TISA Working Group Report

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27th CERES-II Science Team Meeting

16-18 May, 2017, LaRC, Hampton, VA, 23681

TISA Delivery Schedule

- CldTypHist released in March 2017
- SSF1deg-lite and SYN1deg-lite delivered in Feb 2017
  - used to generate the EBAF-TOA product
- SSF1deg Ed4 delivered in April 2017
  - Redelivered to be more consistent with the SSF1deg-lite improvements
- SYN1deg Ed4 to be delivered in May 2017
  - Redelivered to be consistent with the SYN1deg-lite improvements
  - clouds not changed to facilitate EBAF-surface processing
- FluxbyCloudType Ed4 to be delivered in August 2017
  - Update Ed3 code with the new variables and with new NB to BB and ADM codes
- Work on code improvements

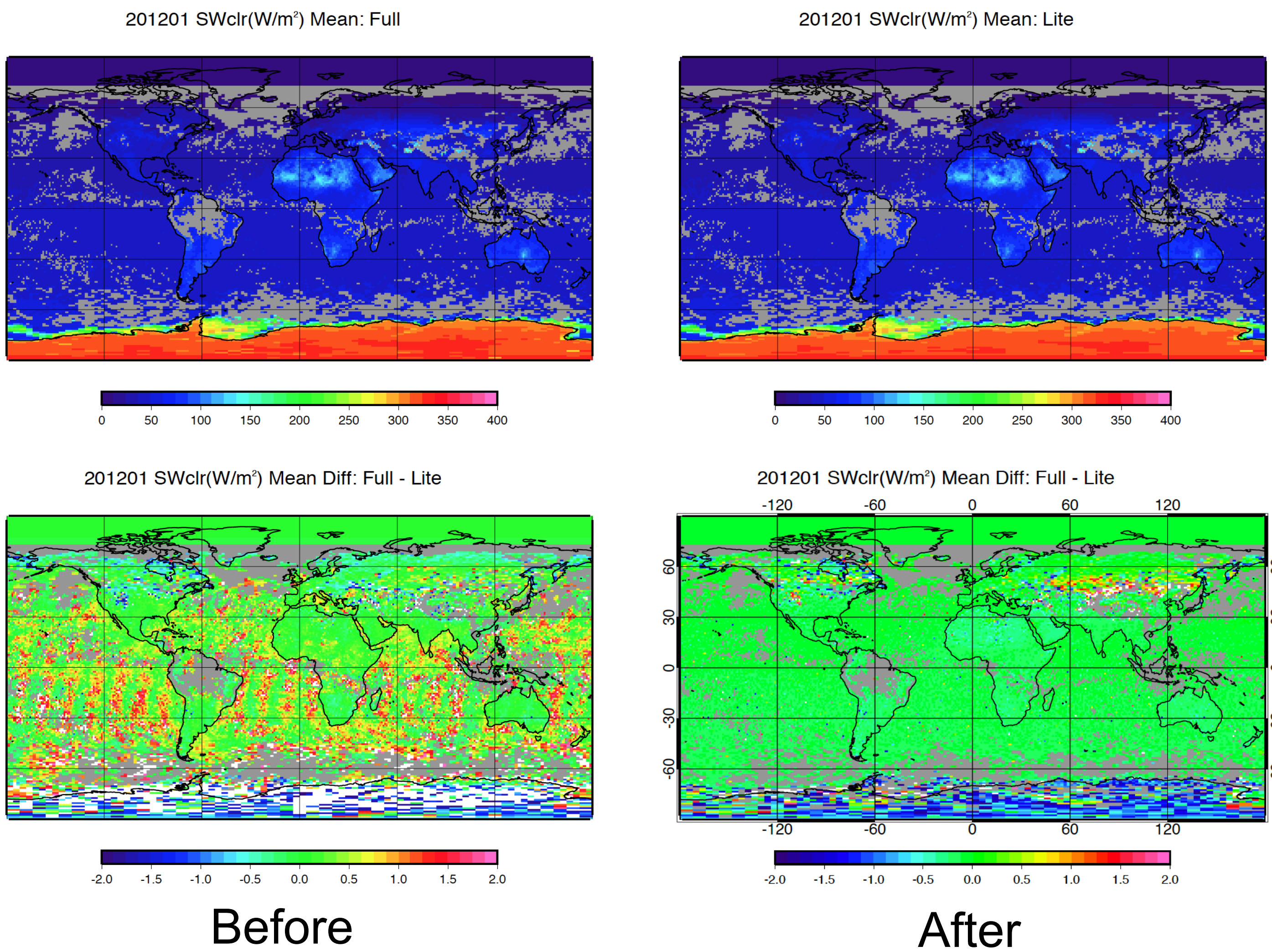
Objective

- For many TISA products, to make them internally consistent with each other for variables that are calculated through similar procedures but with different source codes.
- Apply the improvements from the Lite products (used as EBAF inputs) which have fast update cycles to the Full versions like SYN1Deg Full and SSF1Deg Full.
- Rewrite source codes for better readability, same shared subroutines and functions, robust coding, stability and easier code maintenance, etc.

SSF1Deg Full Ed4 New Delivery

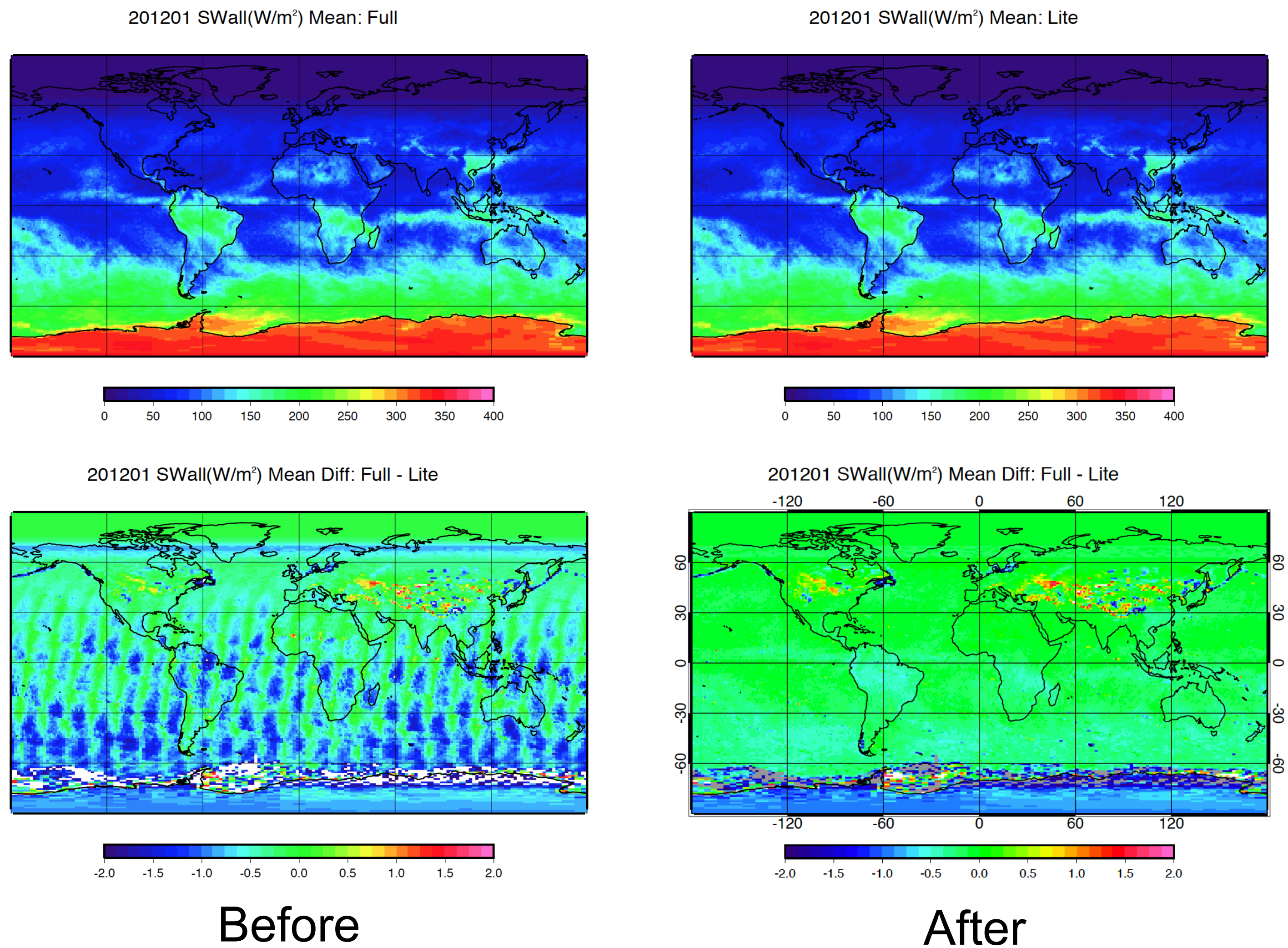
- SWclr
  - In SSF1DegFull, when hourly albedos adjusted by the albedo at the CERES observed hour, add one constraint as follows. This eliminates wave pattern difference vs. Lite
    - when ratio = $alb_{hr}/alb_{ceres\_hr} > 1$, then make $alb_{hr} = alb_{ceres\_h}$
  - New snow/ice directional model
- SWall
  - Before update, in SSF1DegFull, the albedo adjustment is calculated on each of the 20 ADM scene types. Now, the adjustment is first calculated as the ratio of the sum of all 20 ADM scenes and then applied to the adjustment, similar to Lite version. This eliminates wave pattern difference vs. Lite
  - New snow/ice directional model
- LW (Clear and All sky)
  - No new changes

SSF1Deg Full vs. Lite: SWclr 201201



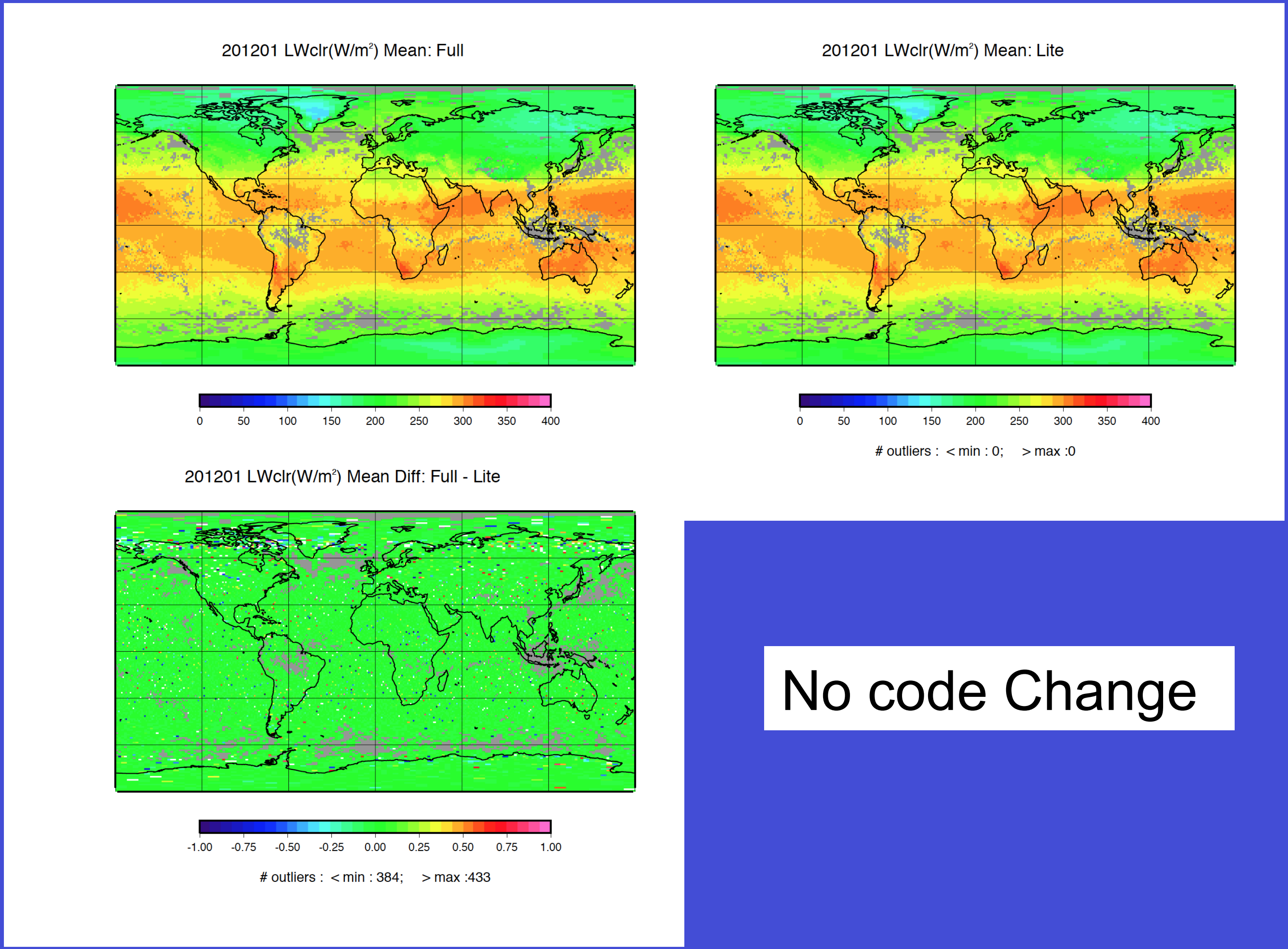
In SSF1DegFull, when hourly albedo adjustment adds one constrain as Lite does. It eliminates wave pattern difference vs. Lite.

SSF1Deg Full vs. Lite: SWall 201201



The hourly albedo adjustment is first calculated as the ratio of the sum of all 20 ADM scenes and then applied to the adjustment, similar to Lite version. This eliminates wave pattern difference vs.Lite.

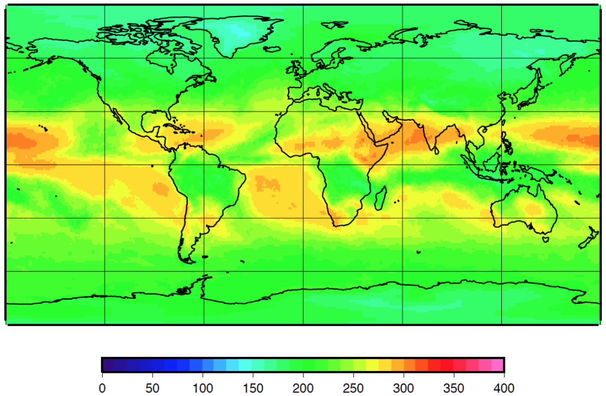
SSF1Deg Full vs. Lite: LWclr 201201



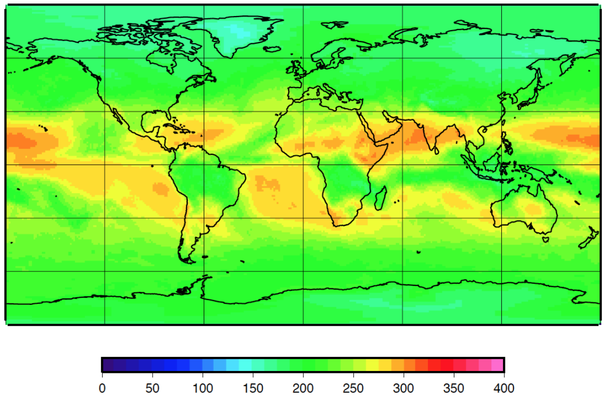
No code Change

SSF1Deg Full vs. Lite: LWclr 201201

201201 LWall(W/m²) Mean: Full

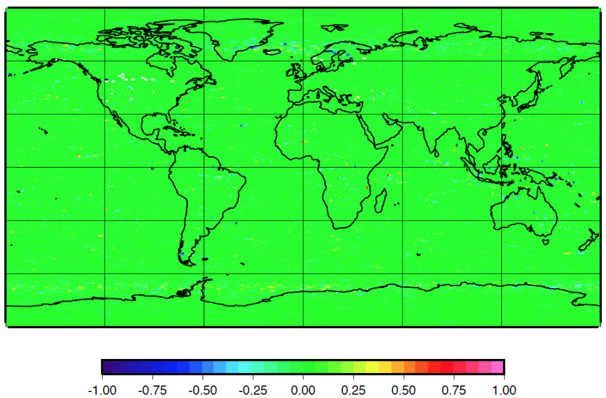


201201 LWall(W/m²) Mean: Lite



outliers : < min : 0; > max :0

201201 LWall(W/m²) Mean Diff: Full - Lite



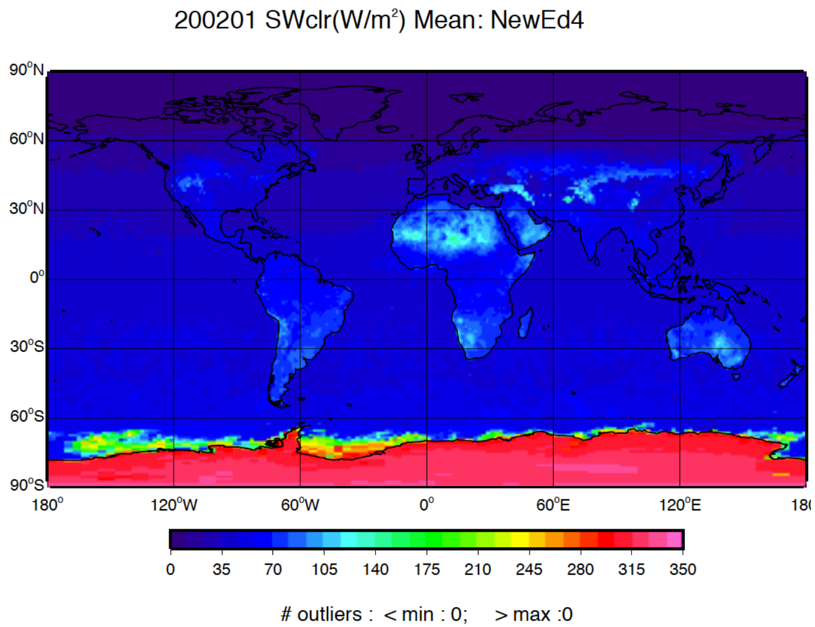
outliers : < min : 38; > max :28

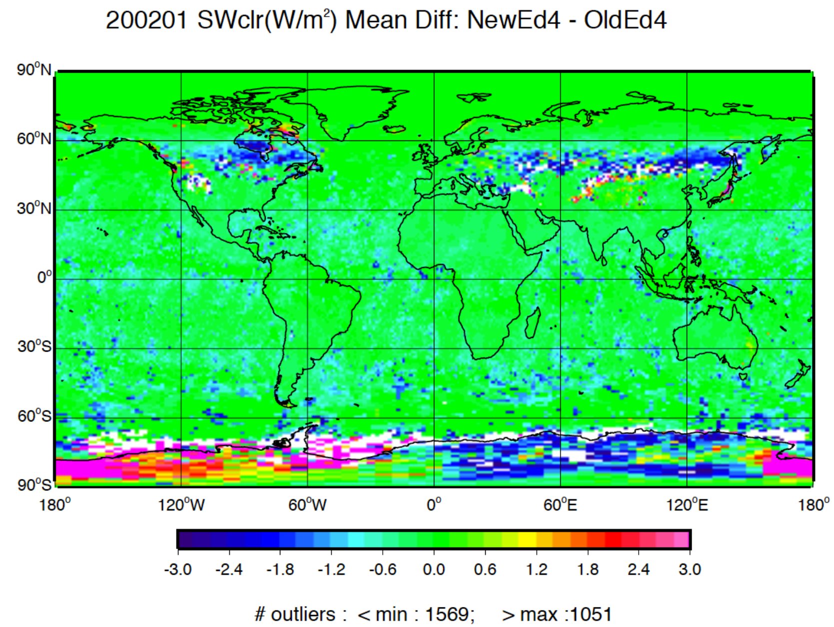
No code Change

SYN1deg New Update

- SWclr
  - New directional model over snow/ice regions
- SWall
  - New directional model over snow/ice regions
  - Only calculate and use GGEO fluxes with SZA < 60^o
- LWclr
  - Updated GGEO LW NB2BB model
- Lwall
  - Bug fix to total IR channel radiance.
  - Linearly interpolate NB2BB coefficients between different angle bins.

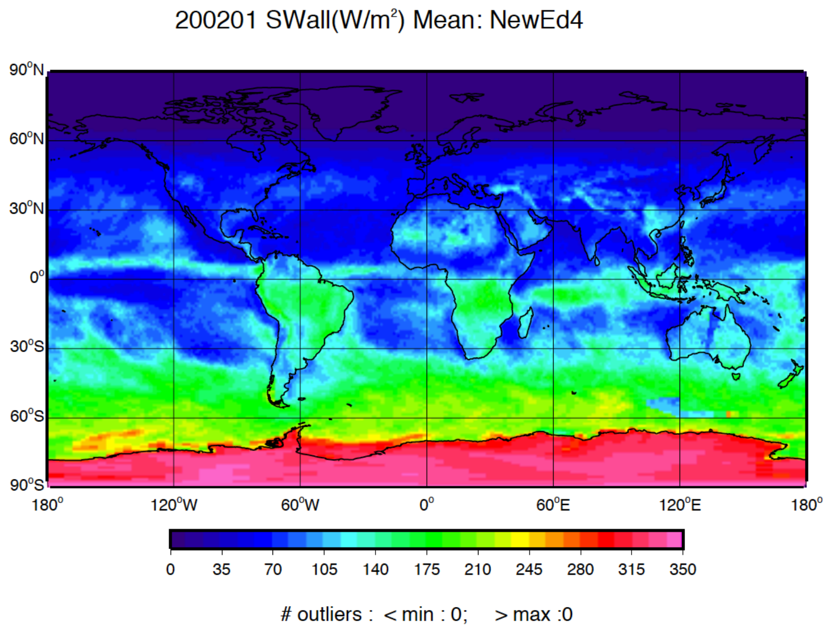
SYN1deg New Update

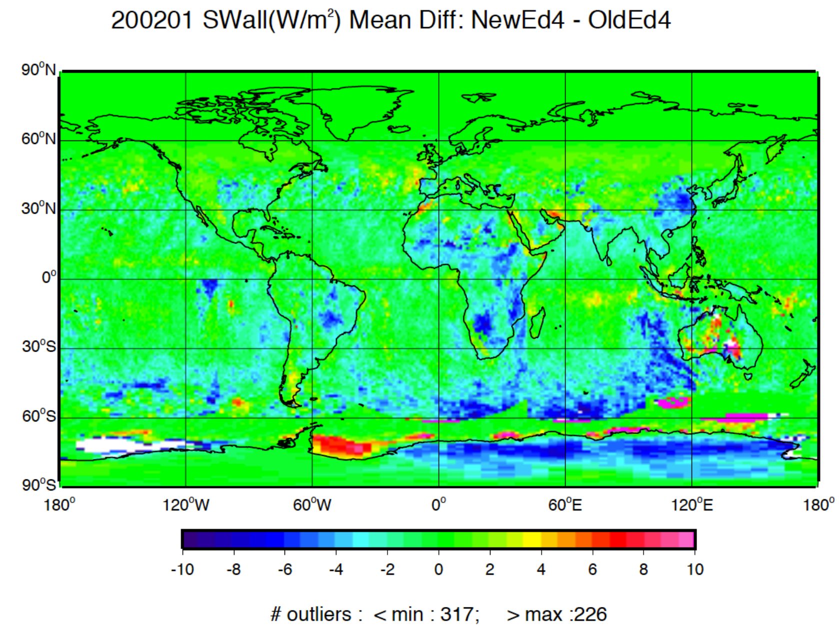




New directional model over snow/ice regions

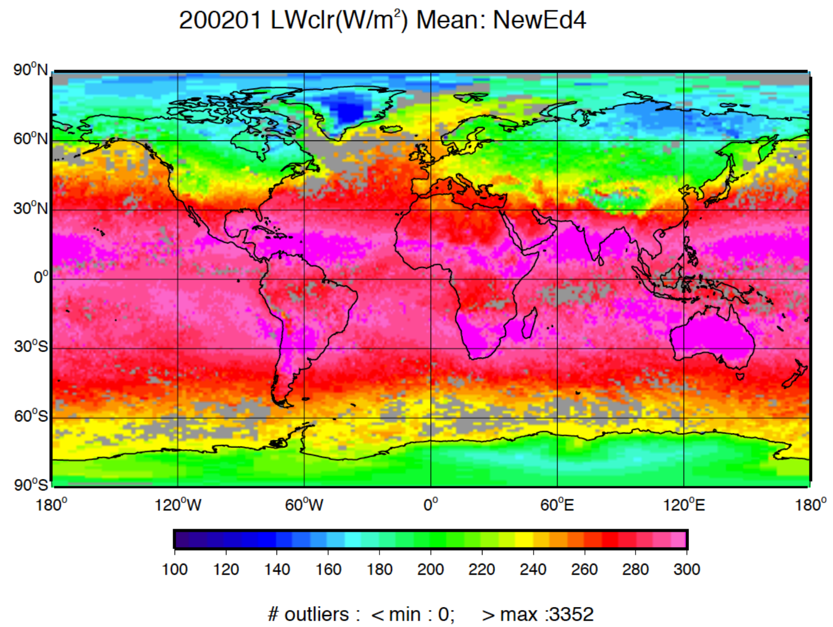
SYN1deg New Update

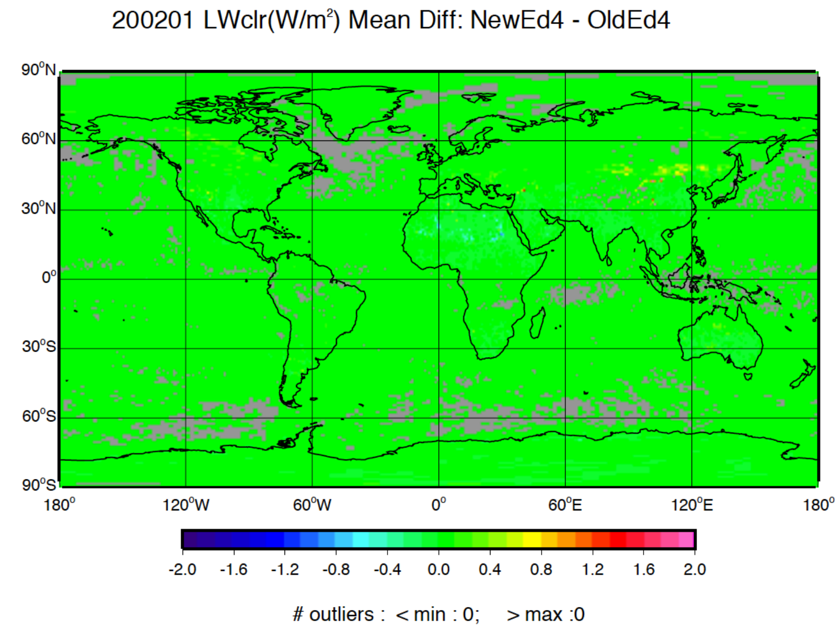




- New directional model over snow/ice regions
- Only calculate and use GGEO fluxes with SZA < 60°

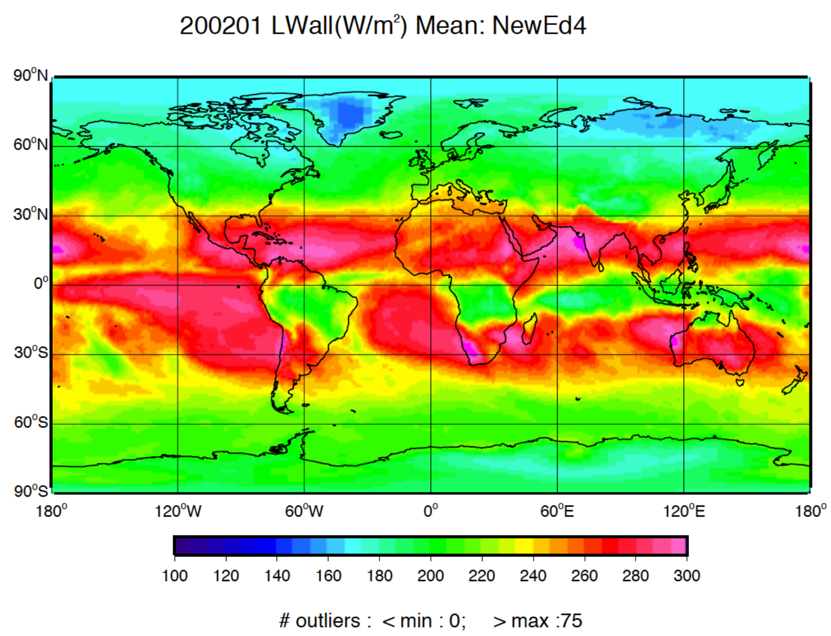
SYN1deg New Update

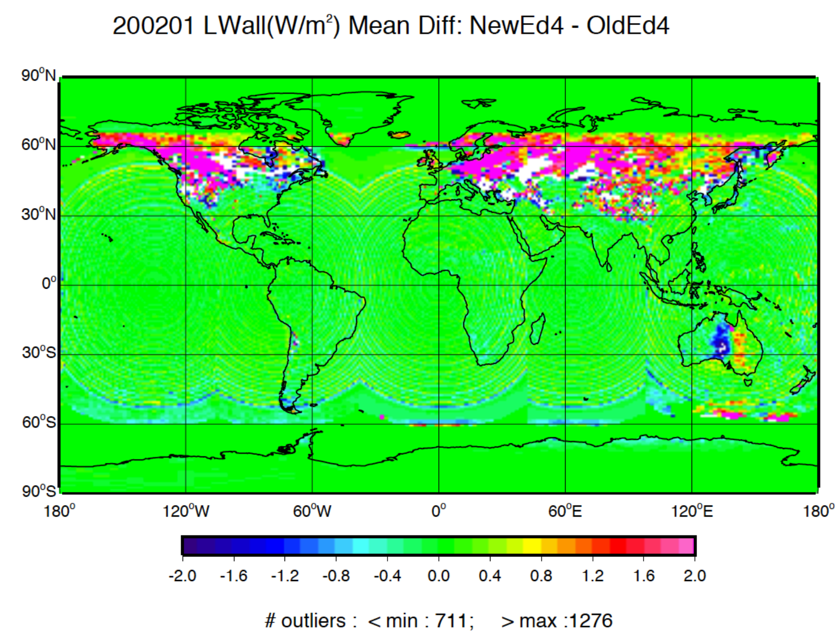




No code difference

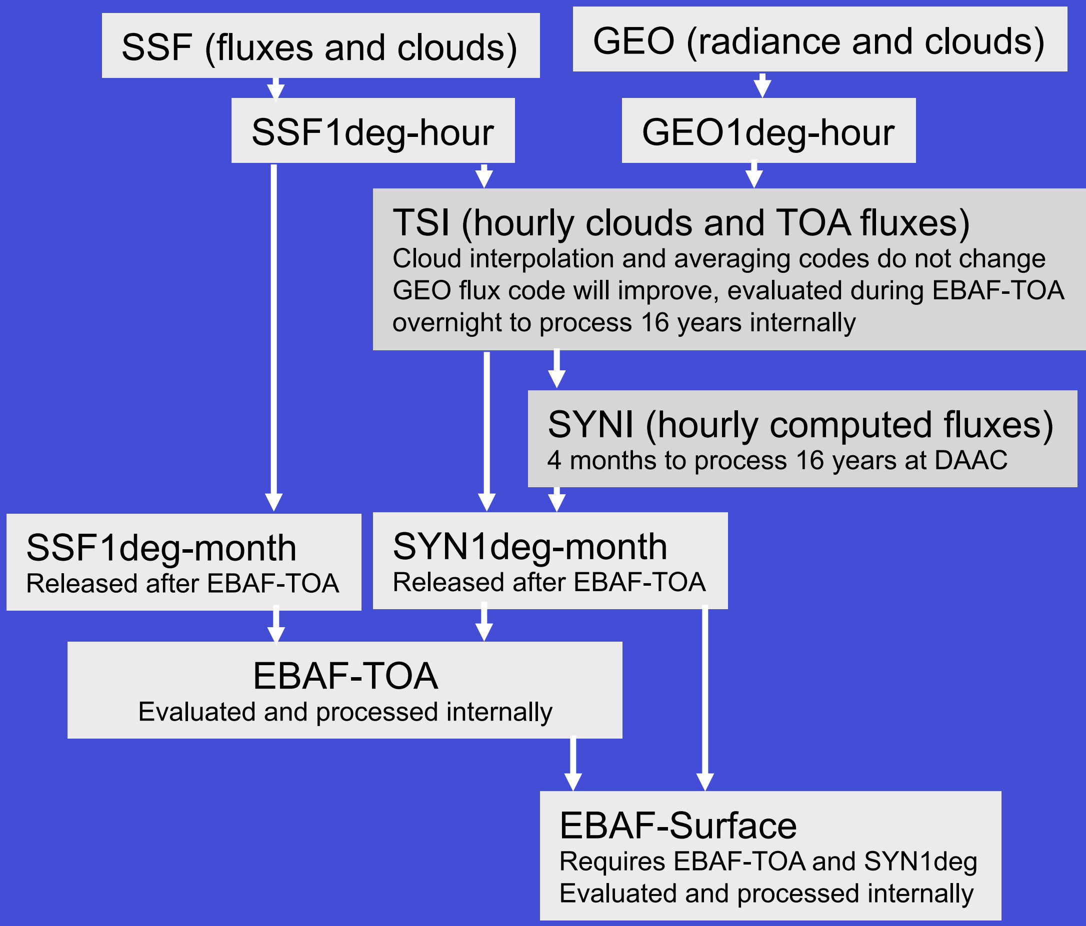
SYN1deg New Update





- Bug fix to total IR channel radiance.
- Linearly interpolate NB2BB coefficients between different angle bins.

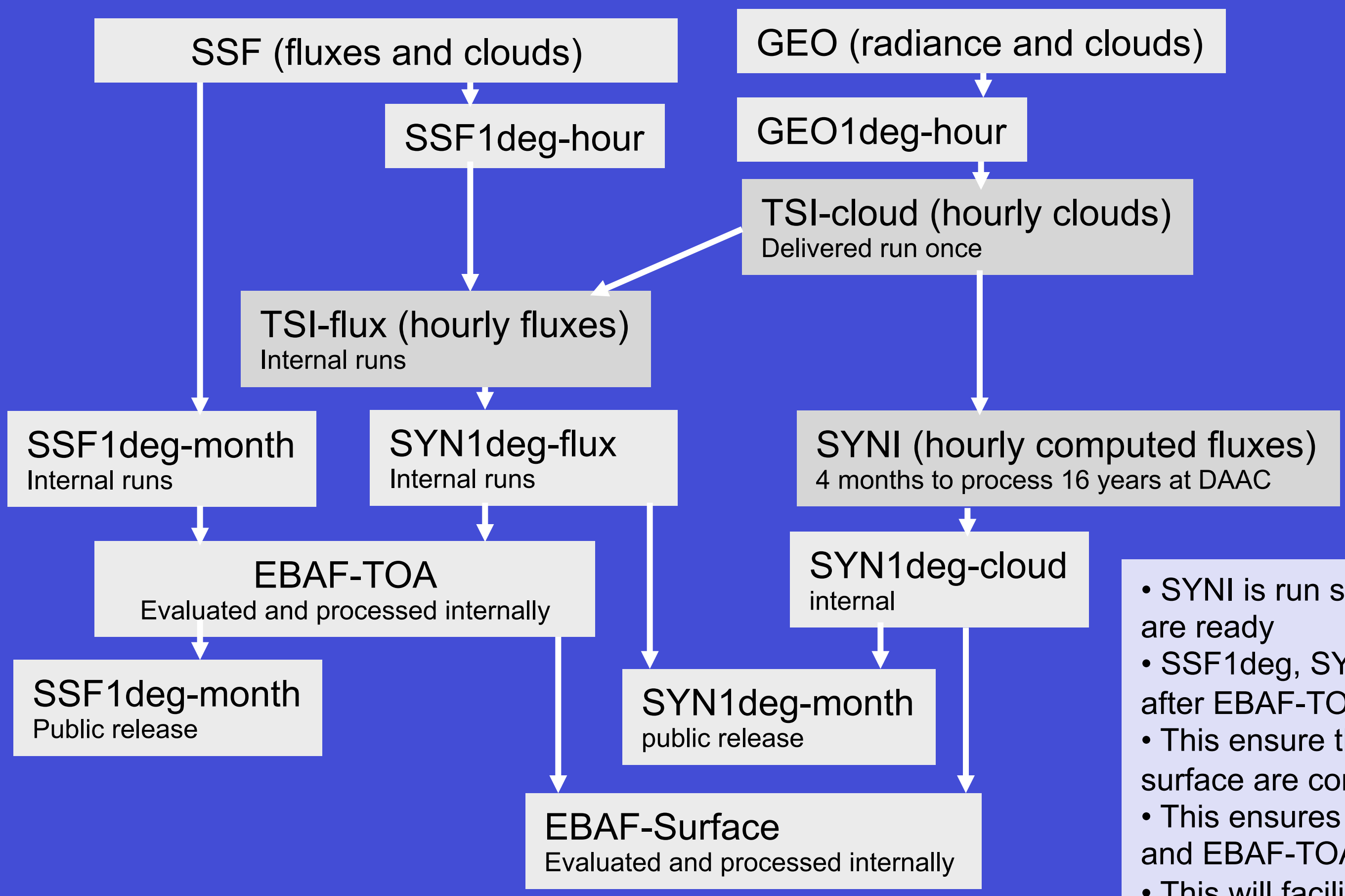
Ed4 processing



GEO derived fluxes is TISA main effort
CERES-only code changes depend on new directional models

Can only be processed at the DAAC
TSI delivery required
TSI might need to be redelivered to improve GEO fluxes for EBAF-TOA

Future processing



- SYNI is run soon after SSF and GEO are ready
- SSF1deg, SYN1deg released soon after EBAF-TOA
- This ensure that SYNI and EBAF-surface are consistent
- This ensures that SSF1deg, SYN1deg and EBAF-TOA are consistent
- This will facilitate quick turn around time for EBAF-TOA and TISA SYN1deg runs

TISA Code Improvement Goals

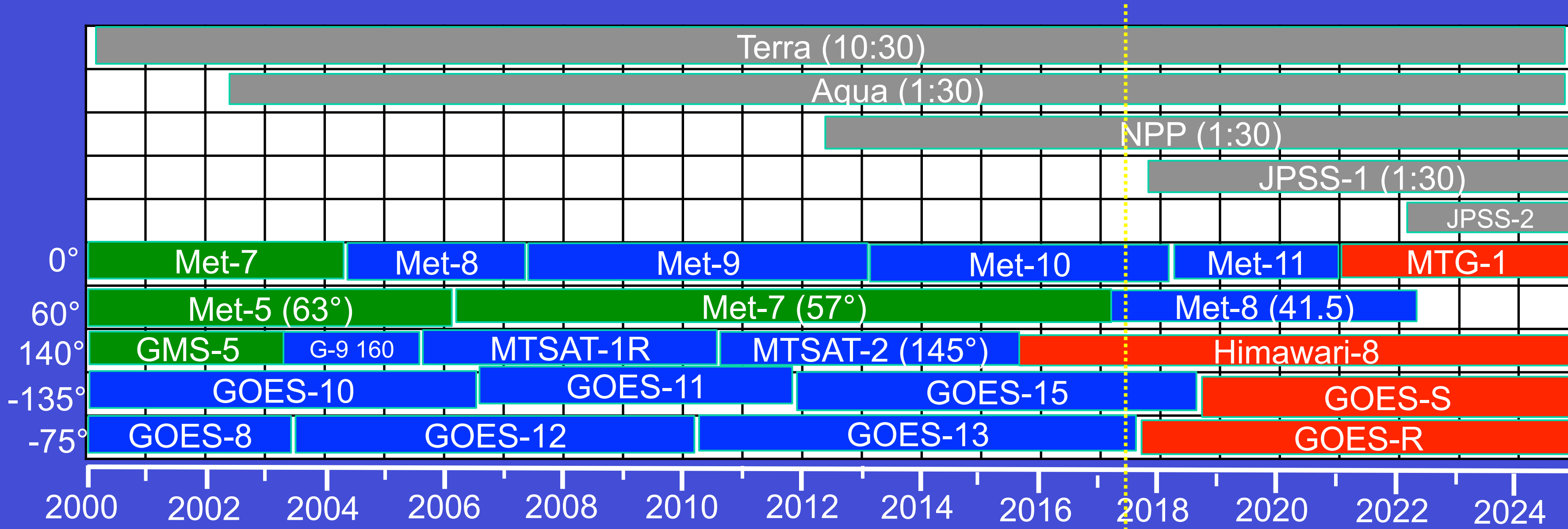
- All TISA code in version control
  - Anytime a dataset is placed on the CERES sub-setter the code is tagged with the dataset
  - Multiple programmers can work on the code simultaneously and then merge later
  - Science testing will not interfere with delivered code and the code can be tagged for future testing to specific case studies
  - All codes are in a repository, code differences between versions can be easily visualized and tracked
- Consistency of parameter names, units, and dimensioning (# of days in the month)
  - Ease the tracking of parameters through the code

TISA Code Improvement Goals

- Consolidate multiple instances of the same subroutine into libraries
  - Many subroutines are shared across multiple product codes
  - To ensure subroutine consistency through out the code
  - These prevents multiple reading of the same apriori input datasets
- Modularize the code
  - This provides the code frame work to allow multiple approaches to be developed and tested
  - The same modules can be used in multiple products
  - Flags can be set in the code to turn modules on and off to evaluate improvements
- Work with Katie and Jeff to implement CERES next generation processing framework across TISA codes

GEO STATUS

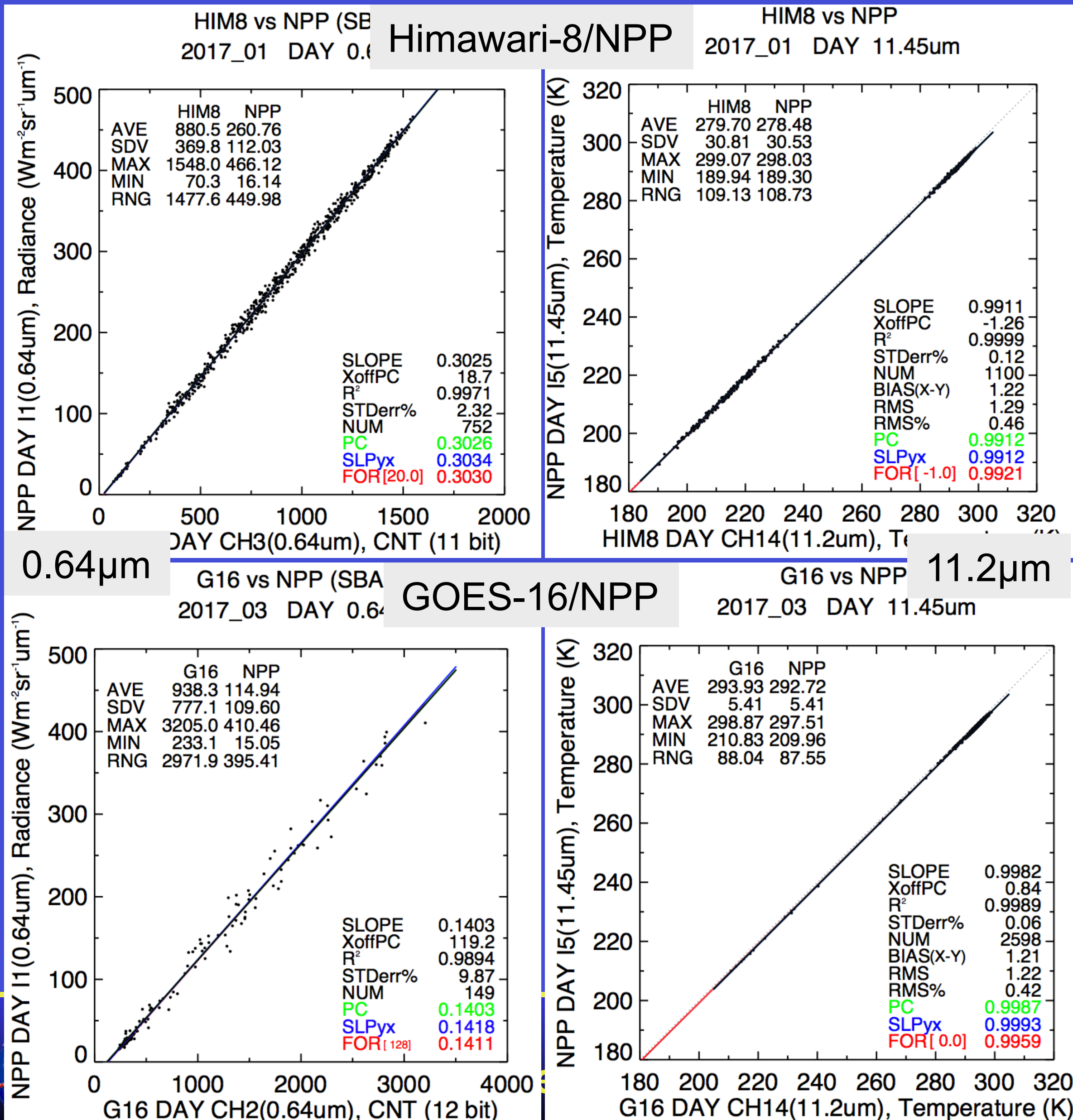
CERES record Geostationary Time Series



1st generation
2nd generation
3rd generation
MODIS/VIIRS

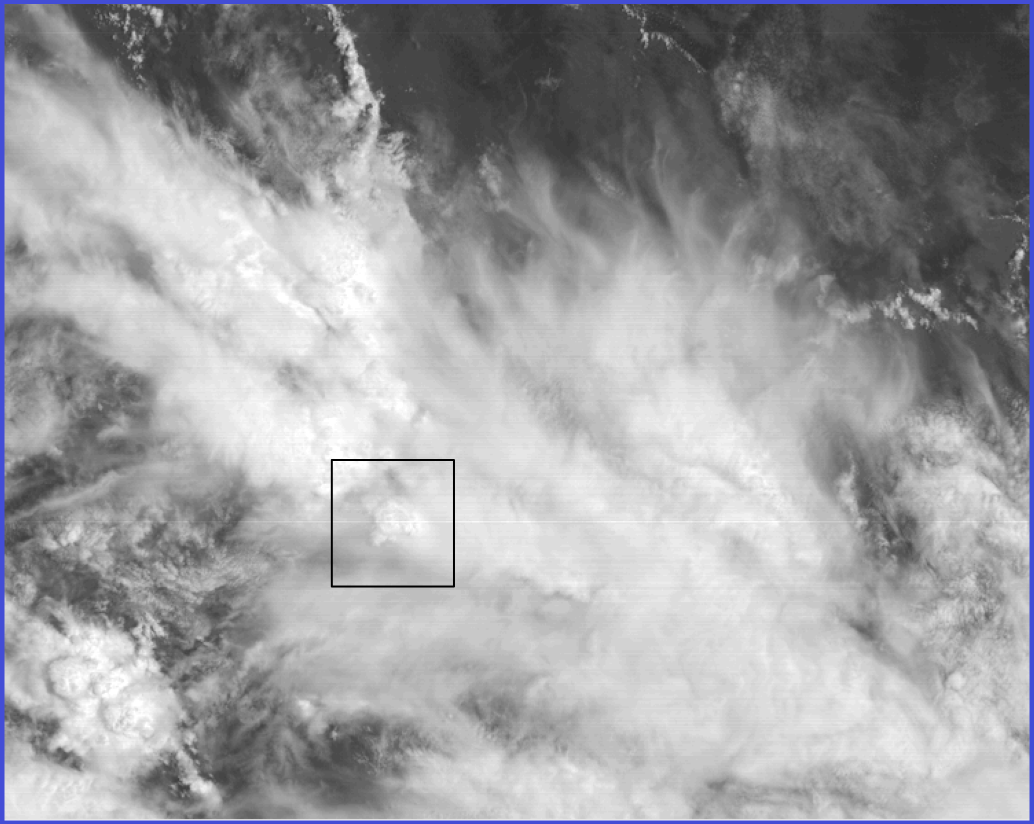
- INSAT-3DR (74E) launched Sept 8 , 2016, INSAT-3D (82E)
- Himawari-9 (140E) launched Nov 1, 2016, standby Him-8
- GOES-R launched Nov 19, 2016, GOES-S launch in 2018
- FY-4A (100E) launched Dec 10, 2016 (2nd generation Chinese)
- Met-7 (57E) decommissioned March 31, 2017
- Met-8 (41.5E) operational Oct 21, 2016
- JPSS-1 to launch in 4th quarter 2017, JPSS-2 in 1st quarter 2022
- Met-11 (0E) to replace Met-10 in March 2018

GOES-16 March 2017 NPP calibration checkout



- GOES-16 has 4X more visible noise than Him-8
- GOES-16/NPP IR calibration uncertainty is similar to Him-8
- The GOES-16 is available for testing. Still in commissioning phase
- We will re-calibrate when the instrument team

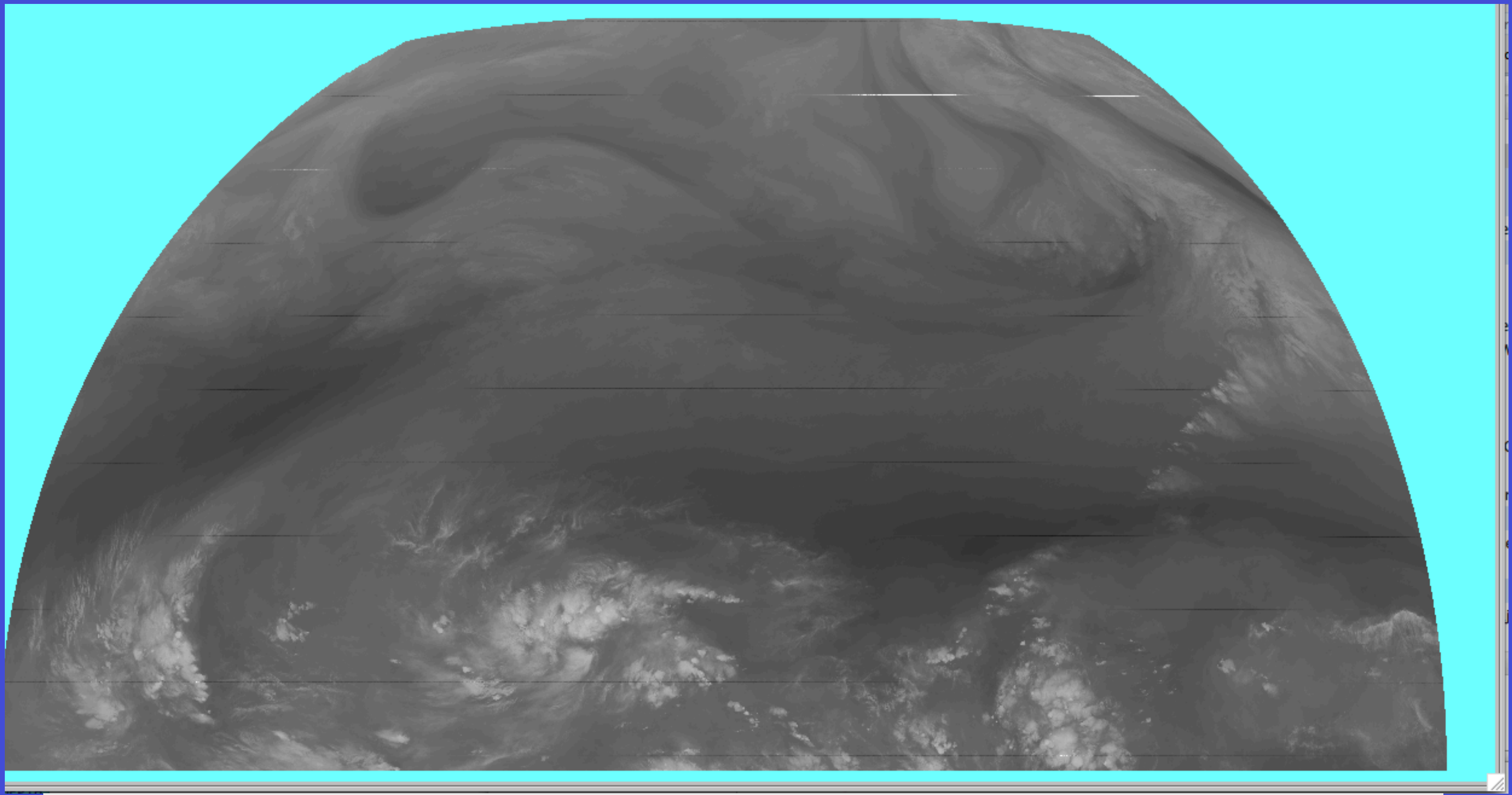
GOES-16 visible imager detector noise



GOES-16 has 0.5km resolution in the 0.64μm band
Twice the resolution of GOES-15

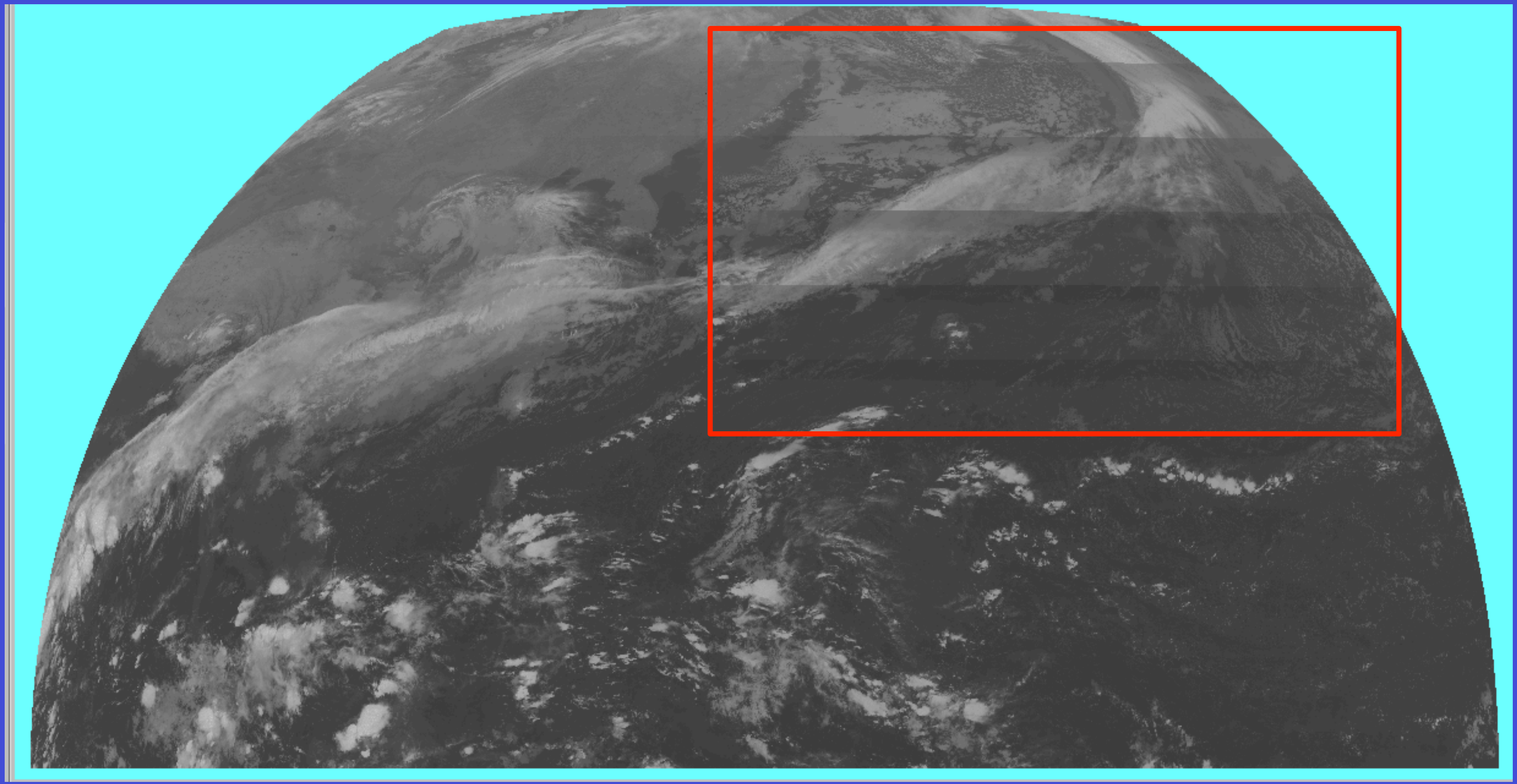
GOES-16 has 1000 detectors per scan
GOES-15 has 8 detectors per scan

Himawari-8 WV (6.7μm) image
Jan 6, 2017 19:30 GMT

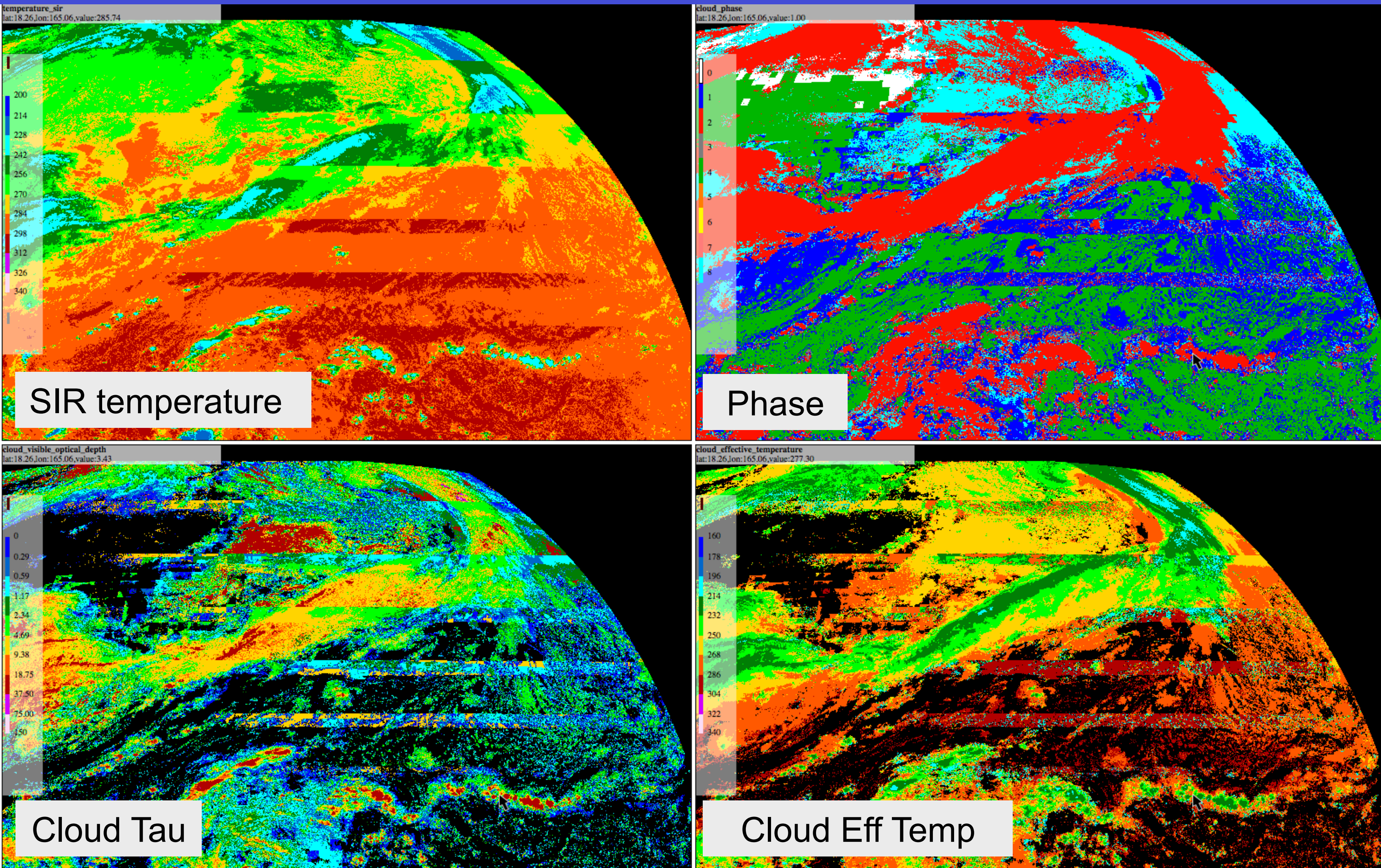


Even with the 3rd generation GEOs detector striping will still be a concern

Himawari-8 SIR (3.8µm) image
Oct 31, 2015, 14:30 GMT



Himawari-8 SIR (3.8μm) image
Oct 31, 2015, 14:30 GMT



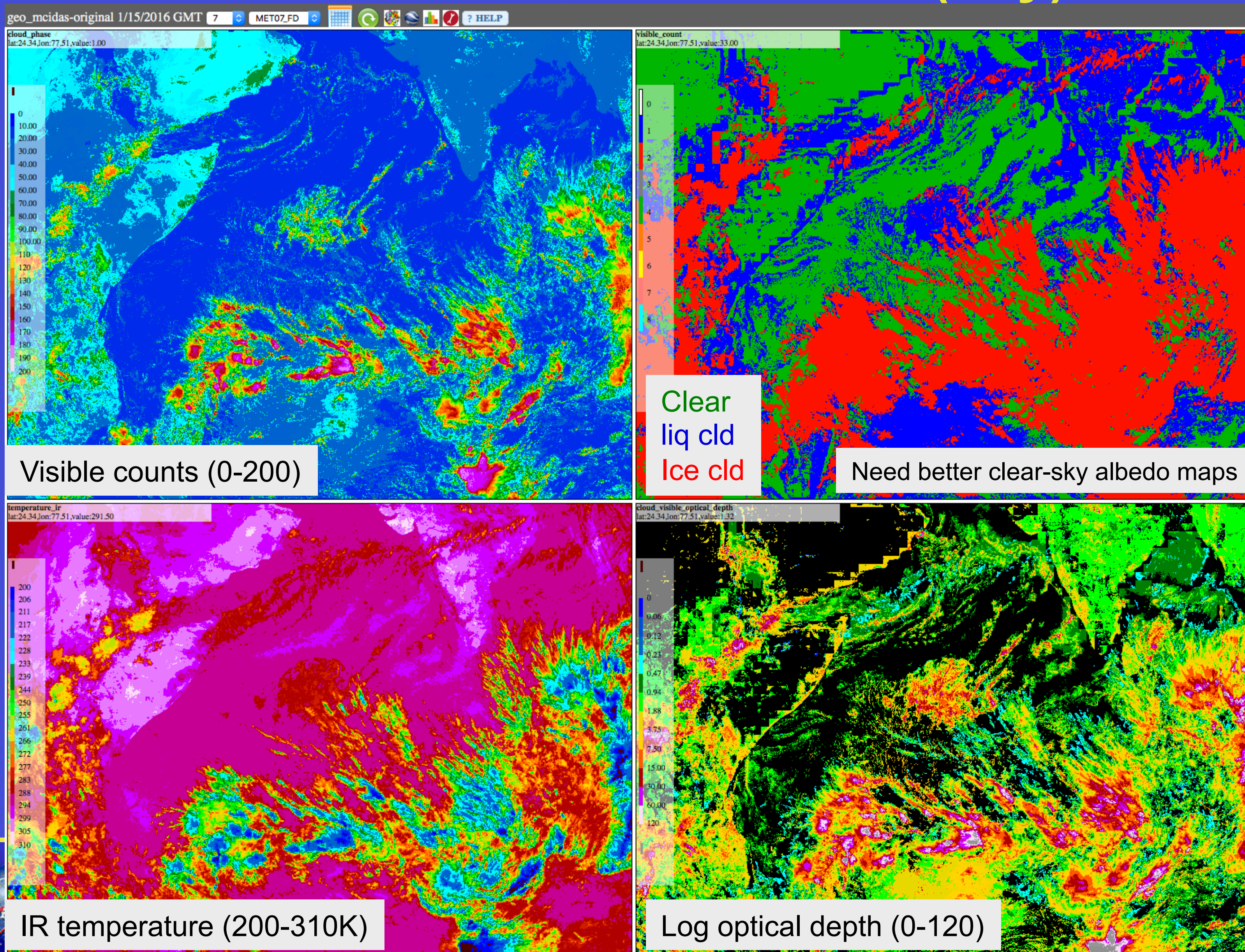
Met-7 to Met-8 transition

- Met-8 successfully moved to 41.5E and became operational on Oct 21, 2016
- Met-8 first 2nd generation satellite in the Indian Ocean
  - 11 channels, Met-5/7 only had a visible, WV and IR channel
- Met-8 has been routinely calibrated monthly against Aqua-MODIS since November 2016
- Met-8 had a de-icing event that resulted in a data gap in Jan 17-22, 2017
- Met-7 had a de-icing event Mar 10-13, 2017
- Cloud group working on cloud retrieval code
  - Focusing on land snow regions using the 1.6µm channel
- Begin Met-8 processing Mar 2017 for Ed4A

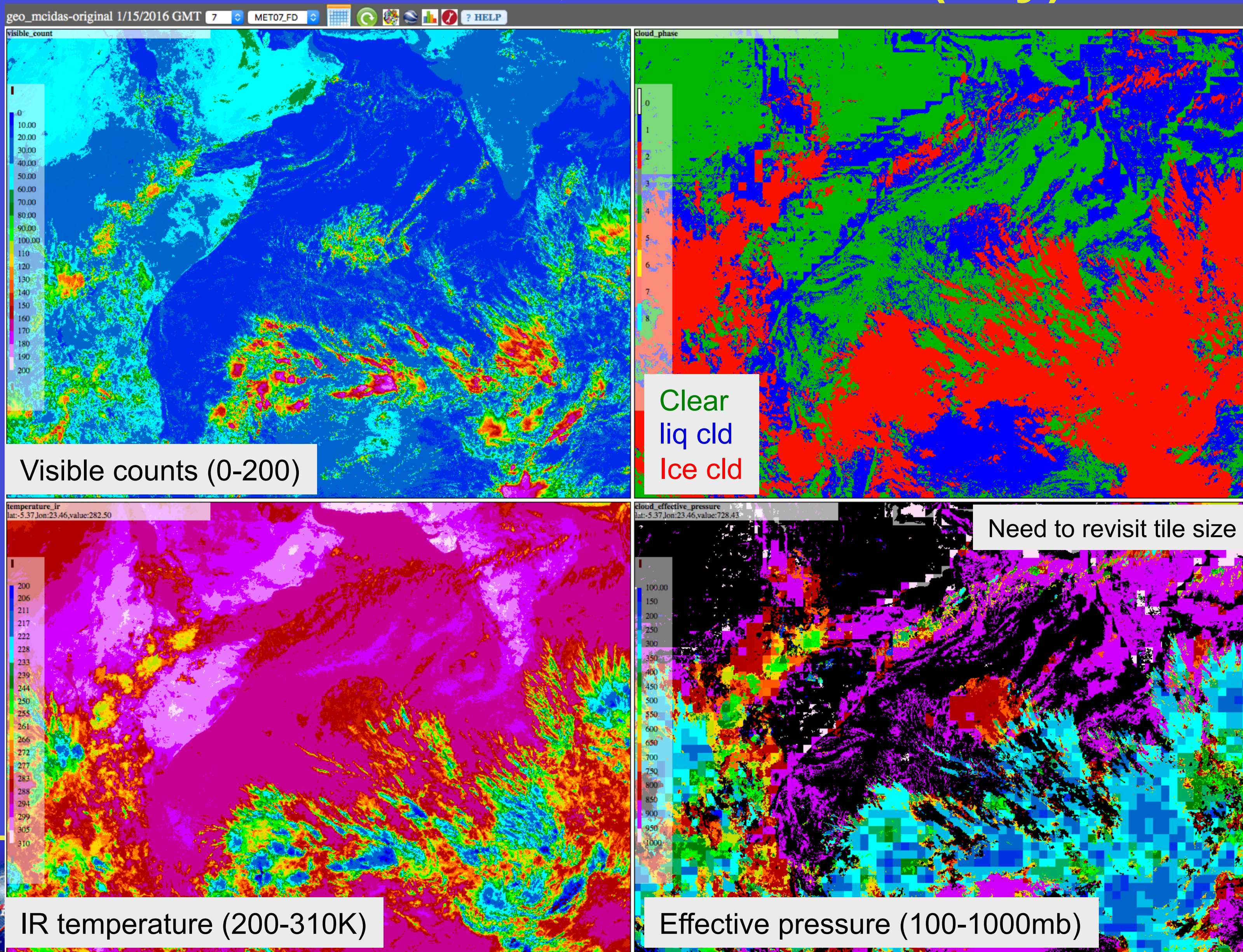
GEO 2-channel pixel-level clouds

- Ed4 GEO 2-channel output consisted of 4-layer gridded means
  - The CldTypHist product would need to use a gamma distribution based on the linear and log optical depth to bin the optical within a layer.
  - Two sets of code were required to process and composite the individual GEO satellite retrievals into a hourly gridded instantaneous global maps
- Raja examined the vintage 1996 GEO 2-channel retrieval code for the possibility of writing out pixel-level cloud properties
  - Found that the cloud code contained a wrapper written 20-years ago by TISA , which layer averaged the pixel-level clouds
  - Another advantage of performing TISA code reviews
  - Created a version of the GEO 2-channel cloud code that produced a pixel-level netCDF dataset that matched the format of the multi-channel GEO cloud code
- For Ed5 all GEO retrievals will be pixel-level. The GEO composite and CldTypHist codes will be simplified

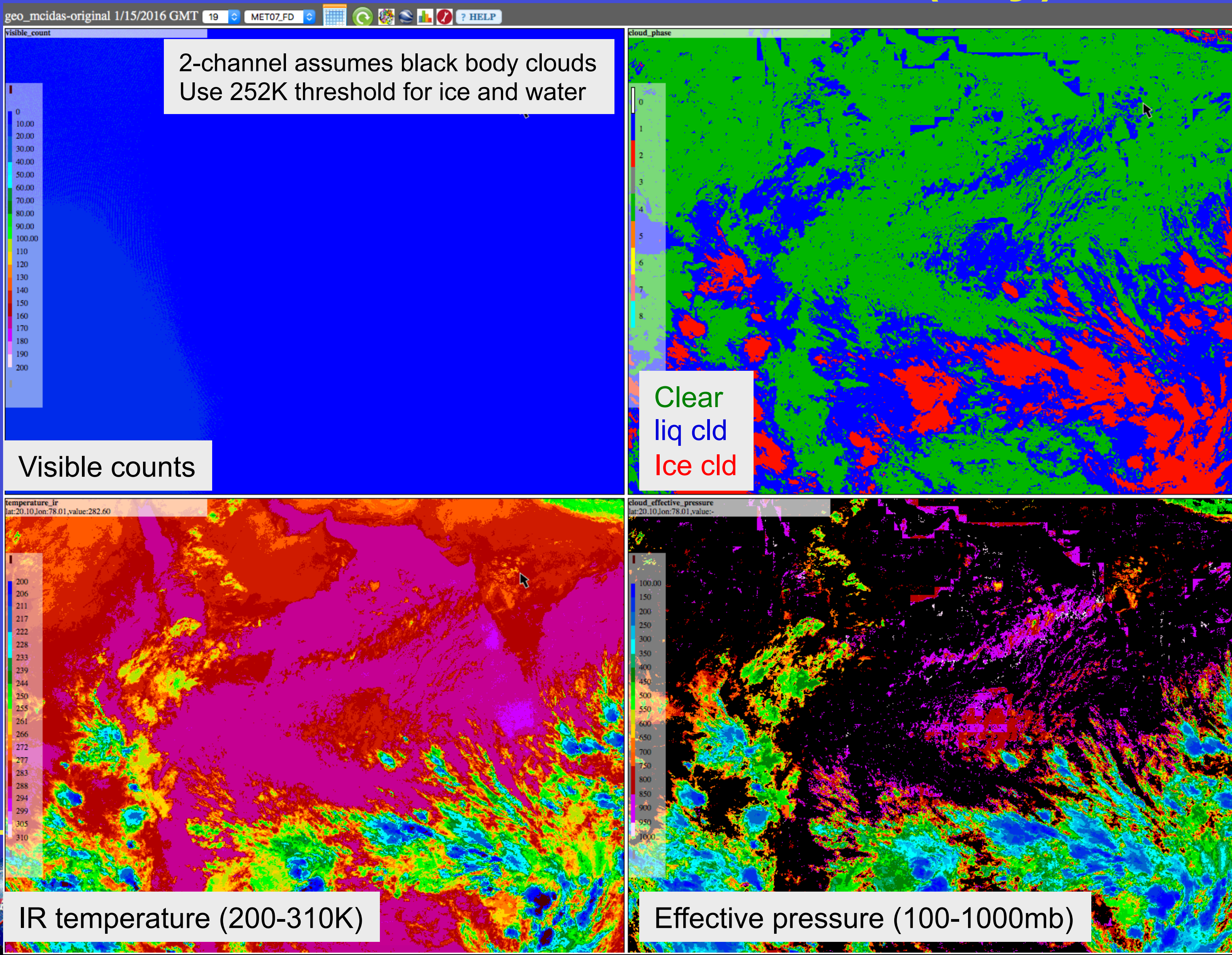
Met-7, Jan 15, 2016 7 GMT (day)



Met-7, Jan 15, 2016 7 GMT (day)



Met-7, Jan 15, 2016 7 GMT (day)



ED4 AND ED3 SYN1DEG TREND ANOMALIES

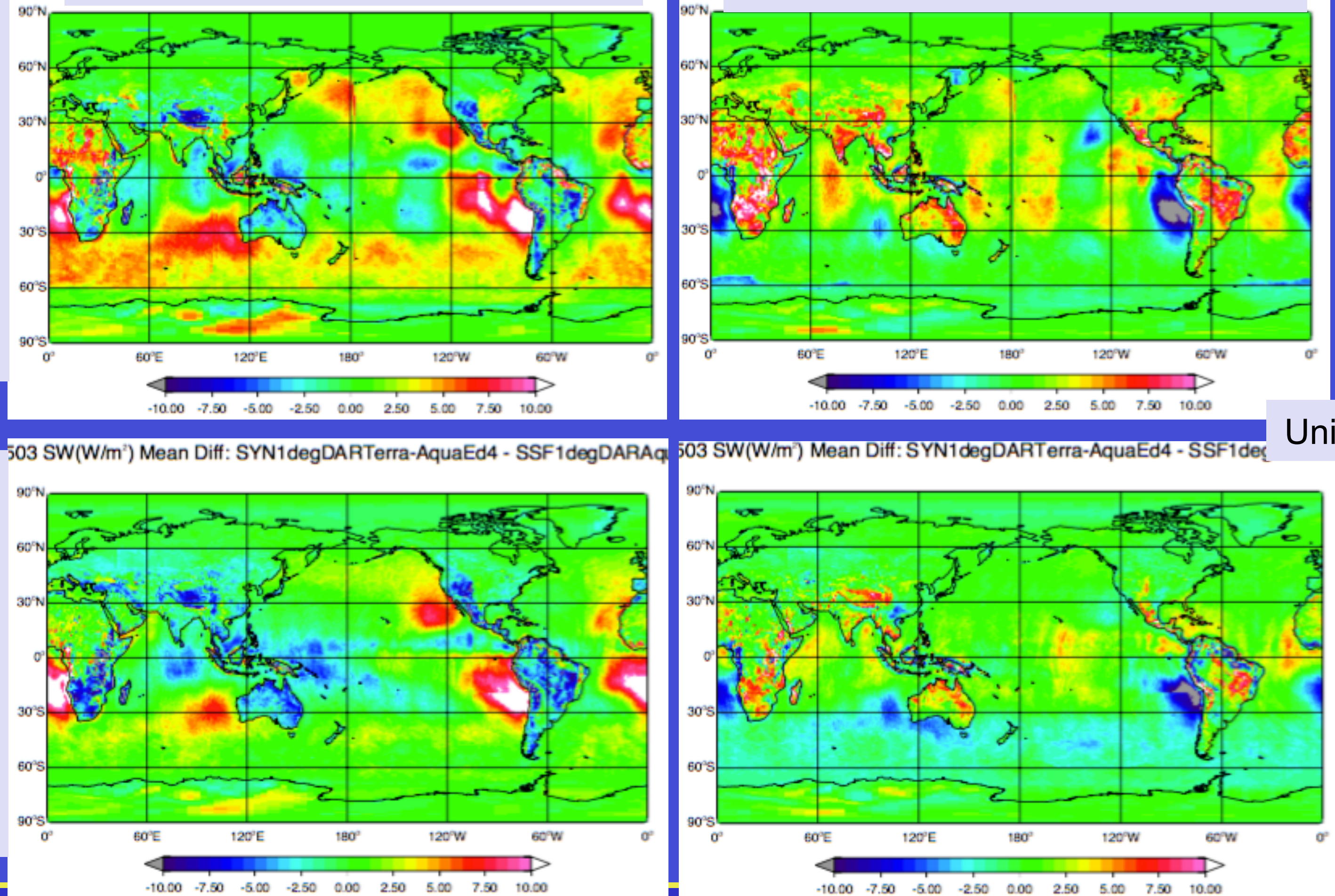
SYN – SSF 12-year SW flux difference

SYN minus SSF-Aqua

SYN minus SSF-Terra

Edition 3

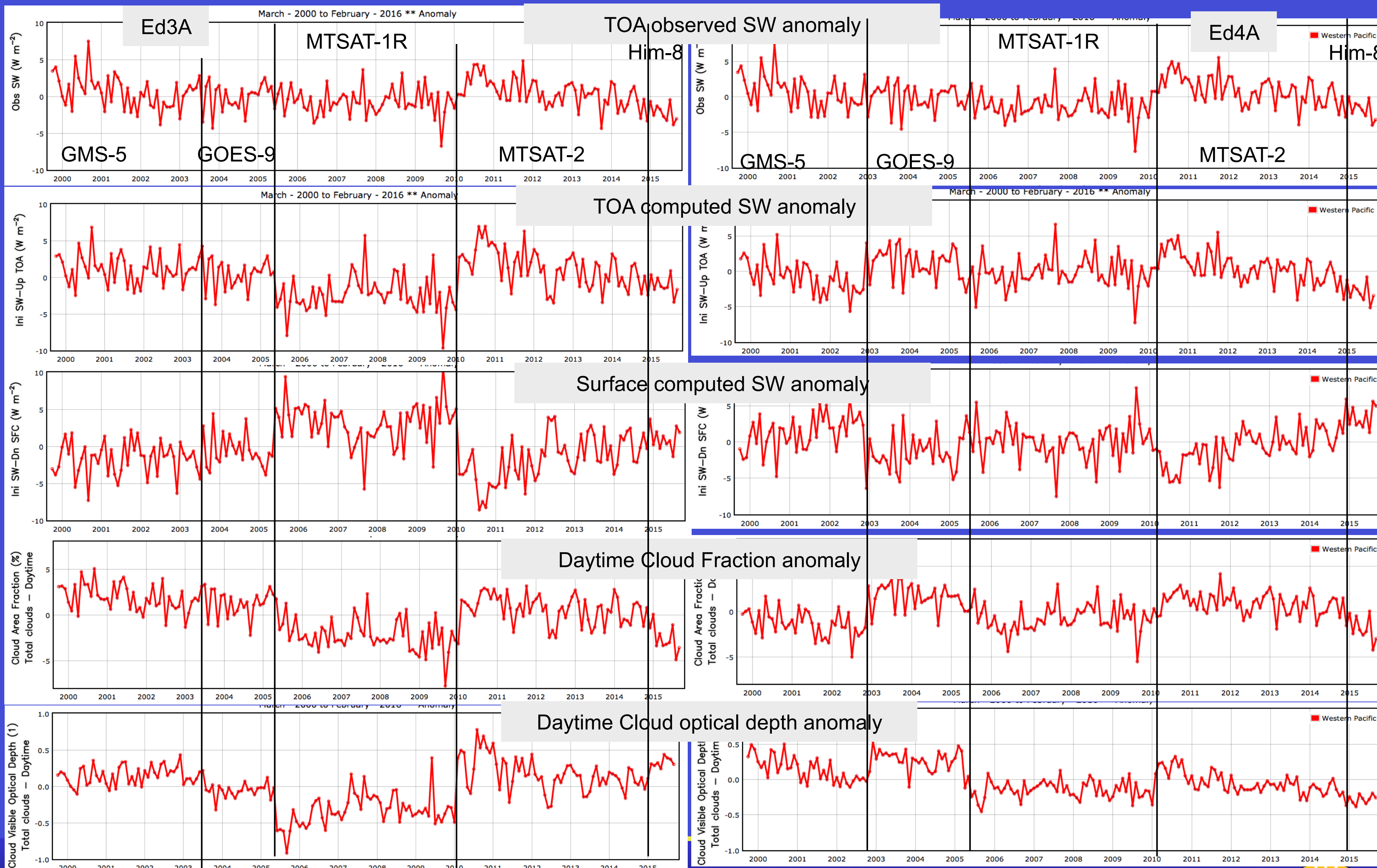
Edition 4



Units: Wm^{-2}

• Expect diurnal regional differences, but not GEO artifacts

SYN1deg TWP GEO domain anomalies 2000-2016

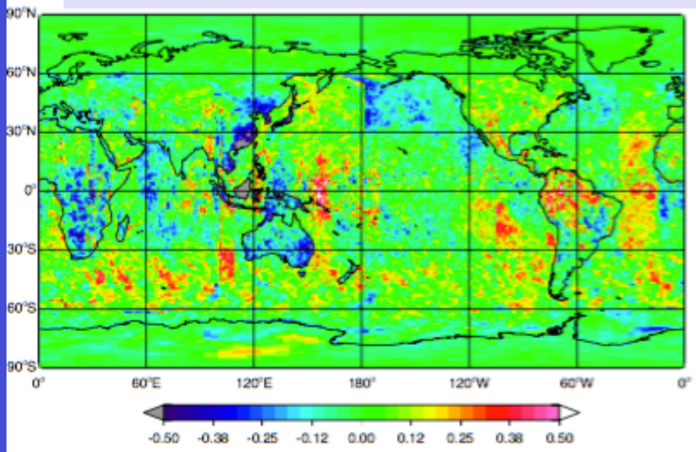


- The MTSAT-1R PSF removed most of the flux and cloud discontinuities
- The GEO/CERES SW regional normalization mitigates most GEO discontinuities

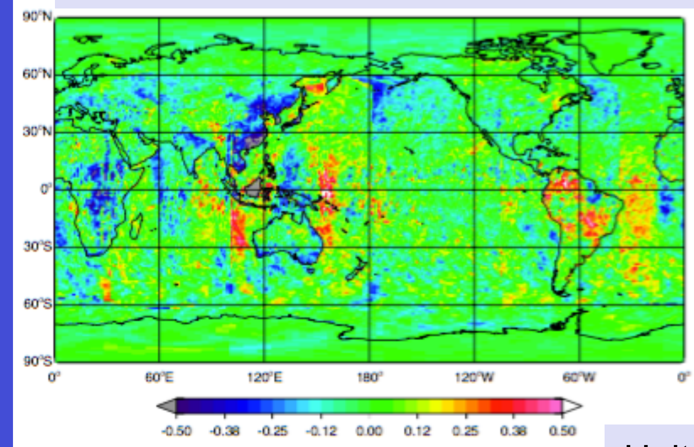
SYN – SSF SW regional trend anomalies

Edition 3

SYN minus SSF-Aqua



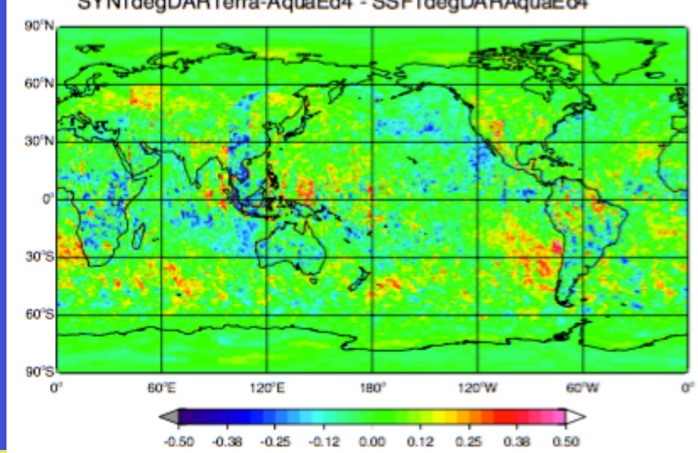
SYN minus SSF-Terra



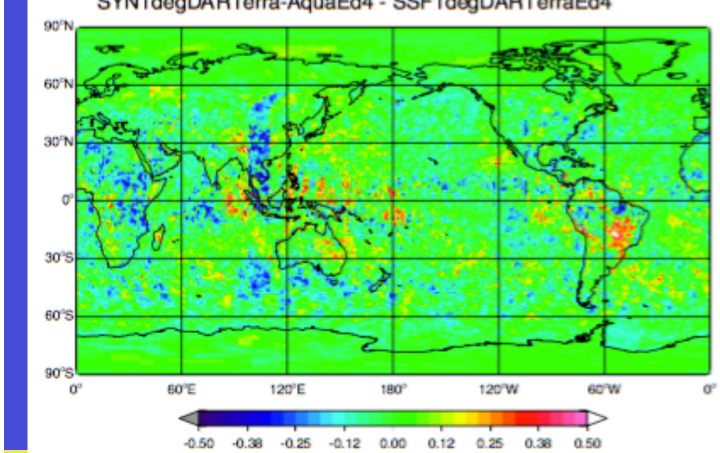
Units: Wm^{-2}yr^{-1}

Edition 4

SYN1degDARTerra-AquaEd4 - SSF1degDARAquaEd4

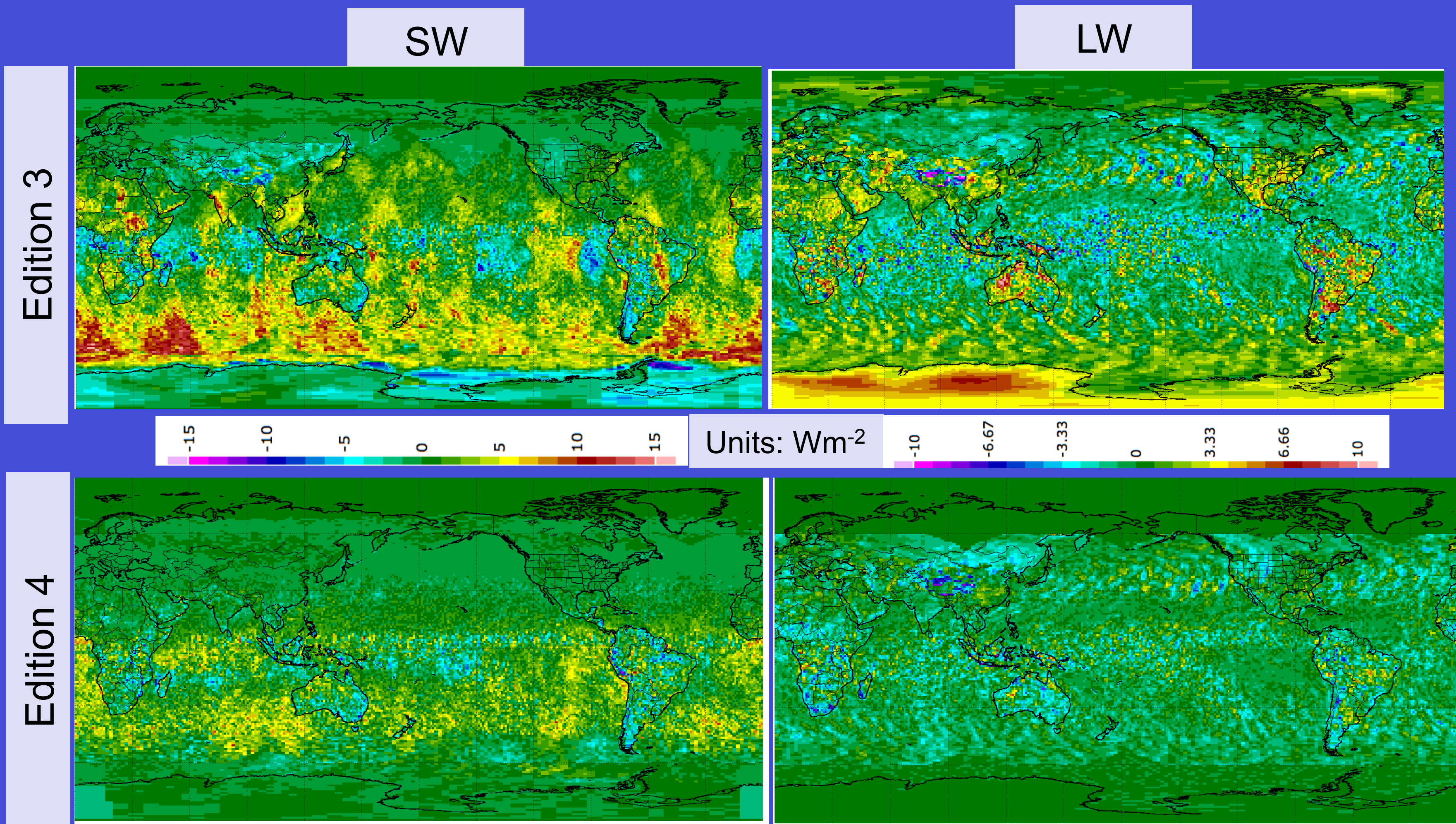


SYN1degDARTerra-AquaEd4 - SSF1degDARTerraEd4



- The vertical striping are GEO artifacts

Jan 2014, SYN minus SSF Ed4 Terra+Aqua



- The hourly GEO reduced regional monthly and trend trend artifacts
- Hourly fluxes improve diurnal shape and GEO/CERES normalization
- Over the poles, there is no GEO data.

MEGHA-TROPIQUES AND CERES FLUX COMPARISONS

Planned GEO visible to SW flux studies

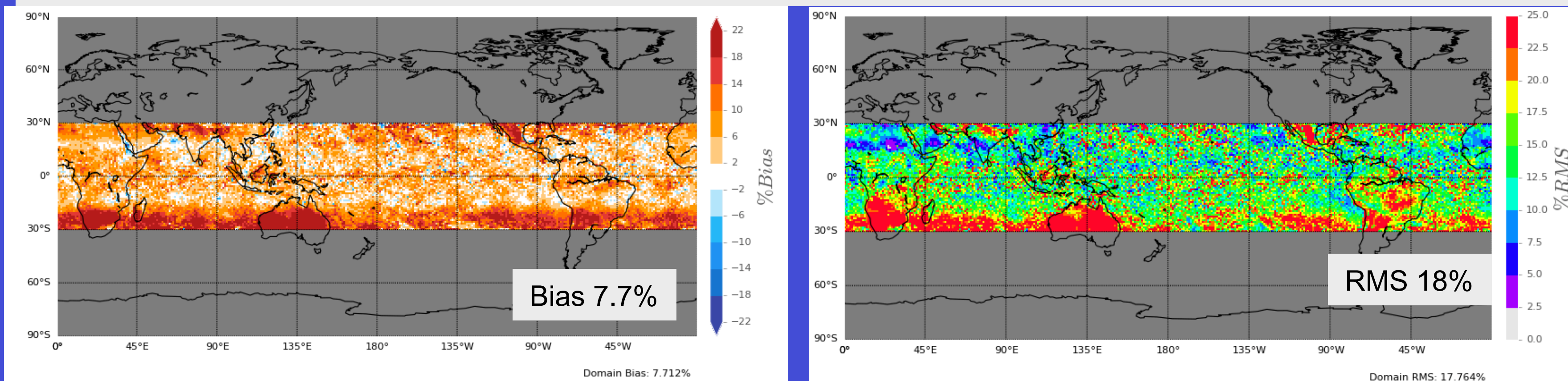
- Ed4 GEO derived SW flux
  - Theoretical GEO visible to MODIS band 1 (0.65µm) radiance conversion
  - Empirical (SSF) GEO-MODIS like to BB radiance conversion
  - Convert BB radiance to flux using CERES TRMM ADMs
  - Normalize GEO fluxes with CERES using coincident data
  - 1-hourly GEO from 3-hour reduced the Aqua-based GEO minus Terra observed fluxes RMS error from 13.6 to 9.0 Wm^{-2}
  - Ed5 studies
- Footprint vs regional, MODIS vs GEO clouds, TRMM vs Ed4 ADM
- Improve NB to BB using multiple channel MODIS/VIIRS models
  - Adding 11µm improves SSF based NB2BB from 10.3 Wm^{-2} to 8.6 Wm^{-2}
  - Enhance with theoretical Radiative Transfer radiances (2400 spectra)
  - Compare with Himawari-8, GOES-R, and VIIRS DNB
- Test improved NB to BB radiance and ADMs
  - Use Megha-Tropiques and GERB
  - Use Aqua based models and compare with Terra observations

Megha-Tropique (MT) and Aqua SW flux comparison

- Motivation: The GEO derived SW fluxes were very dependent on cloud properties for SZA>60.
  - The SYN1deg Ed4A uses hourly GEO derived fluxes for SZA<60 and directional models for SZA>60
- MT is in a tropical precessionary orbit and is very suitable to validate the GEO derived broadband fluxes for large SZA
- Validate the MT with Aqua-CERES radiances and fluxes

MT and CERES hourbox matched SW fluxes March-August 2013

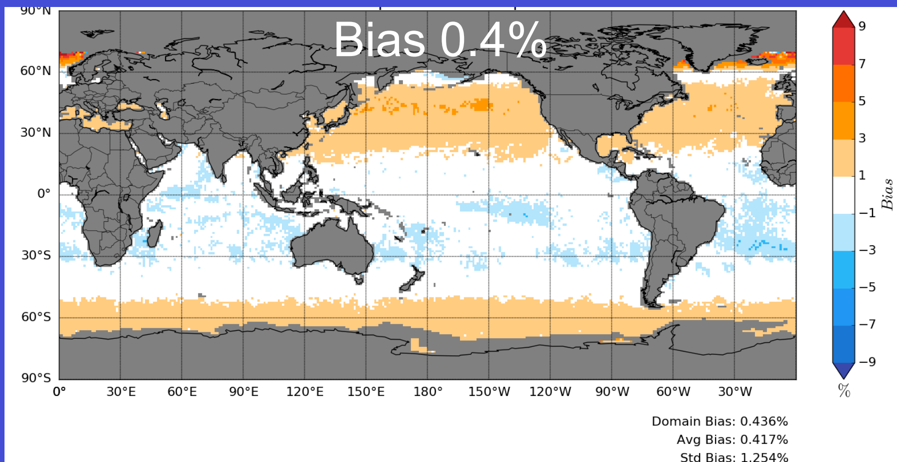
MT SANN and CERES Ed4 flux

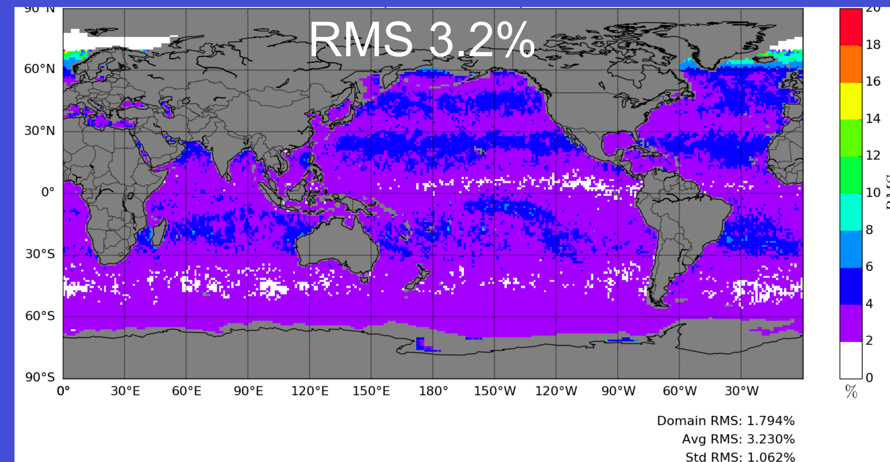


- The MT SANN fluxes do not seem to work well over land and large VZA
- Can MT radiances be converted using the TRMM ADM to flux?
- How close are the MT TRMM ADM fluxes to the CERES fluxes?

CERES-Aqua (TRMM ADM MODIS clouds) minus CERES (Ed4 ADM) SW flux

Using Aqua CERES footprint radiances and MODIS clouds, March 2013

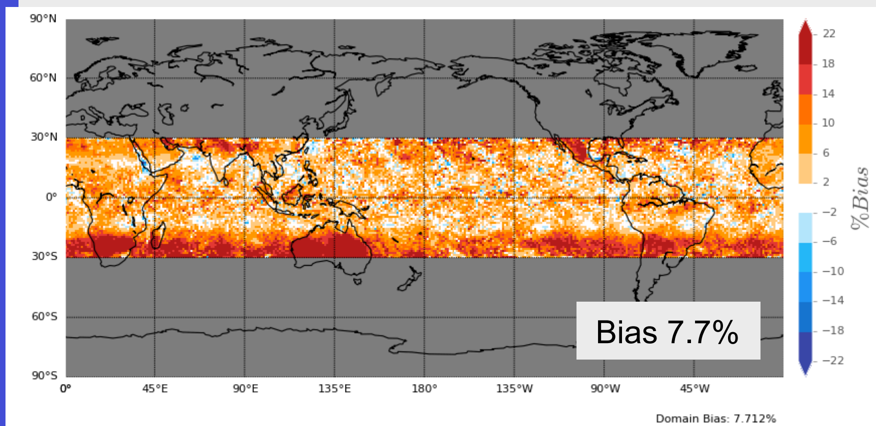


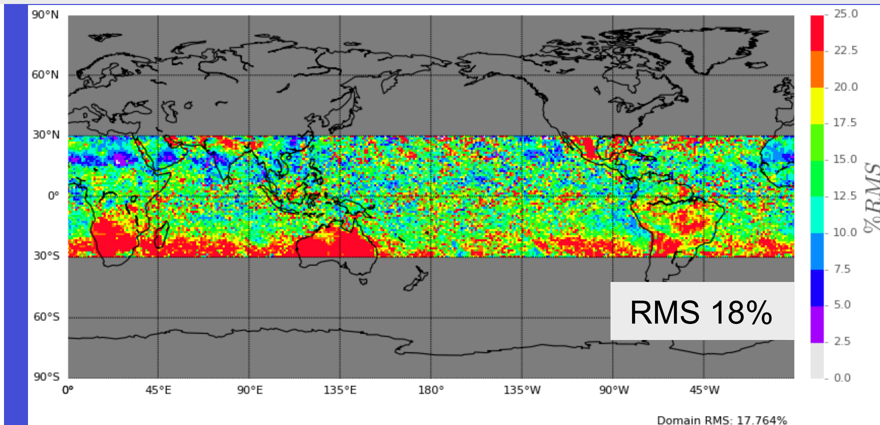


- SZA (zonal) dependent TRMM vs Ed4 SW ADM bias
- TRMM orbit within ±35°latitude
- The TRMM ADM with MODIS clouds can be used within the MeghaTropique domain, since the CERES TRMM ADM SW fluxes are close to the Ed4 ADM fluxes

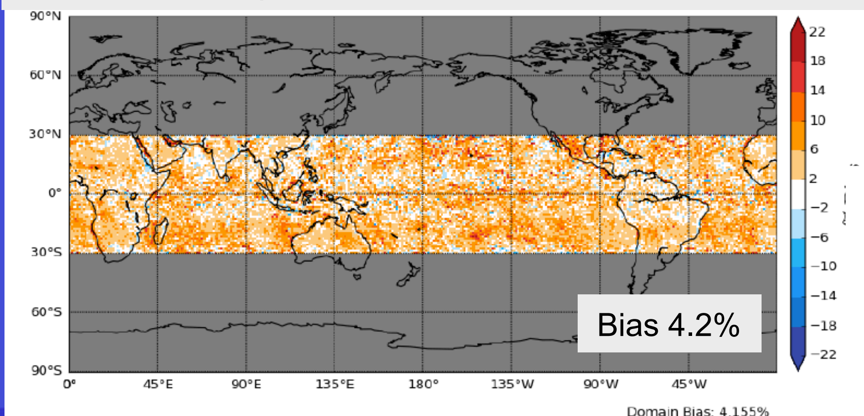
MT and CERES hourbox matched SW fluxes March-August 2013

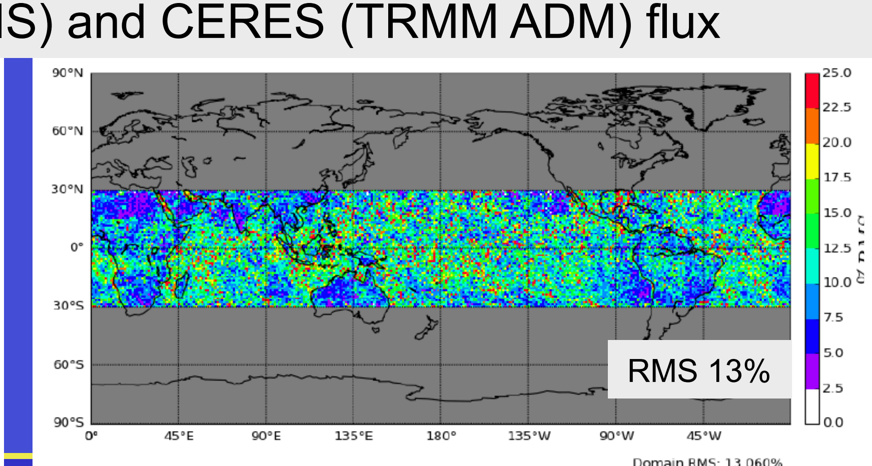
MT SANN and CERES Ed4 flux





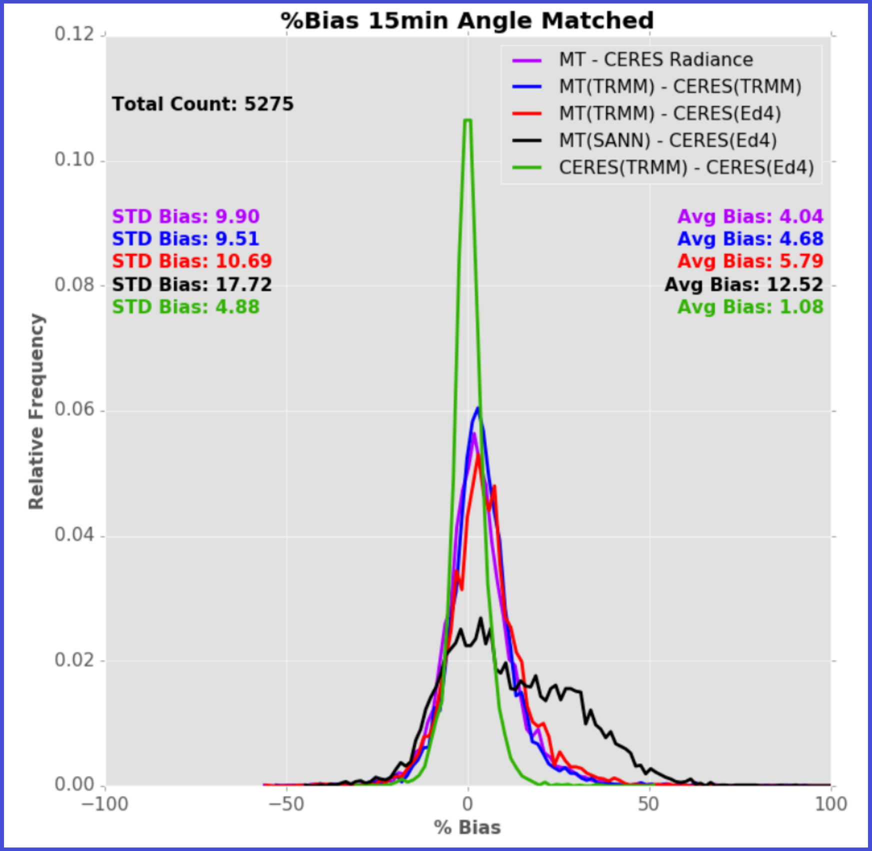
MT (TRMM ADM based on MODIS) and CERES (TRMM ADM) flux

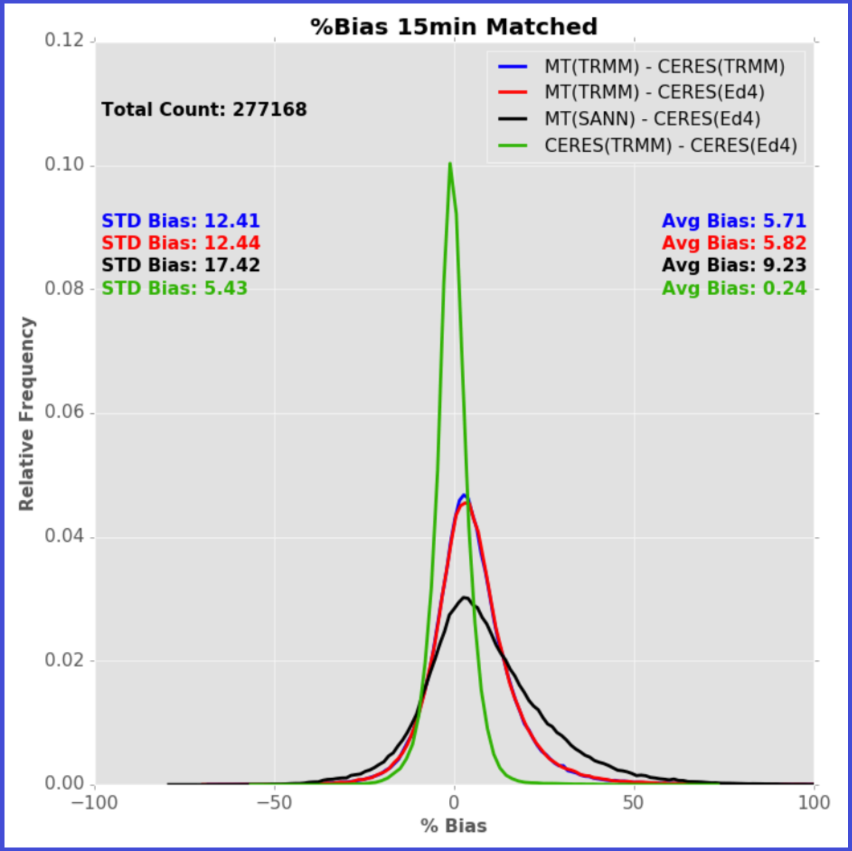




- The MT SANN fluxes do not seem to work well over land and large VZA
- The MT TRMM ADM fluxes have improved the VZA dependency but not over land

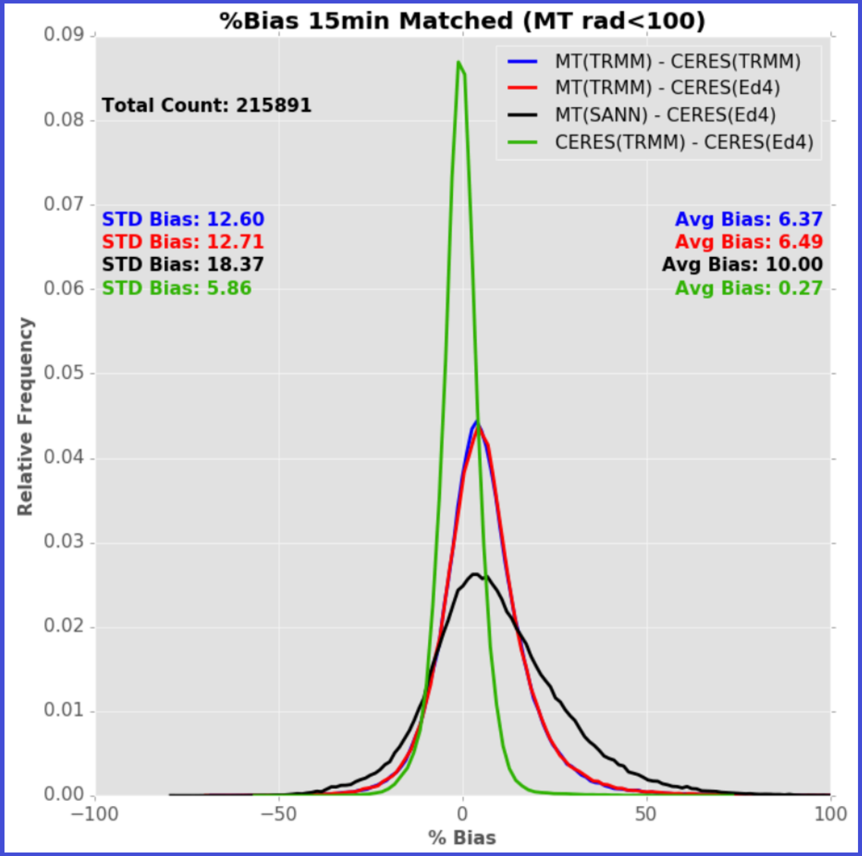
MT and CERES 15 minute matched SW fluxes March-August 2013

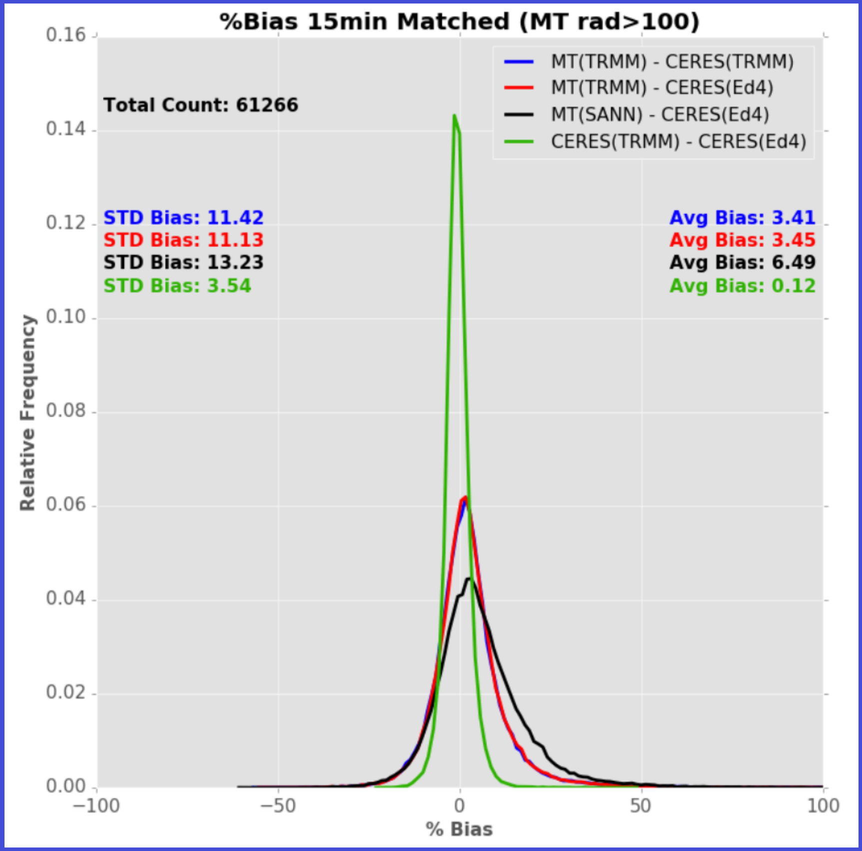




- The angle matched MT and CERES radiances and fluxes have similar bias and RMS error
- The angle matched and non-angle matched have similar MT and CERES flux statistics
- The MT-SANN fluxes have a large positive bias compared with MT-TRMM

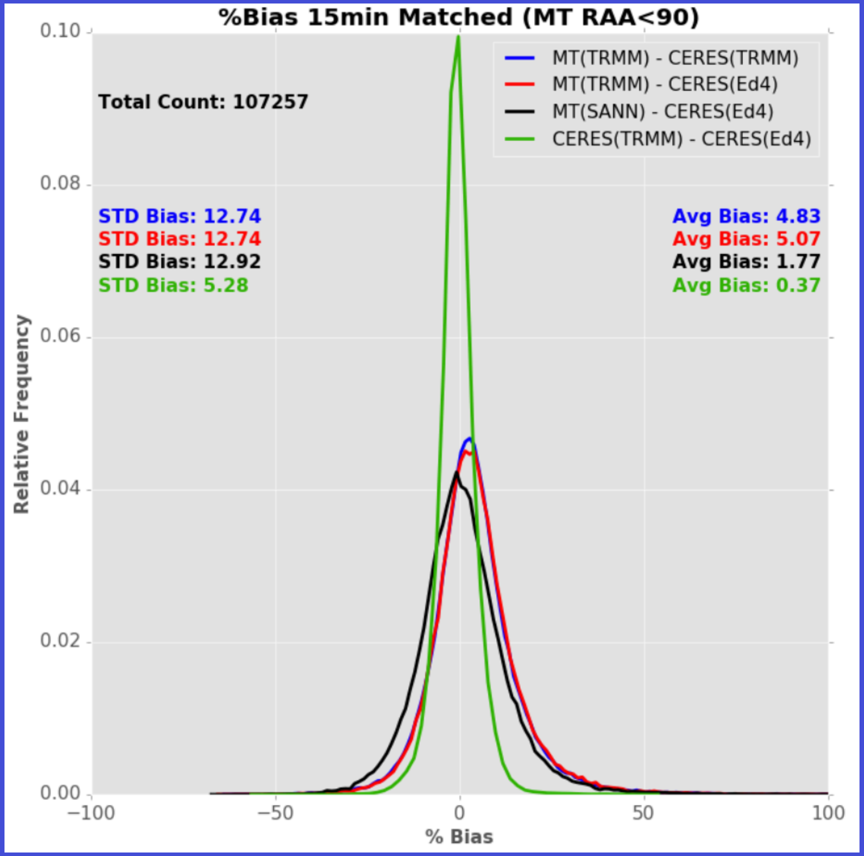
MT and CERES 15 minute matched SW fluxes March-August 2013

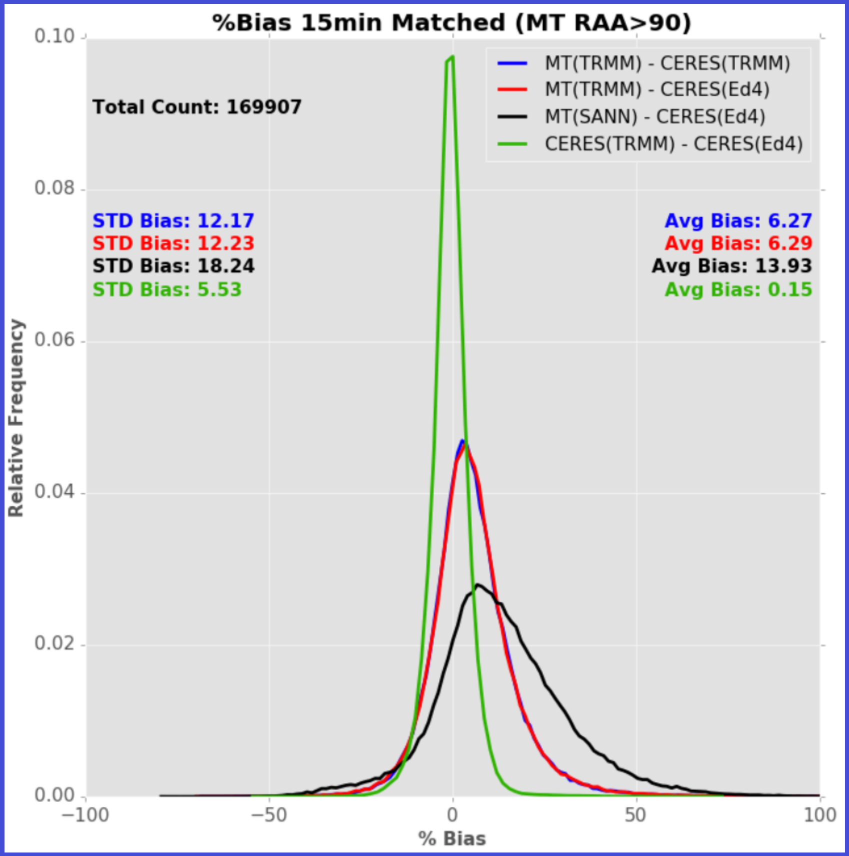




- Bright MT-SANN fluxes have lower bias and RMS error compared with CERES
- Most of the TRMM ADM error compared to Ed4 is for low flux conditions, because brighter scene conditions are more Lambertian

MT and CERES 15 minute matched SW fluxes March-August 2013





- MT-SANN fluxes are biased with respect to relative azimuth angle (RAA)
- The MT1_L2-FLUX-SCAOL1A2-1.06_2013-03-09T00-34-14_V2-00.hdf RAA seem to be reversed (0°is backscatter), We reversed the RAA for this study, much worse if we did not

Megha-Tropiques Conclusions

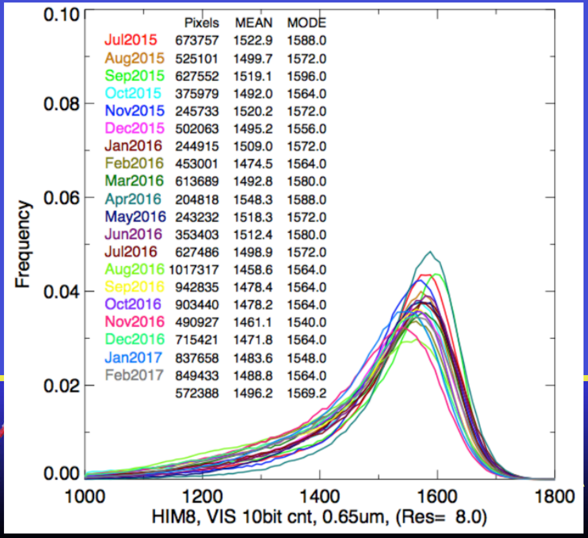
	Footprint vs 1° region ADM	TRMM adm MODIS cld	TRMM adm GEO cld	MT vs CERES rad ang match	MT-SANN CERES flux	MT-TRMM CERES flux	GERB CERES flux	GERB CERES rad ang match
bias	-0.1%	0.4%	-1.0%	4.0%	7%	5.8%	0.6%	4.0%
RMS	1.8%	3.2%	7.6%	9.9%	18%	12.5%	11.5%	14.9%

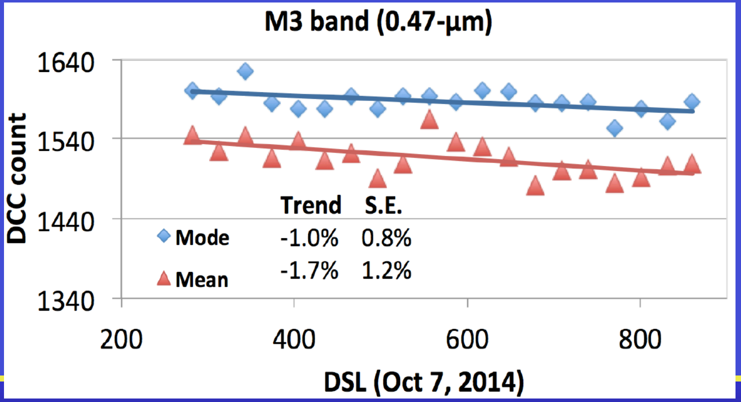
- Megha-Tropique SANN flux seems to have relative azimuth angle dependency
- Megha-Tropique radiances can be used to check GEO NB to BB derived radiances and possibly fluxes using TRMM ADM in a similar fashion to GERB

VIIRS/MODIS VISIBLE STABILITY USING DCC

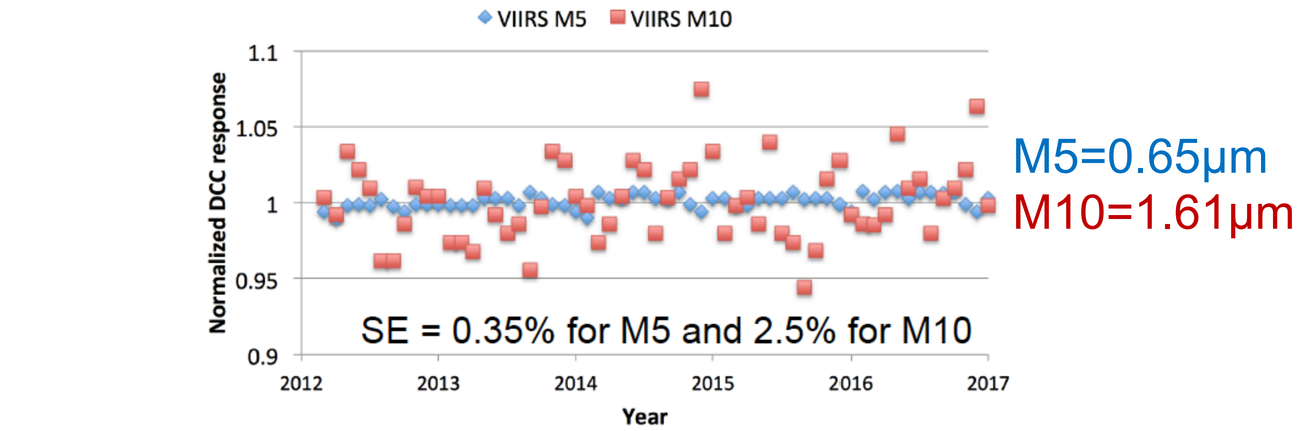
Himawari-8 DCC calibration

- Deep Convective Clouds (DCC) are the brightest, near Lambertian, invariant earth targets
  - For low view<40 and sun<40 angles behave as solar diffusers
  - Use IR (11µm) temperature threshold<205K to identify DCC
  - Use σ(VIS) <3%, and σ(BT11µm) < 1K to detect core
- Pixel-level identified DCC visible radiance or counts are compile into monthly probability distribution functions (PDFs).
  - Anisotropic correct the DCC radiances using the Hu ADM
  - For wavelengths <1µm the monthly mode counts provide the stability





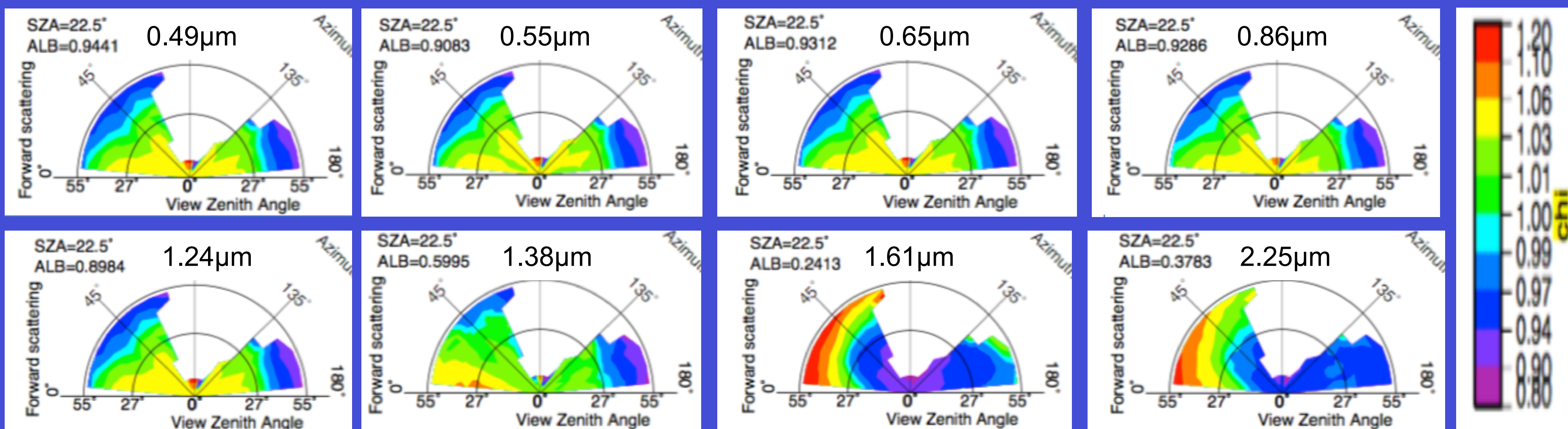
Can the DCC method be optimize by wavelength?



- Spectrally optimize by reducing the temporal standard using NPP VIIRS
  - NPP VIIRS best calibrated imager (should be stable)
  - Vary temperature thresholds, PDF mean or mode, land or ocean DCC, BRDF, deseasonalization

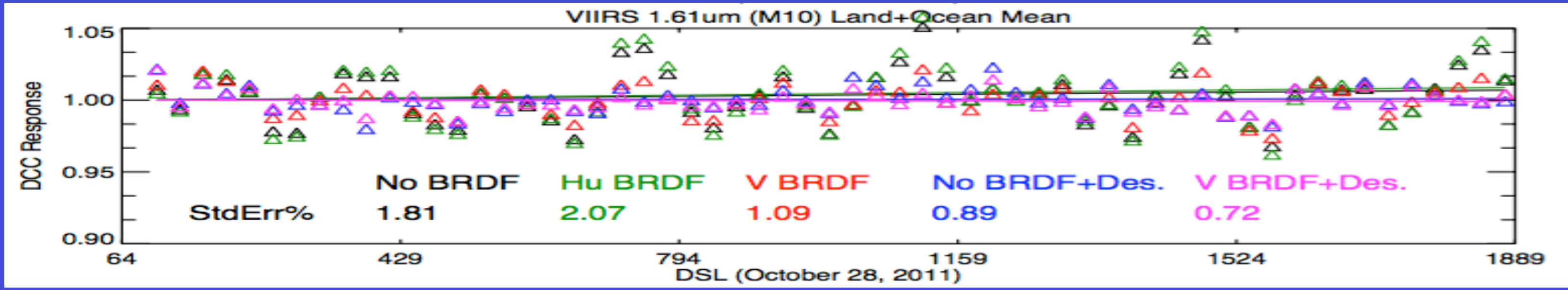
DCC BRDF Sensitivity

- Use 5-years of VIIRS DCC radiances to construct DCC BRDFs for each visible wavelength



- For wavelengths <1.3 µm, the BRDF is very similar
- For wavelengths >1.3 µm, the BRDF is wavelength dependent, back-scatter reflectances more stable
- Hu model is valid for the 0.65µm band
- Wavelengths > 1.3µm a wavelength specific BRDF is recommended

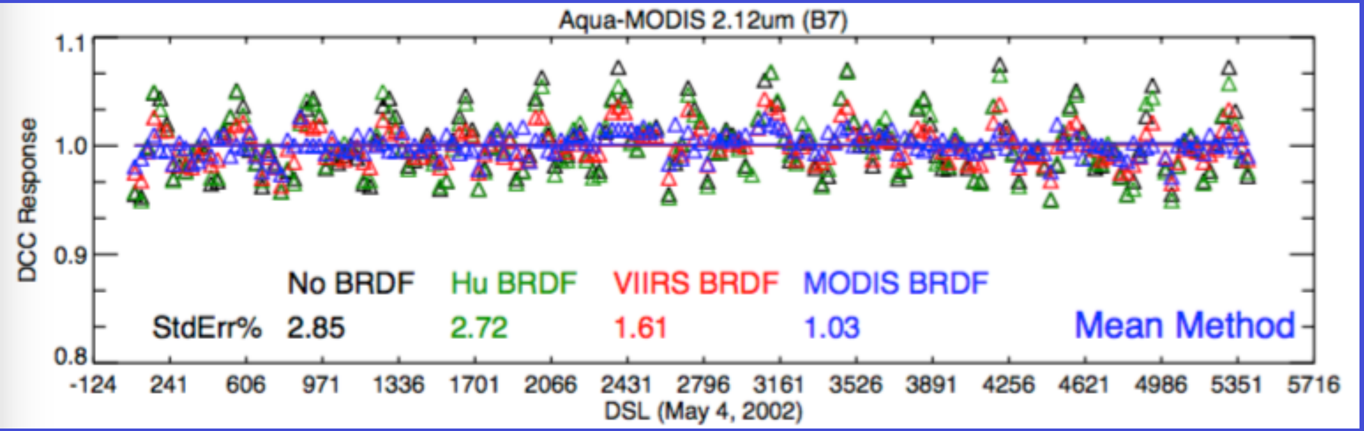
DCC temporal sigma (%) by VIIRS channel



µm	Mode Mean	No BRDF Ocn/All	Hu BRDF All	VIIRS BRDF Ocn/All	No BRDF de Ocn/All	BRDF de Ocn/All
0.49	Mode	0.66/0.62	0.42	0.63/0.56	0.63/0.58	0.45/0.37
0.55	Mode	0.73/0.66	0.35	0.78/0.70	0.67/0.56	0.44/0.36
0.65	Mode	0.67/0.50	0.35	0.59/0.60	0.64/0.46	0.36/0.30
I1	Mode	0.74/0.58	0.41	0.66/0.64	0.65/0.51	0.43/0.36
0.86	Mode	0.65/0.57	0.33	0.45/0.48	0.53/0.42	0.25/0.30
1.24	Mean	0.52/0.61	0.82	0.46/0.50	0.36/0.33	0.33/0.31
1.38	Mean	1.35/1.33	1.49	1.33/1.21	0.82/0.74	0.78/0.70
1.61	Mean	1.63/1.81	2.07	0.99/1.09	0.90/0.89	0.72/0.72
I3	Mean	1.62/1.80	2.05	1.02/1.10	0.93/0.92	0.75/0.75
2.25	Mean	1.19/1.35	1.61	0.76/0.85	0.67/0.65	0.54/0.55

- For wavelengths < 1µm use current method, Otherwise use mean and BRDF
- To deseasonalize several years of data is required

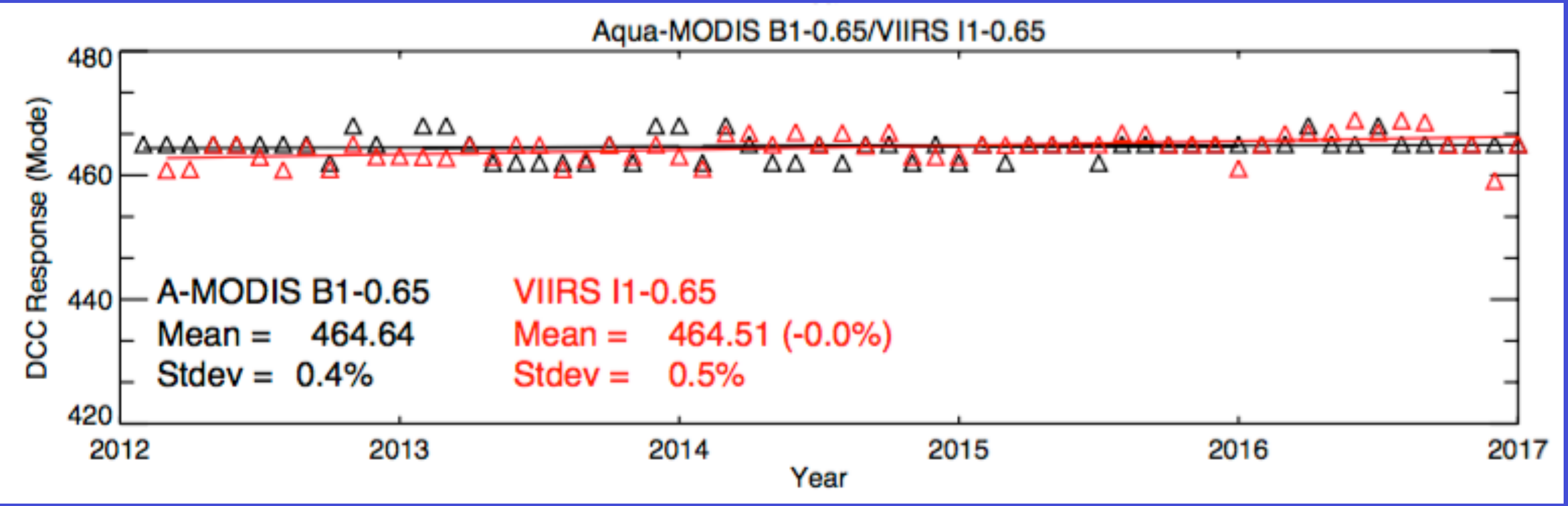
Can VIIRS BRDFs be used with MODIS?



μm	No BRDF	VIIRS BRDF	MODIS BRDF
1.24	0.71	0.36	0.41
1.37	1.36	0.80	0.82
1.61			Bad detectors
2.12	2.85	1.61 (2.25μm)	1.03

- Hu model has been tested across GEO, MODIS and VIIRS sensors
- Future JPSS VIIRS can use NPP BRDFs for SWIR bands

Compare MODIS B1 and VIIRS I1 DCC mode radiance



Pair	Ray-match	All AZ	AZ<90	AZ>90	AZ ratio
B1/I1	All-sky Ocean	0.9954	0.9926	0.9993	0.67
	DCC	0.9917	0.9867	0.9959	0.92

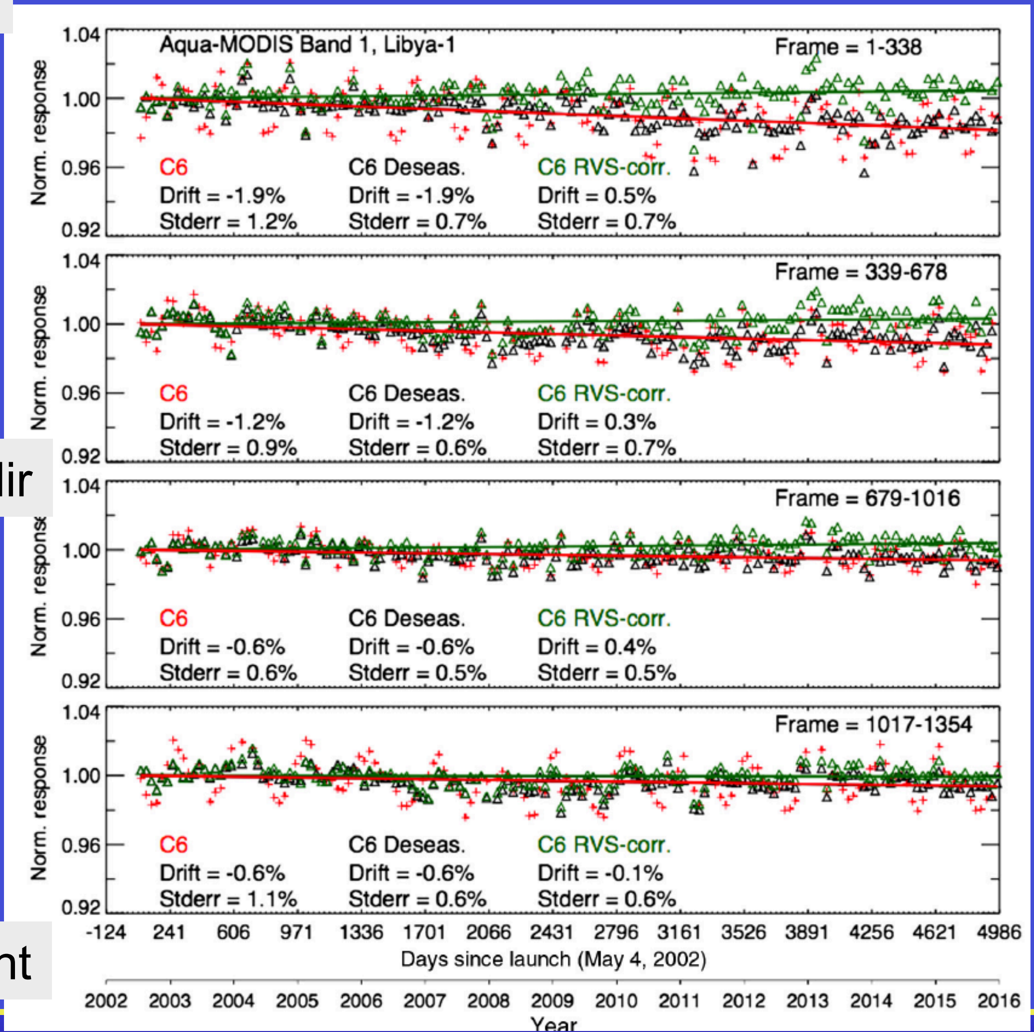
- The 0.65µm DCC mode radiance should be similar across sensors in same orbit
- Still investigating
- Aqua-MODIS imager has scan angle dependency

MODIS scan angle dependency over Libya-4

left

nadir

right



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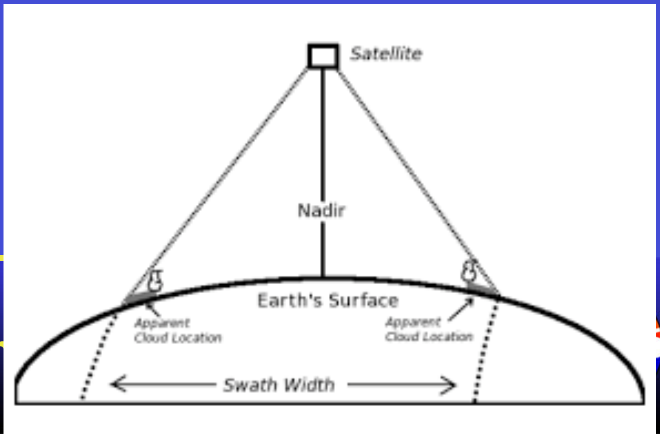
- The azimuthal scan angle dependency between left and right of nadir is 0.5 to 1.0% based on ray-matching
- This is confirmed using the Libya-4 invariant target, C6 • RVS corrections were based on the DCC mode method



DCC calibration

- DCC calibration has been optimized as a function of wavelength
  - Wavelengths <1µm use Hu DCC BRDF and mode, trend sigmas <0.5% are achieved
  - Wavelengths >1µm use VIIRS BRDF, mean, and deseasonalization, trend sigmas <1% are achieved
  - Less dependent on IR BT or ocean or land
- Future VIIRS imagers can use either MODIS or NPP VIIRS BRDFs that are in the same orbit
- DCC calibration be able transfer VIIRS calibration across non-overlapping satellites if they are in the same orbit
  - Similar to characterized desert and polar ice targets