P1.2 SATELLITE TO GROUND-BASED LIDAR COMPARISONS USING MPLNET DATA PRODUCTS

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1. MPLNET BACKGROUND

The Micro-Pulse Lidar Network (MPLNET) is a network of ground-based lidar systems that provide continuous long-term observations of aerosol and cloud properties at approximately 10 different locations around the globe. Each site in the network uses an elastic scattering lidar co-located with a sunphotometer to provide data products of aerosol optical physical properties. Data products from sites are available on a next-day basis from the MPLNET website[1].

Expansion of the network is based on partnering with research groups interested in joining MPLNET. Results have contributed to a variety of studies including aerosol transport studies and satellite calibration and validation efforts [2-4].

One of the key motivations for MPLNET is to contribute towards the calibration and validation of satellite-based lidars such as GLAS/ICESAT and CALIPSO. MPLNET is able to provide comparison to several of the key aerosol and cloud CALIPSO data products including: layer height and thickness, optical depth, backscatter and extinction profiles, and the extinction-to-backscatter ratio.

2. SPATIOTEMPORAL SAMPLING ISSUES

Direct comparisons between surface and space-borne measurements is complicated due to the spatial and temporal differences between measurements. Both the GLAS/ICEsat and the CALIPSO lidars pass over grounds sites at ~ 7 km per second, while ground-based lidars typically obtain measurements with a stationary vertical pointing beam. Consequently, direct temporal overlap between lidar measurements is extremely brief, and signal averaging outside the coincident sample volume can introduce unknown errors due to atmospheric dynamics. This is particularly true for cloud backscatter properties which are highly variable over short temporal and spatial scales.

3. STOCHASTIC ILLUSTRATION

To investigate signal behavior for different averaging intervals and orientations of observations, a bounded cascade (fractal) algorithm was used to simulate a horizontal 200x200 km random signal scene. Although not intended to simulate actual backscatter properties from clouds, this simple 2-D approach can illustrate the statistical relationship on spatial averaging and orientation effects. As shown in Figure 1, two different intersecting measurement paths through the cloud field can be used to imitate the ground-based lidar observation due to advection (P1), and satellite track (P2) that intersects the ground-based measurement at the center of the field. The different measurement paths can then be compared for different orientations and spatial average intervals about coincidence.

A Monte-Carlo analysis was used to examine the statistical deviation in P1-P2 as a function of path length average and for different angle orientations. This was accomplished by generating multiple cloud scenes for a trial of 1000 cases and compiling the results. Figure 2 shows the resultant standard deviation from the trial, where distance averaging interval from 0-200 km was evaluated for each scene.

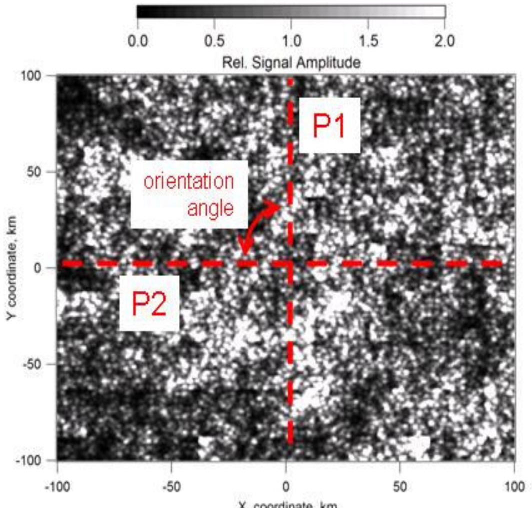

Fig. 1. Cloud scene example used in Monte-Carlo analysis. MPL and GLAS observational tracks are represented by path P1 and P2 respectively.

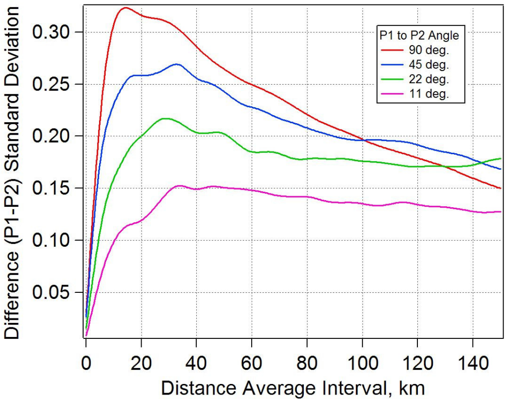

Fig. 2. Deviation in signal difference (P1-P2) from a trial of 1000 cloud scenes.

For very short distance intervals (< 20 km, the deviation between signals is low, as expected when close to coincidence. As the distance average interval is increased about coincidence, the deviation between the two results increases, as uncorrelated features dominate the signal average. After reaching a maximum, the signal differences begin to decline, as the sampling of both paths start to converge on the statistical mean for the full-field.

The largest deviation case corresponds to 90 deg. angle (perpendicular relationship) between the two paths, where the geometric overlap is minimized. However, even in this case, Monte-Carlo results illustrate the possibility of improved correlation, by extending the signal average to the full field mean. Reducing the path angle between P1 and P2, the deviation (shown for 30, 20, and 10 deg. cases) diminishes as the two paths begin to geometrically align. Other cloud sizes and densities were also evaluated producing a similar set of functions.

3. GLAS-MPL COINCIDENT DATA SET

On 26 February, 2004 at 08:54 UTC, GLAS/ICEsat passed over the NASA Goddard Space Flight Center (GSFC) located in Greenbelt, Maryland. This location is a MPLNET site, and simultaneous ground-based MPL measurements were recorded during this overpass. Although the satellite nadir track was to the west of GSFC, GLAS/ICEsat was pointed to the GSFC location for this overpass, resulting in the measurement ground track directly passing over the site with a high degree of spatial accuracy.

Figure 3 shows the resultant backscatter observations both from GLAS/ICEsat and the MPL. The MPL data are shown for +/-1 hour duration about the 08:54 UT satellite overpass and has 1 minute time and 75 meter vertical resolution. The GLAS/ICEsat 532 nm backscatter data are presented for +/- 50 km travel distance about the MPL location and has 0.2 second temporal resolution. Signal magnitudes for both measurements are independently calibrated in units of attenuated backscatter. As seen from the lidar images, cirrus were present from 7-10 km, and exhibited a high degree of structural variability. Signal attenuation through the layer relatively low reducing the need to account for profile attenuation shape differences due to upward and downward viewing directions.

4. EXAMPLE CAPL PROFILES

In this study, “spatial constant” lidar profiles were generated from ground-based MPL measurements by varying the temporal average at each altitude bin to maintain a constant advection path length (CAPL). Wind velocity information was obtained from the NOAA RAOB Forecast Systems laboratory database for the IAD radiosonde launch site (WMO station #72403) for 26 February 12:00 UTC, approximately 55 km the west of NASA GSFC. Examination of additional profile launched at 11:00 UTC from the APG site (WMO station #74002), 90 km to the northeast showed nearly identical data in the 7 to 12 km range, indicating a consistent west-to-east wind direction with ~ 1 km/min horizontal velocity at the base and 3 km/min at the top of the cirrus layer. These velocities provide significant cloud motion over the MPL site, allowing for the observational time domain to be related to a spatial path length.

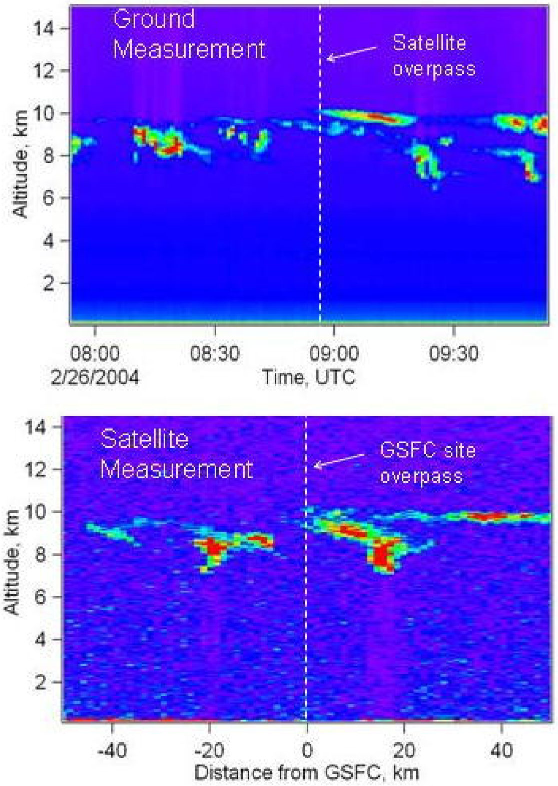

Fig. 3. Attenuated backscatter images from the MPL (top) and GLAS (bottom)for the 26 Feb. 2004 overpass.

Figure 4 shows an MPL image representing a continuum of MPL CAPL profiles for different distance averaging intervals (0 to 200 km) centered on the 08:54 UT MPL-GLAS coincidence. The corresponding GLAS image is also shown illustrating the signal properties for this data set. For this result, MPL CAPL and GLAS signal averages are represented by color intensity in units of attenuated backscatter. For very short intervals (< 12 km) where correlation is expected, agreement can be seen. For distance intervals beyond 12 km, the differences between the two images increases, as uncorrelated cloud contributions begin to dominate. As the distance interval is increased beyond 100 km, data sets appear to converge to a more stable solutions, resulting in the quasi-matched profiles observed for a 200 km average interval.

Figure 5 shows four example profiles taken from these image (20, 50, 100, and 200 km), enabling more direct comparisons between the MPL CAPL and GLAS profiles. Although these observations are matched in spatial path-length, the measurement orientations are not. The GLAS path is oriented in the North-South direction, while the MPL observation track is oriented towards the westerly direction of the jet-stream. Despite the very different orientations, statistical agreement between signals would be possible if the cloud structure over the region was consistent and the measurement distance long enough to reflect the representative sample over the larger scene.

The stochastic illustration previously described supports improved correlation, as seen in the Figure 5. However, the use of approach is highly dependent on spatial statistics being translationally invariant over the full field of interest. Anisotropic field characteristics and other non-uniform properties such gradient changes, will inhibit signal correlation.

5. SUMMARY

MPLNET data products have significant utility for long-term observations of vertical distribution of aerosol and clouds properties. Long-term studies of optical parameters, such as aerosol extinction-to-backscatter properties, can be developed for different regions and seasons on a global scale, providing useful contributions to spaceborne observations and transport modeling studies.

Direct vertical profile comparisons between ground-based to space-borne sensor comparisons have to be carefully considered in context of sampling differences between observations. Trajectory information can help to

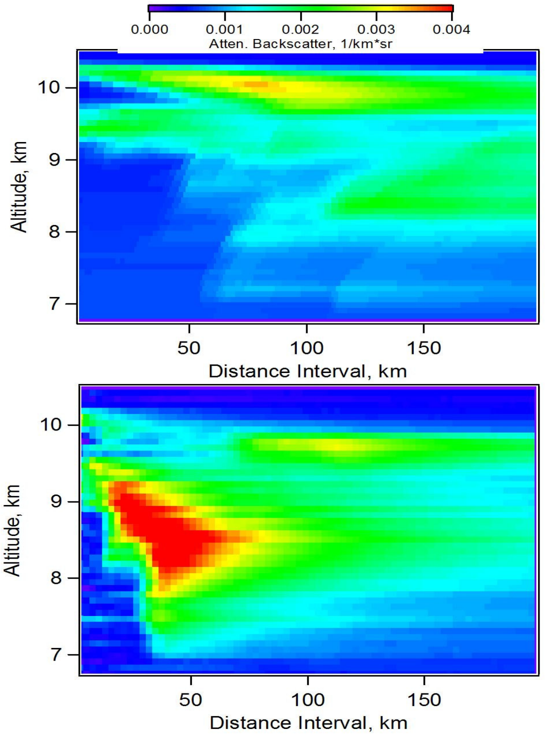

Fig. 4. MPL(top) and GLAS(bottom) profiles for different distance averaging intervals (x-axis) centered on the 08:54 UTC MPL-GLAS coincidence on 26 Feb. 2004.

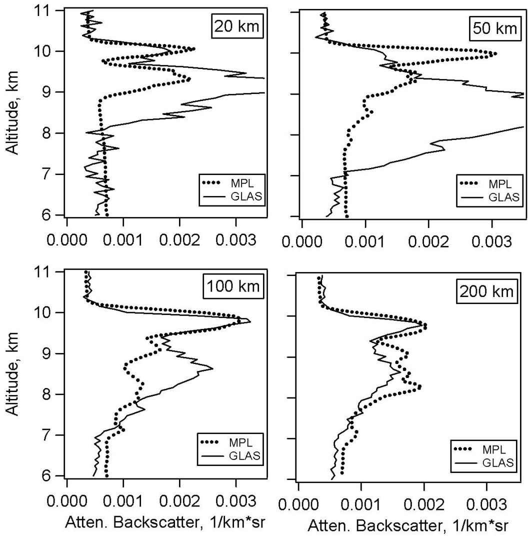

Fig. 5. Backscatter profiles for GLAS (solid) and MPL (dashed) for four different distance intervals (20, 50, 100, and 200 km) about coincidence.

improve the value of data comparisons. For aerosol properties with larger time and spatial scales, mismatched observational paths would less likely contribute sampling errors. Cloud properties however, present a greater challenge due to the highly variable temporal and spatial properties.

Although cloud signals de-correlate rapidly when averaging outside coincident measurement volumes, both stochastic modeling and measured data shown here indicate it is possible, under certain atmospheric conditions, to improve correlations by extending averaging intervals to obtain a representative mean for a larger spatial area.

To further enhance utility of MPLNET data for satellite comparisons, future improvements are planned to allow users to more easily subset and display MPLNET data products with coincident observations. This would include automated algorithms to integrate wind trajectory with results and the permit generation of constant advection path length (CAPL) profiles from MPLNET data.

6. ACKNOWLEDGEMENTS

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