Cloud Property Comparisons Among CERES, CALIPSO Version 3 and CALIPSO Version 2

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Outline

• References for CERES cloud retrievals
• Data used for the cloud property comparisons
• Cloud top height comparisons
• Cloud column optical depth comparisons
• Summary
References for CERES Cloud Retrievals

Minnis et al.

CERES Edition-2 Cloud Property Retrievals Using TRMM VIRS, Terra and Aqua MODIS data.


Part II: Examples of Average Results and Comparison with other. Submitted to TGRS Feb 2010, currently in review.
DATA
C3M (CALIPSO, CloudSat, CERES, MODIS)

Collocate:

**Aqua - MODIS:**
- L1B --- MAC02 (radiance)
- L1B --- MAC03 (geolocation)
- L2 --- MAC04 (aerosol)

**CALIPSO:**
- L2 --- Vertical Feature Mask (VFM)
- L2 --- 5 km Cloud Profile (05kmCPro)
- L2 --- 5 km Aerosol Layer (05kmALay)
- L2 --- 5 km Cloud Layer (05kmALay)

**CloudSat:**
- L2 --- Cloud Scenario Classification (CLDCLASS)
- L2 --- Cloud Water Content (2B-CWC-RO)

Contain:
1. CERES derived cloud properties with MODIS data
2. CERES TOA radiative flux (SW, LW, and WN)
3. Vertical radiative flux profiles
4. Heating rate vertical profiles
Cloud Top Height Comparisons
Cloud Top Height Histogram
ATrain C3M, July 2008, Single Layer, Non-Polar, Day Time

Ocean

Land
Cloud Top Height Histogram
ATrain C3M, July 2008, Single Layer, Non-Polar, Day Time

Ocean

Land

Normalized Frequency
### Agreement and Disagreement in Cloud Top Heights (%) between CALIPSO V3 and CERES

<table>
<thead>
<tr>
<th></th>
<th>CALIPSO</th>
<th></th>
<th>CERES</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low (0-4 km) (%)</td>
<td>Mid (4-8 km) (%)</td>
<td>High (8-18km) (%)</td>
<td></td>
</tr>
<tr>
<td>Low (0-4 km)</td>
<td>83</td>
<td>24</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>Mid (4-8 km)</td>
<td>4</td>
<td>44</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>High (8-18km)</td>
<td>1</td>
<td>14</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>No Retrieval</td>
<td>2</td>
<td>5</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Clear</td>
<td>10</td>
<td>13</td>
<td>14</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>CALIPSO</th>
<th></th>
<th>CERES</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low (0-4 km) (%)</td>
<td>Mid (4-8 km) (%)</td>
<td>High (8-18km) (%)</td>
<td></td>
</tr>
<tr>
<td>Low (0-4 km)</td>
<td>80</td>
<td>16</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Mid (4-8 km)</td>
<td>6</td>
<td>51</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>High (8-18km)</td>
<td>1</td>
<td>20</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>No Retrieval</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Clear</td>
<td>13</td>
<td>13</td>
<td>23</td>
<td></td>
</tr>
</tbody>
</table>
## Agreement and Disagreement in Cloud Top Heights (%) between CALIPSO V3 and CERES

### Day Time

<table>
<thead>
<tr>
<th>CALIPSO CERES</th>
<th>Low (0-4 km) (%)</th>
<th>Mid (4-8 km) (%)</th>
<th>High (8-18km) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low (0-4 km)</td>
<td>84</td>
<td>36</td>
<td>17</td>
</tr>
<tr>
<td>Mid (4-8 km)</td>
<td>5</td>
<td>33</td>
<td>13</td>
</tr>
<tr>
<td>High (8-18km)</td>
<td>1</td>
<td>11</td>
<td>22</td>
</tr>
<tr>
<td>No Retrieval</td>
<td>2</td>
<td>7</td>
<td>15</td>
</tr>
<tr>
<td>Clear</td>
<td>8</td>
<td>13</td>
<td></td>
</tr>
</tbody>
</table>

### Night Time

<table>
<thead>
<tr>
<th>CALIPSO CERES</th>
<th>Low (0-4 km) (%)</th>
<th>Mid (4-8 km) (%)</th>
<th>High (8-18km) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low (0-4 km)</td>
<td>49</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>Mid (4-8 km)</td>
<td>12</td>
<td>44</td>
<td>26</td>
</tr>
<tr>
<td>High (8-18km)</td>
<td>2</td>
<td>10</td>
<td>37</td>
</tr>
<tr>
<td>No Retrieval</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Clear</td>
<td>37</td>
<td>31</td>
<td>25</td>
</tr>
</tbody>
</table>
Cloud Top Height Difference (CALIPSO - CERES) (km) for Both Low clouds

**Non-Polar, Day Time**
- Mean = -0.05 km
- std = 0.7 km
- 83%
- 10%

**Non-Polar, Night Time**
- Mean = 0.34 km
- std = 0.8 km
- 80%
- 13%

**Polar, Day Time**
- Mean = 0.46 km
- std = 0.8 km
- 84%
- 8%

**Polar, Night Time**
- Mean = 0.22 km
- std = 0.8 km
- 49%
- 37%

Ocean

Land

**ATrain July 2008**

Mean = -0.23 km
- std = 0.7 km

Mean = 0.17 km
- std = 0.8 km

Mean = -0.34 km
- std = 1.0 km

Mean = 0.04 km
- std = 1.0 km

80%
Cloud Top Height Difference (CALIPOS - CERES) (km) for Both Mid Level clouds

Non-Polar, Day Time
- Mean = 0.03 km, std = 1.1 km
- Mean = 0.27 km, std = 1.0 km

Non-Polar, Night Time
- Mean = -0.39 km, std = 1.1 km
- Mean = -0.19 km, std = 1.0 km

Polar, Day Time
- Mean = -0.06 km, std = 1.5 km
- Mean = -0.22 km, std = 1.1 km

Polar, Night Time
- Mean = -0.01 km, std = 1.2 km
- Mean = -0.26 km, std = 1.3 km

ATrain July 2008

Non-Polar, Day Time
- 44 %
- 13 %

Non-Polar, Night Time
- 51 %
- 13 %

Polar, Day Time
- 33 %
- 13 %

Polar, Night Time
- 44 %
- 31 %
Cloud Top Height Difference (CALIPOS - CERES) (km) for Both High clouds

- Non-Polar, Day Time:
  - Mean = 1.0 km, std = 1.7 km
  - Mean = 0.3 km, std = 1.5 km

- Non-Polar, Night Time:
  - Mean = 0.64 km, std = 1.74 km
  - Mean = 0.17 km, std = 1.8 km

- Polar, Day Time:
  - Mean = 0.25 km, std = 0.9 km
  - Mean = 0.19 km, std = 1.0 km

- Polar, Night Time:
  - Mean = 1.42 km, std = 1.6 km
  - Mean = 1.31 km, std = 2.1 km

63 \% 23 \%
22 \% 33 \%
60 \% 14 \%
37 \% 25 \%
C3M, July 2008
Single layer
Both detected clouds
Day time

CALIPSO
Cloud Top Height (km)

CERES
Cloud Top Height (km)
C3M, July 2008
Single layer
Both detected clouds

Day time

Cloud Top Height Difference
(CALIPSO – CERES) (km)

Night time
**Zonal Cloud Top Height Difference (CALIPSO – CERES) (km)**

<table>
<thead>
<tr>
<th>Region</th>
<th>Day Time</th>
<th>Night Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global</td>
<td>1.5</td>
<td>0.8</td>
</tr>
<tr>
<td>Polar</td>
<td>1.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Non-polar</td>
<td>1.5</td>
<td>0.9</td>
</tr>
</tbody>
</table>

**Cloud Top Height Difference (CALIPSO - CERES) (km)**

- Global: 1.4 km
- Polar: 0.9 km
- Non-polar: 1.4 km

**Legend:**
- Ocean
- Land

**Graphs:**
- **Day Time**
- **Night Time**

**Notes:**
- C3M, July 2008, Single layer, Both detected clouds
Cloud Top Height Difference (CALIPSO – CERES) (km)

C3M, July 2008, Single Layer

ocean

Day Time

land
Column Cloud Optical Depth Comparisons

• CALIPSO Version 3 vs Version 2
CALIPSO Feature Optical Depth 532 (column integrated from Cld Layer Product)

C3M July 2008, ExtQC532 not used

Normalized Frequency

Day Time

Ocean

Night Time

Ocean

Day Time

Land

Night Time

Land
## CALIPSO Version 3 Quality Statement

### Extinction QC Flag 532

<table>
<thead>
<tr>
<th>Bit</th>
<th>Value</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>unconstrained retrieval; initial lidar ratio unchanged during solution process</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>constrained retrieval</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Initial lidar ratio reduced to prevent divergence of extinction solution</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>Initial lidar ratio increased to reduce the number of negative extinction coefficients in the derived solution</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>Calculated backscatter coefficient exceeds the maximum allowable value</td>
</tr>
<tr>
<td>5</td>
<td>16</td>
<td>Layer being analyzed has been identified by the feature finder as being totally attenuating (i.e., opaque)</td>
</tr>
<tr>
<td>6</td>
<td>32</td>
<td>Estimated optical depth error exceeds the maximum allowable value</td>
</tr>
<tr>
<td>7</td>
<td>64</td>
<td>Solution converges, but with an unacceptably large number of negative values</td>
</tr>
<tr>
<td>8</td>
<td>128</td>
<td>Retrieval terminated at maximum iterations</td>
</tr>
<tr>
<td>9</td>
<td>256</td>
<td>No solution possible within allowable lidar ratio bounds</td>
</tr>
<tr>
<td>16</td>
<td>32768</td>
<td>Fill value or no solution attempted</td>
</tr>
</tbody>
</table>

The bits assignments are additive.
CALIPSO Feature Optical Depth 532 (column integrated from Cld Layer Product)

CALIPSO Feature Optical Depth Histogram
C3M July 2008, ExtQC532=0,1,16,17

Day Time

Ocean

Night Time

Ocean

Day Time

Land

Night Time

Land

Normalized Frequency

CALIPSO Version 2

CALIPSO Version 3
CALIPSO Optical Depth Histogram, Version 3

CPR0 Product: Column Optical Depth Cloud 532, July 2008, Day Time, Ocean

New in Version 3:
Column_Optical_Depth_Cloud_532
Column_Optical_Depth_Cloud_Uncertainty_532

Normalized Frequency

Day Time, Ocean

Uncertainty = no restriction
Uncertainty = 0 - 2
Uncertainty = 0 - 1.5
Uncertainty = 0 - 1

Column Optical Depth Cloud 532 (CALIPSO CPR0 Product)
## Optical Depth Distributions for all CALIPSO Detected Cloud

**C3M, July 2008**

<table>
<thead>
<tr>
<th></th>
<th>Ocean</th>
<th>Day</th>
<th>Day</th>
<th>Night</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Version 2</td>
<td>Version 3</td>
<td>Version 2</td>
<td>Version 3</td>
<td></td>
</tr>
<tr>
<td>Optical Depth</td>
<td>4,089,483</td>
<td>3,313,896</td>
<td>4,528,947</td>
<td>3,744,702</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(81%)</td>
<td>(83 %)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tau &lt; 1.5</td>
<td>61 %</td>
<td>55 %</td>
<td>61 %</td>
<td>54 %</td>
<td></td>
</tr>
<tr>
<td>1.5 &lt; Tau &lt; 4</td>
<td>9 %</td>
<td>13 %</td>
<td>10 %</td>
<td>15 %</td>
<td></td>
</tr>
<tr>
<td>Tau &gt; 4</td>
<td>30 %</td>
<td>32 %</td>
<td>29 %</td>
<td>31 %</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Land</th>
<th>Day</th>
<th>Day</th>
<th>Night</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Version 2</td>
<td>Version 3</td>
<td>Version 2</td>
<td>Version 3</td>
<td></td>
</tr>
<tr>
<td>Optical Depth</td>
<td>1,639,370</td>
<td>1,376,061</td>
<td>2,255,267</td>
<td>2,150,331</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(84%)</td>
<td>(83 %)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tau &lt; 1.5</td>
<td>62 %</td>
<td>65 %</td>
<td>74 %</td>
<td>74 %</td>
<td></td>
</tr>
<tr>
<td>1.5 &lt; Tau &lt; 4</td>
<td>10 %</td>
<td>12 %</td>
<td>11 %</td>
<td>13 %</td>
<td></td>
</tr>
<tr>
<td>Tau &gt; 4</td>
<td>28 %</td>
<td>23 %</td>
<td>15 %</td>
<td>13 %</td>
<td></td>
</tr>
</tbody>
</table>
Cloud Fraction Difference (CALIPSO V3 - CERES)
July 2008, Night Time

Global: 0.11 0.14
Polar: 0.12 0.11
NonPolar: 0.11 0.14
**Day Time**

Cloud Detection as a Function of Optical Depth

A-Train (July 2006 - June 2007), Day Time

- **Ocean**
  - \( \tau > 0.1 \) where CERES Day-Ocean Cloud Detection Probability > 0.67

- **Land**
  - \( \tau > 0.2 \) where CERES Day-Land Cloud Detection Probability > 0.67
Night Time

Cloud Detection as a Function of Optical Depth
A-Train (July 2006 - June 2007), Night Time

**Night-Ocean**

- Tau > 0.15 where CERES Night-Ocean Cloud Detection Probability > 0.67

**Night-Land**

- CERES Night-Land Cloud Detection is **not** sensitive to Tau.

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**Ocean**

- CALIPSO Ocean - Solid Blue Line
- Ed3 Ocean - Dashed Blue Line

**Land**

- CALIPSO Land - Solid Red Line
- Ed3 Land - Dashed Red Line

Frequency (Normalized to CALIPSO Total Cloudy Count) vs. CALIPSO Optical Depth (Normalized to CALIPSO Total Cloudy Count)
Summary

• **CERES Cloud-top height distributions for single layer clouds quite good**
  - Best height matching for low clouds (81%) and high clouds (61%)
  - CERES tops too low (~1.4 km) for high clouds, small tau?

• **CALIPSO V3 vs V2**
  - V3 has fewer clouds
  - V3 has more very thin clouds
  - When using V3 new parameter: Column_Optical_Depth_Cloud_532”
    in V3, make sure to use
    “Column_Optical_Depth_Cloud_Uncertainty_532”
    to remove false Tau.