Using LiDAR data to characterize forest parameters in order to improve snow modeling in the Cedar River Municipal Watershed, Seattle WA

2012 SEED Project

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1. LiDAR System Description and Specifications

This survey was performed with an Optech Gemini Airborne Laser Terrain Mapper (ALTM) serial number 06SEN195 mounted in a twin-engine Piper Chieftain (Tail Number N31PR). The instrument nominal specifications are listed in table 1.

Operating Altitude	150-4000 m, Nominal
Horizontal Accuracy	1/5,500 x altitude (m AGL); 1 sigma
Elevation Accuracy	5 - 35 cm; 1 sigma
Range Capture	Up to 4 range measurements, including 1st, 2nd, 3rd, last returns
Intensity Capture	12-bit dynamic range for all recorded returns, including last returns
Scan FOV	0 - 50 degrees; Programmable in increments of ±1degree
Scan Frequency	0 – 70 Hz
Scanner Product	Up to Scan angle x Scan frequency = 1000
Roll Compensation	±5 degrees at full FOV – more under reduced FOV
Pulse Rate Frequency	33 - 167 kHz
Position Orientation System	Applanix POS/AV 510 OEM includes embedded BD960 72-channel 10Hz (GPS+GLONASS) receiver
Laser Wavelength/Class	1064 nanometers / Class IV (FDA 21 CFR)
Beam Divergence nominal (full angle)	Dual Divergence 0.25 mrad (1/e) or 0.80 mrad (1/e)

Table 1 – Optech GEMINI specifications (http://www.optech.ca/pdf/Gemini_SpecSheet_100908_Web.pdf).

See http://www.optech.ca for more information from the manufacturer.

2. Areas of Interest.

The requested survey area consisted of four separate polygons within the Cedar River Municipal Watershed approximately 12 km west of Hyak, Washington. The main polygon measures 8 km by 5 km and encloses 40 square km; the other three small polygons are approximately +/- 1 square km each. Figure 1 (below) is an image from Google Earth showing the shape and location of the survey.

Figure 1 – Shape and location of survey polygons (red outlines) with the planned flight lines shown in white. (Google Earth).

3. Data Collection

a) Survey Dates: The survey required 2 flights; the first took place on August 31, 2012 and the second on September 1, 2012 (DOY 244 and 245).

b) Airborne Survey Parameters: Survey parameters varied considerably due to the mountainous terrain and are provided in Table 2 below.

Nominal Flight Parameters		Equipment Settings		Survey Totals	
Flight Altitude	800-1400 m	Laser PRF	50,70,100 kHz	Total Flight Time	3.9 hrs
Flight Speed	+/- 60 m/s	Beam Divergence	0.25 mrad	Total Laser Time	1.1 hrs
Swath Width	625-1100 m	Scan Frequency	50 Hz	Total Swath Area	48.9 km^2
Swath Overlap	Min 50 %	Scan Angle	± 20°	Total AOI Area	42 km^2
Point Density	7.5 p/m^2	Scan Cutoff	1.0°	Pass spacing	195 m

Table 2 – Nominal flight parameters, equipment settings and survey totals; actual parameters vary with the extreme terrain.

c) Ground GPS: Six GPS reference station locations were used during the survey: one station (PARA) was set and operated by NCALM at the lower parking area of the Paradise Inn in MRNP while another NCALM station was run at the Renton airport. Three of the remaining stations are part of UNAVCO's PBO network (see http://pbo.unavco.org/ for more information from UNAVCO); and the final station (ZSE1) is part of the CORS network. See http://www.ngs.noaa.gov/CORS/ for more information about CORS. All GPS reference observations were logged at 1 Hz. Table 3 (below) gives the coordinates of the stations and Figure 2 shows the project area and the GPS reference station locations.

GPS station	PARA	P4	P431	P432	CPXX	ZSE1
Agency	NCALM	NCALM	UNAVCO	UNAVCO	UNAVCO	FAA
Latitude	46.78431	47.50045	46.57208	46.62285	46.84008	47.28699
W Longitude	121.74201	122.21832	121.98844	121.68321	122.25650	122.18835
GRS80 Height	1618.821	-14.661	1423.978	319.241	533.982	81.998

Table 3 – Coordinates of GPS reference stations in NAD83 (2011) Epoch 2010.0000 - Ellipsoid Height in meters.

Figure 2 - Project area and GPS reference locations.

4. GPS/IMU Data Processing

Reference coordinates (NAD83 (2011) Epoch 2010.0000) for all stations are derived from observation sessions taken over the project duration and submitted to the NGS on-line processor OPUS which processes static differential baselines tied to the international CORS network. For further information on OPUS see http://www.ngs.noaa.gov/OPUS/ and for more information on the CORS network see http://www.ngs.noaa.gov/CORS/

Airplane trajectories for this survey were processed using KARS (Kinematic and Rapid Static) software written by Dr. Gerald Mader of the NGS Research Laboratory. KARS kinematic GPS processing uses the dual-frequency phase history files of the reference and airborne receivers to determine a high-accuracy fixed integer ionosphere-free differential solution at 1 Hz. All final aircraft trajectories for this project are blended solutions from at least three of the five available stations.

After GPS processing, the 1 Hz trajectory solution and the 200 Hz raw inertial measurement unit (IMU) data collected during the flights are combined in APPLANIX software POSPac MMS (Mobile Mapping Suite Version 5.2). POSPac MMS implements a Kalman Filter algorithm to produce a final, smoothed, and complete navigation solution including both aircraft position and orientation at 200 Hz. This final navigation solution is known as an SBET (Smoothed Best Estimated Trajectory).

5. LiDAR Data Processing Overview

The following diagram (Figure 3) shows a general overview of the NCALM LiDAR data processing workflow

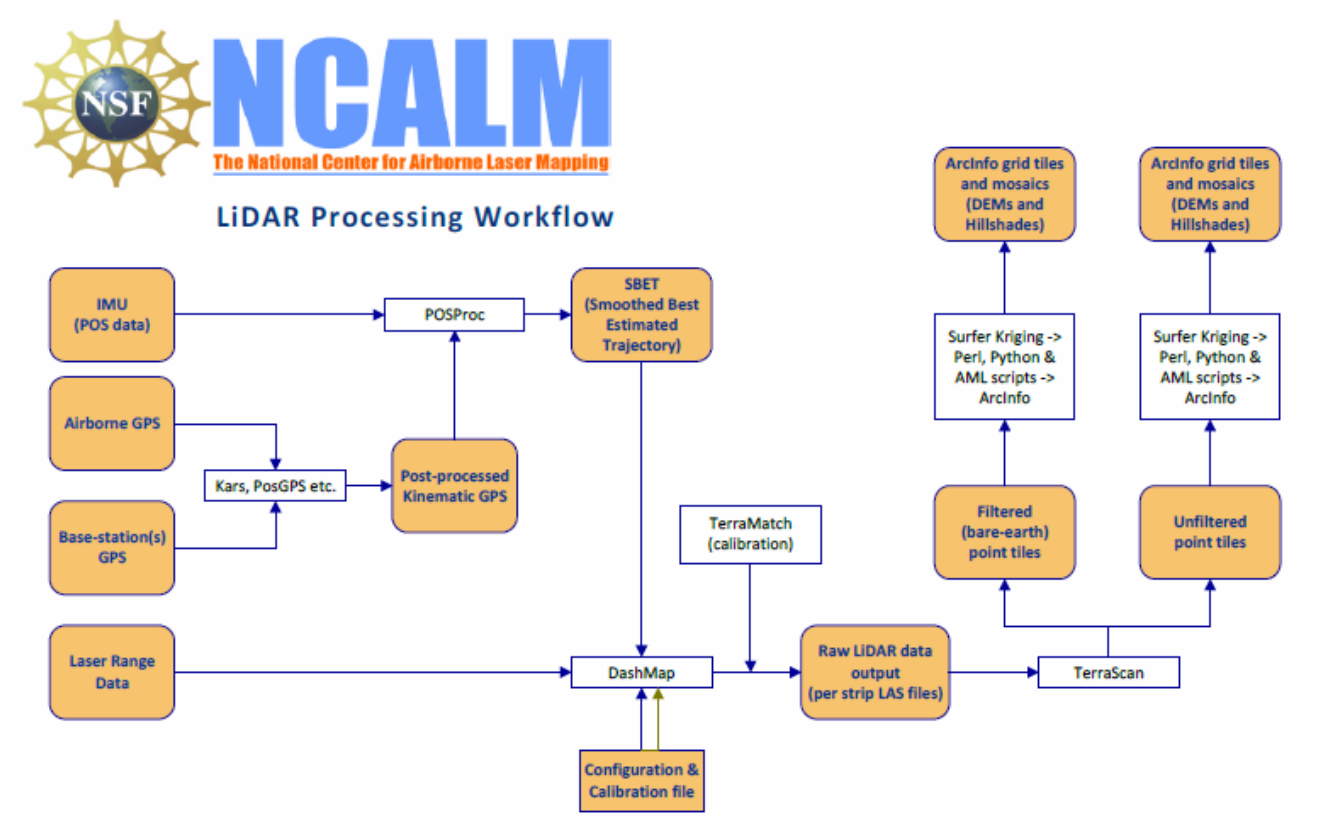

Figure 3 - NCALM LiDAR Processing Workflow

System calibration of the 3 sensor boresight angles (roll, pitch, and yaw) and scanner mirror scale factor is done by automated means using TerraSolid Software (TerraMatch). Project lines and off-project lines flown with opposite headings combined with perpendicular cross lines are used as input to TerraMatch (Version 12.009). The calibration values are checked on a flight-flight basis.

Classification done by automated means using TerraSolid Software (TerraScan Version 12.017). http://www.terrasolid.fi/en/products/4

NCALM makes every effort to produce the highest quality LiDAR data possible but every LiDAR point cloud and derived DEM will have visible artifacts if it is examined at a sufficiently fine level. Examples of such artifacts include visible swath edges, corduroy (visible scan lines), and data gaps. A detailed discussion on the causes of data artifacts and how to recognize them can be found here:
http://ncalm.berkeley.edu/reports/GEM_Rep_2005_01_002.pdf .
A discussion of the procedures NCALM uses to ensure data quality can be found here:
http://ncalm.berkeley.edu/reports/NCALM_WhitePaper_v1.2.pdf

NCALM cannot devote the required time to remove all artifacts from data sets, but if researchers find areas with artifacts that impact their applications they should contact NCALM and we will assist them in removing the artifacts to the extent possible – but this may well involve the PIs devoting additional time and resources to this process.

6. Data Deliverables

a) **Horizontal Datum**: NAD83 (2011)
b) **Vertical Datum:** NAVD88 (GEOID 03)
c) **Projection:** UTM Zone 10N – meters.
d) **File Formats:**

1. Point Cloud in LAS format (Version 1.2), classified as ground or non-ground, in 1 km square tiles.
2. ESRI format 1-m DEM from ground classified points.
3. ESRI format 1-m Hillshade raster from ground classified points
4. ESRI format 1-m DEM from all points (canopy included).
5. ESRI format 1-m Hillshade raster from all points (canopy included).

e) **File naming convention:** 1 Km tiles follow a naming convention using the lower left coordinate (minimum X, Y) as the seed for the file name as follows: XXXXXX_YYYYYYY. For example if the tile bounds coordinate values from easting equals 610000 through 611000, and northing equals 5243000 through 5244000 then the tile filename incorporates 610000_5243000. These tile footprints are available as an AutoCAD DXF or ESRI shapefile. The ESRI DEMs are single mosaic files created by combining together the 1KM tiles. Their name consists of prefix ‘ume’ and the lowest Easting coordinate rounded to the nearest 1000, for e.g. ‘ume604000’. The hillshade files have a prefix ‘sh’ after the name, for e.g. ‘ume604000sh’

7. Notes

This project was flown in tandem with 2 other seed projects in Mount Rainier National Park. Geoid03 was used in order to maintain compatibility with these NSF seed projects and the 2008 Watershed Sciences LiDAR survey of MRNP.

Figures 4 and 5 (below) are images of the LiDAR point densities achieved on this project.

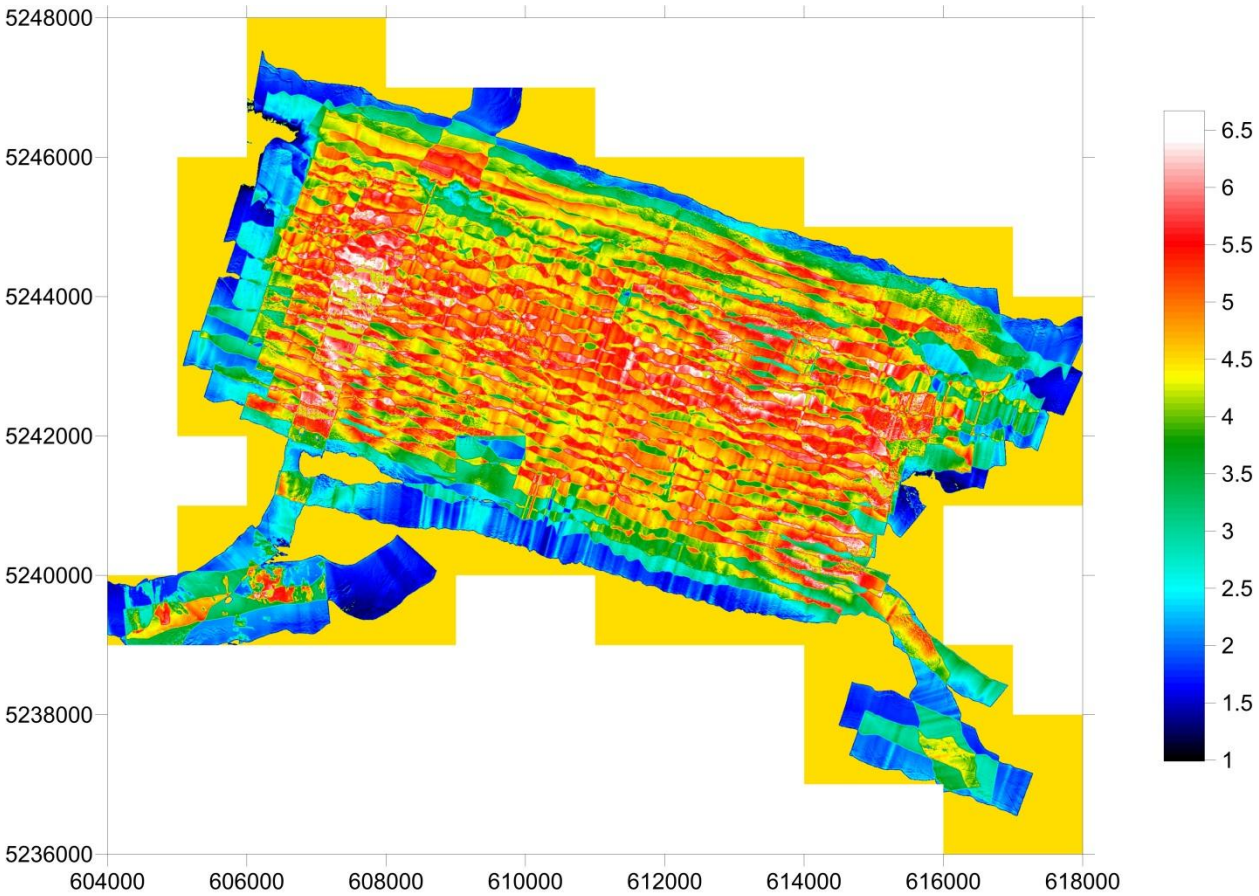

Figure 4 - Laser shots fired per square meter.

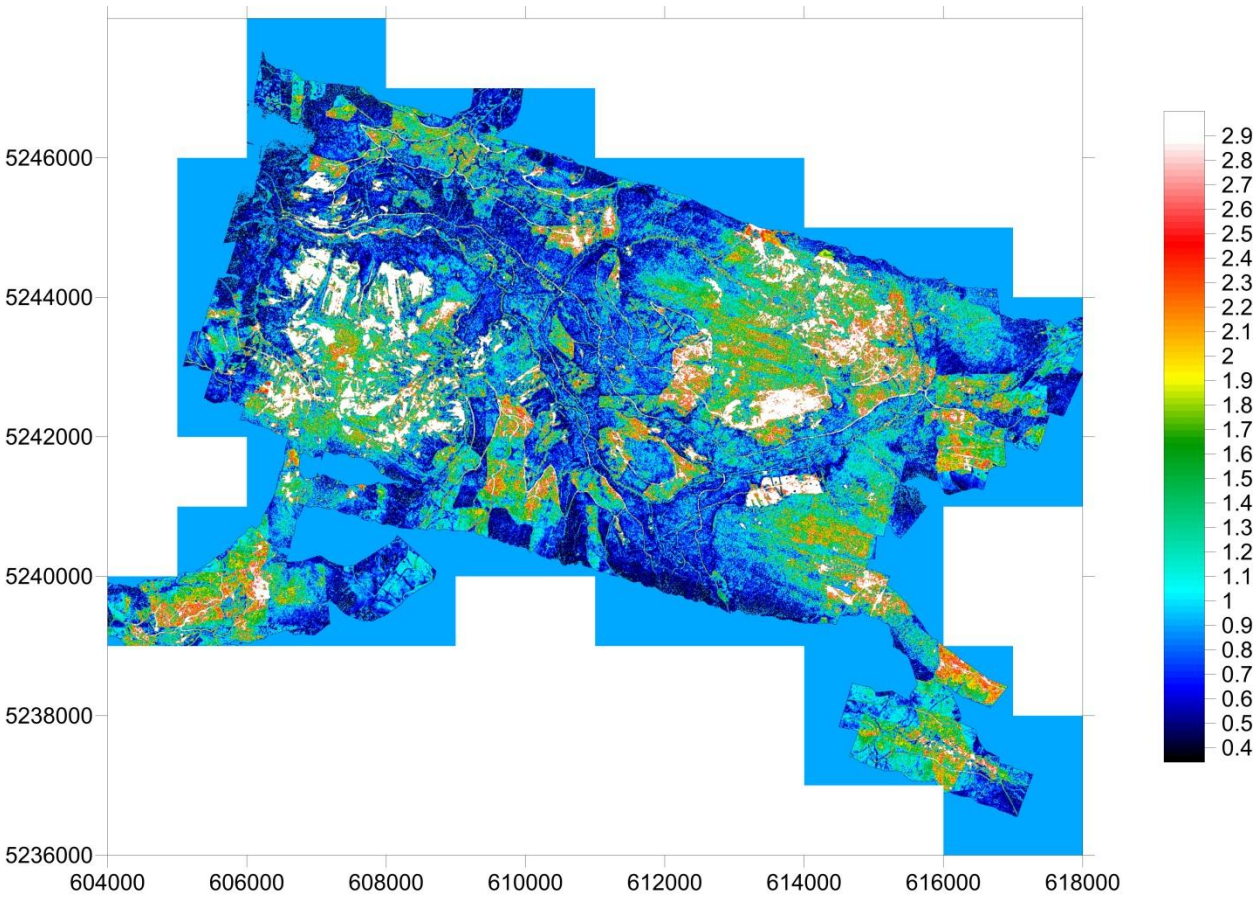

Figure 5 - ground class shots per square meter.