Estimating the Amount, Spatial Distribution, and Statistical Uncertainty of Aboveground Carbon Stocks of the North American Boreal Forest Using the ICESAT-GLAS Spaceborne Lidar

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Introduction

The boreal forest of North America contains a vast amount of sequestered carbon that is potentially vulnerable to climate change. The objective of this study is to assess the capacity of the GLAS lidar sensor on the ICESAT satellite (Fig. 1) to estimate the amount, spatial distribution and statistical uncertainty of aboveground tree biomass (AGTB) for the ~6.2 million sq km area of the boreal biome of North America (Figs. 2 and 3). We relate the biomass of ground plots located in different regions to tree height data collected from an airborne profiling small-footprint lidar system. We then relate the airborne data to GLAS data for a sample of ICESat orbits. Finally, the full set of available GLAS data is combined with land cover and topographic data to predict aboveground tree biomass as well as the sources and magnitude of the uncertainty.

Fig. 1 – ICESat and the GLAS instrument

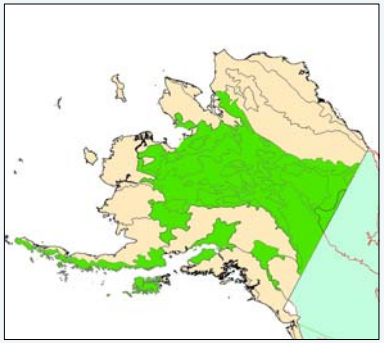

Fig. 2 - The boreal biome of Alaska covers more than 588,000 sq km and accounts for 41% of Alaska's total land area.

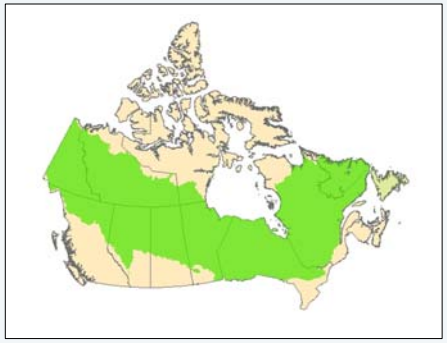

Fig. 3 - The boreal biome of Canada covers ~5.6 million sq km and accounts for 58% of Canada's total land area. 57% of Canada's boreal biome is classified as forest.

Relating Aircraft Lidar Measurements to Ground Inventory Plots

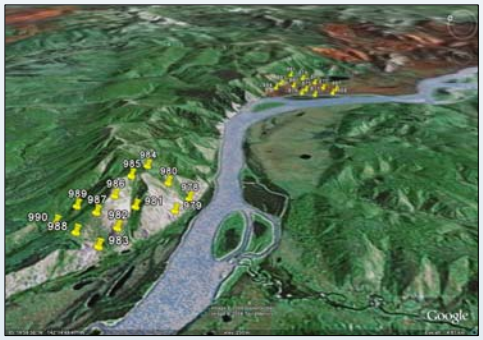

Fig 4 – Google Earth image showing some of the ground plots in the Yukon-Charley Rivers Natural Preserve in Alaska around the Yukon River. Scale: 10 km between the two point clusters, 500 m between individual plots.

The Portable Airborne Laser System (PALS) is a small-footprint profiling lidar that can be run from a light fixed-wing aircraft. PALS observations over previously established ground sample plots are used to develop predictive ground-to-aircraft equations based on several hundred plots located in Alaska, Saskatchewan, Manitoba, Ontario, Quebec, and the Northwest Territories. Ground plots in the Yukon-Charley region of Alaska (Fig. 4, left) were flown in summer 2008. These equations relate the field measurements of biomass to height metrics from the airborne Lidar. Once PALS biomass equations are calculated, then AGTB can be derived from any set of PALS observations.

PALS data are collected along GLAS orbital transects and used to estimate biomass on thousands of GLAS pulses.

Relating Aircraft Lidar Measurements to Satellite Lidar Measurements and Then Scaling to the Continent

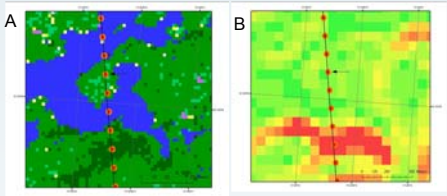

Fig. 5 – Example of a PALS flight line intersecting GLAS footprints along a GLAS orbit. The arrows mark the pulse shown in Fig. 6.

A: Land cover classification. Landsat-derived land cover is available for entire study area. The inset depicts complex of lakes and conifer forest.

B: SRTM slope map. The slope (green) is ≤ 2°.

To define the intersection between GLAS and PALS, the GLAS footprints are represented as 64-meter diameter circles in a geographic information system (GIS). Statistics for the profiling airborne laser system are then computed for the portion of the profile within the satellite laser footprint. This dataset allows us to develop regressions on data from the two lidar systems. PALS provides biomass estimates for each GLAS pulse and GLAS provides the height measurement used to predict biomass.

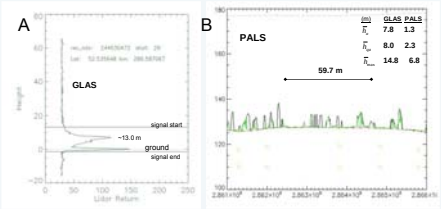

Fig. 6 - Example of the intersection of PALS with a GLAS footprint.

A: View of the GLAS waveform for the footprint selected in Fig 5.

B: View of the PALS profile within the same footprint.

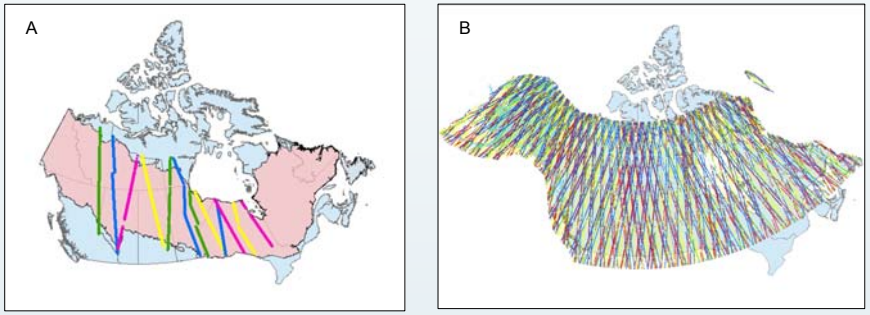

Fig. 7 – (A) In summer 2009, we will fly as many as 15,000 km of GLAS transects with the PALS lidar. Different colors indicate different dates of GLAS acquisitions between 2003 and 2006. (B) The statistical relations that we will develop will permit us to use the 7 million GLAS pulses available in North America to estimate aboveground tree biomass. Quebec was flown as part of an earlier project. Western Canada is too mountainous to fly but data obtained in eastern Alaska will partially mitigate this sampling problem.

Progress To Date (February 2009)

We have completed a successful pilot project (2004-2007) for the 1.2 million sq km forest area of Quebec. These results demonstrated the capacity of the GLAS instrument to estimate the amount and distribution of aboveground tree biomass at large spatial scales. In summer 2008, we flew 505 ground plots and ~2300 km of GLAS transects in Alaska. Summer 2009 will be a busy aircraft campaign in Canada.