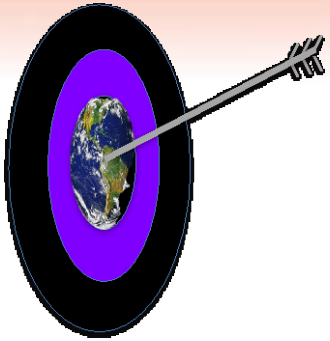
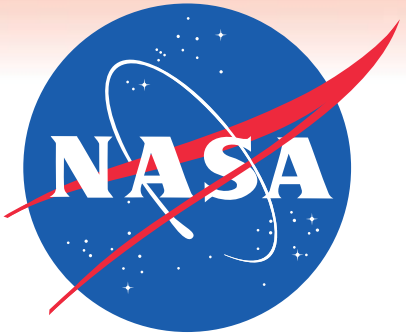


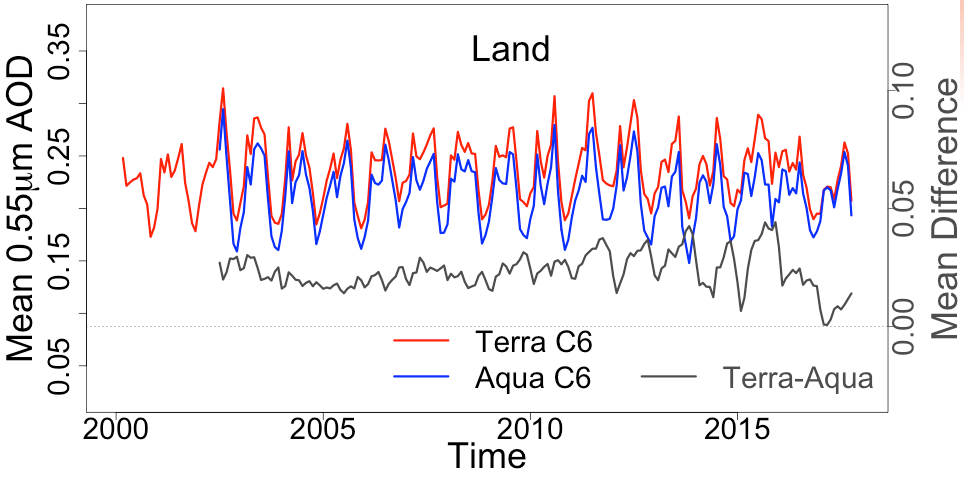


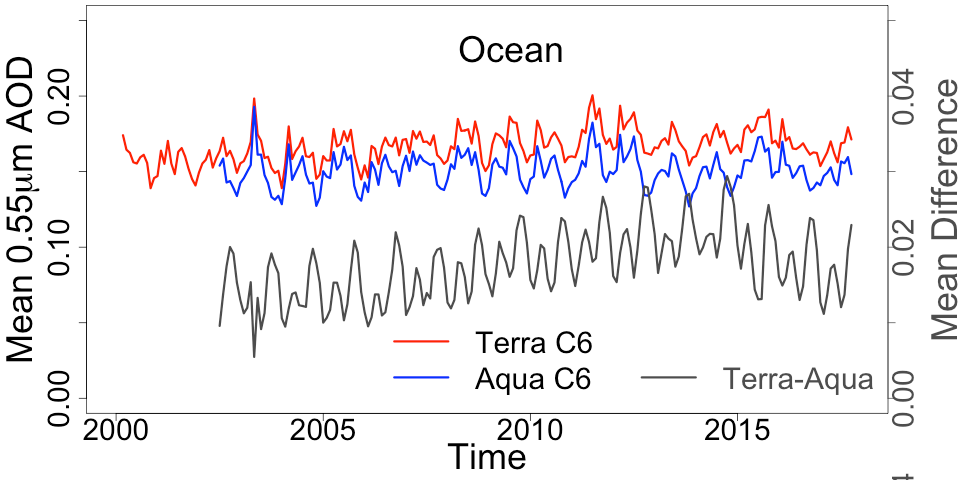
Offsets in Dark Target Aerosol Retrieval for Terra-MODIS, Aqua-MODIS, and SNPP-VIIRS

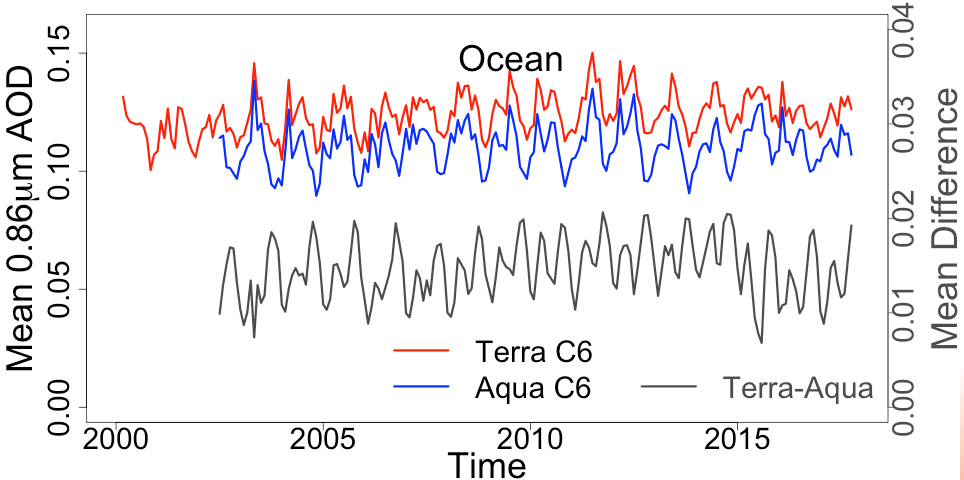
Robert C. Levy, Shana Mattoo, Virginia Sawyer, Yingxi Shi, Peter R. Colarco, Alexei I. Lyapustin, Yujie Wang, Lorraine A. Remer

Dark Target AOD for Climate

- Uses the contrast between aerosol and “dark” underlying ocean surface or vegetation (Deep Blue retrieval also included in M*D04_L2 has a different basis) with separate processes for land and ocean
- Retrieves AOD at λ = 0.47, 0.55, 0.65, 0.86, 1.24, 1.63 and 2.11 µm with additional bands for cloud masking, snow identification, etc.
- Terra and Aqua use the same algorithm and have concurrent data records starting in 2002
- MODIS Dark Target is getting close to the precision and accuracy requirements for a climate data record, but will not last long enough for a multidecadal record
- SNPP-VIIRS Dark Target can extend the AOD record beyond Terra and Aqua lifespans, but significant offsets exist between all three

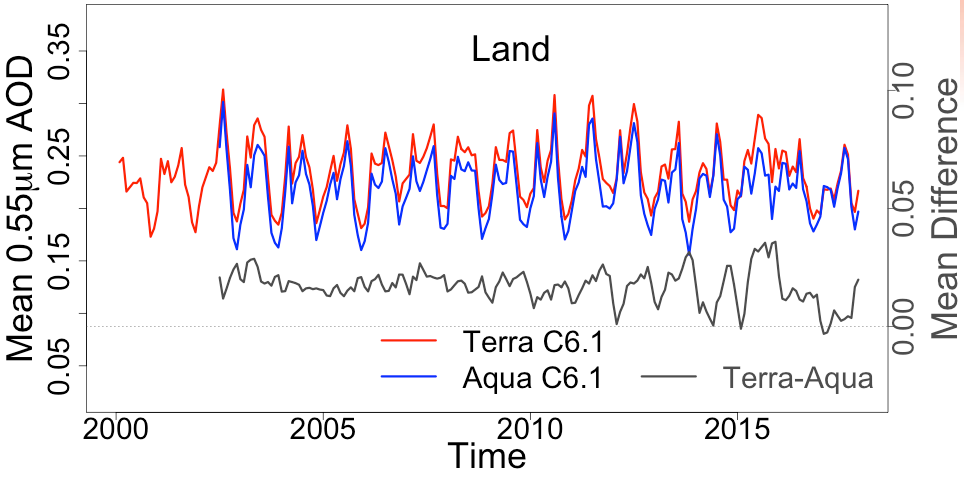


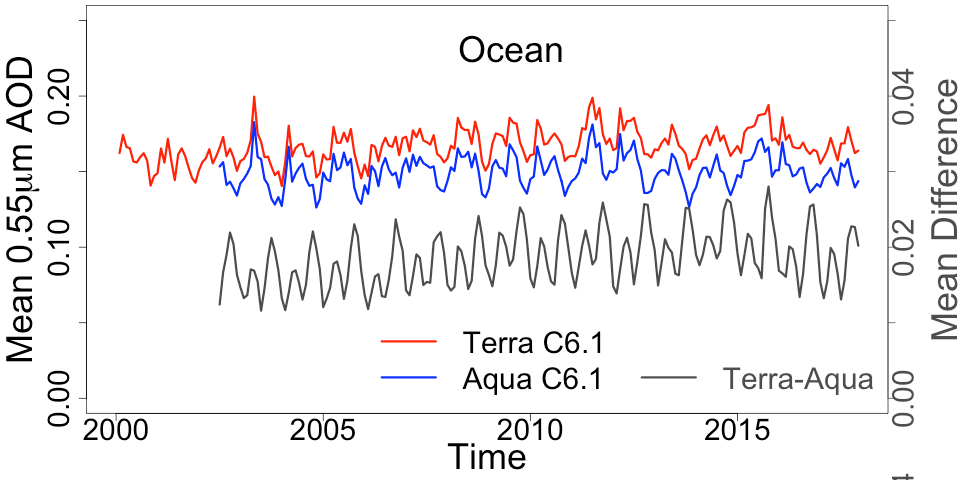


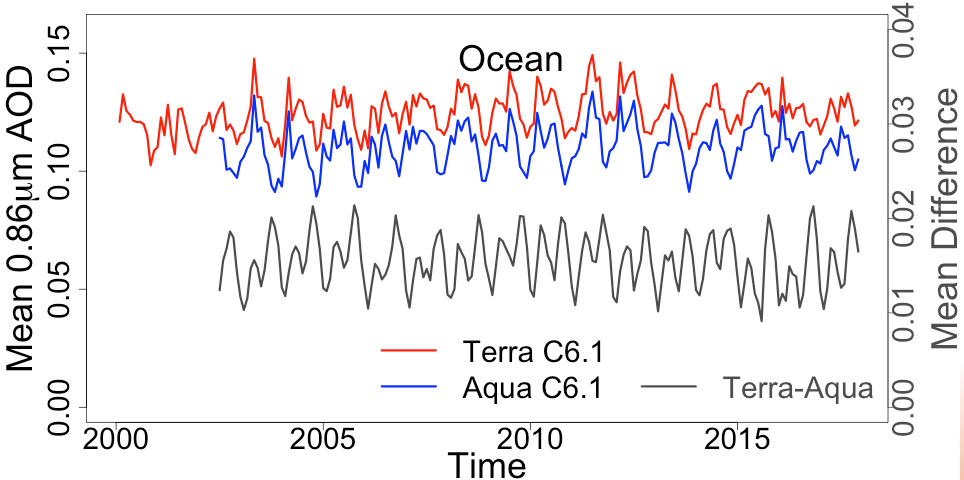


C6 Terra-Aqua

- Offset is not constant over the globe, but mostly small positive Terra-Aqua
- Terra ~12% higher than Aqua for land and ocean, varying seasonally
- Terra-Aqua AOD variability over land increases abruptly in 2011
- Terra-Aqua AOD over ocean has a non-physical apparent trend at 0.55µm and a smaller corresponding trend at 0.86µm





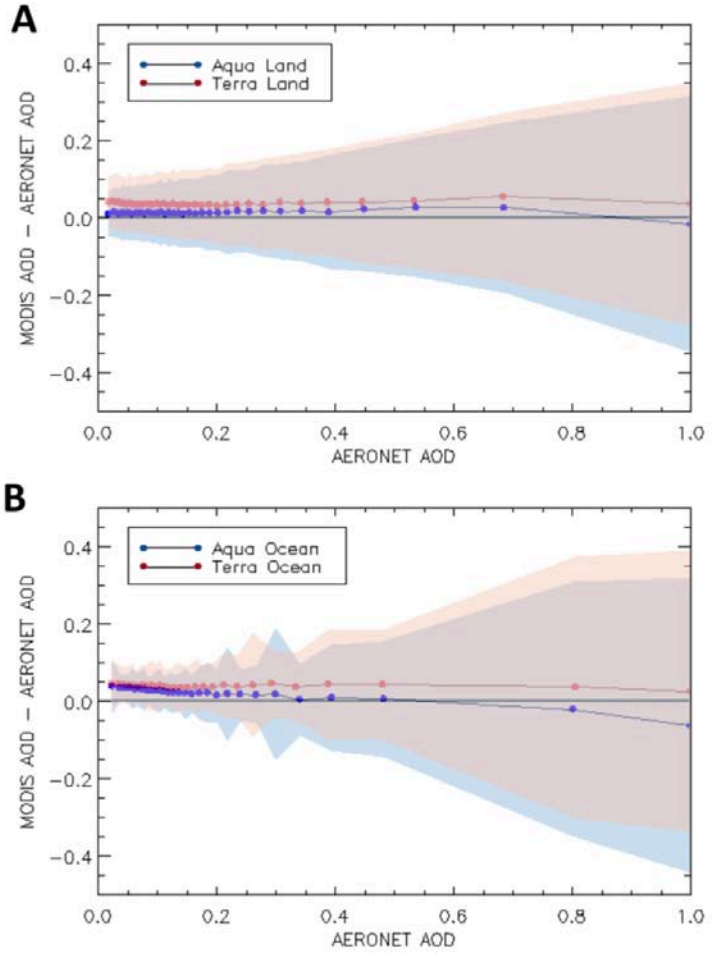


C6.1 Terra-Aqua

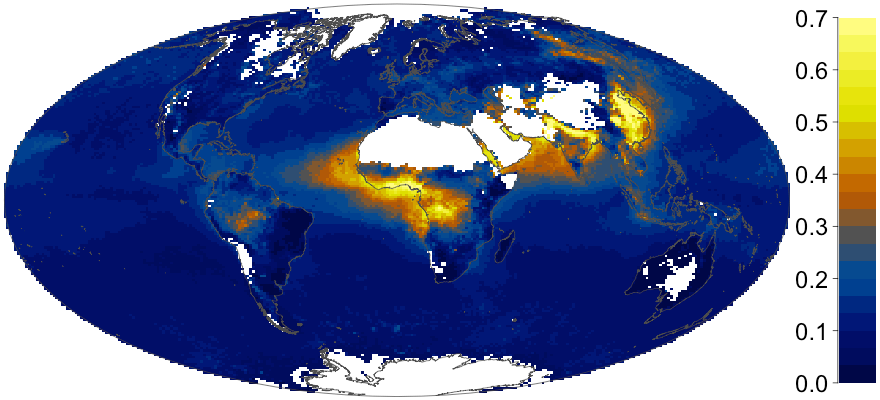
- Dark Target algorithm improvements for C6.1 affect small scale aerosol events (urban surfaces, heavy smoke) and have little effect on global average
- Upstream adjustments to L1b C6.1 calibration account for reduction in offset variation and drift
- Average offset remains ~12%, but becomes more constant over time

Validation with Ground Networks

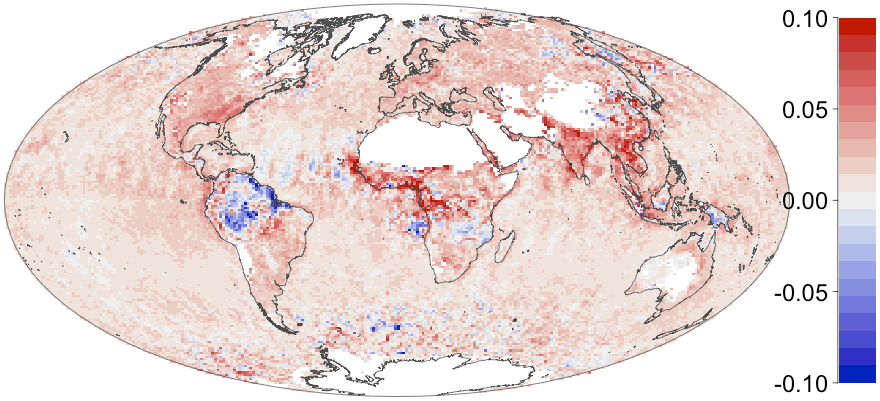
- In C6, Terra has a higher positive bias than Aqua vs. AERONET
- Major rewrite of validation code just completed for MODIS C6.1 vs. AERONET V3 and MAN, underway for VIIRS
- Current AERONET validation uses coastal sites for ocean validation and must exclude high-elevation sites (e.g. Mauna Loa). MAN is a more direct alternative



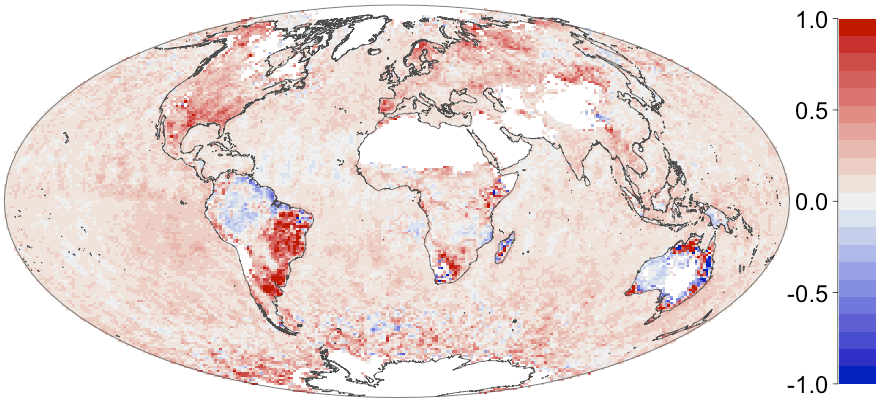
C6 Aqua 0.55μm AOD, 2008



C6 Terra-Aqua 0.55μm AOD, 2008



C6 (Terra-Aqua)/Aqua 0.55μm AOD, 2008

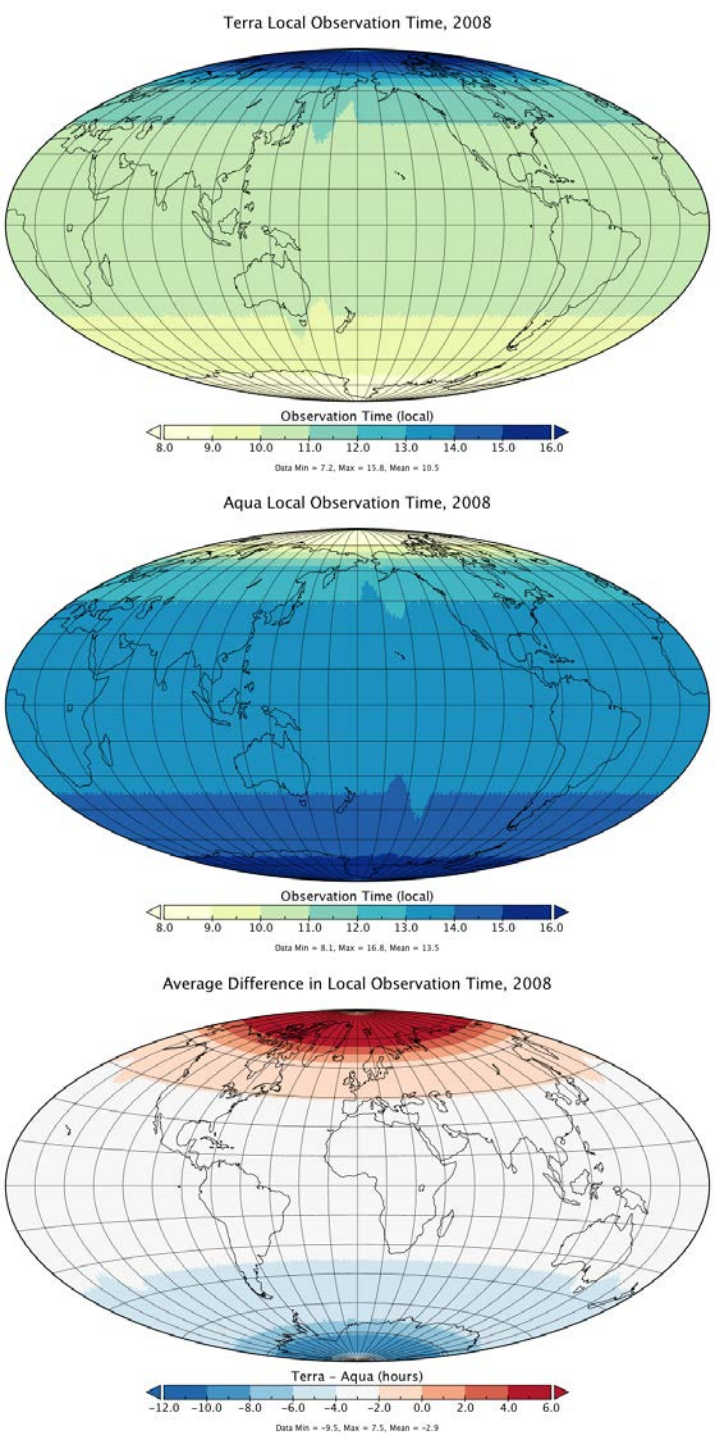


Spatial Differences

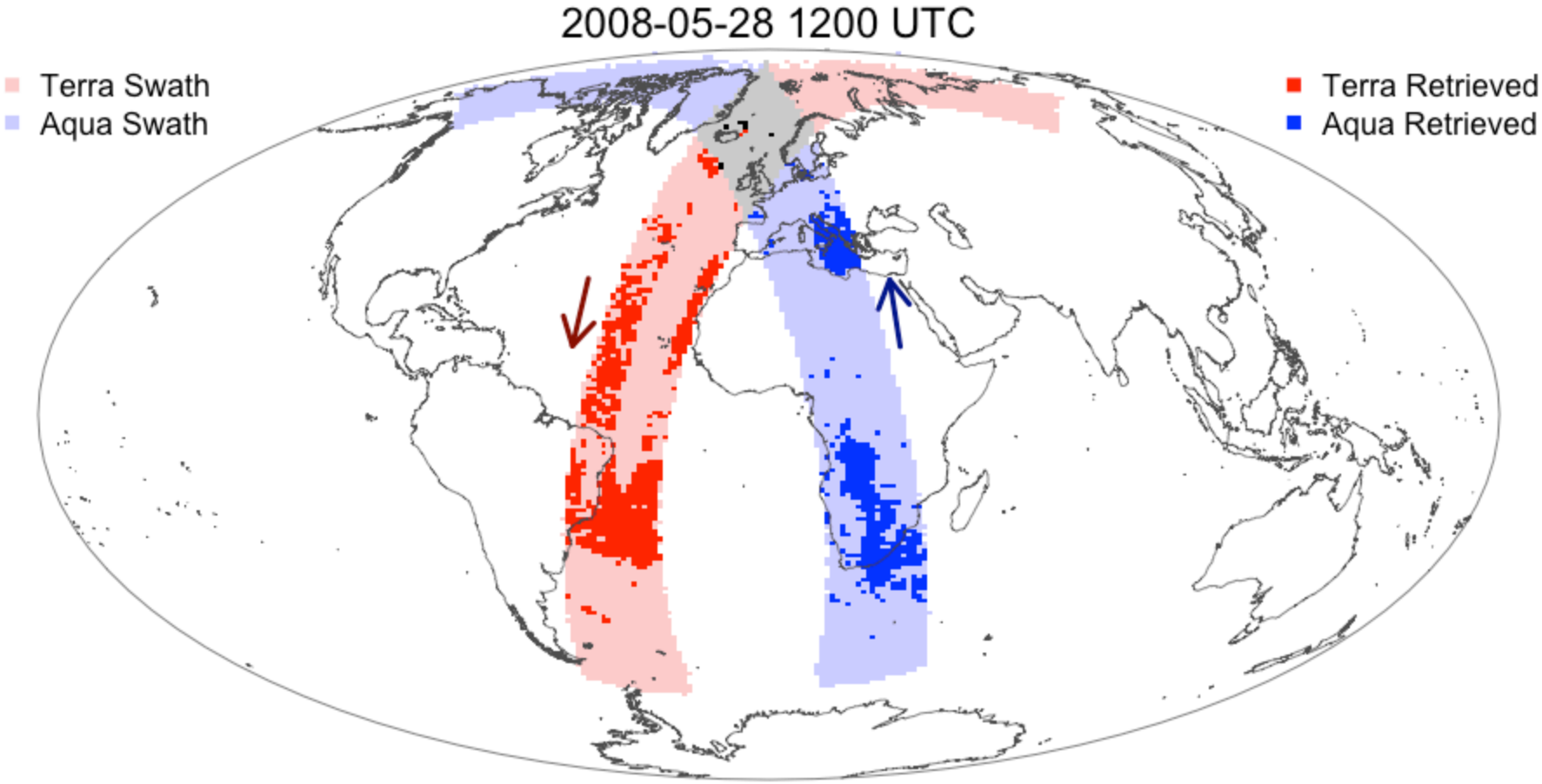
- Absolute and relative difference respectively emphasize bias at high and low AOD
- Aqua AOD > Terra AOD only in a few areas over land in the tropics (blue)
- Otherwise, widespread Terra bias of +0.015-0.025 (red)
- Ångström exponent shows similar widespread bias with Terra retrieving larger particles than Aqua
- C6.1 reduces the offset slightly and uniformly overall

Local Time of Observation

- Sampling geometry may be different for morning and afternoon retrievals
- However, annual average difference in solar zenith and scattering angles between Terra and Aqua is less than 3° and cannot account for the AOD offset
- Alternatively, some Terra-Aqua differences may be physical if there is reason to expect the diurnal cycle to affect sampling
- MERRA reanalysis AOD is not subject to cloud cover, glint, etc.

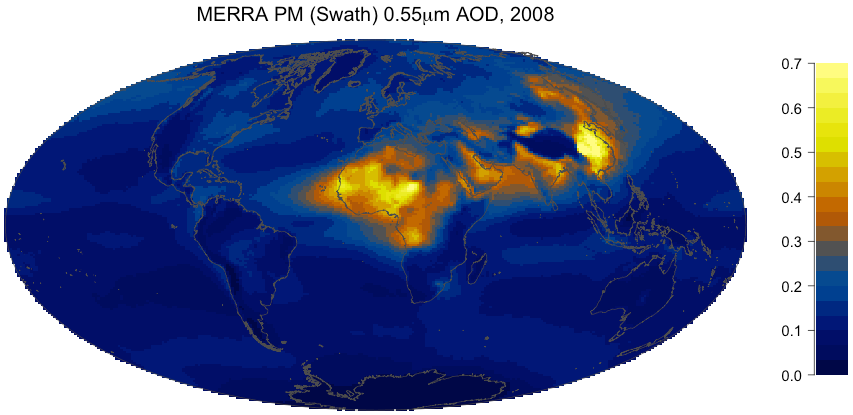


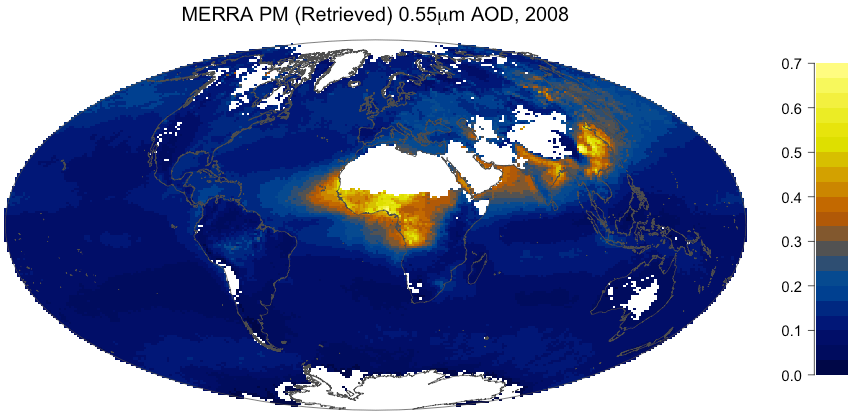
MERRA – Swath vs. Retrieved

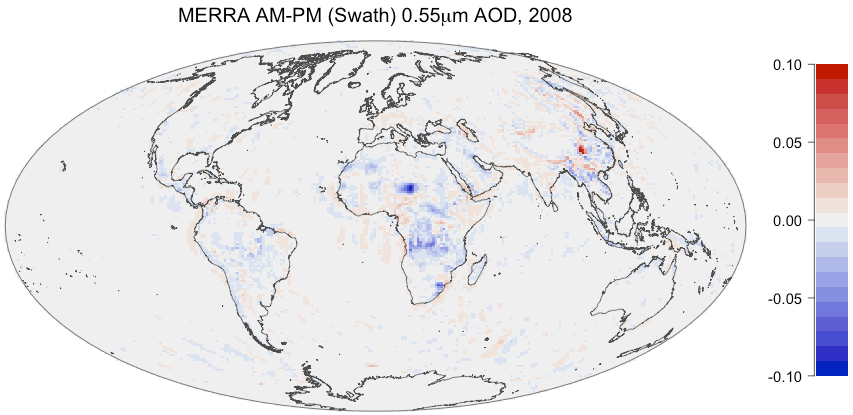


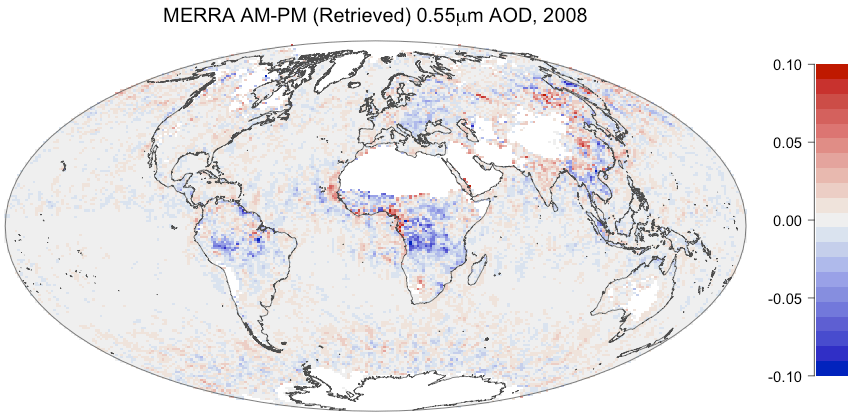
Simulated AOD sampled for the entire MODIS swath (retrievable or not) and for MODIS-retrieved gridpoints only

MERRA – Swath vs. Retrieved

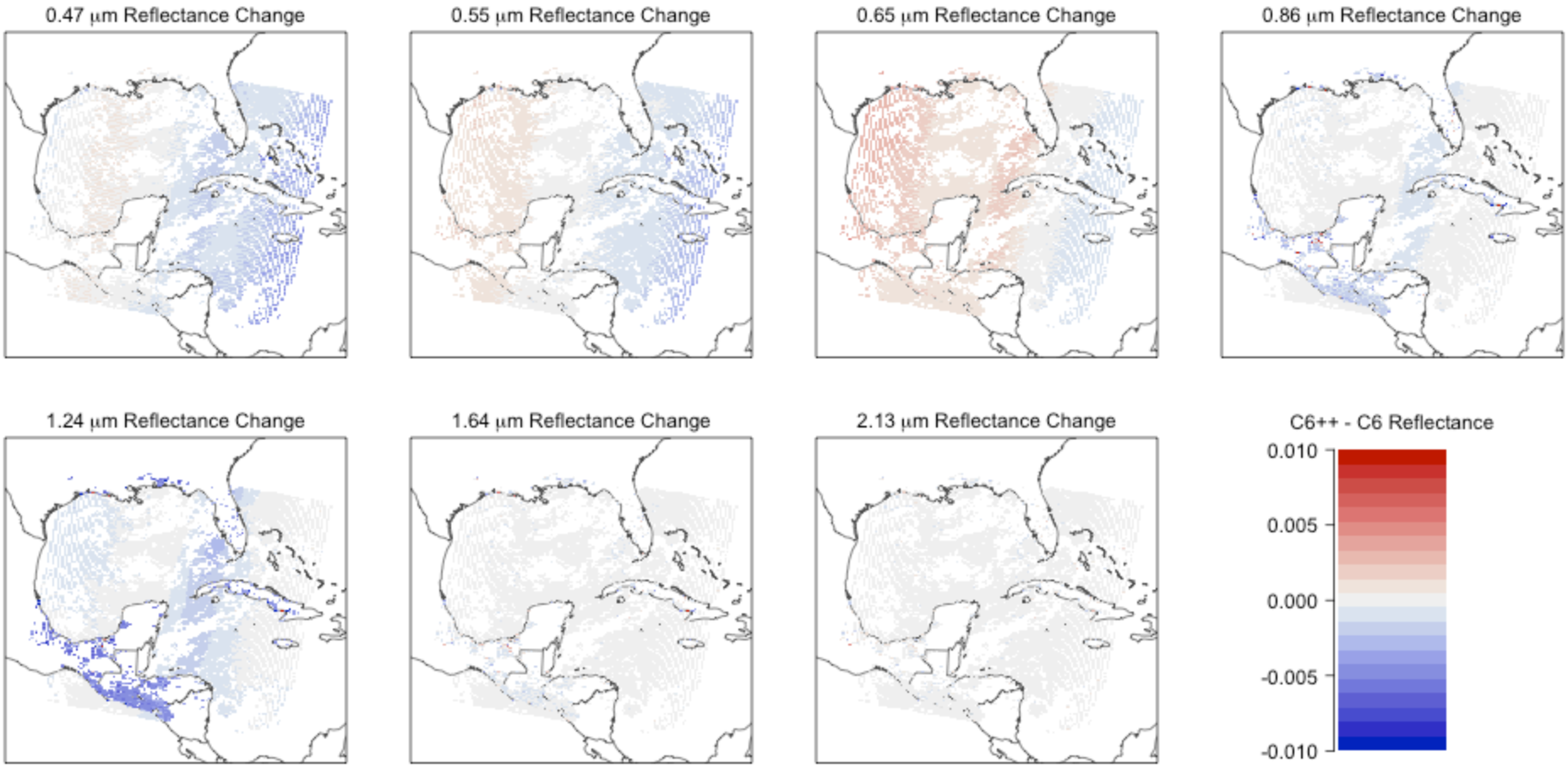








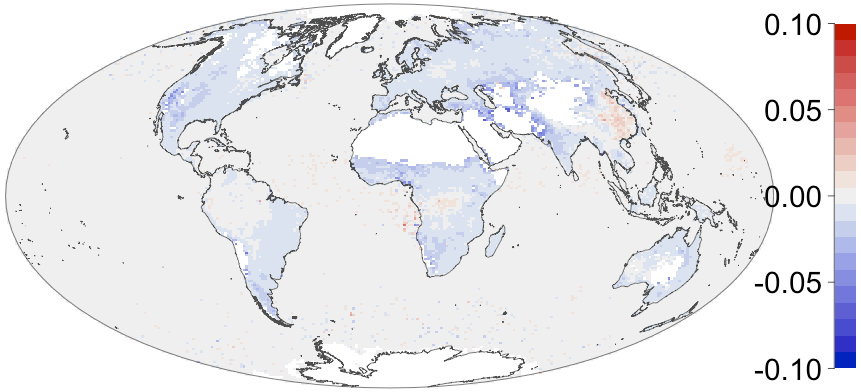
Some Terra-Aqua difference is due to sampling (i.e. diurnal cloud cycle) but it does not account for overall positive offset



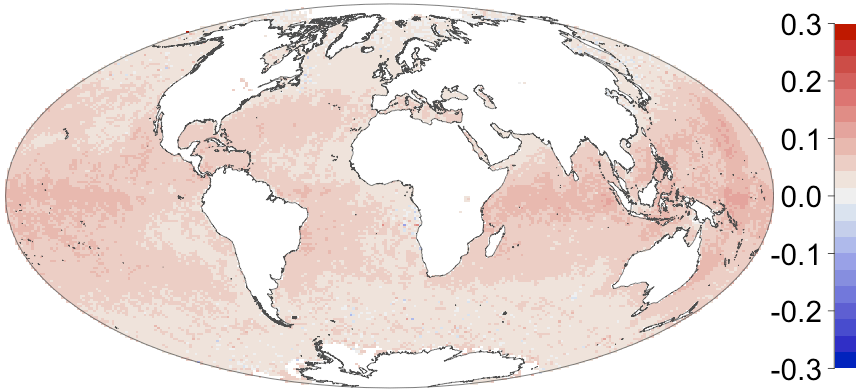
- Lyapustin et al. (2014) corrects L1b reflectances at each wavelength individually, accounting for polarization, drift, and that Aqua is more stable than Terra
- Resulting C6+ reflectances applied to Dark Target retrieval in place of C6 L1b to examine calibration effects

Differences between C6+ and C6

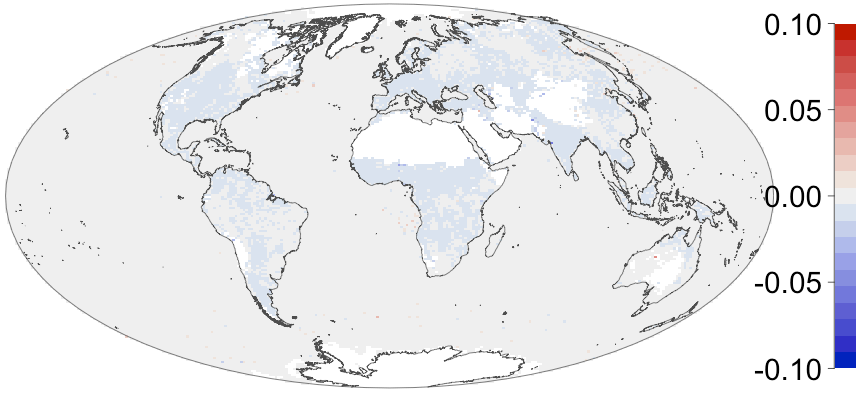
C6+ - C6 Terra 0.55μm AOD, 2008



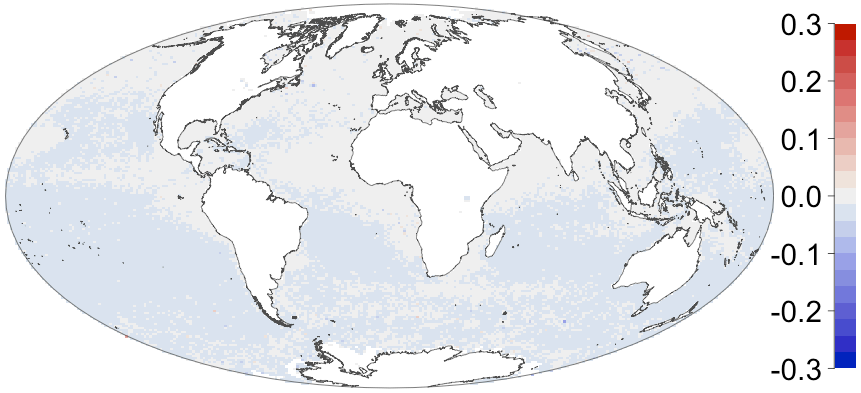
C6+ - C6 Terra Angstrom Exponent, 2008



C6+ - C6 Aqua 0.55μm AOD, 2008

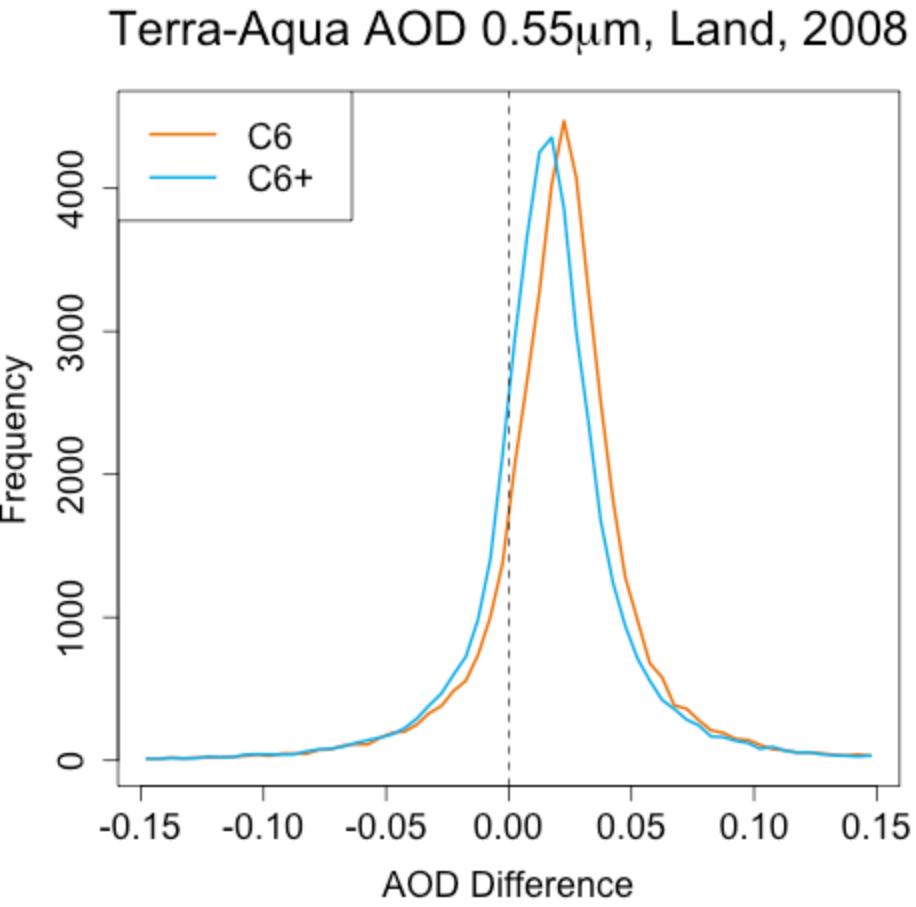


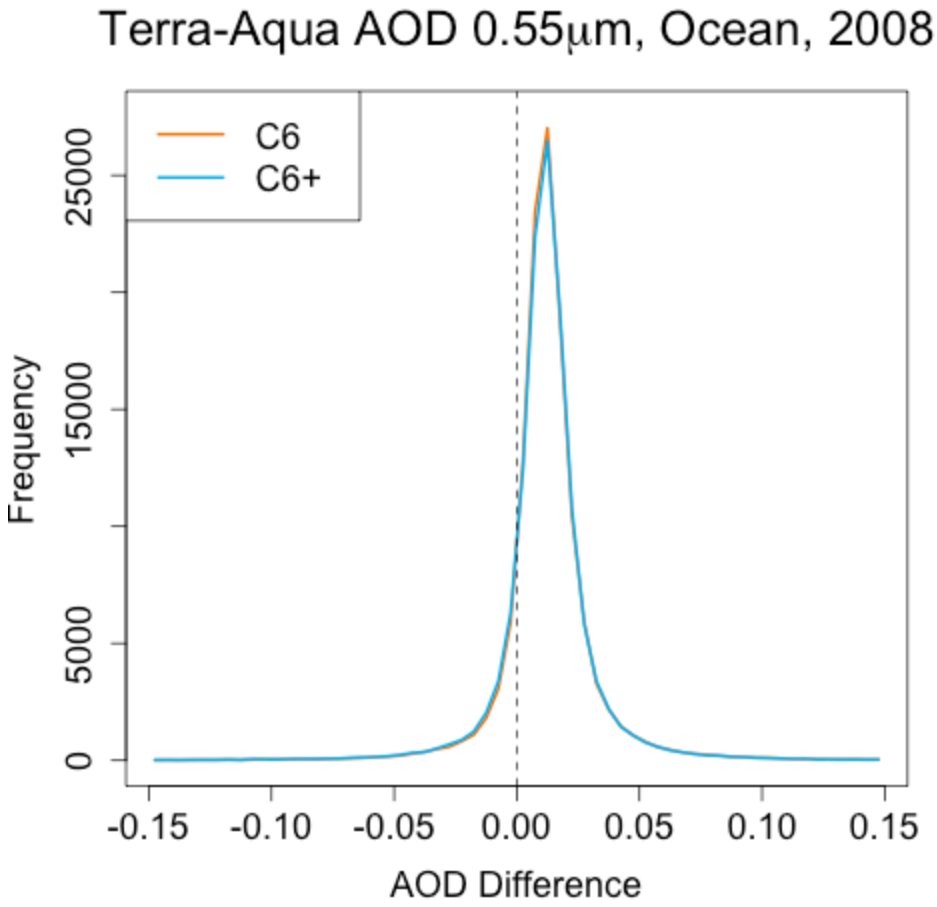
C6+ - C6 Aqua Angstrom Exponent, 2008



C6+ reduced 0.55μm AOD over land but made almost no difference over ocean, though it did change 0.86μm AOD and AE

Differences between C6+ and C6

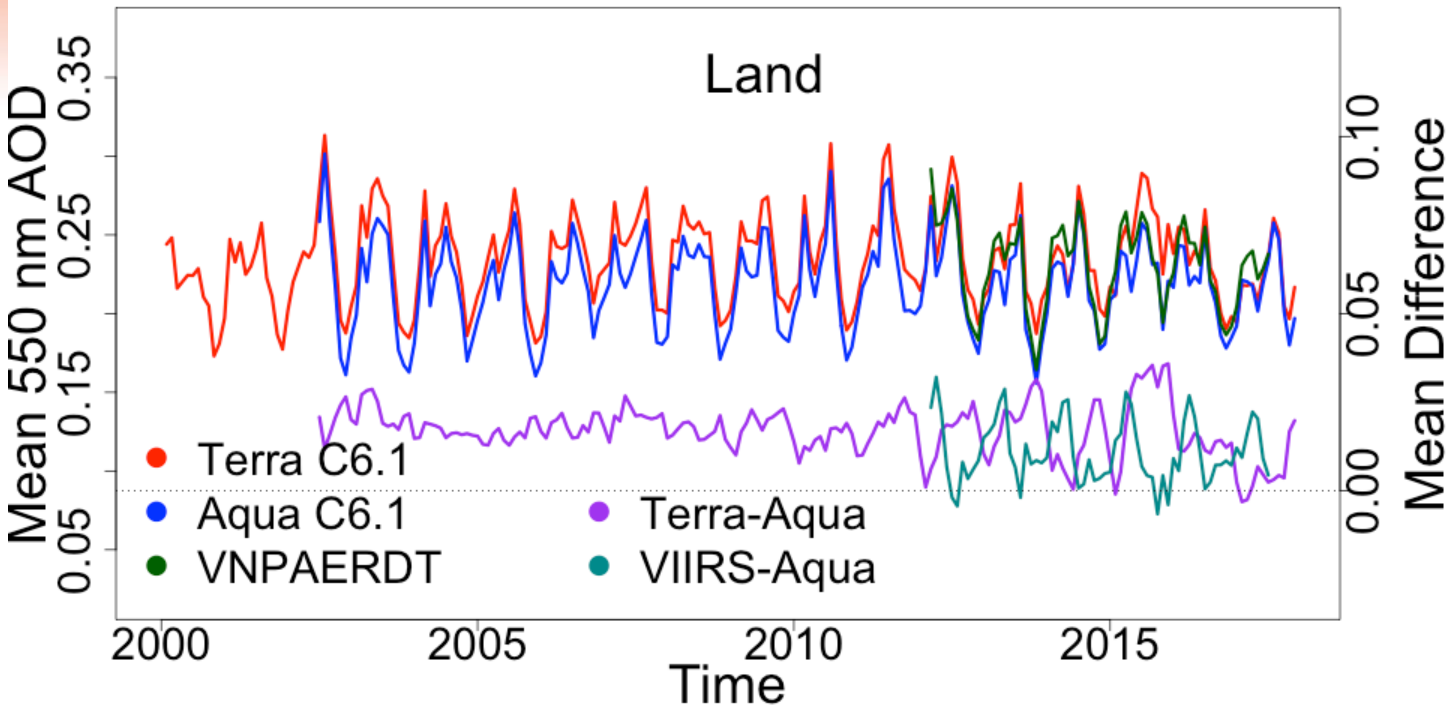


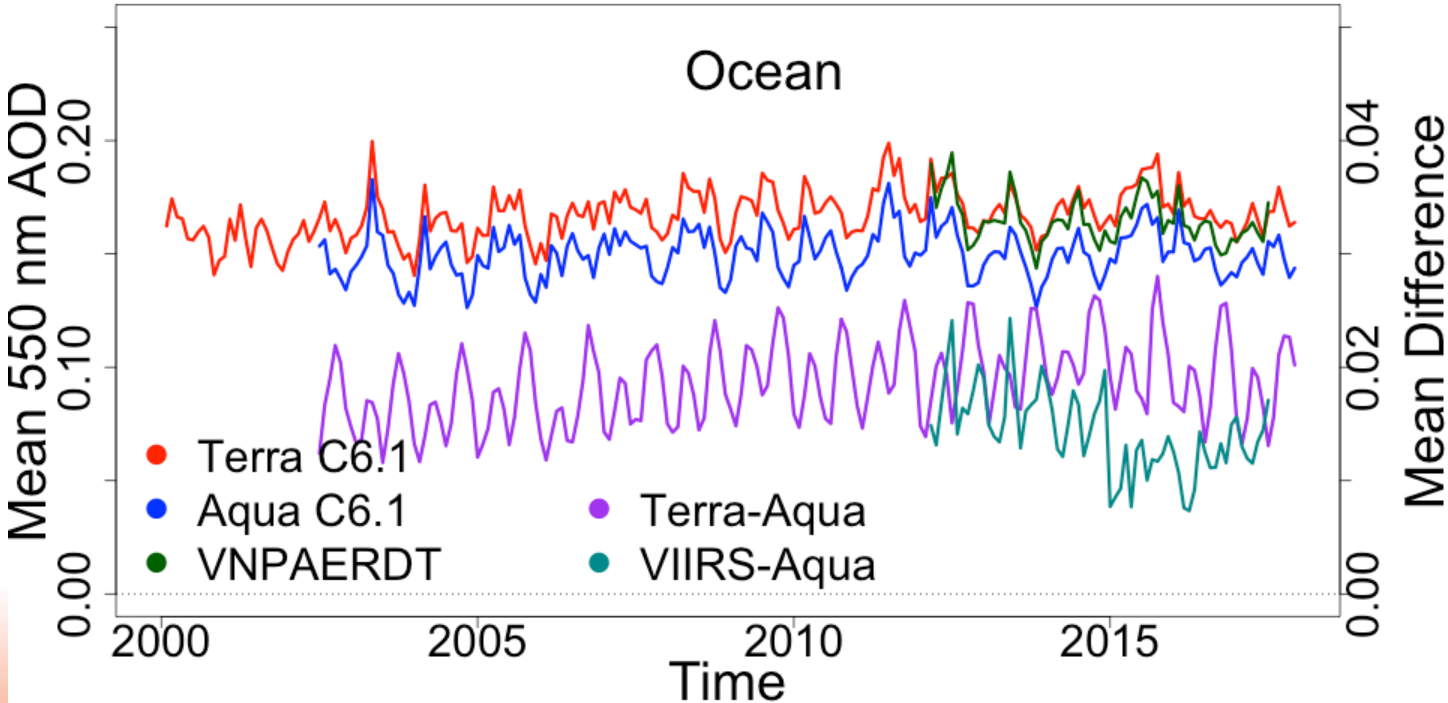


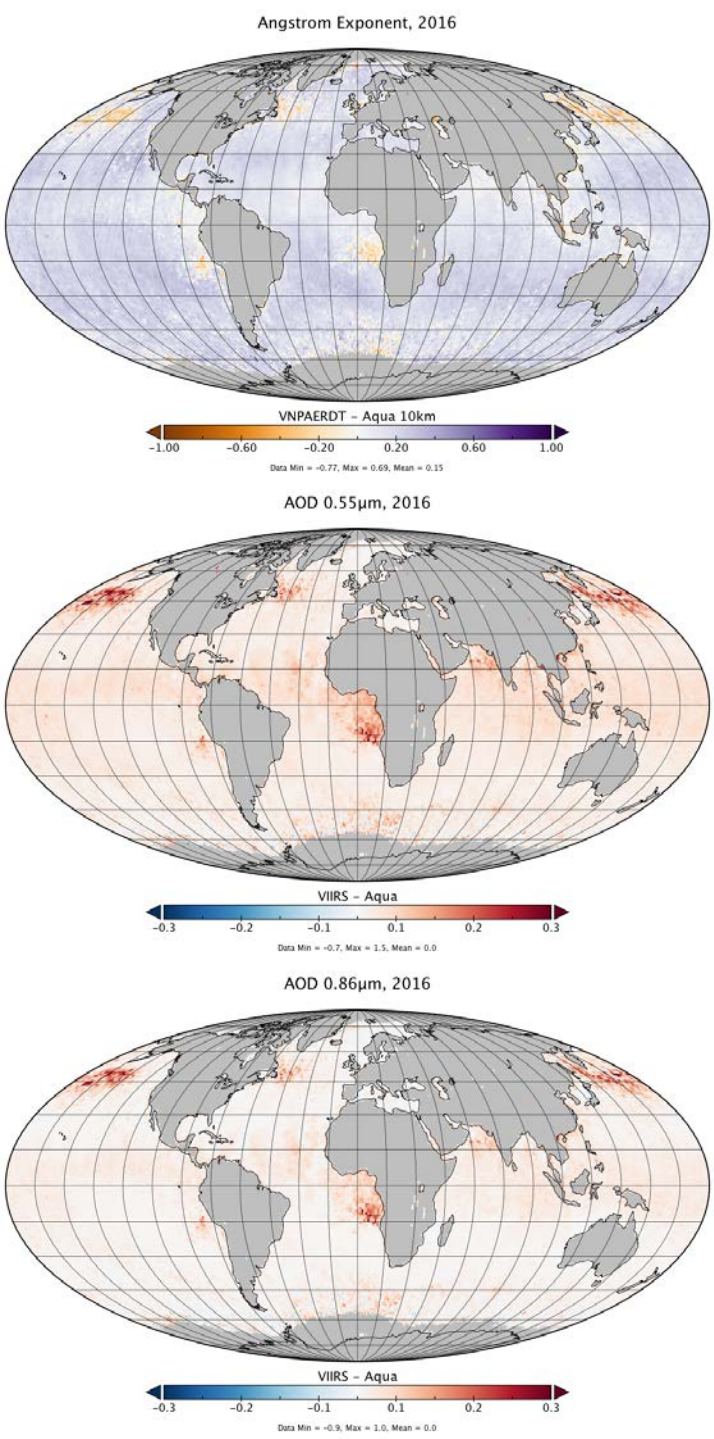
C6+ brings down the positive bias in Terra over land (though not to zero) but leaves the bias over ocean unchanged

VIIRS

SNPP-Aqua difference averages slightly smaller than Terra-Aqua difference. C6.1 agrees better than C6 due to MODIS calibration

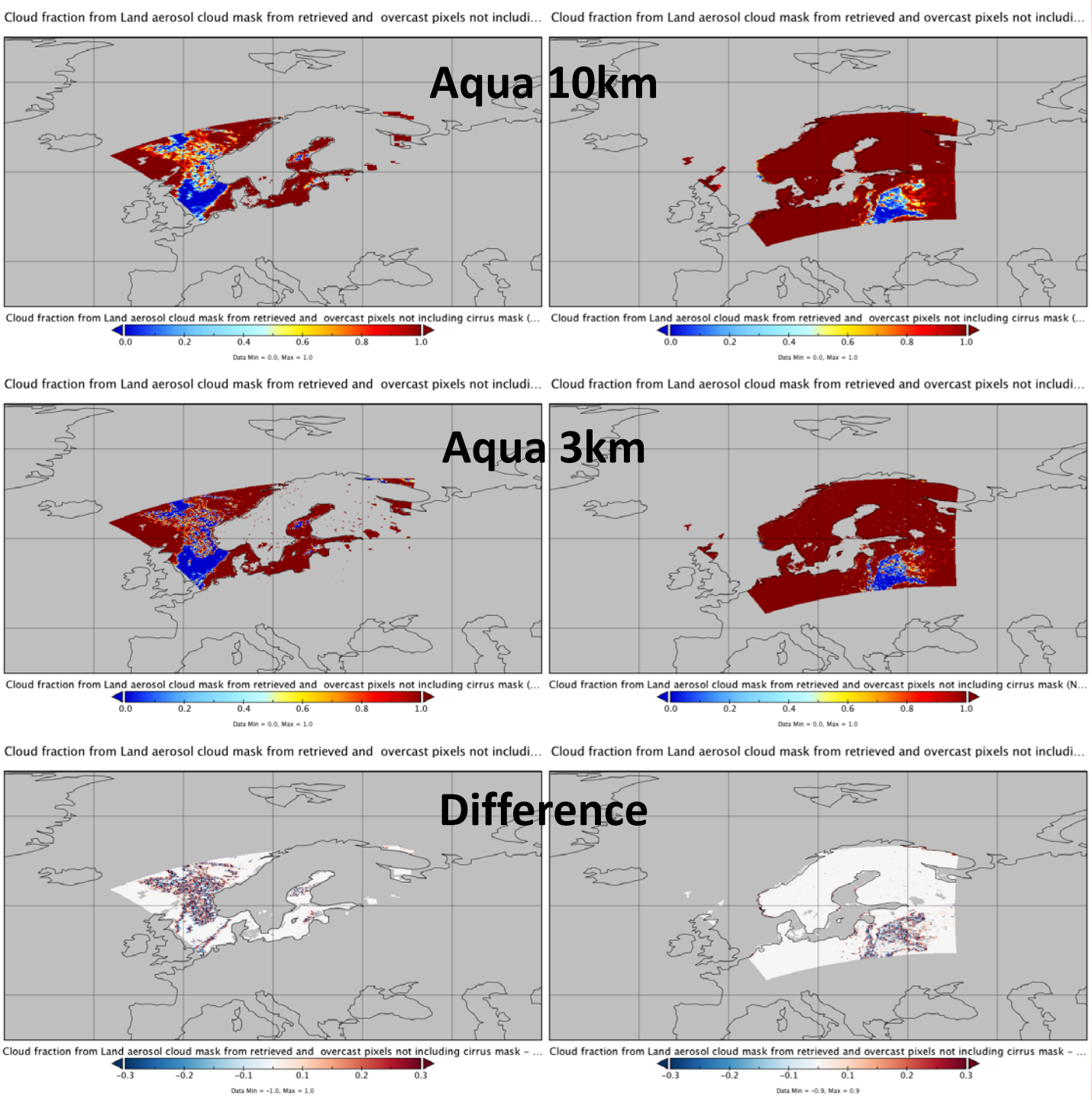






Spectral Dependence of L1b Differences

- VIIRS Dark Target does not adjust reflectances to match MODIS, though we may do so in future work
- Preliminary testing shows that it reduces but does not eliminate MODIS-VIIRS offset
- Ångström exponent has much greater differences than Terra-Aqua because VIIRS 0.86µm AOD is closer to Aqua than 0.55µm AOD, and the 0.55µm/0.86µm ratio exacerbates the difference in offset by wavelength



- Higher-resolution cloud fraction has more pixels 100% cloudy or 100% clear than lower resolution, but only 100% cloudy are excluded from AOD retrieval.
- At 6 km VIIRS will sample differently from MODIS at 10km even using an otherwise identical algorithm

Conclusion

- Terra-MODIS and Aqua-MODIS have a consistent offset in Dark Target AOD of about 12%
- Some regional differences are probably sampling changes due to the cloud diurnal cycle, but the widespread Terra positive bias is not physical
- C6+ reflectances adjusted for polarization sensitivity and instrument drift reduce offsets over land but not over ocean
- VIIRS Dark Target can extend MODIS AOD record to multiple decades, long enough to examine for climate trends
- VIIRS-Aqua offsets are comparable to Terra-Aqua. Adjusted reflectances may help, though sampling differences remain