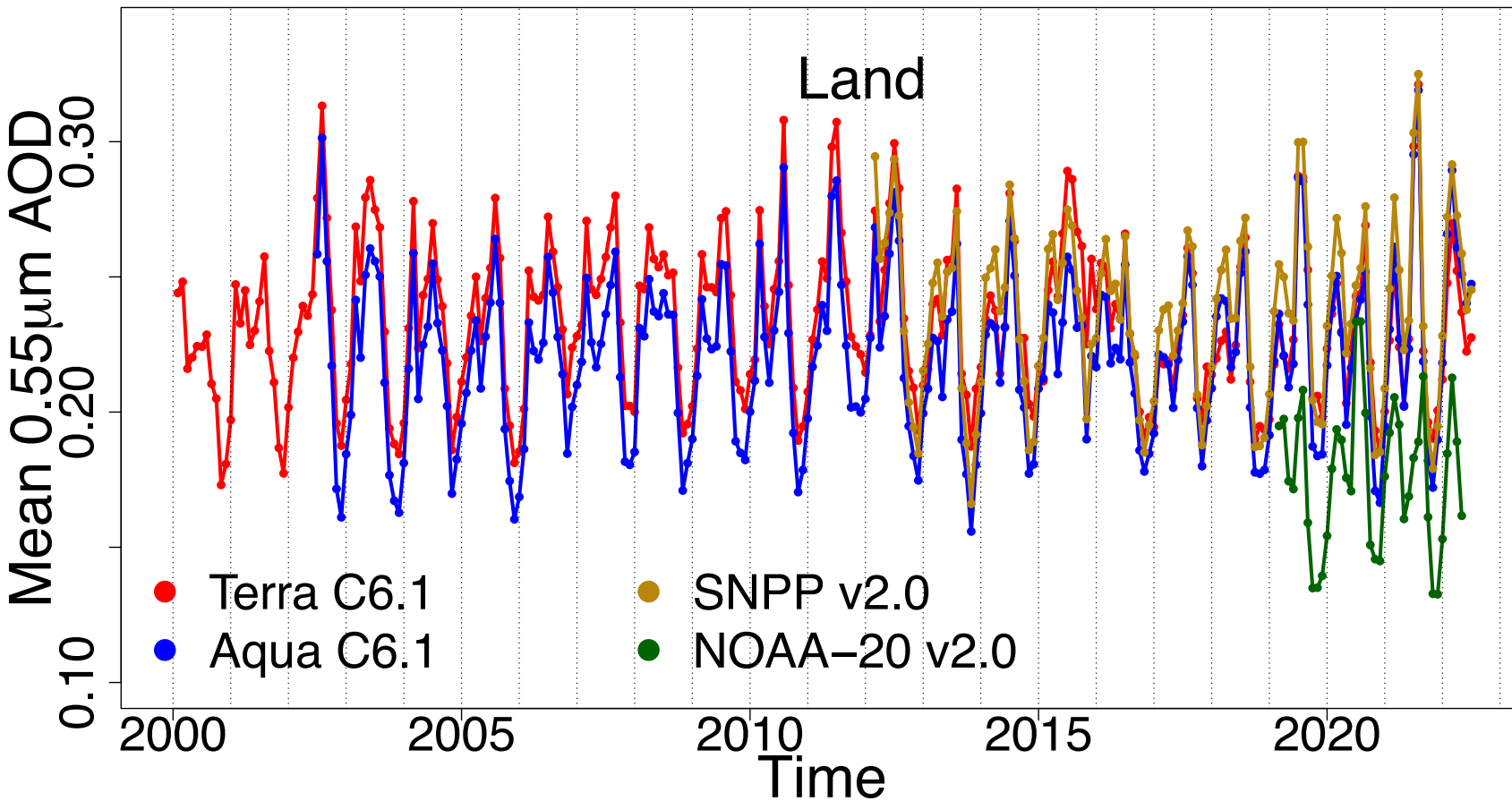


# Dark Target/Deep Blue Aerosol Retrieval Merge for VIIRS SNPP and NOAA-20

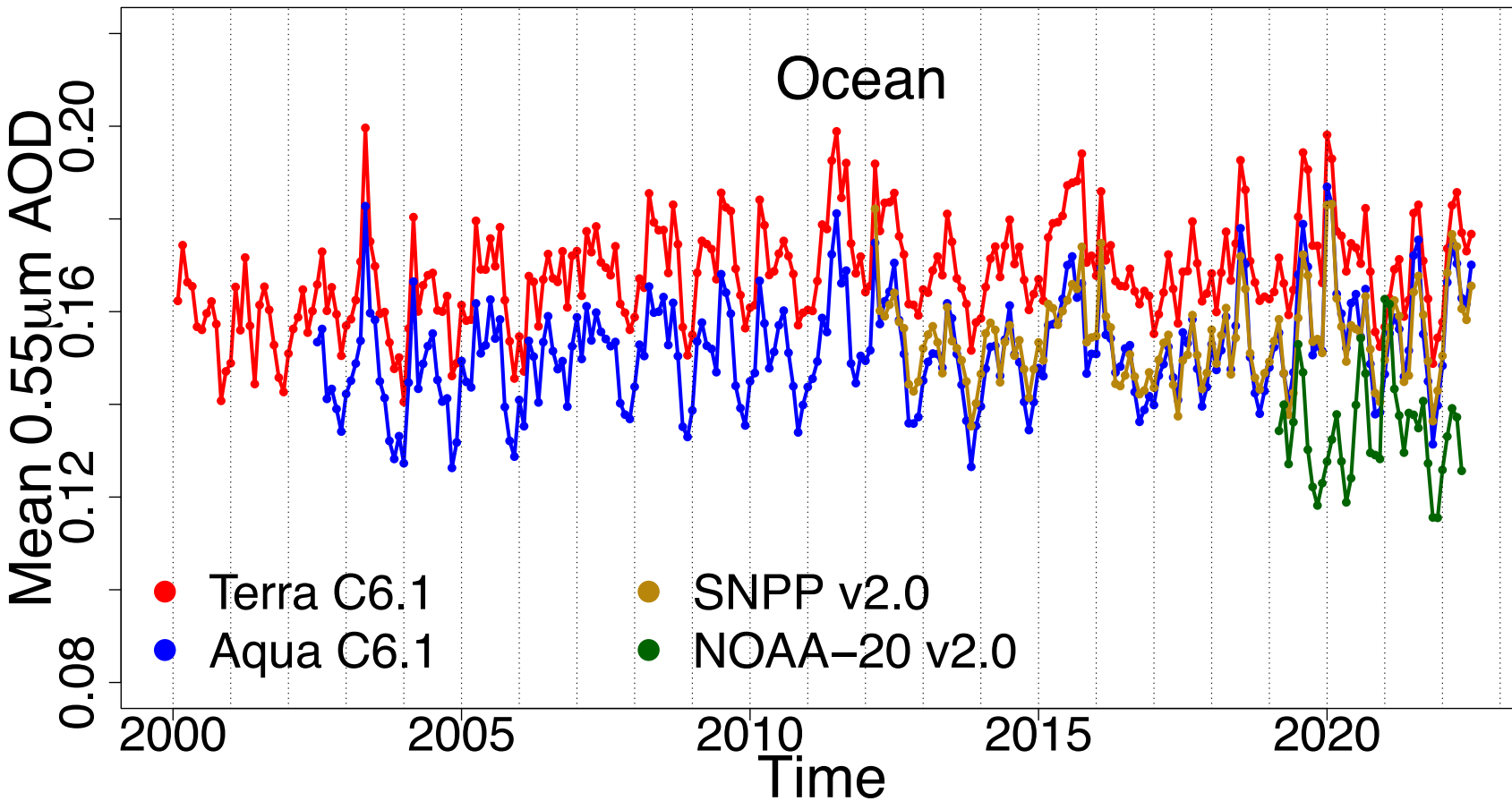
Virginia Sawyer, Mijin Kim, Praju Kiliyanpilakkil, Paul Hubanks, Vincent Kim, Robert C. Levy, Yingxi Shi, Shana Mattoo, Lorraine A. Remer

# Aerosol Optical Depth as a Climate Data Record



- Dark Target uses the same retrieval algorithm across multiple sensors
- Offsets in AOD caused by differences in instrument design, calibration, or degradation over time (Remer et al. 2020, Sawyer et al. 2020, Levy et al. 2018)

# Aerosol Optical Depth as a Climate Data Record

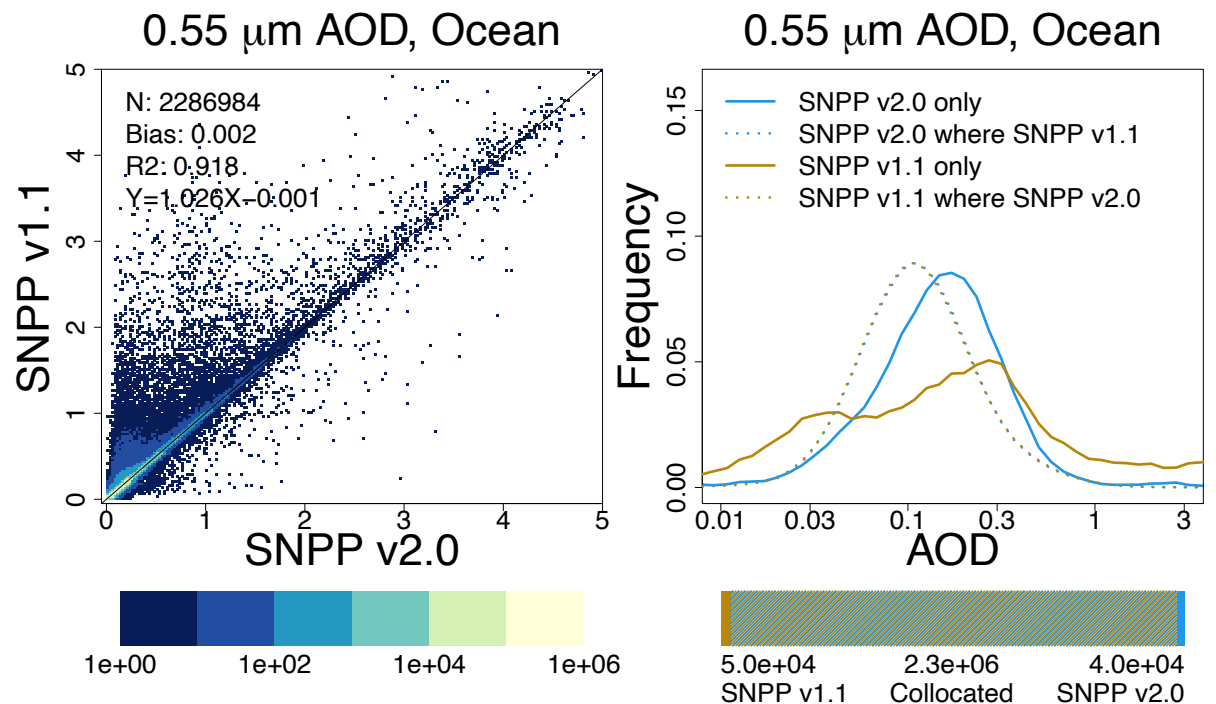
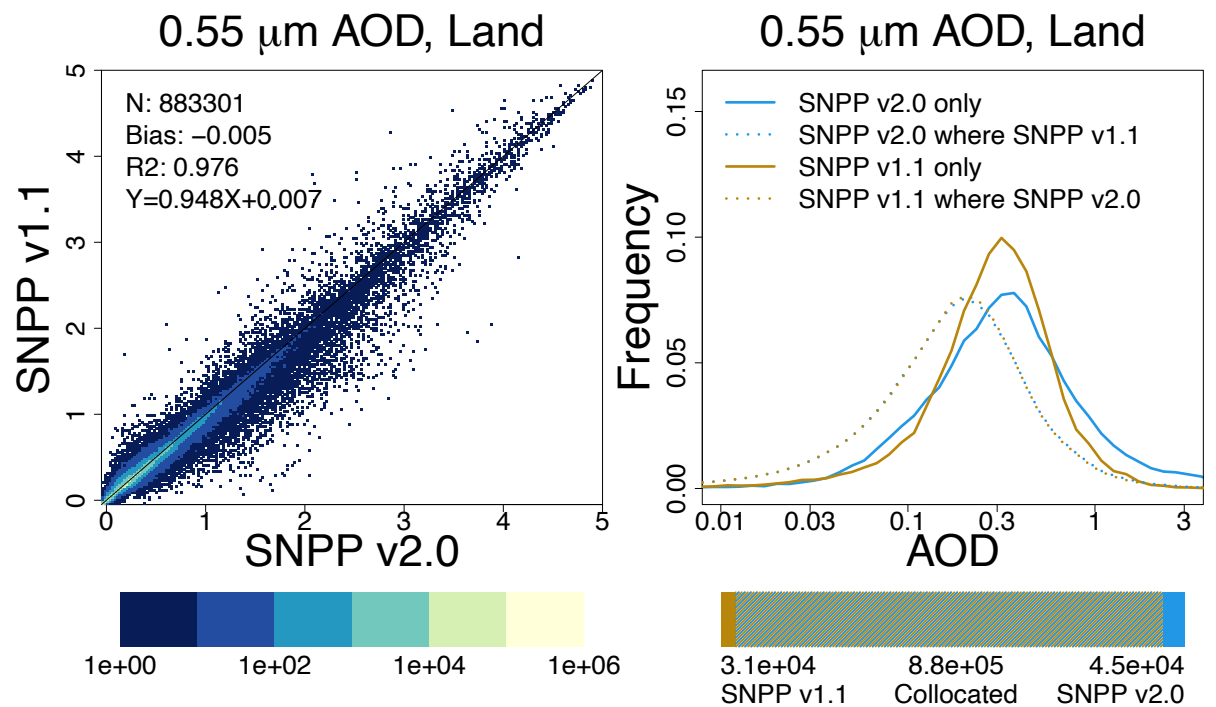


- MODIS Aqua reached 20 years and VIIRS SNPP reached 10 years in 2022, with MODIS Terra at 22
- Terra and Aqua crossing times are now drifting, but planned to continue through 2026
- VIIRS v2.0 is now publicly available for SNPP and NOAA-20 (archive set 5200)

# Differences between Dark Target versions

Scatter plots and histograms taken from  $1^\circ \times 1^\circ$  gridded daily average AODs, May-Aug 2019

- Algorithm now uses image resolution L1b for cloud masking, GMAO for ancillary data,  $1.64\mu\text{m}$  channel for snow mask
- Fixes several bugs, including blank stripes caused by cirrus flag/quality flag issue
- Now reports Mean\_Reflectance\_Land and STD\_Reflectance\_Land for all seven channels
- Metadata expansion and clarification
- Overall distribution of QA-filtered AOD values remains the same
- Higher-resolution cloud mask can retrieve closer to cloud edges with less cloud contamination

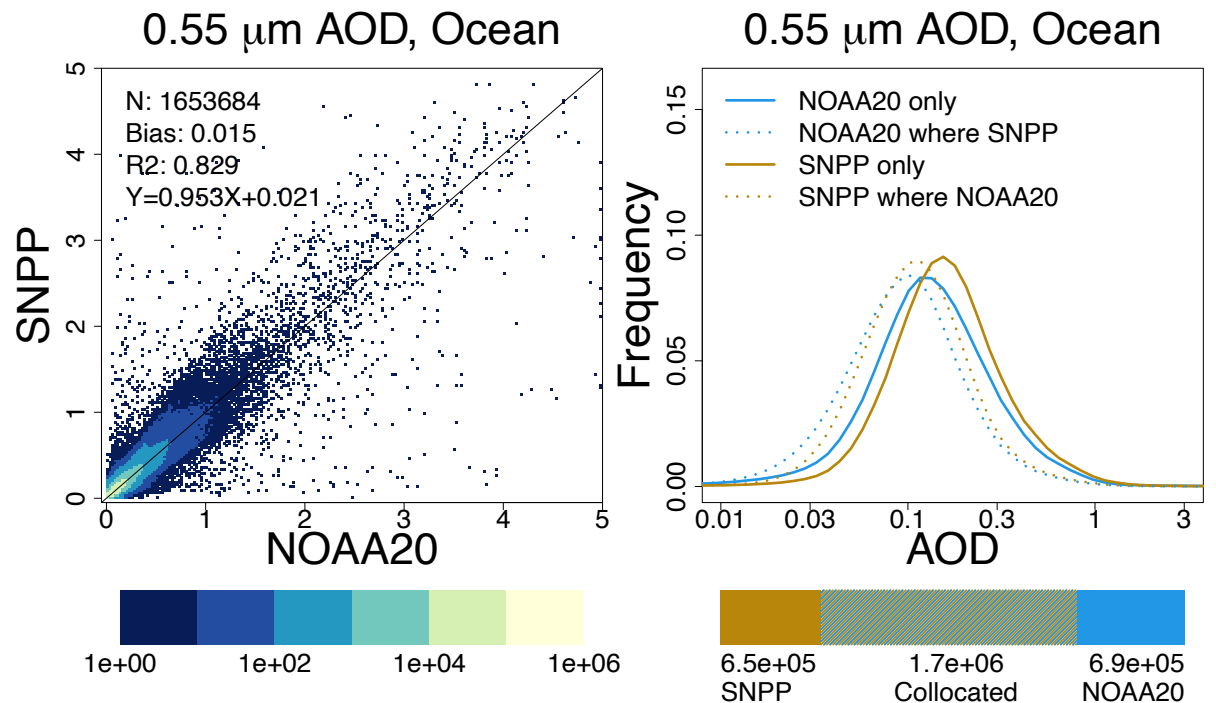
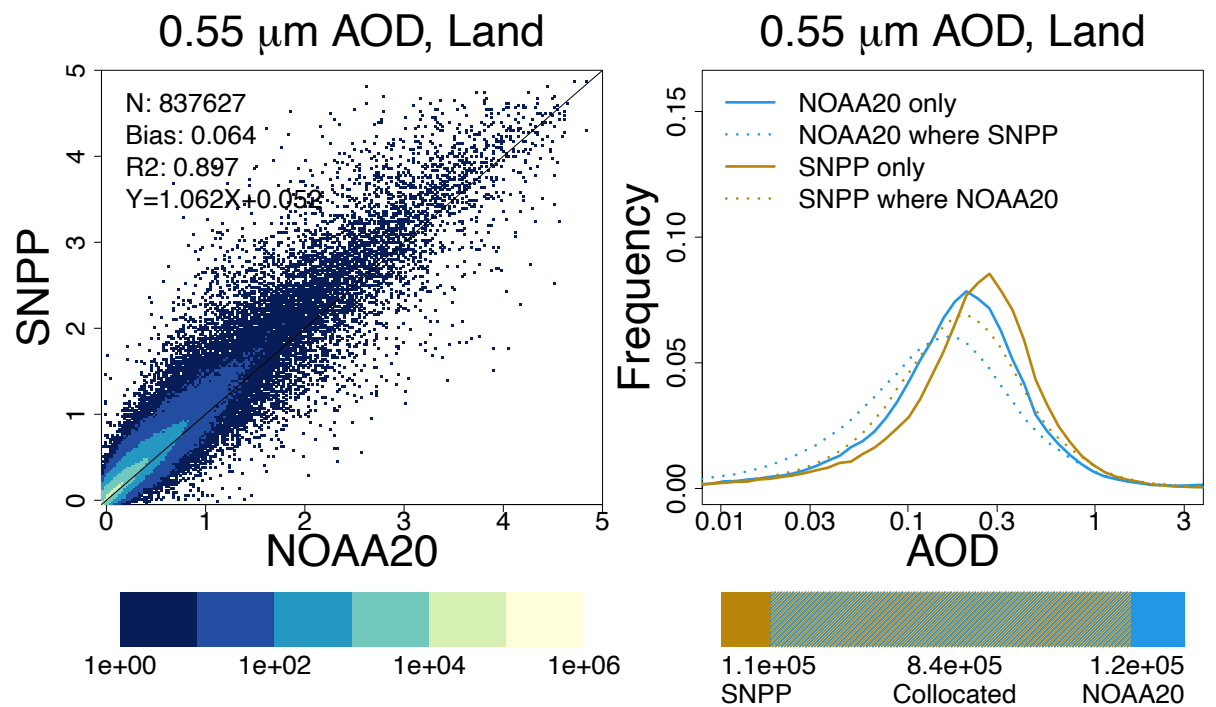




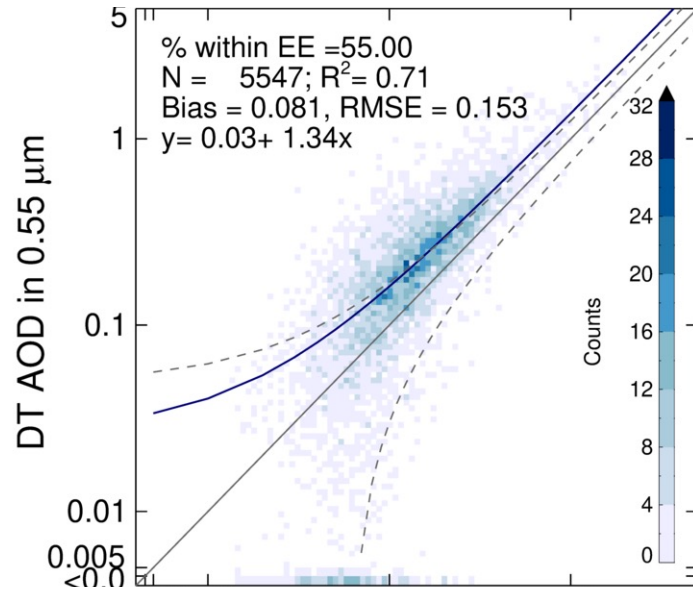
# Differences between VIIRS sensors

Scatter plots and histograms taken from  $1^\circ \times 1^\circ$  gridded daily average AODs, May-Aug 2019

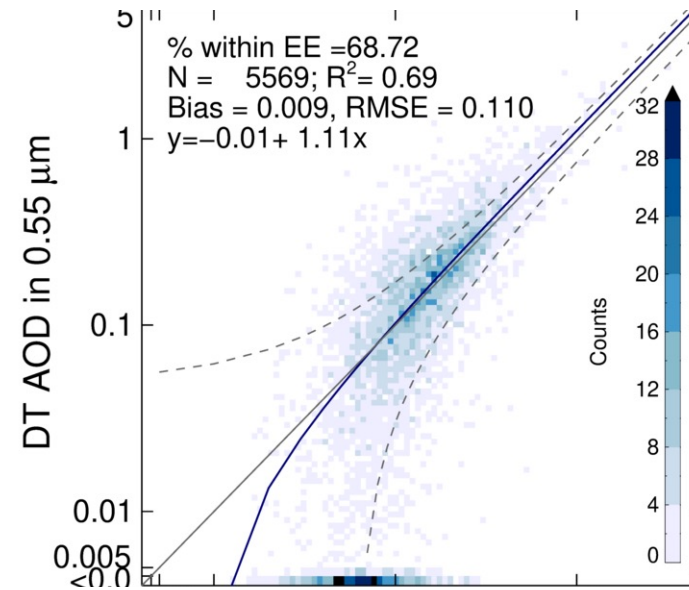
- SNPP and NOAA-20 have the same equatorial crossing time but fly half an orbit apart, so true collocation is rare
- Matched grid cells may come from multiple orbits, especially at swath edges
- Single-sensor retrievals are more common
- Correlation is as expected for Dark Target on different sensors
- AOD distribution is higher for SNPP than for NOAA-20, whether for matched grid cells or single-sensor retrievals
- SNPP is biased high compared to AERONET. Is NOAA-20 too low, or just low enough?



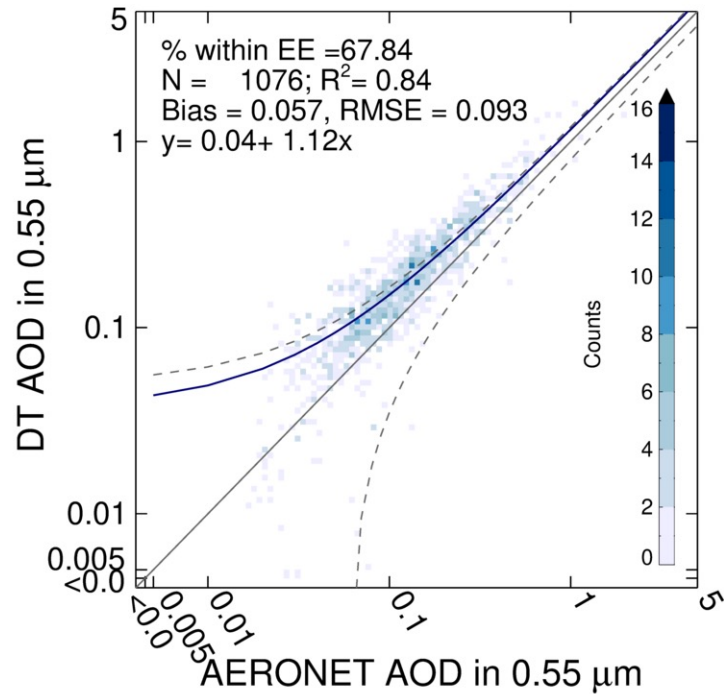
SNPP over land, May-Aug 2019



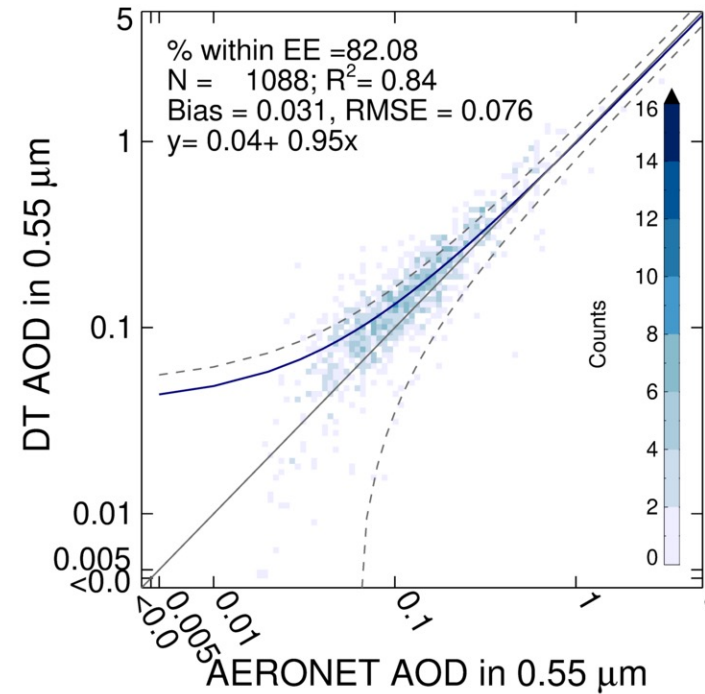
NOAA-20 over land, May-Aug 2019



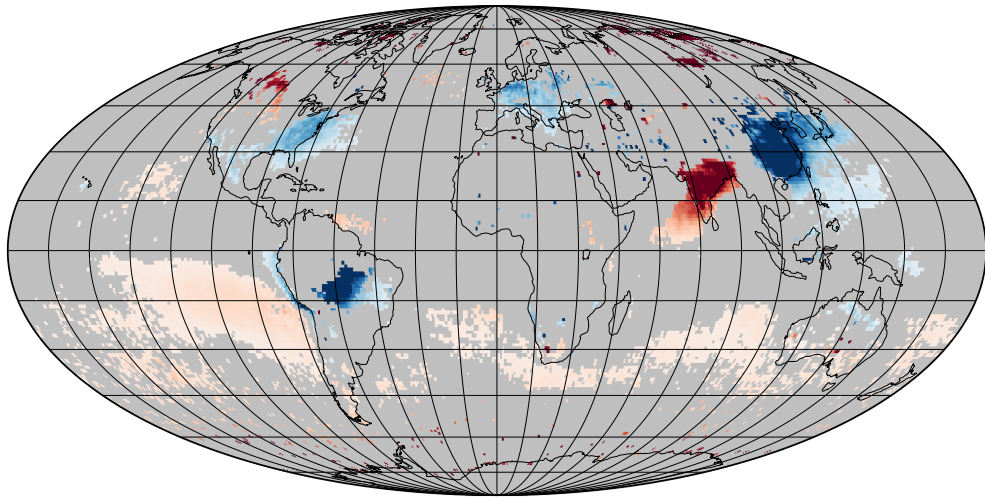
SNPP over ocean, May-Aug 2019



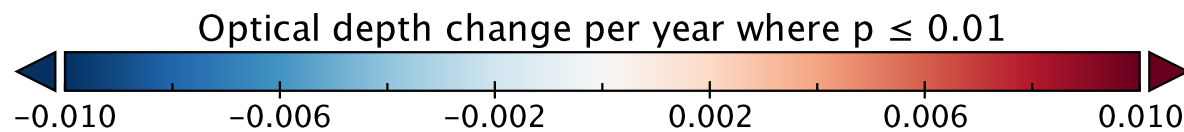
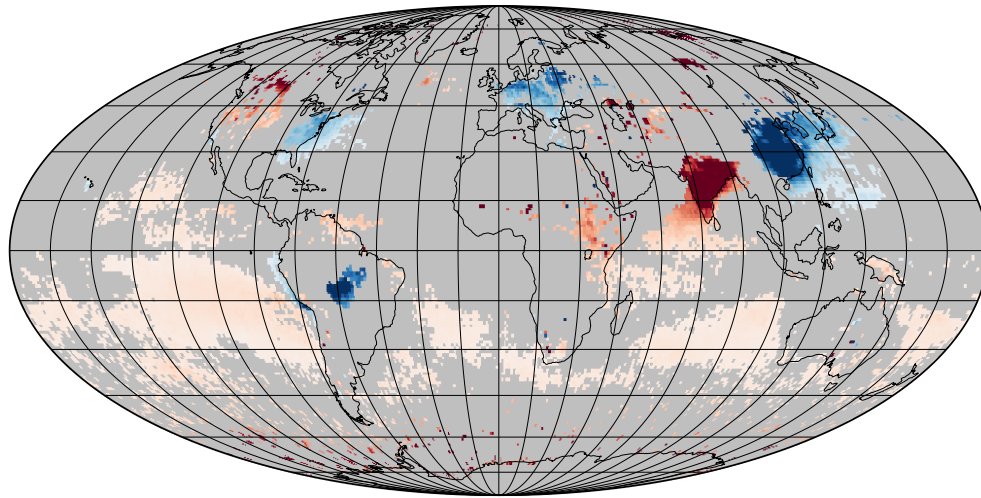
NOAA-20 over ocean, May-Aug 2019



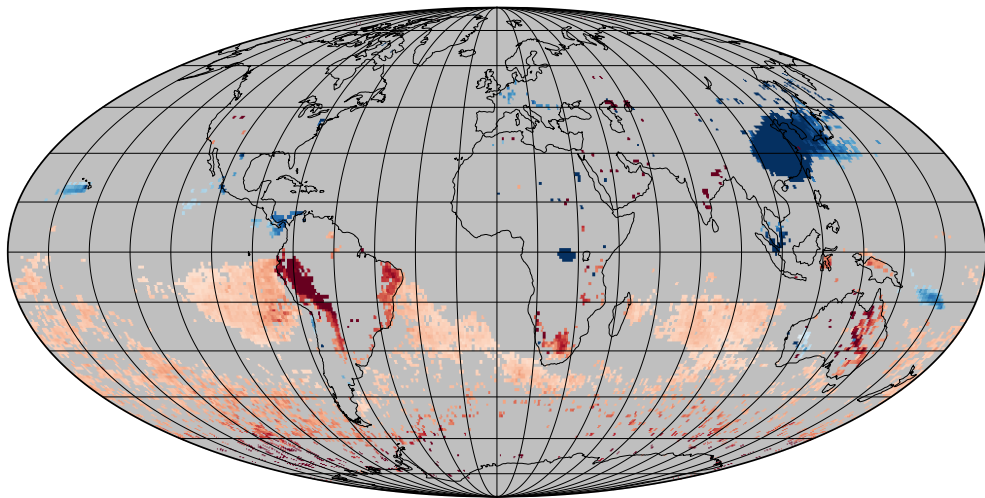
Trend in Aerosol Optical Depth, Terra, July 2002 - June 2023



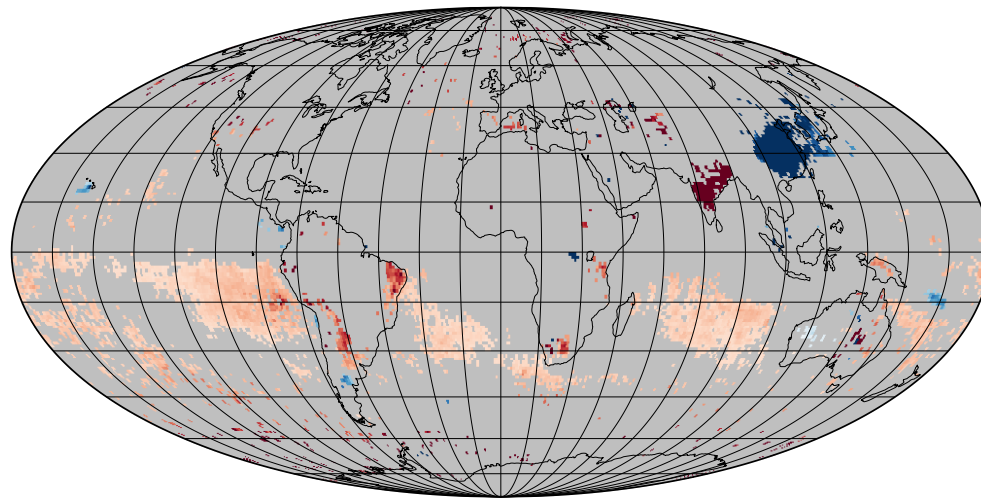
Trend in Aerosol Optical Depth, Aqua, July 2002 - June 2023



Trend in Aerosol Optical Depth, SNPP, April 2012-March 2023



Trend in Aerosol Optical Depth, Aqua, April 2012-March 2023

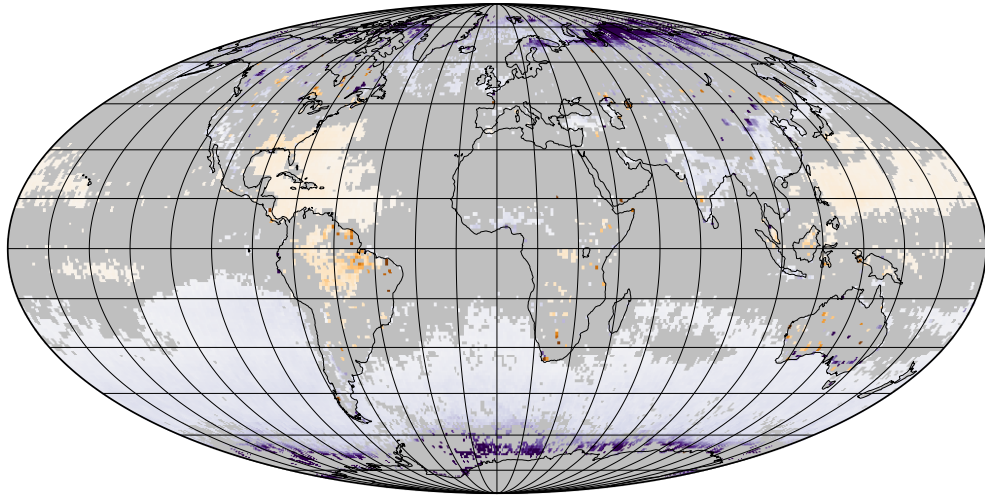


**Slope of the linear regression for each  $1^\circ \times 1^\circ$  grid cell plotted where  $p \leq 0.01$**

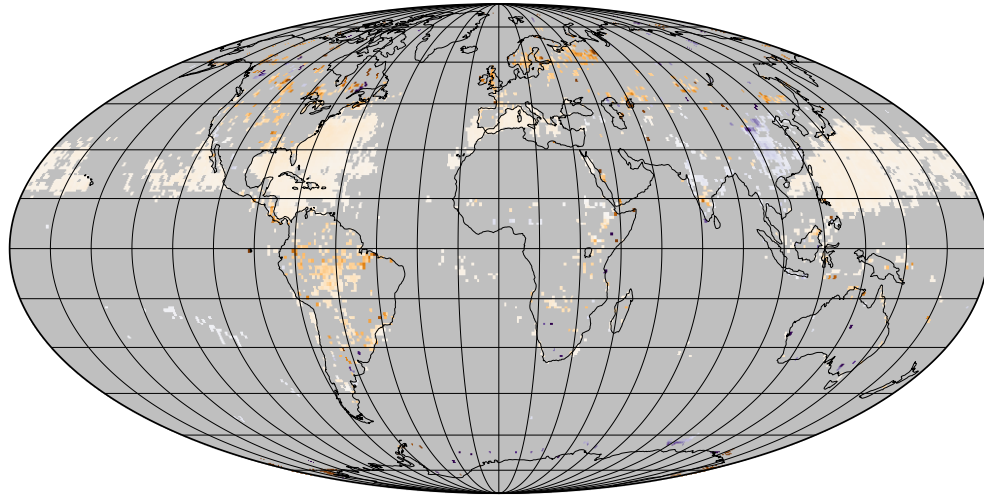
21-year (top) and 11-year (bottom) trends in monthly mean QA-filtered AOD show regional and seasonal agreement between Terra, Aqua, and SNPP



Trend in Angström Exponent, Terra, July 2002 - June 2023



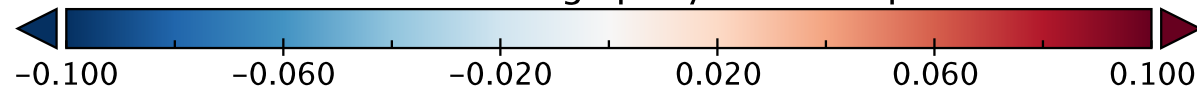
Trend in Angström Exponent, Aqua, July 2002 - June 2023



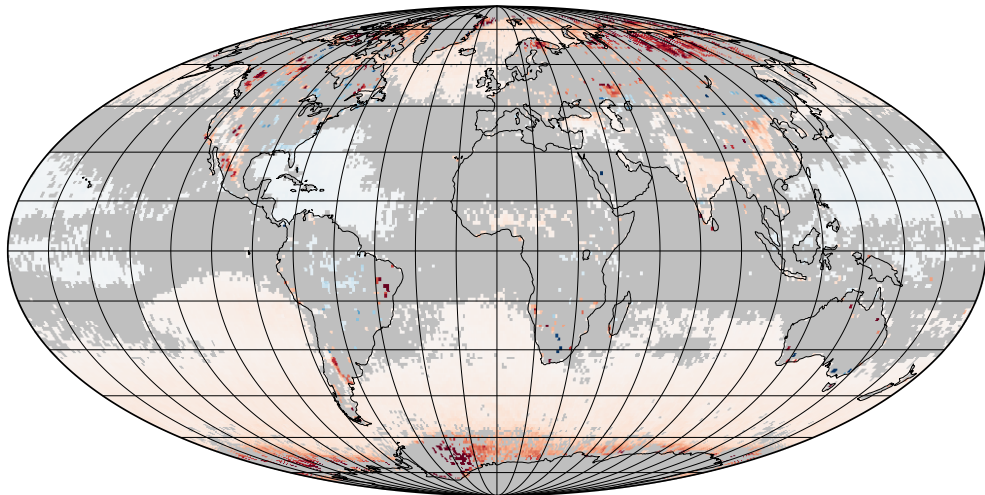
Angström exponent change per year where  $p \leq 0.01$



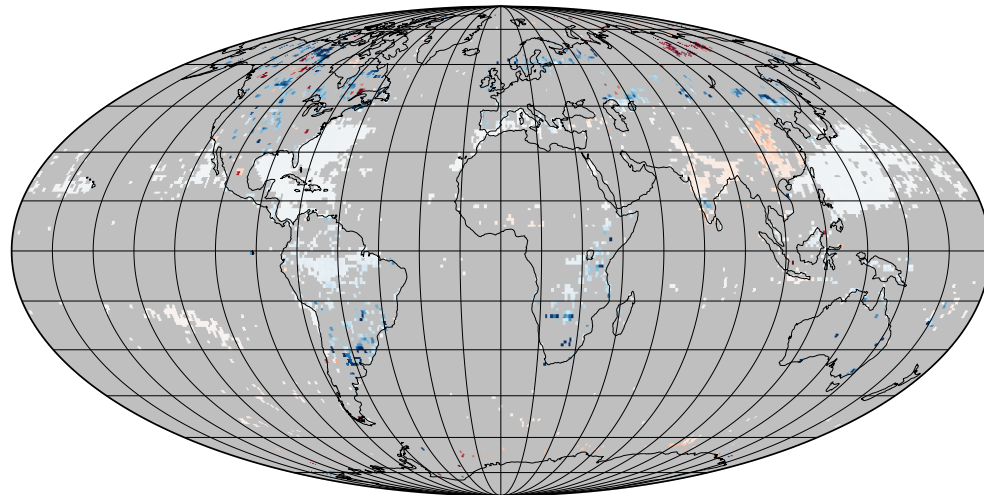
Small mode ratio change per year where  $p \leq 0.01$



Trend in Small Mode Ratio, Terra, July 2002 - June 2023



Trend in Small Mode Ratio, Aqua, July 2002 - June 2023

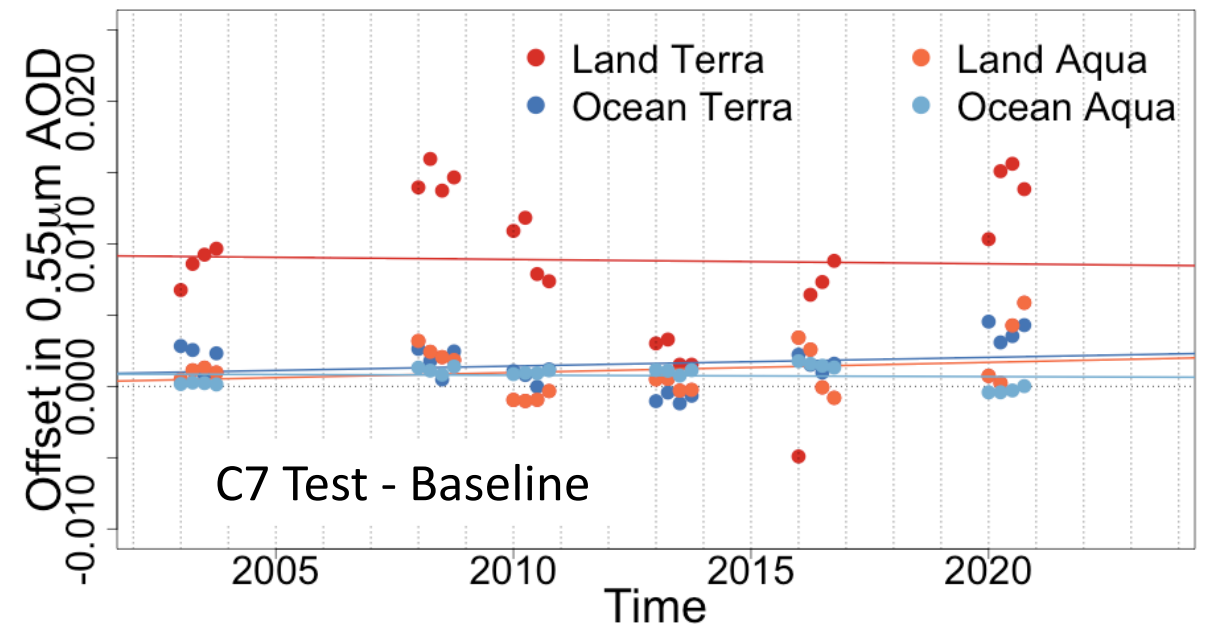
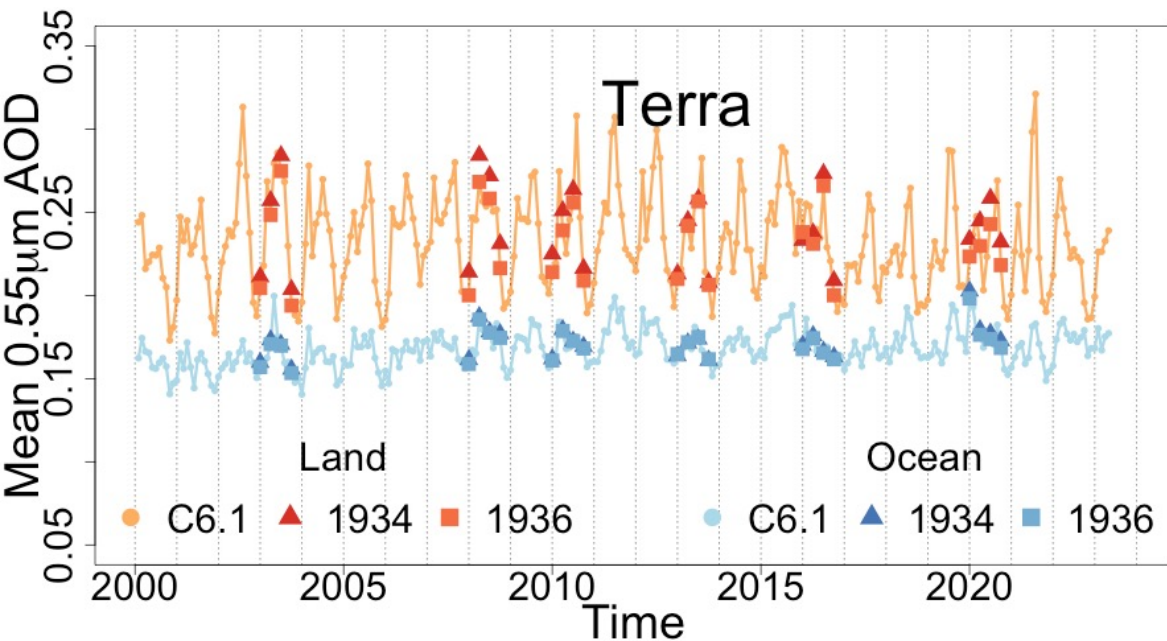


**Slope of the linear regression for each  $1^\circ \times 1^\circ$  grid cell plotted where  $p \leq 0.01$**

21-year trends in Ångström exponent (top) and fine mode fraction (bottom) show less agreement between Terra and Aqua

# MODIS C7 L1b and Dark Target

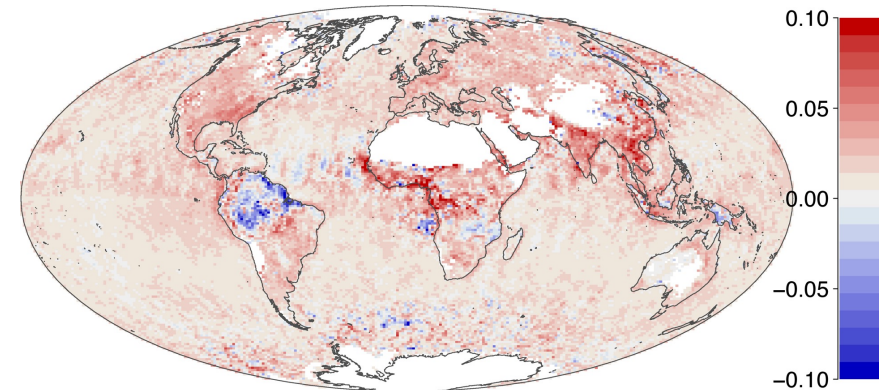
- Latest C7 L1b test does not significantly change Aqua Dark Target, but increases Terra AODs over land, thereby **increasing Terra-Aqua offset** compared to C6.1
- Found systematic changes in cloud masking, sampling, and aerosol model selection
- Changes in retrieved AOD have magnified effects on particle size parameters
- MODIS atmosphere teams have discussed results with MCST



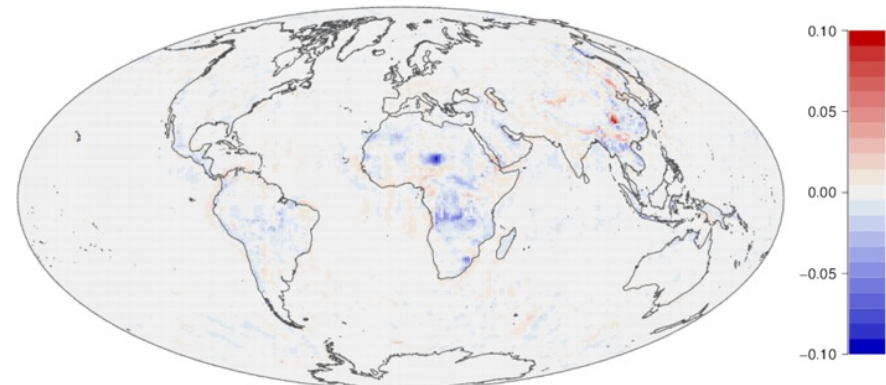
# MODIS-VIIRS Continuity for the AOD Record

- Without calibration adjustment, VIIRS Dark Target AODs show offsets comparable to the offset between MODIS Terra and Aqua, which is mostly due to calibration rather than diurnal cycle differences in AOD or sampling
- Applications that already use mixed Terra and Aqua retrievals can consider SNPP and NOAA-20 in continuity with MODIS without adjustment
- Applications that require a single seamless record may need calibration adjustments to bring SNPP closer to a reference sensor
- The reference sensor must be current if adjustment factors change over time—SNPP/Aqua factors will become outdated after the end of the Aqua record
- Transition from MODIS Aqua to VIIRS NOAA-20 as the reference sensor would keep the calibration closest to AERONET

C6 Terra-Aqua 0.55  $\mu\text{m}$  AOD, 2008



MERRA AM-PM on MODIS Swaths





# Dark Target/Deep Blue Merge for MODIS C7

The screenshot shows the Panoply Sources window. The top toolbar includes 'Create Plot', 'Combine Plot', 'Open Dataset', 'Remove', 'Remove All', and 'Hide Info'. Below the toolbar are tabs for 'Datasets', 'Catalogs', and 'Bookmarks'. The main area is a table with columns 'Name', 'Long Name', and 'Type'. The table lists various datasets, with 'geophysical\_data\_Dark\_Target\_Deep\_Blue\_Combined' selected. To the right of the table is a netCDF metadata panel for the selected group.

Name	Long Name	Type
MYD04_L2.A2017152.184...	MODIS L2 Aerosol (MYD04_L2)	Local File
geolocation_data	geolocation_data	—
Glint_Angle	Glint Angle	Geo2D
Latitude	Geodetic Latitude	Geo2D
Longitude	Geodetic Longitude	Geo2D
Relative_Azimuth_A...	Relative azimuth angle (Gordon co...	Geo2D
Scattering_Angle	Scattering Angle	Geo2D
Sensor_Azimuth_An...	Sensor Azimuth Angle, Cell to Sensor	Geo2D
Sensor_Zenith_Angle	Sensor Zenith Angle, Cell to Sensor	Geo2D
Solar_Azimuth_Angle	Solar Azimuth Angle, Cell to Sun	Geo2D
Solar_Zenith_Angle	Solar Zenith Angle, Cell to Sun	Geo2D
geophysical_data_Dar...	geophysical_data_Dark_Target	—
geophysical_data_Dar...	geophysical_data_Dark_Target_De...	—
geophysical_data_Dee...	geophysical_data_Deep_Blue	—

```
Group "geophysical_data_Dark_Target_Deep_Blue_Combined"
In file "MYD04_L2.A2017152.1840.007.2023289132018.nc"

dimensions:
  number_of_lines_10x10 = UNLIMITED; // (203 currently)
variables:
  short AOD_550_Dark_Target_Deep_Blue_Combined_QA_Flag(number_of_lin
    :FillValue = -9999S; // short
    :units = "None";
    :valid_range = 0S, 3S; // short
    :long_name = "Combined Dark Target, Deep Blue Aerosol Confidence
    :Parameter_Type = "Output";
    :scale_factor = 1; // int
    :add_offset = 0.0; // double
    :Geolocation_Pointer = "Internal geolocation arrays";
    :coordinates = "/geolocation_data/Longitude /geolocation_data/La
    :ChunkSizes = 1U, 135U; // uint

  short AOD_550_Dark_Target_Deep_Blue_Combined(number_of_lines_10x10
    :FillValue = -9999S; // short
    :units = "None";
    :valid_range = -100S, 5000S; // short
    :long_name = "Combined Dark Target, Deep Blue AOT at 550 nm for
    :Parameter_Type = "Output";
    :scale_factor = 0.001; // double
    :add_offset = 0.0; // double
    :Geolocation_Pointer = "Internal geolocation arrays";
    :coordinates = "/geolocation_data/Longitude /geolocation_data/La
    :ChunkSizes = 1U, 135U; // uint
```

- MODIS C7 will include Dark Target/Deep Blue in single M\*D04 product, as in previous collections
- File structure based on netCDF for VIIRS
- Geophysical parameters grouped by Dark Target, Deep Blue, or Combined
- L3 products will follow this structure, gridded averages via Yori
- Deep Blue will retrieve over land and ocean for MODIS as well as VIIRS
- Final DTDB merge logic TBD

# Dark Target/Deep Blue Merge for VIIRS

- In the meantime, how to create a C6.1-like merge for VIIRS v2.0?
  - Preliminary code (Shana Mattoo) applies C6.1 merge logic to AERDB\_L2 and AERDT\_L2 products to generate DTDB arrays
  - Does it make more sense to share merge code, or to publish a third product?
  - Problem: major algorithm updates to Deep Blue v2.0 make the merge less similar to Aqua C6.1 over bright surfaces
- Should a VIIRS continuity product also include SNPP-Aqua or NOAA20-Aqua radiometric adjustments?
  - Different groups suggest "Xcal" and "trend" corrections for different combinations of MODIS and VIIRS bands
  - Currently testing a Dark Target retrieval for SNPP adjusted to Aqua-like reflectances (Mijin Kim)



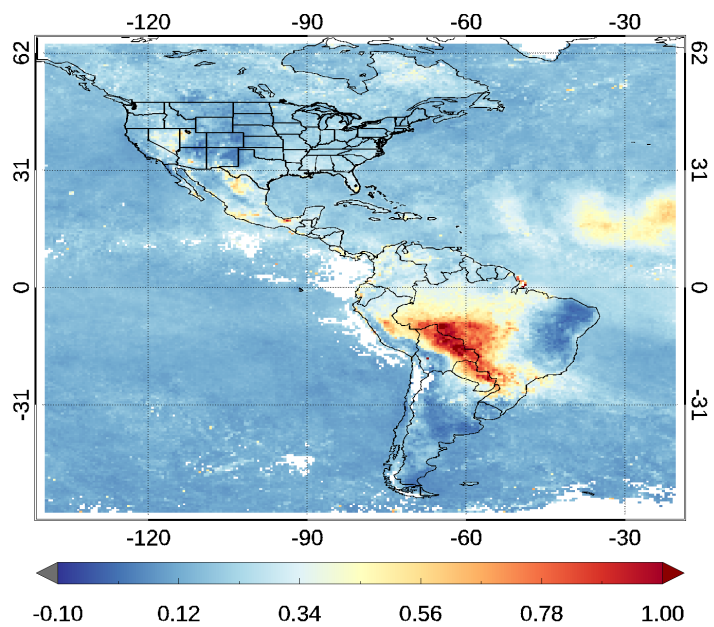
# VIIRS (SNPP) X-calibration Coefficient

from 2023 MODIS/VIIRS Science meeting, A. Lyapustin et al.

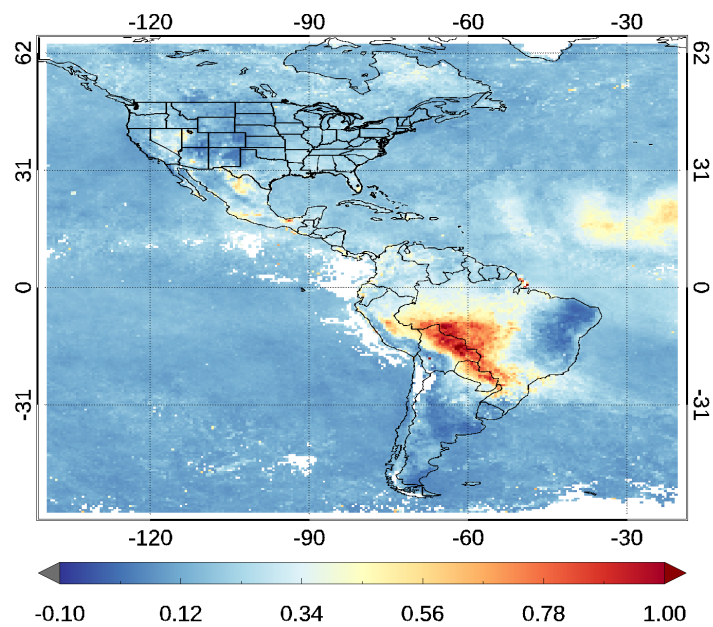
Band Pair		MAIAC		MCST/VCST (Wu et al., 2022)	CERES-IGCG (LaRC)	Meyer et al (2020)	Sayer et al (2017)
VIIRS		MODIS		AQUA/SNPP	AQUA/SNPP	AQUA/SNPP	AQUA/SNPP
M1	0.402 - 0.422			0.97	0.99		1.00
M2	0.436 - 0.454	B3	459–479	0.95			
<b>M3</b>	<b>0.478 - 0.488</b>	<b>B3</b>	<b>459–479</b>	<b>0.98</b>		0.98	0.99
<b>M4</b>	<b>0.545 - 0.565</b>	<b>B4</b>	<b>545–565</b>	<b>0.98</b>	1.02	0.97	0.96
<b>M5</b>	<b>0.662 - 0.682</b>	<b>B1</b>	<b>620–670</b>	<b>0.98</b>	0.97	0.97	0.94
M6	0.739 - 0.754						
<b>M7</b>	<b>0.846 - 0.885</b>	<b>B2</b>	<b>841–876</b>	<b>0.97</b>	0.99	0.98	0.96
<b>M8</b>	<b>1.23 - 1.25</b>	<b>B5</b>	<b>1230–1250</b>		0.95	0.97	1.01
M9	1.371 - 1.386						
<b>M10</b>	<b>1.58 - 1.64</b>	<b>B6</b>	<b>1628–1652</b>		0.98	0.99	0.98
<b>M11</b>	<b>2.23 - 2.28</b>	<b>B7</b>	<b>2105–2155</b>			0.97	0.93

A. Lyapustin et al., 2023, RSE

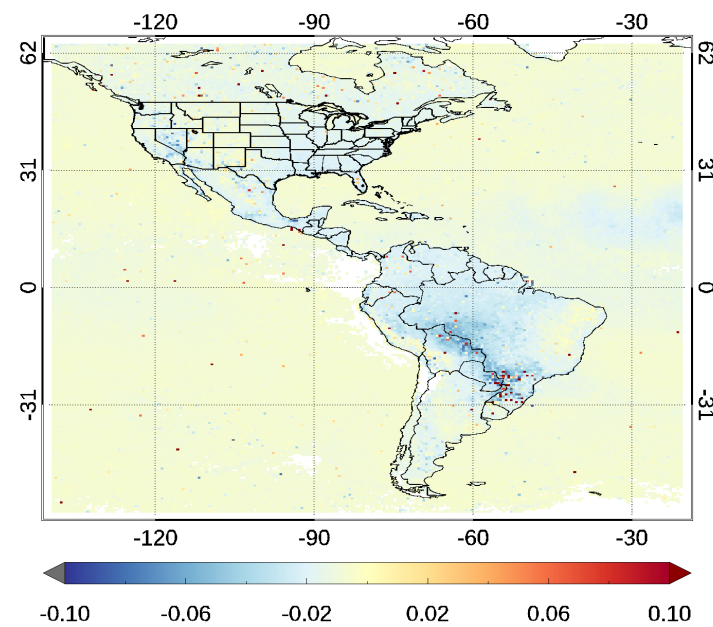
### VIIRS SNPP AOD Baseline (all quality, Sept 2019)



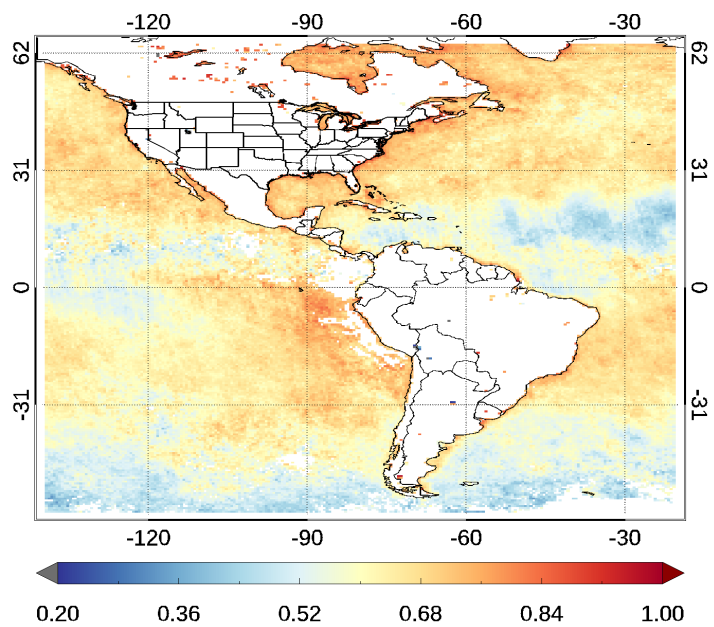
### With Xcal



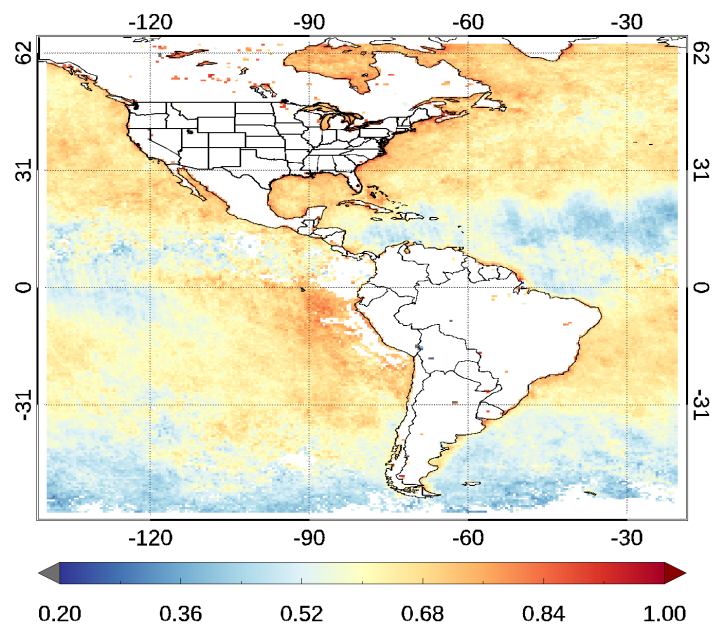
### Xcal - Baseline



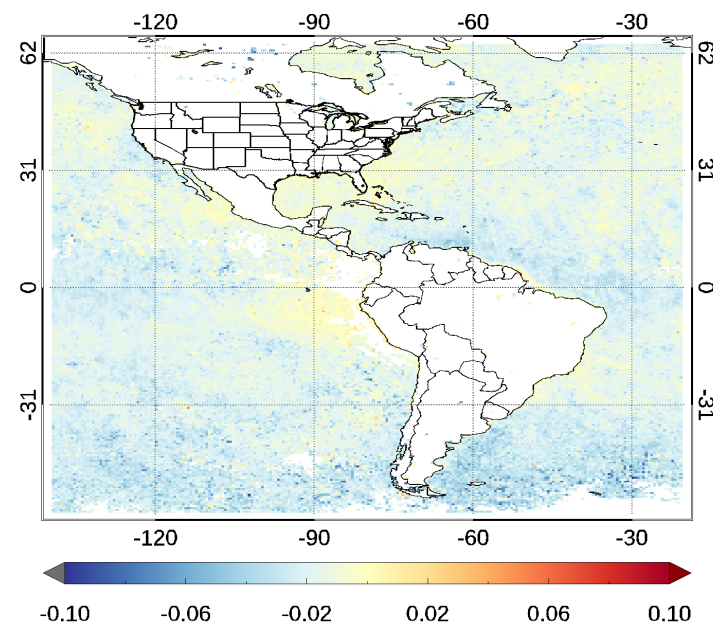
### VIIRS SNPP FMF Baseline (Sept 2019)



### With Xcal

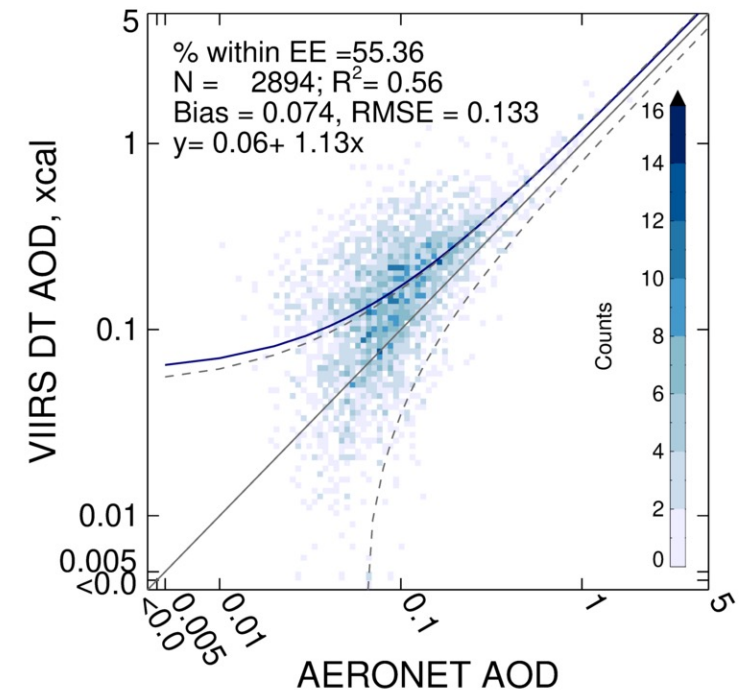
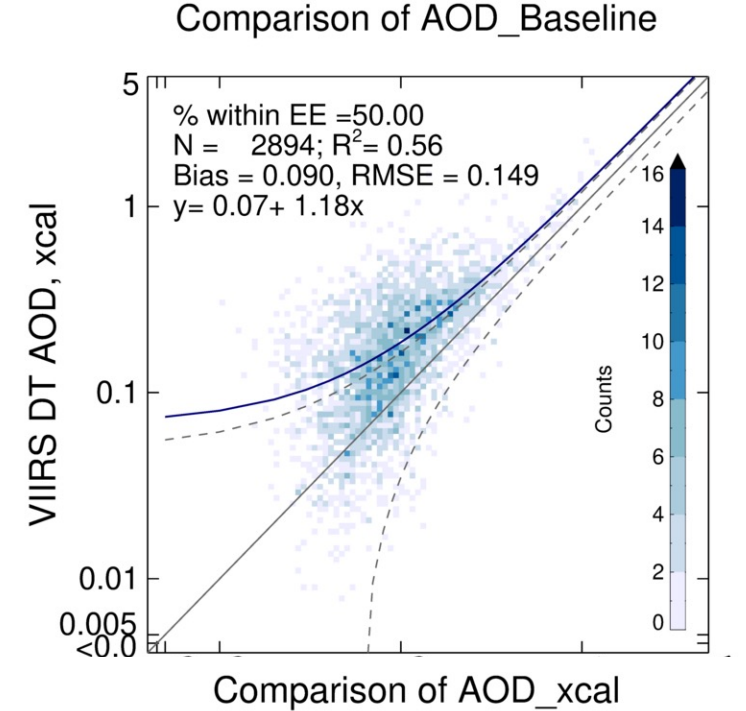


### Xcal - Baseline



# VIIRS SNPP with xCal vs. AERONET, September 2019

- Brings greater number of AERONET-  
collocated SNPP retrievals within expected  
error
- Reduces, but does not eliminate, SNPP high  
bias
- Greater reduction in SNPP vs. Aqua bias  
found when combined with corrections to  
surface reflectance parameterization (Mijin  
Kim)



# Summary

- Dark Target for VIIRS v2.0 is now available on LAADS (AS5200) for SNPP and NOAA-20
- Algorithm updates improve cloud masking, fix bugs, and expand on reported parameters and metadata, but AOD distributions remain close to v1.1
- VIIRS NOAA-20 is offset lower than both SNPP and Aqua
- Trends in AOD largely agree between sensors
- MODIS C7 will have new L1b calibration, new file structure, new DTDB merge logic
- VIIRS DTDB requires a continuity merge with different logic from intended future versions
- Dark Target group is testing calibration adjustments to SNPP and NOAA-20