TISA Working Group Report

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28th CERES-II Science Team Meeting
September 26-28, 2017, NASA GSFC, Greenbelt, MD
CERES ED4A LEVEL 3 PRODUCTS
CERES Ed4A level 3 products

• SSF1deg, is the gridded SSF product
  – Single satellite product
  – Gridded 1-hour instantaneous, daily and monthly average
  – The temporal stability is based on the well-calibrated CERES fluxes
  – Use constant meteorology based on the satellite local equator crossing time to account for the regional diurnal cycle
  – Observed clouds and TOA fluxes, and hourly-only (no daily or monthly) parameterized surface fluxes

• SYN1deg, is the gridded synoptic product
  – Terra+Aqua Ed4A, and a Terra+NPP Ed1A product (Oct 2017)
  – Gridded hourly, 3-hourly, daily, monthly hourly, and monthly
  – Use 1-hourly GEO radiances and clouds to account for the regional diurnal cycle (residual GEO cloud and flux artifacts)
  – Observed clouds and TOA fluxes, and hourly regional computed Fu-Liou surface, TOA and profile fluxes (all temporal resolutions)
CERES Ed4A level 3 products

- EBAF, combines the temporal stability of the SSF1deg product and the regional diurnal fluxes of the SYN1deg product
  - Monthly and climatological averages
  - Clear-sky fluxes have been spatially filled, by using sub-footprint imager clear-sky fluxes.
  - The TOA fluxes have been net balanced
  - The GEO artifacts have been mitigated
  - The surface fluxes have been tuned to remove known anomalies
  - Ed4A has included cloud properties
New CERES product selection page

**Energy Balanced and Filled (EBAF)**
Climate Data Record (CDR) of monthly TOA fluxes and consistent computed surface fluxes and clouds suitable for analysis of variability at the intra-seasonal, inter-annual, and longer time scales.

<table>
<thead>
<tr>
<th>Data Product Information</th>
<th>Description</th>
<th>Parameter Resolution</th>
<th>Version/Availability</th>
<th>Order Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>EBAF-TOA</td>
<td>Monthly and climatological averages of TOA clear-sky (spatially complete) fluxes, all-sky fluxes and clouds, and cloud radiative effect (CRE), where the TOA net flux is constrained to the ocean heat storage. Data Quality Summaries</td>
<td>3</td>
<td>3</td>
<td>Browse &amp; Subset</td>
</tr>
<tr>
<td>EBAF-Surface</td>
<td>Monthly and climatological averages of computed surface clear-sky fluxes, all-sky fluxes, and cloud radiative effect (CRE), consistent with the CERES EBAF-TOA fluxes. Data Quality Summaries</td>
<td>3</td>
<td>3</td>
<td>Browse &amp; Subset</td>
</tr>
</tbody>
</table>

**Synoptic TOA and surface fluxes and clouds (SYN)**
Hourly gridded observed TOA and Fu-Liou RT surface fluxes and clouds. Suitable for regional diurnal and process studies.

<table>
<thead>
<tr>
<th>Data Product Information</th>
<th>Description</th>
<th>Parameter Resolution</th>
<th>Version/Availability</th>
<th>Order Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYN1deg</td>
<td>Hourly CERES and repositionary GEO TOA fluxes, MODIS/VIIRS and GEO cloud properties. MODIS/VIIRS aerosols, and Fu-Liou RT surface and in-atmospheric (profile) fluxes consistent with the CERES observed TOA fluxes. Data Quality Summaries</td>
<td>3</td>
<td>3</td>
<td>Browse &amp; Subset</td>
</tr>
<tr>
<td>CldTypHist</td>
<td>CERES-MODIS/VIIRS and GEO cloud properties stratified by cloud optical depth and pressure. Data Quality Summary</td>
<td>3</td>
<td>3</td>
<td>Browse &amp; Subset</td>
</tr>
</tbody>
</table>

**Single Scanner Footprint (SSF)**
Individual CERES scanner footprint TOA and parameterized surface fluxes and clouds. For comparison with other same orbit sensors, for example, A-train datasets.

<table>
<thead>
<tr>
<th>Data Product Information</th>
<th>Description</th>
<th>Parameter Resolution</th>
<th>Version/Availability</th>
<th>Order Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSF</td>
<td>CERES footprint observed TOA fluxes, MODIS/VIIRS clouds and aerosols, and repositionary surface fluxes by instrument. Data Quality Summaries</td>
<td>3</td>
<td>3</td>
<td>Browse &amp; Subset</td>
</tr>
<tr>
<td>SSF1deg</td>
<td>Gridded daily and monthly averages of the SSF product by instrument. Data Quality Summary</td>
<td>3</td>
<td>3</td>
<td>Browse &amp; Subset</td>
</tr>
<tr>
<td>CCCM (C3M)</td>
<td>Nadir view CERES-SSF/MODIS/CALIPSO/CloudSat collocated parameters. Data Quality Summary Variable Descriptions Data Product Catalogs</td>
<td>3</td>
<td>3</td>
<td>Order via ASDC</td>
</tr>
</tbody>
</table>

**Fast Longwave and Shortwave Flux (FLASHFlux)**
Near real-time, CERES scanner footprint TOA and parameterized surface fluxes and clouds by instrument.

<table>
<thead>
<tr>
<th>Data Product Information</th>
<th>Description</th>
<th>Parameter Resolution</th>
<th>Version/Availability</th>
<th>Order Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLASH_SSF</td>
<td>Near real-time CERES fluxes and clouds in the SSF format. Not of climate quality or to be appended with any other CERES dataset. Data Quality Summaries</td>
<td>3</td>
<td>3</td>
<td>Browse &amp; Subset</td>
</tr>
<tr>
<td>FLASH1dec</td>
<td>Gridded daily averages of the FLASH_SSF product. Data Quality Summary</td>
<td>3</td>
<td>3</td>
<td>Browse &amp; Subset</td>
</tr>
</tbody>
</table>

*FOV: Field-of-View instantaneous footprint data.*
CERES Ed4A level 3 products

- CldTypHist, stratifies the instantaneous SYN1deg MODIS and 1-hourly GEO clouds into pressure and optical depth bins
  - Monthly 1-hourly, and monthly products
  - Replaces the Ed3A ISCCP-D2like products
  - CldTypHist does not temporally interpolate, whereas SYN1deg interpolates within 4-cloud layers
  - CldTypHist contains cloud fraction; effective and top pressure, height and temperature; particle size, IWP/LWP, and IR emissivity
Changes between Ed3A ISCCP-D2like and Ed4A CldTypHist

- ISCCP-D2like consists of 3 products
  - Daytime and nighttime single satellite monthly mean clouds and daytime 7 layer by 6 optical depth cloud amount array
  - GEO monthly mean
  - Merge of Terra and Aqua and GEO clouds
- CldTypHist consists of 1 product
  - Merge of Terra and Aqua and GEO clouds
  - No daytime 7 layer by 6 optical depth cloud amount array
- ISCCP-D2like based on 3-hourly GEO 2-channel (visible and IR) cloud retrievals
- CldTypHist based on hourly multi-channel GEO cloud retrievals that are more similar to MODIS
  - The retrieval quality depends on the number channels available
  - Most of the improvement was at night. ISCCP-D2like maintained an IR emissivity of unity at night
The Ed3A there is a difference between day and night cloud fraction and the cloud fractions are less dependent on GEO satellite. The Ed4A has a more similar day and night cloud fraction, however the cloud fractions depend more on GEO satellite.
FLUX BY CLOUD TYPE
Flux by Cloud Type (FluxByCloudTyp) Data

- A dataset that stratifies instantaneously matched and spatially gridded CERES fluxes and MODIS cloud properties into the ISCCP-D1 cloud types based on 6 cloud optical depth and 7 cloud top effective pressure.

Note: MODIS cloud data here are from the NASA Langley cloud working group. It is NOT GSFC MODIS cloud product.
Motivation

Cloud and radiative fluxes are fundamental atmospheric variables essential for any climate studies, both observational and modeling.

Cloud properties and associated radiative fluxes stratified into different types provide more stringent constrains to models and also reveal more insights into how cloud-climate interacts. Recent studies investigate cloud-climate feedbacks in cloud types, typically ISCCP cloud types (in many studies like Zhang et al, 2005; Zelinka et al, 2011, 2016). But they still rely on RT model for fluxes.

The community has ISCCP-D1 for many years but yet to have observed fluxes matched to each cloud type. The CERES group has the natural position to provide such a product.
FluxByCldType Overview

- Only ~10% of all CERES 20-km footprints are of one scene type.
- Convert the imager pixel level narrowband radiance to broadband for the multi-scene footprints.
- Use the CERES Ed4A ADMs to convert the broadband radiance into flux, which are dependent on the cloud, profile, surface type, angular, and aerosol properties.
- Normalize the 3 sub-footprint fluxes with the footprint flux.
- The FluxByCldType should provide the same gridded instantaneous fluxes as the SSF1deg-hour.
Flux Algorithm

(|SSF Footprints| Single scene footprints|
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>NB2BB: clear/cld1/cld2</td>
<td>NB2BB coefficients</td>
</tr>
<tr>
<td>BB2Flx: clear/cld1/cld2</td>
<td>ADM</td>
</tr>
</tbody>
</table>

Normalize sub-footprint fluxes to footprint flux

Sort clouds/flux into cloud types

Grid into 1° x 1°

Validate with SSF1deg-hour
Narrow-Band radiance to Broad-Band Radiance (NB2BB)

All MODIS NB Channels on both SSF cloud layers are used:
- SW: 0.47, 0.65, 0.86, 11, 12 (um)
- LW: 0.47, 0.65, 0.86, 11, 12 (um)

Define bin (category):
- Flux: SW, LW
- Surface: Ocean, Land (Forests, Savannas, Grass/Crop, Dark Deserts, Bright Deserts, snow/ice)
- Cloud: clear, overcast
- SW
  - SZA (9): 0–90, every 10
  - VZA(7): 0–70, every 10
  - RAZ(9): 0–180, every 20
- LW
  - VZA(7): 0–70, every 10
  - PW(4): (0,1,3,5,10)

SSF must be 100% clear or 100% cloudy.
BB Radiance to BB Flux by ADM

SW BB Rad = a0 + a1*Rad1 + a2*Rad2 + a3*Rad3 + a4*Rad4 + a5*Rad5
LW BB Rad = a0 + a1*Rad1 + a2*Rad2 + a3*Rad3 + a4*Rad4 + a5*Rad5

ADM (Angular Distribution Model)

\[ F(\theta_o) = \frac{\pi I(\theta_o, \theta, \phi)}{R(\theta_o, \theta, \phi)} \]

\( F(\theta_o) \): flux

\( I \): BB Radiance

\( R \): anisotropic factor

R is derived based on angles, cloud amount, optical depth, phase, surface types, etc.

Loeb et al, 2005, JAOT
Validation: Footprint Level

For each footprint: calculated flux vs. observed flux

\[
flux_{fp} = f_{clr} \cdot F_{clr} + f_{cld1} \cdot F_{cld1} + f_{cld2} \cdot F_{cld2}
\]

\( f \): cloud fraction

\( F \): Flux

Perfectly, calculated flux should equal observed flux
FluxByCldType Ed4A gridded instantaneous comparison with SSF1deg, April 1, 2006

- All-sky SW flux
- All-sky LW flux

• Before normalization with the footprint flux
Validation Ed3A: Grid Level, FluxByCloudTyp, April 1, 2006

SW clear-sky    LW clear-sky    SW All-sky    LW All-sky

FluxByCloudTyp

SSF1Deg

Difference
Validation Ed3A: Footprint Level, Jan 2010

**SW**
- Derived Flux (W/m²)
- SSF Observed Flux (W/m²)
- Bias: 0.03
- Stderr: 10.9

**LW**
- Derived Flux (W/m²)
- SSF Observed Flux (W/m²)
- Bias: 0.2
- Stderr: 4.7

Total Samples: 10,000,000

• Before normalization with the footprint flux
The algorithm is free from dependencies on SZA, VZA, cloud fraction, optical and other parameters.
Example Ed3A: 2006/07 vs. 2009/10 El Nino
NET CRF

2006/07 El Nino

2009/10 El Nino
CERES FluxByCloudTyp Product

1. MODIS imager radiances
2. MODIS cloud retrievals
3. Generate subcolumn clouds at overpass time
4. CFMIP 3-hourly gridded output

CERES Flux-by-cloud Type Simulator

5. Cloud freq
6. Evaluate
7. Cloud freq
8. Evaluate

CERES FluxbyCldTyp Simulator by Eitzen et al.

9. Get Langley Fu-Liou radiative transfer model fluxes
10. Grid box sfc alb, T, qv, O₃ profiles

CERES SSF clouds, fluxes

11. OLR by cld typ
12. Evaluate
13. OLR by cld typ
14. Evaluate
CERES Ed4A level 3 products

- All of the CERES Ed4A level 3 products were delivered to the ASDC this year and processing is current to January 2017.
- FluxByCloudTyp is the remaining CERES Ed4A level 3 product that has not been delivered.
  - Moguo, Cathy and Josh are still working on the code
  - The incorporation of the Ed4a ADMs and increased number of narrowband channels used to convert broadband was more complicated than originally thought
  - Still need to validate
  - A November or early December delivery likely
- The Ed3A FluxByCloudTyp will shortly be placed on the subsetter
  - To coincide with the Flux by cloud type simulator paper by Eitzen et al., accepted
  - It has the Edition 2 MODIS clouds
MODIS C6 TO C6.1 SCALING FACTORS
Terra-MODIS C5 had a -1% anomaly in late 2003 and a -1.5% anomaly in early 2009

Wu et al 2013
Terra and Aqua stability analysis till 2013

- MODIS C5 solar diffuser anomaly in early 2009 caused the negative trend
- MODIS C6 is more stable than C5
- The Earth invariant targets also have some natural variability

<table>
<thead>
<tr>
<th>MODIS Band</th>
<th>Trend in %</th>
<th>Terra</th>
<th>Aqua</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Deserts</td>
<td>Dome C</td>
</tr>
<tr>
<td>μm</td>
<td>#</td>
<td>C5</td>
<td>C6</td>
</tr>
<tr>
<td>0.44</td>
<td>9</td>
<td>-8.8</td>
<td>1.0</td>
</tr>
<tr>
<td>0.47</td>
<td>3</td>
<td>-6.3</td>
<td>0.0</td>
</tr>
<tr>
<td>0.55</td>
<td>4</td>
<td>-1.2</td>
<td>0.1</td>
</tr>
<tr>
<td>0.65</td>
<td>1</td>
<td>-2.1</td>
<td>0.9</td>
</tr>
<tr>
<td>0.86</td>
<td>2</td>
<td>-1.9</td>
<td>0.9</td>
</tr>
<tr>
<td>1.24</td>
<td>5</td>
<td>0.4</td>
<td>0.5</td>
</tr>
<tr>
<td>1.38</td>
<td>26</td>
<td>1.4</td>
<td>0.8</td>
</tr>
<tr>
<td>2.12</td>
<td>7</td>
<td>-0.8</td>
<td>-0.3</td>
</tr>
</tbody>
</table>

Trend in %

Doelling et al 2015
MODIS C6.1

- MODIS C6.1 reprocessing corrected the Terra 6.7μm and 8.6μm detector striping problem, due to cross-talk issues after the Terra spacecraft anomaly in late February 2016
  - Both Terra and Aqua MODIS C6.1 is forward processing beginning in Aug 22, 2017
  - Terra is forward processing from the beginning of record (March 1, 2000) and is now at Dec 31, 2003
  - Once Terra has finished processing, Aqua will start from beginning of mission
- CERES will reprocess all products starting in March 2016, once the Terra and Aqua C6.1 data is available (Hopefully early 2018)
  - There should be less of a discontinuity between Feb. and March 2016 due to water vapor channel impact using C6.1 on the MODIS cloud properties and polar LW down surface fluxes
- The CERES Ed4 data products are processed until Jan 2017
MODIS C6.1

• Are there any MODIS channel calibration differences between C6 and C6.1?
  – Channel calibration differences could also cause discontinuities in the cloud retrievals, which can impact the computed surface fluxes

• Regress the C6 and C6.1 pixel level radiances to determine the one time scaling factor
  – Compare C6 and C6.1 granule over ocean equatorial region that contains deep convective clouds, in order to obtain the entire range of earth viewed radiances

• Estimate the predicted C6 and C6.1 scaling factors using Sept 15, 2017 granule
  – MOD02SS1.S2017258.2110.061.2017261190903.hdf
  – MYD02SS1.S2017255.2335.061.2017260224742.hdf
  – The actual scaling factors will be performed using the month before the C6 to C6.1 transition
CERES GEO calibration group web site

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

C6.1 to C6 scaling factors

Slope=1.0019, C6.1/C6=+0.19%
# Table of C6.1/C6 scaling factors (2017)

<table>
<thead>
<tr>
<th>Channel</th>
<th>Terra</th>
<th>Aqua</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band 1 (0.65(\mu m))</td>
<td>0.0</td>
<td>+0.19</td>
</tr>
<tr>
<td>Band 2 (0.86(\mu m))</td>
<td>0.0</td>
<td>+0.21</td>
</tr>
<tr>
<td>Band 3 (0.47(\mu m))</td>
<td>0.0</td>
<td>+0.27</td>
</tr>
<tr>
<td>Band 4 (0.56(\mu m))</td>
<td>0.0</td>
<td>+0.25</td>
</tr>
<tr>
<td>Band 5 (1.24(\mu m))</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Band 6 (1.6(\mu m))</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Band 7 (2.13(\mu m))</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Band 17 (0.91(\mu m))</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Band 20 (3.74(\mu m))</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Band 23 (4.05(\mu m))</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Band 26 (1.38(\mu m))</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Band 27 (6.72(\mu m))</td>
<td>striping</td>
<td>0.0</td>
</tr>
<tr>
<td>Band 29 (8.6(\mu m))</td>
<td>striping</td>
<td>0.0</td>
</tr>
<tr>
<td>Band 31 (11.0(\mu m))</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Band 32 (12.0(\mu m))</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Band 33-36 (CO(_2))</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>
Terra C6 and C6.1 Band 29 8.6µm channel

Terra-MODIS 8.6µm C6 and C6.1 BT density scatter plot

MOD02SS1.S2017258.2110.061.2017261190903.hdf
Terra C6 and C6.1 Band 27 WV 6.7µm channel

• An example cross talk detector to detector striping
Terra-MODIS WV 6.7\(\mu\)m C6 and C6.1 BT density scatter plot

Terra-MODIS Band 27 (6.72-\(\mu\)m) BT (K)

- Free Linear: \(y = 0.073777x + 237.5935\)
- Forced Linear [0]: \(y = 1.0841x + 0\)
- Polynomial: \(y = 0.00048415x^2 + -0.14287x + 261.6277\)
- Num: 655623
MODIS C6 TO C5 SCALING FACTORS
# Table of C5/C6 scaling factors (2007, 2017)

<table>
<thead>
<tr>
<th>Channel (%)</th>
<th>Terra</th>
<th>Aqua</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band 1 (0.65(\mu m))</td>
<td>+1.62, +1.39 RVS</td>
<td>+0.30, -0.37 RVS</td>
</tr>
<tr>
<td>Band 2 (0.86(\mu m))</td>
<td>+0.06, -1.46 RVS</td>
<td>+0.14, -0.68 RVS</td>
</tr>
<tr>
<td>Band 3 (0.47(\mu m))</td>
<td>+1.03, +1.20 RVS</td>
<td>+0.31, -0.85 RVS</td>
</tr>
<tr>
<td>Band 4 (0.56(\mu m))</td>
<td>+0.69, +0.44 RVS</td>
<td>+0.34, -0.61 RVS</td>
</tr>
<tr>
<td>Band 5 (1.24(\mu m))</td>
<td>-3.18, -1.65</td>
<td>-0.09, 0.0</td>
</tr>
<tr>
<td>Band 6 (1.6(\mu m))</td>
<td>-0.26, 0.0</td>
<td>-0.03, 0.0</td>
</tr>
<tr>
<td>Band 7 (2.13(\mu m))</td>
<td>-0.75, -0.05</td>
<td>-0.04, 0.0</td>
</tr>
<tr>
<td>Band 17 (0.91(\mu m))</td>
<td>+0.89, -0.11</td>
<td>+0.23, -0.02</td>
</tr>
<tr>
<td>Band 20 (3.74(\mu m))</td>
<td>low rad saturation</td>
<td>0.0, 0.0</td>
</tr>
<tr>
<td>Band 23 (4.05(\mu m))</td>
<td>low rad saturation</td>
<td>0.0, 0.0</td>
</tr>
<tr>
<td>Band 26 (1.38(\mu m))</td>
<td>+3.94, +4.97</td>
<td>0.0, 0.0</td>
</tr>
<tr>
<td>Band 27 (6.72(\mu m))</td>
<td>striping</td>
<td>0.0, +0.23 striping</td>
</tr>
<tr>
<td>Band 29 (8.6(\mu m))</td>
<td>low rad saturation</td>
<td>0.0, +0.04</td>
</tr>
<tr>
<td>Band 31 (11.0(\mu m))</td>
<td>+0.0, +0.04</td>
<td>0.0, +0.08</td>
</tr>
<tr>
<td>Band 32 (12.0(\mu m))</td>
<td>+0.0, +0.03</td>
<td>0.0, +0.07</td>
</tr>
<tr>
<td>Band 33-36 (CO(_2))</td>
<td>&gt;0.1, &gt;0.1</td>
<td></td>
</tr>
</tbody>
</table>

*Solar diffuser anomaly in 2009*
MODIS Band 1 (0.65μm) C6 to C5 comparison

- Terra reflectance
- Aqua reflectance

• An example of response versus scan angle (RVS) correction in C6

MOD02SS1.S2016307.0010.006.2016307143521.hdf
MODIS B1 0.65\(\mu\)m scan angle dependency over Libya-4

- 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.

Bhatt et al. 2017
Terra-MODIS Band 29 (8.6µm) C6 to C5 comparison

- An example of low radiance saturation in C5
VIIRS V03110 TO V001
SCALING FACTORS
NPP-VIIRS versions

- For Ed1
  - NPP-VIIRS V03100 was processed from Jan. 27 2012 to Dec 31, 2015, V001 has been processed from Jan. 1 2016.

- For Ed2
  - Process the whole record using V001
  - Apply Aqua-MODIS C5 to NPP-VIIRS V001 scaling factors

### I1 (0.65µm) radiance comparison

Slope=0.984, V03110/V001=-1.6%

### M15 (10.8µm) BT comparison

Slope=1.0, V03110/V001=0.0%
### VIIRS V001 to 03100 scaling factors

<table>
<thead>
<tr>
<th>Channel (%)</th>
<th>Sept 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>I1 0.65μm</td>
<td>-1.6</td>
</tr>
<tr>
<td>M7 0.86μm</td>
<td>-0.4</td>
</tr>
<tr>
<td>M3 0.47μm</td>
<td>-2.6</td>
</tr>
<tr>
<td>M 1.24μm</td>
<td>+0.4</td>
</tr>
<tr>
<td>M11 1.64μm</td>
<td>+0.1</td>
</tr>
<tr>
<td>I4 3.7μm (BT)</td>
<td>0.0</td>
</tr>
<tr>
<td>M14 8.6μm</td>
<td>0.0</td>
</tr>
<tr>
<td>M15 10.8μm</td>
<td>0.0</td>
</tr>
<tr>
<td>M16 12.0μm</td>
<td>0.0</td>
</tr>
</tbody>
</table>

- These were performed this morning
- The rest of channels will be updated shortly on the web site
TERRA TO AQUA MODIS C6 SCALING FACTORS
Terra to Aqua C6, July 2002, B1 (0.65µm),
Polar SNOs

- All Terra and Aqua simultaneous nadir overpass (SNO) are between 10 and 15 minutes apart
- Use both nadir and off-nadir radiance pairs, 10x more points
- SNO occur during local noon so that the azimuthal angle are symmetric
Terra to Aqua C6 scaling factors, B1 (0.65µm)

- Only 6 months out of the year are illuminated
- Off–nadir monthly gains have a smaller trend standard error
- The scaling factor trend is unpredictable, use annual gains
### Terra/Aqua MODIS C6 scaling factors

<table>
<thead>
<tr>
<th>Band (%)</th>
<th>15 year mean</th>
<th>15-year range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band 1 (0.65µm)</td>
<td>+0.95</td>
<td>+0.28 to +1.65</td>
</tr>
<tr>
<td>Band 2 (0.86µm)</td>
<td>-0.83</td>
<td>-2.22 to -0.11</td>
</tr>
<tr>
<td>Band 3 (0.47µm)</td>
<td>-1.10</td>
<td>-1.55 to -0.53</td>
</tr>
<tr>
<td>Band 4 (0.56µm)</td>
<td>+0.27</td>
<td>-0.23 to +0.84</td>
</tr>
<tr>
<td>Band 5 (1.24µm)</td>
<td>-6.93</td>
<td>-7.38 to -6.23</td>
</tr>
<tr>
<td>Band 7 (2.13µm)</td>
<td>-0.48</td>
<td>-2.25 to +0.1</td>
</tr>
<tr>
<td>Band 26 (1.38µm)</td>
<td>+3.60</td>
<td>+2.4 to +4.6</td>
</tr>
</tbody>
</table>

- Scaling factors need to updated annually.
AQUA MODIS C5 OR C6 TO VIIRS V001 SCALING FACTORS
Tropical intersects provide greater dynamic range and are illuminated for all 12 months of the year.

Polar intersects provide half of the dynamic range and are only illuminated 6 months out of the year.
Aqua and NPP ground track intersects

- The Aqua satellite altitude is ~705 km, whereas the NPP is at 824 km.
- NPP leaves no scan gaps at the equator.
Feb. 2012 Aqua-MODIS C6 B1 and NPP-VIIRS V001 I1 (0.65µm) ray-matched pairs

Deep Convective Cloud (DCC) 30-km ray-matched

- The DCC-ray and ATO-ray Feb. 2012 gains are almost identical for this month
- Each method has a differing spectral band adjustment

0.5°gridded all-sky ocean (ATO) ray-matched
The DCC-ray and ATO-ray timeline gain means are within 0.35%.
There is a relative gain drift in early 2015 with respect to Aqua-MODIS.
Aqua-MODIS C5/C6 and NPP-VIIRS V001 scaling

<table>
<thead>
<tr>
<th>Channel</th>
<th>C5 DCC</th>
<th>C6 DCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>I 1 0.65µm</td>
<td>-2.46%</td>
<td>-2.48%</td>
</tr>
<tr>
<td>M5 0.65µm</td>
<td>-3.83</td>
<td>-3.84</td>
</tr>
<tr>
<td>M7 0.86µm</td>
<td>-6.74</td>
<td>-6.75</td>
</tr>
<tr>
<td>M3 0.47µm</td>
<td>-2.73</td>
<td>-2.65</td>
</tr>
<tr>
<td>M4 0.55µm</td>
<td>-3.41</td>
<td>-3.37</td>
</tr>
<tr>
<td>M 1.24µm</td>
<td>-0.75</td>
<td>-0.79</td>
</tr>
<tr>
<td>I3 1.64</td>
<td>-3.75</td>
<td>-3.79</td>
</tr>
<tr>
<td>M11 1.64µm</td>
<td>-2.17</td>
<td>-2.20</td>
</tr>
<tr>
<td>M 2.11µm</td>
<td>-60.59</td>
<td>-60.66</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Channel</th>
<th>C5 ATO</th>
<th>C6 ATO</th>
</tr>
</thead>
<tbody>
<tr>
<td>I 3.7µm</td>
<td>-0.42K</td>
<td>-0.40K</td>
</tr>
<tr>
<td>M 3.7µm</td>
<td>+0.06</td>
<td>+0.08</td>
</tr>
<tr>
<td>M 8.6 µm</td>
<td>-0.21</td>
<td>-0.22</td>
</tr>
<tr>
<td>I 11.0µm</td>
<td>+0.52</td>
<td>+0.56</td>
</tr>
<tr>
<td>M 11µm</td>
<td>-0.13</td>
<td>-0.07</td>
</tr>
<tr>
<td>I 12.0µm</td>
<td>-0.11</td>
<td>-0.06</td>
</tr>
<tr>
<td>M 12.0µm</td>
<td>+0.10</td>
<td>+0.14</td>
</tr>
</tbody>
</table>

- There is only a slight difference between C5 and C6 in the later Aqua-MODIS record
- All MODIS and VIIRS bands are independently calibrated
How to scale and maintain stability

• When a new imager version is available, the newer version will be scaled to the older version during the transition month.

• The stability will be reexamined yearly. If there are significant imager calibration drifts the LUT will be updated.
  – If there is a significant calibration anomaly during the year, the LUT tables can be updated with a delta delivery.