SIMULATING THE GEOSCIENCE LASER ALTIMETER SYSTEM IN A GCM

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INTRODUCTION

The Geoscience Laser Altimeter System (GLAS) orbits the Earth onboard the Ice, Cloud and Land Elevation Satellite (ICESat). This space-borne lidar observes multiple cloud and aerosol layers in the atmosphere, as well as ground elevation. As the lidar signal passes through each atmospheric layer, the signal strength weakens. In optically thick clouds the lidar signal can be fully attenuated, obscuring the view of layers below.
When comparing these observations to model data, it is important to take into account signal attenuation.

OBJECTIVES

It is our goal to find an appropriate way to compare the GLAS observations to model data taking into account signal attenuation. Most of the time, the GLAS signal is fully attenuated for optical depths around 3, but multiple scattering and signal stretching can let the signal penetrate a little further. It is difficult to determine the equivalent level of signal attenuation in the model. We address this problem by simulating the backscatter GLAS would detect if it were to observe the model clouds.

Fig. 1

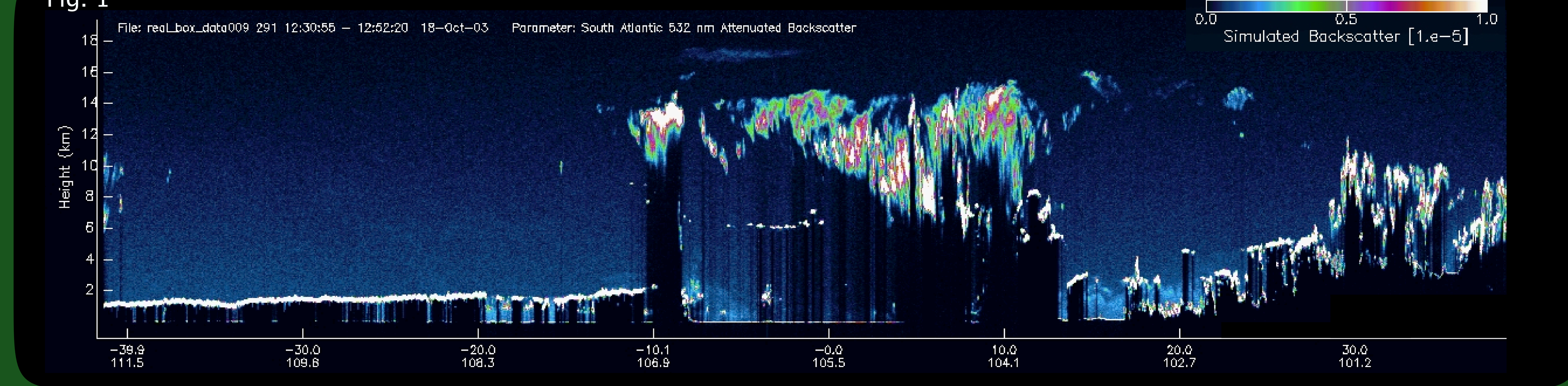


Fig. 2

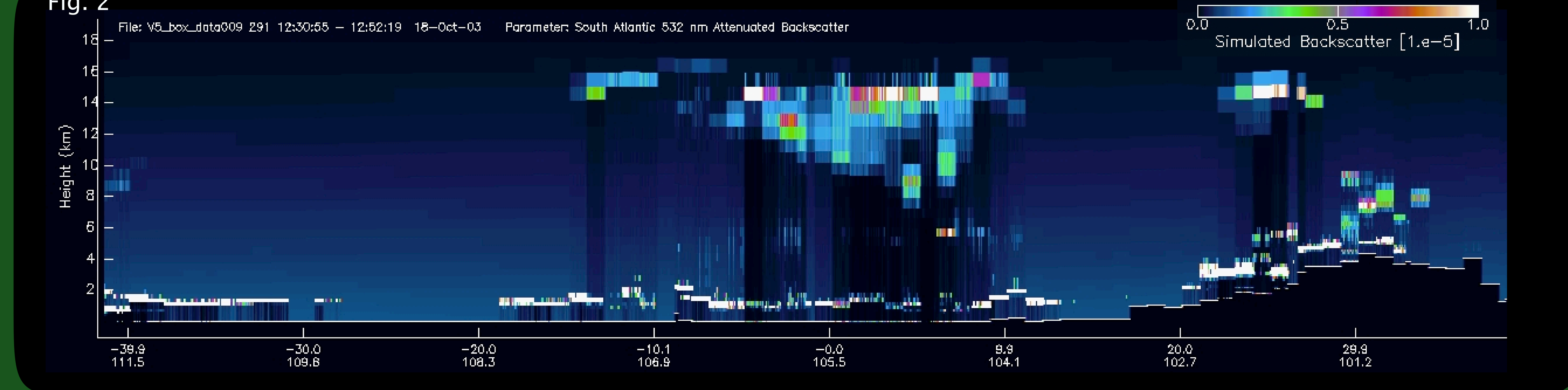
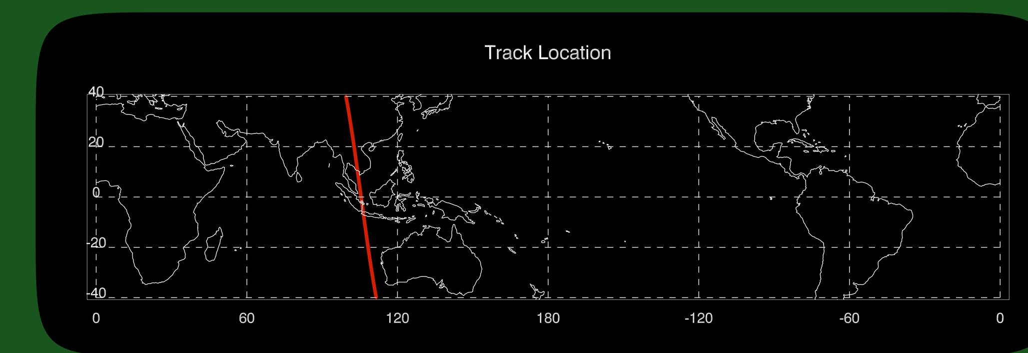


Fig. 1 shows the normalized backscatter of a GLAS track. In addition to cloud and aerosol layers, the lidar signal is also scattered by the atmosphere (molecular backscatter, blue background). White color indicates strong backscatter. The black areas underneath the clouds indicate signal attenuation – the backscatter is weak.
Fig. 2 shows simulated backscatter for the same track from the ECMWF model.



CHALLENGE

The model output provides variables on a much coarser grid than the GLAS observations. In addition, detailed information on the microphysical state of the atmosphere is unavailable. Clouds are described by cloud liquid water and ice content, as well as cloud fraction. In order to calculate backscatter from the model, we have to make assumptions about the distribution of the cloud properties within a grid box (cloud overlap), and about the microphysics of the clouds.

LIDAR EQUATION

$$P(z)\, z^2 = [\beta_{\text{mol}}(z) + \beta_{\text{par}}(z)] \exp\left\{-2\int_0^z [\eta\alpha_{\text{par}}(z') + \alpha_{\text{mol}}(z')]\, dz'\right\}$$

The left hand side of this equation is the normalized backscatter plotted in Fig. 1 and 2. In order to calculate it, we need to estimate the molecular and particulate backscatter coefficient (β), the molecular and particulate attenuation (α) and the multiple scattering parameter (η).

Calculating the molecular parameters is relatively straightforward using Rayleigh theory and the model pressure and temperature. For the particulate parameters, an estimate of the particle size distribution and concentration is needed. We calculate ice effective radii from temperature following Ou and Liou (1995), and assume droplet size scales linear with pressure (as done in ECMWF model). With these assumptions we can calculate a number concentration. A lookup table is used for the multiple scattering parameter (same as used in GLAS algorithm).

SIMULATING CLOUD OVERLAP

GLAS samples the atmosphere every 175m, roughly 650 times in a 1°×1° grid column. The clouds within that grid column are described by only one average value for cloud liquid water, ice water and fraction per model layer, but no additional information is provided as to how individual clouds are distributed in the grid column. Räisänen et al. (2004) suggest a method that stochastically samples the model column to generate sub-columns whose average cloud liquid water, ice water and fraction correspond to the column average values.
The number of sub-columns generated is the same as the number of times GLAS would sample the 1°×1° column. Each sub-column is treated as a simulated lidar shot.

Fig. 3 is a plot of the GLAS products for cloud top, base and PBL depth. Each detected cloud top and base is connected with a blue line. The PBL tops are marked with green dots. In cases where optically thick boundary layer clouds exist, the PBL top coincides with the cloud top.
Fig. 4 is the same type of plot as Fig. 3, but in this case for the cloud tops and bases found by the GLAS algorithm using the simulated backscatter from the ECMWF model as input.

Fig. 3

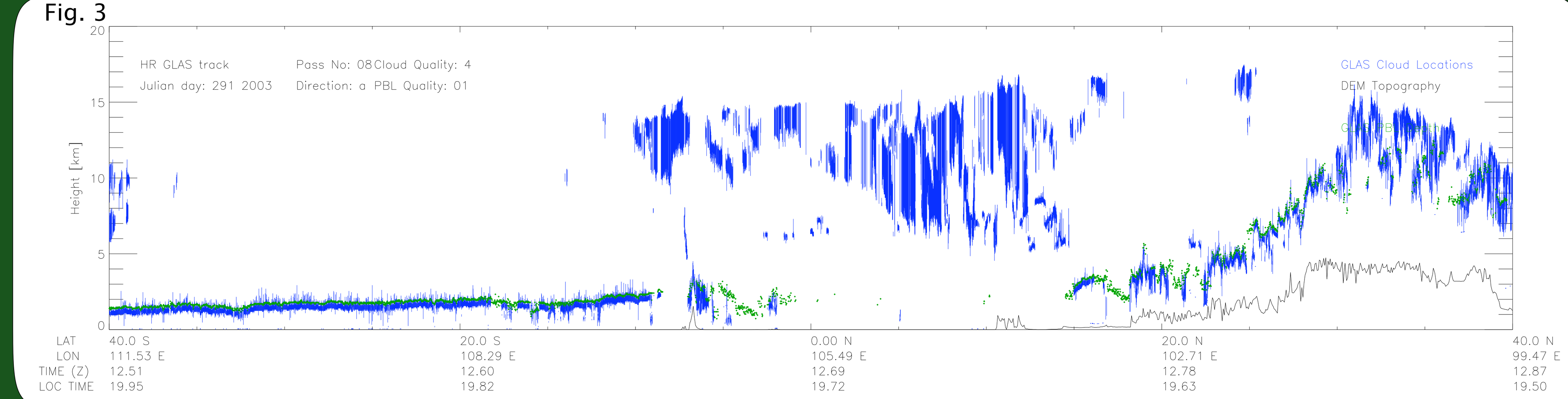
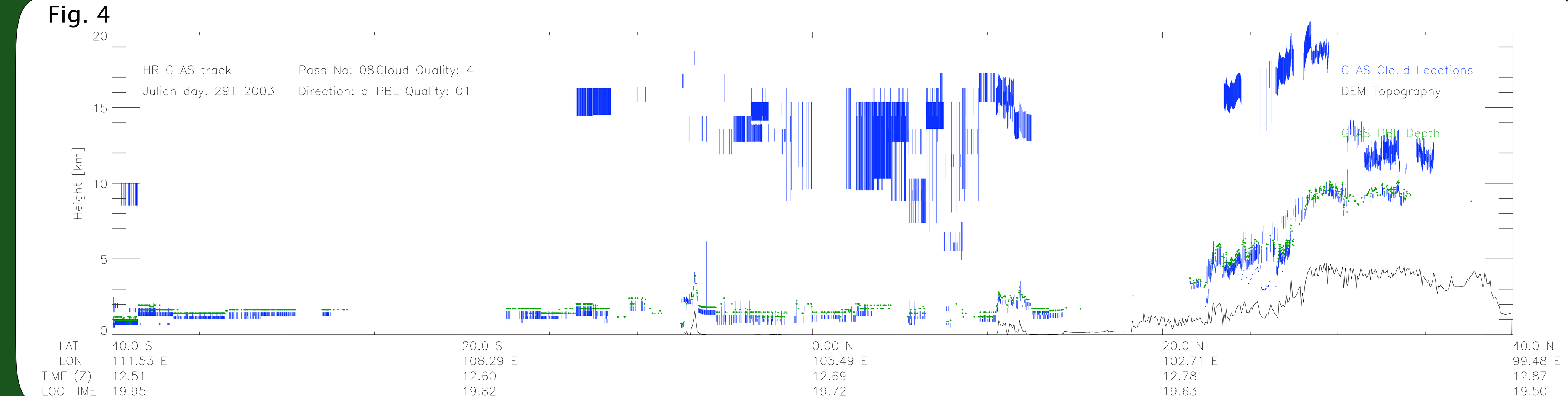


Fig. 4



NEXT STEP: GLAS PRODUCTS

Working with the actual GLAS backscatter is work intensive: the data sets are large and require some computing time and memory. The GLAS science team has done a lot of work to create secondary products (such as cloud top height, cloud base height and PBL depth) from the raw backscatter. It would be advantageous if we could relate the model data directly to the GLAS products, rather than having to generate and work with the raw backscatter data.

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