6.5 AEROSOL AND CLOUD OBSERVATIONS AND DATA PRODUCTS BY THE GLAS POLAR ORBITING LIDAR INSTRUMENT

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1. Introduction

The first polar orbiting satellite lidar instrument, the Geoscience Laser Altimeter System (GLAS), was launched in 2003 and is approaching eight months of data operations. As part of the NASA Earth Observing System (EOS) project, the GLAS instrument is intended as a laser sensor fulfilling complementary requirements for several earth science disciplines including atmospheric and surface applications on the Ice, Cloud and Land Elevation Satellite. In this paper we present examples of atmospheric measurement results and explain data products now accessible for the science community.

2. GLAS Instrument

GLAS is a nadir viewing laser radar system. Diode pumped Nd:YAG lasers transmit at both the fundamental and doubled wavelengths. The wavelengths, pulse rate and other parameters are listed in Table 1. Three lasers are used singly. The receiver is dual wavelength and dual purpose. The 1064 nm channel applies analog signal acquisition for surface ranging and dense cloud tops. The 532 nm channel uses high efficiency GAPD solid-state detectors for photon counting signal acquisition and is the primary channel for aerosol signal acquisition. Important aspects of the 532 nm atmospheric receiver channel are the small FOV and very narrow band filter to minimize the solar background noise signal and enable daytime observations. In order to meet the dynamic range of the signal and background, eight GAPD detectors are used through equal power splitting of the optical signal. Since dense cloud signals will saturate the photon counting, the full atmospheric signal is also acquired with analog detection at 1064 nm (Spinhirne et al., 1996). Special design features of GLAS for surface altimetry are an advantage for the atmosphere measurements (Zwally et al, 2002). These include a precise measurement of the surface pulse waveform, the ability to point to validation targets with 50 m accuracy and a 94^o orbit inclination for good coverage of polar region

Table 1 GLAS Instrument Parameters

PARAMETERS:	532nm	1064nm
Laser Pulse Energy	36 mJ	74 mJ
Laser PRF	40 Hz	40 Hz
Telescope Diameter	0.9 m	0.9 m
Receiver FOV	0.19 mrad	0.5 mrad
Optical Bandwidth	25 pm	1.4 nm
Detector Quantum Efficiency / Type	0.7 / GAPD photon count	0.3 / APD analog
Range resolution	75 m	0.075 m & 75 m
Pointing Knowledge	3 arcsec	3 arcsec

3. Operations and Data

The initial on orbit full operation of the GLAS instrument began in 28 September 2003. The first period of data in February and March of 2003 was with only the 1064 nm channel. An example of the 532 nm data is shown in Fig.1 for a single orbit track on October 6. Data are color scale coded in the image as the normalized attenuated backscatter (NAB) return corrected for solar background offsets. The track starts in the central Pacific, crosses Antarctica, proceeds over Africa and Europe and then covers northern Greenland and Alaska. These data, and others from thousands of such orbits, illustrate the ability of space lidar to accurately and dramatically measure the height distribution of global cloud and aerosol to an unprecedented degree. The data show boundary layer aerosol and PBL height over the clean Pacific, elevated dust layers over

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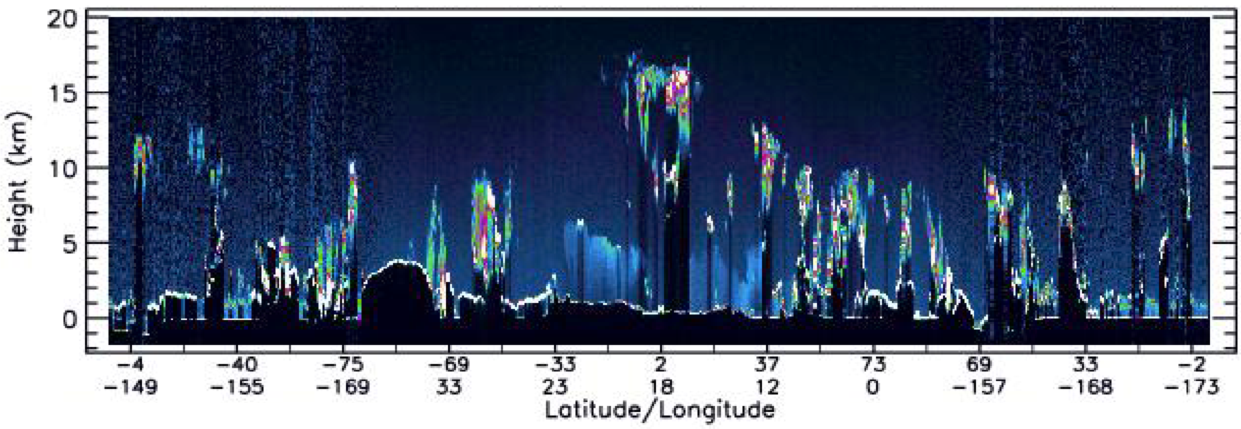

Figure 1. GLAS cloud and aerosol signal for one global orbit

Africa, the distribution of high thin cloud (and associated tropopause height) and multi-layer clouds. Many specific, unique atmospheric phenomena have been profiled for the first time on a global basis.

The measurement requirement for GLAS atmospheric observations were stated most basically as measuring the vertical NAB distribution for all significant cloud and aerosol scattering, defined as values down to 10^{-7} 1/m-sr for 20 km horizontal resolution. GLAS 532 nm data meets the requirements for both day and night data. The 1064 nm channel was not intended to be as sensitive but has preformed better than expected. An example of the 532 and 1064 nm data for the same track over and north of Australia is shown in Fig. 2. Both channels show smoke related aerosol emanating from convective clouds over Australia, but structure is much more defined and extensive in the 532 nm data. At the right of the images, both channels show tropical boundary layer aerosol with cross sections greater than 10-6 1/m-sr.

As an EOS project requirement, the GLAS science team is responsible for developing algorithms for instrument level correction of data, data calibration and higher-level data products for general research applications. A list of the GLAS atmospheric data products is given in Table 2. The GLA02 and GLA07 products are the lidar signal with instrument corrections and calibration and thus of special interest to the lidar community. Products 08 through 11 are higher-level retrievals dependent on the particular algorithms developed by the GLAS atmospheric group.

An illustration of GLA07, GLA09 and GLA10 are shown in Fig. 3 for daytime data of extensive cloud and aerosol layers from a portion of a GLAS orbit track over central China on October 18, 2003. In the top frame is shown the backscatter cross section uncorrected for attenuation. The increased noise in the cloud region is a result of increased solar background noise for this day time cases. The second image show the derived extinction cross sections for the cloud and aerosol formations. The data image for the extinction cross section also indicate the defined cloud and aerosol layers as reported in the GLA09 data product. The extinction cross sections are only produced within the retrieval cloud ad aerosol layers. In Fig. 3 both cloud and aerosol extinction are shown together, however the processing algorithms employ a sophisticated segregation of aerosol and cloud layers and are so flagged in the data products.

Table 2. GLAS data products for atmospheric measurements

•GLA02	532 and 1064 normalized lidar signal
•GLA07	Calibrated, attenuated backscatter cross section profiles for 532 and 1064 at 40 Hz and 5 Hz
•GLA08	Planetary Boundary Layer (5 Hz and 4 sec) height and elevated aerosol layer top and bottom height
•GLA09	Cloud layer top and bottom height at 40 Hz, 5 Hz, 1Hz and 4 seconds
•GLA10	532 attenuation corrected backscatter and extinction profiles
•GLA11	Thin cloud and aerosol layer optical depth

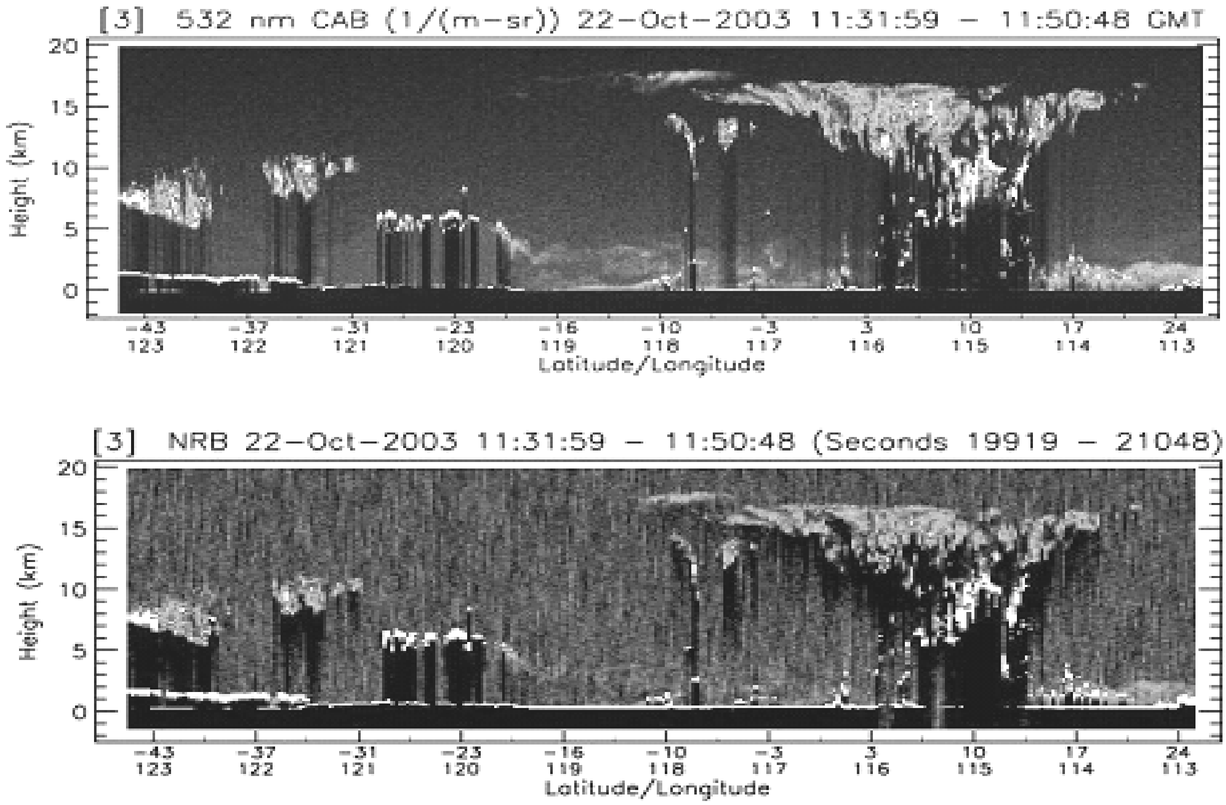

Figure 2 GLAS 532 and 1064 nm data over Australia and warm pool region (quality degraded by pdf file conversion)

4. Access, Applications and Status

As an EOS mission, GLAS data are freely available through the NASA Distributed Active Archive Centers (DAAC) system. Both data sets and data input and visualization tools are available. In addition the atmospheric group maintains a web portal with convenient access to quick look images of all data and other information such as documents describing There were many intended science applications of the GLAS data and significant results have already been realized. One application is the accurate height distribution and coverage of global cloud cover with one goal of defining the limitation and inaccuracies of passive retrievals. Comparison to MODIS cloud retrievals shows significant discrepancies (Mahesh et al., 2004). Conversely initial comparisons to NOAA 14&15 satellite cloud retrievals show basic similarity in overall cloud coverage, but important differences in height distribution. Because of the especially poor performance of passive cloud retrievals in polar regions, and partly because of high orbit track densities, the GLAS measurements are by far the most accurate measurement of Arctic and Antarctica cloud cover from space to date. Global aerosol height profiling is a fundamentally new measurement from space with multiple applications. A most important aerosol application is providing input to global aerosol generation and transport models. Another is improved measurement of aerosol optical depth. Oceanic surface energy flux derivation from PBL and LCL height measurements is another application of GLAS data that is being pursued (Palm et al., this conference). A special area of work for GLAS data is the correction and application of multiple scattering effects (Duda et al., 2001). Stretching of surface return pulses in excess of 40 m from cloud propagation effects has been observed.

Validation of GLAS calibration and data products is an important part of science team activities. The principle approach for the atmospheric measurements has been under flights by the NASA ER-2 aircraft and use of surface networks by taking advantage of the 50 m off nadir pointing accuracy of the instrument.

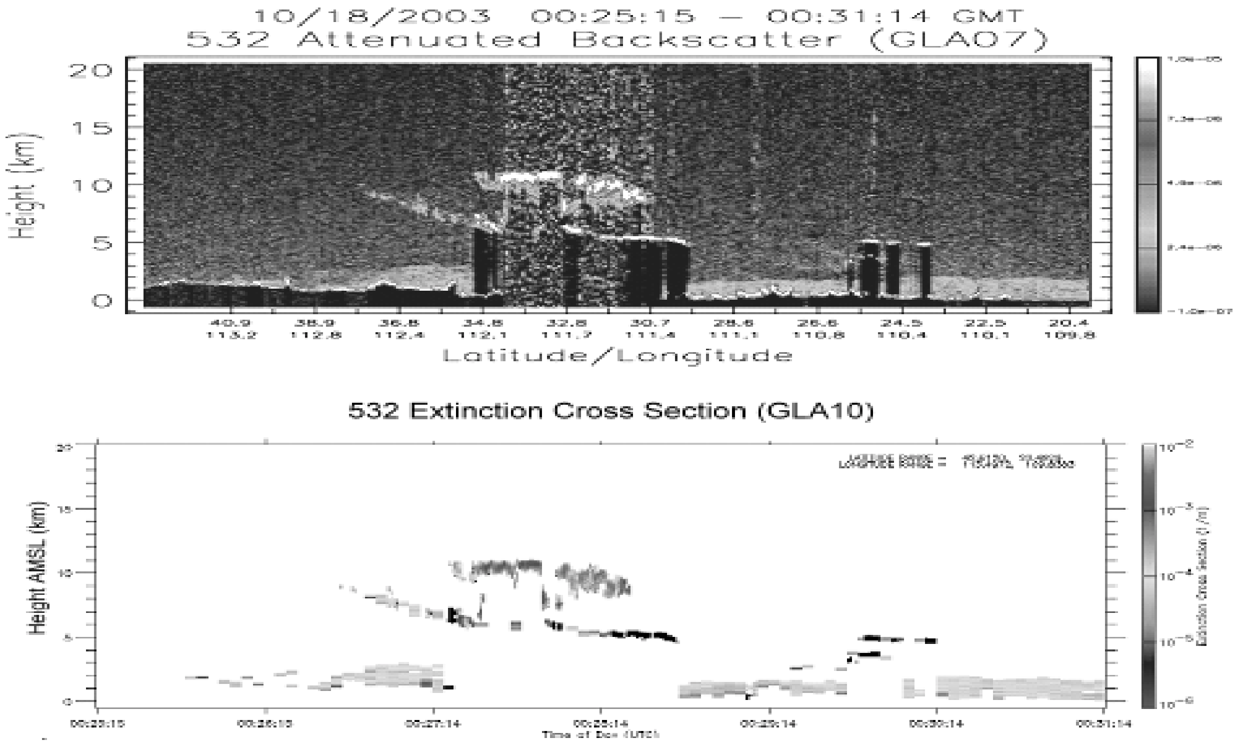

Figure 3 GLAS data products for backscatter and extinction for day time data over China (quality degraded by pdf file conversion)

The validation experiments to date have verified and proven the measurement sensitivity and calibration of the lidar measurements (see Hart et al. and Mcgill et al. this conference).

The GLAS instrument was designed with three lasers to obtain a three to five year mission life. Life testing indicated that each laser should last for two years. During the initial on orbit test operation with the first GLAS laser there was a premature failure of a pump diode module. Subsequent review indicated a shelf life related corrosive degradation of the pump diodes, due to an improper material usage in manufacture, which affect the reliability of the lasers. The operational life for the GLAS instrument is now expected to be less than a year as a result. After the two months of full operation in the fall of 2003, the operational plan for GLAS has been to operate for a one-month periods out of every three to six months in order to extend the time series of measurements, particularly for the ice sheets. The laser reliability failure limits the use of the data for climate applications requiring a time series of measurements. Overall the mission has clearly demonstrated the important applications for space borne lidar and created a unique data set from thousands of orbits with many research applications.

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