Snow depth ground truth guidelines for validating lidar products

CZO lidar snow survey planning group

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To ensure the comparability of the ground truth data among CZO sites we recommend the following snow survey protocol.

1. **Each CZO group should determine in advance of the survey the number of stratified measurements feasible given available resources and time. Ground sampling should be stratified by vegetation types, canopy density, ground cover density, absolute slope, aspect and elevation from regions that most represent the range of the lidar flight area with respect to vegetation and terrain physiography. For rationale supporting this see (Ellis and Pomeroy 2007; Jost, Weiler et al. 2007). A spatial analysis of representative areas based on spatial data, previous ground surveys, and/or terrain analysis (e.g. regression tree, energy field analysis, vegetation cover) should be used to guide location selection. An explanation of regression tree analysis can be found in (Molotch, Colee et al. 2005) .**

2. **In order to conduct robust statistical analysis the ground truth stratifications must have a minimum of 30 samples and cover the full range of variability found at the location (i.e. transects include the full range of snow depths found in each area). Depth measurements are taken on transects at 10 m intervals within a diamond-shape plot consisting of five snow depth measurements that are averaged to represent the snow depth of the plot (Figure 1).**

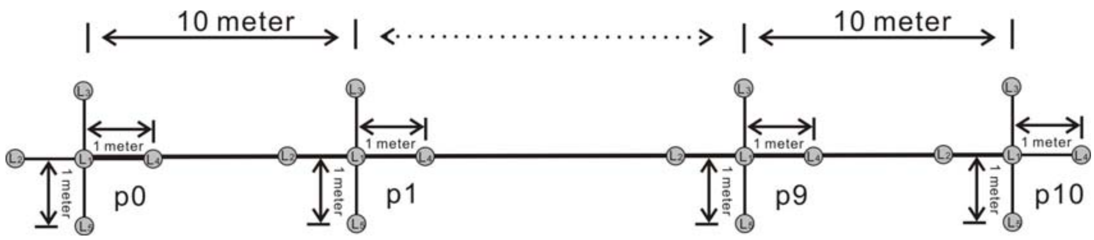

Figure 1. sampling design for a transect

3. **Acquiring highly accurate locations for each transect is necessary to validate the lidar products. For this reason we recommend using transects that can be located from either a known point that will be clearly visible in a lidar image (e.g. buildings, roads, trails, large isolated tress, rock outcrops, meadow edges) and or a highly accurate, <3m, GPS position. GPS positions should be collected in an area with good reception and transects should be located using accurate surveying methods (e.g. laser range finder, total station, or digital compass) to locate the reference point for each transect (see Figure 2). GPS measurements should be differentially corrected shortly after returning from the field and collected as geographic coordinates in NAD83. To obtain > 30 points multiple transects will be required in each stratification. Transects can be configured to radiate from a point or cross as long as accurate locations for each point can be determined. The location of each sample point will be calculated based on the coordinate of the starting point, the angle, and distance between samples. When possible use long (e.g. 100m) transects since these will have lower angle survey**

error.

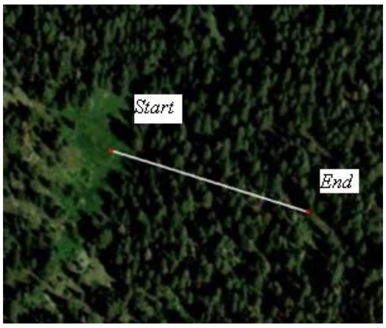

Figure 2. An example of setting a transect in the forest. Accurate GPS coordinates are more likely in the open area and can be used as starting points. A digital compass, laser range finder, or other accurate survey methods can be used to derive the starting points at locations in the forest. However transects should use GPS coordinates and/or land feature identification directly whenever possible.

4. Note that the snow image for meadow and bare earth will be very similar, but it is important to conduct the ground survey for both types as the snow-off lidar scenes are affected by vegetation growth and under canopy vegetation for this reason open areas such as meadows or thick forest with undercanopy vegetation should be included in the survey (Hopkinson, Sitar et al. 2001). Furthermore, vegetation types such as conifer, deciduous, mixed forest types should be stratified and surveyed based on canopy density (e.g. dense, medium and sparse as in Figure 3).

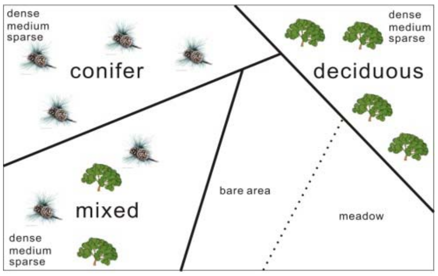

Figure 3. Sampling stratification among different land cover types

5. To characterize tree well affect select trees from south and north facing slopes to represent the observed averages for the site. Snow depth at these trees is sampled in all cardinal directions, (true N,S,E,W) with measurements spaced at 0.5 m and out to a distance of 2 m from the stem. To identify the snow depths in canopy gaps gap openings should have a diameter >2 times the height of the adjacent trees and represent a depth gradient due to the vegetations effect on the local energy balance. Depth in these locations should be measured in a linear north south transect. For the rational supporting this see (Link, Marks et al. 2004; Pomeroy, Marks et al. 2009).

6. **If the transect site is located at or near an instrument cluster site, five additional depth measurements should be made at each snow depth sensor (center point and all four cardinal directions each separated by 1 m).**

				Data format for lidar ground truth					
			depth	**depth**	**depth**	**depth**	**depth**		
ID	**lat**	**lng**	**1**	**2**	**3**	**4**	**5**	**canopy d,m,s,n**	**notes:**
	NAD83		Depth in cm					Canopy density dense, medium sparse, none	Survey and location supplemental info, e.g. grain size

Figure 4, Recommended data format.

Ellis, C. and J. Pomeroy (2007). Estimating sub-canopy shortwave irradiance to melting snow on forested slopes. 21: 2581-2593.

Hopkinson, C., M. Sitar, et al. (2001). Mapping the spatial distribution of snowpack depth beneath a variable forest canopy using airborne laser altimetry. 58th Eastern Snow Conference, Ottawa, Ontario, Canada.

Jost, G., M. Weiler, et al. (2007). "The influence of forest and topography on snow accumulation and melt at the watershed-scale." Journal of Hydrology 347(1-2): 101-115.

Link, T., D. Marks, et al. (2004). A deterministic method to characterize canopy radiative transfer properties. 18: 3583-3594.

Molotch, N. P., M. T. Colee, et al. (2005). Estimating the spatial distribution of snow water equivalent in an alpine basin using binary regression tree models: the impact of digital elevation data and independent variable selection. 19: 1459-1479.

Pomeroy, J., D. Marks, et al. (2009). The impact of coniferous forest temperature on incoming longwave radiation to melting snow. 23: 2513-2525.