CERES Cloud Working Group Report

CERES Science Team Mtg., Berkeley, CA, 29-31 May 2019

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Thanks to Dave Doelling and his TISA/calibration teams!
Topics

• VIIRS Ed2 Status
• Recent validation results
• Low-level cloud trends over the U.S.
• GOES-17 update
Update of CERES Cloud-related Papers (2019)


Improved ML clouds and ice cloud detection


## Clouds - Processing Status

Terra: Feb 2000 – Aug 2019 (~19 y) |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CERES-VIIRS Edition 1 Status</td>
<td>SNPP: Jan 2012 – July 2019 (~7.5 y)</td>
</tr>
</tbody>
</table>
MODIS/VIIRS Cloud Product Continuity

Terra and Aqua are near their end of lifetime; CERES continues on S-NPP and the JPSS series but will rely on cloud properties derived from the VIIRS imagers. Continuity between the MODIS and VIIRS cloud properties is essential.

Challenges for achieving continuity using different instruments:

1. Spatial resolution and sampling
   - VIIRS (375, 750 m) vs. MODIS (1000, 500, 250 m) at nadir
   - VIIRS pixel size nearly constant with scan angle (unlike MODIS)

2. Calibration
   - Relative consistency between sensors is required including spectral band adjustments
   - Solar reflectance channels most problematic (e.g. JPSS-1 is 2-4% higher than SNPP)

3. Spectral coverage
   - No CO2 (13 µm) or Water Vapor (6.7 µm) channels on VIIRS
   - 2.x µm window channels much different (MODIS 2.1 µm vs. VIIRS 2.2 µm)
CERES LEO Cloud Product Continuity

Ed4 MODIS designed to provide consistent cloud properties between Terra and Aqua and across their entire observational record

- Use same frozen retrieval algorithms
- Calibrations unified (all data scaled to Aqua MODIS Collection-5 radiances)
- Aqua-MODIS data provide the most consistent long-term cloud data record ever produced
- But, Ed4 Terra-MODIS not as consistent (degradation in several channels not addressed in Ed4)
  - primarily impacts polar cloud trends

MODIS Ed4 was not designed for continuity with VIIRS

- MODIS Ed4 delivered before VIIRS data became available (no experience with VIIRS)

Some continuity considerations were made during VIIRS Ed1 development

- Cloud mask tuning to help account for resolution and channel differences
- Split window method (11 and 12 µm) developed to aid in ice cloud height assignment and cloud phase determination to help achieve consistency with MODIS which relies heavily on the 13 µm channel

But, Ed1 uses forward processing calibrations (a significant update came in 2016)

- Inconsistencies in current record
- Not scaled to MODIS
VIIRS/MODIS Consistency Summary
(from previous meetings)

- VIIRS Ed1 and MODIS Ed4 cloud properties are tracking very well but are not consistent enough for continuity due to different channels being used in the algorithms, calibration inconsistencies, and resolution differences.
- While there is excellent agreement in global mean cloud fractions for ice, liquid and total clouds, regional differences are large.
- Largest differences are found for polar night cloud detection, cirrus detection everywhere, and cloud phase determination.
- Inconsistent cloud phase determination leads to inconsistencies in other cloud properties (COD, Re, Z).
- Bug fixes and new models implemented in VIIRS Ed 1 also cause some differences.

MODIS ED5 and VIIRS ED3 will have consistent calibrations, use a common set of spectral channels, employ forward models and algorithms that are as consistent as possible to achieve continuity.
Primary objective is to normalize VIIRS calibrations to MODIS (use scaling factors)

- Evaluate consistency between Ed2 VIIRS and Ed4 MODIS cloud properties (different algos)
- Develop MODIS/VIIRS continuity algorithms for Ed5 (use common channels)

VIIRS Ed2 will use same cloud algorithms as in NPP VIIRS Ed1, but

- with L1 VIIRS Radiance Version 2 (in netCDF format)
- apply to both NPP and J1 (the first delivery for J1)
- L1 VIIRS Radiance Version 2 scaled to MODIS Collection 5

L1 NPP VIIRS Radiance V2 expected to be in production mid-November, 2019

L2 Aerosol Product

- Aerosol for CERES NPP-VIIRS Edition 2 (AERDB_L2_VIIRS_SNPP)
  - GSFC SNPP VIIRS Deep Blue (Deep Blue algo over land and SOAR for ocean)
- No Aerosol for CERES J1-VIIRS Edition 2

CERES Clouds Code is ready. Currently testing VIIRS -to- Aqua-MODIS scaling factors on NPP V1 and J1 V2.
• VIIRS CF changes by ~11%, Aqua 14%
  - some impact of constant resolution w/VZA along scan path?

• MODIS COD drops more than VIIRS
  - 19% for ice, 18% for water
  - VIIRS only 4% for ice, 5% for water
Viewing Angle Dependence, 2013 Nonpolar Averages

V – VIIRS, A - Aqua

**Effective Radius**

- **Liquid**
  - VIIRS: 13.2 vs Aqua: 14.3
  - Decrease more than Aqua for liquid

- **Ice**
  - VIIRS: 26.7 vs Aqua: 27.6
  - Decrease more than Aqua for ice

**Cloud Water Path**

- VIIRS increases more than Aqua
  - -11% vs -4% for Aqua liquid
  - -13% vs -4% for Aqua ice

- VIIRS water path less dependent on VZA
  - Flat for water, -10% for ice
  - Aqua: -13% for water, -16% for ice

- VIIRS constant resolution seems to diminish VZA dependence in most variables
- Broken clouds and 3-D effects still cause significant dependencies
Recent Validation & Comparisons with other Methods

Cloud Mask Paper

Cloud Algorithm Paper

Validation Paper
CERES Ed4 Cloud Fraction vs other groups/satellites

Monthly Mean Zonal Cloud Fraction Comparisons

- CALIPSO highest, CMSAF lowest (mean values in legend)
- SatCORPS, PATMOS-X from AVHRR
- CERES MODIS Ed4 generally in the middle

Ed4 cloud mask paper
Trepte et al, 2019
Mean cloud fraction by phase from October 2008 Aqua MODIS data

Ed4 vs MYOD08

CERES Ed4 has fewer no retrievals and therefore larger ice and liquid cloud fractions than MYOD08

Ed4 phase validated extensively with CALIPSO (Yost et al. 2019, in prep)

Ed4 misses some thin Ci in overlapping conditions and has more water than CALIOP – new neural net method looks promising to address this in Ed5

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Liquid</th>
<th>Ice</th>
<th>Total</th>
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<tbody>
<tr>
<td></td>
<td>MYOD08</td>
<td>CM</td>
<td>MYOD08</td>
</tr>
<tr>
<td>NP Fraction retrieved</td>
<td>0.339 (0.367)</td>
<td>0.393</td>
<td>0.201 (0.197)</td>
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<tr>
<td>PO Fraction retrieved</td>
<td>0.358 (0.348)</td>
<td>0.391</td>
<td>0.226 (0.237)</td>
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</table>

Minnis et al., 2019
### Classification for Single-Phase 100% Cloud-Covered 5-Km Footprints

<table>
<thead>
<tr>
<th>Scene #</th>
<th>Scene Type</th>
<th>Fraction Correct (HR)</th>
<th>Bias</th>
<th>Ice FAR</th>
<th>Water FAR</th>
<th>Hanssen-Kuiper</th>
<th># x 10³</th>
<th>% all matches</th>
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</thead>
<tbody>
<tr>
<td></td>
<td><strong>Day</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Nonpolar, Land SIF</td>
<td>0.919</td>
<td>-0.049</td>
<td>0.034</td>
<td>0.098</td>
<td>0.874</td>
<td>555</td>
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<td>2</td>
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<td>-0.011</td>
<td>0.096</td>
<td>0.051</td>
<td>0.849</td>
<td>123</td>
<td>61.5</td>
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<td>3</td>
<td>Nonpolar Ocean, SIF</td>
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<td>0.006</td>
<td>0.048</td>
<td>0.014</td>
<td>0.947</td>
<td>2,371</td>
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<td>4</td>
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<td>0.018</td>
<td>0.880</td>
<td>308</td>
<td>65.0</td>
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<tr>
<td>5</td>
<td>Global, SIF</td>
<td>0.958</td>
<td>-0.003</td>
<td>0.053</td>
<td>0.027</td>
<td>0.923</td>
<td>3,358</td>
<td>69.1</td>
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<tr>
<td>6</td>
<td>Global, SIC</td>
<td>0.920</td>
<td>0.036</td>
<td>0.157</td>
<td>0.032</td>
<td>0.851</td>
<td>719</td>
<td>64.3</td>
</tr>
<tr>
<td></td>
<td><strong>Night</strong></td>
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<td></td>
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</tr>
<tr>
<td>7</td>
<td>Nonpolar, Land SIF</td>
<td>0.873</td>
<td>0.051</td>
<td>0.137</td>
<td>0.109</td>
<td>0.715</td>
<td>598</td>
<td>68.5</td>
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<tr>
<td>8</td>
<td>Polar Land SIF</td>
<td>0.823</td>
<td>0.132</td>
<td>0.280</td>
<td>0.050</td>
<td>0.679</td>
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<td>9</td>
<td>Nonpolar Ocean, SIF</td>
<td>0.918</td>
<td>0.048</td>
<td>0.174</td>
<td>0.027</td>
<td>0.851</td>
<td>2,500</td>
<td>69.5</td>
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<tr>
<td>10</td>
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<td>0.840</td>
<td>0.135</td>
<td>0.336</td>
<td>0.023</td>
<td>0.746</td>
<td>384</td>
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<tr>
<td>11</td>
<td>Global, SIF</td>
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<td>0.187</td>
<td>0.036</td>
<td>0.817</td>
<td>3,606</td>
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<tr>
<td>12</td>
<td>Global, SIC</td>
<td>0.798</td>
<td>0.186</td>
<td>0.252</td>
<td>0.034</td>
<td>0.520</td>
<td>1,381</td>
<td>74.0</td>
</tr>
</tbody>
</table>

- Daytime HR 92-97%
- Nighttime HR 80-90%
- Lowest skill scores over snow/ice
- Ice cloud false alarms pretty high at night

Yost et. al., 2019
Cloud Phase (Fraction Correct)
*SIF*: snow/ice-free, *SIC*: snow/ice-covered

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</tr>
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</tr>
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<td>3</td>
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<tr>
<td></td>
<td><strong>Night</strong></td>
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</tr>
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</table>

Single-phase clouds

Error bars show range for all cloud conditions and using different methods to assess CALIPSO

Accuracy depends on how you do the evaluation

Yost et. al., 2019
FAA In-Cloud ICing and Large drop Experiment (ICICLE)

- extensive, high quality, in-situ cloud microphysics dataset was collected

- ICICLE Convair-580 sampled super-cooled liquid clouds forming over Lake Michigan, and transition to glaciated, snow-producing clouds over western Michigan

- GOES-16 accurately captures phase transition across uniform cold cloud tops (~ -26°C)
Mean Cloud Top Heights from Aqua MODIS, MODIS Science Team (MAST) & CERES Edition 4
October 2008

MAST, Day & Night

CERES, Day & Night

• On average, CERES clouds are ~1.4 km higher and in much better agreement with CALIPSO than MAST
• MAST has better day/night consistency (employs daytime IR method)
MODIS ED4 CLOUD HEIGHT COMPARISONS WITH CALIPSO
Single-layer Ice Clouds

- Nighttime cirrus heights better than daytime
- New ice scattering model (THM) will improve agreement in Ed5
- Will still need more effective empirical adjustments than those applied in Ed4

Opaque Clouds

CALIPSO CTH (km) vs. MODIS Ed4 CTH (km)

Non-Opaque Clouds

CALIPSO CTH (km) vs. MODIS Ed4 CTH (km)

January, April, July, and October 2010
MODIS ED4 CLOUD HEIGHT COMPARISONS WITH CALIPSO
Single-layer Water Clouds

- Nighttime cirrus heights better than daytime
- New ice scattering model (THM) will improve agreement in Ed5
- Will still need more effective empirical adjustments than those applied in Ed4

January, April, July, and October 2010
MODIS ED4 CLOUD HEIGHT COMPARISONS WITH CALIPSO
Single-layer Water Clouds

Current Lapse-rate method has pretty good skill overall but there are some problem areas for boundary layer clouds:

- Heights often too high over ocean
- Poor skill over land (too low during day; too high at night; poor correlation)

Zhujun Li testing new approaches:

- Temperature dependent lapse rate method working much better over ocean
- Increased use of reanalysis data over land
  - PBL heights (RH profile)
  - Wet bulb temperature profiles

New lapse rate method reduces bias and rms over ocean
Ed4 1.24 µm optical depths retrieved over snow/ice seem to be too high for thinner clouds.

A method using 1.61 µm has been implemented and compares better with CALIPSO.

Sunny Sun-Mack will discuss this in detail on Thursday.
Regional trend of Liquid Cloud Optical Depth (per decade)

Aqua_MODIS (July 2002 – January 2019)

- Significant large negative trends in liquid COD over eastern U.S and adjacent Atlantic are found in 17 year CERES-MODIS record
- 10-15% COD reduction per decade dwarfs changes seen elsewhere
Regional trend of Liquid Cloud Effective Radius ($R_e$): $\mu$m / per decade


- A positive trend in liquid cloud $R_e$ is also found, largest over the western Atlantic (~0.5 $\mu$m or 4% per decade)
- Increases most apparent after 2009

Liquid Cloud Effective Radius at 37.5N 82.5W (5 deg region)

- 0.4 $\mu$m/decade

Liquid Cloud Effective Radius at 37.5N 67.5W

- 0.5 $\mu$m/decade
Regional Trend of Total Cloud Fraction:  % / decade


- Cloud fraction trends unremarkable compared to rest of world
- For Reg 1, no trend in total clouds (small increase in ice clouds, decrease in water clouds, 2.5%/decade)
- For Reg 2, total clouds increasing (2%), ice clouds increasing (3%), low clouds decreasing (1%)
MODIS CDNC Trends per decade

Cloud droplet number conc. $N_d$

(cc/decade)
Sulfate AOD trend per decade
U.S. pollution emissions have been decreasing during the MODIS record

Largest decreases over eastern U.S. and major cities from 2005-2008, then unexpectedly levels off – implications for air quality management

Relative contribution of different sources of emission changing

Jiang et al., PNAS, 2018
MODIS 0.55 µm Aerosol Optical Depth Trends (per decade)

- AOD is also decreasing over eastern U.S
- Largest decreases early in record from Feb-Oct

Reg 1 (land) 35-40N, 80-85W

-0.07 AOD per decade
MODIS 0.55 µm Aerosol Optical Depth Trends (per decade)

-0.03 AOD per decade

Reg 2 (ocean) 35-40N, 60-65W

- Similar story downwind over the ocean but changes not as large
- Aerosol and cloud property relationships over the eastern U.S. appear to be well correlated
- Still need to look for possible meteorological changes
- Plan to look at new FBCT product (radiative trends)
ABI cooling system not operating at capacity on the new GOES-17 satellite

- Can degrade IR data or render it unusable for 2-6 hours at night
- Greatest impact during eclipse season near equinox’s (~40 days?) when detectors are heated by direct sunlight
- No impact near solstices but not yet clear how long this lasts.
- Impact on derived products worse than imagery for qualitative use in NWS

Impact to CERES: Some IR data unusable for variable lengths of time across midnight depending on the time of year
3.9, 10.35 µm channels ok
8.5 11.2, 12.3, 13.3 µm NOT ok

Will impact ability to derive accurate and consistent cloud properties at bad image times.

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**Estimated Channel Availability**

Below is the current assessment of channel availability, as of September 13, 2018.

**Note:** This is a preliminary estimate that is subject to change as experts refine channel availability.

<table>
<thead>
<tr>
<th>COLOR KEY: Available 24hrs/day</th>
<th>Availability Exceptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Available Channel Logo]</td>
<td></td>
</tr>
</tbody>
</table>

### Tables scroll horizontally on smaller windows and devices.

<table>
<thead>
<tr>
<th>Band</th>
<th>Channel</th>
<th>Function</th>
<th>Estimated Unsaturated Signal Cold Season (Solstice)</th>
<th>Estimated Unsaturated Signal Warm Season (Pre-Eclipse)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.47 µm</td>
<td>Blue</td>
<td>24 hr</td>
<td>24 hr</td>
</tr>
<tr>
<td>2</td>
<td>0.64 µm</td>
<td>Red</td>
<td>24 hr</td>
<td>24 hr</td>
</tr>
<tr>
<td>3</td>
<td>0.66 µm</td>
<td>Veggie</td>
<td>24 hr</td>
<td>24 hr</td>
</tr>
<tr>
<td>4</td>
<td>1.38 µm</td>
<td>Cirrus</td>
<td>24 hr</td>
<td>24 hr</td>
</tr>
<tr>
<td>5</td>
<td>1.61 µm</td>
<td>Snow/Ice</td>
<td>24 hr</td>
<td>24 hr</td>
</tr>
<tr>
<td>6</td>
<td>2.25 µm</td>
<td>Cloud Particle Size</td>
<td>24 hr</td>
<td>24 hr</td>
</tr>
<tr>
<td>7</td>
<td>3.90 µm</td>
<td>Shortwave Window</td>
<td>24 hr</td>
<td>24 hr</td>
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<tr>
<td>8</td>
<td>6.18 µm</td>
<td>Upper-Level Water Vapor</td>
<td>24 hr</td>
<td>18 - 20 hr</td>
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<tr>
<td>9</td>
<td>6.95 µm</td>
<td>Mid-Level Water Vapor</td>
<td>24 hr</td>
<td>18 - 20 hr</td>
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<td>Cloud-Top Phase</td>
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<td>21 hr</td>
</tr>
<tr>
<td>12</td>
<td>9.61 µm</td>
<td>Ozone</td>
<td>24 hr</td>
<td>18 - 20 hr</td>
</tr>
<tr>
<td>13</td>
<td>10.35 µm</td>
<td>Clean IR Longwave Window</td>
<td>24 hr</td>
<td>24 hr</td>
</tr>
<tr>
<td>14</td>
<td>11.20 µm</td>
<td>IR Longwave Window</td>
<td>24 hr</td>
<td>24 hr</td>
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<tr>
<td>15</td>
<td>12.30 µm</td>
<td>Dirty Longwave Window</td>
<td>24 hr</td>
<td>21 hr</td>
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<tr>
<td>16</td>
<td>13.30 µm</td>
<td>CO2 Longwave Infrared</td>
<td>24 hr</td>
<td>18 - 20 hr</td>
</tr>
</tbody>
</table>
Example showing 11-12µm Brightness Temperature Differences

Feb. 19, 2018
What to do?

- Need an objective way to flag bad images
- Could fill gaps with linear interpolation (TISA group)
- Or, somehow use the good channels to extract more information...
What to do?

We are exploring a ‘Data Fusion’ approach to extrapolate information from a previous good image time to a bad image time

• Uses unaffected bands to transfer information from a previously unaffected hour
• Employs KDTREE - multivariate nearest neighbor search algorithm
  - developed by industry, highly efficient
  - available in MatLab and other programming languages
  - Method has been demonstrated to create the missing 6.7 µm and 13 µm channels for VIIRS using CrIS data – i.e. make VIIRS more like MODIS (Weisz et al 2017)
  - UW-Madison/NOAA testing the creation of synthetic GOES-17 radiances to replace bad images affected by the cooling issue
• Two approaches being tested by CERES CWG
  1. Create the missing radiance fields synthetically and apply cloud retrieval algorithm to derive cloud properties
  2. Create synthetic cloud properties (translate cloud properties from good hour to a bad hour)

Both approaches are based on use of two unaffected bands; 7 (3.9 µm) and 13 (10.3 µm)
Initial Test Case

- GOES-17 nighttime data from 25th July, 2019
- The 0930 UTC image is used as the reference (unaffected by Eclipse)
- Synthetic BTs created at 1030, 1130 and 1230 UTC for Bands 11(8.4mm), 14(11.2mm), 15(12.3mm), and 16(13.3mm)
- CERES GEO cloud retrieval algorithm run using the synthetic BTs for these bands.
- Synthetic cloud properties for the 3 hours based also created based on those retrieved at 0930 UTC (cloud_phase, cloud_visible_optical_depth, and cloud_top_height)
GOES-17, 10:30 UTC, 25th July, 2019

PHASE FROM SYNTHETIC RAD

SYNTHETIC PHASE

REGULAR PHASE

TAU FROM SYNTHETIC RAD

SYNTHETIC TAU

REGULAR TAU
GOES-17, 10:30 UTC, 25th July, 2019

PHASE FROM SYNTHETIC RAD
SYNTHETIC PHASE
REGULAR PHASE

ZTOP FROM SYNTHETIC RAD
SYNTHETIC ZTOP
REGULAR ZTOP
PHASE FROM SYNTHETIC RAD
SYNTHETIC PHASE
REGULAR PHASE

TAU FROM SYNTHETIC RAD
SYNTHETIC TAU
REGULAR TAU

GOES-17, 11:30 UTC, 25th July, 2019
GOES-17, 11:30 UTC, 25th July, 2019

PHASE FROM SYNTHETIC RAD
SYNTHETIC PHASE
REGULAR PHASE

ZTOP FROM SYNTHETIC RAD
SYNTHETIC ZTOP
REGULAR ZTOP
GOES-17, 11:30 UTC, 25th July, 2019

PHASE FROM SYNTHETIC RAD
SYNTHETIC PHASE
REGULAR PHASE

TAU FROM SYNTHETIC RAD
SYNTHETIC TAU
REGULAR TAU
Decent agreement overall but somewhat noisy
Synthetic phase looks a little better than that retrieved from synthetic radiances
Synthetic Phase vs. Regular Phase

Phase From Synthetic Rad vs. Regular Phase

11:30 UTC

Agreement much worse at 1130 UTC
- Standard retrieval affected by Eclipse problem

Blue: Synthetic Phase
Yellow: Phase from synthetic radiances
Both compared to retrieved phase from observed radiances
Note: 1130 utc has bad obs (Eclipse)
Synthetic CTH vs. Regular CTH

CTH From Synthetic Rad vs. Regular CTH
11:30 UTC

Synthetic CTH vs. Regular CTH

CTH From Synthetic Rad vs. Regular CTH
Synthetic Tau vs. Regular Tau

G17 Fusion Correction of Nighttime Data Issue
Training = 2019206 0930 UTC, Target = 2019206 1030 UTC

\[ y = 0.9287x + 0.00000 \]
\[ y = 0.7352x + 1.2640 \]
X mean: 4.53
Y mean: 4.21
Bias: 0.32
SDD: 8.69
R^2: 0.52
Num: 1120971

G17 Fusion Correction of Nighttime Data Issue
Training = 2019206 0930 UTC, Target = 2019206 1030 UTC

\[ y = 0.9094x + 0.00000 \]
\[ y = 0.7162x + 1.3153 \]
X mean: 4.63
Y mean: 4.21
Bias: 0.42
SDD: 8.89
R^2: 0.51
Num: 1110494

Tau From Synthetic Rad vs. Regular Tau
Synthetic Tau vs. Regular Tau

11:30 UTC

G17 Fusion Correction of Nighttime Data Issue
Training = 2019206 0930 UTC, Target = 2019206 1130 UTC

--- Synthetic Tau From Synthetic Rad vs. Regular Tau ---

Actual-Synthetic Tau: 2019206 1130 UTC

- \( y = 0.9307x + 0.00000 \)
- \( y = 1.1156x + 0.3385 \)
- X mean: 4.24
- Y mean: 3.95
- Bias: 0.29
- SDD: 12.16
- \( R^2: 0.50 \)
- Num: 1164177

--- Actual-Synthetic Tau: 2019206 1130 UTC ---

- \( y = 0.8876x + 0.00000 \)
- \( y = 1.0456x + 0.5306 \)
- X mean: 4.45
- Y mean: 3.95
- Bias: 0.50
- SDD: 12.27
- \( R^2: 0.50 \)
- Num: 1138611
### STATISTICAL COMPARISON OF SYNTHETIC CLOUDS VS RETRIEVED VALUES

NOTE:  1130 UTC IS A BAD HOUR AFFECTED BY ECLIPSE

<table>
<thead>
<tr>
<th>Time</th>
<th>CTH</th>
<th>Bias (km)</th>
<th>SDD (km)</th>
<th>R²</th>
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<td>10:30</td>
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<td>0.01</td>
<td>3.55</td>
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<td>From Syn Rad</td>
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<th>R²</th>
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<td>From Syn Rad</td>
<td>0.32</td>
<td>10.21</td>
<td>0.48</td>
</tr>
</tbody>
</table>
Example for Cloud Optical Thickness (COT)

- Reference image (or training) is JD 196 at 18 UTC (left image)
- COT retrievals from standard cloud product shown in middle (note terminator effects, default values)
- Synthetic COT (right) generated using 3 IR channels, lat/lon in nearest neighbor search minimization

Upshot: Method produces more realistic nighttime COT (albeit synthetic), eliminates terminator issues, and matches the COT observations the next day quite well
QUESTIONS ?