Probability of Cloud-Free Line of Sight (PCFLOS) derived from CloudSat Cloud Profiling Radar (CPR) and coincident CALIPSO lidar data

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The Problem: CFLOS, beneath an opaque cloud layer, has been impossible to determine, directly, from passive space sensors.

Corollary: Passive satellites measure cloud tops well … and surface observers the bases … but neither do an adequate job of characterizing the intervening layers …
Addressing the Problem – Cloud Profiling Radar

Here an opaque cloud at “B” hides the fact that there is a poor CFLOS at levels below the cloud top, while at “A” it hides a significantly better CFLOS just below the upper cloud layer.

Passive vis/ir sensors likely see this cloud top as a homogenous opaque layer.
CloudSat: 94 GHz Cloud-Profiling Radar

Near circular, sun-synchronous orbit ... ~705km altitude, 14.5 orbits/day, 16-day revisit cycle
**CloudSat:** 94 GHz Cloud-Profiling Radar

**Wavelength** \( \sim 3 \text{ mm} \)

**Near-nadir Pointing** \((0.16^\circ \text{ forward})\)

**Pulse Repetition Freq.** \( \sim 4000 \)

- Return signal processed every 160 milliseconds \((\sim 6 \text{ times/sec})\)
- at 4000 PRF \(\ldots\) \(\sim 630\) pulses are averaged to produce a vertical cloud image \(\text{\textquotedblleft profile\textquotedblright}\)

160 msec = 1.07 km along ground track
Granules, Profiles and Bins: CPR footprint & granule size

1 GRANULE = 1 orbit of data (~40,786 km / ~37,082 profiles)

- Each "Profile" has 125 vertical "BINS" (~30 km)
- Each vertical bin is 240 m thick
- 1.7 km along-track
- 1.3 km
- 98.9 minutes per orbit
- 14.56 orbits/day
- (CALIOP) “Cloud-Aerosol Lidar with Orthogonal Polarization”
  - 532 and 1062 nm wavelengths
  - Nadir Pointing
  - Vertical resolution 30m, 60m (< 8km)
  - 80m instantaneous footprint
  - Products generated at a horizontal resolution of 333m, 1km, and 5km
For each CloudSat profile, CFLOS is determined by looking at 10° intervals from nadir to 90° (horizontal) at each of 20 vertical levels. These levels extend from .96-km to 19.2-km altitude at ~1-km intervals. (every 4 bins in the vertical = 4X240m = .96km)
CFLOS Calculation

**CFLOS** is calculated by determining the distance (km) that we can see before encountering a cloud. “0” indicates that we did not have a cloud in the line-of-sight.

<table>
<thead>
<tr>
<th>View angle from Nadir</th>
<th>Vertical Level</th>
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</table>
The probability of Cloud-Free-Line-of-Sight (PCFLOS) was generated for each month from June 2006 – Aug 2010.

**PCFLOS** – Observation Count & CFLOS Distance

Observation Count

January (2007-2010)

**CFLOS Distance:** For all of the following examples, if the distance to the first cloud encountered was greater than 25km, it was considered a Cloud-Free-Line-of-Sight. (or ... if there was a cloud-free view to the land/ocean surface)
Comparison With Typical Cloud Fraction Products

Probability of CFLOS from CloudSat CPR
Location: L20 (TOA)
View: Nadir
January

MODIS Cloud Fraction
(January 2007)
PCFLOS from CloudSat CPR

Probability of CFLOS from CloudSat CPR
Location: L20 (TOA)
View: Nadir
January 2007-2010

Probability of CFLOS from CloudSat CPR
Location: L20 (TOA)
View: Nadir
July 2006-2010
PCFLOS from CALIPSO Lidar

Probability of CFLOS from CloudSat CPR

Location: L20 (TOA)
View: Nadir
January 2007-2010

Probability of CFLOS from CloudSat CPR

Location: L20 (TOA)
View: Nadir
July 2006-2010
CFLOS from CloudSat CPR … Varying Levels
CFLOS from CloudSat CPR … Varying Levels

Probability of CFLOS from CloudSat CPR
January 2007-2010

10-km altitude
view: nadir

5-km altitude
view: nadir

2-km altitude
view: nadir
CFLOS from CloudSat CPR … Varying View Angle
PCFLOS from CloudSat CPR ... Varying View Angle

Probability of CFLOS from CloudSat CPR
January 2007-2010

5-km altitude view: Nadir

5-km altitude view: 50° off nadir

5-km altitude view: 60° off nadir

5-km altitude view: 70° off nadir

5-km altitude view: 80° off nadir
Summary ...

- CloudSat CPR data provides an exciting new view of the vertical distribution of cloud.

- This 3-D view can be used to calculate CFLOS at varying vertical levels and view angles.

- CPR-derived CFLOS can be used to validate CFLOS derived by "apriori cloud thickness" methods ... or for model cloud fraction initialization.

- PCFLOS Viewer
Visit the CloudSat Data Processing Center Website …

http://www.cloudsat.cira.colostate.edu