1-Year of Global Cloud Climatologies from CloudSat/CALIPSO: A New Era in Cloud Research

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Our Goal: To create remote sensor algorithms for identifying clouds that approximate what a trained human observer would report from the surface.
The Active A-train Satellites

1. CloudSat: 94 GHz (3.2 mm) Cloud Profiling Radar
   500 m vertical and 1.4 km horizontal resolutions
   -29 dBZ MDS

2. CALIPSO: CALIOP lidar
   1.06 µm and 0.532 µm (with depolarization) channels
   30-60 m vertical and 1.0 km horizontal resolutions
Cloud Detection Algorithms

1. CloudSat-only Cloud Type Algorithm
   Based on extended ground-based mm-wave radar dataset.
   Uses maximum Z, temperature, and spatial layer properties.

CloudSat Project: Level 2 Cloud Scenario Classification Product
Process Description and Interface Control Document

Sassen, K., and Z. Wang, 2008: Classifying clouds around the
globe with the CloudSat radar: 1-year of results. *Geophys.
<table>
<thead>
<tr>
<th>Type</th>
<th>$Z_{\text{max}}$</th>
<th>Precipitation</th>
<th>Length (km)</th>
<th>Highest $Z_{\text{max}}$ frequency</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cirrus</td>
<td>&lt;-3 dBZ, T &lt;-22.5 °C</td>
<td>No</td>
<td>2 $\Rightarrow$ 1000</td>
<td>-25 dBZ @ -40 °C</td>
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<tr>
<td>Altostratus</td>
<td>&lt;10 dBZ,  -20°&lt; T &lt;-5 °C;</td>
<td>No</td>
<td>50 $\Rightarrow$ 1000</td>
<td>-10 dBZ @ -25 °C</td>
<td></td>
</tr>
<tr>
<td>Altocumulus</td>
<td>&lt;0 dBZ,  -20°&lt; T &lt;-5 °C;</td>
<td>No</td>
<td>2 $\Rightarrow$ 1000</td>
<td>-25 dBZ @ -10 °C</td>
<td></td>
</tr>
<tr>
<td>St</td>
<td>&lt;-5 dBZ,  -15°&lt; T &lt;25 °C</td>
<td>Yes/No</td>
<td>50 $\Rightarrow$ 1000</td>
<td>-25 dBZ @ 5°C (bright bd)</td>
<td>$T_{\text{top}} &gt;$-35 °C</td>
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<tr>
<td>Sc</td>
<td>&lt;-5 dBZ,  -15°&lt; T &lt;25 °C</td>
<td>Yes/No</td>
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<td>-25 dBZ @ 5°C (bright bd)</td>
<td>Altitude of $Z_{\text{max}} &lt;$ 2 km</td>
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<tr>
<td>Cumulus</td>
<td>&lt; 0dBZ,  -5°&lt; T &lt;25 °C</td>
<td>Yes/No</td>
<td>2-25</td>
<td>-25 dBZ @ 15 °C</td>
<td>$\Delta Z &gt;$2 km</td>
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<td>Deep (cb)</td>
<td>&gt;-5dBZ,  -20°&lt; T &lt;25 °C</td>
<td>Yes</td>
<td>10-50</td>
<td>10 dBZ @ 5 °C</td>
<td>$\Delta Z &gt;$ 6 km</td>
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<td>Ns</td>
<td>-10&lt; Z &lt;15 dBZ,  -25°&lt; T&lt;10 ° C</td>
<td>Yes</td>
<td>&gt;100</td>
<td>+5 dBZ @ 0°C</td>
<td>$\Delta Z &gt;$ 4 km</td>
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</table>
Comparison with ISCCP (+) and Surface Data (---)
Table 1. Comparison of 1-y CloudSat global cloud type frequency averages over land and ocean with annual means of extended surface observer reports [*Hahn and Warren*, 1999] and ISCCP annual means from 1986-1993 [*Rossow and Schiffer*, 1999].

<table>
<thead>
<tr>
<th>Type</th>
<th>CloudSat</th>
<th>Surface</th>
<th>ISCCP</th>
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<tbody>
<tr>
<td></td>
<td>Land</td>
<td>Ocean</td>
<td>Land</td>
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<tr>
<td>High</td>
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<td>19.3</td>
<td>15.6</td>
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<td>12.0</td>
<td>4.8</td>
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<tr>
<td></td>
<td>8.7</td>
<td>9.7</td>
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<tr>
<td>Ac</td>
<td>6.8</td>
<td>6.7</td>
<td>17.2</td>
</tr>
<tr>
<td></td>
<td>8.6</td>
<td>10.2</td>
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</tr>
<tr>
<td>St+Sc</td>
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<td>22.5</td>
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<td>18.3</td>
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</tr>
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<td>1.7</td>
<td>4.2</td>
</tr>
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<td>12.7</td>
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<tr>
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<td>8.4</td>
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<tr>
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<td>3.2</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>Deep</td>
<td>1.8</td>
<td>1.9</td>
<td>3.2</td>
</tr>
<tr>
<td></td>
<td>2.5</td>
<td>2.4</td>
<td></td>
</tr>
</tbody>
</table>
2. Combined CloudSat/CALIPSO Cirrus Algorithm
   Based on radar-lidar cloudmask, $\tau < ~4$, cloud base $T<-40^\circ$, tropopause height.

Average Global Cirrus Frequency
Latitudinal Cirrus Heights
Seasonal Cirrus Dependence
Seasonal Height Dependence
Average Cirrus cloud Heights
Seasonal Height Dependence
Average Cirrus Temperatures
Seasonal Cirrus Temperatures
Cirrus Cloud Thicknesses

Graph showing the thickness of single-layer and multi-layer cirrus clouds as a function of latitude. The graph includes three lines:
- Single-layer (blue line)
- Multi-layer (red line)
- Single-layer + Multi-layer (black line)

The thickness is measured in kilometers and the latitude is measured in degrees. The graph is labeled with the years 2006, 2007, and 2008, and the latitude resolution is 2.5°.
Zonal Average Comparisons
Height Dependence - ALL Cirrus

Summer (JJA)

Fall (SON)

Winter (DJF)

Spring (MAM)

Frequency of Cirrus Cloud Occurrence
Seasonal Height Dependence

- **Summer (JJA)**
- **Fall (SON)**
- **Winter (DJF)**
- **Spring (MAM)**

![Graphs showing seasonal height dependence](image)
Global Cirrus Day Vs. Night
Day Vs. Night Cirrus Heights

(a) Daytime

(b) Nighttime
CONCLUSIONS

• CALIPSO/CloudSat working admirably up there
• 1-Y of data applied to Cloud Detection Algorithms
• Radar-only Cloud Type Results have limitations
• Combined Cirrus Cloud Climatology very promising
• More algorithm development and applications to come…