

Estimating Aboveground Biomass of North American Forests Using a Three-Phased Sampling Approach Based on Ground Plots, Airborne Lidar, and the GLAS Satellite Sensor



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Introduction

The forests of North America contain a large amount of sequestered carbon that is vulnerable to climate change. The objective of our studies is to assess the capacity of the GLAS lidar sensor on the ICESAT-1 satellite to estimate the amount, spatial distribution and statistical uncertainty of aboveground tree biomass (AGB) of the forests of North America. We conducted airborne lidar campaigns in Quebec (2005), the rest of Canada (2009), Alaska (2008), the eastern US (2011), the western US (2012), and Mexico (2013). In each campaign, we related the biomass of ground plots located in different regions to tree height data collected from an airborne small-footprint profiling lidar system for the boreal forest and from a scanning lidar for the US and Mexico. We then related the airborne estimates of biomass to GLAS height measurements for a sample of ICESat orbits. Finally, the full set of 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. Here, we report partial results from this effort.

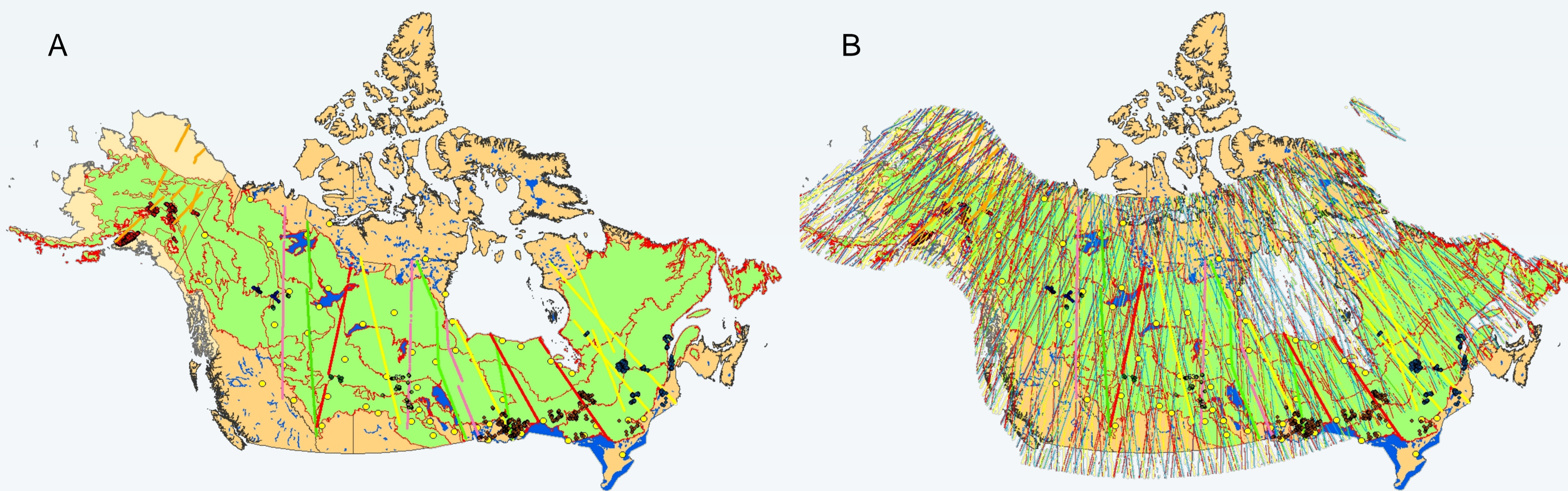


Fig. 1 – (A) PALS airborne profiling lidar flights, 2005-Quebec, 2008-Alaska, and 2009-central & western Canada. GLAS transects in purple, green, red, and yellow denote different GLAS acquisitions (2a, 3a, 3c, 3f) between 2003 and 2006. Clusters of brown dots and blue dots mark the 1,000 ground plots overflowed with the airborne lidar profiler. For subsequent analyses of boreal forests, we used only the 3c and 3f acquisitions taken during the northern growing season. (B) The statistical relations permit us to use the 229,356 quality-filtered GLAS pulses available in boreal North America to estimate AGB across the entire area of interest.

Aboveground Biomass of the Boreal Forest of North America as Derived by GLAS

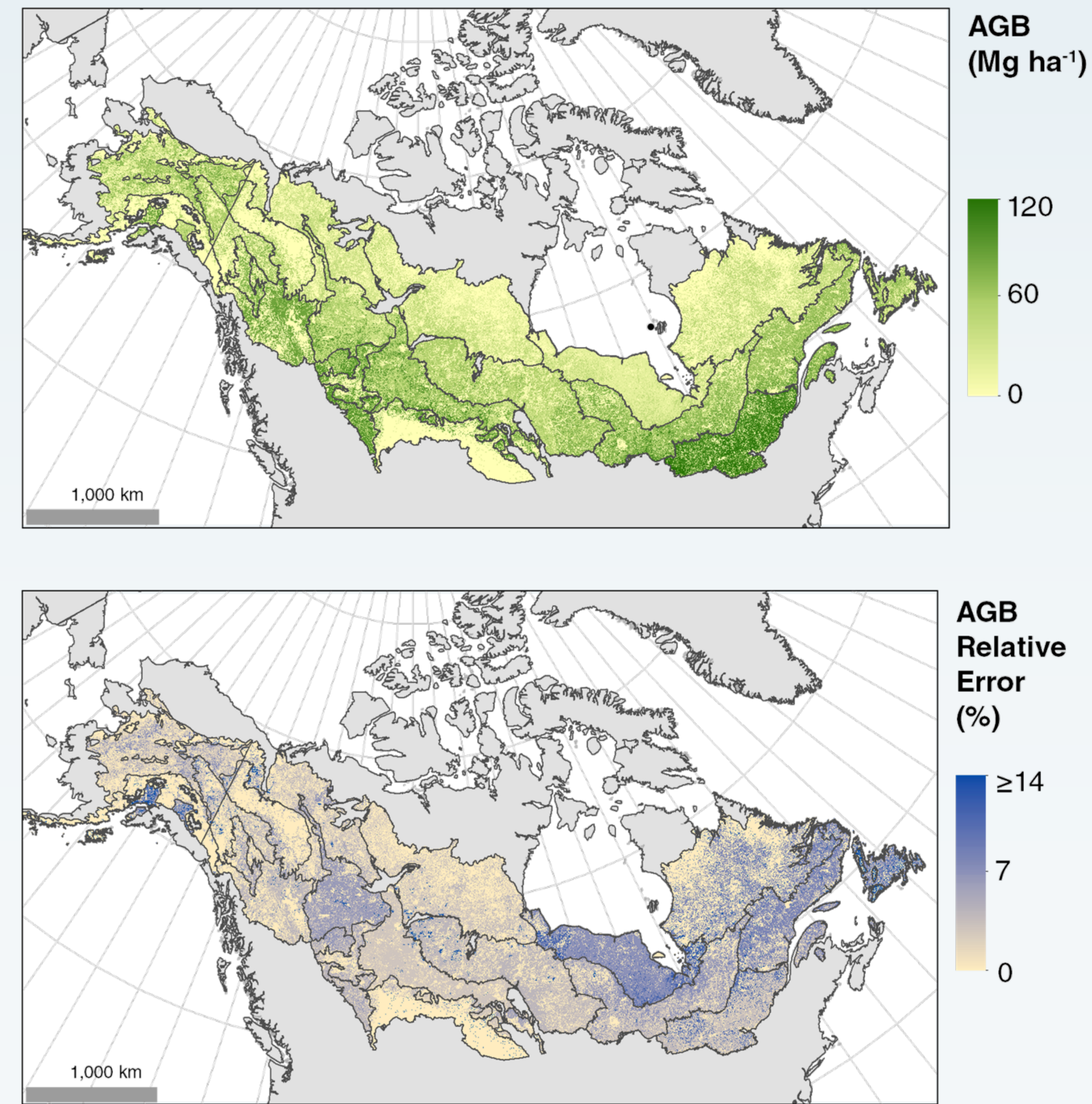


Fig 3 - The distribution of aboveground biomass (AGB) of the boreal forest of North America and its uncertainty (relative error = (std dev/mean) as estimated by the GLAS spaceborne lidar.

AGB is calculated for each cover type within an ecozone.

The total AGB for boreal North America was estimated at 21.8 ±4.1 Pg with 9.7% in Alaska, 46.6% in western Canada, and 43.7% in eastern Canada.

Overall, 51.3% of the boreal biomass was in conifers, 22.0% in mixedwoods, 14.3% in hardwoods, 11.4% in forested wetlands, and 1.1% in recent burns.

Comparing GLAS Estimates With Canada's National Forest Inventory Estimates

Table 1. Comparison between GLAS and direct Canada National Forest Inventory (NFI) estimates of mean biomass density by Canadian boreal ecozone. Greyed areas indicate Canadian ecozones well-inventoried by the NFI whereas clear areas indicate partially- or poorly-inventoried northern ecozones. Ecozones are sorted by increasing absolute values of relative differences of means for well-inventoried and partially/poorly-inventoried ecozones, respectively.

Canadian Ecozone	NFI Mean Biomass Density Mg/ha	Equivalent WWF Ecozones	Weighted GLAS Mean Biomass Density Mg/ha	Difference of Means (GLAS-NFI), Mg/ha	Relative Difference of Means (GLAS-NFI)/NFI, %
Boreal Cordillera *	71.4	Northern Cordillera Forests + Interior Yukon-Alaska Alpine Tundra (latter only partially overlaps Boreal Cordillera)	79.1	7.7	10.8
Boreal Shield *	81.4	Midwestern Canadian Shield Forests + Central Canadian Shield Forests + Eastern Forest-Boreal Transition + Eastern Canadian Forests	72.3	-9.1	-11.2
Boreal Plains *	79.9	Mid-Continental Canadian forests + Canadian Aspen Forests and Parklands + Alberta-British Columbia Foothills Forests (latter only partially overlaps with Boreal Plains)	66.9	-13.0	-16.3
Hudson Plains	24.4	Southern Hudson Bay Taiga	26.1	1.7	7.0
Taiga Shield	54.8	Eastern Canadian Shield Taiga + Northern Canadian Shield Taiga	41.5	-13.3	-24.3
Taiga Cordillera *	76.7	Ogishvie-Mackenzie Alpine Tundra (smaller than Taiga Cordillera)	56.8	-19.9	-26.0
Taiga Plains *	82.9	Northwest Territories Taiga + Muskwa-Slave Lake Forests (latter has only minor overlap with Taiga Plains)	45.9	-37.0	-44.7
Canadian Boreal	72.9		59.3	-13.6	-18.6

*Indicates significant differences in geographic matching between the two systems.

There was good agreement (<16.3% difference) between the GLAS-derived aboveground biomass estimates and those estimated independently from Canadian National Forest Inventory (NFI) data for ecozones which were well inventoried by NFI. On the other hand, for ecozones that are not well-inventoried, differences between the two estimation methods was much greater (up to 44.7%). Overall, the differences between the two methods was 18.6% with GLAS providing lower estimates, perhaps because it samples the entire landscape whereas NFI plots tend to be placed in areas with significant standing forest.

Regressions Between Ground Plot Biomass and Airborne Lidar Metrics for Mexico

Table 2. Results from all possible subsets regressions (APSR) for the relationship between various G-LiHT lidar variables related to forest height and forest biomass measured at NFI plots in Mexico. Biomass in Mg/ha.

Mexico Ecozone	Adjusted R ²	Mean Biomass	RMSE	n
Northern Mexico Desert and Dry Forest	0.63	48.7	19.9	78
Veracruz Moist Forests	0.63	27.6	11.9	18
Central Mexico Dry Forest: Conifer	0.73	64.4	29.9	53
Central Mexico Dry Forest: Non-Conifer	0.47	30.8	19.4	26
Yucatán Moist Forest: Hardwood	0.54	111.1	56.1	59
Yucatán Dry Forests: Hardwood	0.86	83.3	23.8	39
Yucatán Moist and Dry Forests: Burned and Non-Forest Areas	0.65	52.3	28.1	19

We have developed initial regressions relating aboveground biomass of NFI ground plots to lidar metrics for the ecozones where we conducted our sampling. This has also been done for the United States (results not shown).

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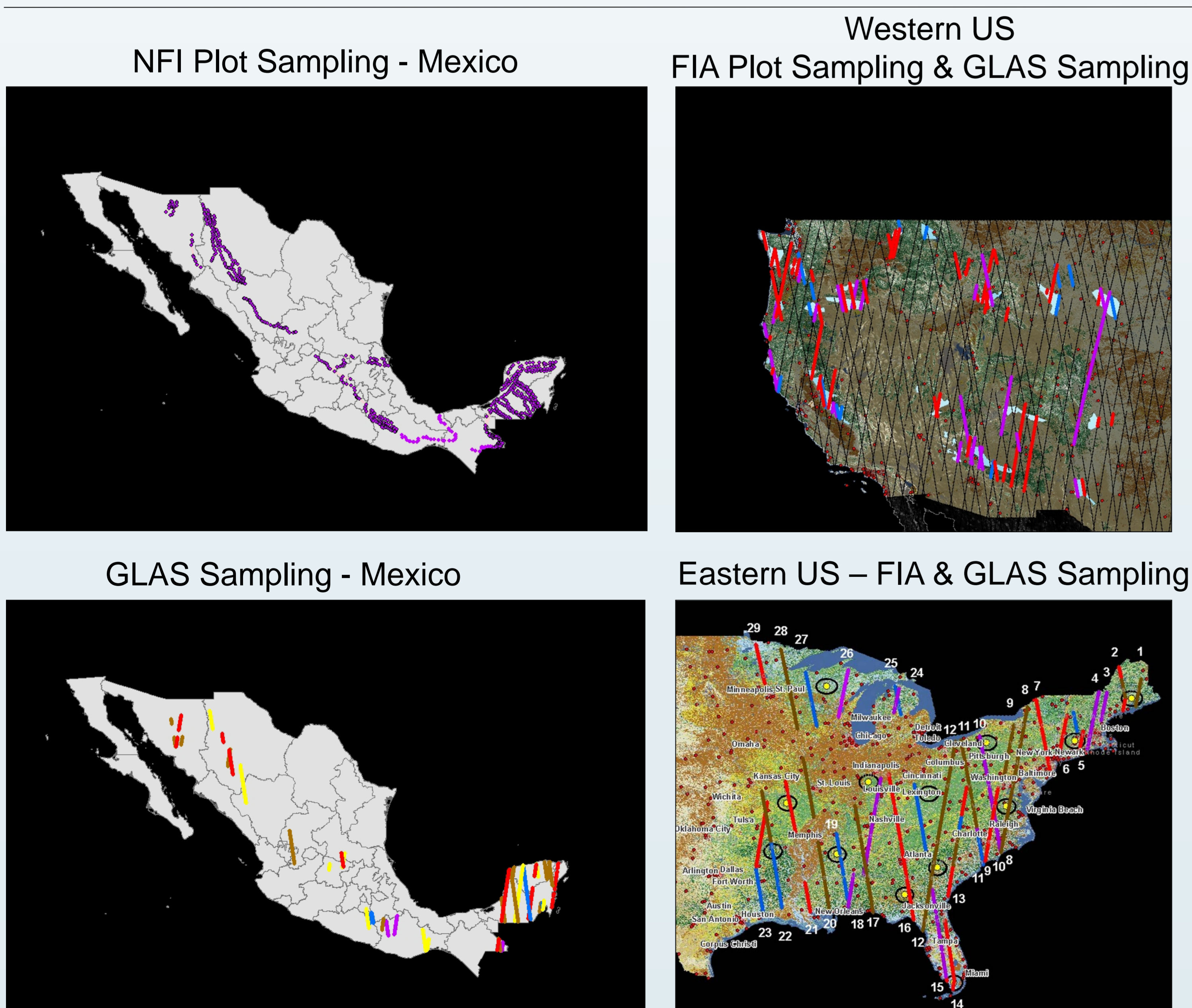


Fig. 2 – Strategy and flight plan for the airborne sampling of GLAS lines and forest inventory plots in Mexico, the western US, and the eastern US. The G-LiHT scanning lidar was used for this sampling. For forests in the western US, areas where ground plots were sampled is shown by pale blue polygons, sampled GLAS lines are colored lines, and all other GLAS lines are shown in black. For the eastern US, areas where plots were sampled are shown as circles and sampled GLAS lines are the colored lines.