TISA Working Group Report

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29th CERES-II Science Team Meeting

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TISA ED5 IMPROVEMENTS

Science, GEO LW NB to BB

Ed4

GEO WV and Window (IR) radiances inter-calibrated with MODIS

↓

Derive SSF MODIS IR and WV to CERES BB flux monthly conversion coefficients

↓

GEO radiance to BB flux empirical (SSF) conversion

↓

GEO BB flux normalized with CERES fluxes

Ed5

GEO WV and Window (IR) radiances inter-calibrated with CrIS

↓

Use climatology SSF MODIS IR and WV to CERES BB flux monthly conversion coefficients

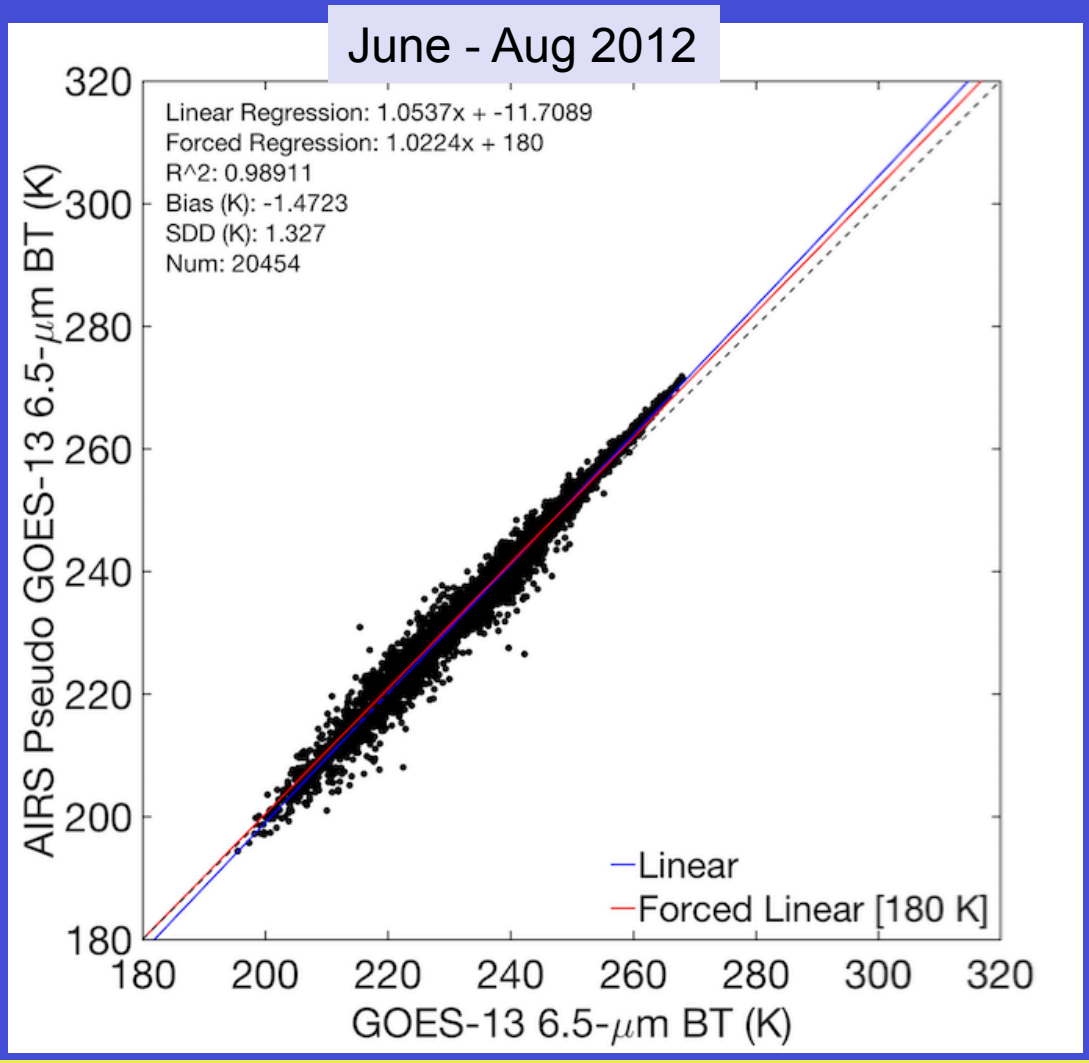
↓

GEO radiance to BB flux empirical (SSF) conversion

↓

GEO BB flux normalized with CERES fluxes

GOES-13 WV and Aqua-AIRS inter-calibration



Science, GEO SW NB to BB

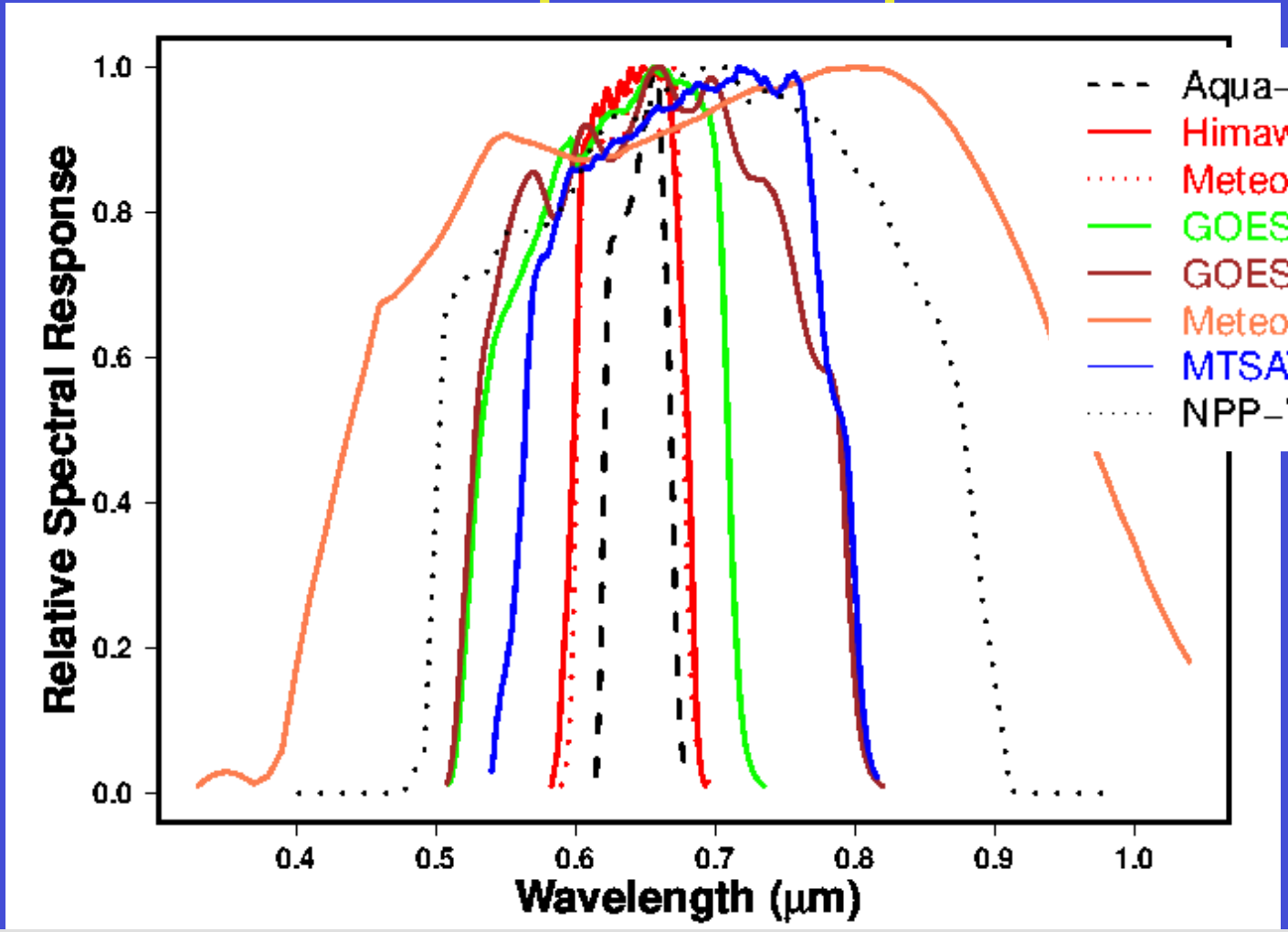
Ed2/Ed4

- GEO visible radiances inter-calibrated with MODIS
- GEO to MODIS-like radiance RTM conversion
- MODIS visible to BB radiance empirical (SSF) conversion
- GEO BB radiance to flux using TRMM ADM
- GEO BB flux normalized with CERES fluxes

Ed5

- GEO visible radiances inter-calibrated with MODIS/VIIRS
- Broad GEO visible imagers
  - GEO to BB radiance RTM (unique to each GEO) conversion
- MODIS/VIIRS-like GEO imagers
  - MODIS/VIIRS visible to BB radiance empirical (SSF) conversion
- GEO BB radiance to flux using TRMM ADM
- GEO BB flux normalized with CERES fluxes

GEO visible spectral response functions



Ed4 SW NB to BB converts from broad GEO channel to MODIS visible and then to broadband
ED5, Either VIIRS DNB or MODIS B1 to BB (SSF) conversion, or RTM to BB conversion
Ed5, No GEO channel to MODIS RTM conversion

GEO 2-channel cloud code, convert regional layer means to pixel level output, CLDTYPHIST

Ed4

GEO 2-channel
GMS-5, Met-5, met-7

↓

GEO grid 4-layer cloud retrieval

↓

Gamma distribution to convert 4-layer to 3x3 cloud bins

GEO multi-channel
All GEOs

↓

GEO pixel-level cloud retrieval (Cloud WG)

↓

Publicly released netCDF file

↓

Region and cloud type 3x3 histogram binning

Ed5

GEO 2-channel
GMS-5, Met-5, met-7

↓

GEO pixel-level cloud retrieval (2-ch)

↓

GEO multi-channel
All GEOs

↓

GEO pixel-level cloud retrieval (Cloud WG)

↓

Publicly released netCDF file

↓

Region and cloud type 3x3 histogram binning

Provide SARB time ordered regional clouds

Ed4

GEO 2-channel
GMS-5, Met-5, met-7

GEO multi-channel
All others

GEO grid 4-layer cloud retrieval

GEO pixel-level cloud retrieval (Cloud WG)

Publicly released netCDF file

SARB

TISA

(TISA) regional cloud binning

Clouds, GEO derived hourly fluxes, region ordered

Composite GEO zonal binary files (region ordered)

Surface/TOA/layer hourly flux computations (TUNE to TOA)

Clouds, GEO derived hourly fluxes

Temporal interpolation and averaging

SYN1deg Ed4 product

- If SARB does not tune, the GEO derived hourly fluxes are not required.
- Also SARB prefers to compute sequentially in time, TISA processes by region

Provide SARB time ordered regional clouds

Ed5

GEO 2-channel
GMS-5, Met-5, met-7

GEO multi-channel
All others

GEO pixel-level cloud retrieval (2-ch)

GEO pixel-level cloud retrieval (Cloud WG)

Publicly released netCDF file

SARB

(SARB) Regional cloud binning

Composite GEO daily binary files (time ordered)

Surface/TOA/layer hourly flux computations (NO TUNING)

Time to region ordered and averaged

TISA

(TISA) regional cloud binning

Composite GEO zonal binary files (region ordered)

GEO derived hourly fluxes

Temporal interpolation and averaging

SYN1deg computed product

SYN1deg observed product

- SARB independent of TISA processing and deliveries

TISA code modularization

TISA Products

SSF1deg	SYN1deg	CldTypHist	FlxByCldTyp
Cloud	Cloud	Cloud	Cloud
FluxCM	FluxCM	Averaging	Averaging
Averaging	FluxGEO		
	Averaging		

- Each TISA product has its unique cloud code
- If there is a cloud averaging code change, it must be updated in multiple product codes, a bookkeeping and testing nightmare
- For Ed5 create a library module that handles all cloud interpolation and averaging routines

FluxCM = constant meteorology flux interpolation

FluxGEO = GEO flux temporal interpolation

Cloud = cloud temporal interpolation

Cloud/flux Averaging

Regional instantaneous directional models

ED4

SSF1deg-hour

Regional flux
Scene Fraction(20)
Scene albedo(20)
ADM#(20)

GEO1deg-hour

Regional NB radiance
Cloud Fraction(4)
Cloud Optical Depth(4)
Phase(4)

SSF1deg-day

Convert the 20 scenes into a single Albedo directional (SZA) model

If a region has over 20 scene types information is lost usually over regions with multiple surface and complex clouds

SYN1deg-day

Convert the 4-cloud layers into a single Albedo directional (SZA) model

SYN1deg incorporates 1-hourly GEO albedos, so that albedo directional models are rarely used

ED5

SSF1deg-hour

Convert the 20 scenes into a single Albedo directional SZA model(9)

GEO1deg-hour

Convert the 4-cloud layers into a single Albedo directional SZA model(9)

SSF1deg-day

No scene information is lost and the regional directional model is not recomputed every time it is used

Also the SSF1deg-hour file has fewer variables and size is smaller

SYN1deg-day

Now the SYN1deg clouds can be interpolated and averaged in their own module

Only the clouds needed for NB to BB are passed through

SYN1deg Ed5 code modularization

Clouds as required for SARB

Flux computations

Flux and cloud averaging

Clouds as required for SYN1deg product

cloud temporal interpolation and averaging

Clouds and GEO radiances as required for **SW** NB to BB and ADM

Pass 1

NB to BB conversion

TRMM ADM flux conversion

Coincident CERES and GEO fluxes for 5x5 regional normalization coefficients

Pass 2

NB to BB conversion

TRMM ADM flux conversion

GEO flux normalization

SW Flux Temporal interpolation directional models and averaging

No clouds required for **LW**

GEO WV and IR to BB flux conversion

Coincident CERES and GEO flux for 5x5 regional normalization coefficients

GEO WV and IR to BB flux conversion

GEO flux normalization

LW Temporal interpolation and averaging

SYN1deg computed product

SYN1deg observed product

Code Status

Product	Archived	Sub-version	Bit-bucket	Processing
EBAF and lite codes	Yes		No	SCF
CERES GEO cloud code	Yes		No	SCF
GEO gridding (Gran/Composite)	Yes		Yes	SCF
SSF1deg-hour	Yes		Yes	ASDC
SSF1deg-day/month	Yes		Yes	ASDC
TSI	Yes		Yes	ASDC
SYN1deg-hour/day/month	Yes		Yes	ASDC
CldTypHist	Yes		Yes	ASDC
FluxByCloudType*	Yes		Yes	ASDC
CERES subsetter (public)	Yes	Yes	No	N/A
CERES web site	Yes	Yes	Yes	N/A

* TISA will be running FluxByCloudType for the complete Aqua and Terra record in CATALYST on the SCF before delivery to catch any unknown issues. (in order to test CATALYST)
* All CERES delivered codes are run using CATALYST at the ASDC

• CERES web pages and public sub-setter are being migrated to OpenShift container ASDC platform

Ed5 GEO cloud code status

- The GEO cloud code is run on the science side
  - GEO images need to be QC, both automated and human interface
  - Each GEO is unique, GEO issues are usually unforeseen (G-16 examples), and often requiring code changes and reruns.
  - EBAF is processed in 2-month chunks as soon as the CERES instrument calibration and spectral response function coefficients are ready and the SSF is produced, which is about 3 months of real-time
  - All the SSF1deg-lite, SYN1deg-lite and EBAF codes are run on the SCF to facilitate timely releases of the EBAF product and to identify any input issues before the remaining products are processed.
- When a GEO is replaced
  - Need to validate the GEO clouds against MODIS for consistency
  - Need to evaluate the computed surface fluxes
- Currently the CERES GEO cloud code is not in version control but has been archived

Ed5 GEO cloud code delivery improvements

- All new GEO cloud code deliveries will be versioned controlled in Bitbucket (to be finished by this summer)
  - Packaged with all static LUTs, ancillary files, and flags
  - With documentation on how to compile and run the code properly
  - With proper error, exception handling and exit handling to determine successful processing
- Cloud code to come with a PCF like file, to properly handle file input, aerosol, snow maps, GEOS atmosphere
  - All the aerosol, snow maps, GEOS atmosphere and other input files are consistent other CERES products use
  - Remove all hard coded file reads
  - When a file is missing the cloud code will exit
- Secondary Priority
  - When cloud code bombs, the offending pixels to be identified as bad data, and the remaining image is processed.

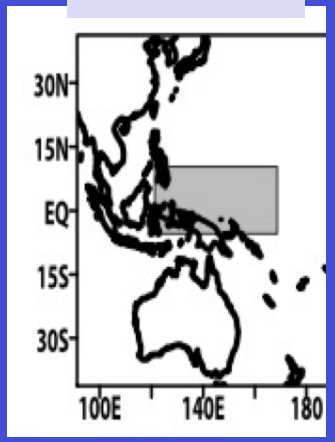
FluxByCloudType Delivery

- All CERES TISA Ed4 products have been delivered except FluxByCloudType (FBCT)
- FBCT stratifies the daytime CERES fluxes into PC/tau bins
  - Stratify the sub-footprint (clear/cloud1,cloud 2) fluxes into 7 cloud layers and 6 optical depth bins
  - Where the sub-footprint fluxes are estimated using MODIS NB to BB derived fluxes and then normalized to the observed footprint flux
  - Presented at the Sept. 2017 CERES STM
- Moguo has finalized the FBCT1deg-hour code,
  - Combined Terra and Aqua in code.
- Validating the FBCT fluxes
  - FBCT fluxes are not dependent on angles, cloud properties, PW, surface type
  - Run FBCT for the complete Aqua and Terra record to catch any unknown issues. Run in CATALYST on SCF, to test CATALYST
  - Check for monthly regional cloud type flux consistency and outliers

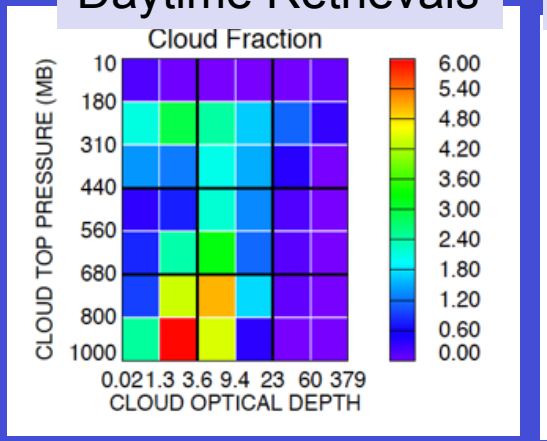
FluxByCloudType Delivery

- Contemplating a FBCT1deg-month product
  - Already computing daily SW flux averages using constant meteorology
  - The daily LW flux requires night time fluxes. The cloud height and optical depth retrievals are not consistent between day and night
  - Check the possibility if the night time PC/tau bins can be mapped into the daytime

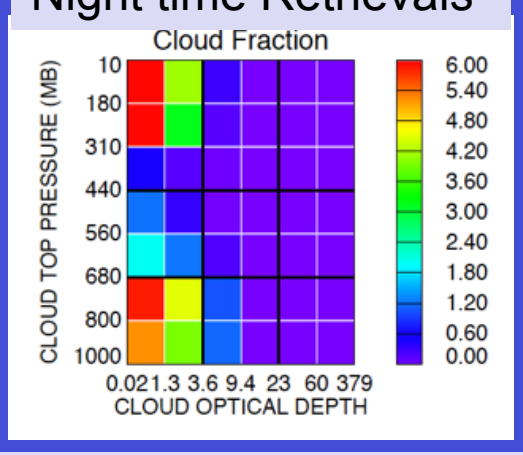
Jan 2010



Daytime Retrievals



Night time Retrievals



Can the night time retrievals bins be mapped into a similar daytime bins?

• Night-time retrieval code, applied during the day. The 3.7μm has both solar and IR component, was not properly handled in this test night time run. Will take a lot of effort

• Possible to apply the CWG night time optical depth neural net, however, was intended for ice clouds only, water clouds are unaffected.

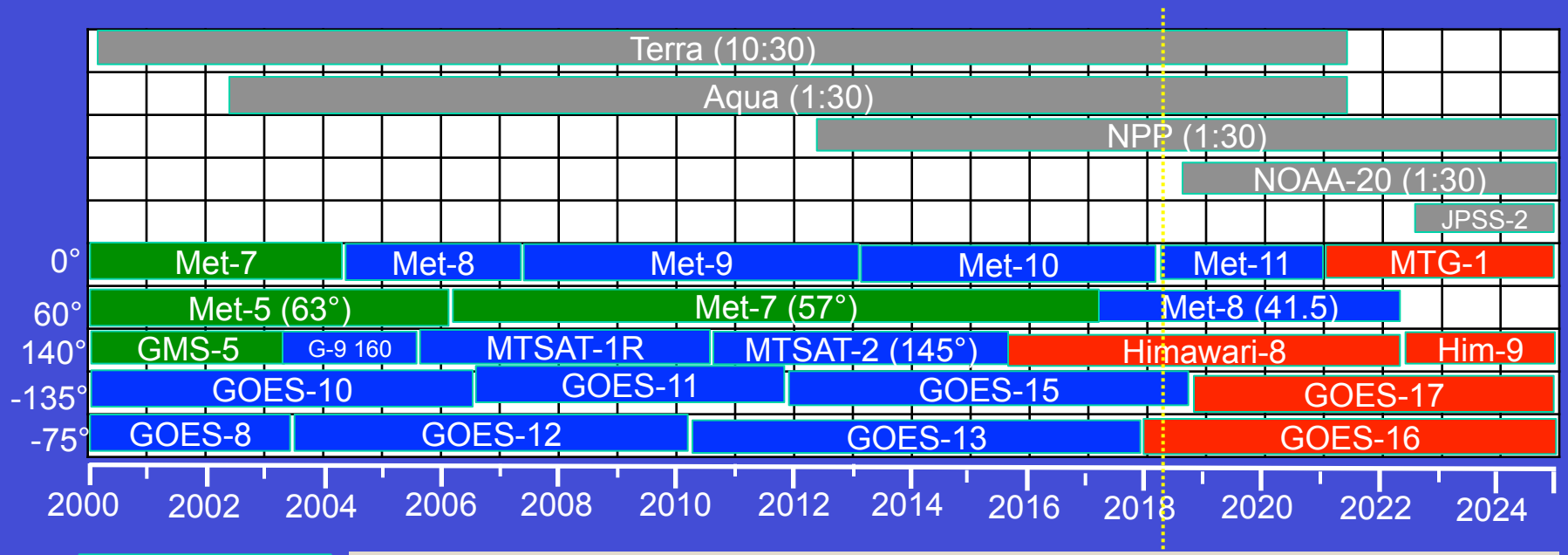
I suggest to wait until Ed5 to product a FBCT1deg-month, with improved imager cloud retrievals

TISA code status and Ed5 improvements

- Ed5 Science improvements
  - Improve the SW NB to BB algorithm, use a combination of RTM and empirical LUT, multiple GEO channels
  - Modify the GEO cloud code to output pixel-level retrievals
  - Provide SARB time ordered regional customized clouds, which removes the TISA contingency for RTM processing
  - Assign SW directional models to flux observations rather than carrying scene information in the daily interpolation code
  - Inter-calibrate GEO WV channels with CrIS (VIIRS does not have WV channel)
- Ed5 code improvements
  - All TISA codes run at the ASDC are now bitbucket
  - Multiple TISA members can now run the TISA codes, no bottle necks were only one person can run the code
  - The CERES GEO code to be versioned controlled with file handling capabilities
  - All multiple copy subroutines replaced with a single general subroutine in a library and move exception out of subroutine
  - Modularize the SW NB to BB, LW NB to BB, cloud and flux interpolation and averaging codes to run independently so that all TISA products use the same modules
  - All binary intermediate files to be in HDF/netCDF format

GEO STATUS

CERES record Geostationary Time Series



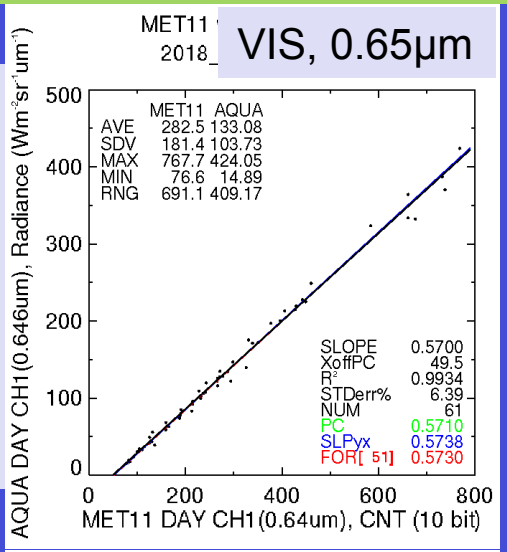
1st generation
2nd generation
3rd generation
MODIS/VIIRS

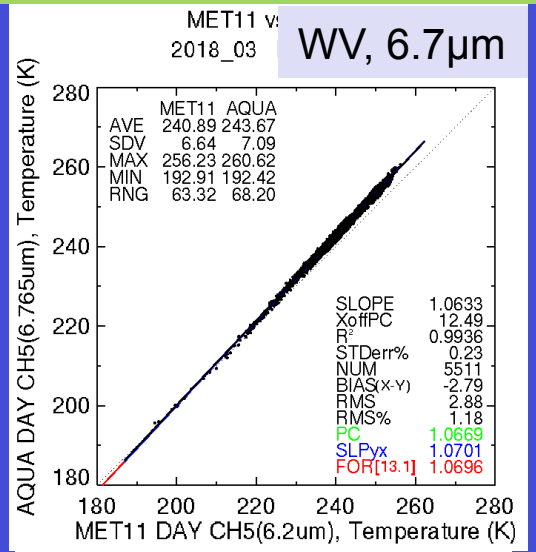
- Himawari-9 (140E) launched Nov 1, 2016, standby for Him-8, operational in 2022
- GOES-16 launched Nov 19, 2016, operational Dec 18, 2017 in East location, CERES record begins Jan 2018
- GOES-17 launched Mar 1, 2018, GOES-West
- Met-8 (41.5E) operational Oct 21, 2016, CERES record Feb 2017
- Met-11 (0E) to replace Met-10 in Feb 18, 2018
- JPSS-1 (NOAA-20) launched Nov. 18, 2017, JPSS-2 in 2022

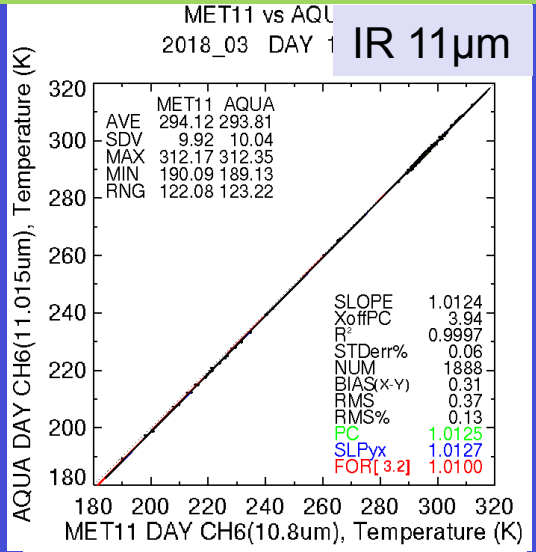
Met-11/Aqua-MODIS inter-calibration

Met-11 became operational on Feb 18, 2018, replaced Met-10, Met-10 and Met-11 are copies and show similar calibration gains. Met-11 suffered an outage on May 7.

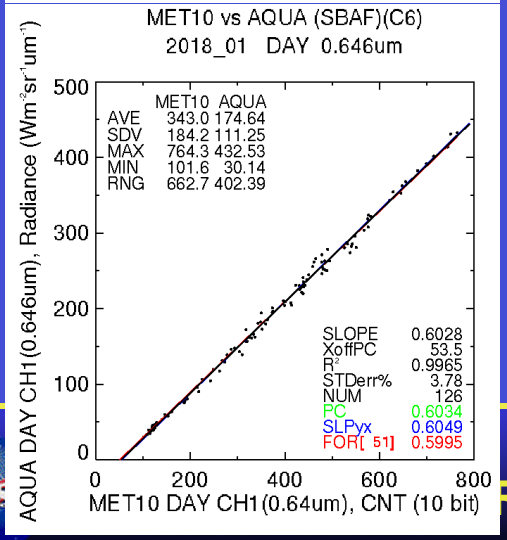
Met-11, March 2018

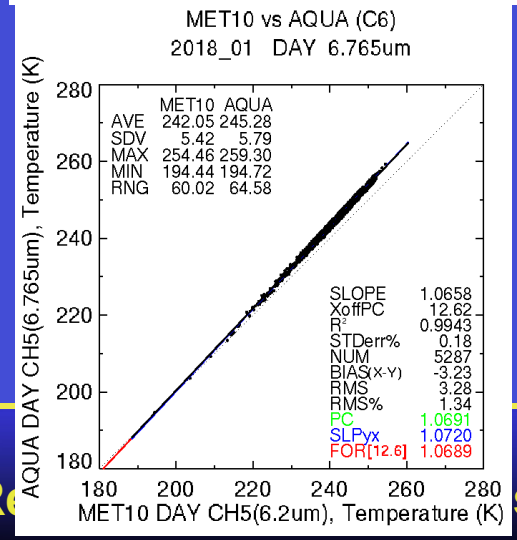


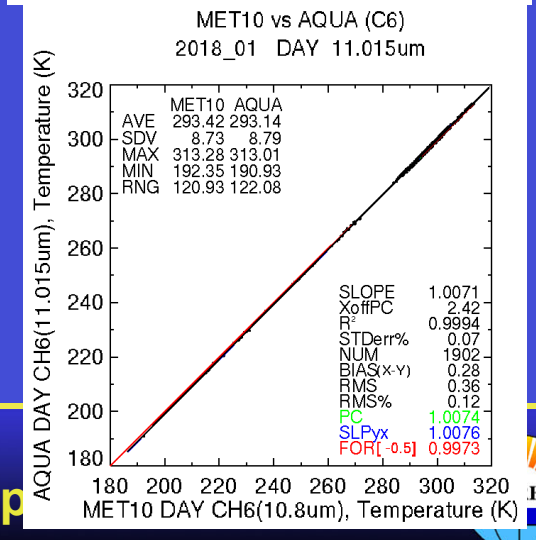




Met10, Jan 2018



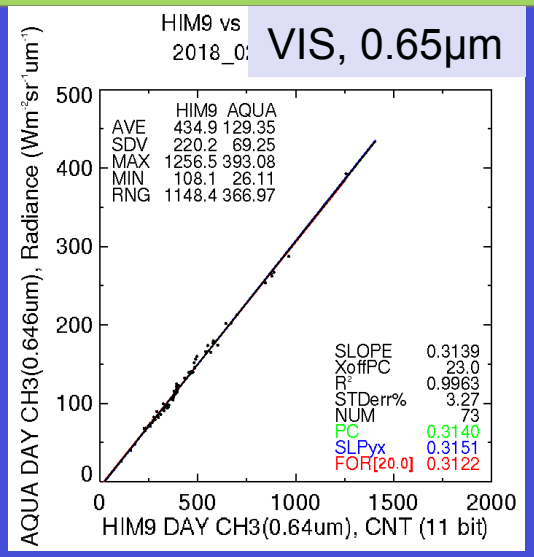


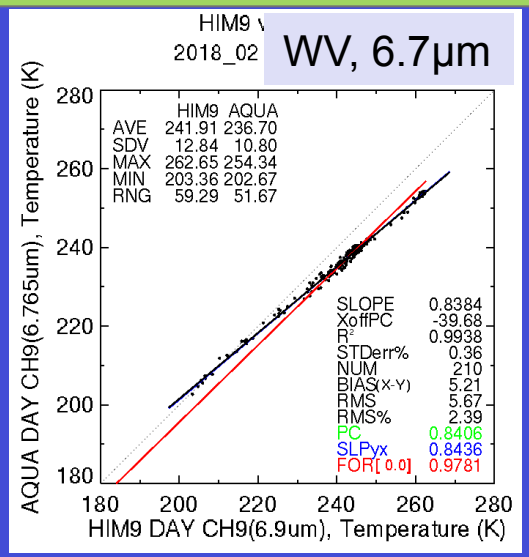


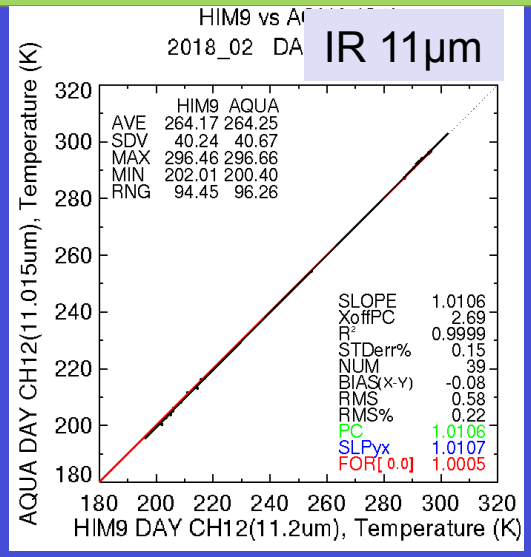
Himawari-9/Aqua-MODIS initial calibration

Him-9 was operational for Feb 13, 2018 for the first time, to update the Him-8 ground systems, Him-8 and Him-9 are copies and show similar calibration gains

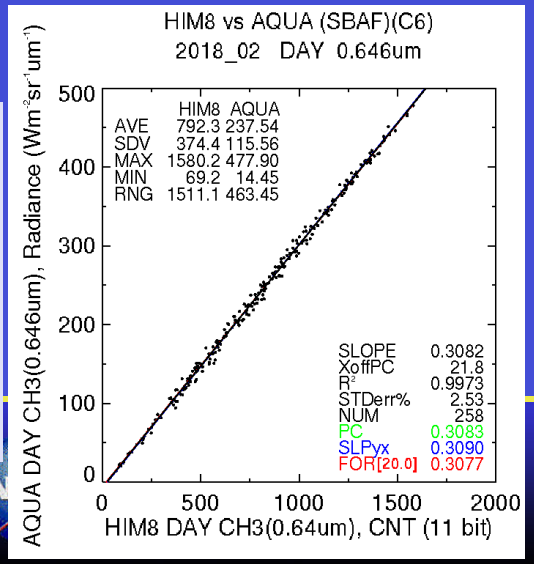
Him-9, Feb 2018

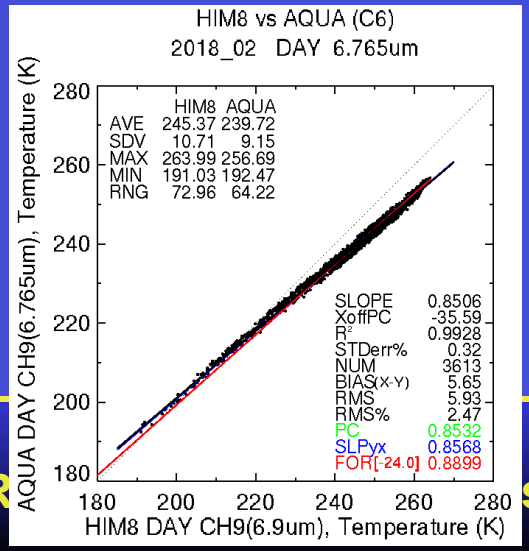


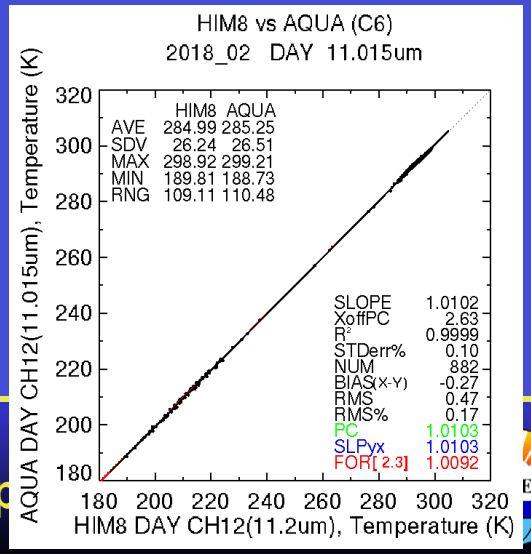




Him-8, Feb 2018



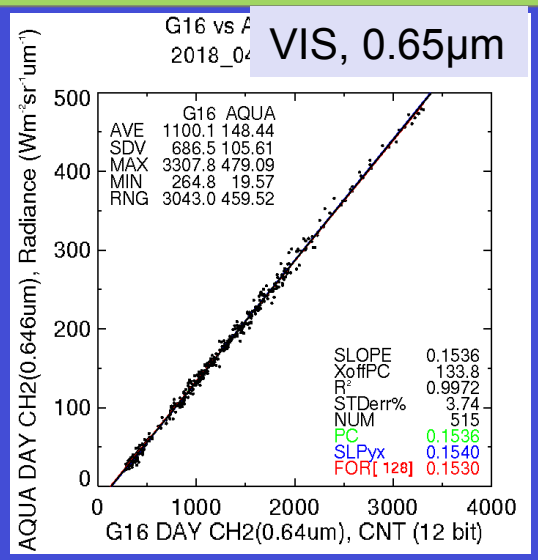


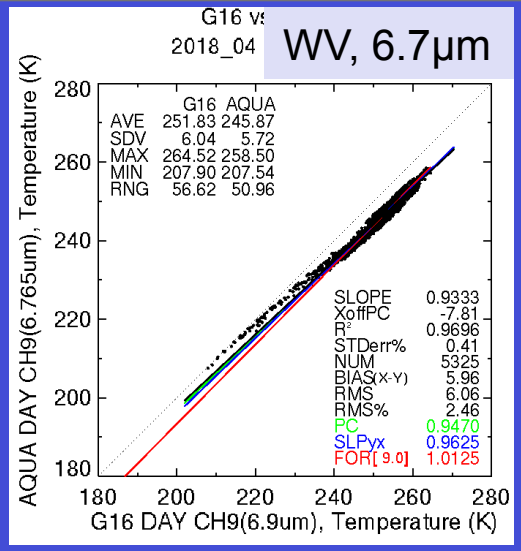


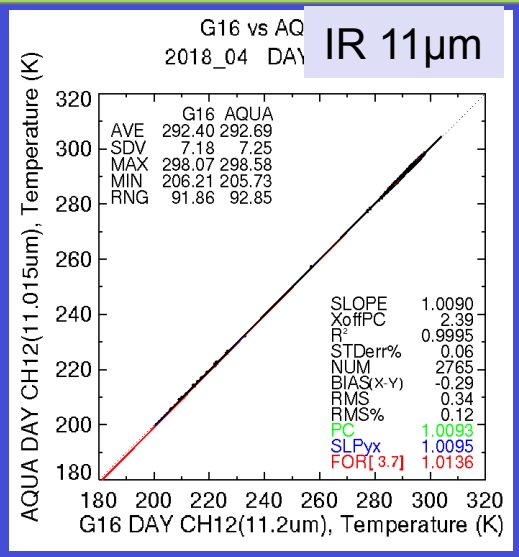
GOES-16/Aqua-MODIS initial calibration

GOES-16 was operational for Dec18, 2017, replaced GOES-13 over GOES-EAST, GOES-16 and Him-8 are copies and show similar calibration gains

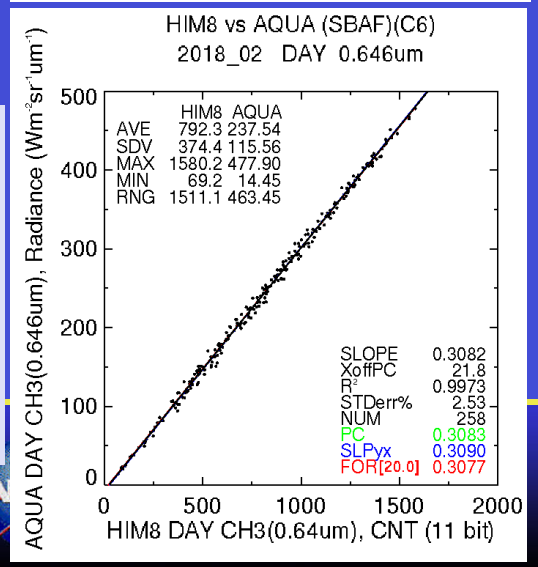
GOES-16, Apr 2018

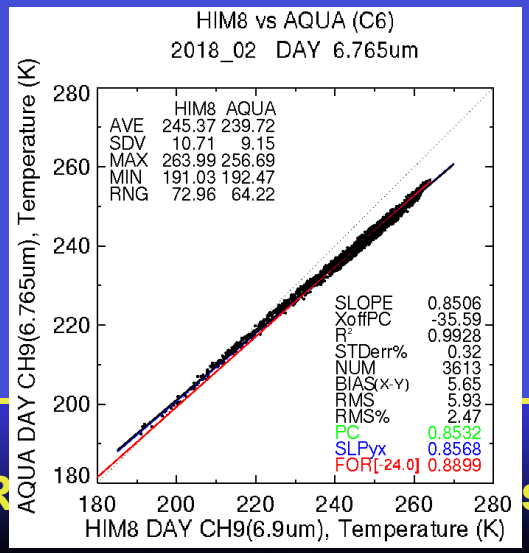


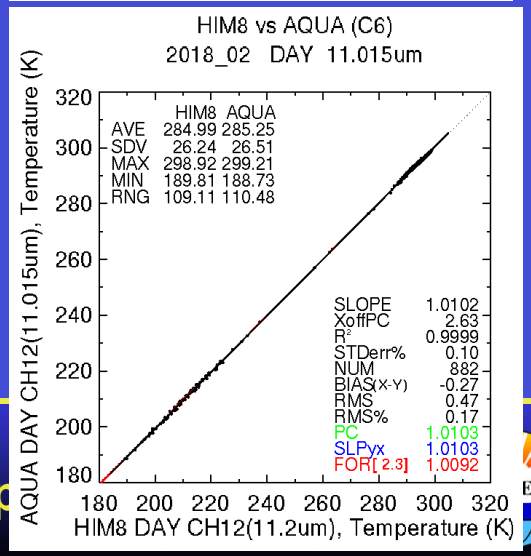




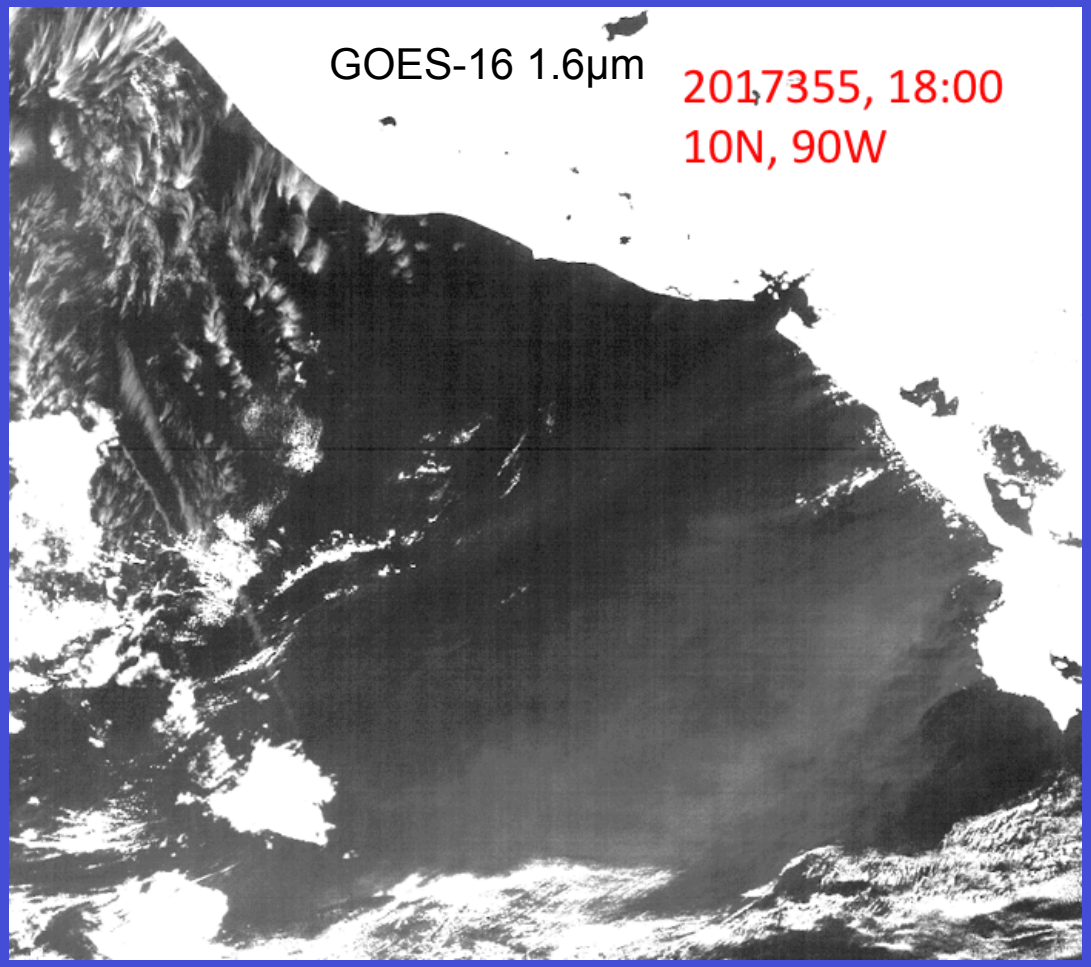
Him-8, Feb 2018

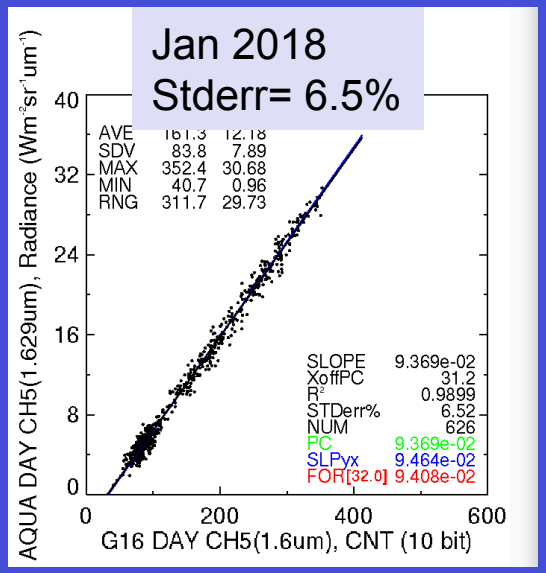


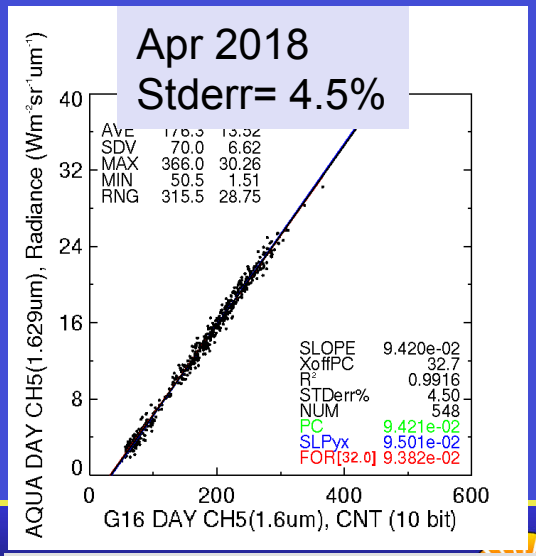




GOES-16 1.6µm channel



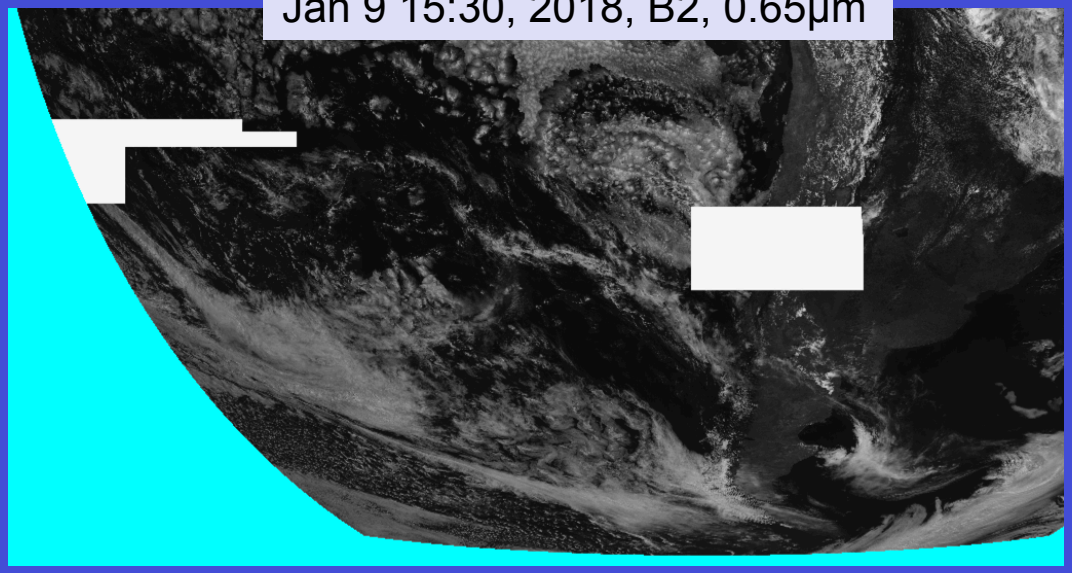




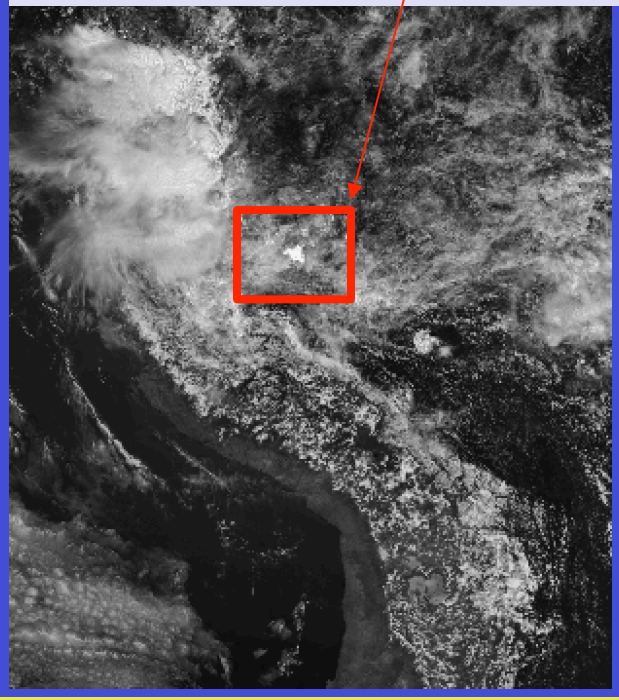
- On Dec 21, 2017 there was a 12.9% increase in counts for the 1.6µm channel
- On Apr 10 for a few hours the 0.65µm counts jumped by 10%, due to a ground segment issue, need to monitor for anomalies

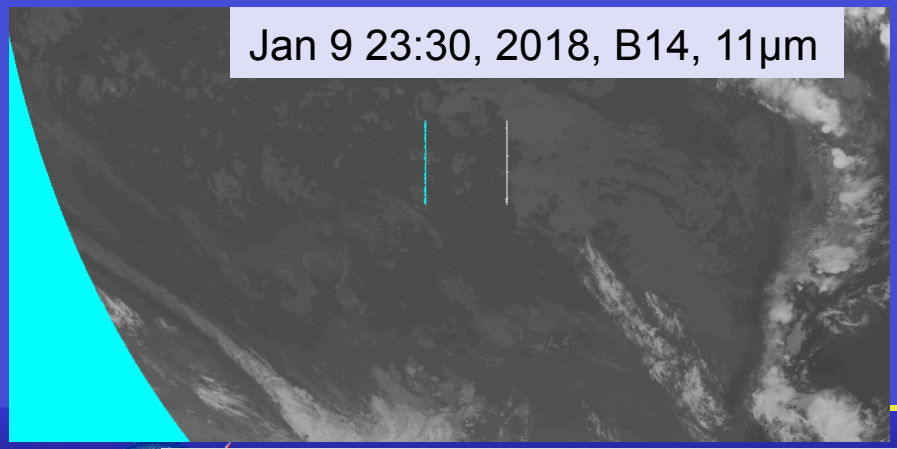
- There seems to be less noise in the 1.6µm channel now

GOES-16



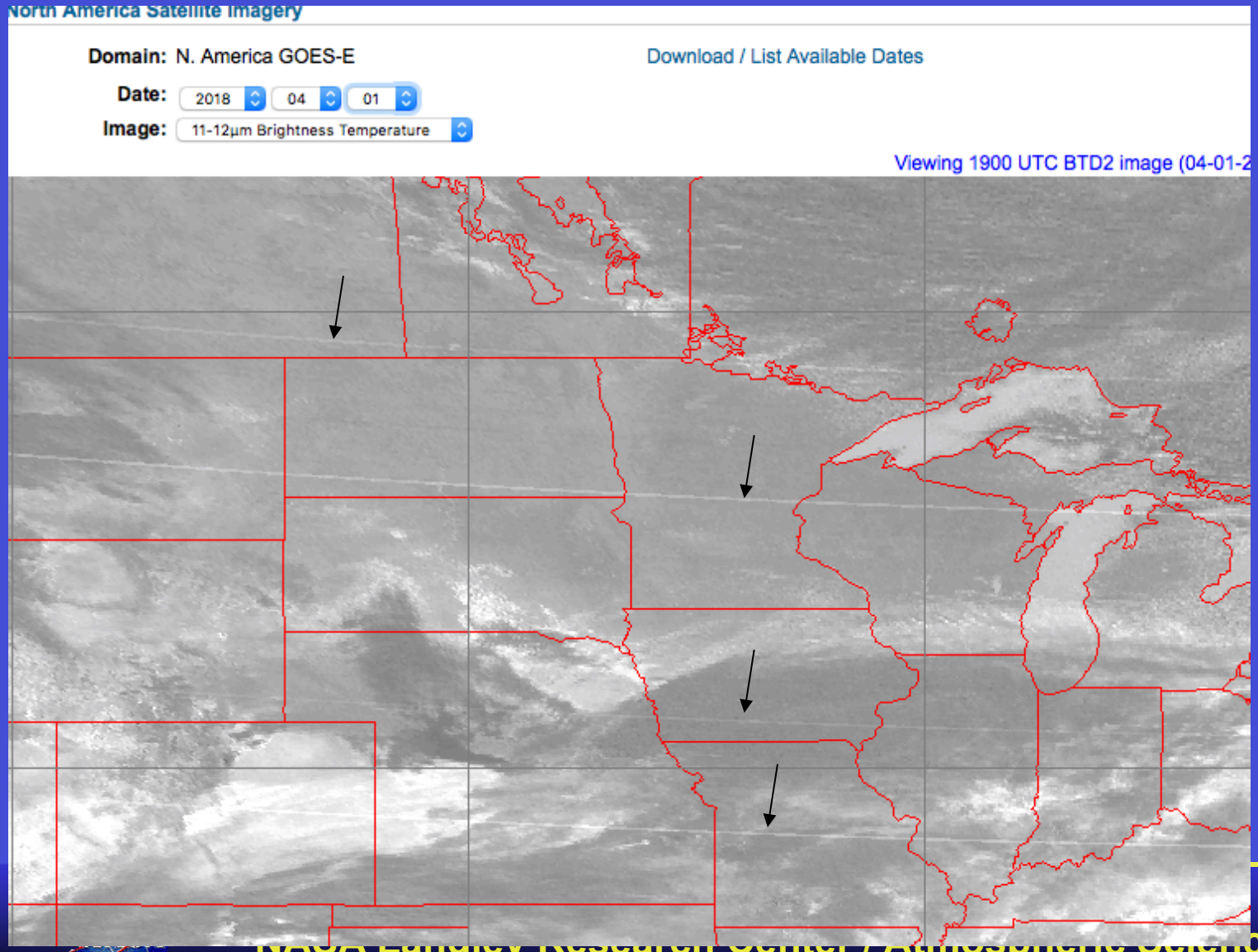
GOES-16 B2 is 12-bit, other channels are 10-bit, there are some channels with saturated locations





- Given that GOES-16 is a copy of Him-8, we did not expect the number of bad scan lines and blocks, needed to adjust GEO QC algorithm

GOES-16 11-12µm



MODIS/GEO instantanoues cloud comparison tool

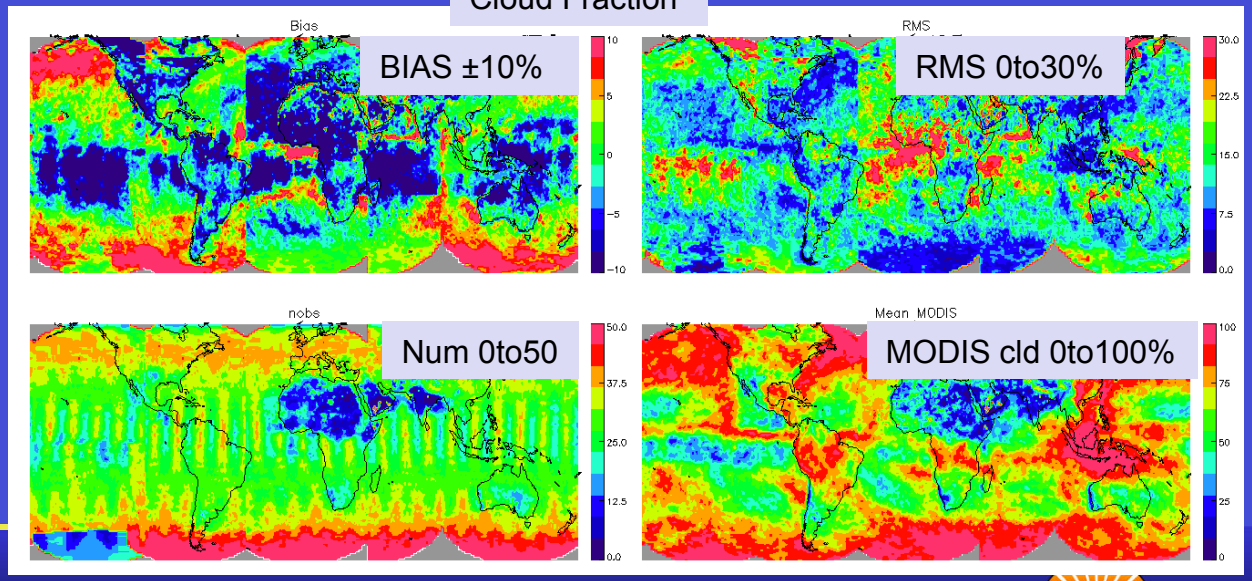
- Since TISA has code that matches instantaneous gridded GEO and CERES fluxes within 15 minutes for NB to BB normalization, this code was modified to facilitate comparing GEO and MODIS cloud retrievals that are within 15 minutes.
- The cloud comparison tool has an IDL GUI interface, it is hoped that once some of the CERES web sites have migrated to the Openshift container framework, that this tool can be hosted in this framework using PYTHON
- The cloud, TISA and SARB working groups can use the tool to evaluate GEO cloud property consistency with MODIS to optimize the surface flux computations
- The tool can evaluate cloud code changes during development along with other CWG plots.
- The tool has been useful to validate the GOES-16 cloud retrievals, before running SYNI offline, which takes about a week.

ASCII stats table for GOES-16

	Total Mean	Total Bias	Total RMS
cld	68.60	-0.60	19.43
teff	262.33	3.92	5.44
ttop	260.34	3.04	4.96
bop	273.22	2.70	4.27
peff	622.48	33.71	51.03
ptop	605.93	30.36	47.07
pbase	744.04	20.34	44.45
zefft	4.68	-0.56	0.83
ztop	4.97	-0.45	0.76
zbot	-99.99	-99.99	-99.99
phase	1.29	-0.07	0.22
LWP	85.90	14.23	39.94
IWP	210.50	140.26	234.28
liq_radius	13.67	1.48	1.91
ice_radius	54.40	4.15	11.39
emiss	0.84	0.04	0.06
tau	4.43	1.21	1.38

Euro-Africa (0W) | Indian Ocean (57E) | Western Pacific (140E)

Cloud Fraction

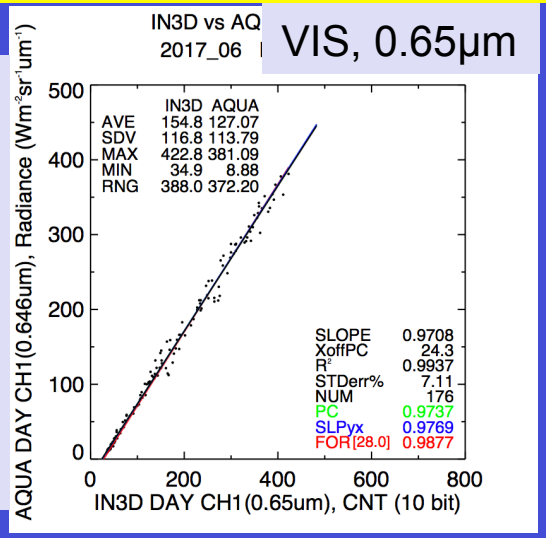


INSAT-3D/Aqua-MODIS inter-calibration

INSAT-3D (82E) operational since March 2014 over Indian Ocean, potential to replace Met-7 (2-ch) for Ed5, IR in current state not suitable for CERES

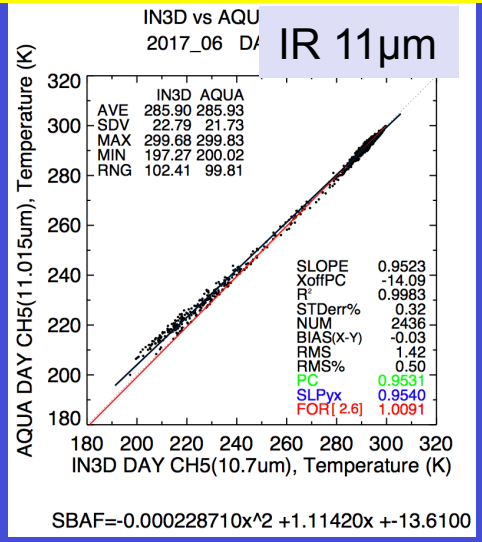
INSAT-3D, June 2017

VIS, 0.65µm

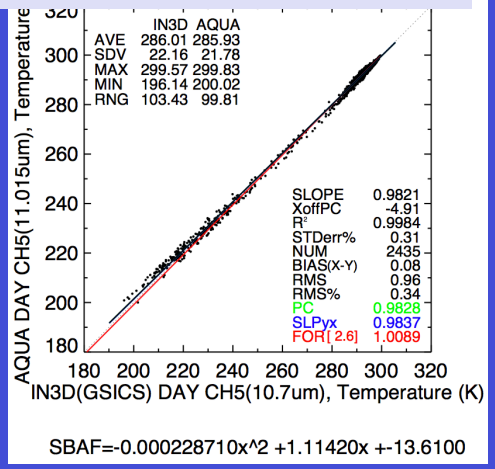


Visible inter-calibration looks good

IR 11µm



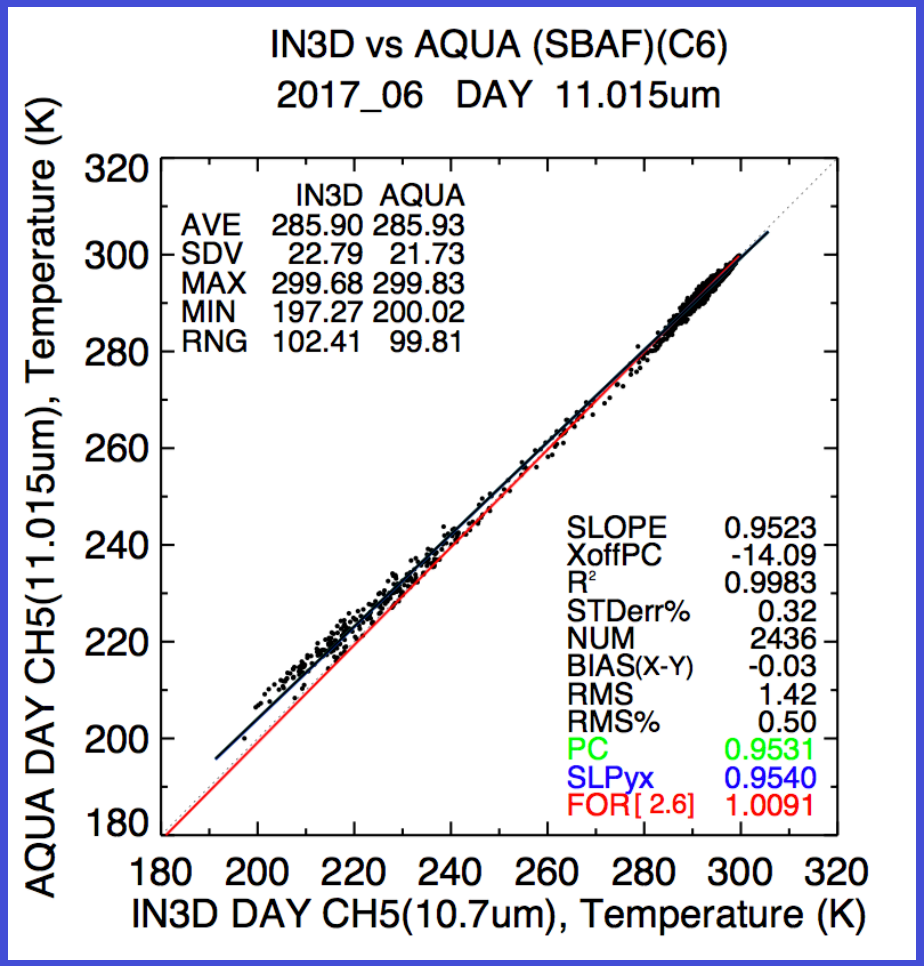
GSICS corrected IR 11µm

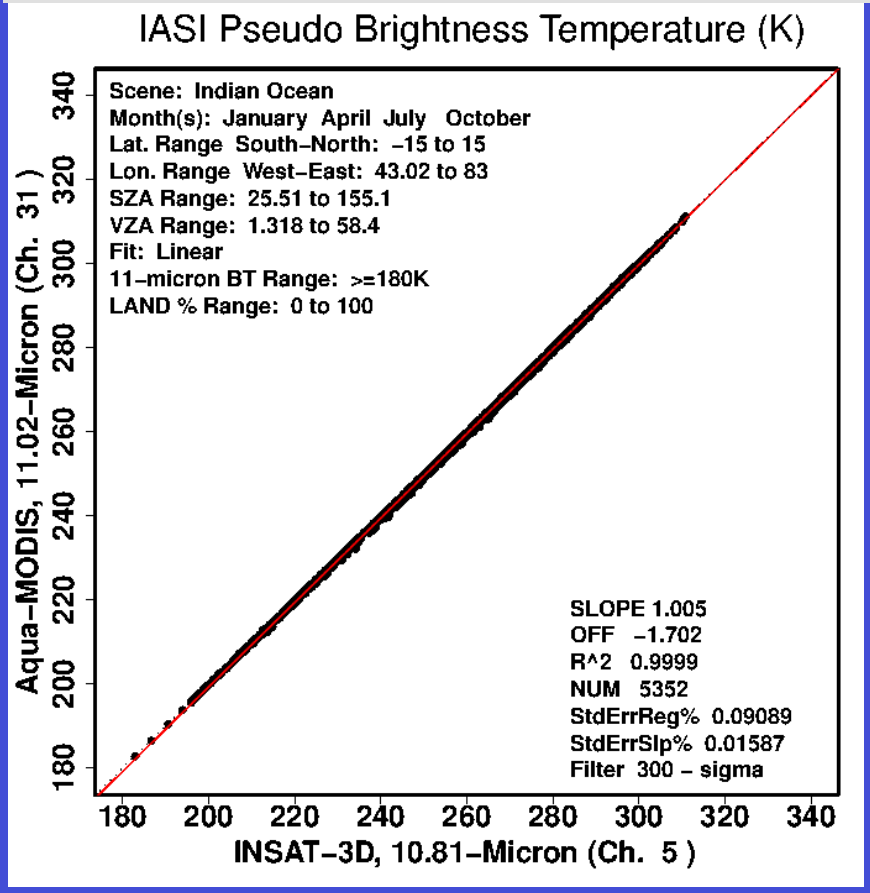


GSICS IR correction gets us half way there

Comparison of MODIS/INSAT-3D intercal

https://satcorps.larc.nasa.gov/cgi-bin/site/showdoc?mnemonic=SBAF&mode=IR



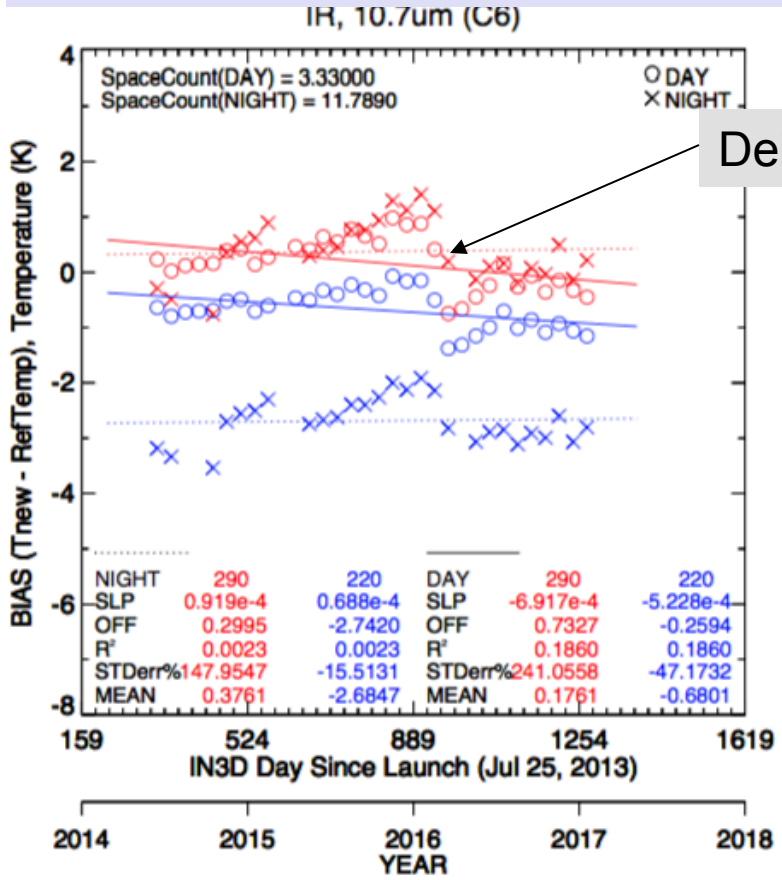


- Most of the INSAT-3D BT dependence with BT is due to the sensor calibration

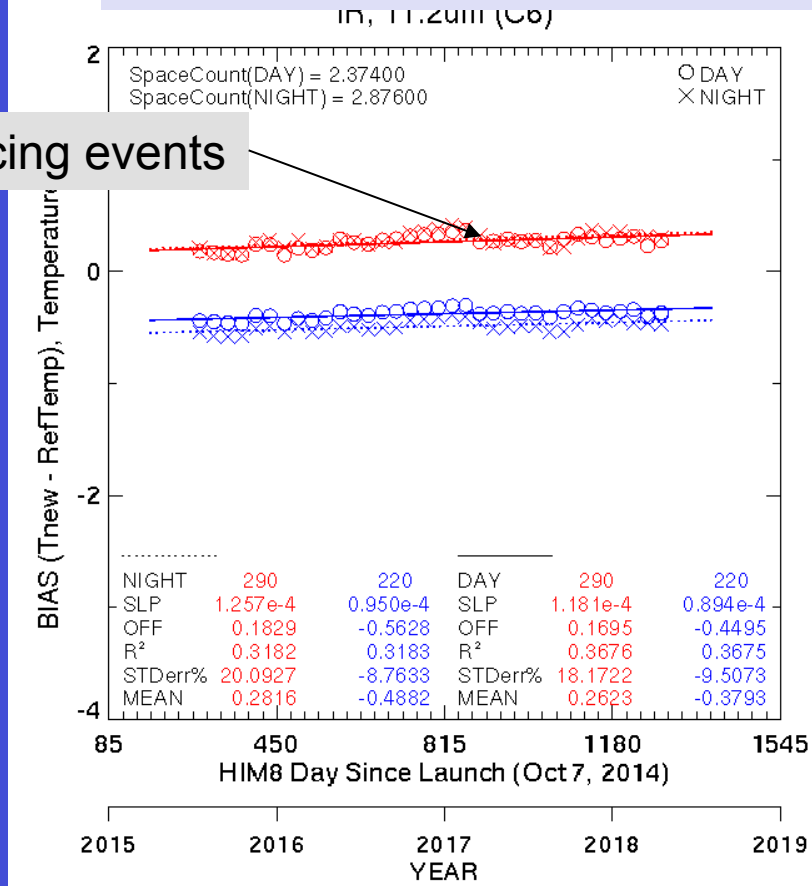
- The IASI pseudo BT Aqua and INSAT-3D pseudo BT pairs show near linearity with BT, this is the expected BT difference due to spectral band disparity

INSAT-3D and Him-8/Aqua-MODIS BT drifts

INSAT-3D/Aqua, bias@290, bias @220



Him-8/Aqua, bias@290, bias @220



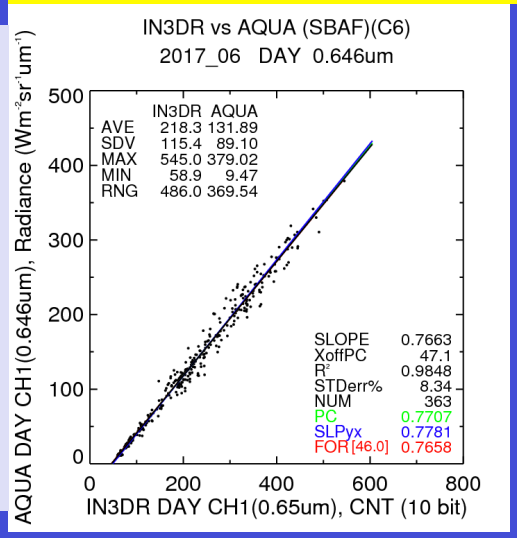
Deicing events

- INSAT-3D IR drifts are much larger than Him-8
- INSAT-3D also has BT non-linearity that needs to be corrected
- This would require some work if used for Ed5.

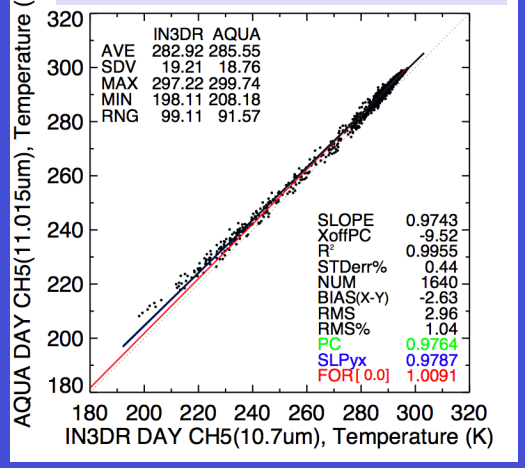
INSAT-3DR/Aqua-MODIS inter-calibration

INSAT-3DR (74E) became operational on July 2017 over Indian Ocean, potential to replace Met-7 (2-ch) for Ed5, IR in current state not suitable for CERES

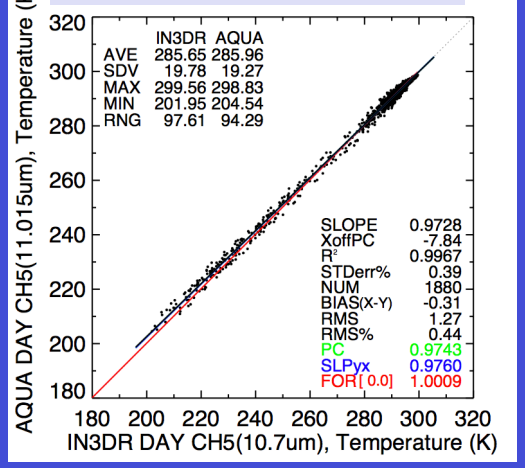
INSAT-3DR, June 2017



Before June 15, 2017

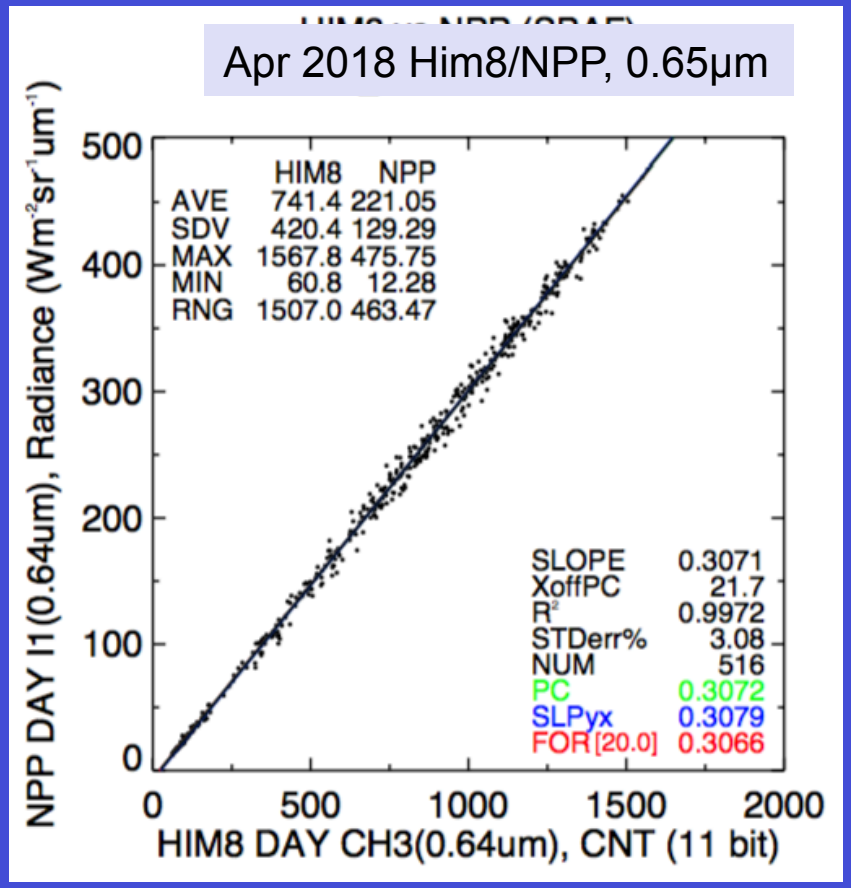


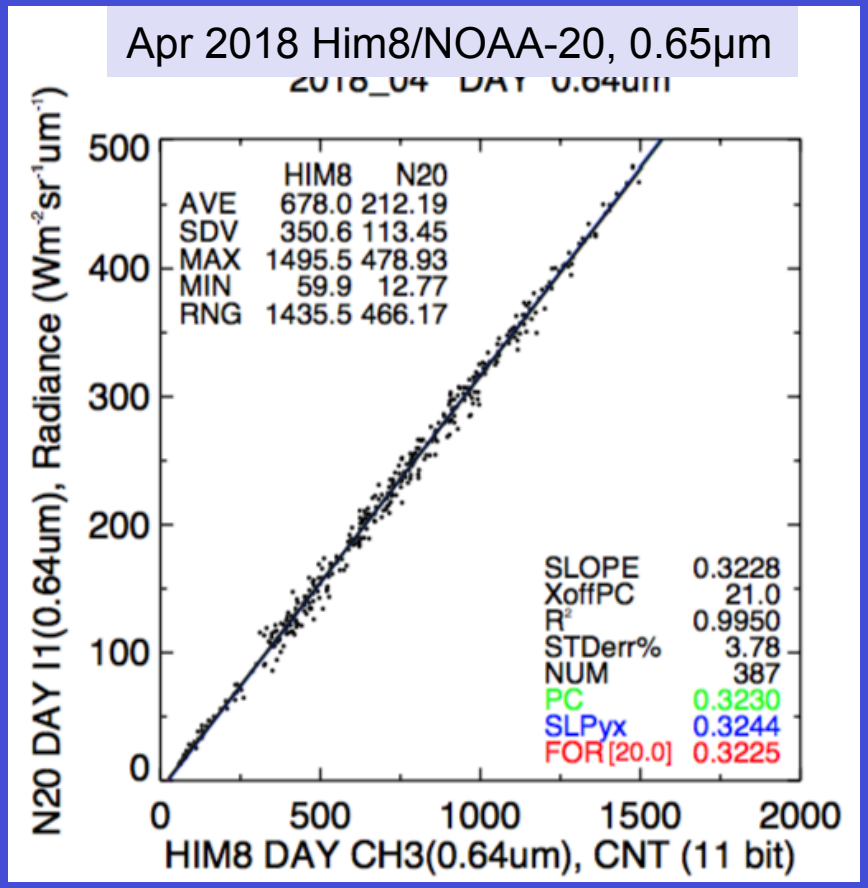
After June 15, 2017



- Difficult to identify INSAT-3DR operational calibration adjustment events and need to rescale inside the CERES framework
- Since INSAT-3DR is a copy of INSAT-3D it seems to have the same issues as INSAT-3D that were previously shown

JPSS-1/Him-8 inter-calibration



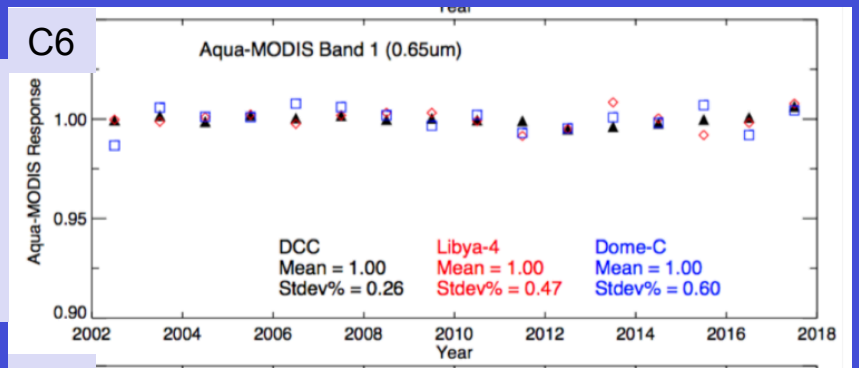


- JPSS-1 or NOAA-20 VIIRS data is now in netCDF format, had to modify read code for inter-calibration
- JPSS1-VIIRS radiances are based on pre-launch coefficients and are not corrected on orbit.
- JPSS1-VIIRS I1 (0.65µm) is 5% greater than NPP-VIIRS
- All JPSS1 VIIRS band Him-8 inter-calibrations are very similar with NPP-VIIRS

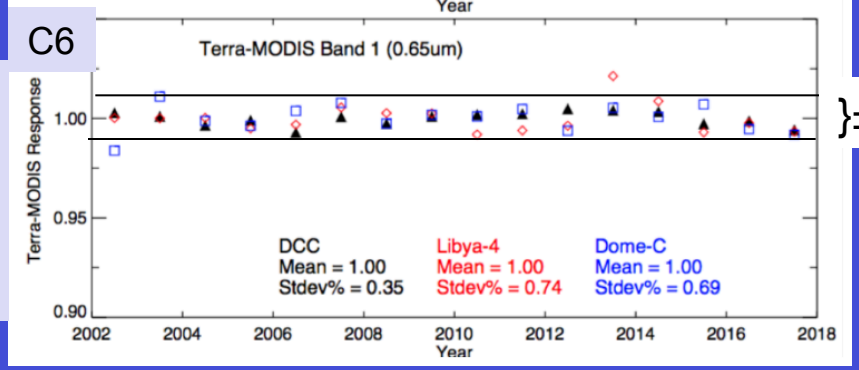
MODIS and VIIRS 0.65µm Stability

https://satcorps.larc.nasa.gov/cgi-bin/site/showdoc?mnemonic=STABILITY-MODIS

Aqua-MODIS

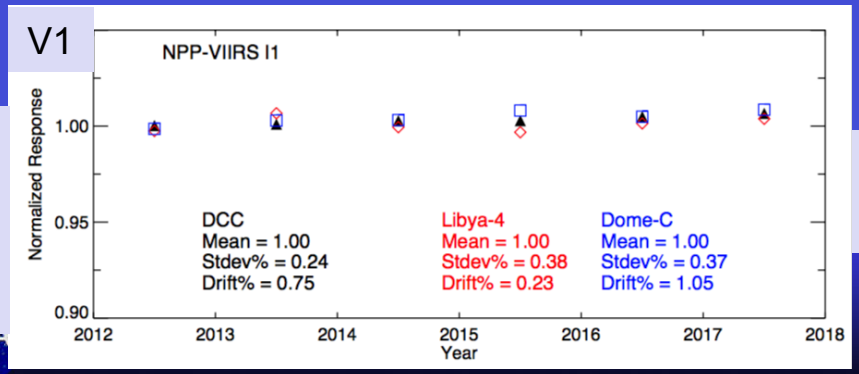


Terra-MODIS



}±1%

NPP-VIIRS

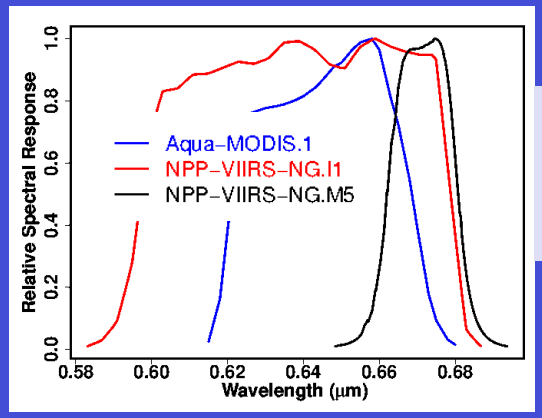


Use DCC, Libya-4 and Dome-C Earth invariant targets to monitor the stability of MODIS and Terra

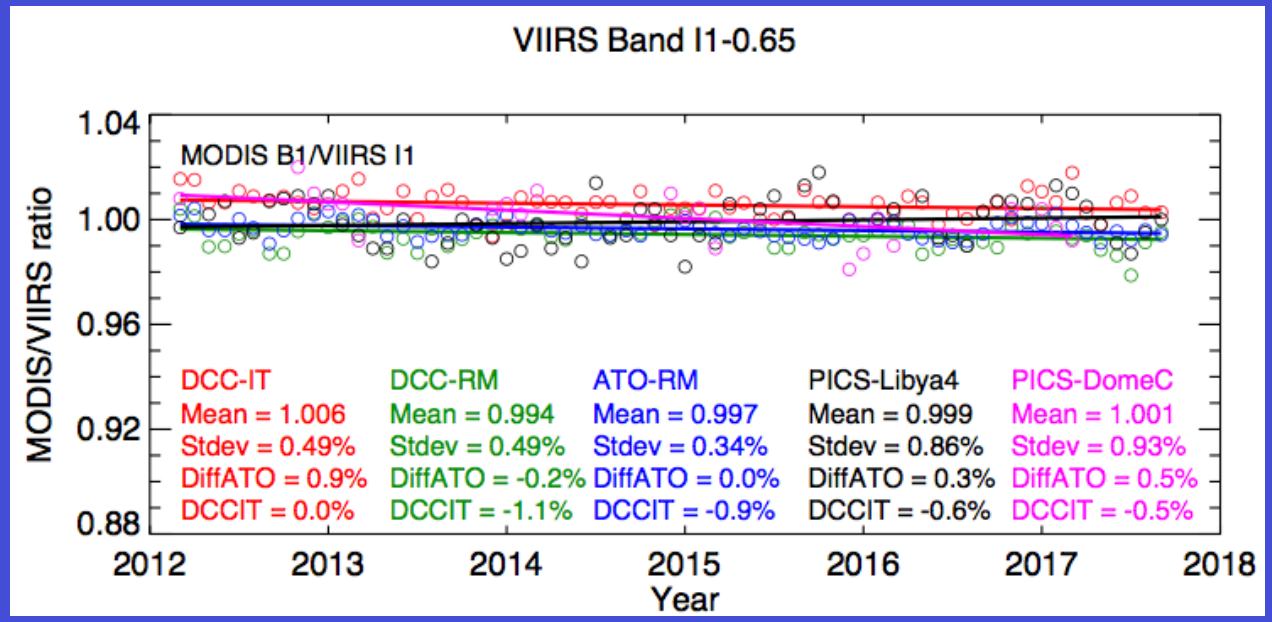
The stability of each instrument is evaluated independently. If the changes by more than 1% baseline it is adjusted in MODIS cloud retrieval code annually.

NPP-VIIRS V1 I1(0.65µm) band, seems to have a calibration drift of 0.75%/6years

Aqua-MODIS B1 to NPP-VIIRS I1 (0.65µm) Scaling Factors

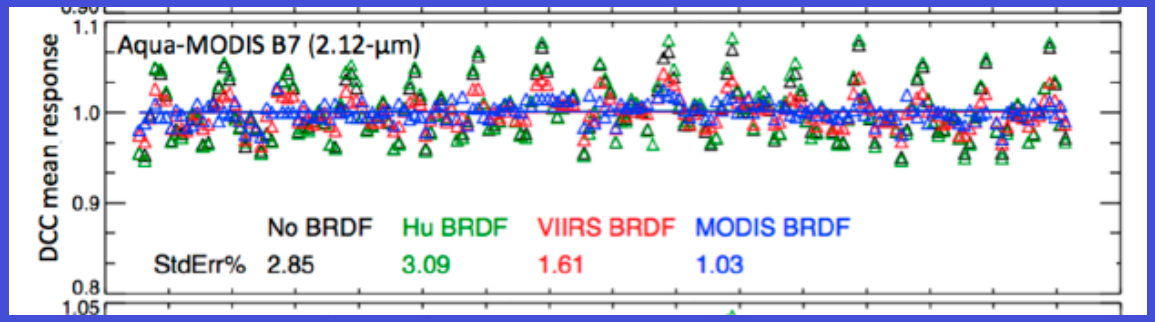


The MODIS B1 and VIIRS I1 band have more similar spectral response functions then does the M5 band



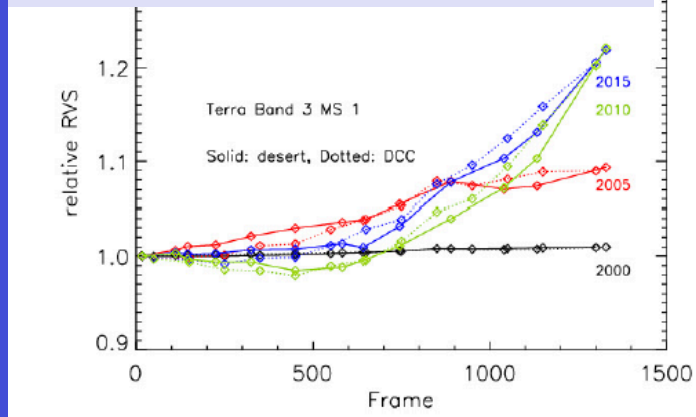
- All 5 inter-calibration methods are within 1%
- No coincident collocated observations will be available between NPP and NOAA-20 VIIRS
- This validates that the invariant target methods can scale the channels between MODIS and VIIRS. Also the VIIRS spectral bands are very similar to each other reducing the scaling uncertainty

Improvements/Applications of the DCC calibration method

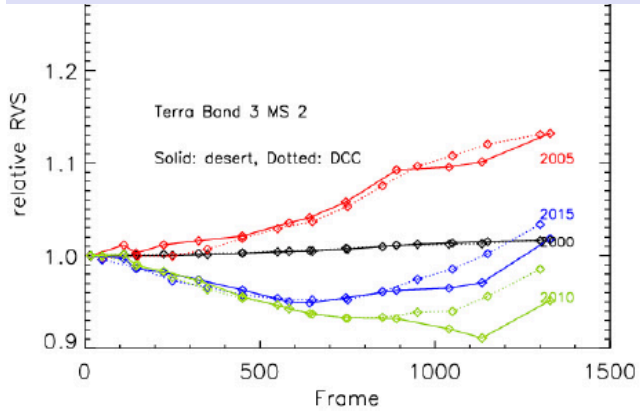


The implementation of climatology BRDFs for SWIR bands has greatly reduced the uncertainty of the DCC invariant target calibration method to determine the MODIS and VIIRS SWIR band stability

Terra Mirror Side 1 Band 3 (0.48µm)



Terra Mirror Side 2 Band 3 (0.48µm)



The DCC calibration method helped validate the MODIS operational response versus scan angle improvements in C6

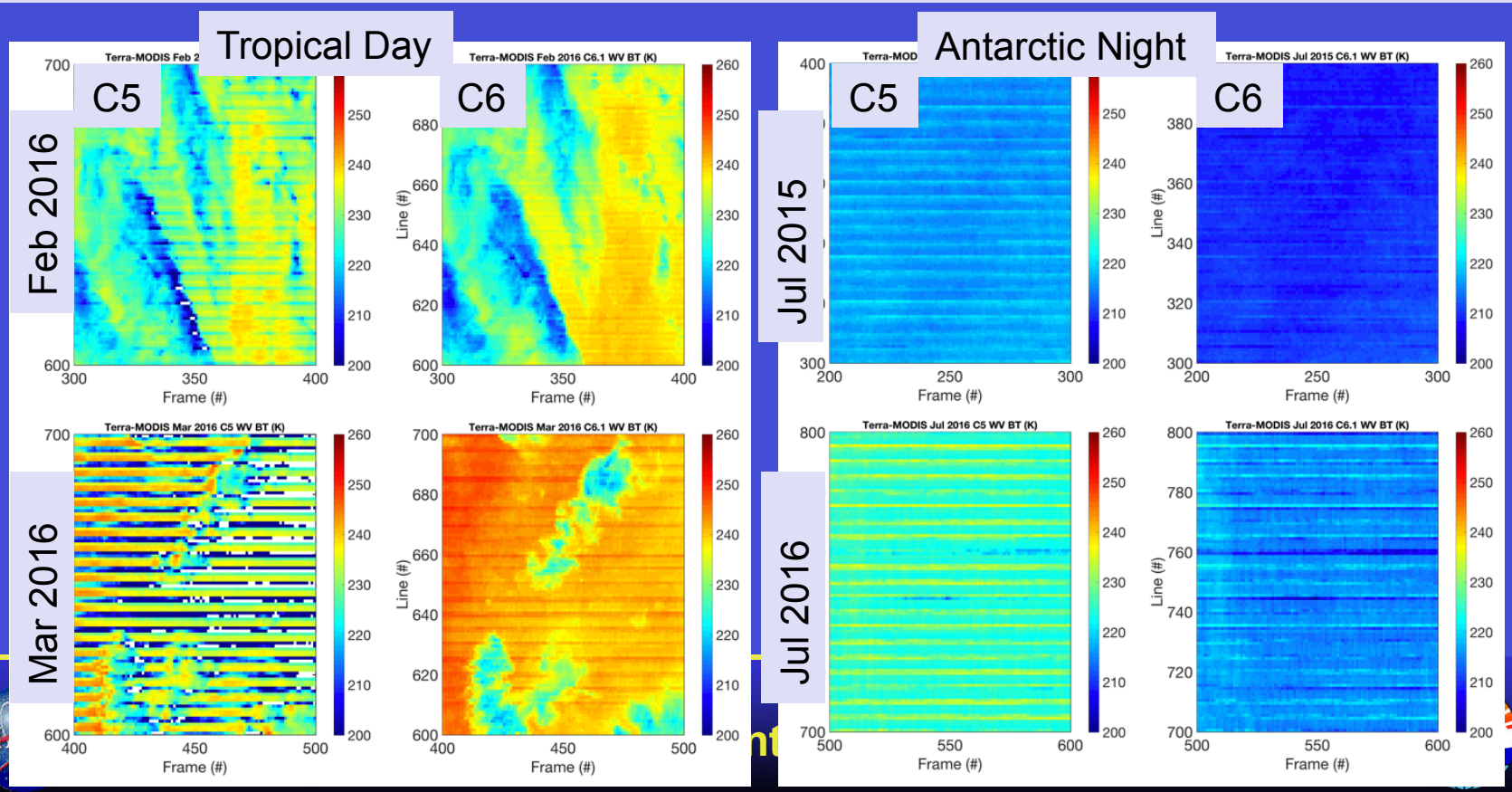
• Mu, Q., A. Wu, X. Xoing, D.R. Doelling, A. Angal, T. Chang, R. Bhatt, 2017, Optimization of a Deep Convective Cloud Technique in Evaluating the Long-Term Radiometric Stability of MODIS Reflective Solar Bands, Remote Sens. 2017, 9, 535; doi:10.3390/rs9060535

• Bhatt, Rajendra; Doelling, David R.; Scarino, Benjamin; Haney, Conor; Gopalan, Arun (2017), Development of Seasonal BRDF Models to Extend the Use of Deep Convective Clouds as Invariant Targets for Satellite SWIR-Band Calibration, *Remote Sensing*, 9(10), 1061. https://doi.org/10.3390/rs9101061

• A. Angal, X. Xiong, Q. Mu, D. R. Doelling, R. Bhatt and A. Wu, "Results from the Deep Convective Clouds-Based Response Versus Scan-Angle Characterization for the MODIS Reflective Solar Bands," in *IEEE Transactions on Geoscience and Remote Sensing*, vol. PP, no. 99, pp. 1-14., 2018, doi: 10.1109/TGRS.2017.2759660

MODIS C6.1 to C5 scaling factors

- Reprocess the CERES record from March 2016 after the Terra spacecraft anomaly to mitigate the Terra-MODIS WV 6.7μm and 8.6μm cross-talk issues found in C5
- Need to scale C6.1 radiances to C5 in order to remove any absolute MODIS channel calibration differences between C6.1 and C5

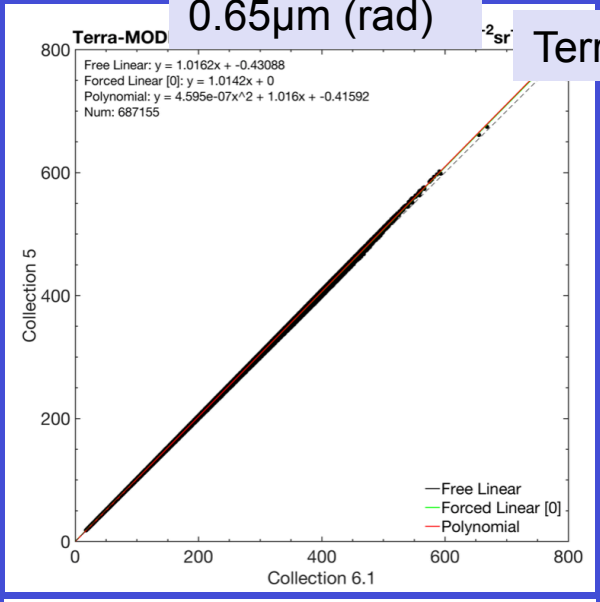


MODIS C6.1 to C5 scaling factors

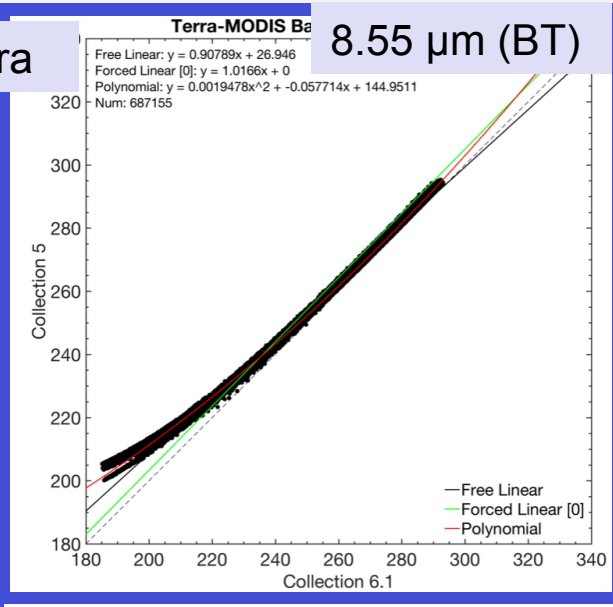
https://satcorps.larc.nasa.gov/cgi-bin/site/showdoc?mnemonic=SCATTER-TERRA5

0.65µm (rad)

Terra

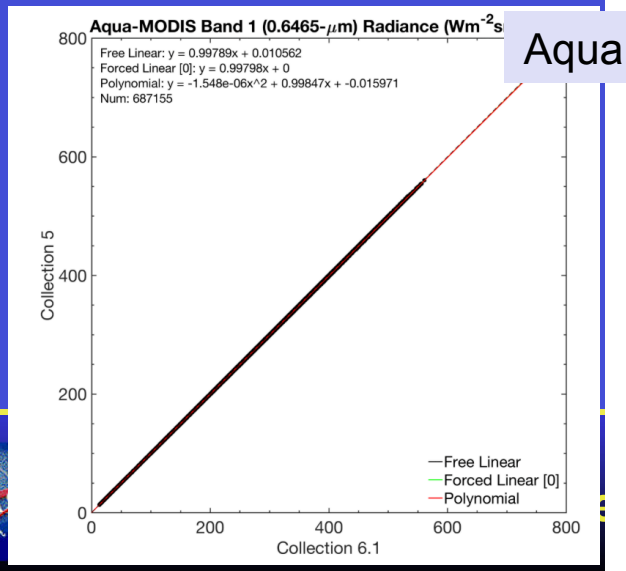


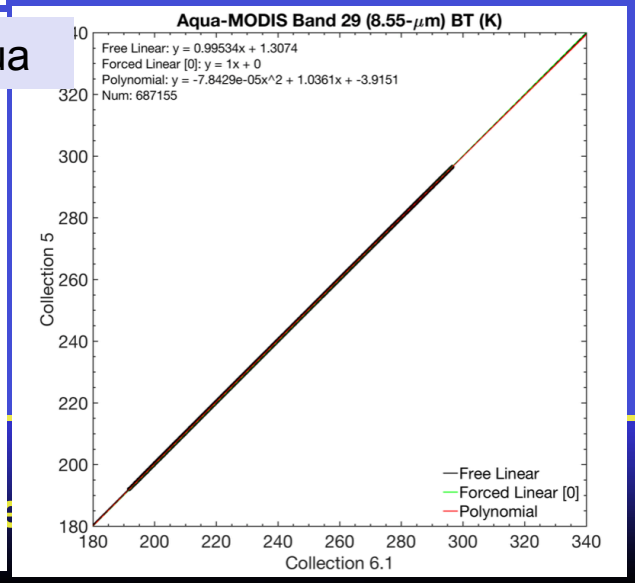
8.55 µm (BT)



- Use a tropical granule, which has the complete range of Earth reflected and emitted radiances
- Regress pixel level C5 and C6.1 radiances to obtain scaling factors

Aqua





Terra-MODIS C6.1 to C5 scaling factors

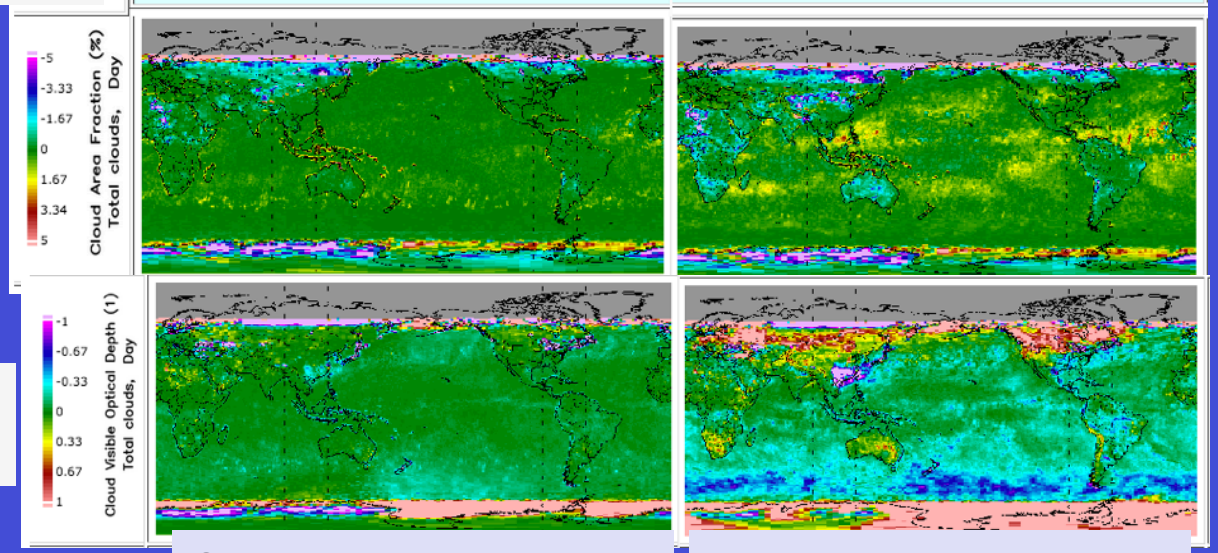
Daytime

Scaled, Jan 2016

Unscaled, Jan 2016

Cloud ±5%

ΔCOD ±1



Before Terra anomaly

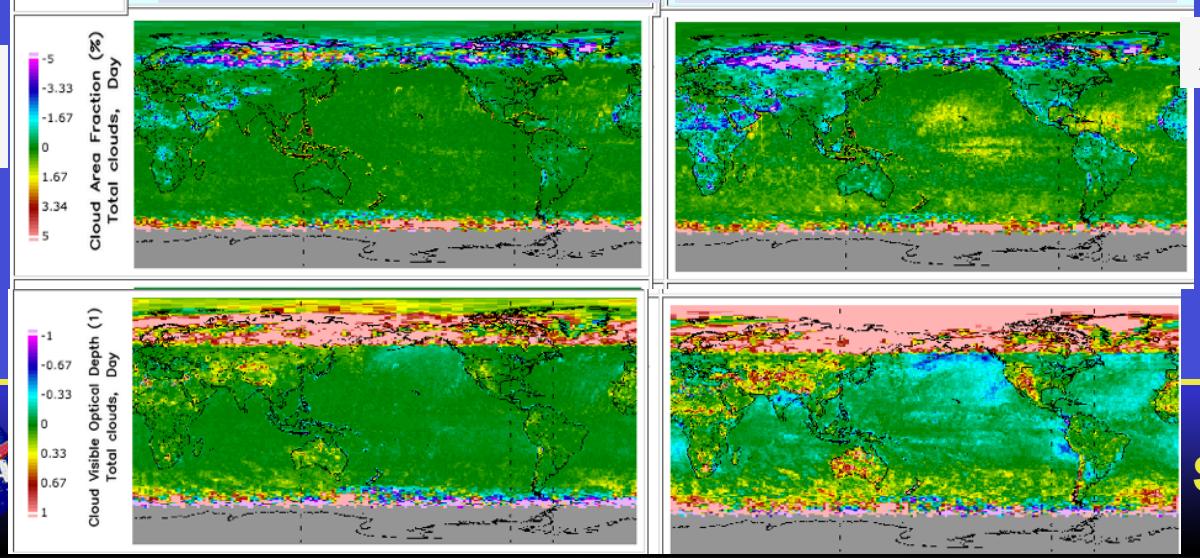
The C6.1 scaled cloud properties are more consistent with C5 than the unscaled

Scaled, July 2016

Unscaled, July 2016

Cloud ±5%

ΔCOD ±1



After Terra anomaly

GEO calibration conclusions

- Initiated JPSS-1 (NOAA-20) VIIRS and GEO inter-calibration
- Monitoring the stability of Terra-MODIS, Aqua-MODIS, and NPP-VIIRS visible bands
- Provided Terra and Aqua C6.1 to C5 scaling factors
  - MODIS C6 stops in April 2018
  - Will reprocess from March 2016 with improved Terra-MODIS C6.1 images
- Initiated Aqua-MODIS C6.1 to NPP-VIIRS V1 scaling factors
- GOES-16 has been calibrated and cloud retrievals are being validated, processing begins in Jan 2018
  - Discovering and monitoring anomalies (GEO anomalies never seem to go away)
  - GOES-17 should be operational late this year and is similar to GOES-16
- Met-11 has been calibrated, preparing for cloud retrieval validation
- Him-9 has been calibrated, run the one day with Him-8 retrieval code
- INSAT-3D and INSAT-3DR need work in the IR for possible use in Ed5
- CERES GEO calibration paper published

Doelling, D.R., C. Haney, R. Bhatt, B. Scarino, A. Gopalan, Geostationary Visible Imager Calibration for the CERES SYN1deg Edition 4 Product, *Remote Sens.* **2018**, *10*(2),288

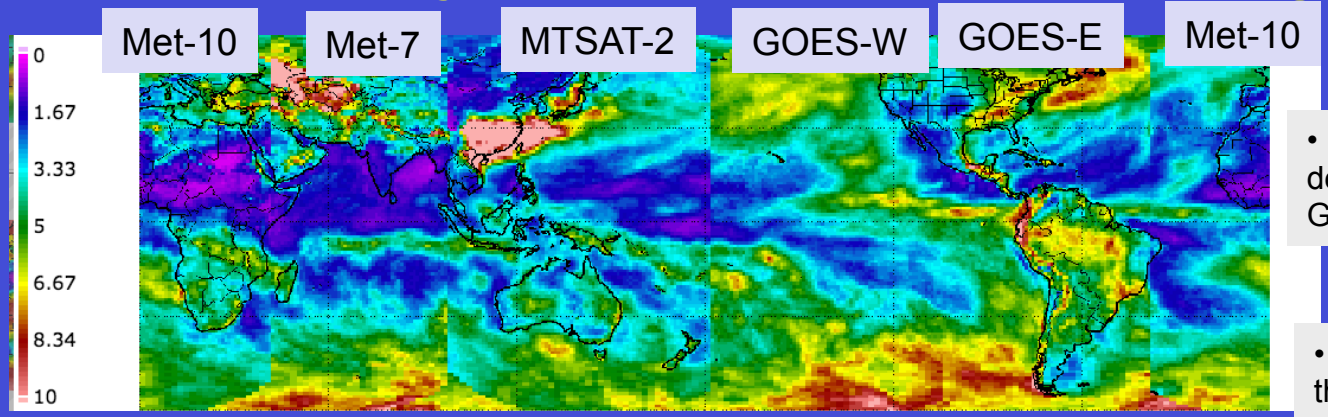
SYN1DEG GEO SW FLUX VALIDATION

CERES SYN1deg GEO SW flux Validation

- Starting to prepare the SYN1deg Ed4A GEO flux paper
- The SW 5x5 regional normalization removes the GEO derived SW flux regional monthly mean biases
  - Which may result from inconsistent LUT bins and cloud properties in both the NB to BB and ADM models
- Test the normalization by artificially increasing the GEO visible calibration by ±3%.
  - This will impact both the GEO derived SW fluxes and the cloud properties.
  - Cloud properties are not normalized
  - GEO cloud property discontinuities apparent at the GEO boundaries
- The GEO derived LW flux algorithm does not use cloud properties
  - Will modify the IR and WV calibration to validate.

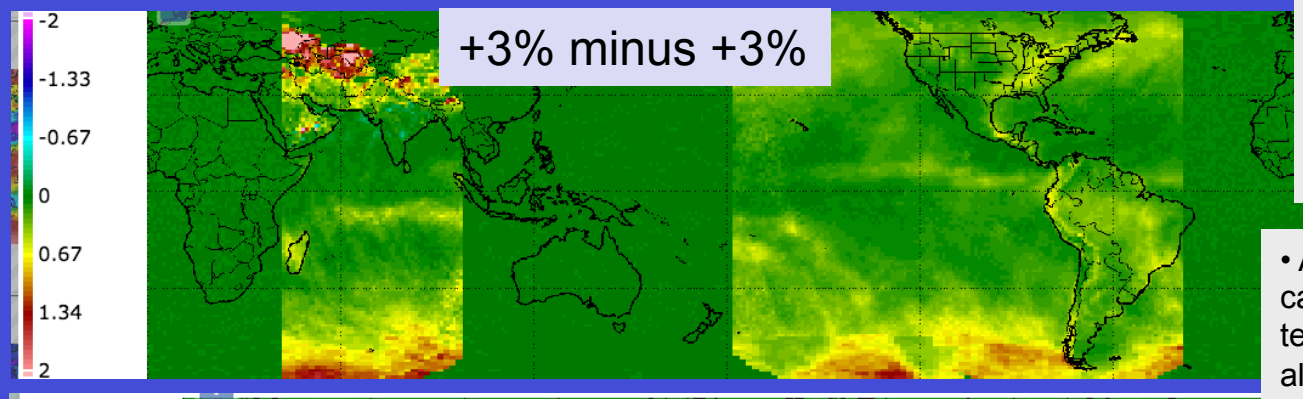
Jan 2012, adjust visible calibration by ±3%

COD 0to10



- Note the cloud optical depth discontinuities at GEO boundaries

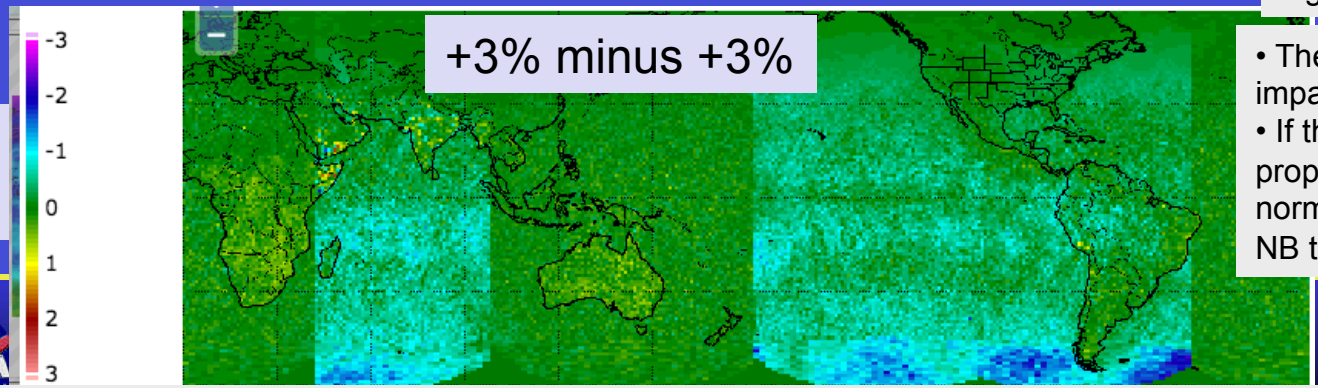
ΔCOD ±1



- COD changes due to the visible calibration change of 6% For Met-7, GOES-W and GOES-E
- The cloud properties were held constant for Met-10 and MTSAT-2

- Adjust the visible calibration for 5 GEOs to test the SW NB to BB algorithm

ΔSW ±3Wm^{-2}

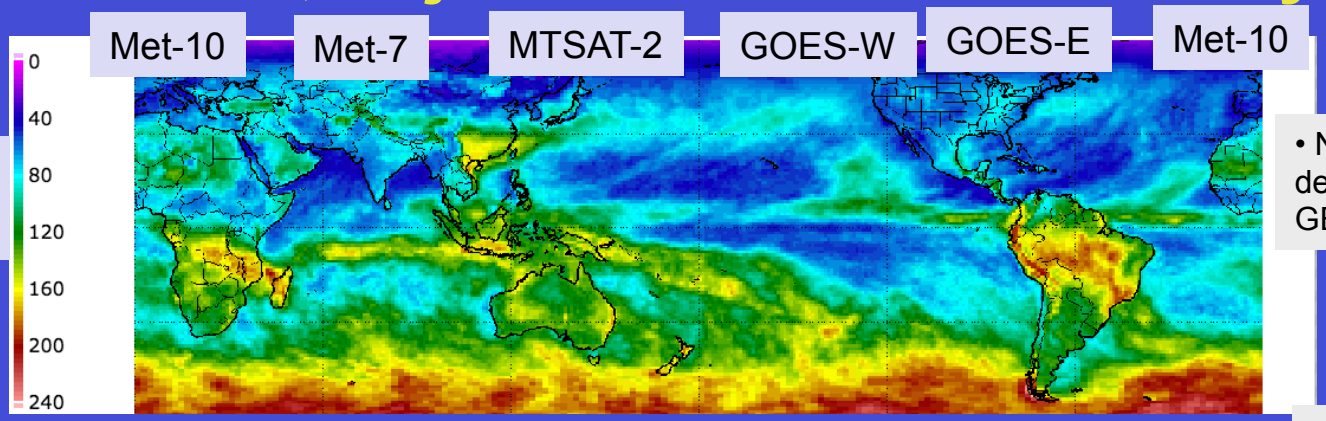


- The cloud properties impact the diurnal models
- If there are no cloud property changes, the normalization removes most NB to BB regional biases

The regional SW flux difference is within 2 Wm^{-2}. Largest differences are not occurring in diurnal varying regions

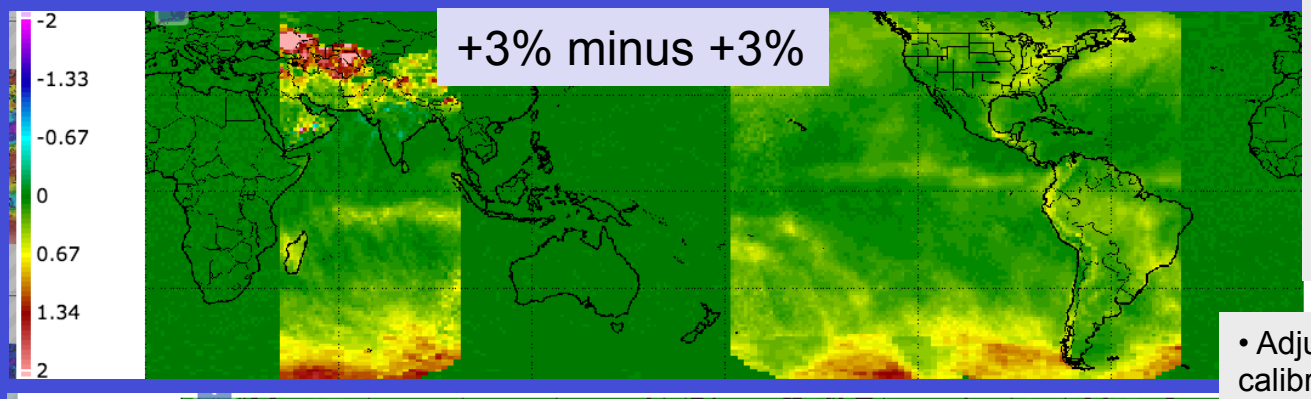
Jan 2012, adjust visible calibration by ±3%

SW 0 to 240Wm^{-2}



- Note the cloud optical depth discontinuities at GEO boundaries

ΔCOD ±1



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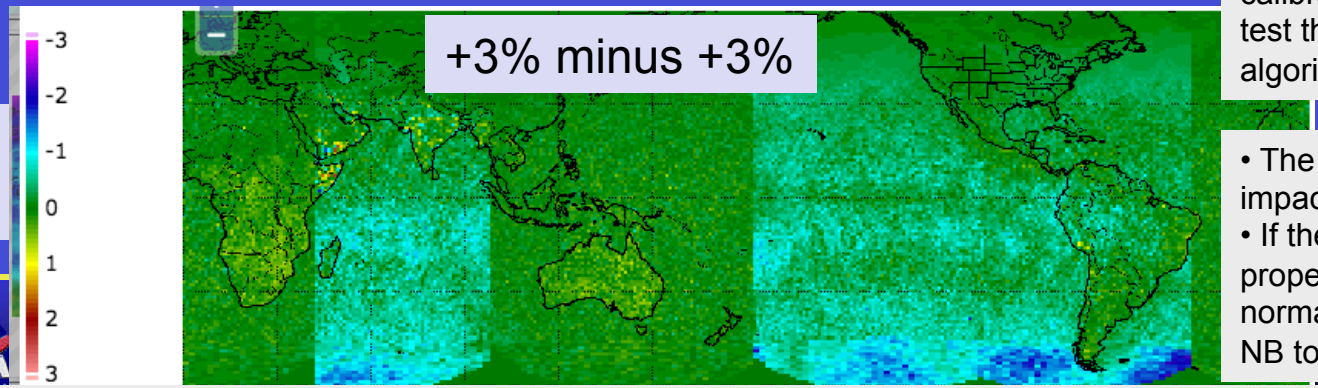
- The cloud properties were held constant for Met-10 and MTSAT-2

ΔSW ±3Wm^{-2}



- Adjust the visible calibration for 5 GEOs to test the SW NB to BB algorithm
- The cloud properties impact the diurnal models
- If there are no cloud property changes, the normalization removes most NB to BB regional biases

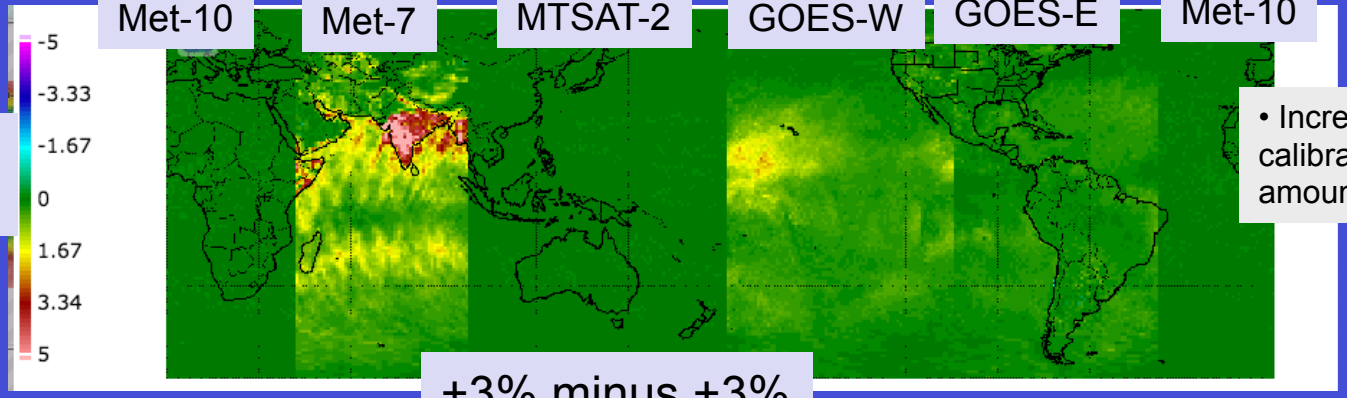
The regional SW flux difference is within 0.8%. Largest differences are not occurring in diurnal varying regions

Jan 2012, adjust visible calibration by +3%

Met-10 | Met-7 | MTSAT-2 | GOES-W | GOES-E | Met-10

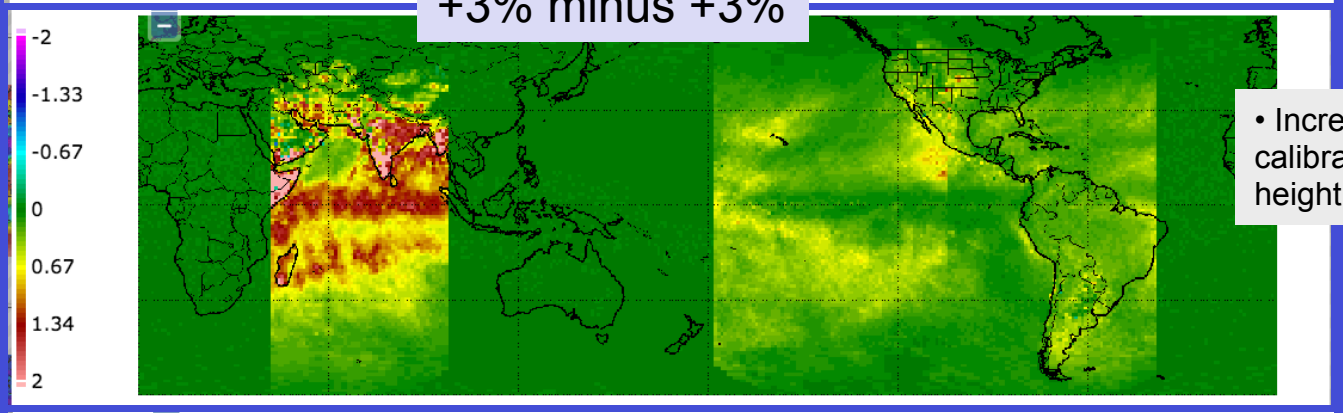
+3% minus +3%

ΔCloud% ±5



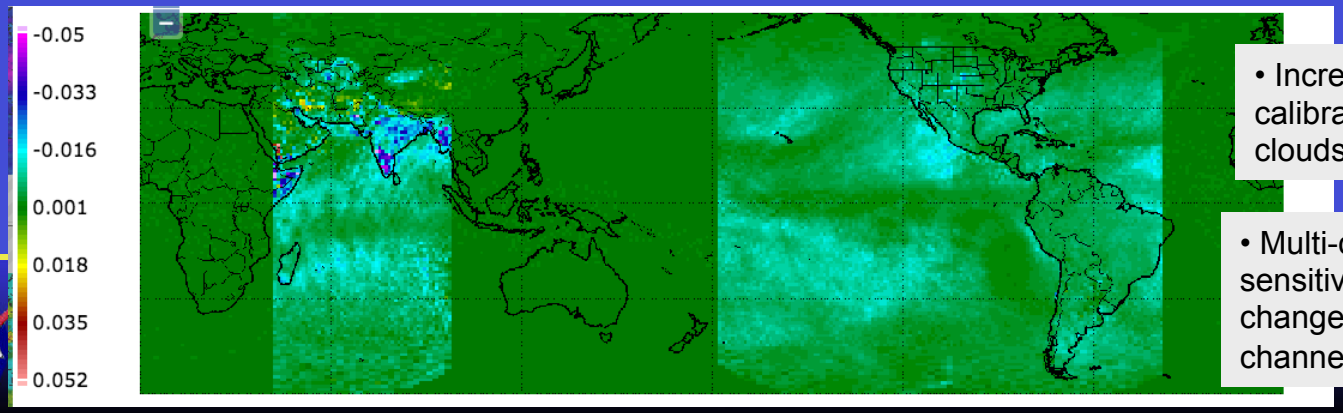
• Increasing the visible calibration increases cloud amount

Δheight ±2km



• Increasing the visible calibration increases cloud height

Δphase ±0.05



• Increasing the visible calibration increases water clouds

• Multi-channel retrieval less sensitive to calibration changes than the two-channel code.