Utilizing Libya-4 to intercalibrate overlapping sensors in the same sun-synchronous orbit

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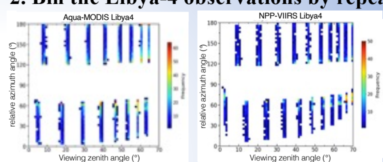
1. Introduction

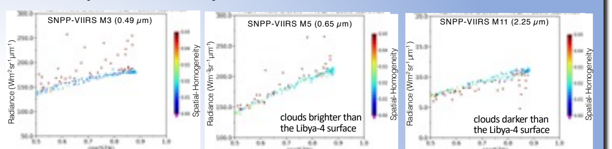
- The Libya 4 site is one of the most often-used Pseudo-invariant Calibration Sites (PICS) by the Committee on Earth Observation Satellites (CEOS) Working Group for Calibration and Validation
- Libya4 (28°-29° North and 22°-23° East) is composed of sand dunes with no vegetation, highly reflective and little cloud cover
- Libya-4 can be used to inter-calibrate sensors in the same sun-synchronous orbit, since the TOA reflectance is predictable

2. Bin the Libya-4 observations by repeat cycle day



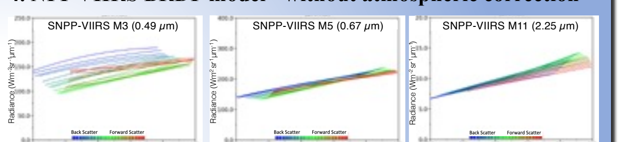
- The MODIS radiances have 16 distinct view zenith and relative azimuth angle bins corresponding to the orbit repeat cycle day
- Use all angular bins
- The lowest solar zenith angles are either in direct back or forward scatter
- Due to the higher altitude, VIIRS has a few more overlapping orbits at higher view zenith angles

3. Identify the clear-sky observations



- Apply spatial homogeneity thresholds to identify the clear-sky observations within each repeat cycle day or angular bin using the 0.65µm and 1.6µm channels, which are least impacted by the atmosphere
- Apply an additional 2-sigma homogeneity filter across each angular bin based on the two channels
- 50% of the Libya-4 observations were identified as pristine clear.

4. NPP VIIRS BRDF model - without atmospheric correction



- The clear-sky radiances can be predicted by $Rad_{pred} = g_0 + g_1 * \cos(SZA) + g_2 * \cos(SZA)^2$
- Each spectral channel and angular bin is characterized by the 2nd order cosine solar zenith angle fit

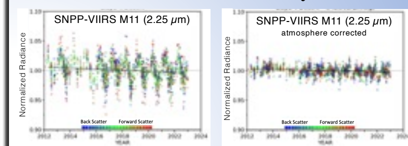
5. NPP VIIRS BRDF model - with atmospheric correction

VIIRS band	SZA-only	AOD-MYDO08	AOD-MATCH	O3 MERRA	O3 MYDO8	PW-RSB	PW-IR	PW-MERRA
M3	1.102	1.042 5.8	1.058 4.0					
M4	0.885			0.846 4.4	0.860 2.9			
M7	0.745					0.630 15.4	0.652 12.5	0.658 11.7
M8	1.051					0.627 40.3	0.742 29.4	0.722 31.3
M11	1.923					0.733 61.9	1.217 36.7	1.022 46.9

standard error (%) without atmosphere
standard error (%) using atmospheric source
% reduction from using atmospheric source

- The atmospheric corrected clear-sky radiances can be predicted by $Rad_{pred} = a_0 + a_1 * \cos(SZA) + a_2 * \cos(SZA)^2 + a_3 * PW + a_4 * O_3 + a_5 * AOD$
- Several sources of precipitable water (PW), ozone (O3) and aerosol optical depth (AOD) were linearly regressed with radiance
- The source with the lowest standard error was used to correct for the atmosphere
- The MYDO08 AOD, MERRA O3, and MYDO08 PW (based on NIR wavelengths) were used for atmospheric correction

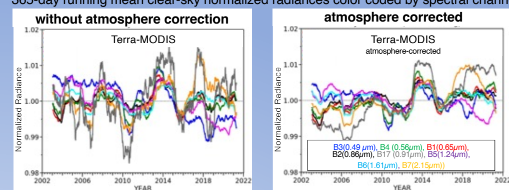
6. Normalized NPP VIIRS Libya-4 radiances



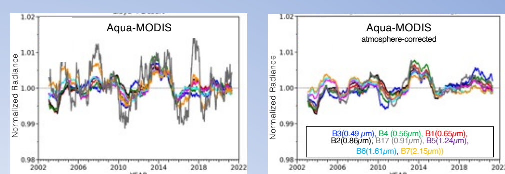
- The daily clear-sky normalized radiances are color coded by their angular bin (see section 4)
- The nadir and oblique views are equally distributed
- Note the seasonal variation without atmospheric correction
- The normalized clear-sky radiance is given by $rad_{norm} = rad_{obs} / rad_{pred}$
- The standard error was 1.92% (left) without and 0.71% (right) with atmospheric correction, a 63% reduction

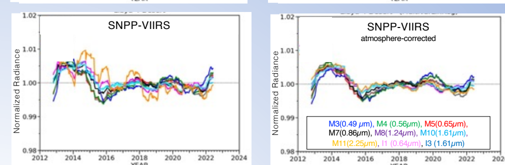
7. Libya-4 normalized MODIS and VIIRS radiances

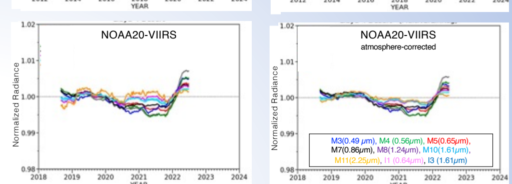
365-day running mean clear-sky normalized radiances color coded by spectral channel



The Feb 2016 Terra satellite anomaly increased the electronic cross talk. The solar diffuser doors are in the open position since 2003



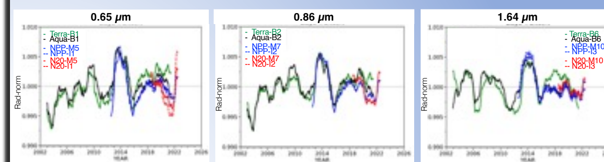




Note the spectral consistency achieved by correcting for the atmosphere

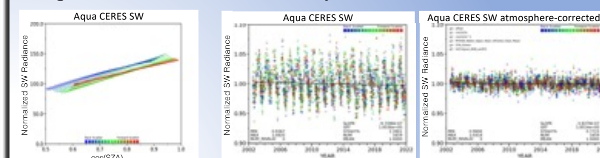
- The normalized radiance 2014 inflection is present in the Terra-MODIS, Aqua-MODIS and SNPP-VIIRS records
- It seems that the normalized radiance variations are in harmony across sensors and may describe the true Libya-4 surface variability

8. MODIS and VIIRS Normalized Libya-4 radiance comparison



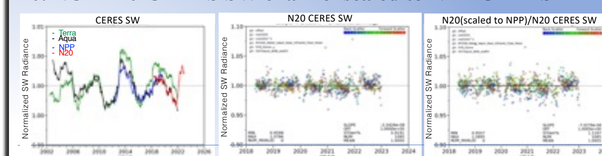
- The MODIS and VIIRS normalized radiances are in synch across spectral channels
- The MODIS and VIIRS sensor anomalies are much smaller that the Libya-4 natural variability
- The Libya-4 natural variability is due to prevailing winds that change the orientation of the sand dunes that define the areal extent of the shadowing
- This suggests that the Libya-4 is not spectrally changing from dust advection, rain events, or vegetation

9. Aqua-CERES SW channel Libya-4 observations



- The Libya-4 Aqua-CERES SW channel angular bin radiances are well behaved
- Linearly regress the CERES SW radiances without atmosphere correction (same as section 4)
- Linearly regress the CERES SW radiances with atmosphere terms (same as section 5)
- The standard error was 2.39% and 0.77% for without and with atmosphere correction, a 68% reduction

10. NOAA20-CERES SW channel scaled to NPP-CERES



- The CERES SW normalized radiances are temporally consistent suggesting excellent onboard calibration
- The NOAA20 CERES SW normalized daily radiances have a temporal uncertainty of 0.9%
- The NOAA20 CERES SW radiances can be normalized using the NPP coefficients to radiometrically scale NOAA20 to the NPP CERES calibration reference

11. Conclusions

- The Libya-4 MODIS, VIIRS and CERES daily full-scan observations were characterized to facilitate inter-calibration between sensors within the same 1:30PM orbit
- The target sensor can be radiometrically scaled to the reference sensor by applying the reference sensor BRDF atmosphere corrected coefficients to the target sensor
- Using full scan observations increased the frequency of daily clear-sky observations
- The Libya-4 observations were identified using the non-absorbing 0.65 µm and 1.6 µm spatial homogeneity
- The radiances were characterized by the 16-day repeat cycle angular bin
- The radiances were also correlated with AOD, O3 and PW data sources to account for the atmosphere
- The atmosphere corrected radiances were found to be temporally consistent across spectral channel and sensors and describe the true Libya-4 surface natural variability.
- The Libya-4 natural variability is driven by changes in the prevailing winds that defines the shadowing