GLOBAL LASER PULSE REFLECTANCE AT 1064 NM OF SNOW AND LAND SURFACES FROM THE GLAS SATELLITE LIDAR

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During the development of the Geoscience Laser Altimeter System (GLAS), launched in 2003, it was understood that the values of surface pusle reflectance was an important design parameter for satellite laser altimeters and that the magnitude of observed pulse reflectance would have valuable applications. Thus a significant effort was made to obtain calibrated surface pulse reflectance from GLAS measurements. In this paper we describe the calibration and atmospheric correction procedures and present global measurement results for earth surface laser pulse reflectance.

Three procedures were applied to calibrate observed pulse reflectance. A value was initially calculated from pre-launch instrument parameters. On orbit, instrumented land test sites were set up where surface pulse reflectance and atmospheric transmission were monitored in situ, and the pointing capability of GLAS was employed to target the sites. Third if wind speed is known, it is possible to calculate the pulse reflectance of the ocean [3]. The ocean based calibration proved to be the most operationally useful since time dependent changes could be tracked. Because of limited overpasses and clouds, only a few calibrations from land test sites were possible but did serve to validate the ocean-based values. The observed pulse reflectance is the product of the actual surface pulse reflectance and atmospheric effective transmission. GLAS was designed with sensitive atmospheric lidar channels for cloud and aerosol profiling that could detect all cloud and aerosol layers of optical thickness above approximately 0.01 [4]. To obtain the measured surface pulse reflectance, the atmospheric data is used to filter out signals with any significant atmospheric attenuation.

A global map of 1064 nm laser pulse reflectance results is shown in Fig. 1. The data are from October, 2003. The values are given as the ratio to the signal from a perfect diffuse Lambertion surface. When averaged over 1 degree grid boxes, as shown, the pulse reflectance for land surfaces are seen to be fairly consistent values in the range 0.4 - 0.6 with somewhat higher values in desert regions. The high value for vegetative surfaces is consistent with the higher values of near-IR bi-directional reflectance seen by passive radiometers.

The altimetry goal of the GLAS instrument was centimeter accuracy measurements of height changes of polar ice sheets. The accuracy was dependent on a proper match of signal levels to the dynamic range of pulse waveform acquisition. Unfortunately in orbit it was discovered that laser returns off snow and ice were severely saturated and degraded in accuracy as a result. Although in design calculations too low atmospheric transmission was used, part of the reason for the signal saturation is that values of snow reflectance are larger than expected. Simulations by Monte Carlo radiative transfer [1] were done of the pulse reflection of snow at 1064 nm as a function of crystal size. The calculated pulse reflectance values expected were between 0.66 to 0.53 for snow crystals from 50 to 1000 um radius. From Fig. 1 it can be seen that for the polar ice sheets there are significant areas well above 0.8. A histogram of values for Antarctica show a peak at 0.8, but many values above 1.0 are found and the highest are near 1.4. The higher values of snow pulse reflectance are consistent with recent measurements of a hot spot effect for snow pulse reflectance by [2] that show a dependence on crystal type and size with coherent backscatter suggested as the hotspot effect. A better understanding of causation for the snow reflectance could lead to snow type retrieval from the pulse reflectance measurements.

The surface wind dependent ocean reflectance varies between near zero at low wind speed to about 0.3. Patterns in global wind data are found to correspond to the patterns in laser reflectance, for example the wave structure seen in the eastern tropical Pacific. Using wind speed data to calculate the expected pulse reflectance, it has been found possible to derive from the observed ocean pulse a value of the effective optical depth of transmissive cloud and aerosol layers. Currently in the GLAS data processing, a 1064 nm optical thickness product for cloud and aerosol is computed from ocean returns. The accuracy of the retrieval is best for larger optical thickness,~ 0.5 -2.0 where lidar forward inversion methods become problematic. The validity and application of the data product are now being studied.

Overall GLAS observations of laser surface pulse reflectance were successfully calibrated and results now give a new parameter to characterize the earth surface. The results have value for the development of new laser sensing satellite missions and new retrieval applications.

Bibliography

1. Duda, D. P., J. D. Spinhirne, and E. W. Eloranta, "Atmospheric multiple scattering effects on GLAS altimetry – Part I: Calculations of single pulse bias," IEEE Trans. Geosci. Rem. Sens., 39, p. 92-101, 2001.
2. Kaasalainen S., M. Kaasalainenc, T. Mielonena, J. Suomalainena, J. I. Peltoniemia, and J. Näränena, "Optical properties of snow in backscatter," J. Glaciol., 52 . p. 574 -590, 2006.
3. Lancaster, R. S., J. D. Spinhirne, and S. P. Palm (2005), Laser pulse reflectance of the ocean surface from the GLAS satellite lidar, Geophys. Res. Lett., 32, L22S10, doi:10.1029/2005GL023732.
4. Spinhirne, J. D., S. P. Palm, W. D. Hart, D. L. Hlavka, and E. J. Welton,: Cloud and aerosol measurements from GLAS: Overview and initial results, Geophys. Res. Lett., 32, L22S03, doi:10.1029/2005GL023507, 2005

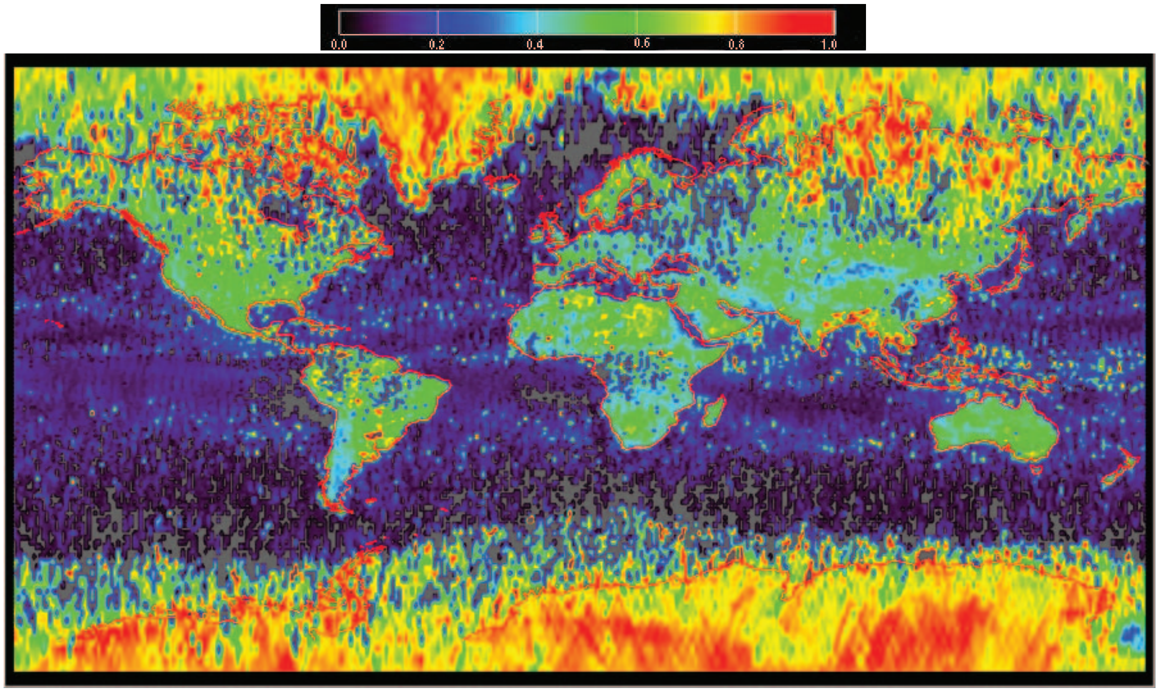

Figure 1. Calibrated and cloud filtered measurements of the 1064 nm laser pulse reflectance of the surface from GLAS observations for October, 2003. The values are shown as the ratio to the signal from a perfect diffuse Lambertion reflection. Only returns with no clouds or significant aerosol layers are used. The areas of gray are where there are insufficient clear observations to derive a meaningful value.