CERES Clouds Working Group Report

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Thanks to Dave Doelling and the TISA/calibration teams!

Fall 2023 CERES Science Team Meeting, New York, NY, 17-19 Oct 2023
Topics

• Satellite datasets and processing status
• Consistency of cloud properties across datasets
• Ed5 algorithm status and recent results
Clouds Processing Status (MODIS & VIIRS)

CERES-MODIS Edition 4 (*CDR)

Aqua: Jul 2002 – Aug 2023 (~ 21 y)
Terra: Feb 2000 – Aug 2023 (~ 23.5 y)

- Uses frozen Ed4 cloud codes delivered in 2013
- MODIS Collection 5 radiances thru Feb 2016,
- MODIS Collection 6.1 March 2016 – present and scaled to C5 for consistency over entire record
- Terra-MODIS normalized to Aqua-MODIS (Sun-Mack, et al. 2018)

CERES-VIIRS Edition 1A

SNPP: Jan 2012 – Jun 2021 (~ 9.5 y)
NOAA-20: Jan 2018 – Jun 2021 (~ 3.5 y)

- Uses VIIRS Ed1A cloud code
- SNPP uses forward processing calibrations (C1 radiances), not scaled to MODIS; has discontinuity ~2016 due to a calibration update by SIPS
- N20 uses C2 radiances and scaled to MODIS C5

CERES-VIIRS Edition 2A

SNPP: Jan 2012 – Aug 2023 (~ 11.5 y)

- Uses VIIRS Ed1A cloud code
- Uses C2 radiances and scaled to MODIS C5

CERES-VIIRS Edition 1B (*CDR)

NOAA-20: Jan 2018 – Aug 2023 (~ 5.5 y)

- Uses VIIRS Ed1b cloud code (temporary continuity version until Ed5 is released)
- Fills Aqua-MODIS gap in Aug 2020
Global Cloud Fraction Timeseries, 2000-2023
Consistency of Current Datasets

Aqua-MODIS is most stable long-term record. On average, no global trends in daytime cloud fraction since 2002. Slight decrease at night.

Terra-MODIS mostly consistent with Aqua but not as stable due to instrument/calibration changes leading to large artificial changes especially in polar regions at night.

VIIRS on NPP and NOAA-20 are tracking Aqua-MODIS well but algo’s detect less clouds.

N20 Ed1B improved consistency with Ed4 in polar regions and non-polar ocean (not shown).

Non-polar (60N – 60S) trends show consistent decreases in last decade, especially at night.
**Jan 2019**

- VIIRS Ed1B tuning to MODIS Ed4 results mixed
- Fewer oceanic clouds detected from VIIRS

**July 2019**

- Ed5 ocean consistency much better (VIIRS 2% lower)
- New land mask and Nnet for polar night coming soon
• VIIRS Ed1B tuning to MODIS Ed4 results mixed
• Fewer oceanic clouds detected from VIIRS

• Ed5 ocean consistency much better (VIIRS still a little low)
• New land mask and Nnet for polar night coming soon
Daytime Total Cloud Fraction Difference: VIIRS minus AQUA

- Large regional diffs (3-8%) between VIIRS Ed2A and MODIS Ed4
- Fewer oceanic clouds detected from VIIRS
- Ocean and polar land consistency better with Ed5 approach
- Non-polar land mask tuning just started (GEOS-IT in place)
Daytime Total Cloud Fraction Difference: VIIRS minus AQUA

- **Ed1B** daytime cloud fraction similar to Ed1A
- Fewer oceanic clouds detected from VIIRS

Ocean and polar land consistency better with **Ed5** approach
- Non-polar land mask tuning just started (GEOS-IT in place)
• Larger differences in areas with inconsistent cloud detection
• Poor consistency polar regions (Ed4 model interpolation bug)

• Ed5 COD consistency very good most ocean areas and over polar regions
Ed5 Cloud Algorithm Status

Ed5 LEO (MODIS and VIIRS)
• Ed5 processing framework for MODIS and VIIRS is completed.
• AQUA-MODIS radiance ingester modified to resurrect 1.6 um band (was not used in Ed4).
• Many bug fixes, algorithm and ancillary dataset improvements are already implemented including improved cloud masks, improved polar cloud properties utilizing the 1.6 µm band. Others in progress: skin temperature, polar night cloud detection, nighttime tau, cloud heights, phase and multi-layered clouds.
• Same algorithm being applied to both instruments using 11 common channels

Ed5 GEO
• A common 3-channel algorithm is implemented in the CERES GEO processing framework for most satellites.
  - daytime: 0.63, 3.7, 11 µm (cloud mask, theoretical optical properties)
  - nighttime: 3.7, 6.7, 11 µm (cloud mask, theoretical optical properties for thin clouds, machine learning method for thick cloud optical properties also ready for implementation)
• A different algorithm is being developed for the 2-channel satellite (GMS-5, Met-5 and Met-7)
• Machine learning approaches to reduce artifacts in sunglint and solar terminator are ready for implementation.

Critical ancillary datasets have recently become available (e.g. GOES-IT, MODIS C7), testing underway
Deep Neural Network to Estimate Satellite Skin Temperature

A DNN can consistently simulate satellite $T_s$ from GMAO inputs

More on Thursday morning
By Ben Scarino
Higher Accuracy Cloud Top Heights using Neural Net
All clouds, daytime, snow/ice free

Edition-4 Methods

Neural Net Method

All Clouds

<table>
<thead>
<tr>
<th></th>
<th>Nnet</th>
<th>Ed4</th>
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<tbody>
<tr>
<td>Bias</td>
<td>-0.01</td>
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<td>MAE</td>
<td>1.07</td>
<td>2.24</td>
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<tr>
<td>RMSE</td>
<td>1.77</td>
<td>3.55</td>
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High Clouds

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<tr>
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<td>1.18</td>
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<td>1.86</td>
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Mid Clouds

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<td>RMSE</td>
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<td>2.20</td>
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Low Clouds

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<th>Nnet</th>
<th>Ed4</th>
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<tr>
<td>Bias</td>
<td>0.60</td>
<td>0.31</td>
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<tr>
<td>MAE</td>
<td>0.85</td>
<td>0.89</td>
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<tr>
<td>RMSE</td>
<td>1.64</td>
<td>2.01</td>
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Zonal Distribution of both Upper & Lower Layer Cloud Top Heights
Snow Free Surfaces, Daytime, 2008

More on Thursday Morning
By Sunny Sun-Mack
Updating Cloud Properties For GEOs With Two Channels

- Ed4 cloud properties derived from the 2-channel satellite (GMS-5, Met-5 & Met-7) are associated with the largest discontinuities in the GEO timeseries.
- The daytime (2-chan) and nighttime (11 µm only) algorithms were applied to modern satellites (Met-8 and Met-11 over Indian Ocean & W. Europe domains) so that they could be assessed against our 8-channel (multi-chan baseline) algorithm applied to the same SEVIRI imager data.
- Adjustments were made to the 2-chan algorithms to improve the consistency of the derived cloud properties with those from the multi-chan algorithm.
- Entire record is currently being reprocessed for intermediate new version of SYN1deg, Ed4.2
GEO Nighttime Cloud Fraction (60°N – 60°S)

Updated 2ch Satellites (MET-5, MET-7, GMS-5) & SEVIRI (Met-8 to MET-11)

- Discontinuities mostly eliminated for 2ch sat’s & SEVIRI
- Have not yet worked GOES-9 or MTSAT’s
GEO Daytime Cloud Fraction (60N – 60S)

Updated 2ch Satellites (MET-5, MET-7, GMS-5)

- MET-5 (IO) and MET-7 (GW) CF still too high
- MET-7 (IO) pretty good
- Have not yet worked GOES-9 or MTSAT’s
- Ed5 will have new clear sky which will further help

Not Re-processed Yet

Ed4.1

MET-5
MET-7

Ed4.2

GMS-5
GOES_9
MTSAT-1
MTSAT-2
HIM-8
HIM-9

Cloud Area Fraction (%) Day clouds
GEO Nighttime Cloud Optical Depth (60N – 60S)

Updated 2ch Satellites (MET-5, MET-7, GMS-5) & SEVIRI (Met-8 to MET-11)

- No Nighttime Tau for IRONLY satellites
- KNN Tau looks good for IRONLY satellites
- Expect MET-10 to be fixed
GEO Nighttime Cloud Height (60N – 60S)

Updated 2ch Satellites (MET-5, MET-7, GMS-5) & SEVIRI (Met-8 to MET-11)

- 2ch heights much better (due to KNN Tau)
- Have not yet worked GOES-9
- Expect MET-10 to be better

Not Re-processed Yet
GEO Daytime Cloud Phase Fraction (60N – 60S)

Updated 2ch Satellites (MET-5, MET-7, GMS-5)

- Marked improvement in cloud phase
- GMS-5 still off a little

Not Re-processed Yet
GEO Nighttime Cloud Phase Fraction (60N – 60S)

Updated 2ch Satellites (MET-5, MET-7, GMS-5)

- Nighttime also better but needs more work

Not Re-processed Yet

Ed4.2
Initial evaluation of 3-ch algorithm

- Monthly cloud properties from G16, M11, M8, and H8 for July 2019
- New nighttime algo (KNN) not yet implemented but ready
**Total Cloud Fraction**

**07/2019 3ch-THM, CF daytime**

**07/2019 3ch-THM, CF nighttime**

Daytime, SZA<75°

Nighttime, SZA>90°

Zonal view:
Cloud height

07/2019 3ch-THM, Cloud height daytime

07/2019 3ch-THM, Cloud height nighttime
Total cloud optical depth

07/2019 3ch-THM, COT daytime

G16  M11  M8  H8

07/2019 3ch-THM, COT nighttime

G16  M11  M8  H8

Zonal view:

Nighttime algorithm updates not yet implemented in 3ch code
Liquid and ice CF

07/2019 3ch-THM, CF liquid daytime

07/2019 3ch-THM, CF ice daytime
Summary mean values Ed4 and 3ch (Ed5)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Ed4 (8ch)</th>
<th>Ed5 (3ch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total CF (day)</td>
<td>67.4 %</td>
<td>65.3%</td>
</tr>
<tr>
<td>Total CF (night)</td>
<td>65.3%</td>
<td>63.8%</td>
</tr>
<tr>
<td>Total cloud temp (day)</td>
<td>271 K</td>
<td>271.3 K</td>
</tr>
<tr>
<td>Total Cloud temp (night)</td>
<td>263.2 K</td>
<td>265.1 K</td>
</tr>
<tr>
<td>Total Cloud height (day)</td>
<td>4.2 km</td>
<td>4.0 km</td>
</tr>
<tr>
<td>Total Cloud height (night)</td>
<td>5.4 km</td>
<td>4.9 km</td>
</tr>
<tr>
<td>Total tau (day)</td>
<td>10.9</td>
<td>10.7</td>
</tr>
<tr>
<td>total tau (night)</td>
<td>5.1</td>
<td>5.0</td>
</tr>
<tr>
<td>Liquid Re (day)</td>
<td>15.1 μm</td>
<td>12.9 μm</td>
</tr>
<tr>
<td>Ice Re (day)</td>
<td>45 μm</td>
<td>33.8 μm</td>
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CERES GEO CLOUDS UPDATE

Next steps for 3-ch algorithm

• Revise Meteosat 3.9 µm solar constants
• Implement new nighttime algorithm
• Revise cloud mask over land
• Expand testing to other satellites
• Optimize 2ch algorithm for consistency
Global Cloud Composites (GCC) from Satellites

**Objectives:** Optimally combine radiances and derived products (cloud properties and radiative fluxes) from multiple GEO and LEO satellite imagers as seamlessly as possible and at high resolutions

- Partially funded by NASA SNWG to produce a multi-year, hourly dataset to serve modeling needs related to cloud parameterizations
- Day & Night, 3-km grid, 30-60 minutes
- Incorporates many CERES Ed5 cloud algorithm enhancements to improve accuracies, cross-platform consistency, and reduce artifacts (e.g. sunglint, terminator)

System is expected to be new backbone to support SatCORPS stakeholders with low latency data needs e.g. NCEP, CERES FLASHFlux, NASA POWER, DOE ARM, field campaigns, etc.
New parameterizations for ice and liquid water path

- Incorporates cloud vertical structure information from CloudSat/CALIPSO
- Incorporates thermodynamic phase partitioning from cloud models and aircraft observations
- Enables simultaneous estimates of IWP and LWP in ice overlapping liquid cloud conditions
  - more analogous to what models produce
QUESTIONS ?