factors	410 nm	490 nm	550 nm	670 nm	860 nm	1240 nm	1610 nm	2250 nm
SNPP/NOAA-20	1.059	1.052	1.069	1.054	1.052	1.026	1.036	1.008
SNPP/NOAA-21	1.075	1.067	1.074	1.058	1.058	1.044	1.013	1.104
Meyer et al. (2020) over clouds (SNPP/NOAA-20)				1.053	1.041	1.030	1.041	1.021

SNPP VIIRS against Aqua MODIS over water

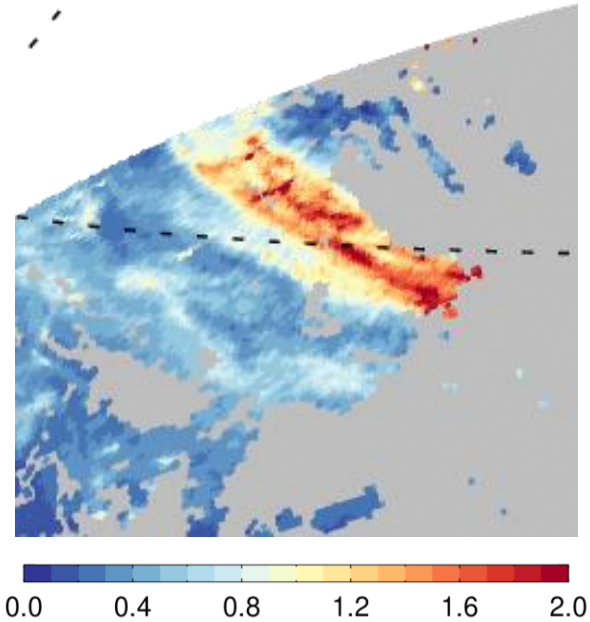
Calibration gain factors for SNPP	410 nm	490 nm	550 nm	670 nm	860 nm	1240 nm	1610 nm	2250 nm
Aqua/SNPP	0.995	0.992	0.956	0.941	0.963	1.011	0.981	0.931
Meyer et al. (2020) over clouds				0.95	0.97	0.99	0.98	0.97

- Terra MODIS is cross-calibrated against Aqua MODIS using RadCalNet data (caveats: gain factors were derived for C6.1 L1b).
- Over land, NOAA-20/21 VIIRS is cross-calibrated against SNPP VIIRS using matchup data over Dome-C cal/val site.
- Aqua MODIS serves as bridge between SNPP and NOAA-20/21.
- Over water, SNPP VIIRS is cross-calibrated against MODIS using multi-sensor co-location files generated by A-SIPS.
- This significantly reduces algorithm maintenance effort across multiple sensors.
- Open to other approaches in the later versions.

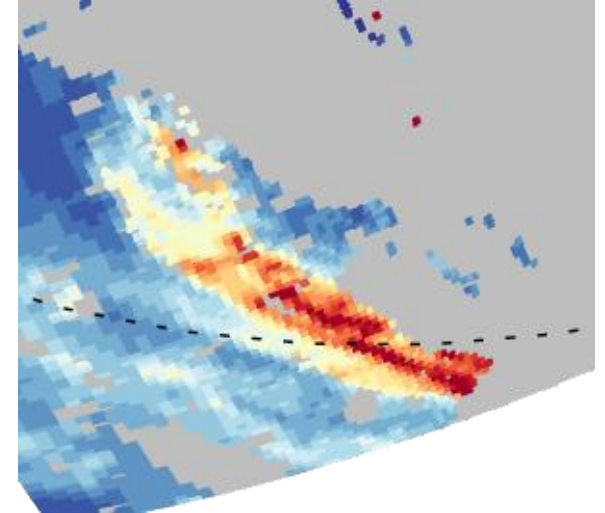
Aerosol Model Adjustments



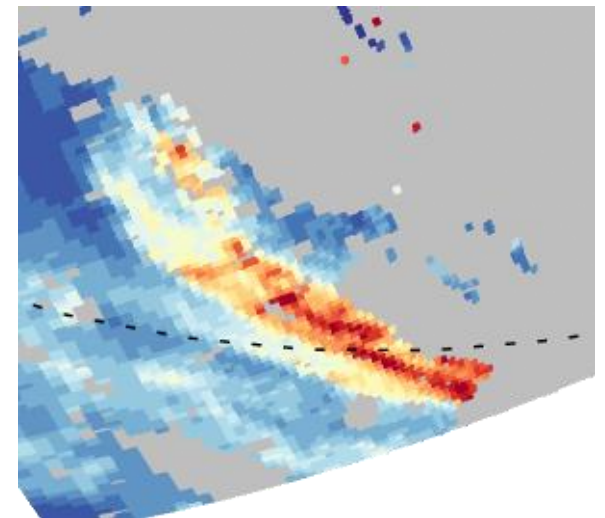
VIIRS V2.1



MODIS C7 original



MODIS C7 SSA adjusted



- Differences in spectral characteristics between MODIS and VIIRS
- Use of original SSA optimized for VIIRS results in slight differences in AOD
- Adjustments to the predefined single-scattering albedo values to improve consistency
- Adjustments within the expected range (<0.01 - 0.02)

MODIS vs. VIIRS File Formats

VIIRS Version 2

- ▼  AERDB_L2_VIIRS_SNPP.A2018001.0000.001.2023180103723.nc
 -  Aerosol_Optical_Thickness_550_Expected_Uncertainty_Land
 -  Aerosol_Optical_Thickness_550_Expected_Uncertainty_Ocean
 -  Aerosol_Optical_Thickness_550_Land
 -  Aerosol_Optical_Thickness_550_Land_Best_Estimate
 -  Aerosol_Optical_Thickness_550_Land_Ocean
 -  Aerosol_Optical_Thickness_550_Land_Ocean_Best_Estimate
 -  Aerosol_Optical_Thickness_550_Ocean
 -  Aerosol_Optical_Thickness_550_Ocean_Best_Estimate
 -  Aerosol_Optical_Thickness_550_STDV_Land
 -  Aerosol_Optical_Thickness_550_STDV_Ocean
 -  Aerosol_Optical_Thickness_QA_Flag_Land
 -  Aerosol_Optical_Thickness_QA_Flag_Ocean
 - ...

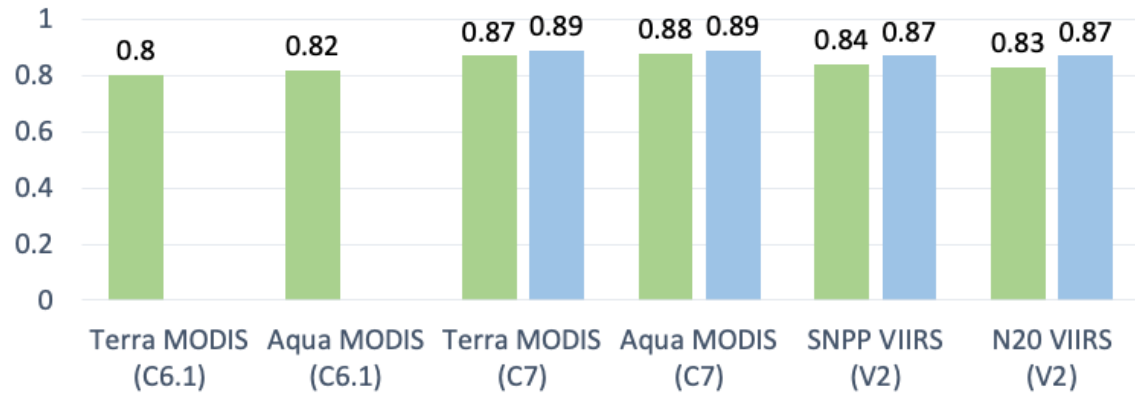
MODIS Collection 7

- ▼  MYD04_L2.A2017277.1135.007.2023296132146.nc
 - ▶  geolocation_data
 - ▶  geophysical_data_Dark_Target
 - ▶  geophysical_data_Dark_Target_Deep_Blue_Combined
 - ▼  geophysical_data_Deep_Blue
 -  Aerosol_Optical_Thickness_550_Expected_Uncertainty_Land
 -  Aerosol_Optical_Thickness_550_Expected_Uncertainty_Ocean
 -  Aerosol_Optical_Thickness_550_Land
 -  Aerosol_Optical_Thickness_550_Land_Best_Estimate
 -  Aerosol_Optical_Thickness_550_Land_Ocean
 -  Aerosol_Optical_Thickness_550_Land_Ocean_Best_Estimate
 -  Aerosol_Optical_Thickness_550_Ocean
 -  Aerosol_Optical_Thickness_550_Ocean_Best_Estimate
 -  Aerosol_Optical_Thickness_550_STDV_Land
 -  Aerosol_Optical_Thickness_QA_Flag_Land
 -  Aerosol_Optical_Thickness_QA_Flag_Ocean
 - ...

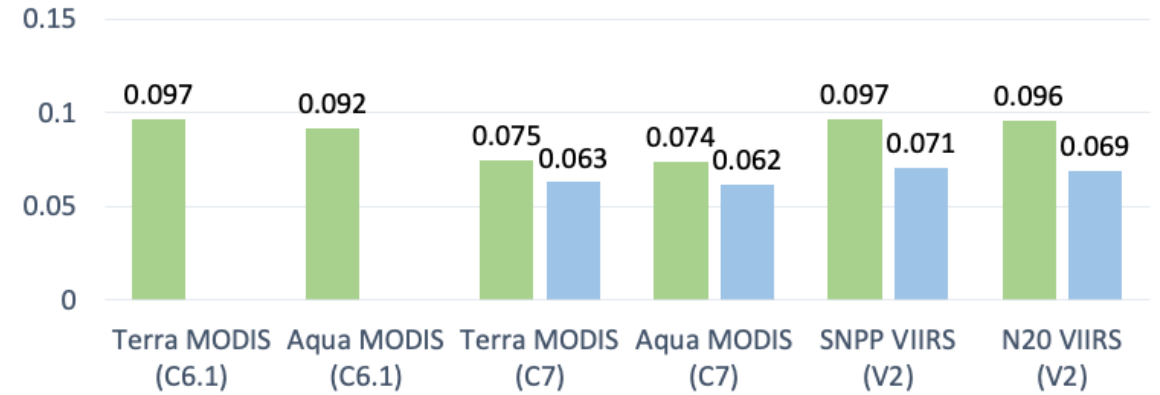
AOD Validation Against AERONET

Land
Water

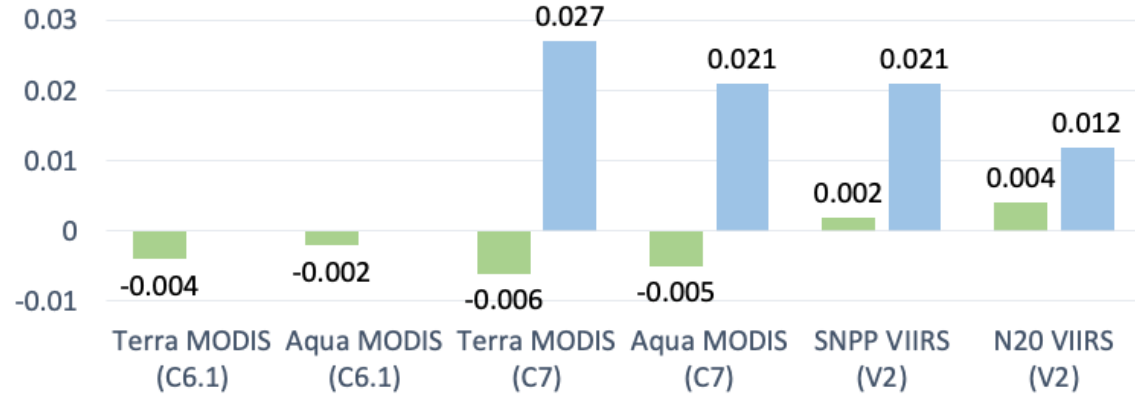
Spearman's Rank Correlation



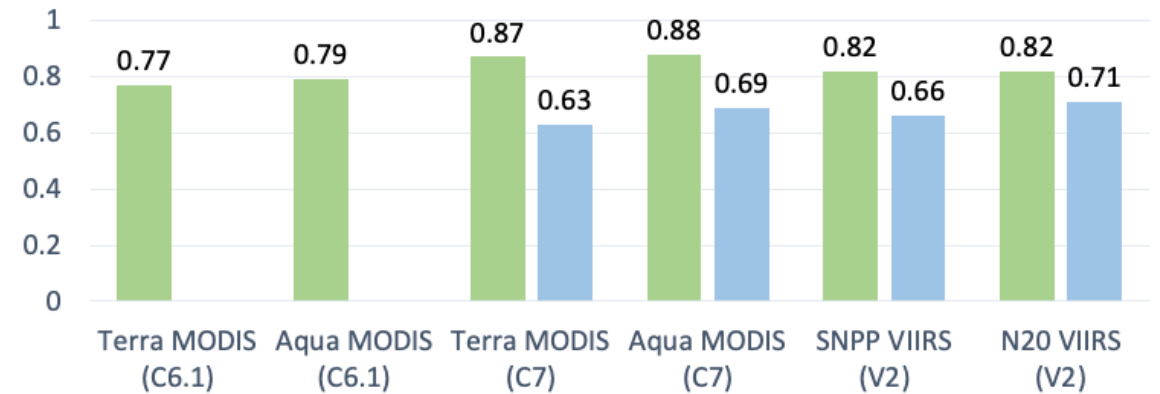
RMSE



Median Bias



Fraction within expected error

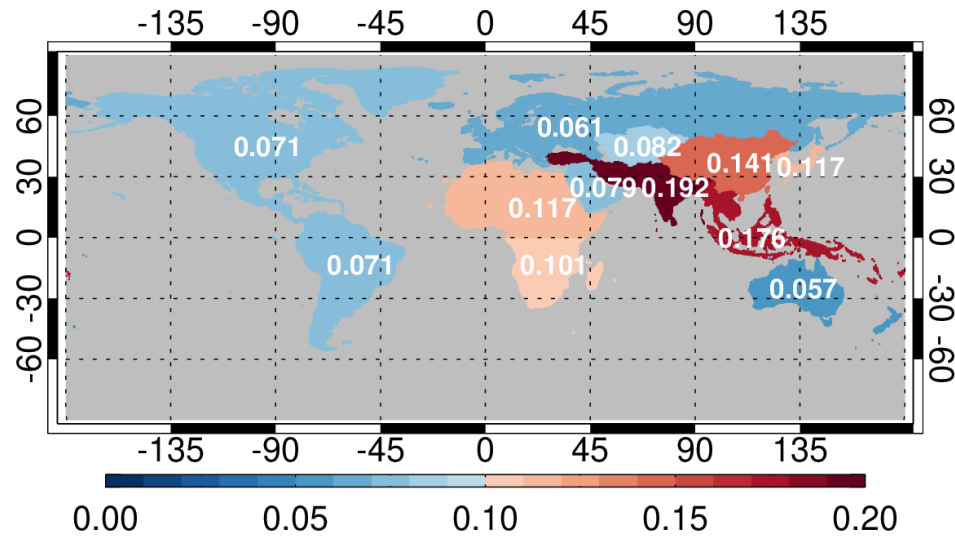


$EE (land) = \pm(0.05+15\%)$
 $EE (water) = \pm(0.03+10\%)$

AOD Validation Against AERONET (Aqua MODIS C6.1 vs. C7; 2008-2018)

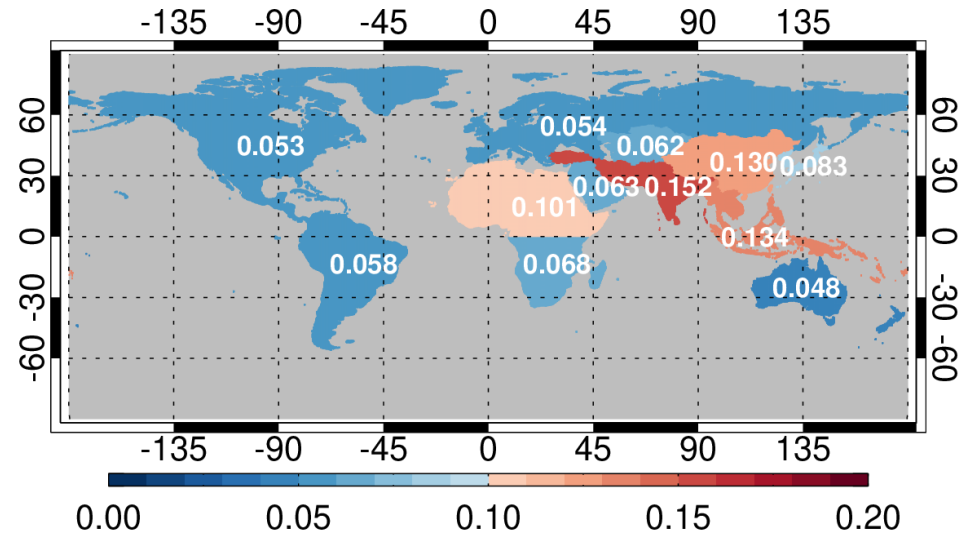
C6.1

RMSE, 550 nm

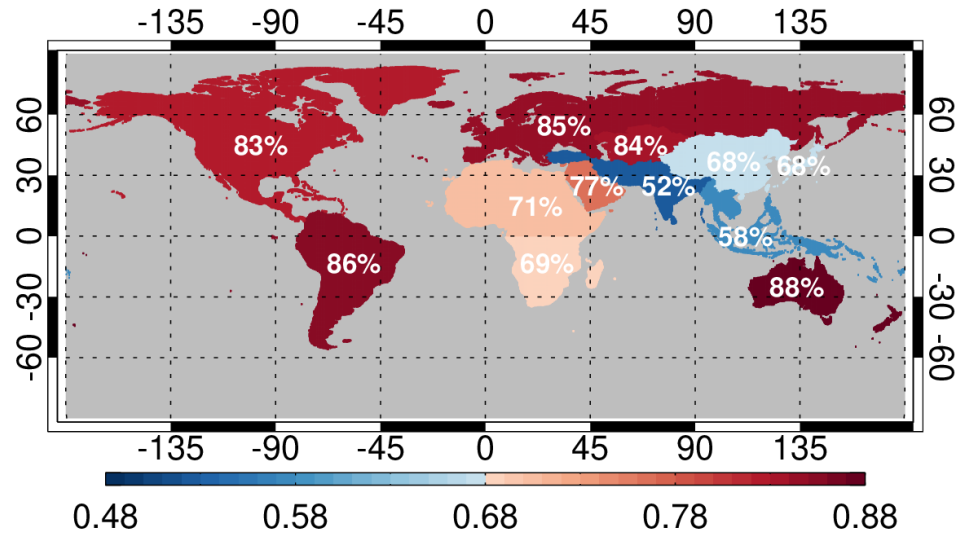


C7

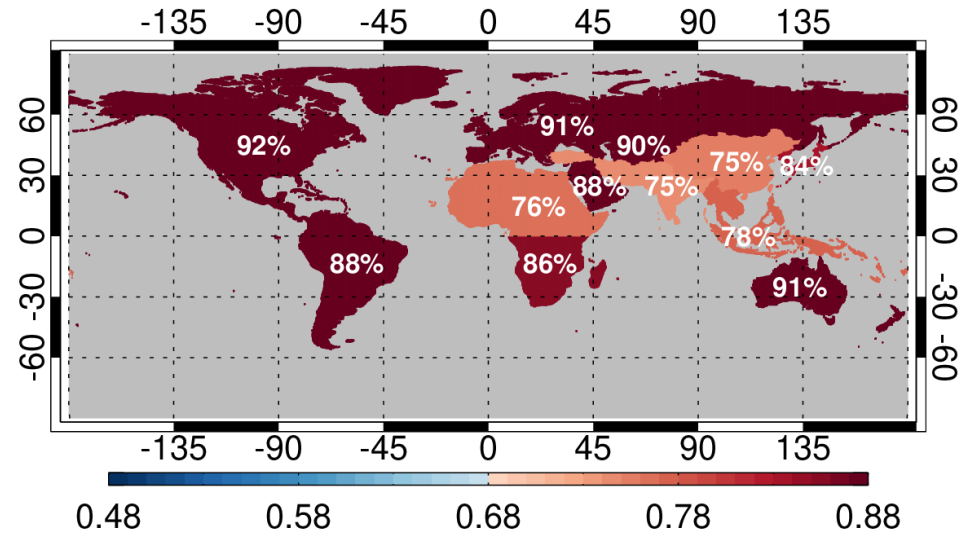
RMSE, 550 nm



Fraction within EE, 550 nm



Fraction within EE, 550 nm



EE (land) = $\pm(0.05+15\%)$
EE (water) = $\pm(0.03+10\%)$

Prognostic Pixel-Level Uncertainty

Framework for the evaluation of uncertainty estimates (Sayer et al. 2020a, b)

Uncertainty estimates: finding 1-sigma confidence interval around retrieved value within which the true value is expected to lie ~68% of the time, following Gaussian statistics

Diagnostic uncertainty

Over land:

$$\epsilon_S = \pm(0.05 + 0.15\tau_A)$$

Over water:

$$\epsilon_S = \pm(0.03 + 0.1\tau_A)$$

Pixel-level uncertainty

Over land:

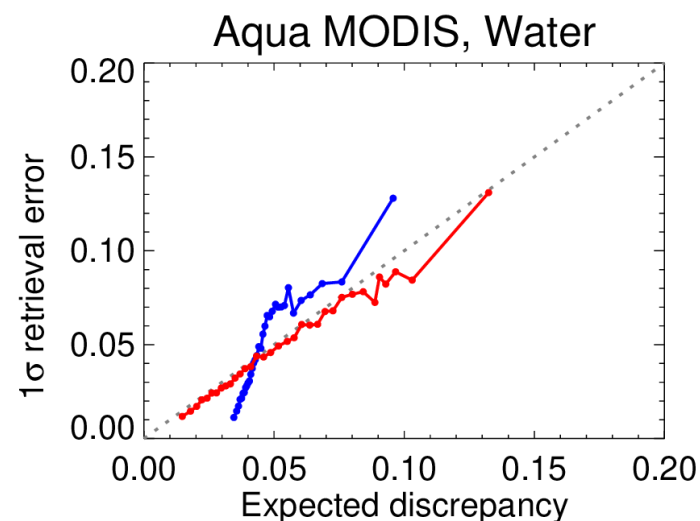
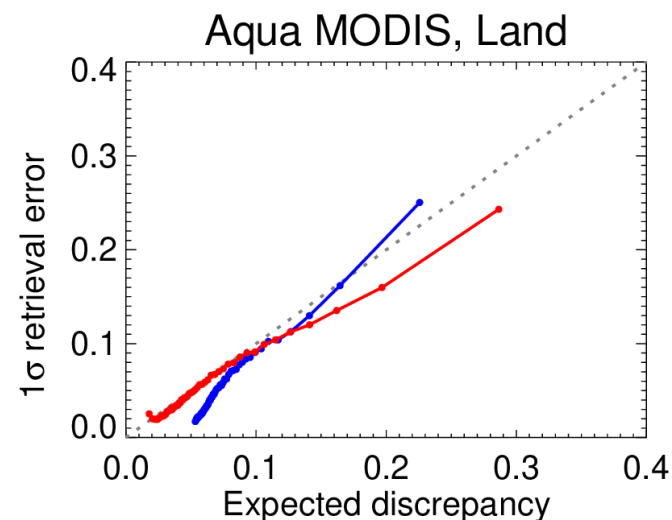
$$\epsilon_S = \pm \left(\frac{a + b\tau_S}{\frac{1}{\mu_0} + \frac{1}{\mu}} \right)$$

a and b are dependent on **surface type** and **quality flag**

Over water:

$$\epsilon_S = \pm(a + b\tau_S)$$

a and b are dependent on **aerosol type** and **turbidity of water**



Summary

- MODIS Collection 7 Deep Blue aerosol products show significant improvements relative to C6.1, particularly over high-elevation regions and heterogeneous/bright surfaces, and for mineral dust and fine-dominated aerosol cases.
- The implementation of a consistent algorithm with cross-calibration enables the creation of a harmonized long-term aerosol data record from the twin MODIS and the VIIRS series.
- Updates made to the MODIS C7 algorithm will be incorporated into the upcoming VIIRS Version 3 production stream.
- The C7 Deep Blue aerosol products are currently in production and will be available through LAADS DAAC and Earthdata (<https://earthdata.nasa.gov>).

Backup slides

Status: Other Sensors

GEO

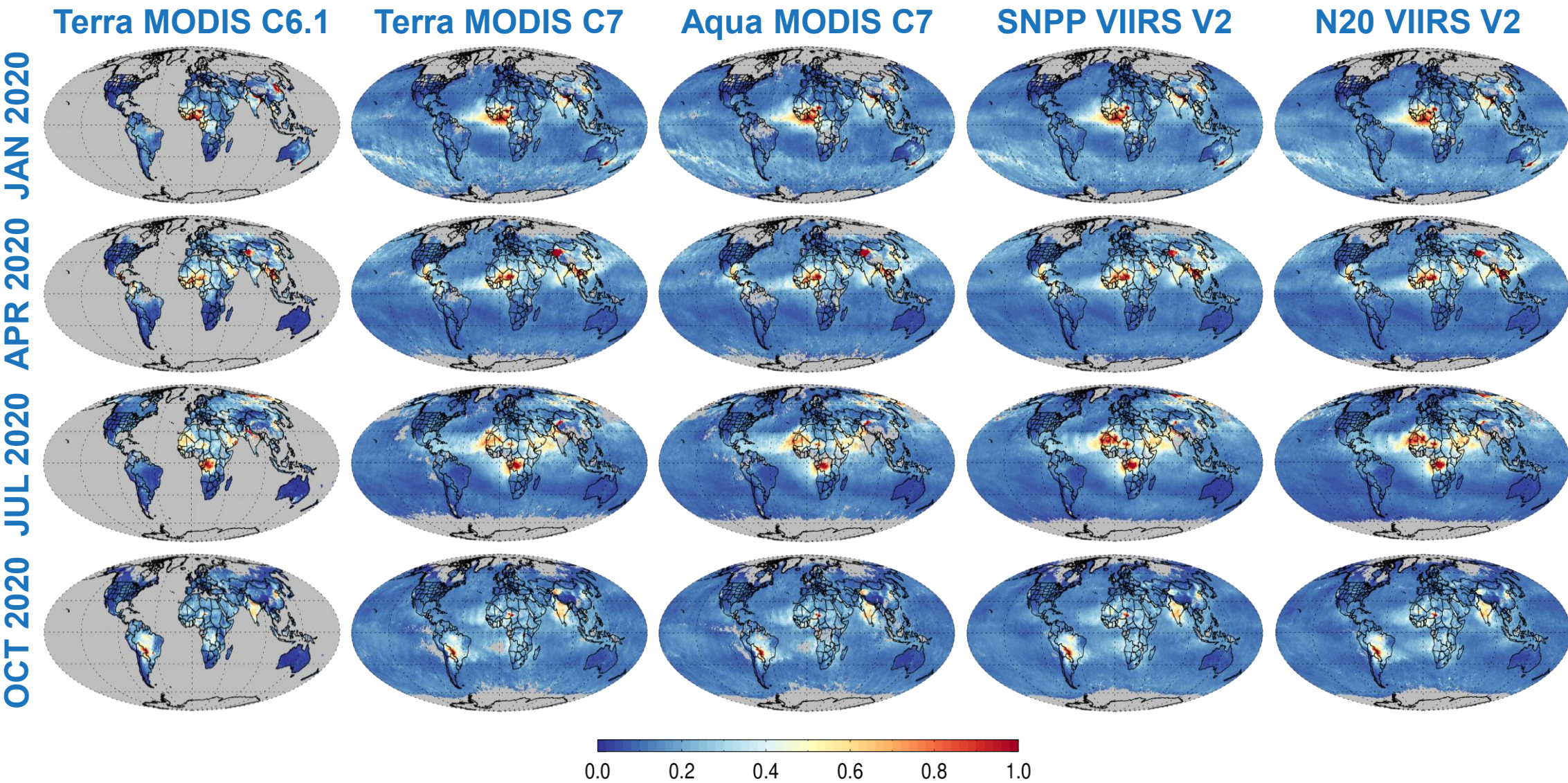
- Demonstration data sets have been released for G16/17 ABI and H8 AHI.
- Algorithm based on VIIRS V2 including over-water retrievals.
- Consistent performance with LEO sensors despite lacking 412 nm band.

AVHRR (funded through MEaSUREs Program)

- A subset of NOAA-11/14/18 AVHRR DB data has been available over both land and water.
- Initial reprocessing for NOAA-7/9/11/14/16/18 is nearing completion for the period from 1981 to 2012.
- Data release is scheduled for the end of 2026.

Multi-Sensor AOD

Monthly Mean AOD (550 nm)



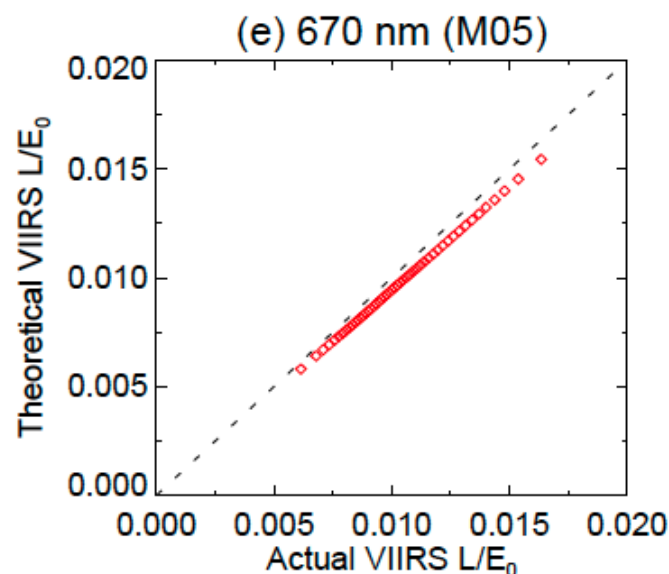
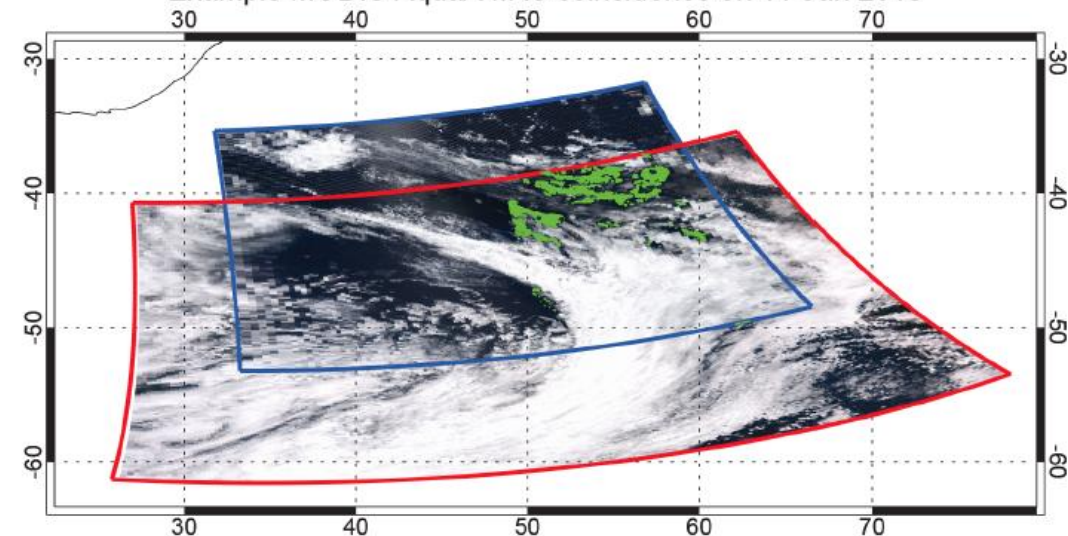
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Angal et al. (2020)	N/A	N/A	0.979	0.992	0.997	0.983	0.956	N/A	0.969

SNPP VIIRS against Aqua MODIS over water

Example MODIS Aqua/VIIRS coincidence on 11 Jan 2015



Across SNPP, N20, N21 VIIRS over land

Calibration gain factors for N20	410 nm	440 nm	490 nm	550 nm	670 nm	860 nm	1240 nm	1610 nm	2250 nm
Dome-C	1.059	1.070	1.052	1.069	1.054	1.052	1.026	1.036	1.008
Meyer et al. (2020) over clouds					1.053	1.041	1.030	1.041	1.021

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- Open to other approaches in the later versions.

SNPP VIIRS Calibration Gain Factors over Water

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	0.995	1.000	0.992	0.956	0.941	0.963	1.011	0.981	0.931