CERES Cloud Working Group Report

CERES Science Team Mtg., Virtual#2, 15-17 September 2020

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

• Publications update
• Clouds Processing Status
  - GOES-17 wrap-up
  - Updated timeseries, trends
• VIIRS Ed1b development for NOAA-20
**Edition-4 References** (https://ceres.larc.nasa.gov/science/publications/)

**ED4 CALIBRATION**  

**ED4 CLOUD MASK**  

**ED4 RETRIEvals**  

**ED4 VALIDATION**  

**Other Recent Edition-4 Related Papers (2020)**


**In Preparation or Review**


Kang, L., R. Marchand, W. L. Smith: Evaluation of MODIS and Himawari-8 Low Clouds Retrievals over the Southern Ocean with In Situ Measurements from the SOCRATES Campaign, submitted to Earth and Space Science.


GOES-17 Wrap-up

- GOES-17 Imager (ABI) has a cooling problem at night causing degraded nighttime IR imagery for most channels between 10:30-16:30 GMT, cloud properties heavily degraded.
- Two bands are not degraded (3.8µm and 10.7µm)
- Two mitigation options
  1. Zero out bad image times and fill with temporal interpolation
  2. Somehow exploit the two good channels to retain hourly cloud properties
- The CWG developed a data fusion approach to reconstruct the radiances for the bad channels using the two good bands
- Nighttime cloud properties derived from the reconstructed radiances have similar accuracies as the standard cloud properties (demonstrated using GOES-16).
- Method delivered in July and has been applied in CERES processing beginning in March 2020 when G17 replaced G15.
- D. Doelling to summarize benefits to TISA subsystem this afternoon.
# Clouds - Processing Status (LEO)

## CERES-MODIS Edition 4 Status

- **Aqua:** Jul 2002 – Jul 2020 (~18 y)
- **Terra:** Feb 2000 – Jul 2020 (~20.5 y)

*MODIS Calibration Strategy:*
- MODIS Collection 5 thru Feb 2016,
- MODIS Collection 6.1 March 2016 - present
- C6.1 radiances are scaled to C5 for consistency over entire record
- Terra-MODIS normalized to Aqua-MODIS (Sun-Mack, et al. 2018)

## CERES-VIIRS Ed 1A Status

- **SNPP:** Jan 2012 – Jul 2020 (~8.5 y)
- **NOAA-20:** Jan 2018 – Jul 2020 (~2.5 y)

*VIIRS Calibration Strategy:*
- Use forward processing calibrations, not scaled to MODIS
- Inconsistencies/discontinuity in this record

*VIIRS Calibration Strategy: Scaled to Aqua-C5 using Jul 2019 data*
• Global mean cloud fraction ~0.65, no apparent trends in Aqua MODIS record since 2002.
• All SNPP, and NOAA-20 VIIRS cloud properties track those from AQUA-MODIS very well.
• Some cloud fraction differences due to calibration and algorithm differences
Global mean cloud fraction ~0.685 (Aqua-MODIS).

- VIIRS and MODIS track well.
- SNPP and N20 VIIRS about 1.5% lower than Aqua-MODIS
- No trends are found in the global Aqua MODIS total cloud fraction since 2002 (not shown)
- Regional trends still large in 18-year record due to ENSO’s and other natural variations

- Generally small or no trends in COD over much of the oceans
- Some interesting trends over/near land areas could be anthropogenic

Regional Trends (Aqua MODIS Ed4)
July 2002 – July 2020
Regional Trends over Eastern U.S.

- Significant negative trends are found in the 18-year record of low-level cloud optical thickness over the eastern U.S. and downwind over the adjacent Atlantic.
- Corresponding increases in cloud effective radius, decreases in droplet number concentration also found.
- These changes appear to be best associated with changes in pollution and sulfate aerosols as observed from satellites and characterized in MERRA-2 reanalyses rather than with changes in cloud fraction or meteorology (EIS).
- In contrast, changes in cloud properties found over the NE pacific are more correlated with changes in cloud fraction and lower tropospheric stability.
Corresponding Radiative Effects

Preliminary analysis using new CERES Flux-by-cloud-type product (see paper #A11B-07)

Decreasing reflected SW associated with MODIS low cloud changes (e.g. decreasing $N_d$) over Eastern U.S.
Extending the MODIS Cloud CDR with VIIRS

• Since Terra and Aqua are nearing end of life and begin drifting in 2021 and 2022, the CERES CDR will transition from Aqua to NOAA-20.

• CERES next edition (Ed5) is being developed specifically for this purpose and the Ed5 cloud algorithms are in development with the goal to provide consistent cloud properties across satellite platforms (MODIS to VIIRS, but also improved GEO), using common algorithms and spectral bands.

• Given the recent AQUA anomaly (need to gap fill), potential for another failure and possibility that Ed5 deliveries/processing may not be ready/current at the time CERES transitions, we will need to extend the Ed4 cloud record with NOAA-20 cloud products as seamlessly as possible without discontinuities.

• VIIRS Ed1A cloud algorithms from S-NPP and NOAA-20 were not designed specifically for continuity with MODIS Ed4. Instead, they were developed (6+ years ago) with a greater focus on accuracy improvements, bug fixes, updated cloud models. Ed1A algorithm also uses different channels.

• Therefore, we will develop a VIIRS Ed1B to improve consistency with Ed4
NOAA-20 VIIRS Ed1A vs MODIS Ed4
2019 Cloud Fraction Difference (DAY)

N20 Ed1A has

- Good agreement with Ed4 for total clouds, most areas in daytime
- Some phase differences: more ice, less water cloud (tropics); less ice, more water clouds (polar regions) except Antarctic plateau
- Phase differences affect other cloud properties (e.g. heights)
N20 Ed1A has substantially higher COD in most polar regions
This is due to a bug in the Ed4 1.24 µm reflectance models used for retrievals over snow/ice that was corrected in Ed1A
Antarctica differences muddled by large cloud fraction differences
N20 Ed1A has

- Less tropical ocean clouds
- Similar over mid-lat ocean
- More clouds over land
- Substantial polar differences
  - +/- 30% over Antarctica & Greenland

Polar differences are due to the use of different spectral channels in the two cloud masks
- VIIRS does not 6.7, 13 µm channel

Only two ways to deal with this
1. Eliminate 6.7, 13 µm usage in MODIS algorithm (Ed5 plan, no help in short term - can not reprocess Ed4)
2. Reconstruct these bands for VIIRS using CrIS data
VNP02IMG: Imagery Bands
VNP02MOD: Moderate Bands
VNP02DNB: Day/Night Band
VNP03MOD: Geolocation fields for Moderate Bands
VNP03DNB: Geolocation fields for Day/Night Band

Land SIP

CERES Clouds Subsystem

VNP0203IMD_SS.A

Send to Langley

Atmosphere SIP

FSNRAD_L2_VIIRS_CRIS_SNPP.A
Fusion Constructed MODIS Radiances for VIIRS using CrIS data:
- Band 23: 4.05 \( \mu \)m
- Band 24: 4.47 \( \mu \)m
- Band 25: 4.52 \( \mu \)m
- Band 27: 6.72 \( \mu \)m
- Band 28: 7.33 \( \mu \)m
- Band 30: 9.73 \( \mu \)m
- Band 31: 11.03 \( \mu \)m
- Band 32: 12.02 \( \mu \)m
- Band 33: 13.34 \( \mu \)m
- Band 34: 13.64 \( \mu \)m
- Band 35: 13.94 \( \mu \)m
- Band 36: 14.24 \( \mu \)m

One Month
MODIS: 630 GB
VIIRS: 4 T
FSNRAD: 1.5 T

More on this product tomorrow aft. (B. Baum talk)
Low Hanging Fruit – Modifications to Ed1A approaches:

- Re-tune the nighttime cloud mask, i.e. increase clouds over tropical ocean and reduce clouds over non-polar land area
- Replace the 1.24 um and 3.7 um reflectance cloud models/parameterizations with those from Ed4 (Ed4 models have interpolation bug)
- Bring in the fusion data (polar night), evaluate and tune if necessary
- Goal is to improve continuity with Ed not create new problems. May compromise some accuracy
- Deliver in 1-2 month timeframe so the new version can be used to fill the missing two weeks of Aqua data
- If we have time, tweak daytime mask, examine phase logic and better homogenize with Ed4, examine use/impact of fusion data in non-polar regions
Tune the NOAA 20 Ed1B nighttime non-polar mask (ocean & land)
Some land and ocean areas are a little better, but mostly the initial tuning exercise over corrected...
Comparisons with CALIPSO
March 2019, nighttime snow/ice-free ocean
Coincident VIIRS and MODIS: time diffs < 20 mins; any VZA

Aqua MODIS Ed4

N20 VIIRS Ed1A

N20 Ed1B
VIIRS Ed1B Initial Results
Cloud Retrieval

Apply in NOAA 20 Ed1B code

- Ed4 MODIS clouds models and parameterizations for retrievals over snow/ice
N20 Ed1A

MODIS Ed4

N20 with Ed4 model (Ed1B)
Ice Fraction Diff, Ed1A – Ed4

Water Fraction Diff, Ed1A – Ed4

Cloud Phase

Ice Fraction Diff, Ed1B – Ed4

Water Fraction Diff, Ed1B – Ed4
Global: -0.8 -2.2 -1.2
Polar: -3.3 -8.4 -4.9
NonPolar: -0.5 -1.3 -0.7

Global: -0.2 -0.6 -0.3
Polar: -0.1 -3.3 -1.3
NonPolar: -0.2 -0.2 -0.2

Linear Tau averaging
Global:     1.1  1.6  1.2
Polar:       4.0  3.3  3.6
NonPolar: 0.7  1.3  0.9

Global:      1.5  2.5  1.9
Polar:        6.2  9.2  7.3
NonPolar:  0.8  1.6  1.1

Water COD Diff, Ed1A – Ed4

Water COD Diff, Ed1B – Ed4

Linear Tau averaging
**Antarctica Night Time**

**Matched Pixels**

- **6.7 µm**
- **13.3 µm**

**20190715 Antarctica Ngt**

<table>
<thead>
<tr>
<th></th>
<th>Mean (StdDev)</th>
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<th>Mean (StdDev)</th>
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</thead>
<tbody>
<tr>
<td><strong>AquaBTemp0670</strong></td>
<td>226.3( 6.16)</td>
<td><strong>AquaBTemp0400</strong></td>
<td>221.5( 9.72)</td>
</tr>
<tr>
<td><strong>CrlSBTemp0670</strong></td>
<td>225.6( 6.01)</td>
<td><strong>CrlSBTemp0400</strong></td>
<td>221.5( 9.78)</td>
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<tr>
<td><strong>Y-X</strong></td>
<td>-0.686( 0.882)</td>
<td><strong>Y-X</strong></td>
<td>0.049( 1.14)</td>
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<tr>
<td><strong>RMS</strong></td>
<td>1.12</td>
<td><strong>RMS</strong></td>
<td>1.14</td>
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</table>
Ed4 mask - with 6.7 and 13 µm

VIIRS Ed1A - No 6.7 and 13 µm
Ed4 mask - with 6.7 and 13 µm

VIIRS Ed1B with 6.7, 13 µm CrIS fusion
Aqua Ed4
- with 6.7 and 13 µm

VIIRS Ed1A
- No 6.7 and 13 µm
Summary

• GOES-17 is delivered and processing using an approach that mitigates the loss of nighttime imagery in some bands due to a detector cooling problem. Appears to be working great.

• We’ve started developing an intermediate VIIRS edition (Ed1B) for NOAA 20 to improve consistency with Ed4 that could be used to extend the Aqua CDR prior to Ed5 (or fill gaps).

• Initial results are encouraging and should improve further once we put everything together (mask + retrieval + fusion).

• Ed1B should significantly improve consistency with Ed4 relative to Ed1A and we will learn a lot moving forward with Ed5 development.
QUESTIONS?