TISA Working Group Update

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Spring 2023 CERES science team meeting

Hampton, VA, May 9-11, 2023

OUTLINE

- Calibration Activity update
- CERES L3 Product status
- Ed5 coding demonstration
- Ed5 0.5-degree grid system

CALIBRATION

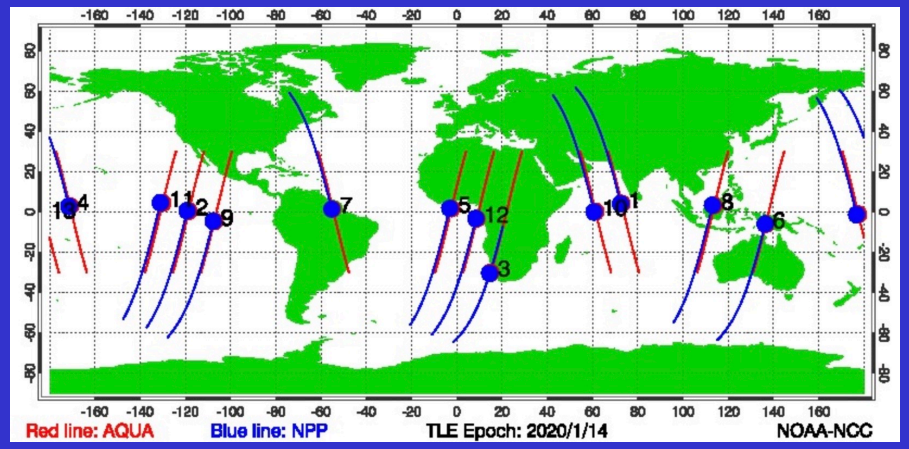
CERES imager and GEO calibration tasks

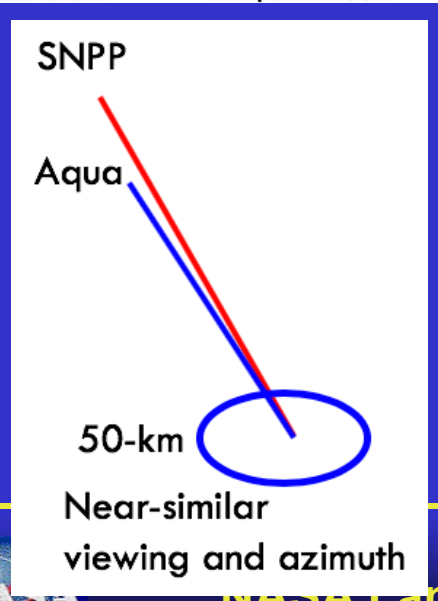
- Assess the stability of the MODIS and VIIRS imager channel radiances
- Provide the NPP and N20 VIIRS to Aqua-MODIS C5 calibration reference coefficients
  - annual updates in January
- Provide GEO visible channel calibration coefficients radiometrically scaled the Aqua-MODIS C5 calibration reference
  - bi-monthly updates of operational GEOs
  - Assess GEO pre-operational image quality
- Improve spectral band adjustment factors using hyper-spectral datasets
- Improved GOES-17 bad scan line detection and cleaning

	2022-2023	Future
Europe/Africa 0°	Met-11 to Met-10 Mar 21, 2023	Met-10 to Met-12 late 2023, Met-13 late 2026
Indian Ocean 45°	Met-8 to Met-9, Jul 1, 2022	
TWP 140°	Him-8 to Him-9 Dec 1, 2022	Him-9 until 2029
GOES-West -135°	GOES-17 to GOES-18 Jan 4, 2023	GOES-18 until 2030 (GOES-19 launch 2024)
GOES-East -75°		GOES-16 until 2032

Aqua-MODIS-B1/N20-VIIRS-I1 0.65μm intercalibration

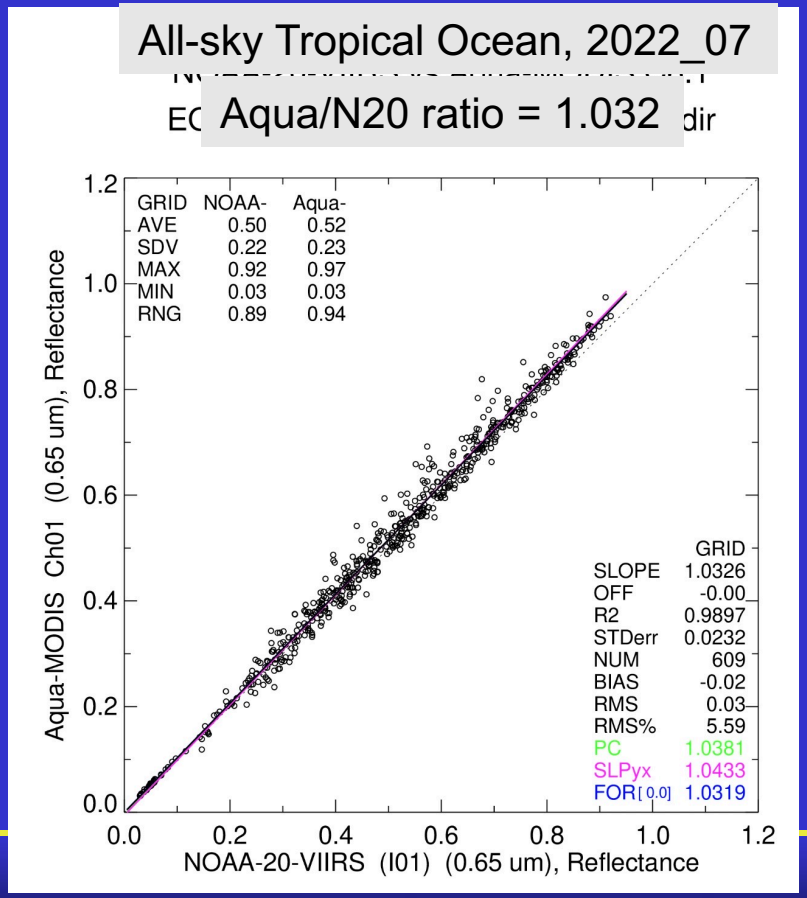
Tropical SNO, Jan 14, 2020





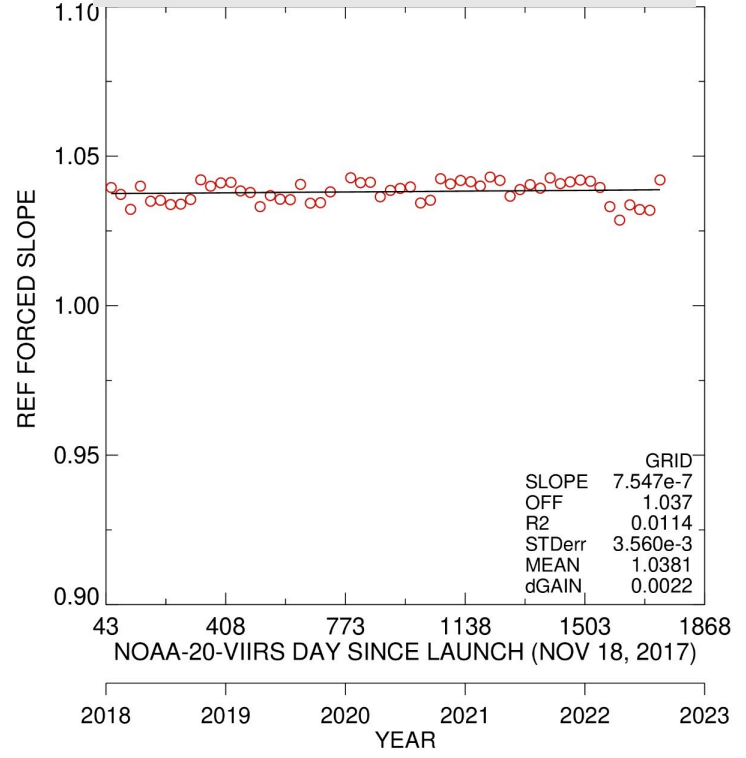
All-sky Tropical Ocean, 2022_07

Aqua/N20 ratio = 1.032



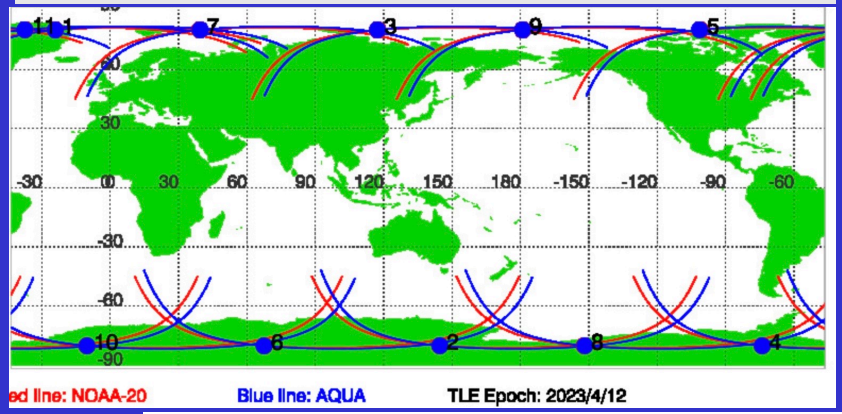
All-sky Tropical Ocean, 2018-2022

Aqua/N20 mean ratio = 1.038



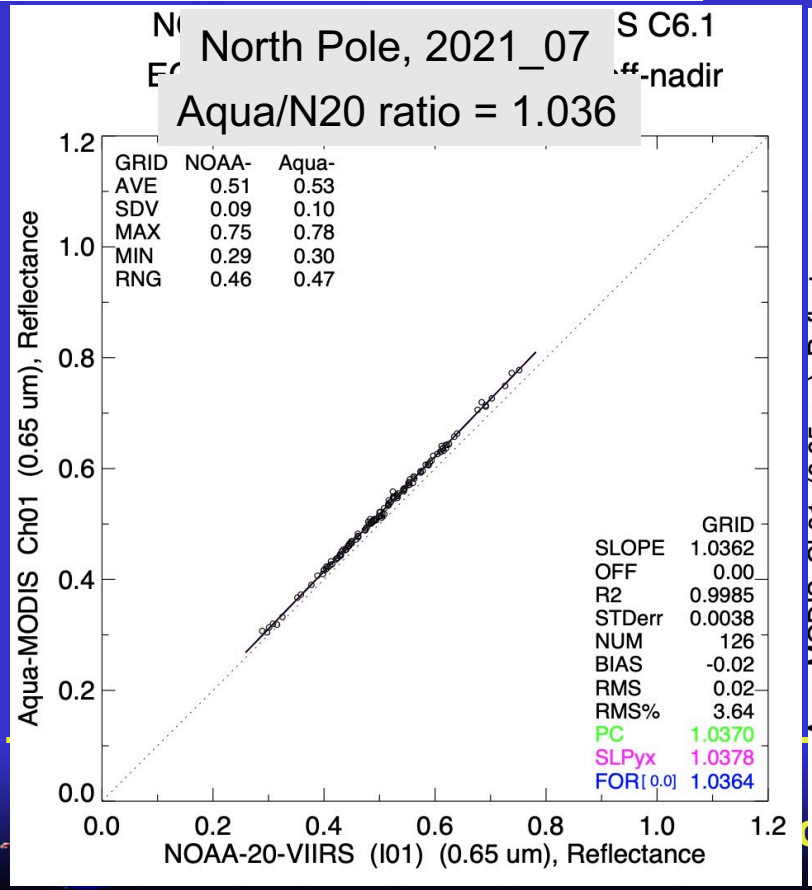
Aqua-MODIS-B1/N20-VIIRS-I1 0.65µm intercalibration

Polar SNO, Apr 12, 2023



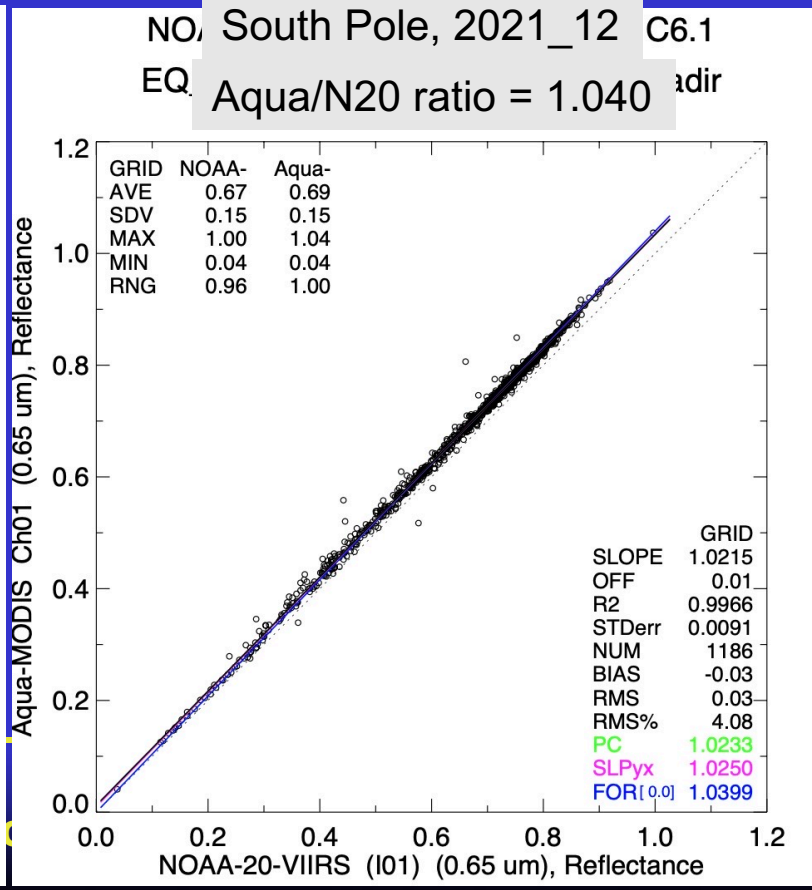
North Pole, 2021_07

Aqua/N20 ratio = 1.036



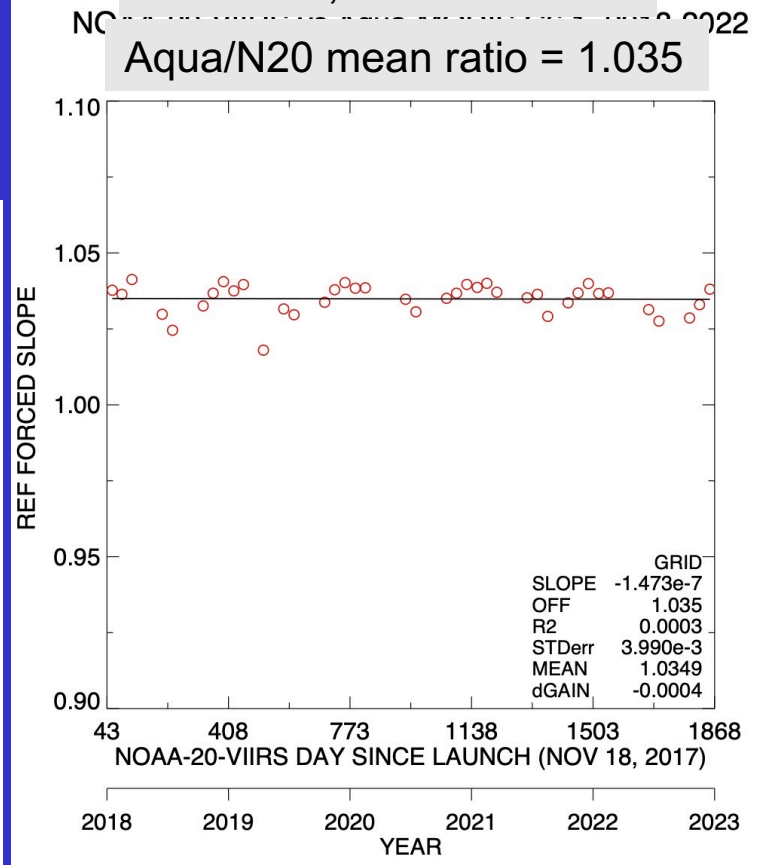
South Pole, 2021_12

Aqua/N20 ratio = 1.040



Poles, 2018-2022

Aqua/N20 mean ratio = 1.035

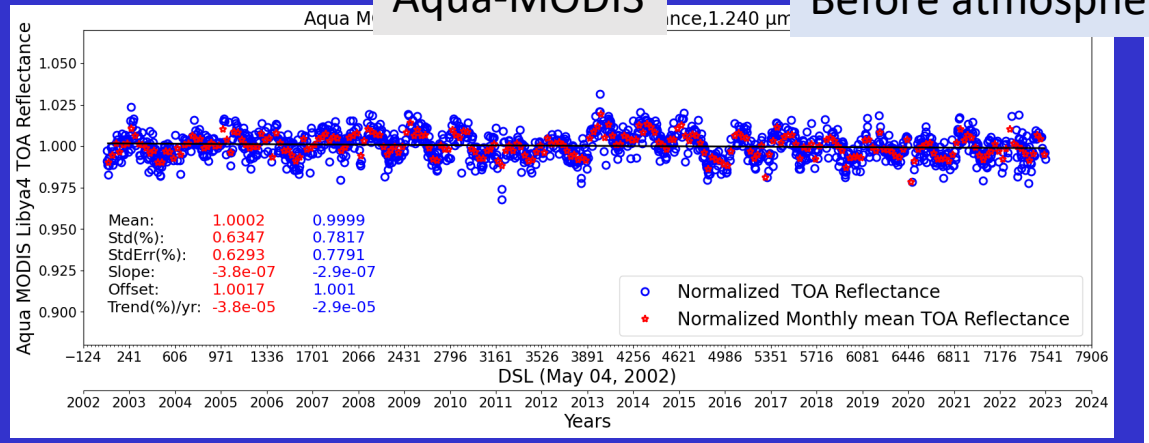


Compare to 2018-2022 All-sky Tropical Ocean 2018-2022, Aqua/N20 mean ratio = 1.038

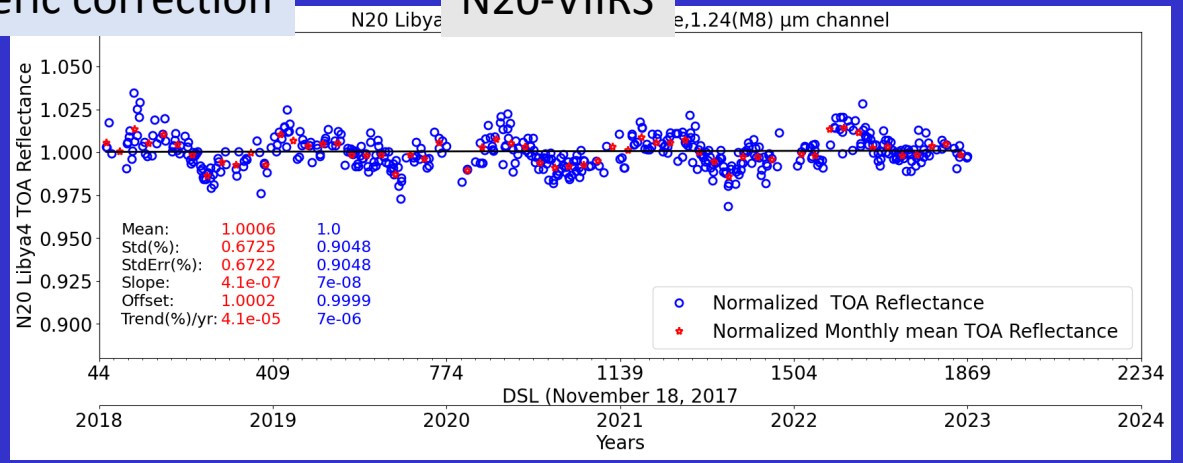
Comparison of Libya-4 1.24μm stability with and without atmospheric parameters

Aqua-MODIS

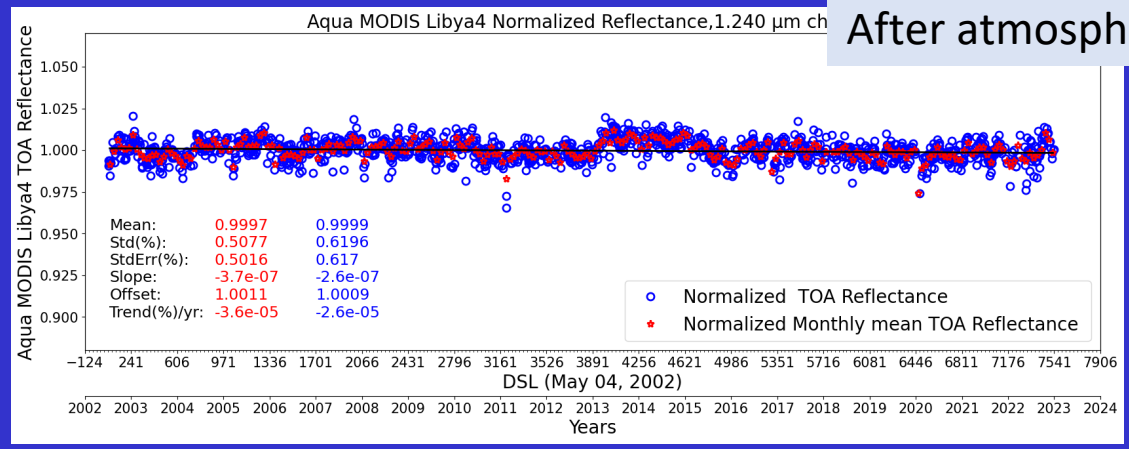
Before atmospheric correction

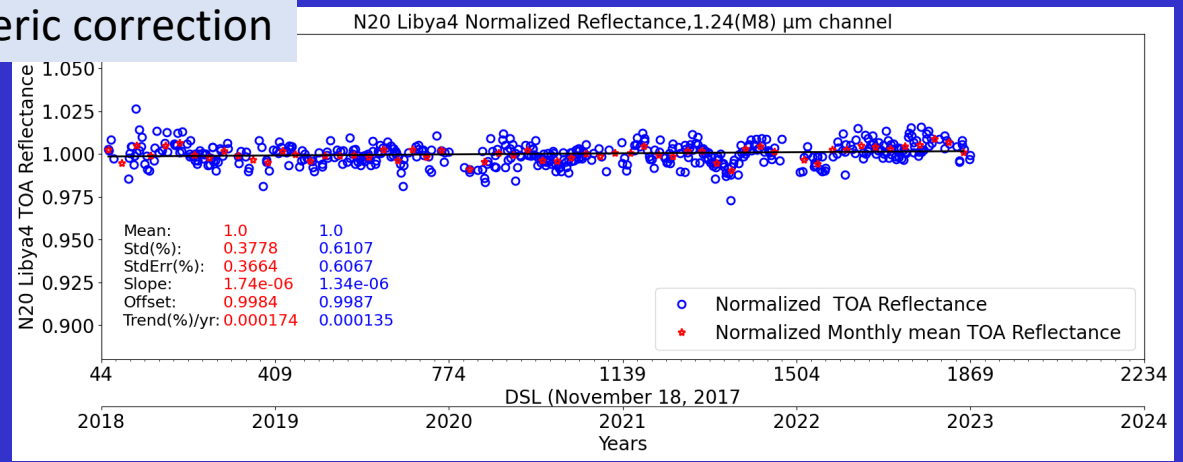


N20-VIIRS



After atmospheric correction

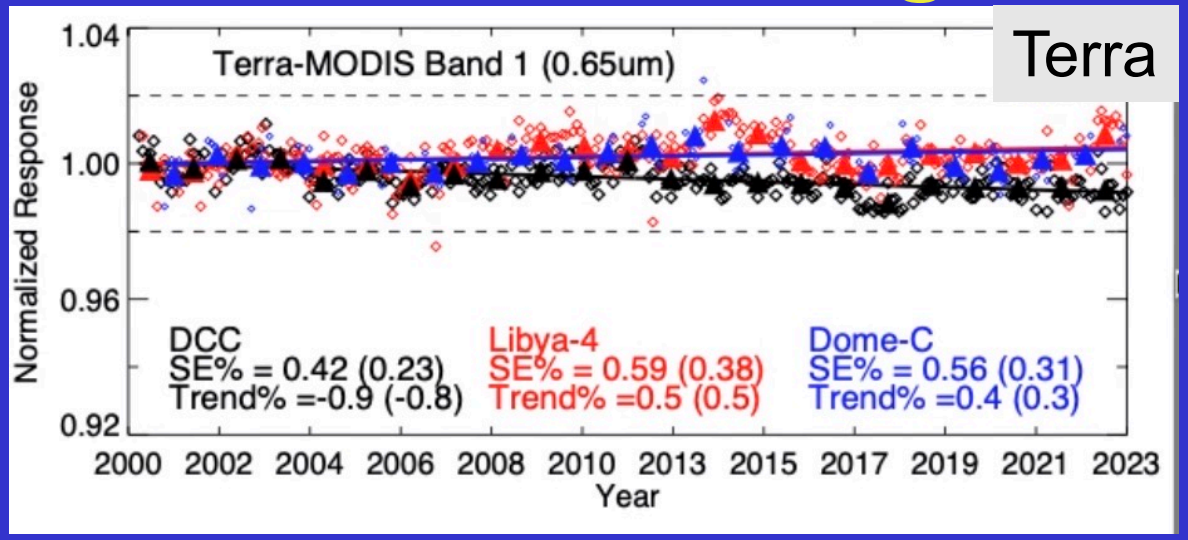


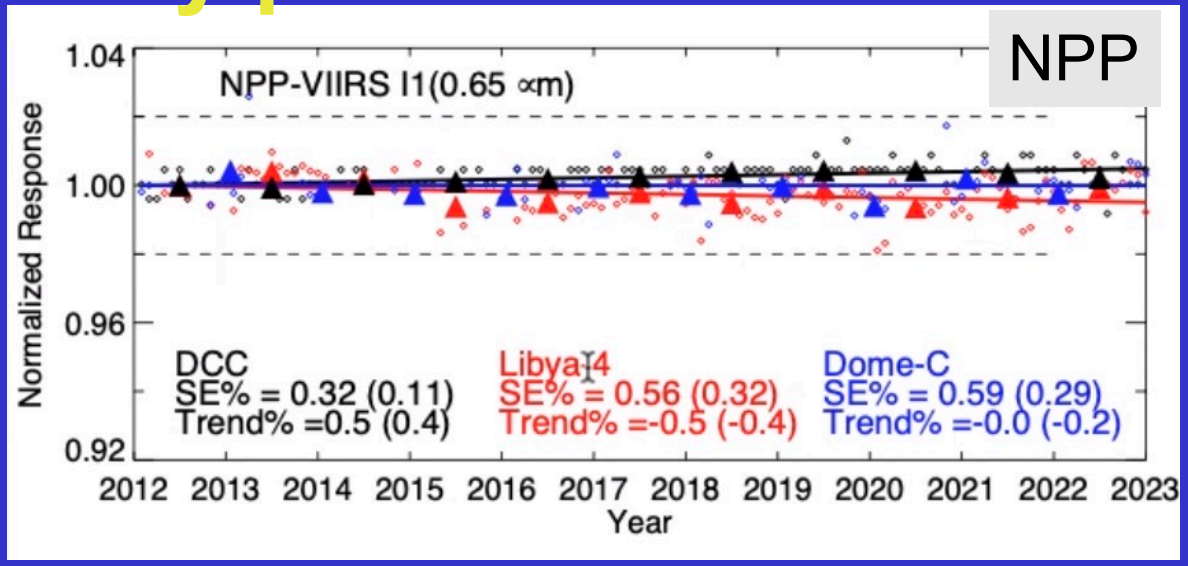


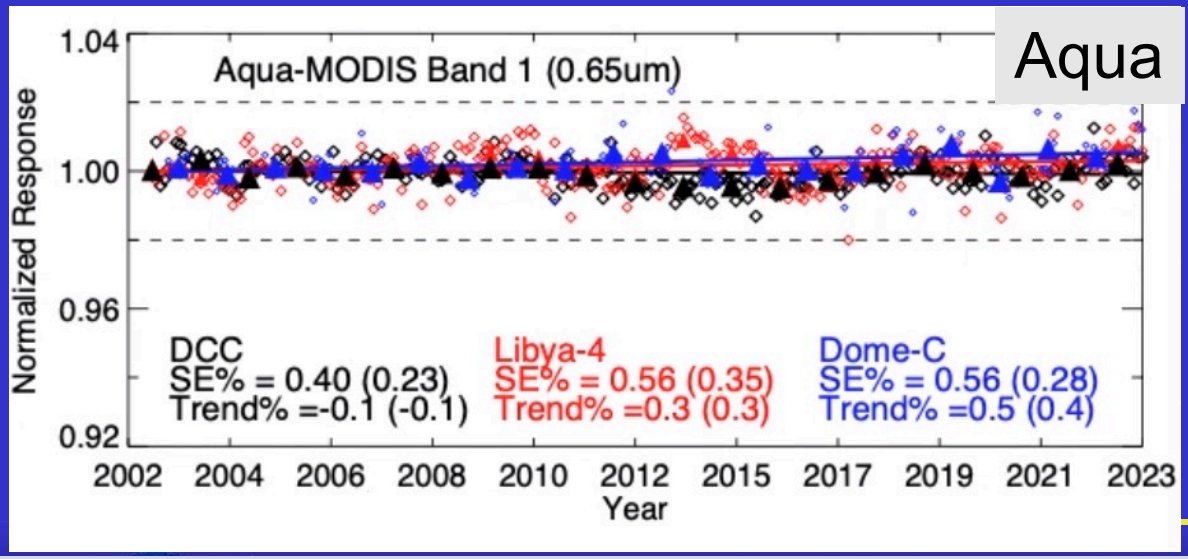
21% sigma reduction for Aqua utilizing atmospheric correction

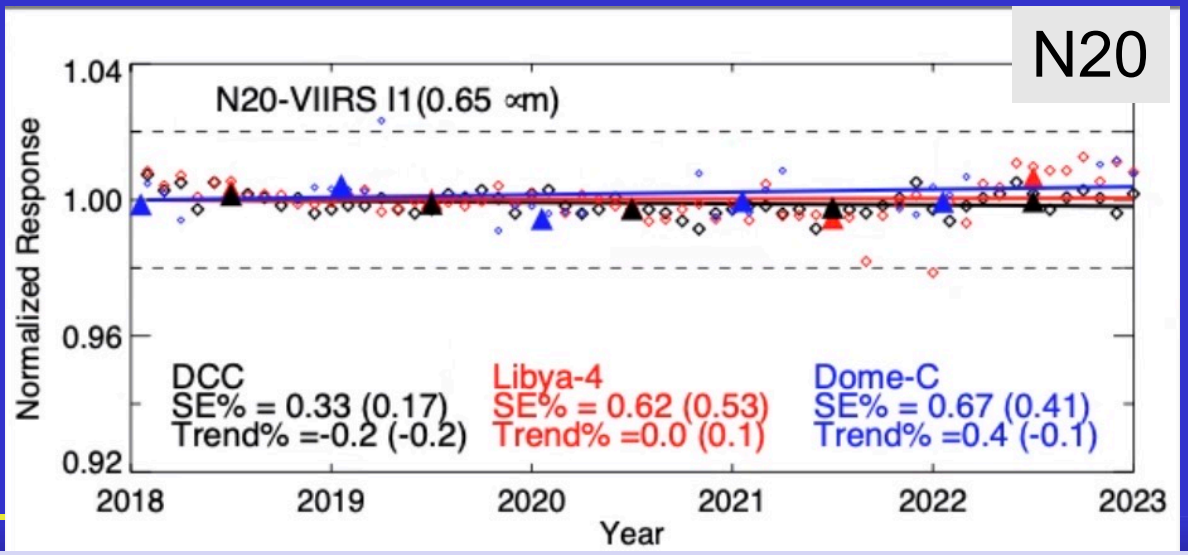
33% sigma reduction for N20 utilizing atmospheric correction

Imager stability plots



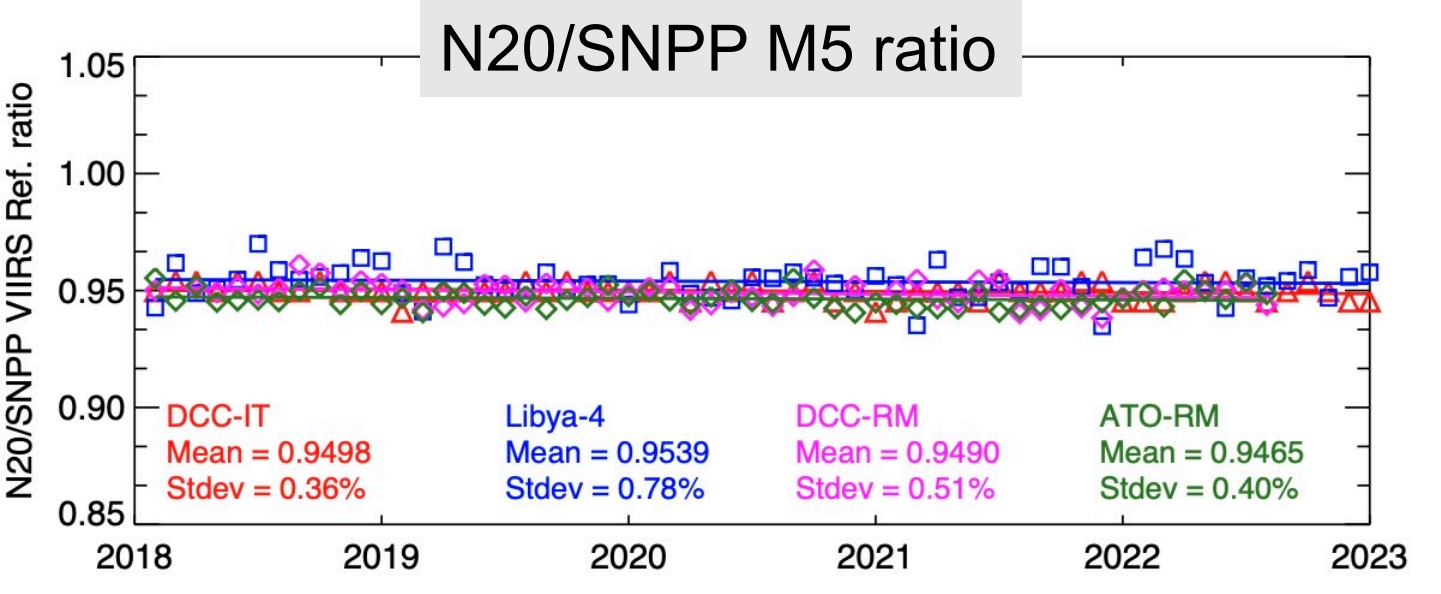






- We independently track the MODIS and VIIRS temporal stability and talk with the MCST and VCST team if we see any significant trends and update annually on the satcorp web site

NPP/N20 VIIRS channel ratios



DCC-IT: Deep Convective Cloud Invariant Earth target approach
Libya-4: Invariant desert target approach
DCC-RM: Coincident collocated ray-matched radiance pair approach using DCC and Aqua-MODIS as a transfer radiometer
ATO-RM: same as DCC-RM except using all-sky tropical ocean

NPP/N20 VIIRS band calibration difference %

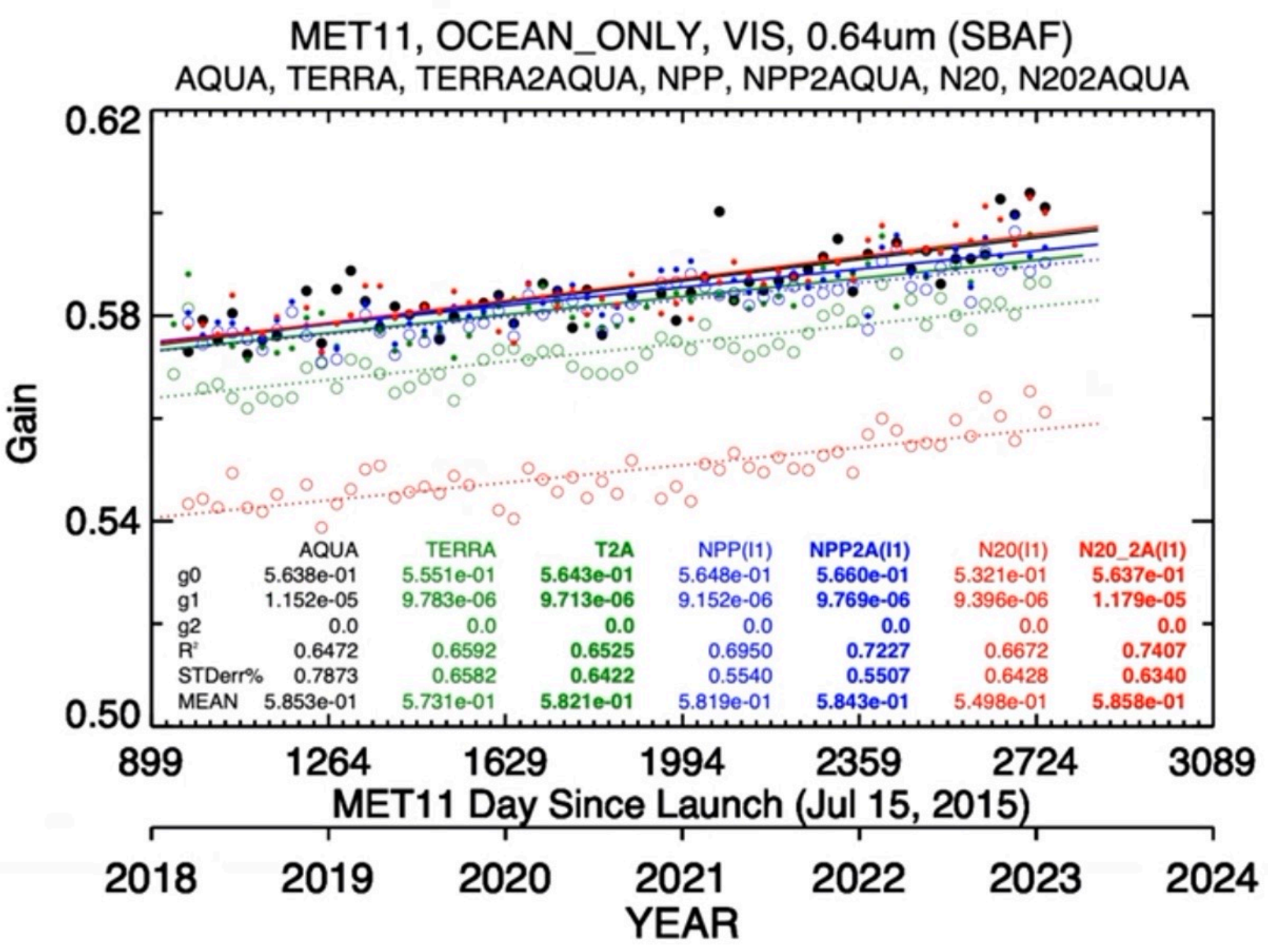
Band	CERES	MAIAC	VCST
M3	5.6	4.8	4.8
M4	5.8	5.5	4.5
M5	5.4	4.4	4.4
M7	4.2	3.8	3.3
M8	2.0	2.6	2.4
M10	2.5	2.2	0.9
M11	1.6	2.0	1.7
I1	4.8	4.0	3.9
I3	5.0	5.4	3.5

Calibration of the SNPP and NOAA 20 VIIRS Sensors for Continuity of the MODIS Climate Data Records, Lyapustin et al. 2023, submitted

The four calibration ratio approaches were consistent within 0.8%, except for band M10 which agreed within 1.3%.

CERES and MAIAC agree within 0.8%
CERES and VCST agree within 1.7%

Met-11/Imager stability and radiometric scaling



LEGEND

- **Aqua-MODIS (reference)** • ——
- Terra-MODIS o -------
- **Terra-MODIS scaled to Aqua** • ——
- NPP-VIIRS o -------
- **NPP-VIIRS scaled to Aqua** • ——
- N20 VIIRS o ------
- **N20 VIIRS scaled to Aqua** • ——

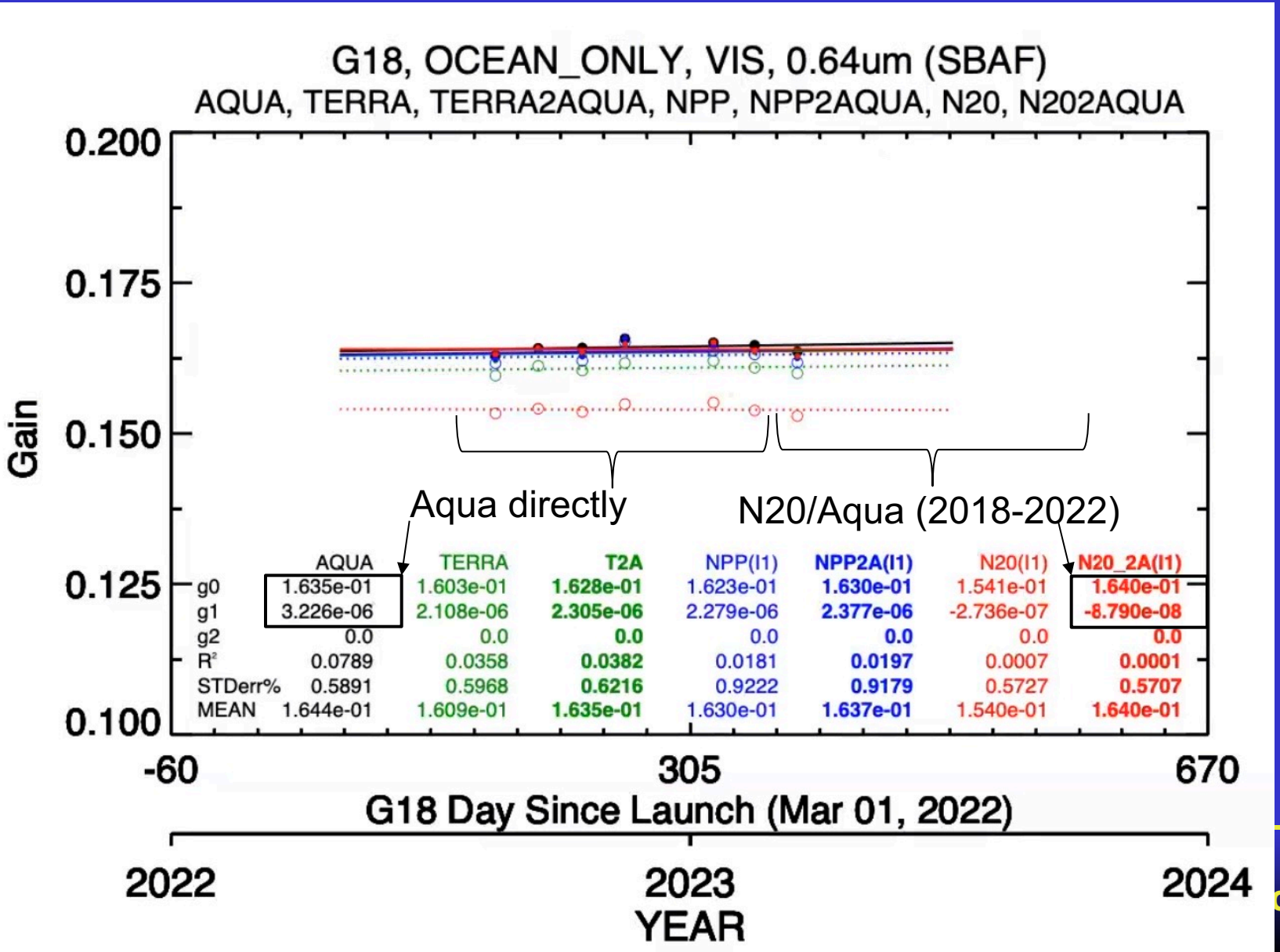
Calibration difference with respect to Aqua-MODIS

%	Before scaling	Scaled to Aqua
Terra	-2.1	-0.5
NPP	-0.6	-0.2
N20	-6.1	+0.1

ces

CERES

GOES-18/Imager stability and radiometric scaling



LEGEND

- **Aqua-MODIS (reference)**
- Terra-MODIS
- **Terra-MODIS scaled to Aqua**
- NPP-VIIRS
- **NPP-VIIRS scaled to Aqua**
- N20 VIIRS
- **N20 VIIRS scaled to Aqua**

Calibration difference with respect to Aqua-MODIS

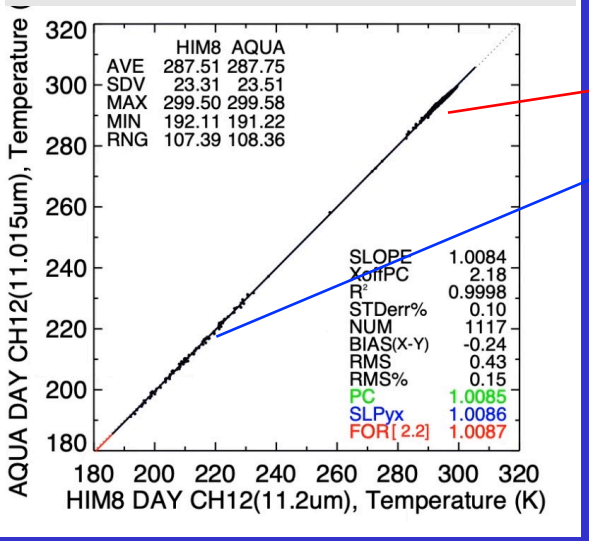
%	Before scaling	Scaled to Aqua
Terra	-2.1	-0.5
NPP	-0.9	-0.4
N20	-6.3	-0.2

ces

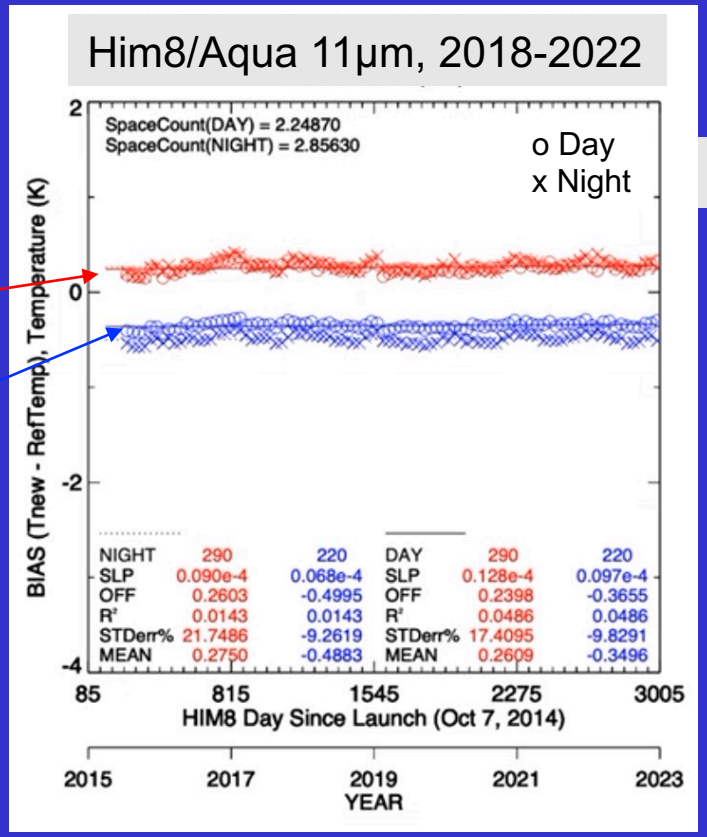
CERES

Himawari-8/imager IR Window (11.2 μm) comparison

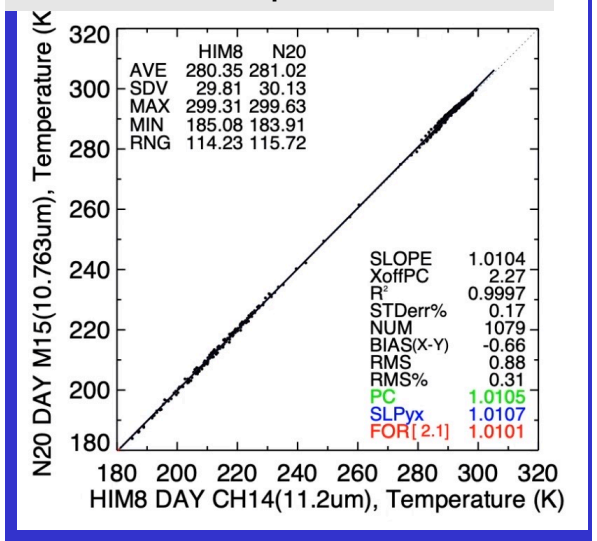
Him8/Aqua 11μm, Jan 2021



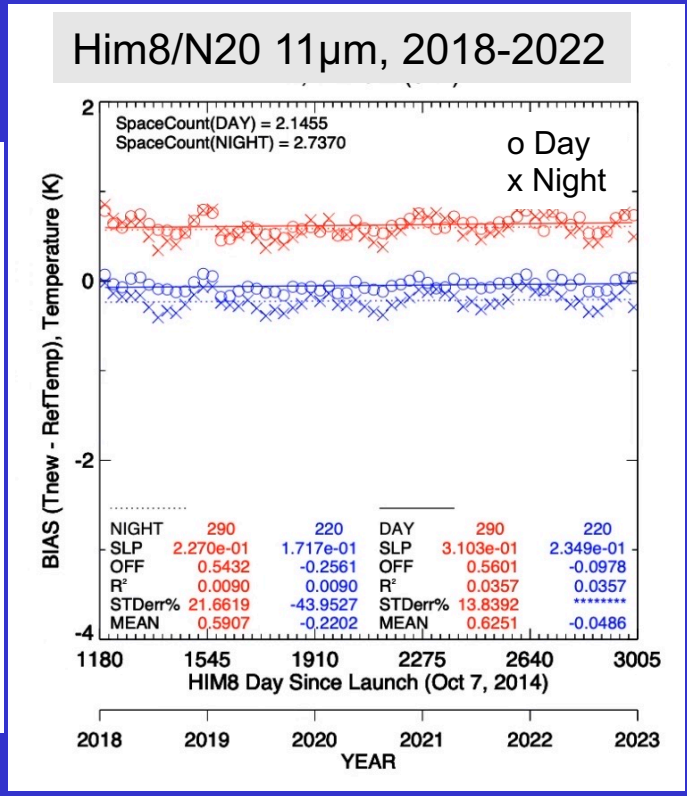
Him8/Aqua 11μm, 2018-2022



Him8/N20 11μm, Jan 2021



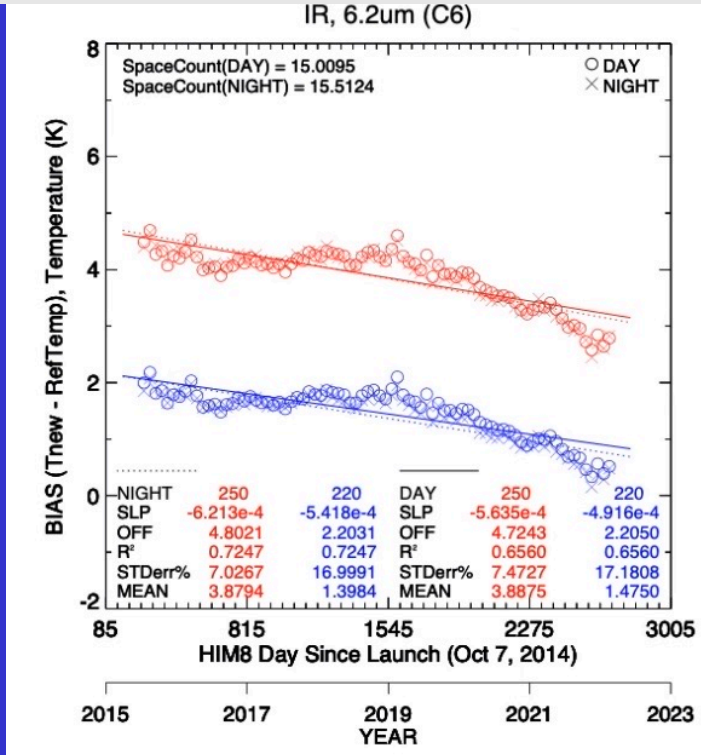
Him8/N20 11μm, 2018-2022



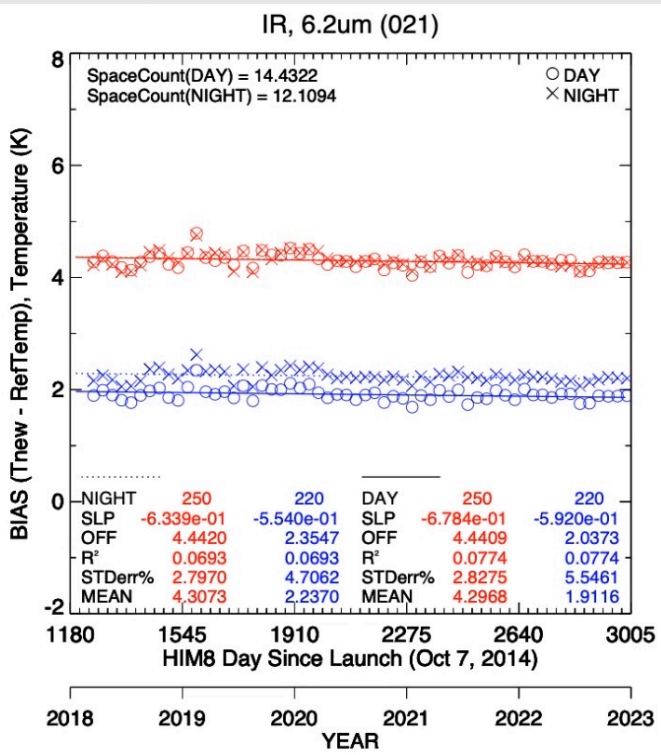
- The GEO/imager IR channel temperature difference is monitored at 220K and 290K
- The GEO and imager IR calibration relies on blackbodies and are fairly consistent across sensors
- The sensor temperature differences are mainly due to spectral response differences

GOES-16/imager IR WV (6.2μm comparison)

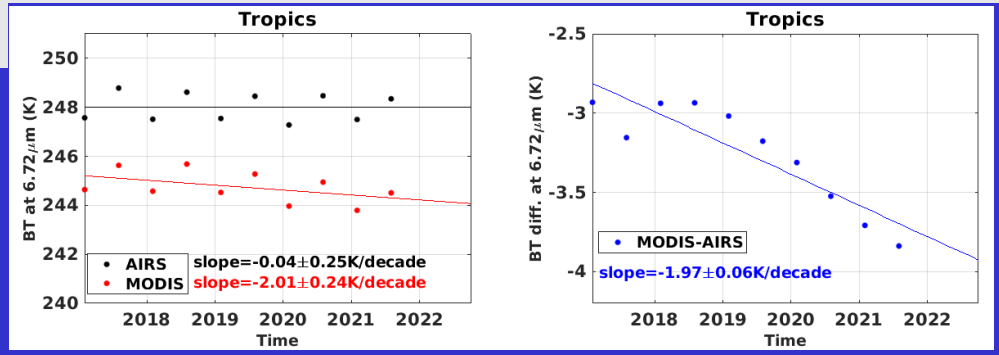
GOES-16/Aqua-MODIS 6.2μm



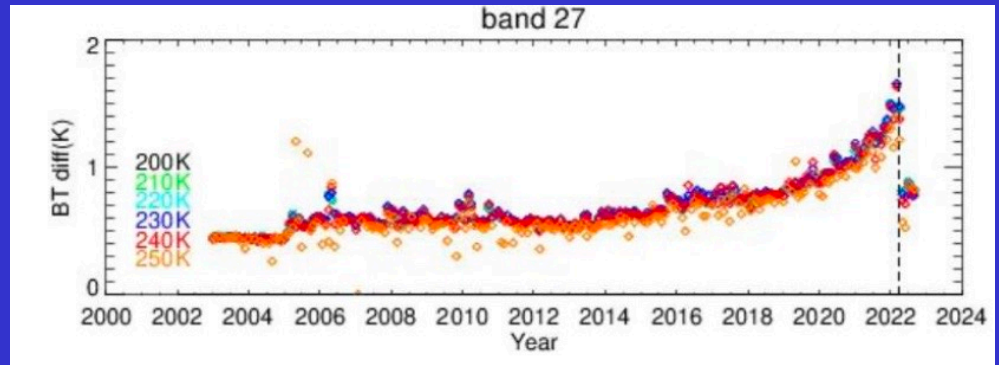
GOES-16/N20-FSNRAD 6.2μm



Comparison between AIRS and MODIS BT at 6.7 μm (Huang group at UM, Mar 21, 2023)

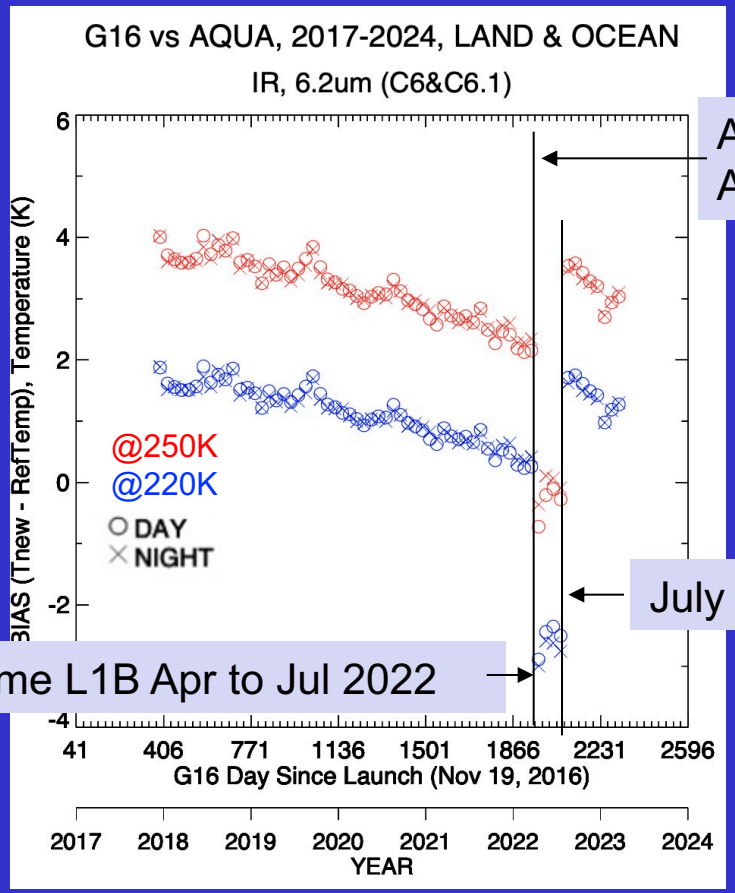


MCST C7 minus C6.1 BT difference



- The Aqua-MODIS IR 6.2μm and 8.6μm channels have been drifting since 2018
- The N20 FSNRAD 6.2 and CO2 channels provide a very stable IR reference

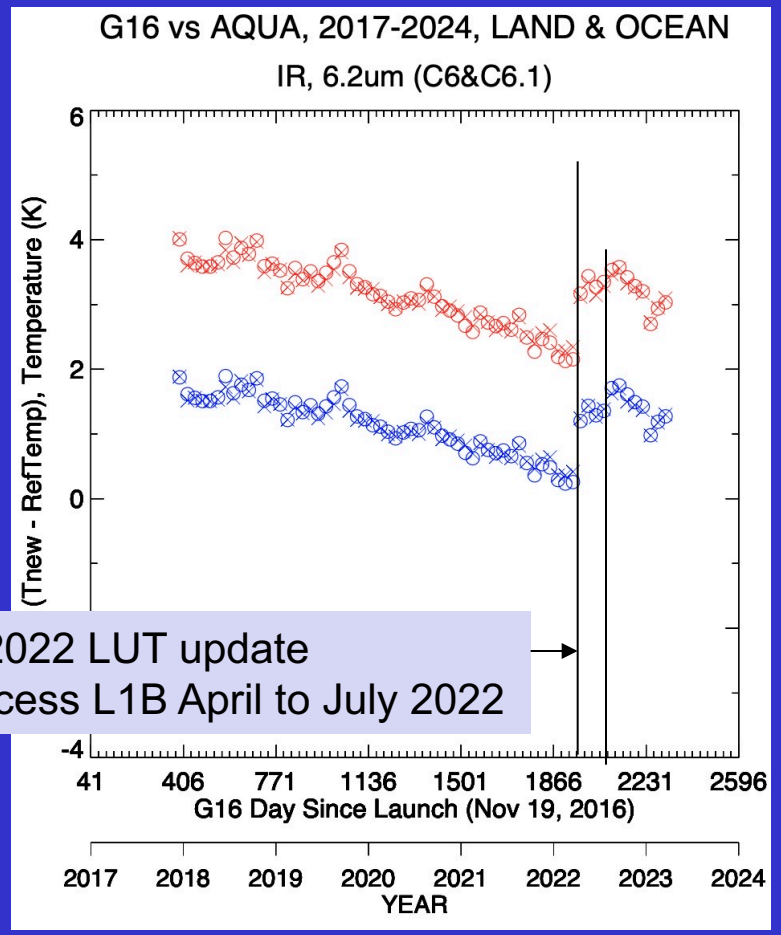
GOES-16/Aqua-MODIS IR WV (6.2μm comparison)



Aqua spacecraft anomaly April 2022

July 2022 LUT update

real-time L1B Apr to Jul 2022



Nov 2022 LUT update
reprocess L1B April to July 2022

- The CERES imager and geostationary calibration team was able to help MCST Tiejun Chang verify his Aqua-MODIS IR LUT 6.2μm and 8.6μm corrections

Migrate to N20-VIIRS stability reference

- Migrate to N20-VIIRS stability reference scaled to Aqua-MODIS C5 calibration reference

	Aqua-MODIS reference	Mar 2023-> N20 scaled to Aqua
MODIS and VIIRS visible channels	Radiometrically scale Terra-MODIS, NPP-VIIRS, N20-VIIRS to the Aqua-MODIS reference annually	Use the 2018 to 2022 overlap to compute the one-time scaling factors with Aqua. No further updates
GEO visible channels	GEO/Aqua inter-calibration (primary) Compare with the GEO/Terra, GEO/NPP, GEO/N20 (imagers scaled to Aqua)	GEO/N20-VIIRS (scaled to Aqua) inter-calibration (primary), Compare with other imagers (scaled to Aqua) Although Aqua and Terra are drifting inter-calibration with GEO not impacted
IR channels	Compare monthly the GEO and Aqua BT differences and radiometrically scale the IR and WV to Aqua-MODIS. Aqua-WV channel quality impacted after Aqua April 2023 anomaly.	Compare monthly the GEO and N20 FSNRAD BT differences and radiometrically scale the IR and WV to N20 FSNRAD

CERES L3 PRODUCTS

Aqua FM3 scan mode started on March 22, 2023

Day	GOES-West	GOES-East	Europe	Indian ocean	TWP
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					

RAPS MODE
GEO Scan
cross-track

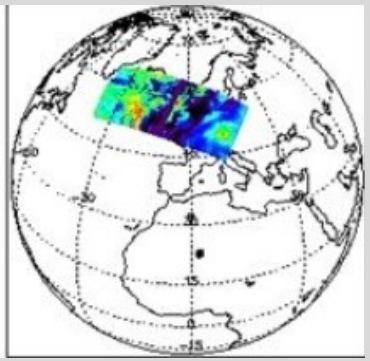
Perform GEO scan mode every 5th day

- The 5th day may vary in order to get perform an Aqua/NPP or Aqua/N20 SNO, which occurs every 64 hours.
- To perform an SNO scan the CERES instruments need to be in cross-track mode

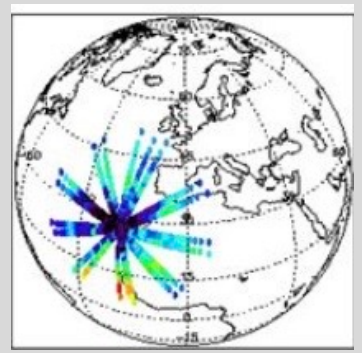
CERES instrument scan modes

- **Cross-track** mode designed for uniform spatial sampling
  - This provides observations for SSF1deg and SYN1deg data products
- **RAPS mode** designed to capture all view and azimuthal angles
  - This provides 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

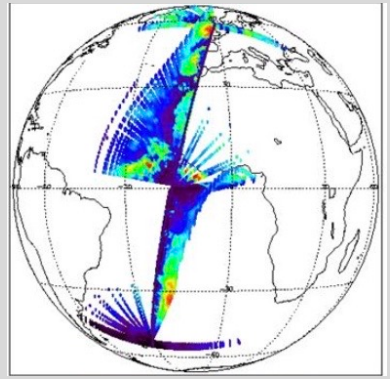
cross-track mode



RAPS mode



GEO scan mode



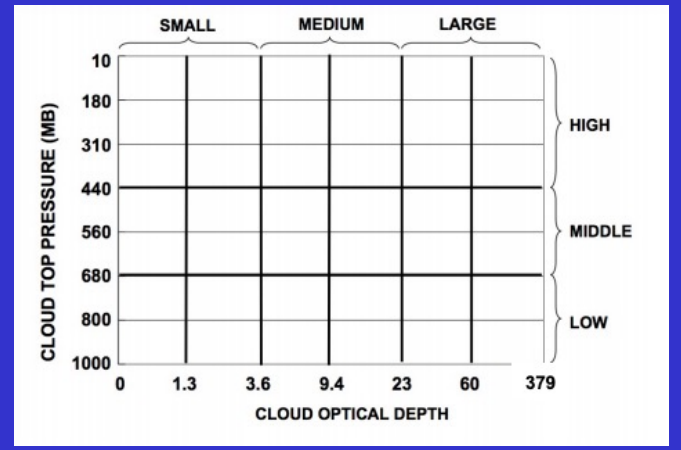
CERES Ed4 L3 data products

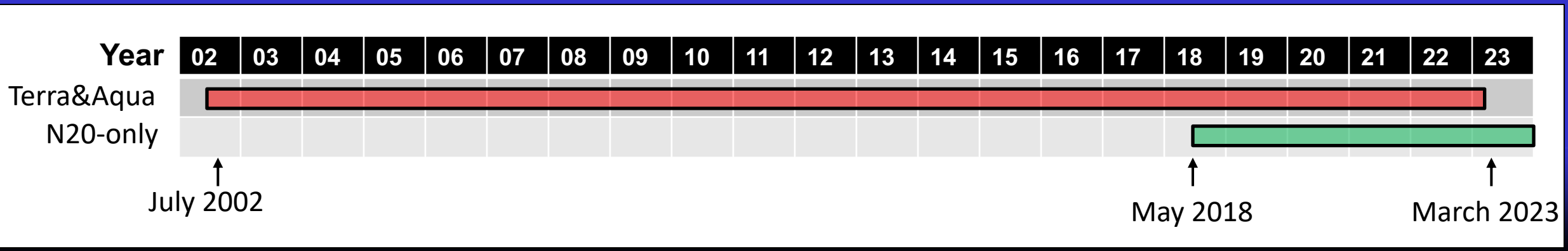
Product	March 2022	April 2022	March 2023	Datagap 2022
EBAF	Terra+Aqua	**N20**	N20	
SSF1deg-Terra-FM1	Terra (cross-track)			Oct 12-25
Terra-FM2	RAPS mode (no product)			
SSF1deg-Aqua-FM3	Aqua cross-track until Feb2023		**RAP mode**	Mar 31-Apr 15
SSF1deg-SNPP	RAPS mode start Oct 2019 (no product), except Sept 2022 cross track			July 27-Aug1
SSF1deg-N20	N20 (cross-track)			
SYN1deg	Terra+Aqua+GEO	**Terra+N20+GEO**	Terra+N20+GEO	
FBCT	Terra+Aqua	Terra+Aqua	**(see next slide)**	
CldTypHist	Terra+Aqua+GEO	Terra+Aqua+GEO	**Terra+N20+GEO**	

- The CldTypHist-Terra+Aqua+GEO record will stop with the February 2023 data month
- The CldTypHist-Terra+N20+GEO record will begin with the March 2023 data month to be publicly available in June

FBCT Ed4 data records

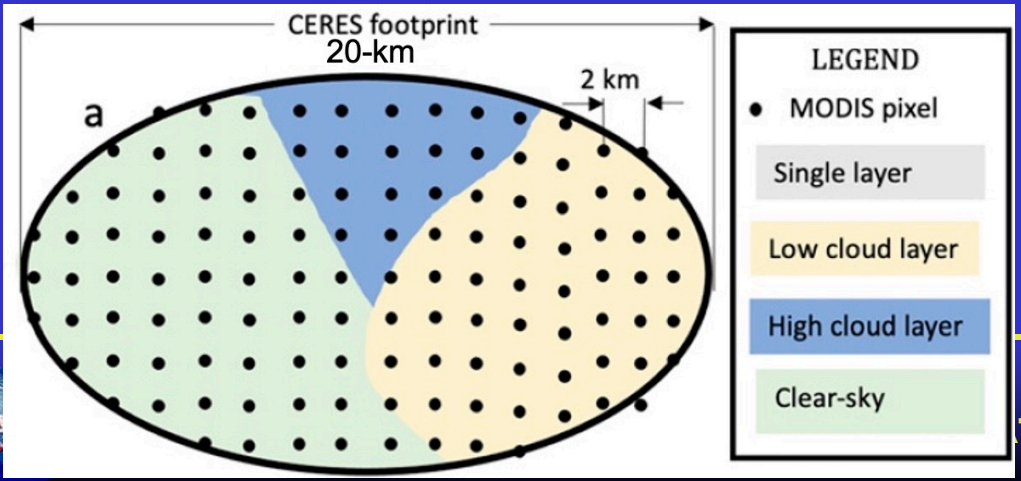
- The FluxByCloudType (FBCT) product provides observed daytime CERES fluxes stratified by 7 cloud layer and 6 optical depth bins (similar to ISCCP)
  - The TRMM directional models are used to compute the daily SW flux
- Now that Terra and Aqua are drifting the observed mean local time is changing conflating the diurnal sampling in the daily SW flux
- Climatology adjustments to bridge the gap between Terra&Aqua and a NOAA20-only record were unsuccessful
  - mostly due to optically thin cloud differences between MODIS and VIIRS
- The FBCT-Terra /Aqua will end in March 2023 and a NOAA-20 record beginning in March 2018 will be in forward processing mode
  - Projected release date at the end of July 2023





FBCT MODIS or VIIRS narrowband to broadband derived sub-footprint cloud layer flux algorithm

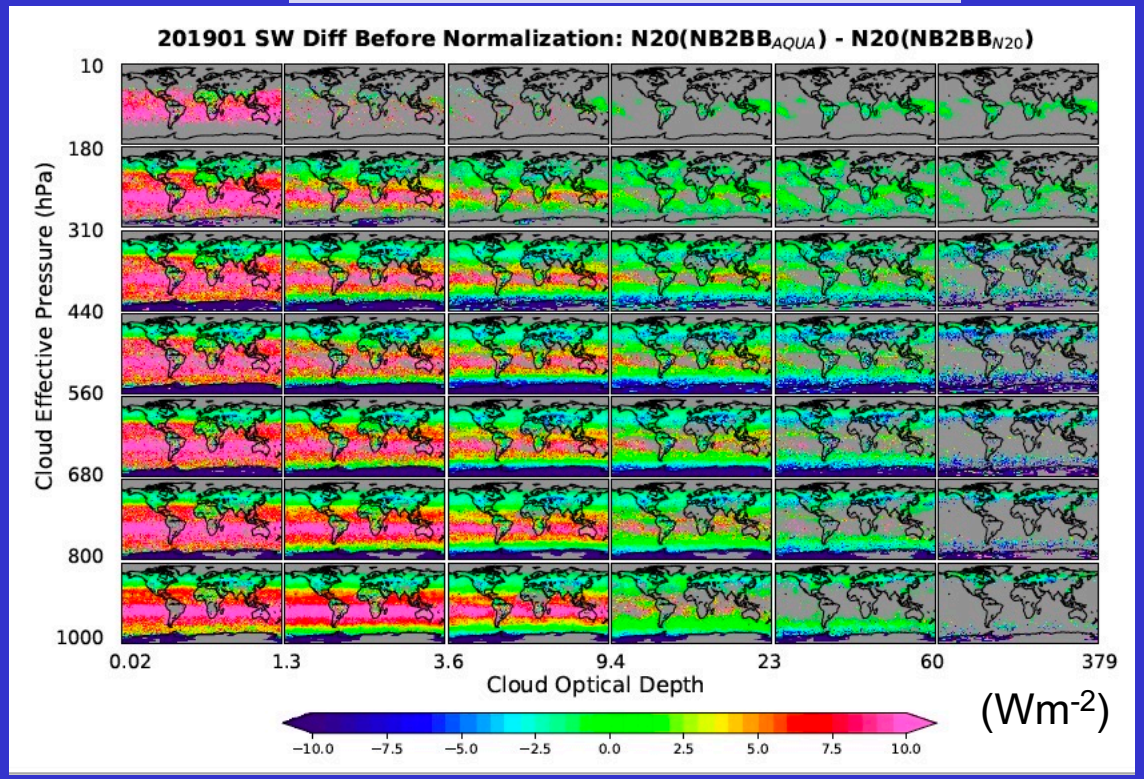
- For multi-scene CERES footprints, MODIS narrowband to broadband (NB2BB) empirical relationships estimate the sub-footprint cloud layer broadband radiance
  - For single scene type CERES footprints, the observed CERES flux is utilized directly
- Convert the cloud layer radiances to fluxes using the CERES ADMs
- The MODIS derived cloud-layer fluxes are normalized to the CERES observed footprint flux
  - Same ratio is applied to the clear or cloud layer portions ($Flux_i$) of the CERES footprint
- Validate the normalization by differencing the MODIS/Aqua and VIIRS/N20 NB to BB based FBCT fluxes before and after normalization applied to N20



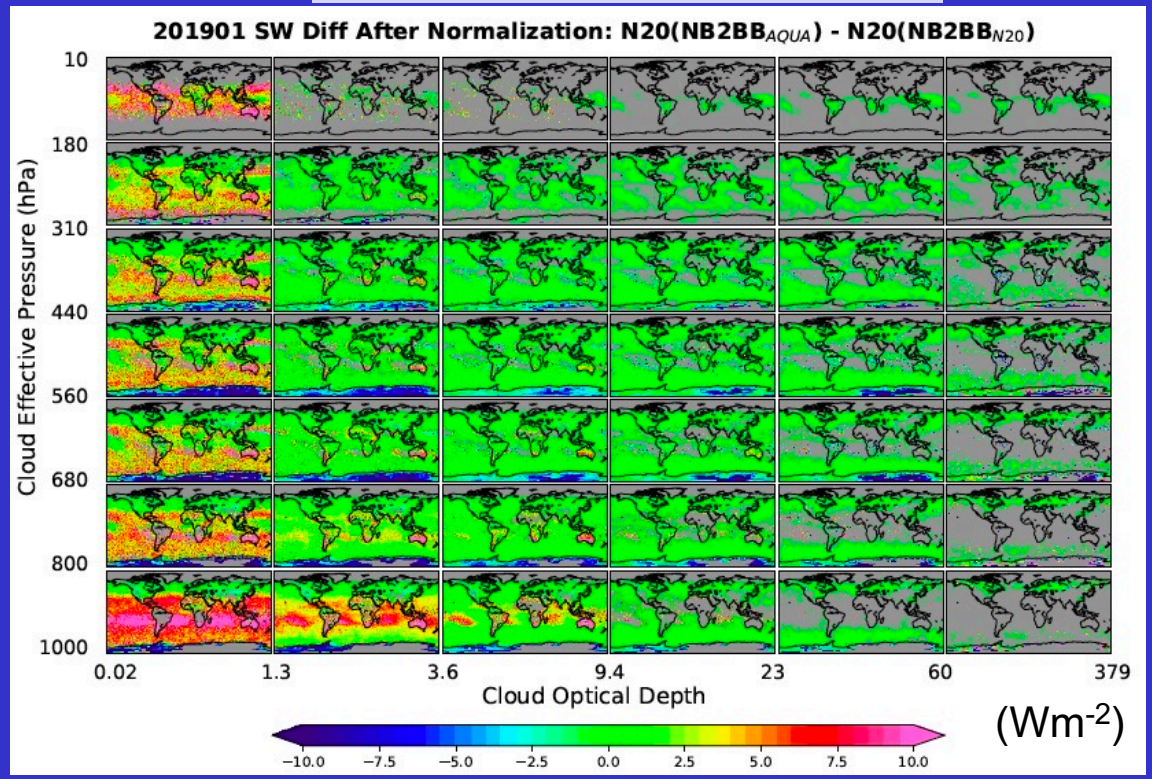
$$\mathrm{Flux}_i^{\mathrm{normalized}} = \left[\frac{\mathrm{Flux}_{\mathrm{CERES}}}{\mathrm{Flux}_{\mathrm{footprint}}}\right] \times \mathrm{Flux}_i.$$

Comparison of Aqua vs N20 narrowband to broadband derived N20 SW FBCT fluxes, Jan 2019

Before footprint normalization



After footprint normalization



- Aqua and N20 narrowband to broadband coefficients were derived over the same N20 and Aqua overlap period (May 2018 to Dec 2022)
- After footprint flux normalization the FBCT fluxes are more consistent. There are remaining differences due to MODIS and VIIRS cloud mask and retrieval differences

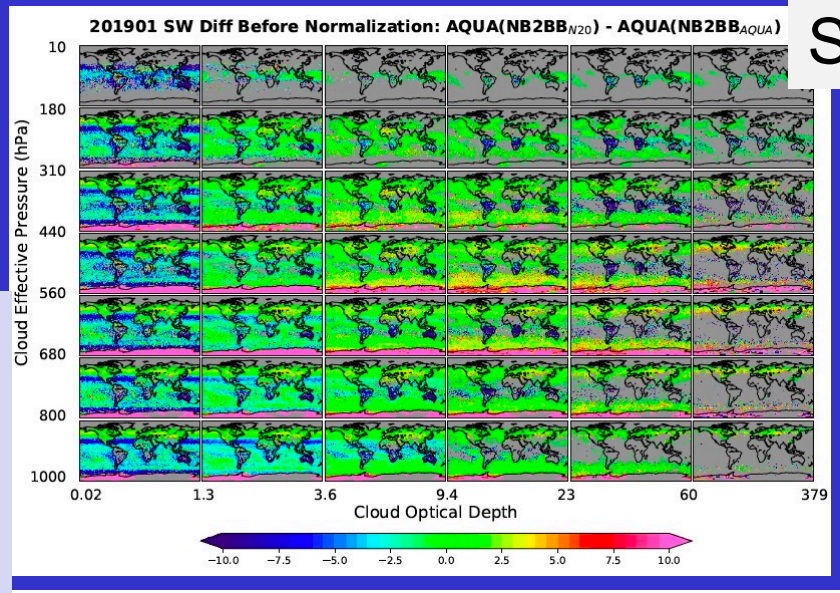
Comparison of Aqua vs N20 narrowband to broadband derived AQUA SW FBCT fluxes, Jan 2019

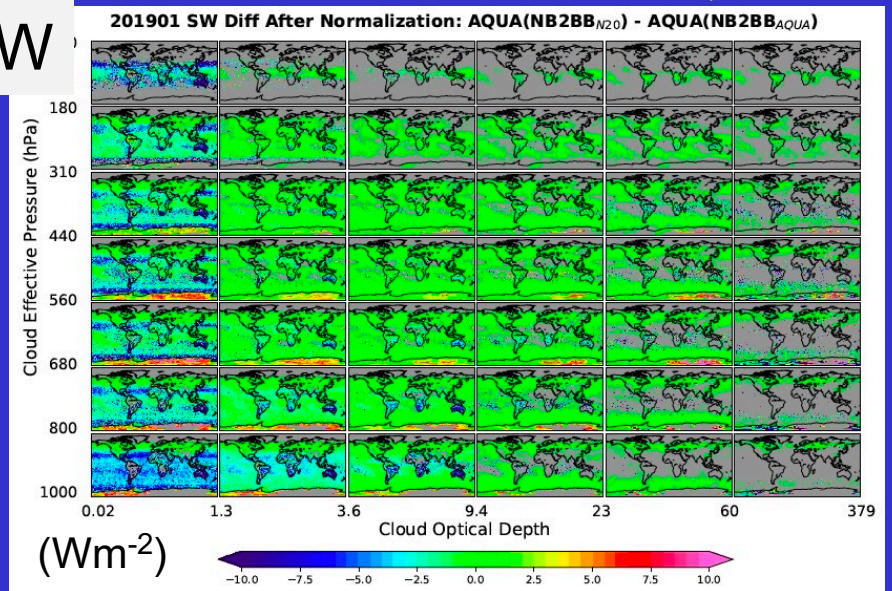
Before footprint normalization

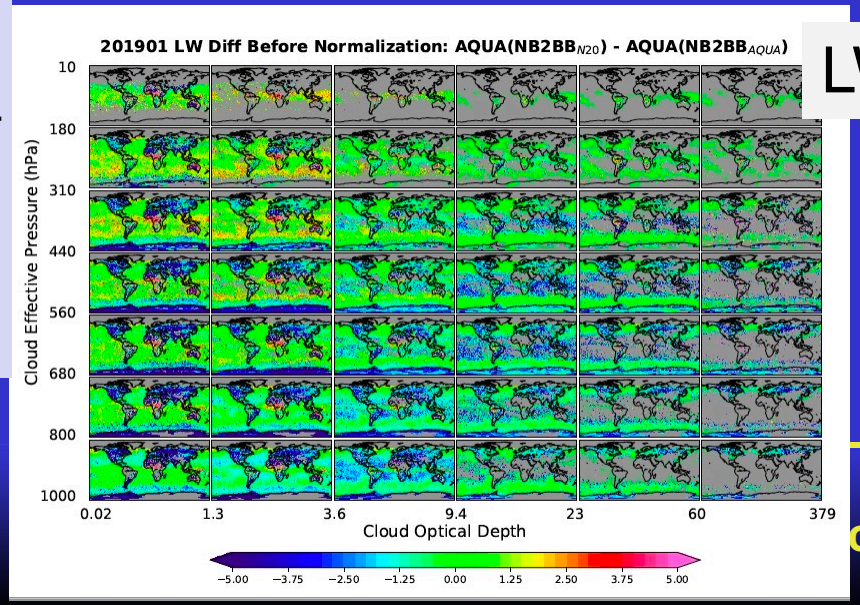
After footprint normalization

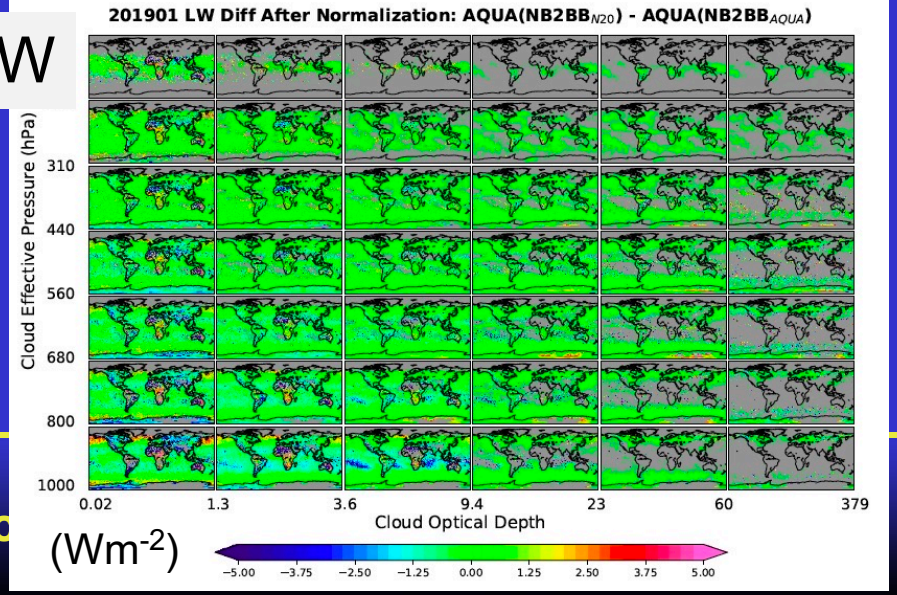
SW

LW









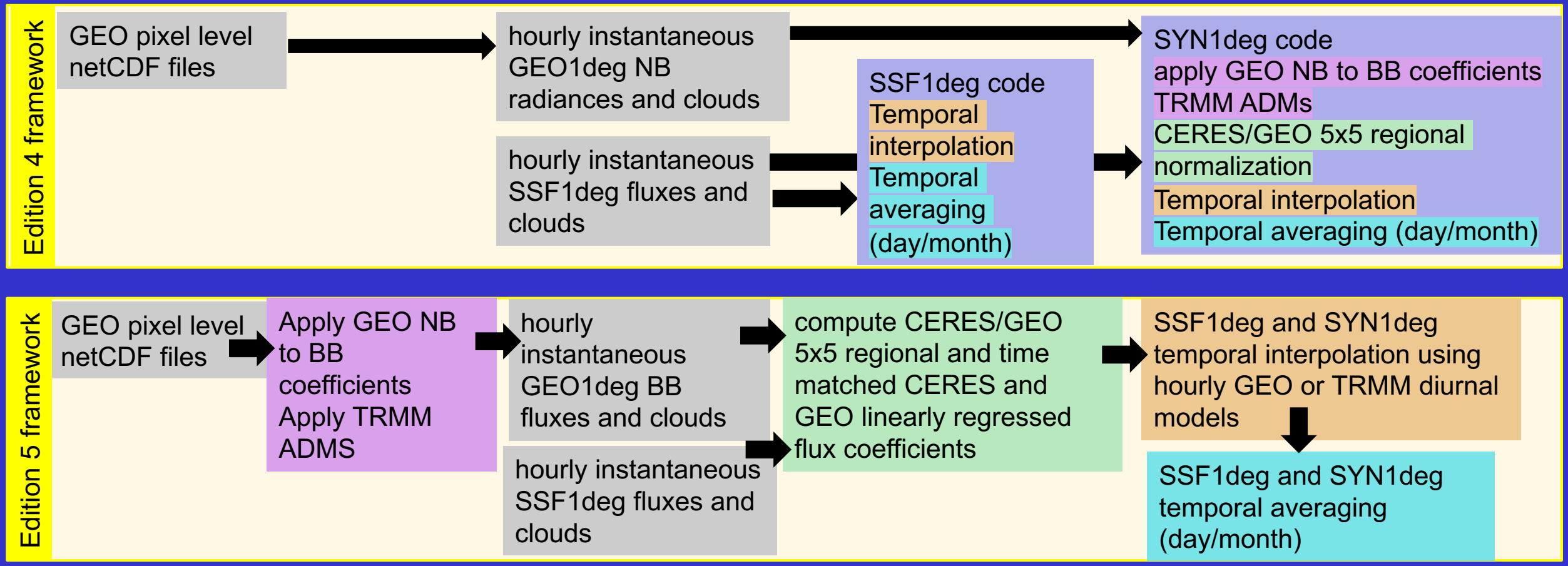
- Similar to N20, the Aqua footprint flux normalization FBCT fluxes are more consistent
- As expected, the Aqua biases are reversed from the N20 FBCT biases
- The LW footprint flux normalization also shows more consistent FBCT fluxes, however the LW biases are smaller than the SW

SYN1deg Ed4B product

- GEO reprocessing of the entire (2000-2022) for greater computed flux and cloud consistency across the record
  - Met 8,9 and 10 reprocessed 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
- Code bug fixes
- Consistent GEO boundaries
- Should be publicly available in summer 2023

Ed5 framework

CERES/GEO flux regional normalization
Test of the TISA Ed5 coding framework



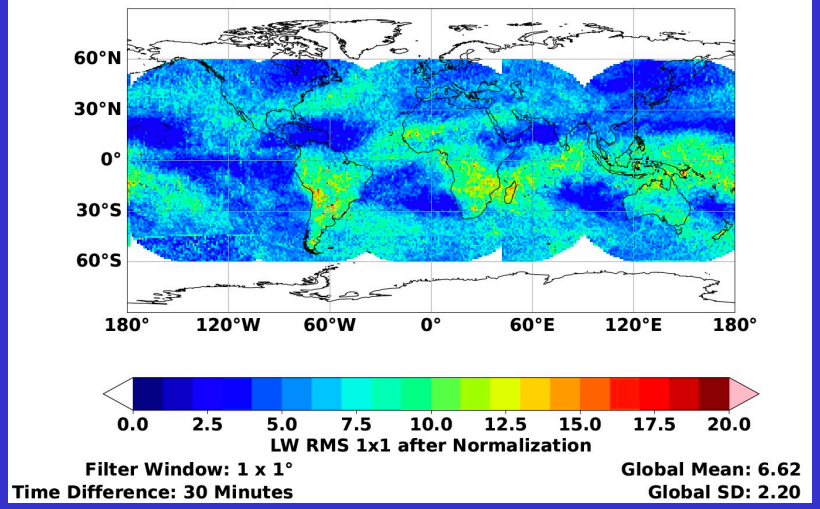
- Edition 5 framework allows flexibility in using multiple GEO channels for NB to BB and scene types
- The CERES/GEO stand alone code allows validation of the GEO NB to BB derived fluxes as well as flexibility in deriving CERES/GEO normalization coefficients outside of the TSI code framework
- Splitting the temporal interpolation and averaging algorithms allows both SSF1deg(no GEO) and SYN1deg (with GEO) to processed with the same code as well as facilitating SARB and FlashFLUX processing

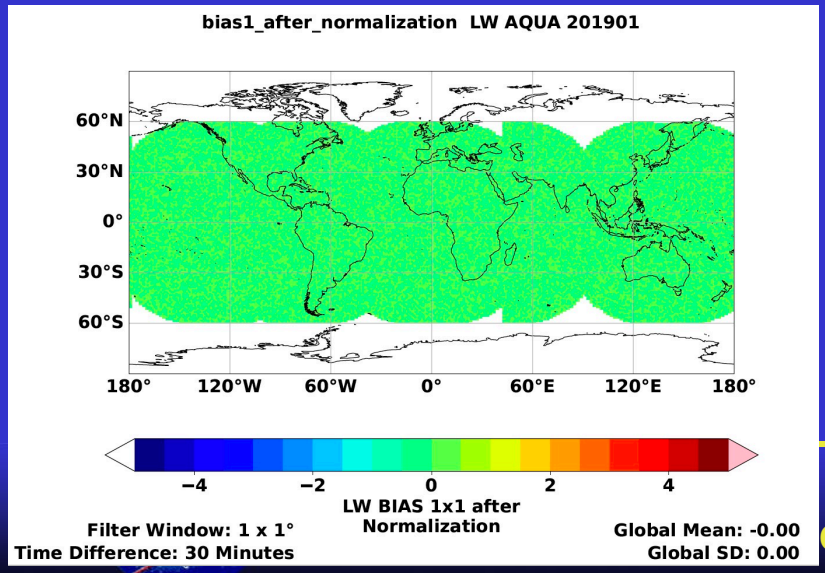
CERES/GEO regional monthly normalization

- For each 1deg region save the coincident within 30 minutes CERES and GEO derived fluxes
- For each 1 degree, use the surrounding regions that are from the same geostationary sensor and surface type
  - For Edition 4, use the surrounding 5x5 regions
- Perform the linear regression of the CERES and GEO fluxes to compute the radiometric scaling factors
- The Ed5 framework can now set the surrounding region domain, the time difference
  - The LW comparison is finished, working on the SW

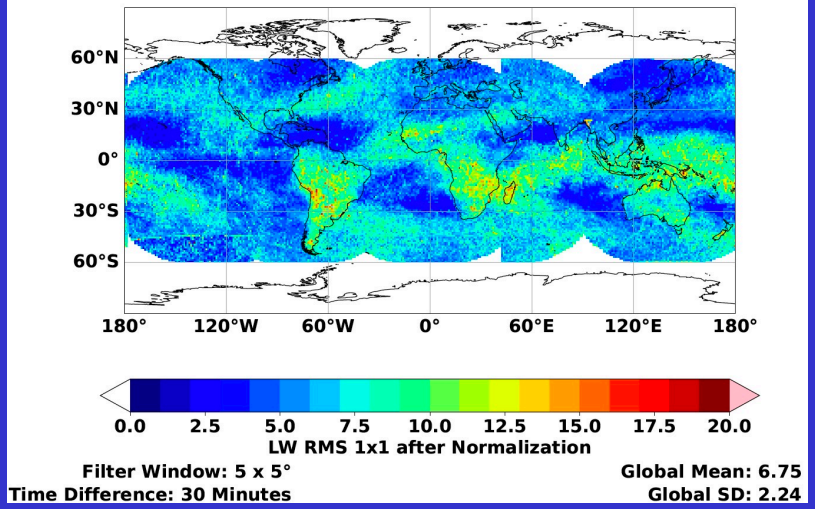
CERES/GEO regional LW flux normalization

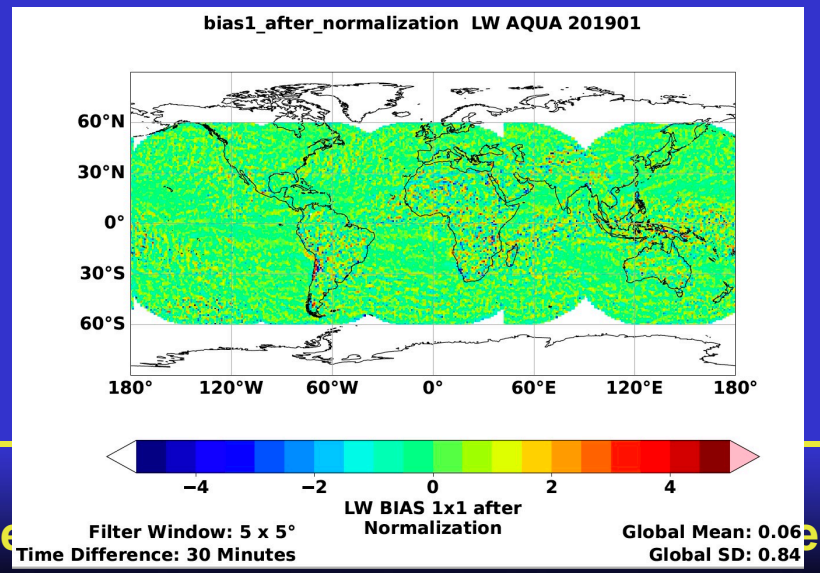
1x1 regional normalization, 30 min



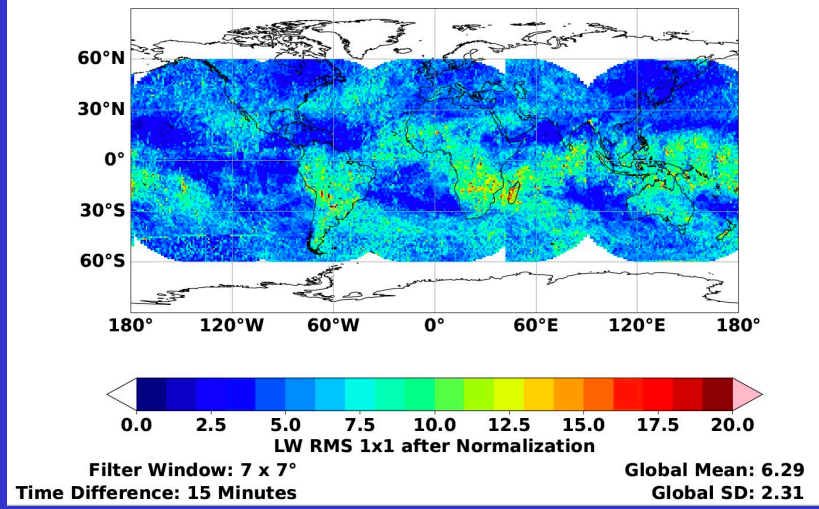


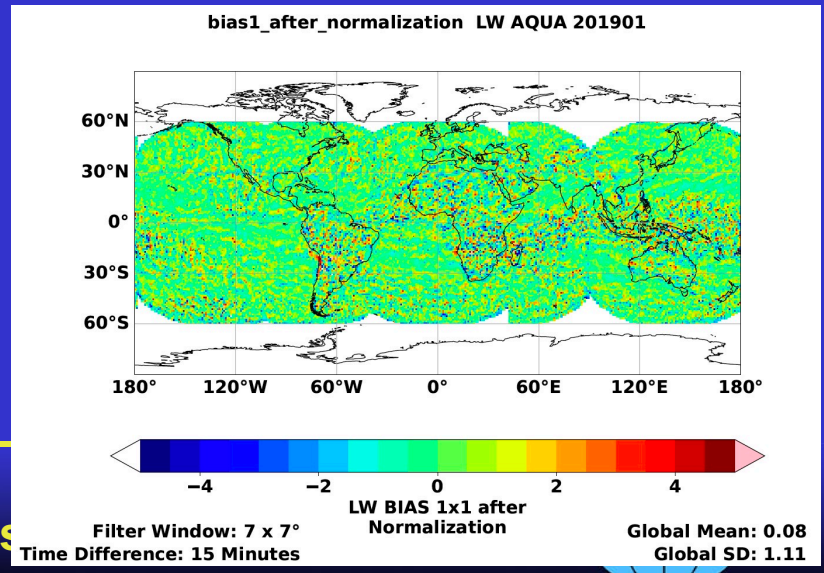
5x5 regional normalization, 30 min





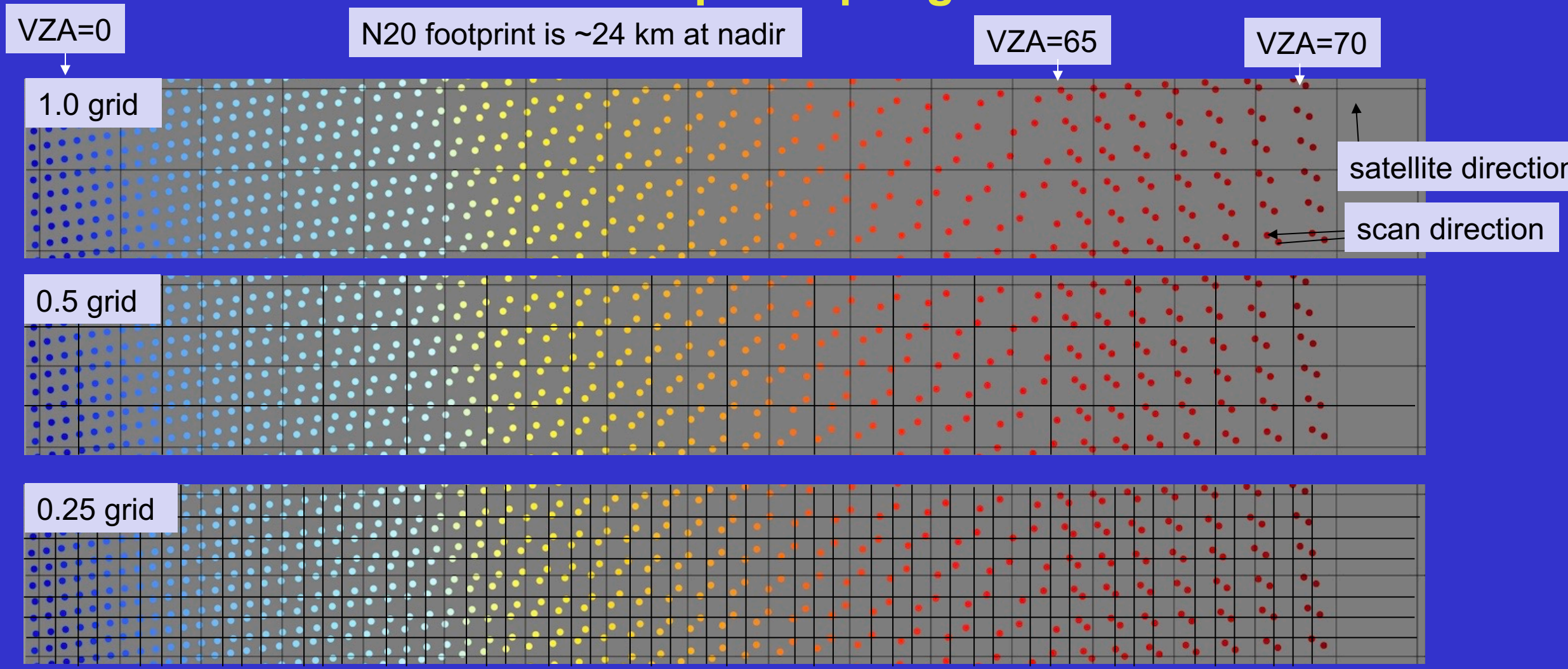
7x7 regional normalization, 15 min





GRID SYSTEMS

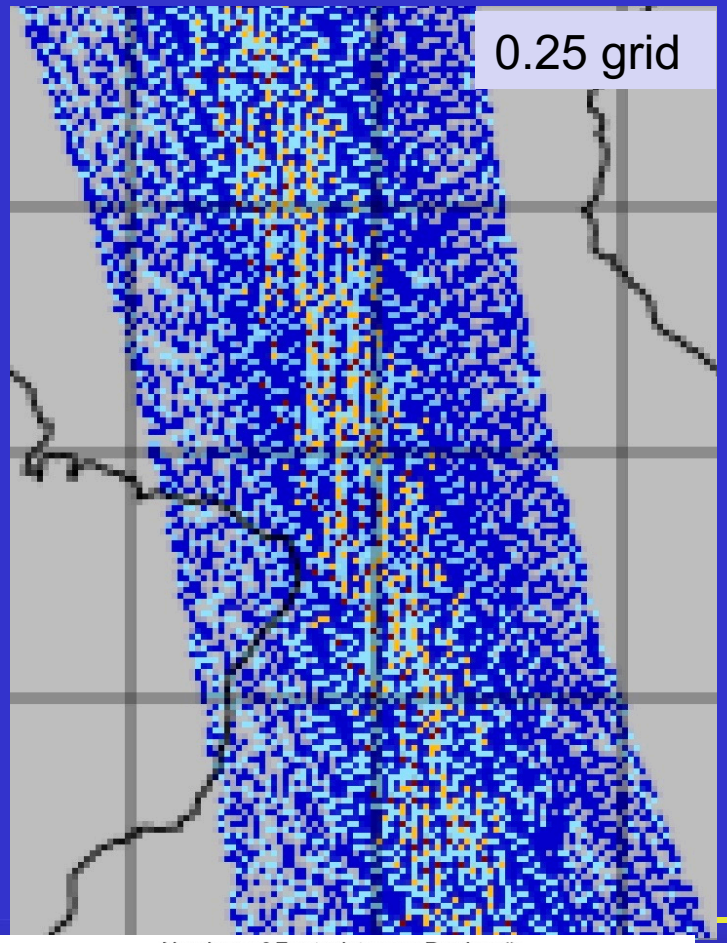
N20 Number of footprints per grid resolution



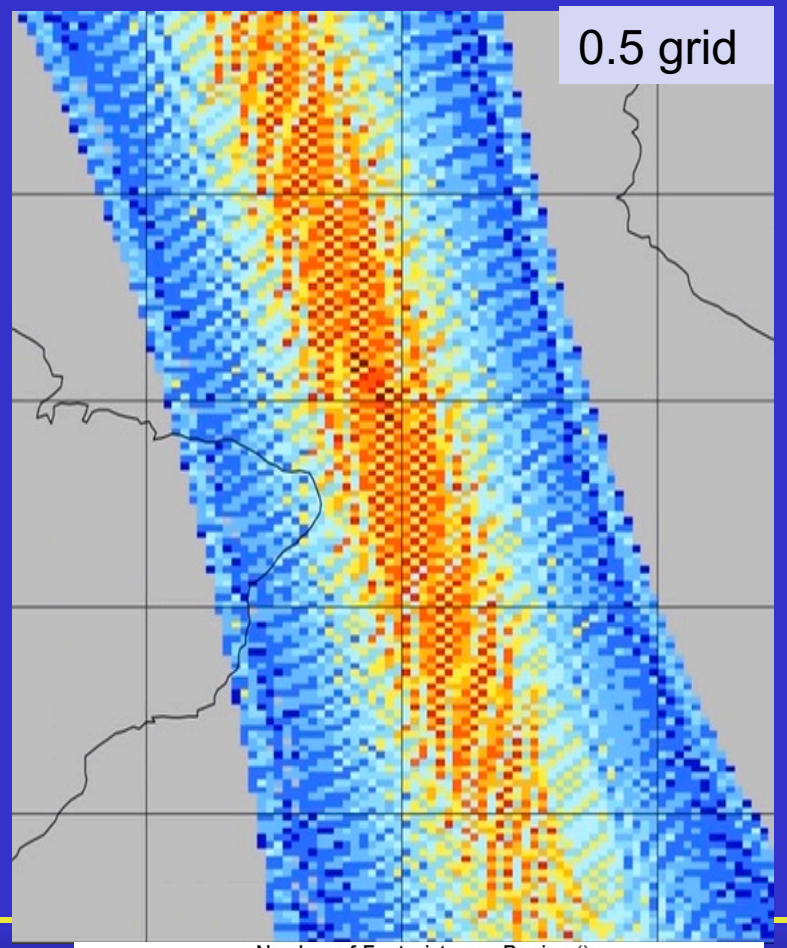
- For Ed4 every other CERES footprint is processed in SSF L2 product, except for VZA>65 then use all footprints
- Even though the footprint may straddle multiple regions, the footprint center determines the region

N20 Number of footprints per grid resolution

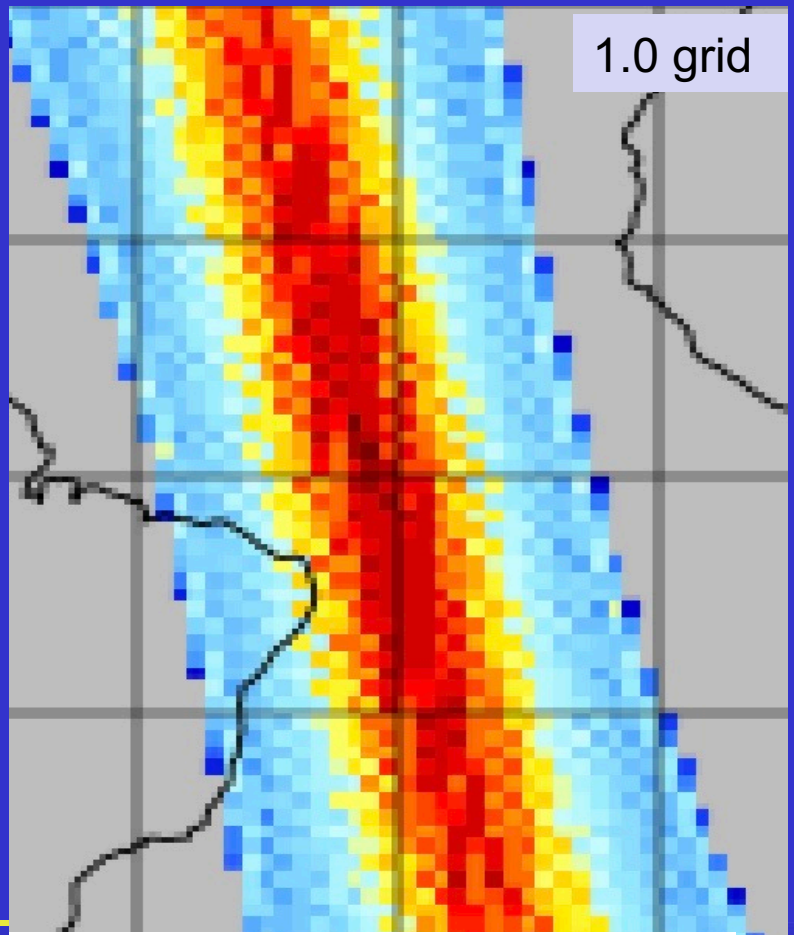
N20 footprint is ~24 km at nadir



range 1 to 4



range 1 to 10



range 1 to 33

Proposed Ed5 0.5 grid system

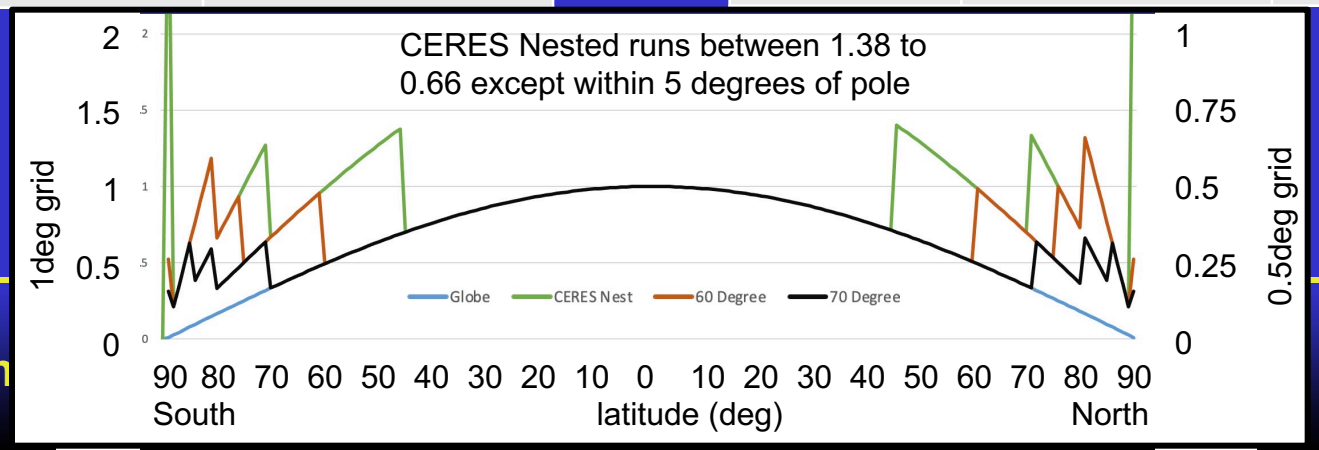
- The Ed4 1.0-degree grid system used every CERES footprint for VZA>65˚
- The Ed5 0.5-degree grid system will use every CERES footprint for VZA>45˚ to ensure that every region will have at least 2 footprints

Edition 4 grid system

latitude	Region size	Total regions
0-45	1.0x1.0	32400
45-70	1.0x2.0	9000
70-80	1.0x4.0	1800
80-90	1.0x8.0	810
89-90	1.0x360	2
total		44012

Edition 5 grid system

latitude	Region size	Total regions
0-45	0.5x0.5	129600
45-70	0.5x1.0	36000
70-80	0.5x2.0	7200
80-90	0.5x4.0	3240
89-90	0.5x180	8
total		176048

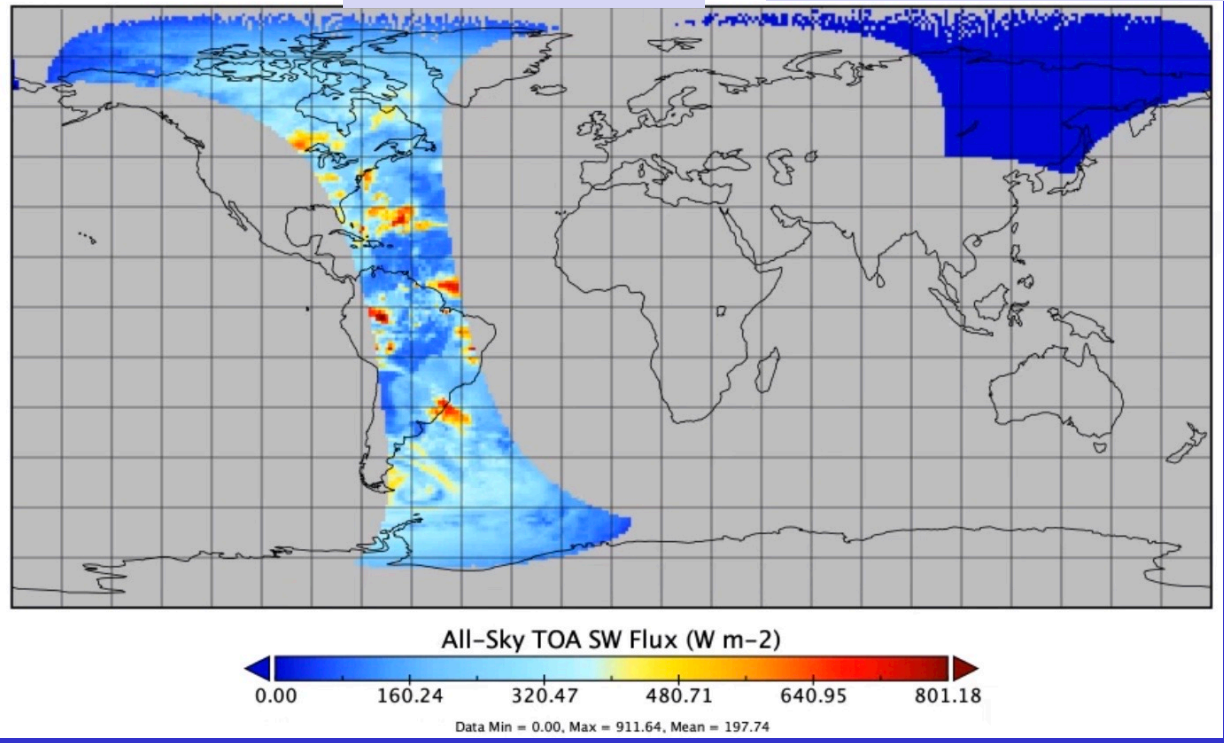


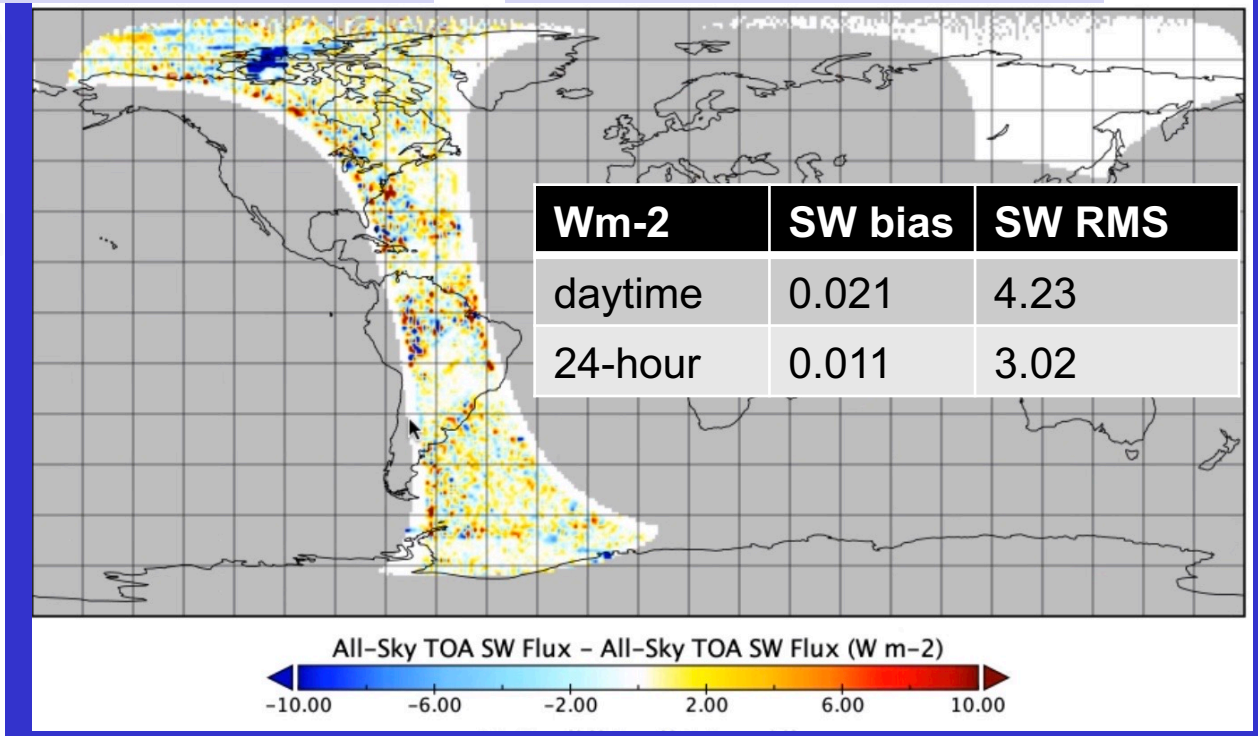
1deg Gridded Instantaneous RMS error using every and every other footprint

All-sky SW flux

1.0deg, N20 March 23, 2020 GMT=6-7

All-sky SW flux RMS error

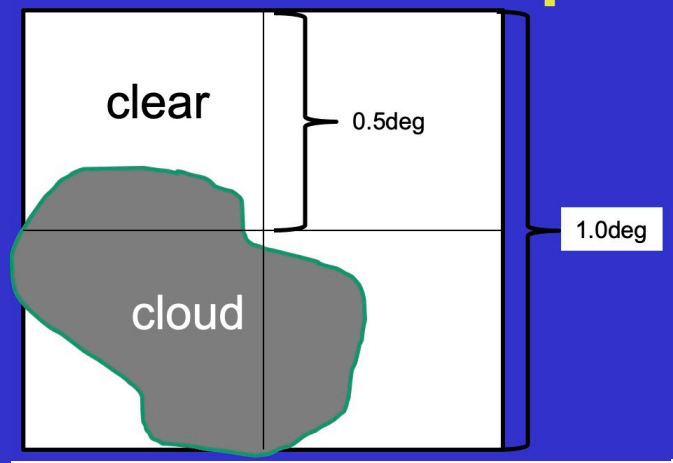


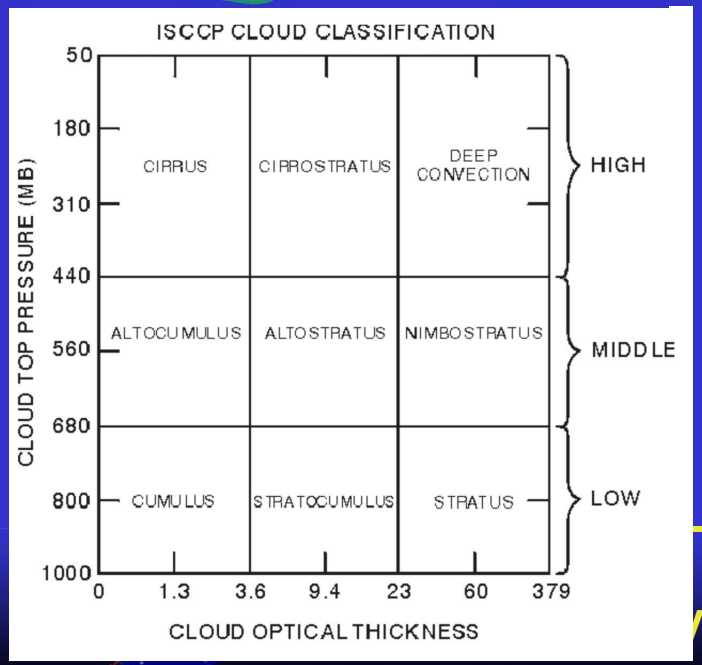


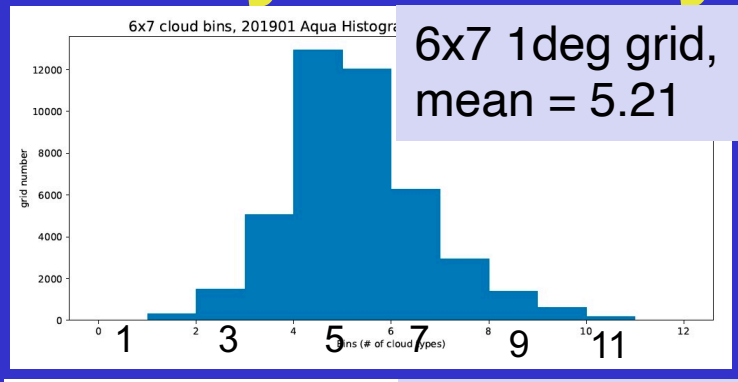
Wm-2	SW bias	SW RMS
daytime	0.021	4.23
24-hour	0.011	3.02

Wm-2	LW bias	LW RMS
daytime	0.0007	0.637
nighttime	0.0005	0.960
24-hour	0.0006	0.817

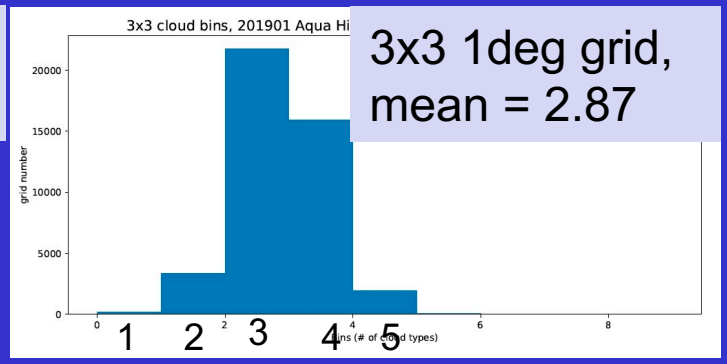
Cloud Type Frequency by grid resolution
Aqua January 2019 daytime



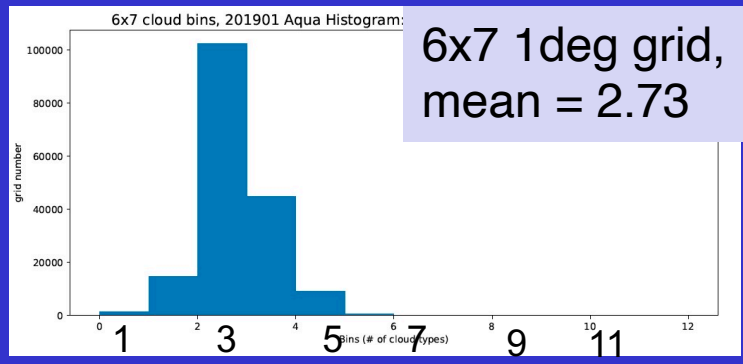




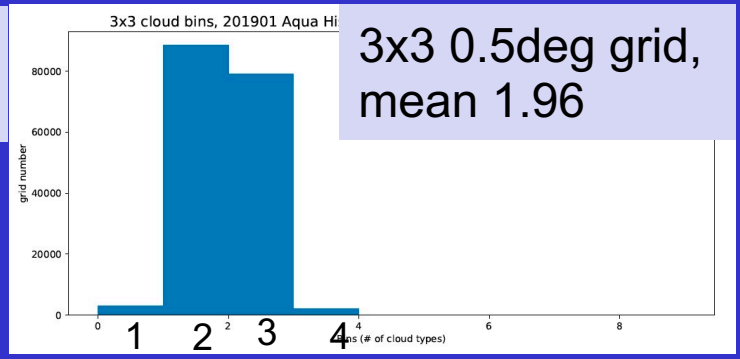
6x7 1deg grid, mean = 5.21



3x3 1deg grid, mean = 2.87



6x7 1deg grid, mean = 2.73



3x3 0.5deg grid, mean 1.96

±60° latitude	1x1 grid	0.5x0.5 grid	Data volume multiple
2x2 pc-tau	2.19	1.67	4*1.67/2.19 = 3.05
3x3 pc-tau	2.87	1.96	4*1.96/2.87 = 2.73
7x6 pc-tau	5.21	2.73	4*2.73/5.21 = 2.10
3-layers	1.98	1.61	4*1.61/1.98 = 3.25
4 layers	2.26	1.74	4*1.74/2.26 = 3.08