P2.28 CFLOS and cloud statistics from satellite and their impact on future space-based Doppler Wind Lidar development

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1. Introduction

Before the launch of ICESat (Ice, Cloud, and land Elevation Satellite) and CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation), the Doppler lidar community relied upon airborne missions to conceptualize the global distribution of backscatter and cloud statistics, with a space-based lidar perspective, were first derived and only possible from < 40 hours of LITE (Lidar In-space Technology Experiment) data obtained during a 14 day shuttle mission (Winker and Emmitt, 1997).

Clouds can be both targets and confounders for lidars. Based upon various cloud studies, global cloud coverage varies from ~ 65% to >80% depending upon the threshold of optical depth chosen for defining a cloud and the "pixel" size. A recent investigation by the authors of global cloud climatologies (Nephanalyses and "passive" climatologies such as ISCCP and HIRS) and comparison with active lidars such as GLAS and CALIPSO indeed show that the total cloud cover is as high as 70 to 80% (Table 1). Data from the AIRS suggests even higher percentage (~ 95%) cloud coverage defined for its footprint.

Given these results, work is now underway to develop a state-of-the-art set of cloud free line-of-sight (CFLOS) statistics and atmospheric optical properties for space-based hybrid Doppler Wind Lidar (DWL) design using LITE, GLAS (aboard ICESat) and CALIPSO data. The goal is to use the cloud/aerosol data from GLAS, LITE and CALIPSO to construct CFLOS cloud penetration statistics that will be used to conduct DWL sampling trade studies and to help guide the instrument design of future space-based DWLs. The primary LOS statistics will be:

- probability of CFLOS penetrations to specific levels (1 km resolution) in the atmosphere;
- probability of multiple level interception of clouds of low to modest optical depths (< .5); and
- probabilities of contiguous CFLOSs for various duration of beam stares and shot integration.

2. Revisiting LITE

The revisit to the LITE data is in recognition of the fact that LITE was the most powerful backscatter lidar ever flown in space. If the weak aerosol distributions are to be investigated, it will probably be the LITE data that is most useful.

Until GLAS and CALIPSO, the only real source of space-based lidar data useful for CFLOS studies were LITE and, to a lesser degree, the Shuttle Laser Altimeter (SLA). The LITE instrument provided 530 mJ at 10 Hz with a 1.1 mrad beam divergence which produced a ~ 200m footprint on the earth's surface. The shuttle orbit bounded the coverage between 57 degrees N and S. Eighteen hours of nighttime LITE data (532 nm) were used by Winker and Emmitt (1997,98) to derive vertical cloud distribution and CFLOS statistics thought to be useful to the design and operation of a future space-based Doppler wind lidar (Wood, et al, 1991; Emmitt and Wood, 1995).

The general conclusions of the LITE data analyses of cloud porosity for lasers were that:

- The 532nm beam provided a ground return more often (~60 - 65%) than the current cloud climatologies based upon passive imagers suggested (~30-40%).
- More than 50% of the time that the lidar beam intercepted a cloud it also provided a ground return. In other words

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the porosity of the clouds to the LITE beams was on the order of 50%.

While the LITE data provided some expectations for CFLOS opportunities for future space-based lidars, the size of the data set (<20 hours) did not allow for stratification by synoptic conditions or by season. The latitudinal bounds of the orbit (57 degrees N/S) preclude statistics for critical flows in the higher latitudes and the larger field of view (FOV) of the LITE beam (1.1 mrad) raise questions about multiple scattering. On the other hand, CALIPSO will provide data that will cover all seasons and all latitudes observed with a beam that produces a 70m footprint on the earth's surface, more similar to proposed DWL systems.

3. GLAS and CALIPSO

More recently, an ESTO funded analysis of GLAS cloud data (Emmitt and Greco (2006a; 2006b)) was used to investigate the following issues:

- Cloud interception statistics (closely related to cloud coverage),
- Multiple cloud layer visibility by lidar beams,
- Ground detection statistics (suggesting aerosol detection opportunities along the entire LOS), and
- Example trade studies involving energy/pulse, integration times and vertical coverage.

For total cloud coverage, the GLAS data has revealed global total cloud values (80%) which are very close to those found with a small set of data from LITE. These values are higher than values determined from ISCCP, suggesting that active optical remote sensing is revealing higher cloudiness due to the increased sensitivity of the measurement. Perhaps this difference is insignificant given the types of data involved, but the sense is that the more sensitive and higher resolution active sensors will continue to sense more cloud than in the past. Even with the new AIRS, the issue of cloud contamination has become more acute with higher sensor sensitivity and resolution. It is noteworthy that the 1064 nm channel of the GLAS instrument is of modest sensitivity compared to the more recently launched CALIPSO.

Details on the ESTO GLAS study can be found at the following web site : (http://esto.nasa.gov/adv_planning_studies_archive.html). Here the results of that study are summarized:

1) 70 - 80% of the GLAS lidar samples involved some return from clouds (assumed that "no cloud/no ground returns" intercepted thick layers of optically thin clouds)
2) 75 - 80% of the GLAS lidar samples detected the earth's surface (adjusted for smooth water returns)
3) When clouds were present, 25 – 40% of the time at least two layers were detected.

4. Ongoing and future work

Statistics on monthly mean 3D cloud fraction will be computed at various horizontal and vertical resolutions from standard CALIPSO data products.. These cloud fraction statistics will be used to estimate the probability of the lidar signal being completely attenuated, as a function of location and season. The analysis will be done at various horizontal resolutions (0.3km, 1km, 5km, 80km) and various vertical resolutions (0.03km, 0.1km, 0.5km and 1km) in order to understand the trades among various configurations of wind lidar.

5. References

Emmitt, G.D. and S. Greco, 2006a: Using ICESAT observations to obtain CFLOS statistics for use in the design of space-based lidars (invited paper), SPIE Europe Remote Sensing, Stockholm, Sweden, September 11 – 14.

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Winker, D. M. and G. D. Emmitt, 1997: Relevance of Cloud Statistics Derived from LITE Data to Future DOPPLER Wind Lidars, 9th Conference on Coherent Laser Radar, June 23-27, 1997, Linkoping, Sweden, 144-147.

GLOBAL CLOUD COVER PERCENTAGE (Land and Sea)

	T511 NR* (1 X 1)	ISCCP**	WWMCA*	HIRS**	GLAS[1]	CALIPSO[2]
Total CC	68.3/59.8	65.9	49.6	76.9	72.0 (80.0)	77.0
Low CC	44.0/34.3	27.4	32.2	30.6	33.5	32.5
Mid CC	28.0/22.9	17.8	21.9	28.2	21.0	13.0
High CC	32.9/30.6	21.1	14.2	32.8	21.0	24.5

* - August 2005
** - Long term mean for August
GLAS[1] - Nov 2003 (from Seze et al., 2007); 2^{nd} Study by Emmitt and Greco (2006)
CALIPSO[2] - August 2006 (from Seze et al., 2007)

Table 1: Computed global cloud climatologies for August from ISCCP, HIRS, Nephanalyses and GLAS (November) and reported results for CALIPSO.