TISA Working Group Update

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Fall 2023 CERES science team meeting
NASA GISS, New York City, NY, October 17-19, 2023

*leaving the team

OUTLINE

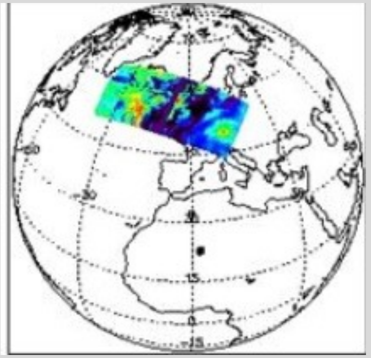
- CERES L3 Products overview and status
  - Transitioning CERES products to NOAA-20 due to the Aqua and Terra drifting orbits
- TISA Ed5 framework
- SYN1deg computed flux temporal interpolation improvement
  - To be implemented in SYN1deg Ed4.2
- MODIS C6.1 to C7 reflective solar band improvements
  - By scan angle and spectrally
- Radiometrically scale N20-CERES to the NPP-CERES calibration reference
  - Method does not require coincident measurements but relies on that NPP and N20 are in the orbit but spaced 8-days apart

CERES L3 PRODUCTS

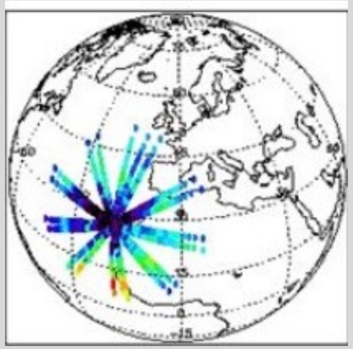
CERES instrument scan modes

- **Cross-track** mode designed for uniform spatial sampling
  - This provides spatially complete observations for SSF1deg and SYN1deg data products
- **RAPS mode** designed to capture all view and azimuthal angles
  - This provides angular observations to build ADMs
- **GEO scan mode** where the CERES instrument is pointed to the same line of sight as the GEO operational scanning.
  - This provides coincident angle matched GEO and CERES observations

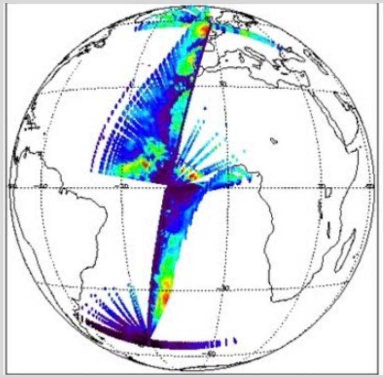
cross-track mode



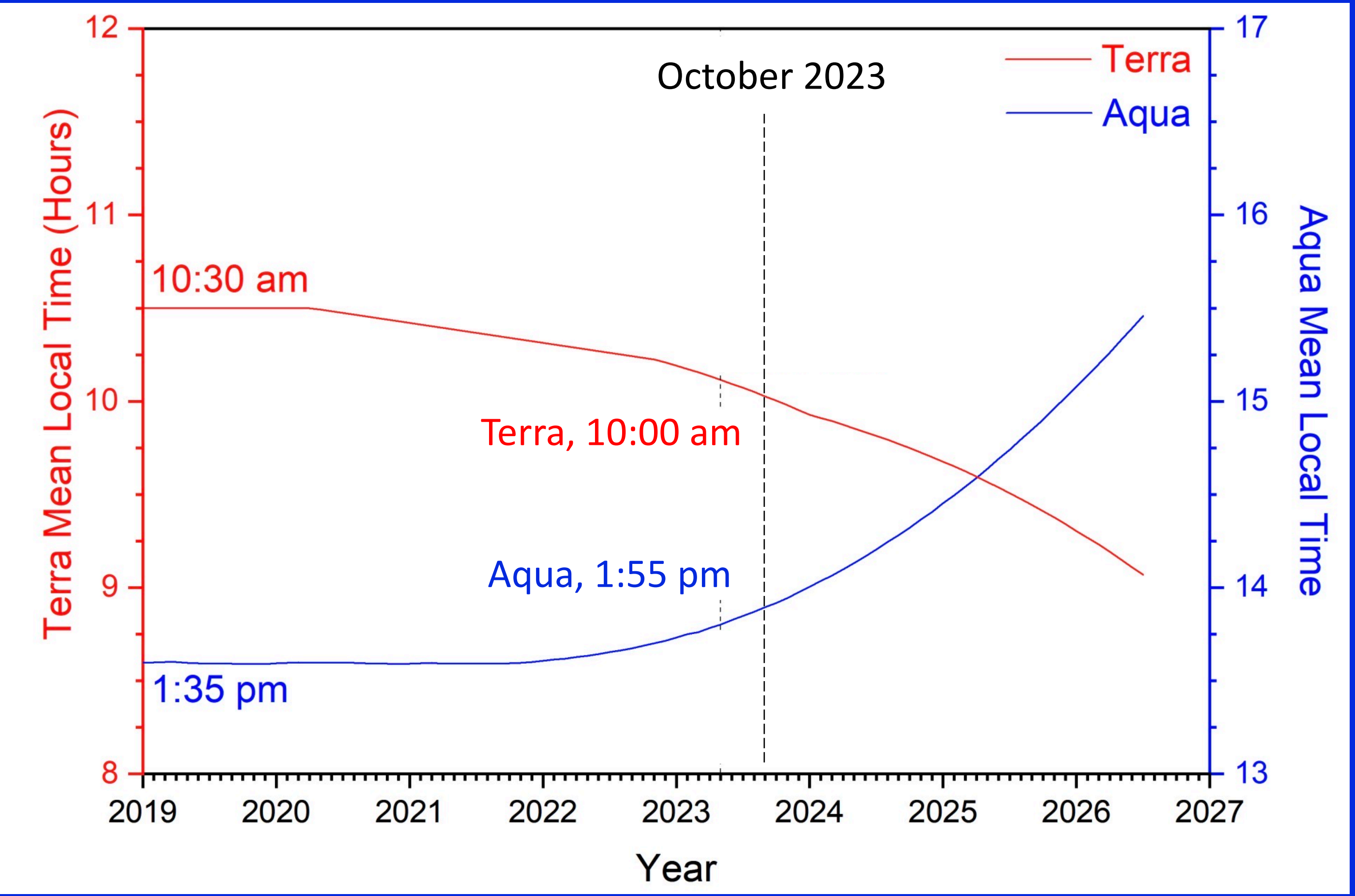
RAPS mode



GEO scan mode



Terra and Aqua orbital drift

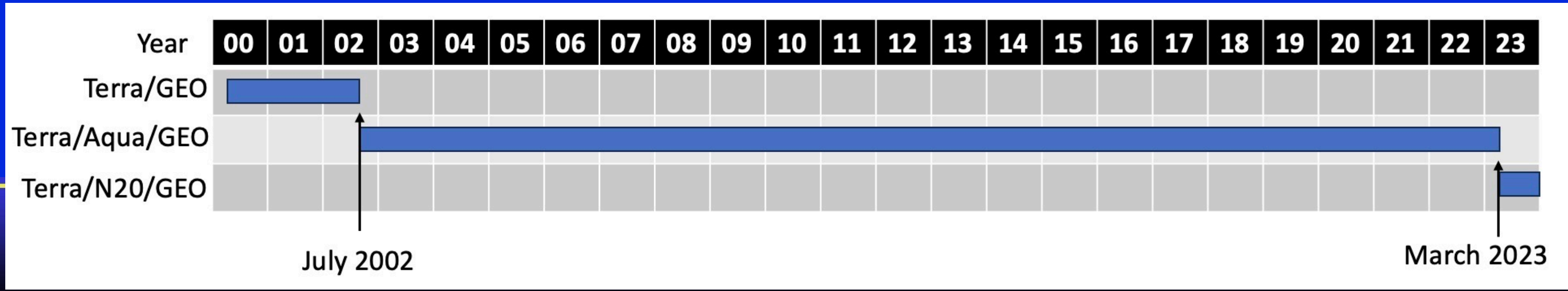


CERES instrument scan mode table

instrument	Prior to March 2023	March 2023
Terra-FM1	Cross-track	Cross-track GEOscan (every 5th day)
Aqua-FM3	Cross-track	RAPS/GEOscan
N20 (FM6)	Cross-track	Cross-track

SYN1deg and CldTypHist Ed4.1 products

- The SYN1deg product utilizes hourly GEO fluxes and clouds to infer the regional diurnal flux in between CERES measurements
  - SYN1deg-hour, SYN1deg-day, SYN1deg-mhour, SYN1deg-month
- The CldTypHist product combines the imager and GEO cloud properties and stratifies them into 3x3 cloud layer and optical bins
  - CldtypHist-mhour, CldtypHist-month(daytime, nighttime, 24-hour)
- The SYN1deg product is in forward processing mode
- The CldTypHist product is in forward processing mode
  - THe CldTypHist was rerun beginning with December 2017, because a few sporadic months had dropped the Aqua input due to a processing glitch

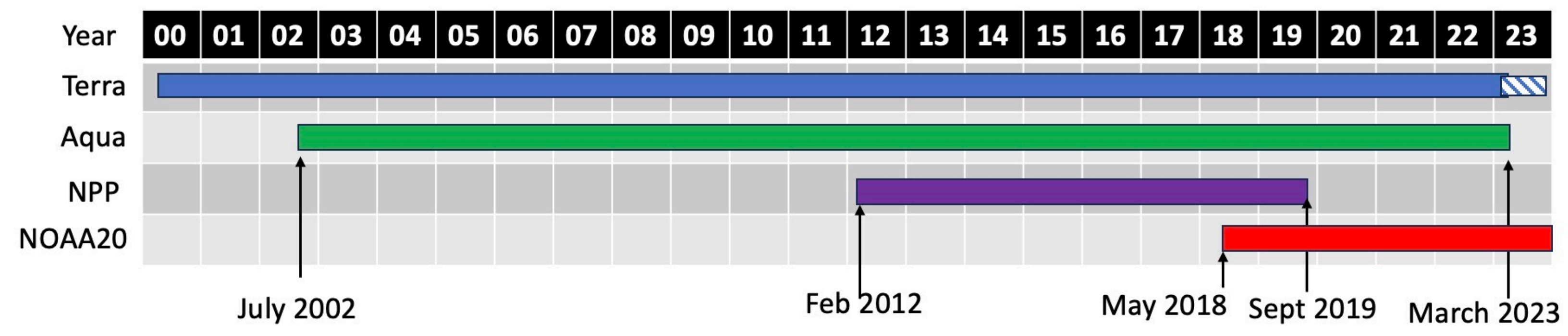


SYN1deg Ed4B product

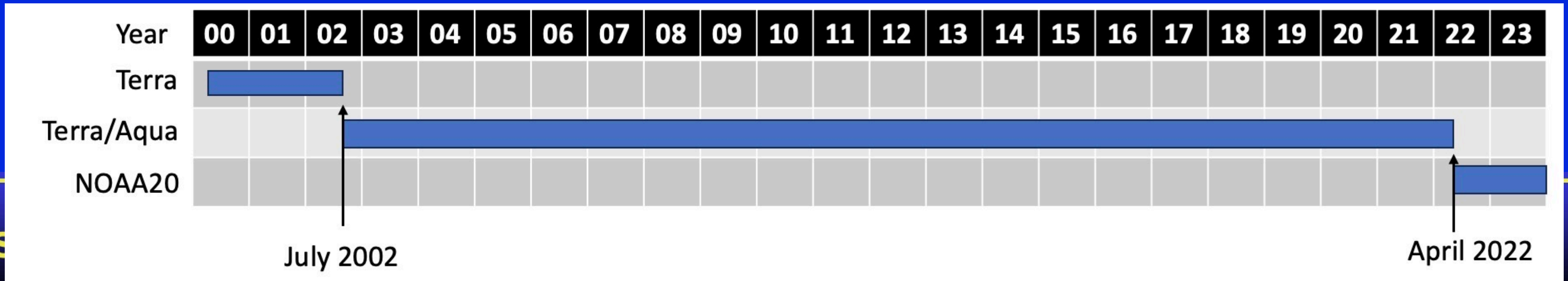
- GEO reprocessing of the entire (2000-2023) for greater computed flux and cloud consistency across the record, projected release date of Spring 2024
  - Met 8,9 and 10 reprocessed consistently using the latest Met-11 code
  - GEO 2-channel satellites, reprocessed with improved cloud mask and night-time optical depths
    - GMS-5 Mar 2000 to Apr 2003
    - Met-5 57° Mar 2000 to Jan 2007
    - Met-7 0° Mar 2000 to Apr 2004
    - Met-7 63° Jan 2007 to Jan 2017
- The twilight cloud retrievals (SZA>60) to be temporally interpolated across the twilight hour-boxes
  - Twilight retrieved clouds caused noisy surface fluxes, use interpolated clouds instead
- Code bug fixes
- Consistent GEO boundaries
  - Rather than the bisecting longitude between satellites

SSF1deg and EBAF products

- The SSF1deg product utilizes constant meteorology albedo diurnal models and LW temporal interpolation to infer the regional diurnal in between CERES measurements

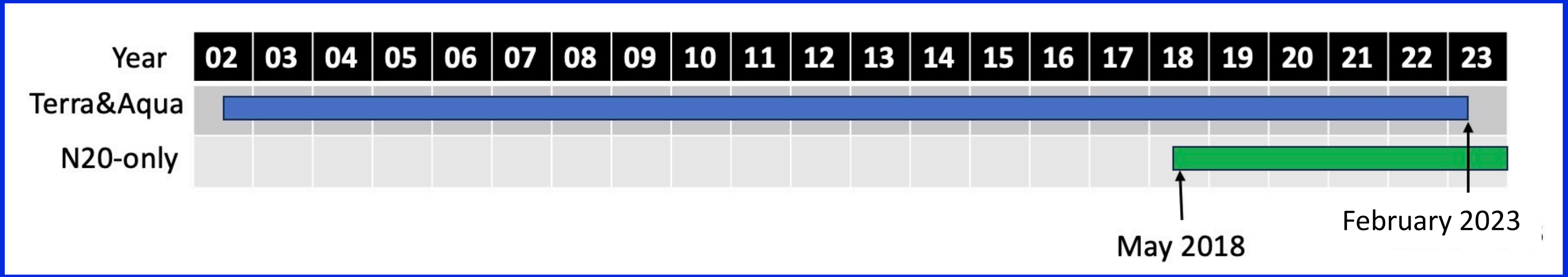


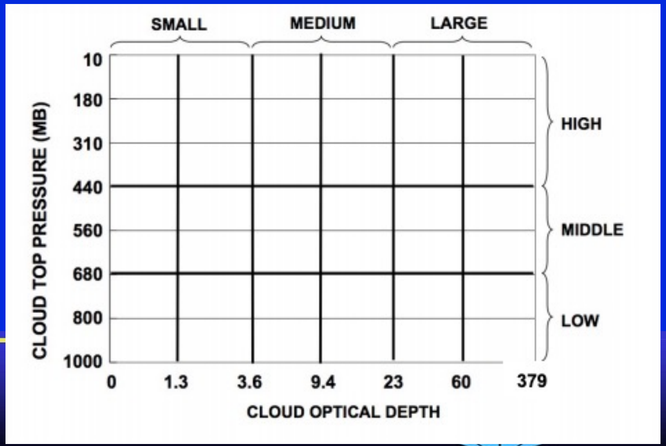
- The EBAF product climate quality fluxes combines the stability of the SSF1deg and regional diurnal flux of the SYN1deg product free of GEO artifacts. Utilizes imager derived BB fluxes for spatially complete clear-sky fluxes. The TOA net flux is constrained to the ocean heat storage. Uses regional climatology adjustment factors to bridge satellite records



FBCT-N20 product

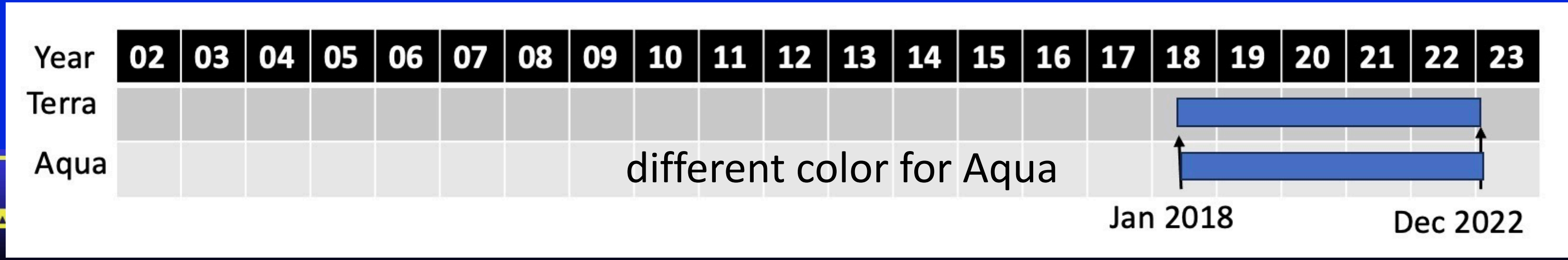
- The FluxByCloudType (FBCT) product provides observed daytime CERES fluxes stratified by 7 cloud layer and 6 optical depth bins (similar to ISCCP)
  - Subfootprint Imager narrowband to broadband derived fluxes are used to resolve the cloud layers fluxes
  - The TRMM directional models are used to compute the daily SW flux
- Climatology adjustments to bridge the gap between Terra&Aqua and a NOAA20-only records were unsuccessful
  - mostly due to optically thin cloud differences between MODIS and VIIRS
- The FBCT-Terra /Aqua will end with February 2023 and a NOAA-20 record begins in May 2018 and is in forward processing mode





CRS1deg-hour product

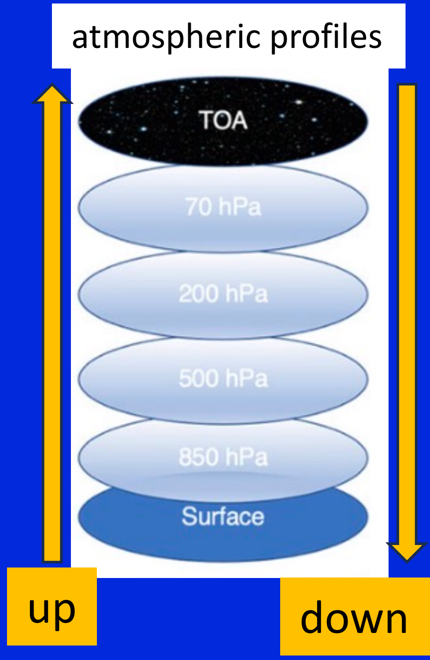
- CRS L2 provides footprint computed profile and surface fluxes with associated cloud and meteorological parameters by instrument.
  - SSF1deg-L2Ed4 provides parameterized surface fluxes
- The TISA group has spatially gridded the CRS L2 footprint computed fluxes into the CRS1deg-hour product using the new Ed5 framework code
- Working on placing the CRS1deg-hour on the subsetter
  - A preliminary version of January 2018 is available internally for validation
- Will eventually combine the SSF1deg-hour and CRS1deg products on the same subsetter ordering page



SYN1deg Computed flux temporal interpolation

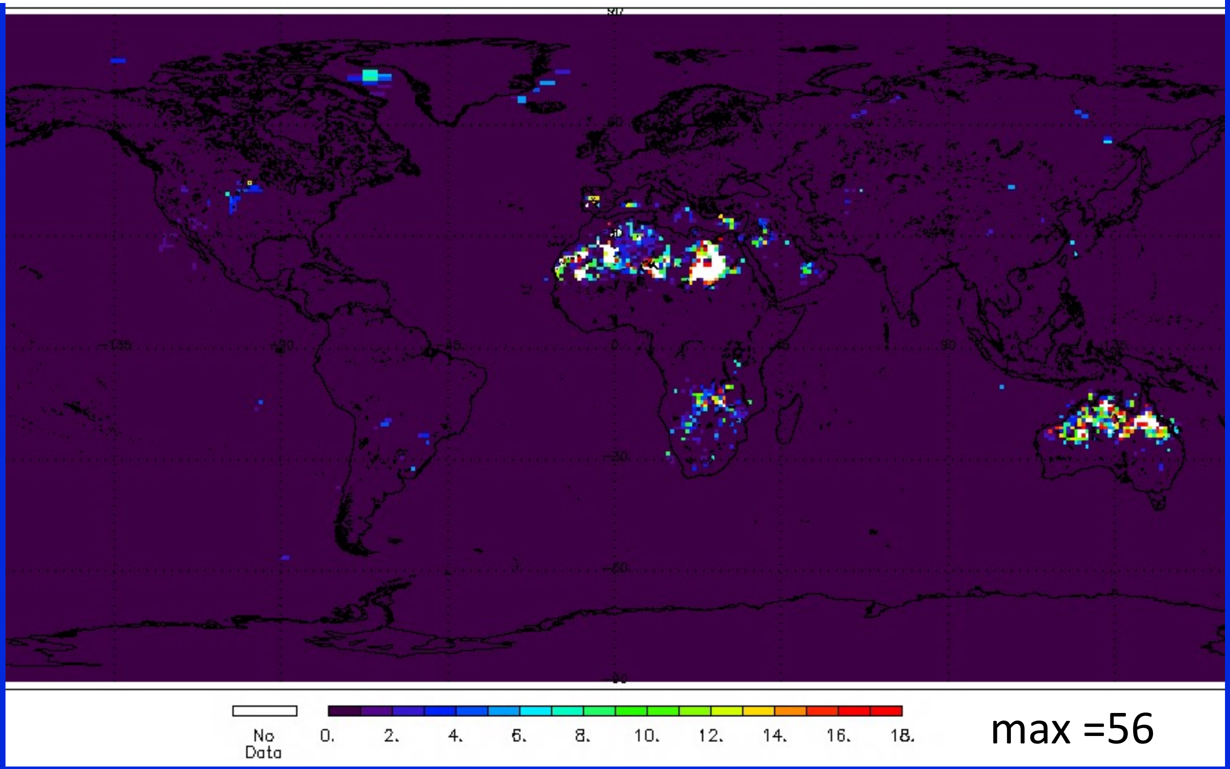
SYN1deg Ed4a computed flux temporal interpolation

- The SYN1deg regional TOA/surface/in-atmospheric fluxes are computed hourly from the cloud/surface/atmospheric-profile inputs
- Fluxes are computed for clear-sky and up to 4-layers of cloud conditions with and without aerosols
  - if any condition fails, all computed fluxes are denoted as default values in the SYNI internal product, this is a rare occurrence
  - The clear-sky and 4-layer computations are aggregated into the all-sky flux
- SYN1deg Ed4 temporally interpolates across the hourly computed flux default values
  - All computed flux parameters are temporally interpolated independently
  - For each parameter, the hourly fluxes over the month are linearly regressed as a function of the cosine of the solar zenith angle (CSZA)
  - The linearly regression slope and offset are applied to the default hourbox CSZA
  - For some interpolated fluxes the surface albedo exceeds 1 or up>down flux.



Ed5 computed flux temporal interpolation strategy

Number of default UpSW_sfc_ClrSky, Terra+Aqua March 2007



Note that the regions with default values is not random but occur over regions with large surface reflectances

Libyan Desert region, clear-sky surface SW flux

Ed4A linear regression temporal interpolation

SWdn	SWup	SWdn-SWup
17.559	17.809	-0.249
172.848	82.166	90.682
418.806	133.085	285.721
641.767	179.244	462.523
826.542	217.497	609.045
960.552	245.24	715.311
1042.975	265.525	777.45
1054.125	269.35	784.775
987.487	250.817	736.67
869.414	226.373	643.042
697.688	190.821	506.867
484.014	146.585	337.429
242.956	96.68	146.276
35.896	36.406	-0.51

Ed4B CSZA bin temporal interpolation

SWdn	SWup	SWdn-SWup
48.104	12.163	35.941
260.72	65.925	194.796
480.924	121.604	359.32
680.54	172.078	508.461
845.967	213.908	632.059
965.945	244.245	721.7
1042.975	265.525	777.45
1054.125	269.35	784.775
990.059	250.342	739.717
884.35	223.613	660.737
730.605	184.738	545.867
539.304	136.366	402.938
323.487	81.796	241.692
98.336	24.865	73.471

interpolated

computed

- The Ed4 TISA code can only temporally interpolate computed fluxes one parameter at a time
- This CSZA bin approach was successful, there are no more SWdn<Swup cases over the 21-year record

Ed5 computed flux temporal interpolation strategy

Libyan Desert region, clear-sky surface SW flux

Albedo at surface → Up/Dn_sfc

transmission at surface → Dn_sfc/TOADn

hr	SZA	Dn_ClrSky	Up_ClrSky	Dn-Up	Up/Dn_sfc	Dn_sfc/TOADn
199	86.39	21.52.	11.60	9.92	0.54	0.25
200	74.03	149.12	70.65	78.47	0.47	0.39
201	61.76	307.08	72.70	234.38	0.24	0.47
202	50.49	477.35	128.18	349.17	0.27	0.54
203	41.13	610.70	172.40	438.30	0.28	0.59
204	35.28	801.47	240.12	561.35	0.30	0.71
205	34.81	776.88	235.12	541.75	0.30	0.69
206	39.91	679.10	209.43	469.67	0.31	0.64
207	48.83	518.88	151.27	367.60	0.29	0.57
208	59.87	329.10	88.05	241.05	0.27	0.48
209	72.02	150.90	32.60	118.30	0.22	0.35
210	84.67	32.03	17.17	14.85	0.54	0.25

the transmission and albedo have a distinct diurnal variation

For Ed5

For SW down, use diurnal regional transmission models (Down/Solar incoming)

For SW up, use diurnal reagional transmission models albedo (Up/Down)

TISA Edition 5 framework

TISA Edition 5 framework update

- The CRS1deg was processed with the new TISA Edition 5 framework
- No need to revise the CRS1deg code for the following, just the JSON file during compilation
  - Variable spatial gridding resolution (0.5°, 1.0°) (equal angle, nested)
  - Each parameter has a spatial averaging strategy (linear, log, weighted, SZA equalized)
  - Dynamic cloud layer or cloud-type binning (3-layers, 4-layers, 3x3 pc-tau)
  - Dynamic computed flux profile levels, and spectral wavelengths
  - Dynamic parameter processing (all parameters, fluxes-only, etc)
  - Parameter specific range min and max checking of input files
- The Ed5 CRS1deg code base will be used for the SSF L2 Ed5 alpha run
  - Just a few parameter specific additional modules will need to be coded

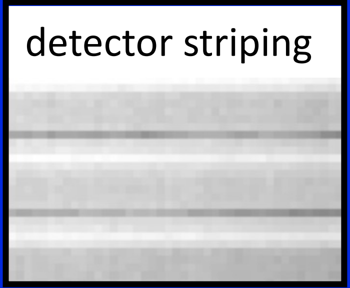
TISA Edition 5 framework update

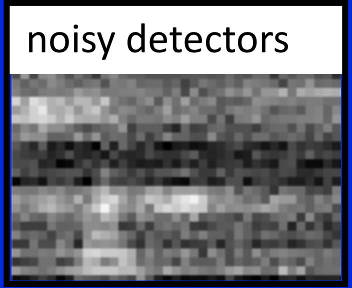
- All of the **new** Ed5 SW and Ed4 SW/LW narrowband to broadband, TRMM ADMs and directional models, CERES/GEO normalization binary LUTs have been converted as self-described netCDF files
  - Where the LUTs, angle and cloud bin bounds and centers can be read, so that the LUT value can be retrieved using generic functions
  - Updated the CERES/GEO regional normalization validation diagnostic in Python
- The ED5 Geostationary spatial gridding will be a joint clouds/flash/TISA effort allowing for a common code base and implementation
  - The Ed5 GEO gridding will be designed to facilitate efficient (surface) flux computations, custom inputs and outputs
- TISA has developed the code that will aggregate the IGBP (18-types), water fraction, and daily snow/ice, at the 10-minute resolution for consistent application across TISA Ed5 products
  - Ed4 relied on the SSF L2 values and temporally interpolated the surface types
- TISA has standardized the cloud property temporal interpolation and averaging diagnostics and can process both monthly (TISA) and 3-day (flash) time intervals using the same code base

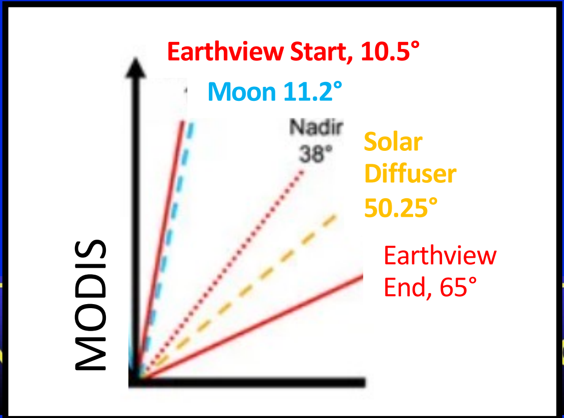
MODIS C6.1 to C7 improvements

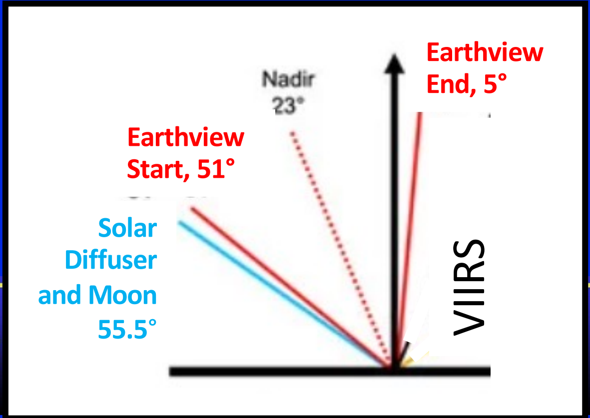
MODIS and VIIRS onboard calibration

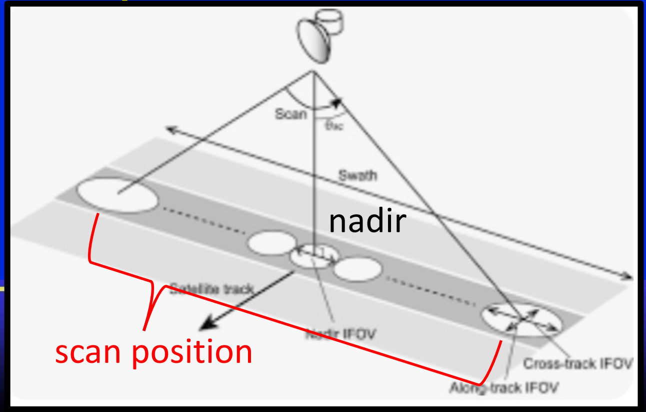
- Detector to detector striping or gain equalization
  - MODIS has a 10-detector swath, whereas VIIRS has 16-detector swath
  - Each detector is individually calibrated with the solar diffuser or blackbody
- Response vs scan angle gain equalization
  - The scanning is performed by rotation of a scan mirror
  - The mirror degrades unevenly overtime and must be characterized on orbit
- Long-term trending
  - MODIS and VIIRS use solar diffusers and lunar looks to monitor stability







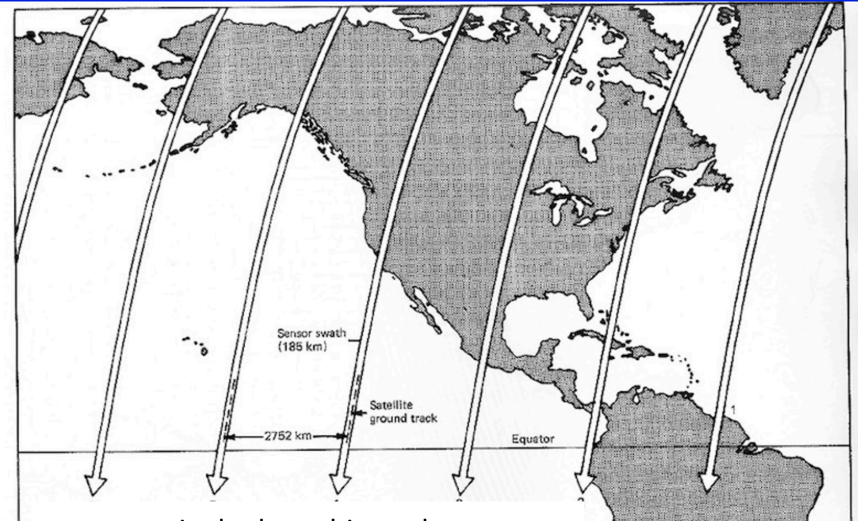




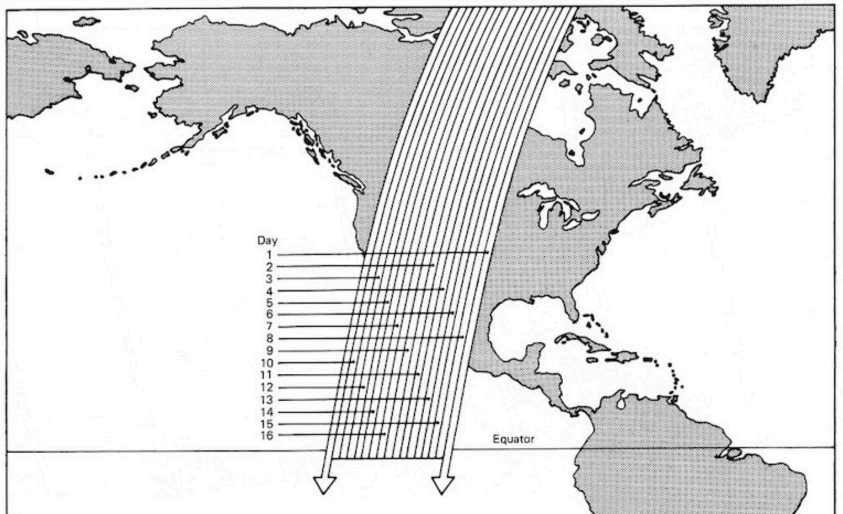
Orbit ground track repeat time

- Terra, Aqua, JPSS, NOAA-20 are sun-synchronous polar orbiters
  - Aqua ~14.5 orbits per day, ~99 minutes per orbit, 720 km altitude, small data gaps between swaths at equator
  - NOAA-20 ~14.3 orbits day, ~101 minutes per orbit, 820 km altitude. swath contiguous at equator
  - The difference in altitude allowed for coincident Aqua/NPP intersects every 64 hours
- Terra, Aqua, JPSS, NOAA-20 have a 16-day orbit repeat time
  - Terra has mean local equator crossing time at 10:30AM
  - Aqua, NPP and NOAA-20 have a mean local equator crossing time of 1:30PM

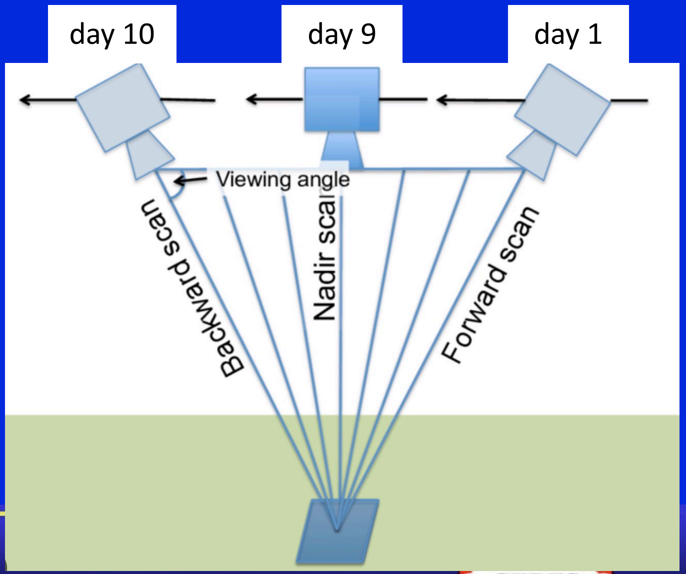
Aqua orbit



single day orbit tracks

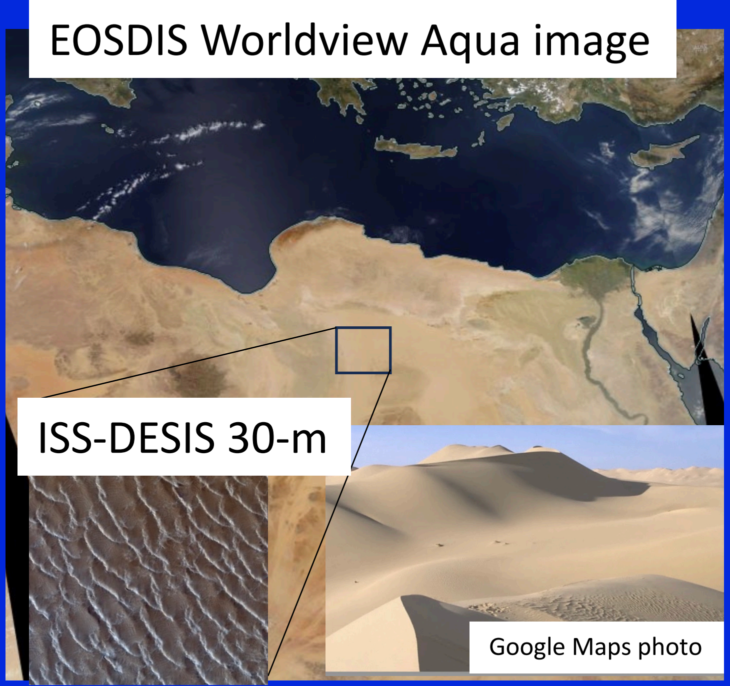


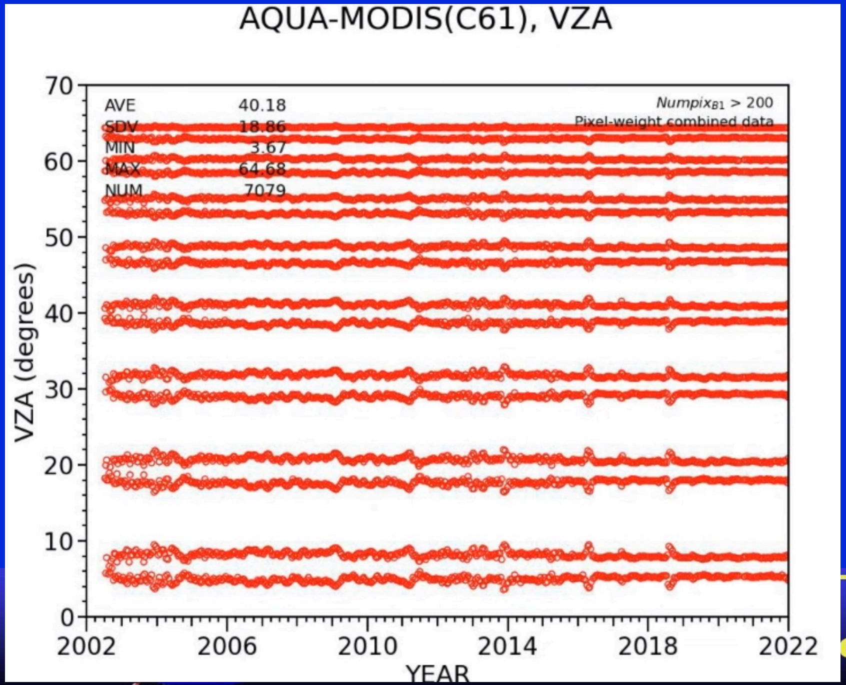
16-day orbit tracks

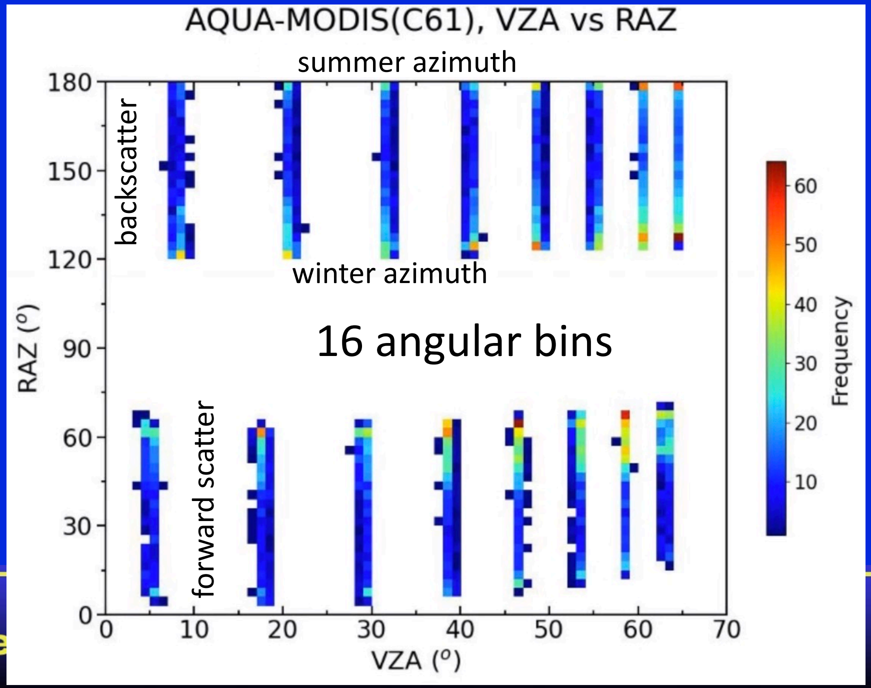


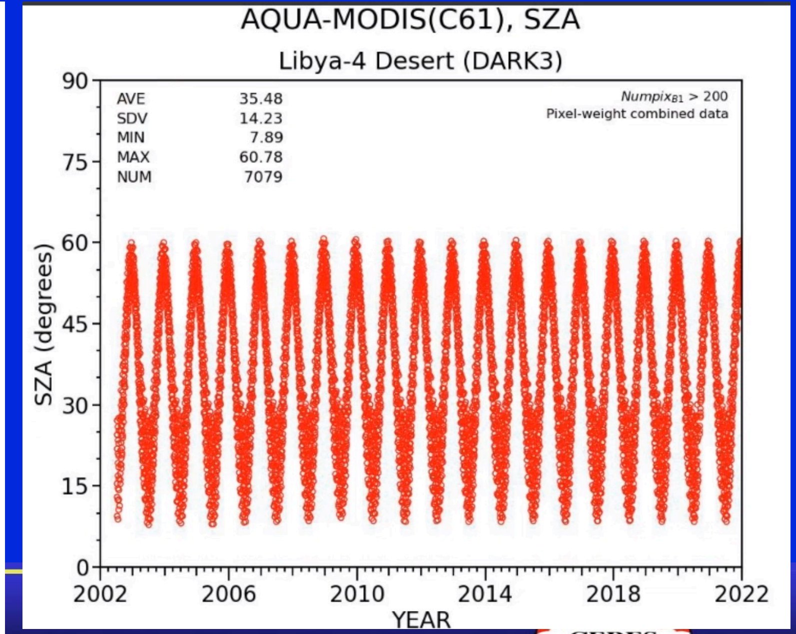
Libya4 invariant target

- 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° to 23° East) is composed of sand dunes and no vegetation, highly reflective and little cloud cover
- Bin the MODIS radiances into 16 repeat day angular bins
- Libya4 SZA range between 10° and 60° over the year









Libya4 clear-sky determination

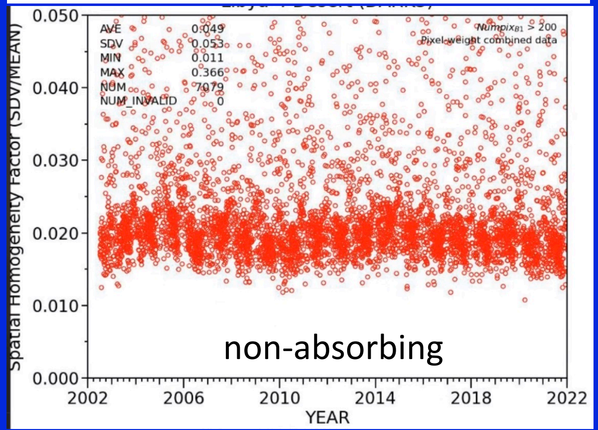
- A spatial homogeneity (SHF) threshold applied to non-absorbing 0.64µm and 1.61µm channels is used to filter cloudy observations
  - Apply a 2-sigma filter of the homogeneity factor to each directional model
  - 50% of the observations were deemed clear

0.65µm clear-sky
SHF = 0.02

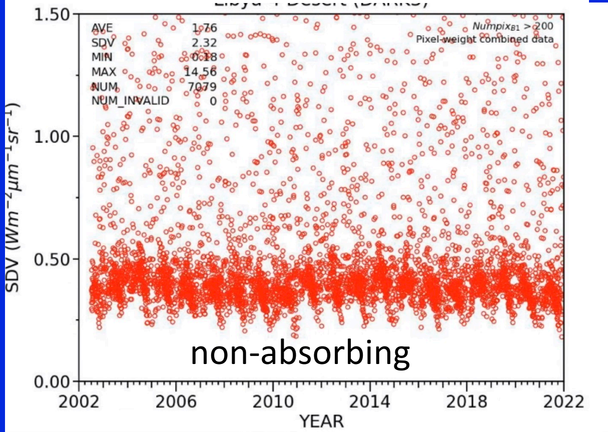
0.65µm cloudy-sky
SHF = 0.06

All observations

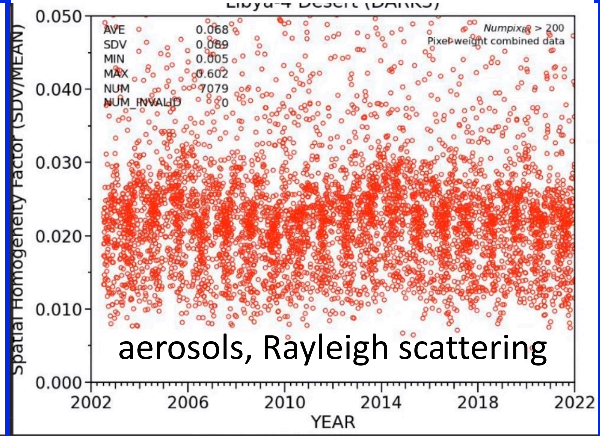
Aqua-MODIS Band 1 0.65µm



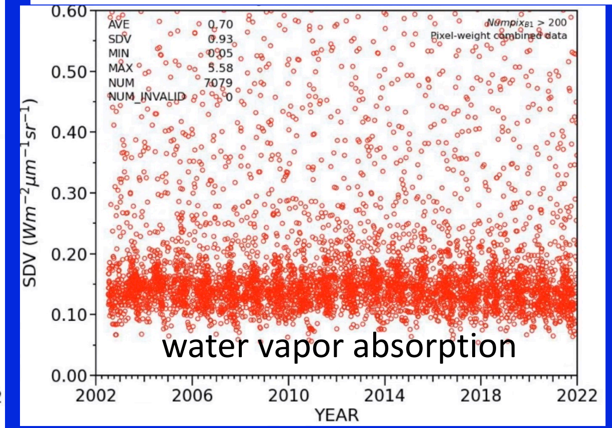
Aqua-MODIS Band 6 1.65µm



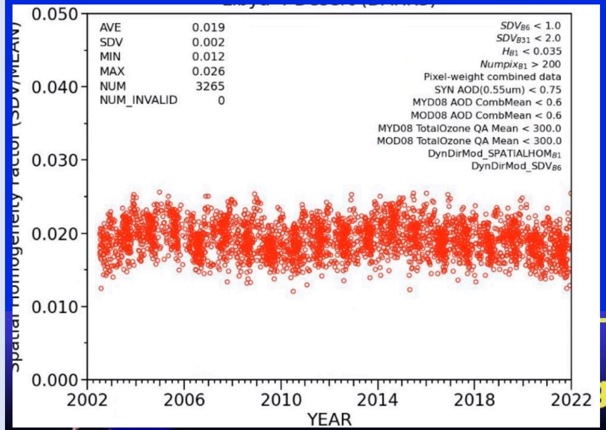
Aqua-MODIS Band 3 0.48µm

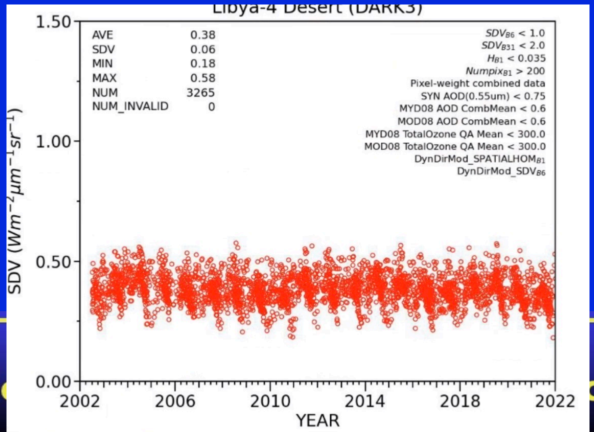


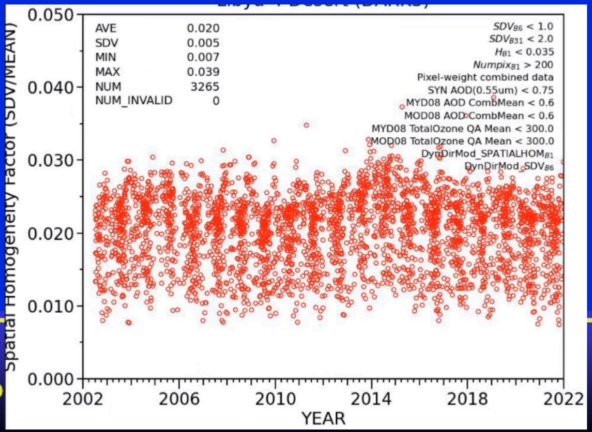
Aqua-MODIS Band 7 2.1µm

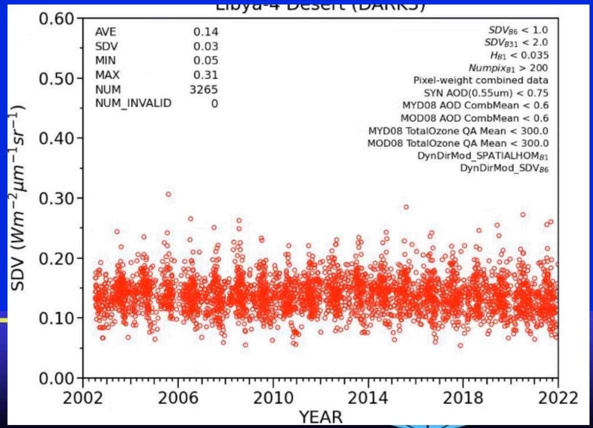


clear-sky filters applied



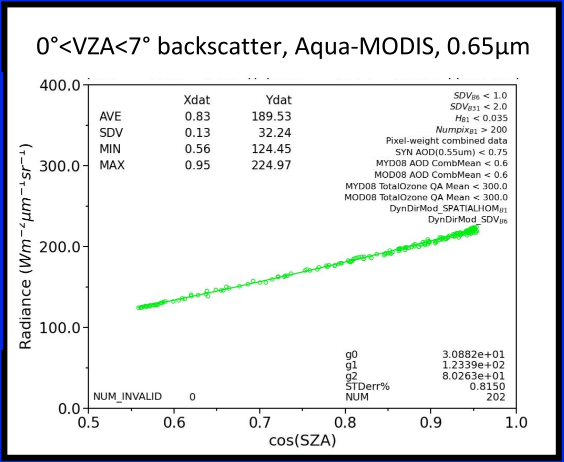


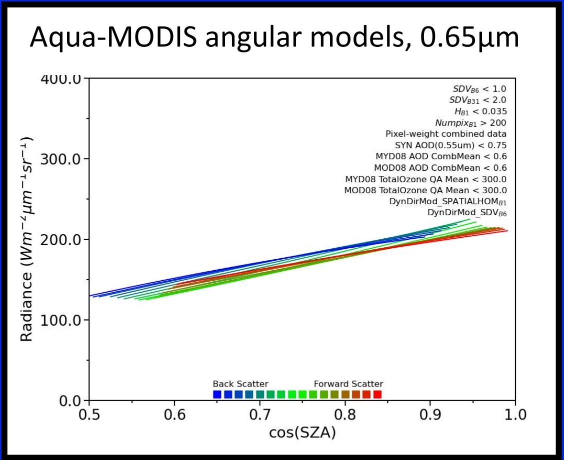


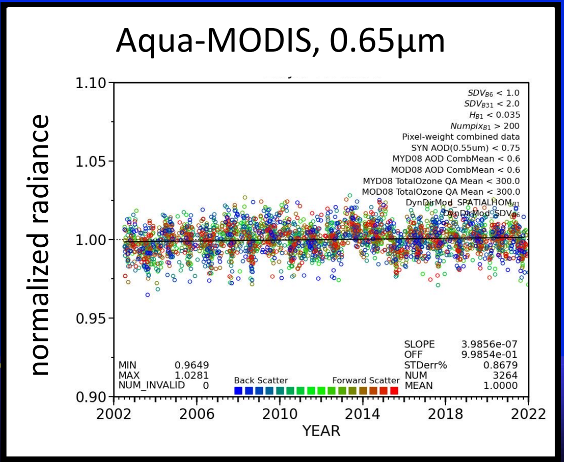


BRDF and Atmospheric Correction

- For each angular bin and spectral channel, the BRDF is characterized by regressing the clear-sky daily radiances over the record as follows
  - $Rad_{pred} = g_0 + g_1 * \cos(SZA) + g_2 * \cos(SZA)^2$
- The atmospheric correction are linear coefficients based on the daily PW, ozone concentration, and AOD retrievals over Libya4
  - MYD08 MODIS deep blue AOD, GEOS O_3, MYD08-D3 PW (based on MODIS NIR channels)
  - $Rad_{pred} = a_0 + a_1 * \cos(SZA) + a_2 * \cos(SZA)^2 + a_3 * PW + a_4 * O_3 + a_5 * AOD$
- The normalized radiance is computed as follows
  - $rad_{norm} = rad_{obs} / rad_{pred}$





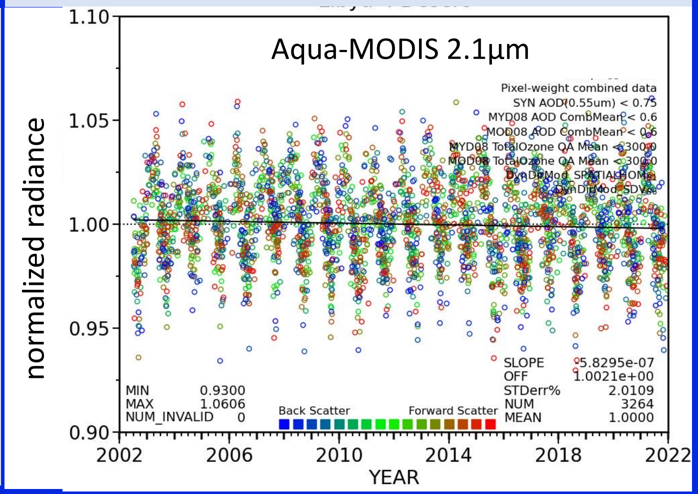


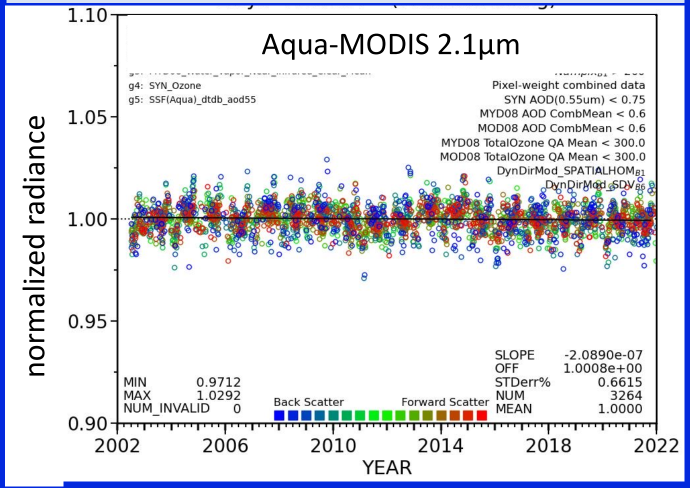
Libya-4 Aqua-MODIS band trend comparison

SZA terms only

with atmospheric terms

daily observations

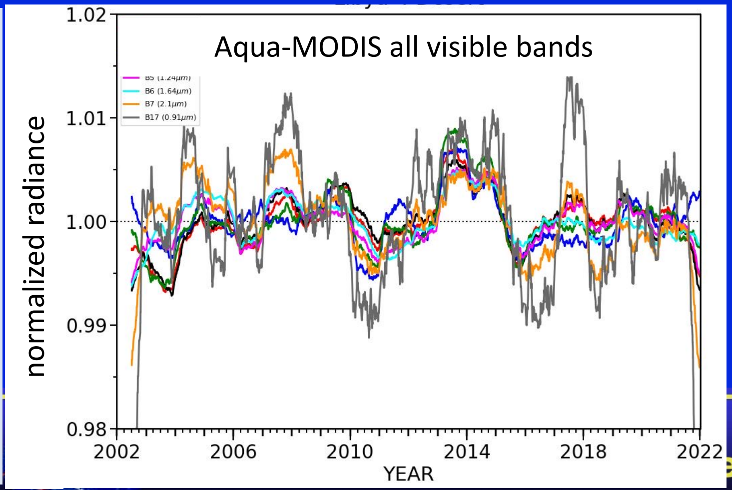


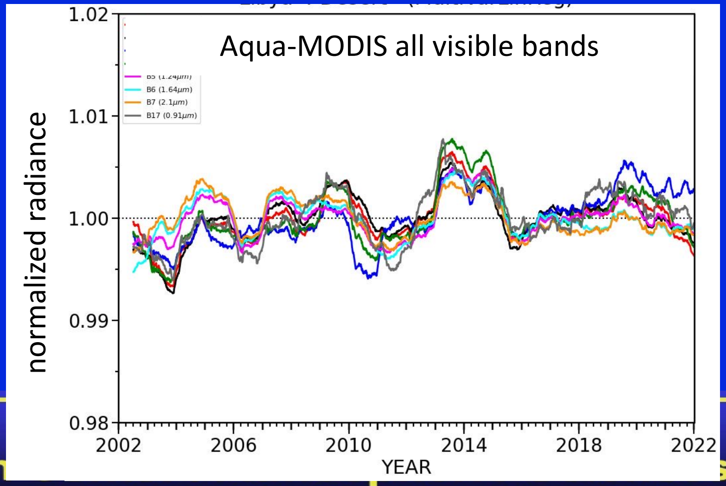


Normalize each clear-sky daily observed radiance by the corresponding angular model

For Aqua-MODIS 2.1µm channel the atmospheric correction has reduced the daily sigma from 2.0% to 0.7%

365-day running mean





Perform a 365-day running mean on the normalized clear-sky radiances

B3(0.49 µm), B4 (0.56µm), B1(0.65µm), B2(0.86µm), B17 (0.91µm), M08(1.24µm), M10(1.61µm), M11(2.25µm)

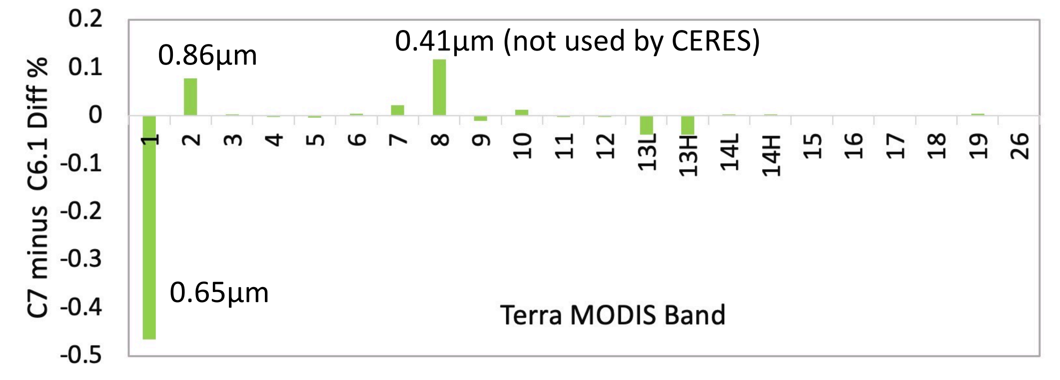
MODIS C6.1 and C7 calibration differences

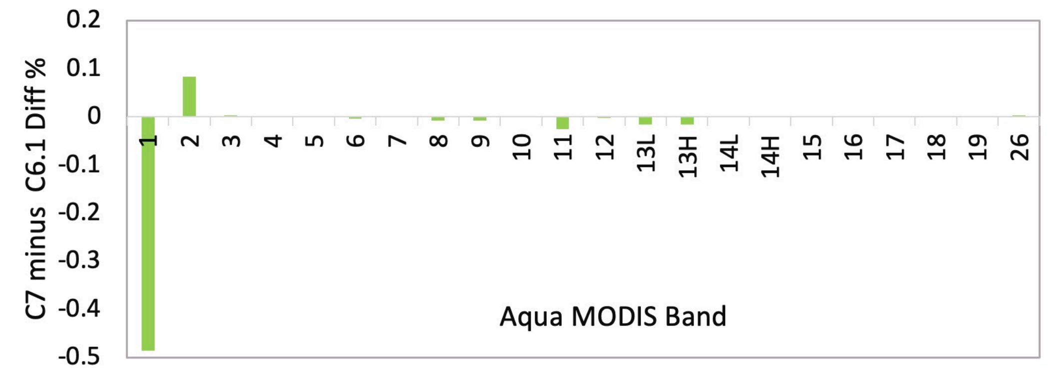
- The NASA MODIS calibration group has given us MODIS C6.1 to C7 visible channel scaling factors
- These are a function of scan angle position, mirror side, and time

For most bands the C6.1 to C7 difference is small <0.1% for both Terra and Aqua

The 0.65µm absolute calibration difference is due to the improved convolution of solar spectra with the spectral response function

absolute calibration difference over the record (%)





MODIS combines 3 solar spectra,
Thuillier et al. (1998) for 350–800 nm,
Neckel and Labs (1984) 800–1100 nm, and
Smith and Gottlieb (1974) 1100–2500 nm.

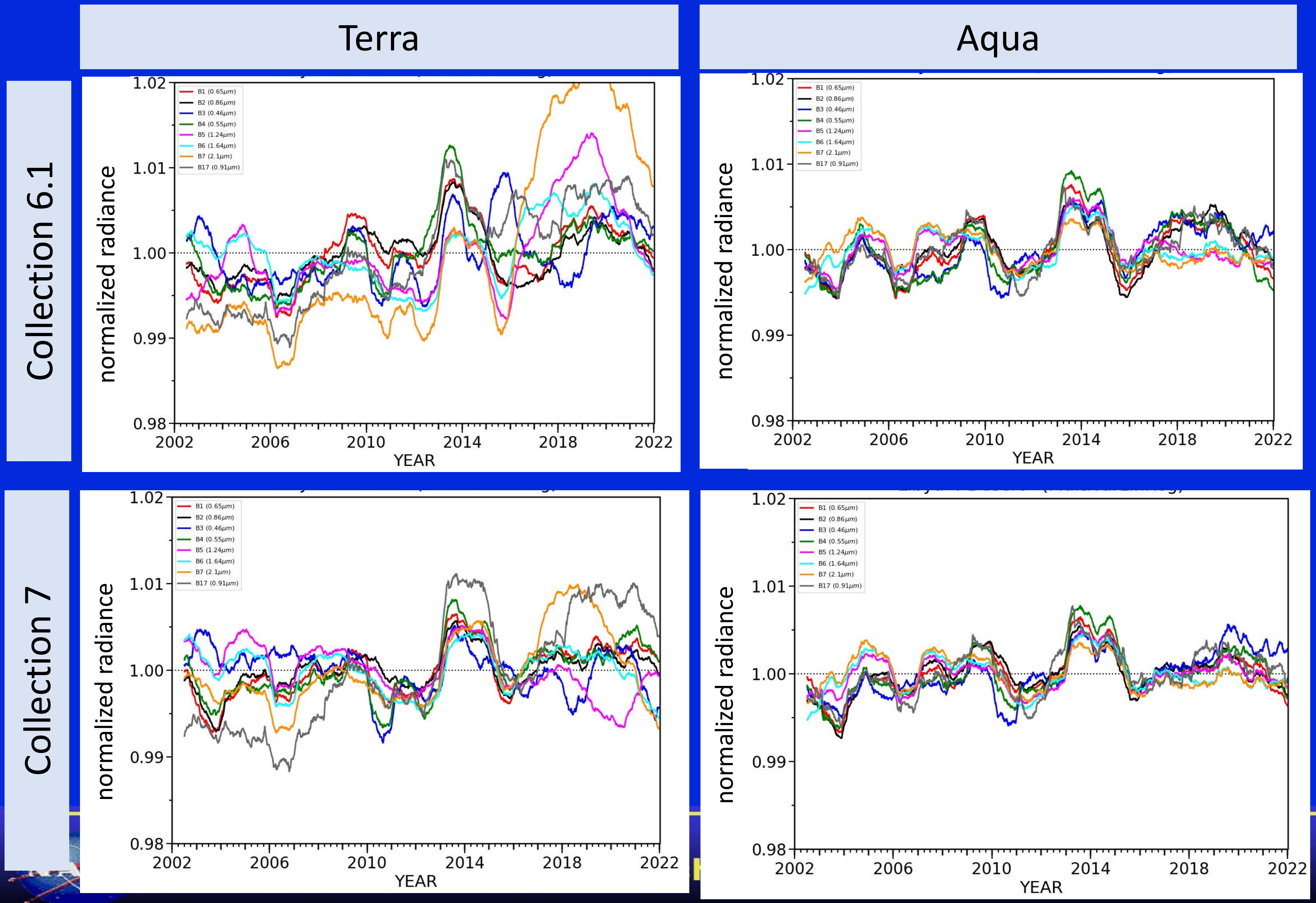
NPP VIIRS solar spectra, Kurucz 1995 (Modtran)
N20 VIIRS solar spectra, Thuillier 2003

MODIS and VIIRS are reflectance-based observations, the L1B radiance is the observed reflectance multiplied by the convolved solar spectra

The band specific NPP/N20 radiance ratio can reach 3% due to the difference of the solar spectra especially for SWIR bands (>1µm)

Remember the NASA MODIS and VIIRS L1B product reflectances are not placed on the same radiometric scale, the CERES GEO and imager calibration group updates the scaling factors tied to the MODIS C5 calibration reference each January

MODIS C6.1 and C7 trend differences



B3(0.49 μm), B4 (0.56μm), B1(0.65μm), B2(0.86μm), B17 (0.91μm), M08(1.24μm), M10(1.61μm), M11(2.25μm)

All MODIS channels were made slightly more stable with C7

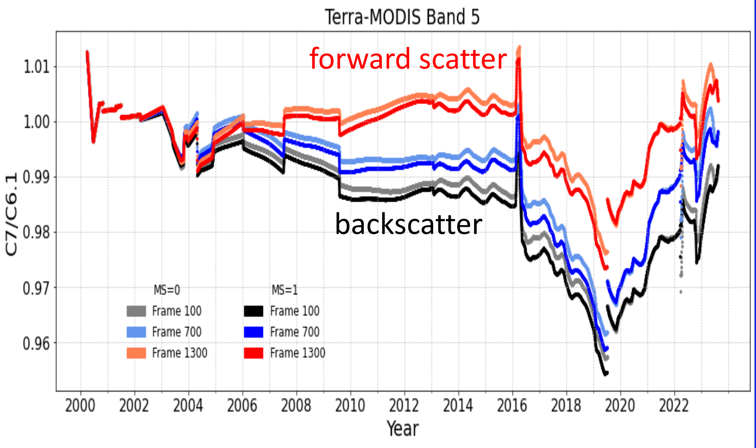
Terra-MODIS SWIR band (>1μm) drift after the Terra satellite safehold event in 2016 was reduced with C7

MODIS C6.1 and C7 scan angle differences

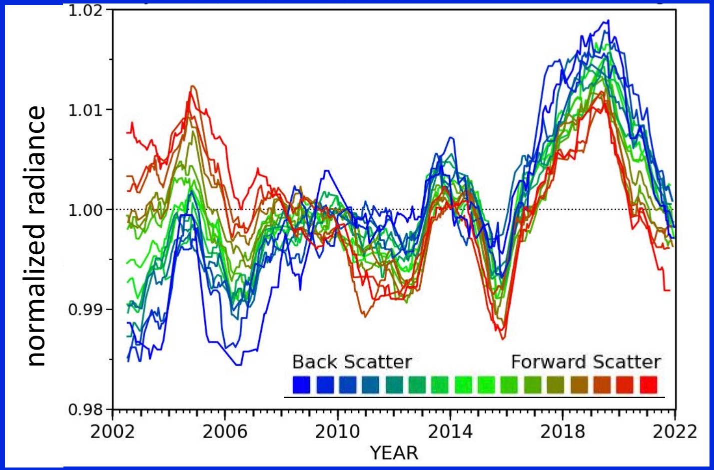
- The C6.1 do C7 corrections are a function of scan angle position, mirror side, and time
- For each scan position (angular model) perform 365-day running mean of the normalized daily radiances

Terra-MODIS 1.24μm channel

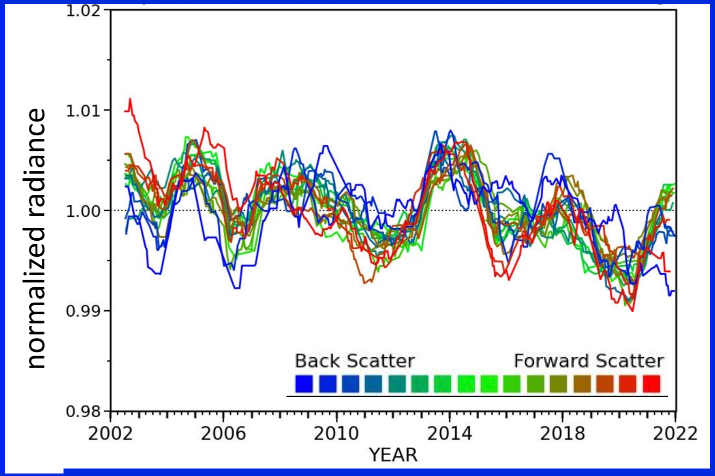
C7/C6.1 ratio



C6.1



C7

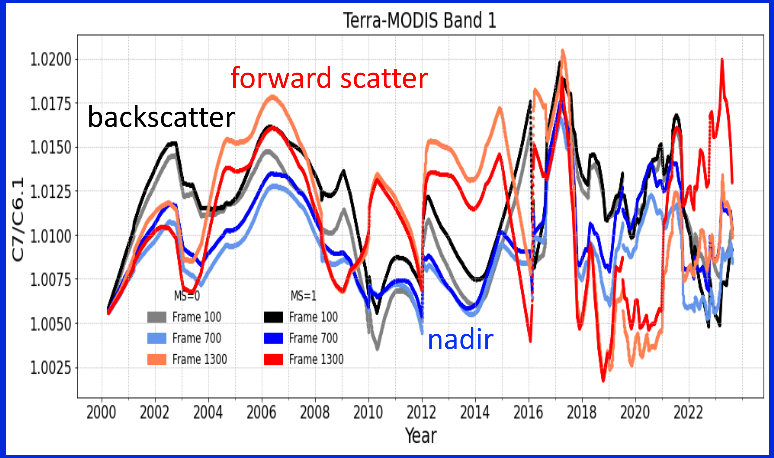


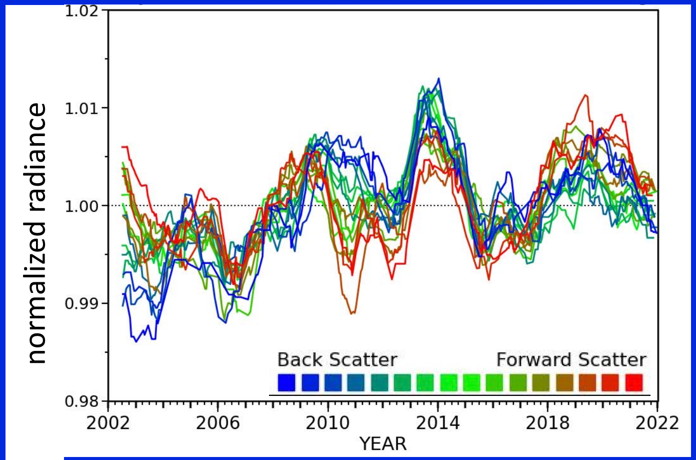
For Terra-MODIS 1.24μm, the angular bin normalized radiances are more **stable** with C7

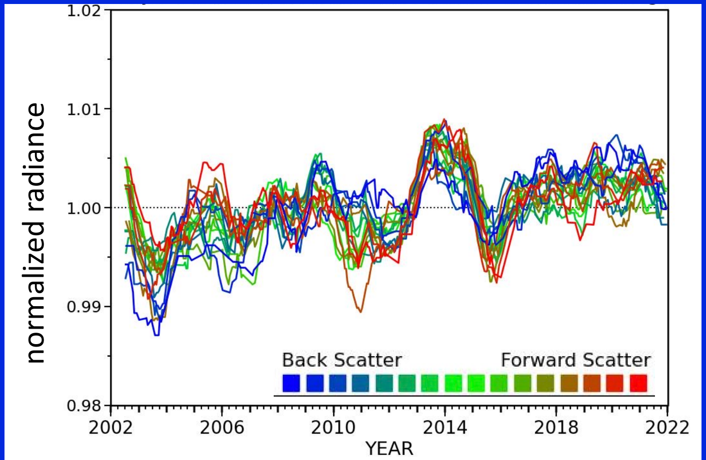
MODIS C6.1 and C7 scan angle differences

	C7/C6.1 ratio	C6.1	C7

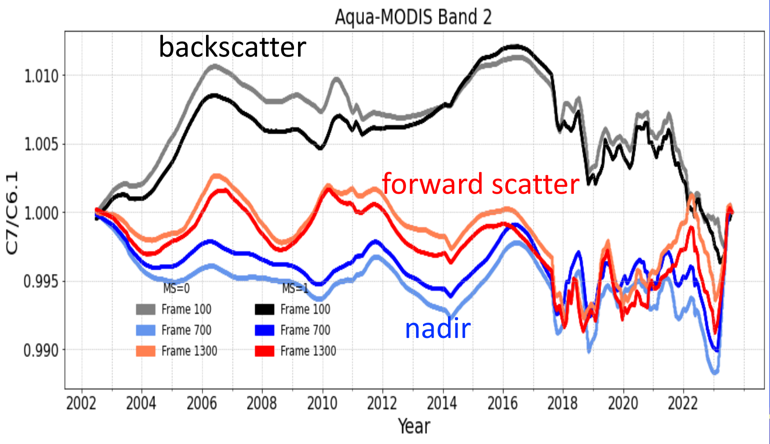
Terra-MODIS 0.65µm

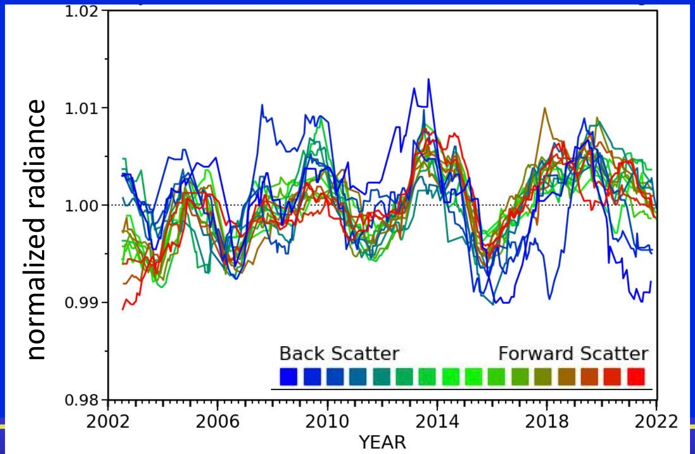


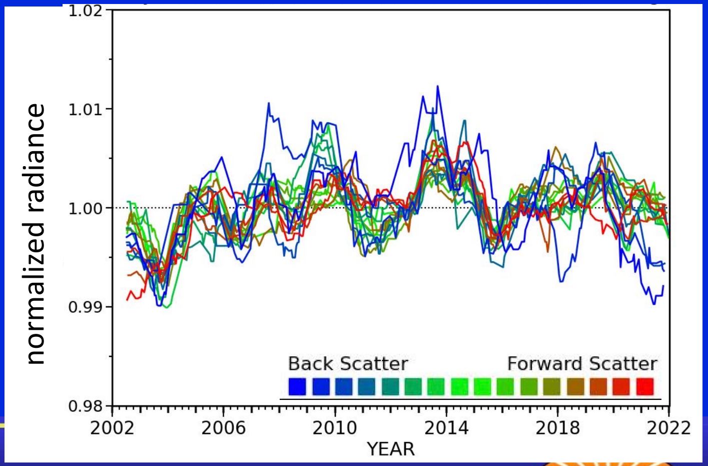




Aqua-MODIS 0.86µm



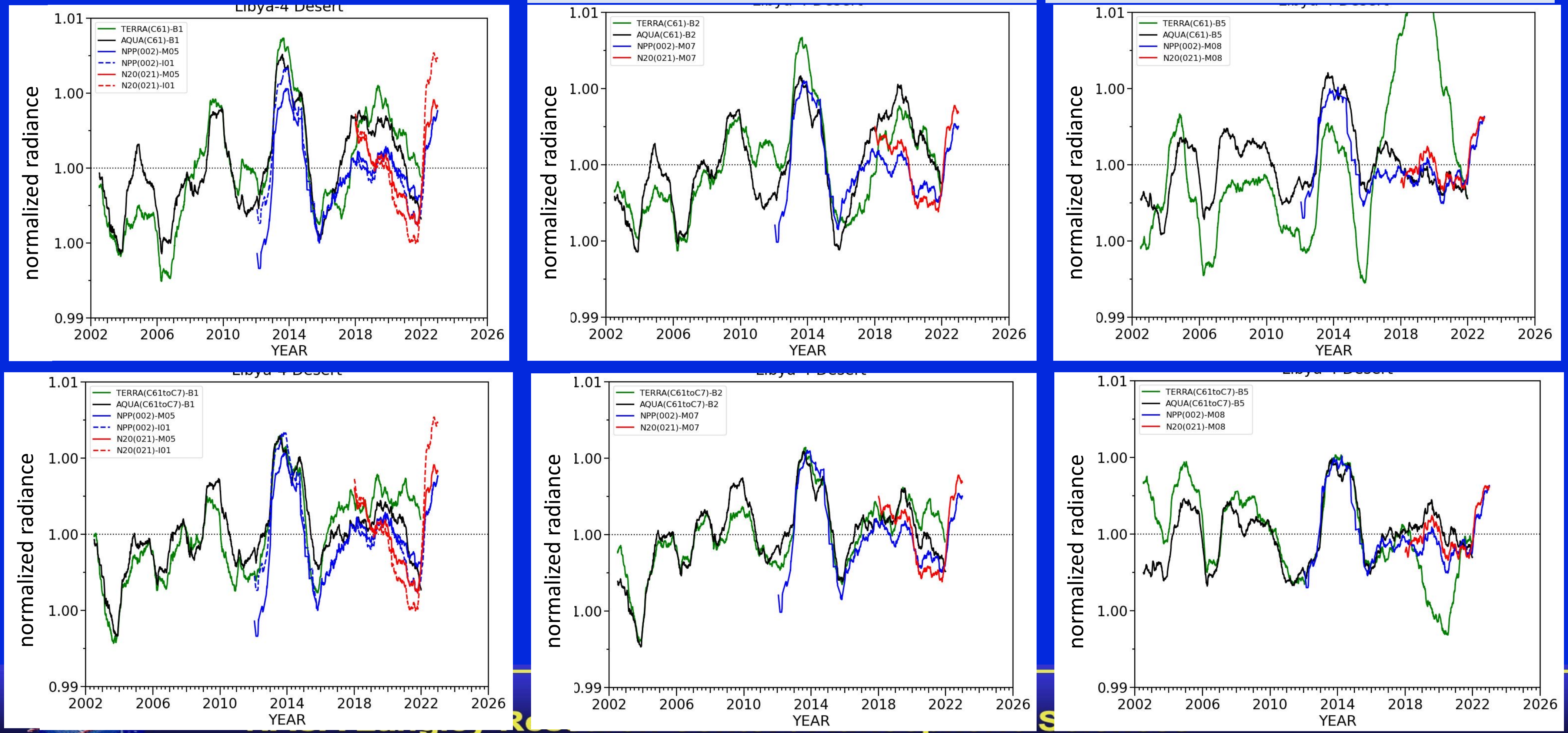




MODIS C6.1 and C7 and VIIRS relative radiances

Terra
Aqua
NPP
N20

	0.65µm channel	0.86µm channel	1.24µm channel
C6.1			
C7			



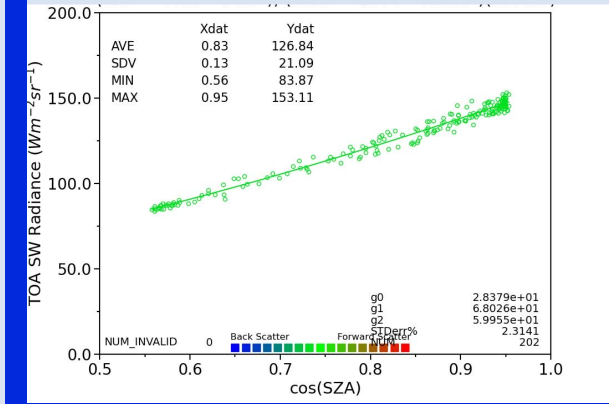
The MODIS C7 is more consistent with VIIRS

Radiometrically scale N20-CERES with NPP over Libya-4

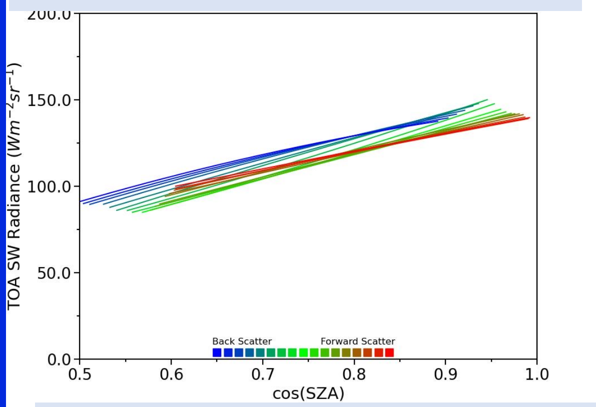
Aqua-CERES Libya-4 angular models

Aqua-CERES SW radiance

(0°VZA<14° backscatter) angular model



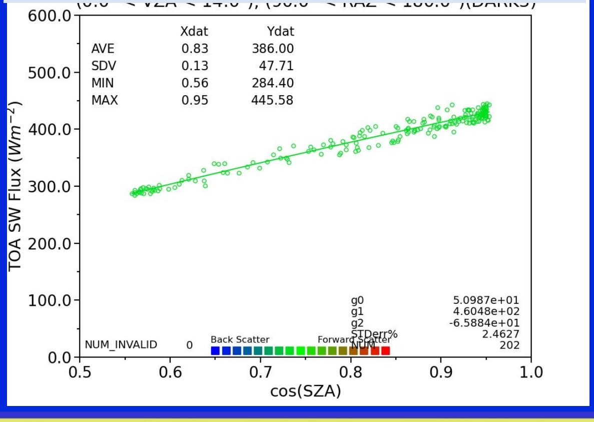
All angular models



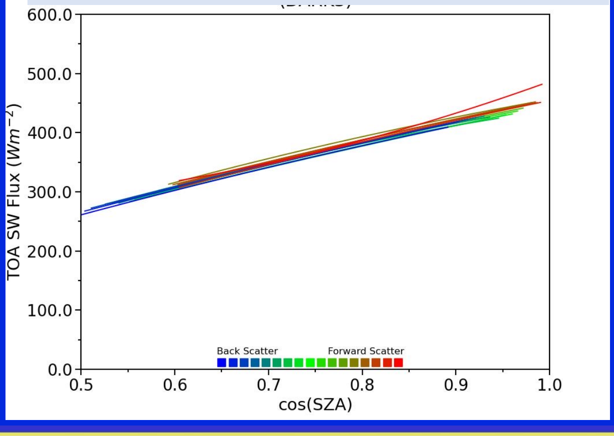
The CERES radiance by angular model shows that the desert is not Lambertian and that the CERES radiances need to be modeled by angular conditions

Aqua-CERES SW flux

(0°VZA<14° backscatter) angular model



All angular models

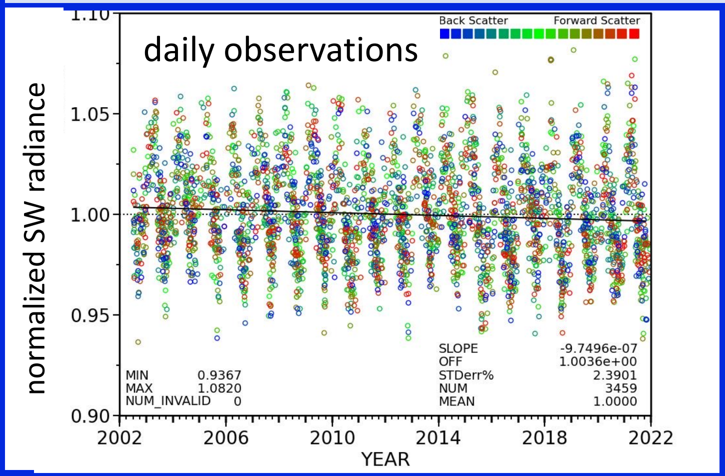


The CERES flux consistency by angular model validates that the CERES ADMs are effective

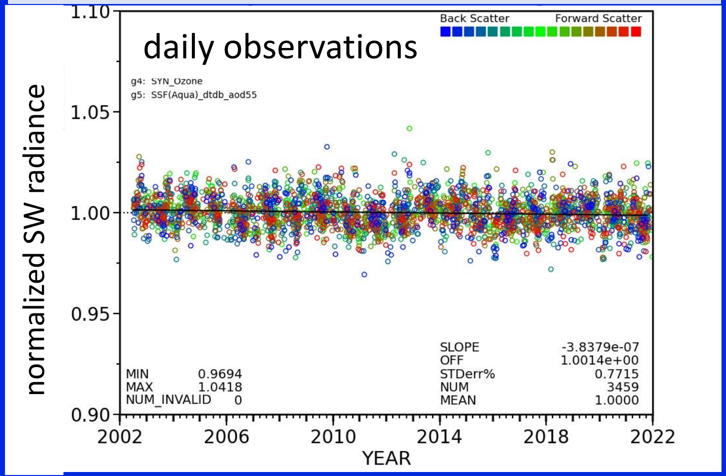
Aqua-CERES Libya-4 stability assessment

- Similar to MODIS, the CERES radiances are normalized their corresponding angular model

SZA terms only

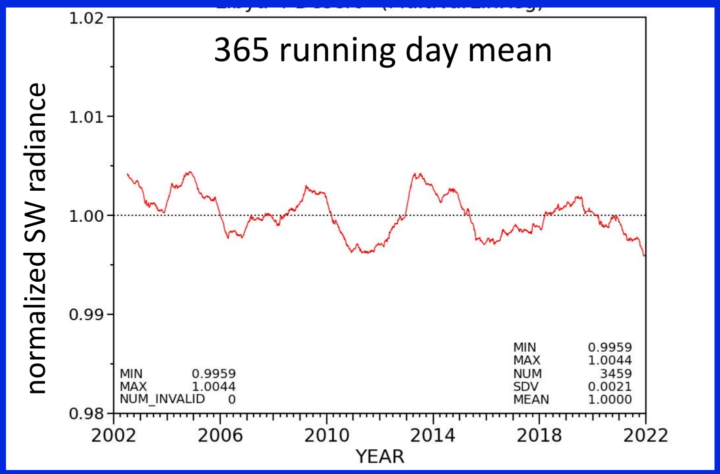


with atmospheric terms



The atmospheric correction has reduced the standard error from 2.4% to 0.8%

with atmospheric terms



The CERES SW radiance temporal variability is similar to MODIS suggesting that the variability is mostly due to the Libya surface reflectance changes

N20-CERES scaled to NPP

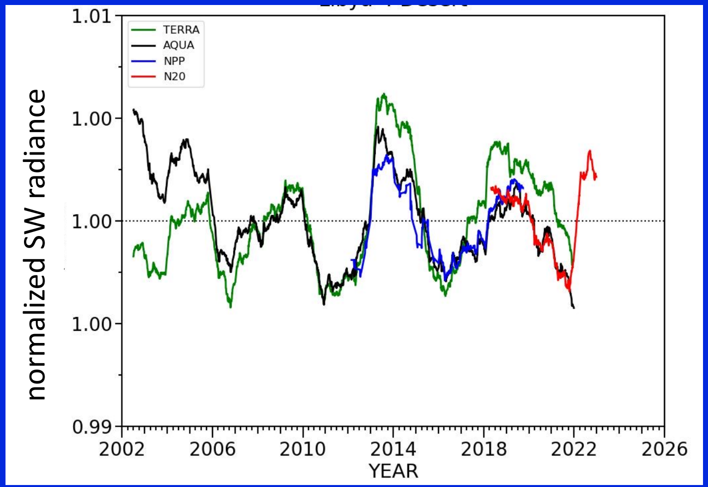
- Make sure the NPP and N20 temporal trends are consistent.
- If not consistent radiometric would be more difficult

The N20 radiances are normalized using the N20 angular models

The N20 radiances can be normalized using the NPP angular models to radiometrically scale N20 to the NPP CERES calibration reference

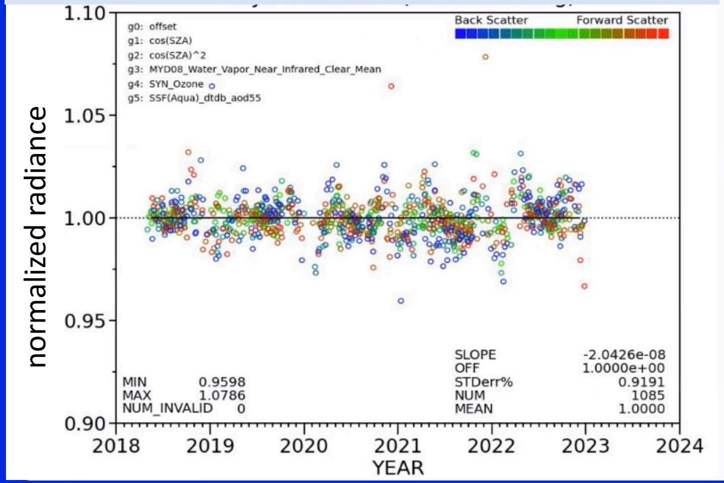
Terra/Aqua/NPP/N20 relative ratios

Lbya-4 CERES radiance



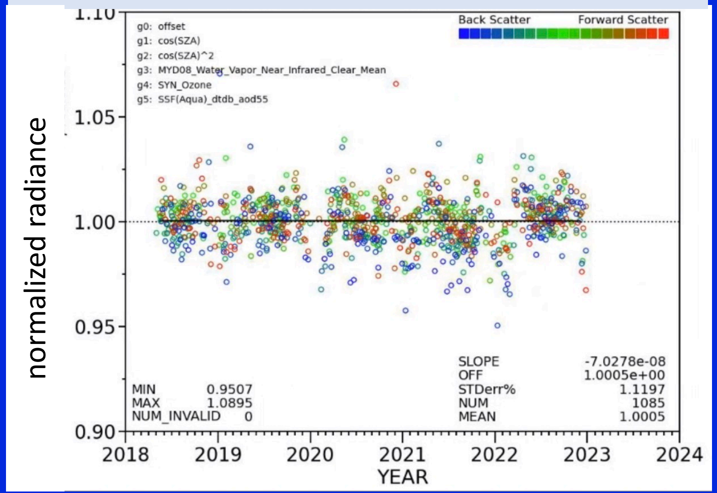
The CERES instrument ratios are temporally consistent suggesting excellent CERES onboard calibration

N20 normalized radiances



The normalized NOAA-20 daily observations have a Libya-4 temporal uncertainty of 0.9%

N20 (scaled to NPP)/N20 radiances



N20 (scaled to NPP)/N20 = 1.0005 and is insignificant since it is within the Libya-4 temporal uncertainty of 1.1%