Examination of CALIPSO cloud detection in broken cloud conditions using high resolution MODIS data

C. R. Yost¹, P. Minnis², S. Sun-Mack¹, L. Nguyen², Y. Yi¹

¹Science Systems and Applications, Inc. (SSAI), Hampton, VA
²NASA Langley Research Center, Hampton, VA

CloudSat Science Team Meeting
Seattle, WA
19 August, 2008
Outline

• The Cloud and the Earth’s Radiant Energy System (CERES) cloud mask
  – Applied to Aqua- and Terra-MODIS data
  – Generally detects more warm clouds than CloudSat alone, but fewer than CALIPSO

• Broken cloud scenes can be problematic for CERES
  – e.g., trade cumulus
  – Cloud edges are also a problem; retrieved optical depth too small
  – Use 250-m MODIS visible reflectance and dynamic threshold technique to detect more small-scale clouds (area << 1 km²)

• Compare results of threshold method with CERES Cloud Mask and CALIPSO
CERES vs GLAS: 26 Sept – 18 Nov 2003

ICESat in near-terminator orbit, 532-nm med res clouds

- Zonal differences with GLAS similar to those between CERES and other passive retrievals, except in north polar areas
  - mean dif = 7.8%
- Regional differences mainly trade Cu, land, Arctic
  - polar mask has better agreement over land

<table>
<thead>
<tr>
<th></th>
<th>Day</th>
<th>Night</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>GLAS 532</td>
<td>62.8 (63.2)</td>
<td>74.1 (74.4)</td>
<td>68.9 (70.3)</td>
</tr>
<tr>
<td>CERES Aqua</td>
<td>62.0</td>
<td>60.6</td>
<td>61.3</td>
</tr>
<tr>
<td>CERES Terra</td>
<td>60.5</td>
<td>61.3</td>
<td>60.9</td>
</tr>
</tbody>
</table>

Daytime agreement!
In general, CERES detects fewer clouds compared to CALIPSO -

Mostly polar night & tropics (high & low clouds)
250-m cloud mask

- Use 250-m MODIS visible reflectance to assess Aqua-CERES cloud amounts
  - Based on the derivative of the reflectance frequency distribution
  - Tuned by comparing initial results with MODIS 250-m reflectance images
  - Apply to every 1-km MODIS pixel
250-m cloud mask

- Use 250-m MODIS visible reflectance to assess Aqua-CERES cloud amounts
  - Based on the derivative of the reflectance frequency distribution
  - Tuned by comparing initial results with MODIS 250-m reflectance images
  - Apply to every 1-km MODIS pixel
250-m cloud mask

• Good overall performance over ocean surfaces
  – Trouble areas
    • Over land (use IGBP index)
    • High viewing zenith angles - pixel smearing
    • Thin cirrus - blends in with the underlying surface, but some is detectable
250-m Mask Performance

- Examined 21 cases of Scu and Cu from Jun 2006 - Mar 2007
- Good linear correlation with CERES for both Cu and Scu fields
- CERES generally has higher cloud fraction values, especially for Scu
- Higher CERES cloud fractions expected - CERES has larger FOV
- CERES may underestimate cloud fraction when true fraction is < 0.30
Cloud Fractions

- Examine cloud fractions along CALIPSO track for same 21 cases
- Matched data from CERES, Aqua-MODIS, and CloudSat to CALIPSO track

CERES

- Scu - fairly good linear correlation; overestimates
- Cu - more scatter; tends to underestimate for cloud fractions < 0.30

CloudSat - very few cloud detections at the highest 2 levels of confidence (clouds too low?)
Cloud Fractions

- Examined 2 CALIPSO products
  - Vertical Feature Mask (VFM)
    - Contains cloud/aerosol classifications
    - 30-m vertical resolution from -0.5 - 8.2 km AMSL
  - 333-m Cloud Layer Product
    - Cloud products for up to 5 cloud layers
    - Valid from the surface to 8.2 km

VFM has many more cloud detections, but very good agreement with the CALIPSO cloud products.
Cloud Fractions

- Relaxed thresholds to match VFM product
- VFM shows solid deck of clouds while satellite images show scattered Cu
- Some cloud detections get averaged out in the Cloud Layers product?

Solid cloud deck in VFM
CF = 0.82

Cloud tops/bases from 333-m cloud products, CF = 0.19

Normal threshold seems to match satellite image, CF = 0.29

Too much cloudiness is areas of scattered cumulus, CF = 0.84, relaxed threshold too low
Summary

- Used 250-m Aqua-MODIS data to determine cloud fraction within each 1-km footprint
  - Based on the derivative of the reflectance frequency distribution

- Generally good agreement with CERES
  - Highly correlated
  - CERES tends to overestimate cloud amount for StCu because its FOV is larger
  - CERES may underestimate cloud fraction for scattered cumulus scenes
  - 250-m MODIS visible reflectance data should help in both cases

- Good agreement with CALIPSO 333-m Cloud Layers product

- CALIPSO VFM finds much more cloudiness than all methods
  - Given large number of water clouds with $\tau < 0.3$, VFM may misclassify haze as clouds

- Future work - examine effects on retrieved cloud properties, especially optical depth and effective size, for cumulus clouds and cloud edges