CloudSat 2B GEOPROF Quality Statement: May 2007 (Version R04)

The primary purpose of the 2B GEOPROF product is to identify those levels in the vertical column sampled by CloudSat that contain significant radar echo from hydrometeors and to provide an estimate of the radar reflectivity factor for each of these volumes. Details on the GEOPROF algorithms and structure of the NetCDF output files are provided in the **Level 2 GEOPROF Product Process Description and Interface Control Document.**

http://www.cloudsat.cira.colostate.edu/dataICDlist.php?go=list&path=/2B-GEOPROF

Summary of changes from R03 to R04

An estimate of surface clutter (contained in 1B-CPR R04) is now subtracted from the return power in bins 2 through 5 above the surface. The original return power is kept in the surface bin, the bin 1 above the surface and all bins below the surface. See text below for more discussion.

There are four additional variables in the R04:

Clutter_reduction_flag

This flag has a value of 1, whenever an estimate of surface clutter has been subtracted from the measured return power (in bins 2 through 5 above the surface). It is zero, otherwise.

SurfaceHeightBin_fraction

This variable indicates the fractional location of the surface with in the pixel given by the variable "SurfaceHeightBin". This value is estimated in the clutter estimation processes. The altitude of the surface with respect to mean sea level is thus given by Height(SurfaceHeightBin) + RangeBinSize*SurfaceHeightBin_fraction.

This variable is real valued. Values less than -5 should not be used and indicate that the 2B GEOPROF code did consider the fraction to be valid.

MODIS_cloud_flag

This variable contains the MODIS summary cloud flag (bits 3 and 4 from MOD35) for the CloudSat column. Values are:

0 = Clear High Confidence
1 = Clear Low Confidence
2 = Cloudy Low Confidence
3 = Cloudy High Confidence

Note: the variable "MODIS_cloud_fraction" in 2B GEOPROF R03 and R04 is the fraction of VISIBLE pixels in the MODIS 250 m mask that are cloudy. This cloud fraction is only valid during the day and does not include cloud detection from at IR channels.

Sigma-Zero

This variable is a pass through from 1B-CPR. It is the estimated surface reflectance (in units of dBZ * 100).

Discussion of Product & Product Quality

The significant echo mask is stored under the variable name "CPR_Cloud_Mask", and contains a value between 0 and 40 for each range bin with values greater than 5 indicating the location of likely hydrometeors. Increasing values of the "CPR_Cloud_Mask" variable indicate a reduced probability of a false detection, as summarized in Table 1.

Mask Value	Meaning	% False Detections Goal	Estimated % False Detection via CALIPSO comparison
-9	Bad or missing radar data		
5	Significant return power but likely surface clutter		
6-10	Very weak echo (detected using along-track averaging)	< 50 %	44 %
20	Weak echo (detection may be artifact of spatial correlation)	< 16%	5 %
30	Good echo	< 2 %	4.3 %
40	Strong echo	< 0.2 %	0.6 %

Table 1 – Description of CloudSat cloud mask values, false detection rates, and percentage of false detections. The percent of false detection is given by 100 times the number of false detections divided by the total number of detections for the specified cloud mask value.

Users are cautioned that radar detections with cloud mask values between 6-10 contain large numbers of false detection. These possible detections represent hydrometeors whose radar-reflecivity is below the single column sensitivity limit of the radar (about –30 dBZe), and have only been identified as a result of an aggressive along track averaging algorithm. For most applications, users should consider using cloud-mask values of 30 to 40, which are high-confidence detections.

In addition to the cloud mask, this product contains the radar reflectivity (i.e., the calibrated measured return power in units of dBZe = dB(mm^6/m^3)), an estimate of gaseous absorption loss of the observed reflectivity, and several quality indicator flags. Unlike typical weather radars, which operate at much longer wavelengths and are primarily designed to detect rain rather than clouds, the effect of water vapor on CloudSat observed reflectivity can be significant. Two-way attenuation from the surface to the satellite of more than 5 dBZ is not unusual in the tropics.

No estimate of loss in reflectivity due to absorption or scattering by hydrometeors is included in the GEOPROF, and users are cautioned that losses of 10 dB/km or higher are possible with large liquid water contents. At times, the CloudSat radar is fully attenuated, or attenuated to the point where multiple-scattering dominates the measured return power – though this is not common.

The cloud mask, reflectivity-field, and gaseous absorption are all provided on a height grid with 125 vertical range bins, where the CloudSat range bin closest to mean sea level has been placed in vertical bin 105. The location of the range bin that is closest to the actual surface location is also provided.

Overall, the most significant difficulty with the CloudSat data is that surface clutter effectively reduces the radar sensitivity near the surface. Figure 1, below, show the estimated radar return power during clear sky conditions. This is a typical result for an orbits colleted early in the mission. As a result of the surface contamination, all cloud mask detections below roughly the 99^{th} percentile of the clear-sky return (dashed lines) are currently being set to a value of 5, to indicate there is return power above the radar noise floor but the signal is indistinguishable from surface clutter. While this conservative threshold should keep the false detection rate (by volume) below 1%, it also means that typically only rain and heavy drizzle can be detected in the third bin above the surface (~ 720 m) and moderate drizzle in the fourth bin (~ 860 m).

Starting with revision 04, we begun subtracting an estimate of the surface clutter from the total measured return power. We refer to this process as clutter rejection. Figure 2 shows the resulting clear-sky noise after clutter rejection. After clutter rejection, detection over ocean is improved with rain and heavy drizzle detectable at ~ 480 m and moderate drizzle at ~ 720 m. Clutter is reduced over land as well, but not as effectively.

Users are cautioned that clutter rejection (and cloud masking near the surface) is not very good over land regions that are not flat. The clutter rejection and cloud masking has been optimized for data collected after August 15, 2006 (starting with orbit 1595). The clutter rejection is being applied to all data (when valid), but cloud masking is based on pre-clutter rejection thresholds prior to orbit 1595 (figure 1).

The clutter rejection technique also estimates the position of the surface to a sub-range-bin scale, such that the position of the surface is given by SurfaceHeightBin + SurfaceHeightBin_fraction.

Finally, the CloudSat orbit follows closely the orbit of the AQUA satellite on which a number of advanced passive remote sensors observe the earth. The GEOPPROF data files include the Moderate-Resolution Imaging Spectroradiometer (MODIS) cloud fraction (from the visible 250 m MOD35 product) integrated over the CloudSat footprint, as well as a cloud scene classification (based on MOD35 cloud detection bit tests). Details of these parameters are given in the **Level 2 GEOPROF Product Process Description and Interface Control Document.** Starting with R04 there is also a MODIS cloud flag output, which provides the MODIS summary cloud test (bits 2 and 3 of standard MODS 35 product) under the CloudSat ground track.

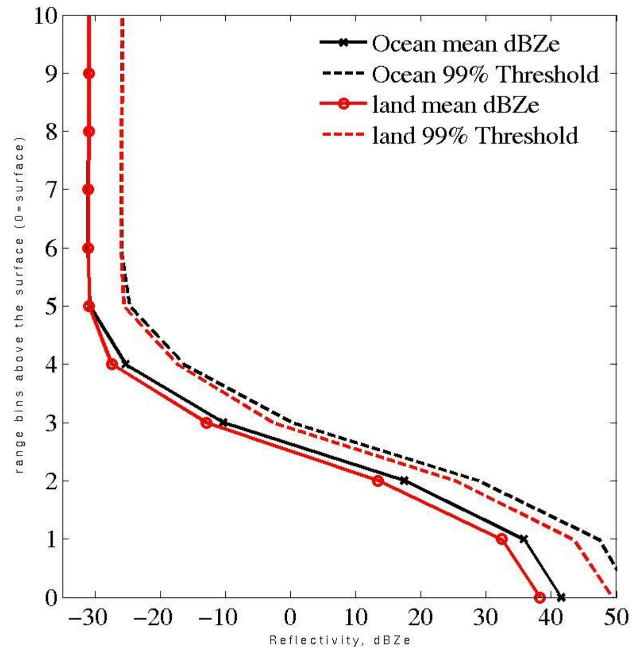

Figure 1 - Estimate of the clear-sky observed return power. At the beginning of the CloudSat mission, the radar was unknowningly pointed 1.7 degrees off nadir. This was corrected starting with orbit 1023, and the radar pointed directly towards nadir. However, it was found that pointing directly at nadir increased the surface reflectance and the effect of surface clutter approximately 10 dB due to specular reflection. Thus, starting with orbit 1595 (August 15 at 20 UTC) the instrument was set to point 0.16 degrees of nadir. This angle put the specular reflection in the first antenna null and reduced the surface clutter to previous levels. Data from these time periods is referred to as epic "E" 00, 01, and 02 (given in each file name), respectively. Data shown here is "typical" for data in epic 00 and epic 02 before clutter rejection.

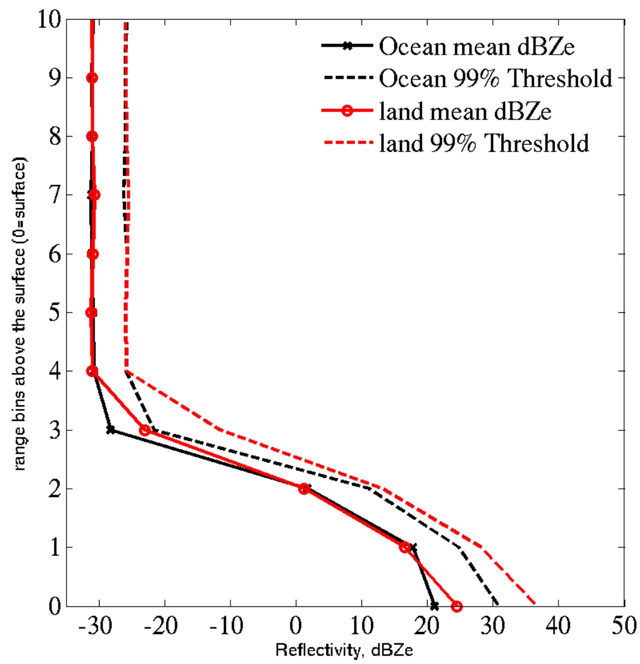

Figure 2 – Estimate of clear-sky return power AFTER application of clutter rejection. The clutter rejection is being applied in all epics, but is only optimal after orbit 1595 (August 15, 2006 20 UTC). Cloud masking prior to orbit 1595, continue to use conservative thresholds (as shown in figure 1). Cloud Mask starting with orbit 1595 use more aggressive thresholds.