TISA Working Group Report

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29th CERES-II Science Team Meeting
May 15-17, 2018, NASA LaRC, Hampton, VA
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

June - Aug 2012

Linear Regression: 1.0537x - 11.7089
Forced Regression: 1.0224x + 180
R^2: 0.98811
Bias (K): -1.4723
SDD (K): 1.327
Num: 20454
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

GEO BB radiance to flux using TRMM ADM

GEO BB flux normalized with CERES fluxes

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
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, CLDTYPEHIST

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

Region and cloud type 3x3 histogram binning

GEO multi-channel
All GEOs

GEO pixel-level cloud retrieval (Cloud WG)

Publicly released netCDF file

GEO pixel-level cloud retrieval (2-ch)

Publicly released netCDF file

Region and cloud type 3x3 histogram binning

Ed4

GEO grid 4-layer cloud retrieval

GEO pixel-level cloud retrieval (2-ch)

Publicly released netCDF file

Region and cloud type 3x3 histogram binning

Ed5

GEO grid 4-layer cloud retrieval

GEO pixel-level cloud retrieval (Cloud WG)

Publicly released netCDF file

Region and cloud type 3x3 histogram binning
Provide SARB time ordered regional clouds

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

GEO grid 4-layer cloud retrieval

GEO multi-channel
All others

GEO pixel-level cloud retrieval (Cloud WG)

Publicly released netCDF file

(TISA) regional cloud binning

Composite GEO zonal binary files
(region ordered)

Clouds, GEO derived hourly fluxes

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

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

Ed4

Ed4

Ed4
Provide SARB time ordered regional clouds

SARB

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

GEO pixel-level cloud retrieval (2-ch)

Publicly released netCDF file

(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

SYN1deg computed product

(SARB) independent of TISA processing and deliveries

Ed5

GEO multi-channel
All others

GEO pixel-level cloud retrieval (Cloud WG)

(TISA) regional cloud binning

Composite GEO zonal binary files
(region ordered)

GEO derived hourly fluxes

Temporal interpolation and averaging

SYN1deg observed product

TISA
TISA code modularization

- 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
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
  - No scene information is lost and the regional directional model is not recomputed every time it is used
  - SYN1deg incorporates 1-hourly GEO albedos, so that albedo directional models are rarely used
  - Also the SSF1deg-hour file has fewer variables and size is smaller

**ED5**

- **SSF1deg-hour**
  - Convert the 4-cloud layers into a single Albedo directional SZA model (9)

- **GEO1deg-hour**
  - Convert the 4-cloud layers into a single Albedo directional SZA model (9)

- **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

Clouds as required for SYN1deg product

Flux and cloud 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

Syn1deg observed product

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

Clouds as required for SYN1deg product

Cloud temporal interpolation and averaging

Flux computations

Clouds as required for SYN1deg product

Flux and cloud averaging

Clouds as required for SARB

Flux computations

Clouds as required for SYN1deg product

Flux and cloud averaging

Clouds as required for SARB

Flux computations

Clouds as required for SYN1deg product

Flux and cloud averaging

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Flux computations

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Flux and cloud averaging

Clouds as required for SARB

Flux computations

Clouds as required for SYN1deg product

Flux and cloud averaging
## Code Status

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<td>CERES GEO cloud code</td>
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* 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 retrieval code, applied during the day. The 3.7 µm has both solar and IR component, was not properly handled in this test night time run. Will take a lot of effort

Night time Retrievals

- 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

- 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.
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.
GOES-16/Aqua-MODIS initial calibration

GOES-16 was operational for Dec 18, 2017, replaced GOES-13 over GOES-EAST, GOES-16 and Him-8 are copies and show similar calibration gains.
• 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

- 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 B2 is 12-bit, other channels are 10-bit, there are some channels with saturated locations.
GOES-16 11-12µm
MODIS/GEO instantaneous 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

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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

Visible inter-calibration looks good

GSICS IR correction gets us half way there
Comparison of MODIS/INSAT-3D intercal

- 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

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

- 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 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 0.65\(\mu\)m Stability

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

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(0.65\(\mu\)m) 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 than 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.

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

- 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
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

• 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
Terra-MODIS C6.1 to C5 scaling factors

Daytime

Cloud ±5%

ΔCOD ±1

Scaled, Jan 2016

Unscaled, Jan 2016

Before Terra anomaly

Scaled, July 2016

Unscaled, July 2016

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

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

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%

- Note the cloud optical depth discontinuities at GEO boundaries
- 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 GEs 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 2 Wm\(^{-2}\). Largest differences are not occurring in diurnal varying regions.
Jan 2012, adjust visible calibration by ±3%

- Note the cloud optical depth discontinuities at GEO boundaries

- 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
- 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%

- Increasing the visible calibration increases cloud amount
- Increasing the visible calibration increases cloud height
- Increasing the visible calibration increases water clouds
- Multi-channel retrieval less sensitive to calibration changes than the two-channel code.

ΔCloud% ±5

Δheight ±2km

Δphase ±0.05