TISA Working Group Report

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GEO calibration: R. Bhatt, C. Haney, B. Scarino, A. Gopalan


Sub-setter: C. Mitrescu, P. Mlynczak, C. Chu, E. Heckert,

Radiation Budget Workshop
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Outline

• Indian Ocean GEO domain processing strategy
• SYN1deg SW terminator flux anomaly and mitigation
• SYN1deg and GERB flux comparisons
• SYN1deg Ed4 and Ed3 mean flux and trend differences
• SW sensitivity studies

• TISA spatially averages the SSF footprint fluxes into 1° x 1° nested grid
• TISA temporally interpolates the TOA flux between Terra and Aqua measurements to estimate the daily flux mean
TISA papers

CERES PRODUCTS
ED3 TO ED4 IMPROVEMENTS
CERES level 3 Products

- SSF1deg, single satellite TOA flux and cloud product, CERES/MODIS-only observations, assume constant meteorology in between CERES observations
  - No changes between Ed3 and Ed4, use CERES TRMM directional models
- SYN1deg, TOA flux, cloud, and computed surface and in-atmosphere flux product, Terra (10:30LT)+Aqua (1:30LT)+GEO (1-hourly) observations
  - GEO flux improvements next page
- CldTypHist, MODIS/GEO monthly hourly cloud properties by 3x3 cloud top and optical depth bins
  - Formally known as ISCCP-D2like product
  - 4-channel GEO cloud properties, Ed3 were 2-channel
- FluxByCloudType, Instantaneous gridded CERES fluxes by MODIS 7x6 cloud types
  - New, no Edition 4 product
  - Sub-footprint multi-channel MODIS narrowband to broadband flux conversion. Sub-footprint fluxes normalized to CERES observation
## Edition 4 SYN1deg Improvements

<table>
<thead>
<tr>
<th>GEO Calibration</th>
<th>Edition 3</th>
<th>Edition 4</th>
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<tbody>
<tr>
<td>• Terra-MODIS Collection 5 reference</td>
<td>• Terra-MODIS Collection 5 reference</td>
<td>• Aqua-MODIS Collection 6</td>
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<tr>
<td>• GEO/MODIS ray-matching</td>
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<tr>
<td></td>
<td></td>
<td>• Validate with DCC and deserts</td>
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<td></td>
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<td>• SCIAMACHY spectral band adjustment factors (SBAF)</td>
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<td></td>
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<td>• MTSAT-1R point spread function</td>
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<thead>
<tr>
<th>GEO Clouds</th>
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<tbody>
<tr>
<td>• Visible &amp; 11µm 2-channel cloud code</td>
<td>• Visible &amp; 11µm 2-channel cloud code</td>
<td>• 4-channel cloud code</td>
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<tr>
<td>• Assumed particle sizes</td>
<td>• Assumed particle sizes</td>
<td>• 3.7µm GEO particle sizes</td>
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<tr>
<td>• Assume night time emissivity=1</td>
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<td>• Emissivity based on 3.7, 11, and 12 µm</td>
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<thead>
<tr>
<th>GEO LW flux</th>
<th>Edition 3</th>
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<tr>
<td>• Column weighted humidity RH and WN radiance to BB global parameterization</td>
<td>• Column weighted humidity RH and WN radiance to BB global parameterization</td>
<td>• WN and WV radiance to BB flux</td>
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<tr>
<td>• Instantaneous Normalization</td>
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<td>• 5° by 5° LW regional normalization</td>
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<th>GEO SW flux</th>
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<th>Edition 4</th>
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<tr>
<td>• GEO visible-&gt;MODIS 0.65µm-&gt; BB</td>
<td>• GEO visible-&gt;MODIS 0.65µm-&gt; BB</td>
<td>• Same as Edition3</td>
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<tr>
<td>• CERES SW TRMM ADM</td>
<td>• CERES SW TRMM ADM</td>
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<tr>
<td>• 5° by 5° SW regional normalization</td>
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<th>Temporal Interpolation</th>
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<tr>
<td>• GEO 3-hr obs (linear interpolation)</td>
<td>• GEO 3-hr obs (linear interpolation)</td>
<td>• GEO 1-hr observations (no interpolation)</td>
</tr>
<tr>
<td>• TRMM SW directional models</td>
<td>• TRMM SW directional models</td>
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<tr>
<th>Surface Fluxes</th>
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<tr>
<td>• GEOS 4.0/5.2 merged atmosphere</td>
<td>• GEOS 4.0/5.2 merged atmosphere</td>
<td>• GEOS 5.4 atmosphere</td>
</tr>
<tr>
<td>• Untuned surface fluxes</td>
<td>• Untuned surface fluxes</td>
<td>• Untuned surface fluxes</td>
</tr>
<tr>
<td>• 2-channel clouds, MODIS skinT</td>
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<td>• MODIS/GEO skinT</td>
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</tbody>
</table>
INDIAN OCEAN GEO DOMAIN PROCESSING STRATEGY
CERES record Geostationary Time Series

- GOES-R to launch Nov 2016, GOES-S launch in 2018
- Met-11 (0E) to replace Met-10 in March 2018
- Himawari-9 (140E) to launch in Nov 2016
- MTSAT-2 (145E) decommissioned in Dec 4, 2015
Indian Ocean Geostationary Time Series

These are the GEOs between 0E and 140E

- FY-4A, to launch in Dec. 2016, 3 axis stabilized, AGRI imager has 14 channels, 0.5km to 4km resolution, FD every 15 minutes, GIIRS imager, IR hyperspectral sounder (15km) over China
- KOMPSAT-2A to launch in 2018, imager similar to GOES-R
- Met-8 (41.5E) beginning Sept 21, 2016,
- Met-7 (57E) decommissioned end of 2016
- INSAT-3DR (74E) launched on Sept 8, 2016
- FY-4A to launch in Dec. 2016
- What to do beginning in 2017, when Met-7 is decommissioned
- There would be 98° longitude separation between Met-8 (42E) and Him-8 (140E), Similar to time between 2003 and 2005, using Met-5 (63E) and GOES-9 (160E)
- Prefer to only process 5 GEOs over the CERES record
- Met-8 is a well behaved imager, and is well-calibrated when referenced to MODIS
- Data not yet available beginning in November on McIDAS servers
The INSAT-3D visible channel has a linear response and well-behaved.
Cloud working group has real-time cloud properties for INSAT-3D.
Indian Ocean INSAT-3D (82E) IR

- Have worked with McIDAS and ISRO to implement new IR (LUT) coefficients and compared them to the old coefficients (COE).

Courtesy Pradeep Thapliyal ISRO
Indian Ocean FY-2E(86E)/-2G(105E)

- The FY-2E/G visible sensor is noisy, the IR is noisy also but linear
- Scans FD hourly
COMS-1 (128E)

- COMS/Aqua-MODIS 0.65µm, Aug 2016
- COM 0.65µm gain 2012 to 2016
- COMS/Aqua-MODIS 11µm, Aug 2016

- COMS-1 is similar to GOES 8-12 and is well-calibrated
- Maybe fill in the small rectangle gap, but scan FD only every 3-hours

Scans FD 3-hourly, NH 15 minutes
Edition 4 GEO processing

- GEO 1-hourly imager and cloud retrievals processed through June 2015
- When Himawari-8 cloud retrievals have been validated with the cloud and SARB working groups continue processing through December 2016
  - Himawari-8 has replaced MTSAT-2 beginning in July 2015
  - Continue to use Met-7 until December 2016
- Beginning January 2017 use Met-8 over Indian Ocean
  - Met-7 will be decommissioned in Jan 2017
SW TERMINATOR FLUX ANOMALY
Validate the GEO SW ED4 fluxes with GERB

Dataset minus GERB monthly SW, Jan 2010

- SYN1deg GEO Ed4 overestimates the monthly SW flux w/r GERB, more than Ed3
- SSF1deg-Terra&Aqua is more similar to GERB
• In SH the Terra (10:30) and Aqua (1:30) are further apart to better capture diurnal
• In NH Terra and Aqua are overpasses are closer in time than in SH
• SSF_Terra overestimates monthly SW flux by +7 Wm-2 of GERB
• SSF_Aqua underestimates monthly SW flux -18 Wm-2 of GERB
• SSF_Terra&Aqua underestimates monthly SW flux by -5 Wm-2 and only has half of the asymmetric flux of GERB
• SYN has same asymmetric flux, small MH RMS error, but monthly SW flux +4 Wm-2 of GERB, due to near terminator flux anomaly
Clearly the SYN-GEO has a near terminator flux anomaly
Do not use GEO fluxes for SZA>threshold, and rely on directional models
The SZA threshold is a delicate balance between removing the GEO diurnal signal or the near terminator flux anomaly.
Near Terminator SW Flux Anomaly

• As a quick fix to release the SYN1deg Ed4 dataset, only use GEO BB fluxes where the SZA <60°
  – Rely on directional model
  – Do not need to rerun SYNI, since the untuned relies on the cloud properties only
  – Deliver the new TSI code, and rerun 15 years at DAAC
  – Rerun the SYN1deg code using existing SYNI and new TSI
• The Ed4 SW derived BB flux code is the same Ed3
  – However, the hourly GEO observations have reduced the time difference from 90 to 30 minutes when linearly regressing the CERES and GEO fluxes to normalize the GEO measurements to CERES
• TISA greatest priority will be to improve the GEO SW flux code
  – Evaluate the ADM, SW NB to BB, GEO/MODIS clouds, etc
CERES/GERB COMPARISONS
# GERB and CERES coincident flux

### GERB 1&2: BARG Ed2
### GERB3: BARG Ver999
### CERES: Ed4

<table>
<thead>
<tr>
<th>CERES-GERB (%)</th>
<th>SW day</th>
<th>LW day</th>
<th>LW night</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 2004</td>
<td>+8.3</td>
<td>-2.3</td>
<td>-2.2</td>
</tr>
<tr>
<td>Jan 2005</td>
<td>+7.3</td>
<td>-2.6</td>
<td>-2.3</td>
</tr>
<tr>
<td>Jan 2010</td>
<td>-0.6</td>
<td>-1.8</td>
<td>-1.7</td>
</tr>
<tr>
<td>July 2010</td>
<td>-0.2</td>
<td>-1.7</td>
<td>-1.6</td>
</tr>
<tr>
<td>Jan 2012</td>
<td>-2.6</td>
<td>-1.8</td>
<td>-1.7</td>
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<tr>
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<td>-2.3</td>
<td>-1.6</td>
<td>-1.6</td>
</tr>
<tr>
<td>Jan 2016</td>
<td>+6.9</td>
<td>-2.0</td>
<td>-2.0</td>
</tr>
</tbody>
</table>
CERES – GERB regional bias, Jan 2005

- Use mean CERES/GERB regional monthly ratio to normalize GERB to CERES
- Use CERES/GERB regional monthly linear regression to normalize
CERES – GERB SW, Jan 2010

- SYN monthly, RMS=2.9%
- SYN daily, RMS=6.1%
- SYN hourly, RMS=17.0%
- SYN Mhour, RMS=6.9%
- SSF-T&A monthly, RMS=3.7%
- SSF-T&A daily, RMS=11.5%
- SSF-T&A hourly, RMS=23.2%
- SSF-T&A Mhour, RMS=9.0%
CERES – GERB LW, Jan 2010

SYN monthly, RMS=0.4%

SYN daily, RMS=1.1%

SYN hourly, RMS=2.5%

SYN Mhour, RMS=0.8%

SSF-T&A monthly, RMS=0.6%

SSF-T&A daily, RMS=2.2%

SSF-T&A hourly, RMS=4.8%

SSF-T&A Mhour, RMS=1.3%
### CERES – GERB SW Comparisons SYN/SSF_TA

<table>
<thead>
<tr>
<th></th>
<th>RMS %</th>
<th>Bias</th>
<th>Monthly</th>
<th>Daily</th>
<th>1hour</th>
<th>M1hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jul 2004</td>
<td>-0.6/-1.8</td>
<td>3.5/4.5</td>
<td>6.3/11.3</td>
<td>17.0/23.1</td>
<td>7.6/9.1</td>
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<tr>
<td>Jan 2005</td>
<td>-0.8/-1.6</td>
<td>3.5/4.2</td>
<td>6.3/10.2</td>
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<td>7.5/8.7</td>
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<tr>
<td>Jan 2010</td>
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</table>

- The SYN product is an improvement over using SSF Terra+Aqua, especially for higher spatial resolutions.
- Daily, hourly, and M1hour RMS errors reduced by 40%, 25% and 15% compared to SSF_TA %, respectively.
<table>
<thead>
<tr>
<th>RMS %</th>
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<th>1hour</th>
<th>M1hour</th>
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- The SYN terminator flux increased the regional monthly flux bias and the monthly hourly flux RMS, which was even greater than the SSF Terra+Aqua.
CERES – GERB LW Comparisons
SYN/SSF_TA

<table>
<thead>
<tr>
<th></th>
<th>RMS%</th>
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- The SYN product is an improvement over using SSF Terra+Aqua, especially for higher spatial resolutions
- Monthly, Daily, hourly and M1hour RMS errors reduced by 30%, 45%, 45% and 15%, respectively, compared to SSF_TA
- The GEO LW is based on IR and WV NB2BB and not dependent on clouds
GERB and CERES Comparison Conclusions

SYN Ed4 is an improvement over Ed3, especially for LW.

The LW is now includes the GEO WV channel and does not use GEO clouds, does not use TRMM ADM.

SW improvements due to hourly GEO rather than 3-hourly and 4-channel clouds, algorithms remained the same.

<table>
<thead>
<tr>
<th>RMS %</th>
<th>SW month</th>
<th>SW daily</th>
<th>LW month</th>
<th>LW daily</th>
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</thead>
<tbody>
<tr>
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<td>3.5</td>
<td>7.8</td>
<td>0.5</td>
<td>1.9</td>
</tr>
<tr>
<td>Ed4</td>
<td>3.5</td>
<td>6.3</td>
<td>0.4</td>
<td>1.1</td>
</tr>
</tbody>
</table>

Ed3 from Doelling et al. 2013
ED4 AND ED3 SYN1DEG TREND ANOMALIES
SYN – SSF 12-year SW flux difference

Edition 3

SYN minus SSF-Aqua

SYN minus SSF-Terra

Edition 4

Units: Wm⁻²
SYN – SSF SW regional trend anomalies

SYN minus SSF-Aqua

SYN minus SSF-Terra

Edition 3

Edition 4

Units: Wm\(^{-2}\)yr\(^{-1}\)

NASA Langley Research Center / Atmospheric Sciences
SYN Ed4 SW flux comparisons

Mean difference
SYN Ed4 minus Ed3
SYN Ed4 minus SSF-Terra+Aqua

Trend anomaly
Units: Wm⁻²
Units: Wm⁻² yr⁻¹

NASA Langley Research Center / Atmospheric Sciences
SYN – SSF 12-year LW flux difference

Edition 3

SYN minus SSF-Aqua

SYN minus SSF-Terra

Edition 4

Units: Wm\(^{-2}\)
SYN – SSF LW regional trend anomalies

SYN minus SSF-Aqua

Edition 3

SYN minus SSF-Terra

Edition 4

Units: Wm\(^{-2}\) yr\(^{-1}\)
SYN Ed4 LW flux comparisons

Mean difference

Trend anomaly

SYN Ed4 minus Ed3

SYN Ed4 minus SSF-Terra+Aqua

Units: Wm$^{-2}$

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

NASA Langley Research Center / Atmospheric Sciences
SYN Ed4 trend anomaly conclusion

<table>
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<tr>
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<th>Ed3 LW</th>
<th>Ed4 SW</th>
<th>Ed4 LW</th>
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<tbody>
<tr>
<td>SSF-Terra</td>
<td>96.27</td>
<td>239.21</td>
<td>96.79</td>
<td>239.21</td>
</tr>
<tr>
<td>SSF-Aqua</td>
<td>96.06</td>
<td>238.96</td>
<td>96.60</td>
<td>238.79</td>
</tr>
<tr>
<td>SYN</td>
<td>97.56</td>
<td>238.79</td>
<td>96.87</td>
<td>238.57</td>
</tr>
</tbody>
</table>

- The SYN Ed4 minus SSF1deg-Terra&Aqua have smaller regional SW and LW flux differences than Ed3
- The relative SYN Ed4 regional SW and LW flux trends are smaller compared to SSF1deg than Ed3
- The SYN1deg Ed4 global mean SW flux is 0.77 Wm\(^{-2}\) less than Ed3, for LW -0.22 Wm\(^{-2}\)
  - SSF1deg Ed4 – Ed3 SW ~0.5 Wm\(^{-2}\)
SW SENSITIVITY STUDIES
Planned GEO visible to SW flux studies

- GEO derived SW flux
  - Calibrate GEO visible channels with MODIS C6
  - Theoretical GEO visible to MODIS band 1 (0.65µm) radiance conversion
  - Empirical (SSF) GEO-MODISlike 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

- ADM studies
  - Footprint vs regional, MODIS vs GEO clouds, TRMM vs Ed4 ADM

- SSF and Himawari-8 multiple visible channel to BB radiance studies
  - Adding 11µm improves SSF based NB2BB from 10.3 Wm⁻² to 8.6 Wm⁻²
  - Use SSF derived multi-channel NB to BB coefficients with Him-8

- Test theoretical GEO NB to BB radiance models designed for each GEO
  - Use ScaRaB BB radiance to evaluate improvement
  - Use Aqua based models and compare with Terra observations
Regional (110km) minus Footprint (20km) TRMM SW ADM application

CERES radiances and MODIS clouds, Jan 2010

- Bias: -0.1%
- RMS: 1.8%

- Little dependence of footprint size when applying TRMM SW ADM
TRMM minus Ed4 SW ADM

Using CERES footprint radiances and MODIS clouds, Jan 2010

Bias 0.4%
RMS 3.2%

• SZA (zonal) dependent TRMM vs Ed4 SW ADM difference
• TRMM orbit within ±35° latitude
GEO minus MODIS clouds ADM fluxes

Using CERES footprint radiances and TRMM SW ADM, Jan 2010

- Bias -1.0%
- RMS 7.6%

• Cloud property quality the largest factor in application of the TRMM SW ADM
Conclusions

• The TRMM ADM greatest limitation is that the GEO cloud properties should be MODIS-like
  – Cloud group working to retrieve GEO clouds similar to MODIS, great potential for Him-8 and other
    3rd generation GEOs
• Ed4 GEO MODIS-like to BB radiance conversion also based on MODIS clouds, based on SSF
  – Use theoretical direct GEO to BB radiance in Ed5
  – Test using ScaRaB fluxes