Lidar Data and Cooperative Research at Panther Creek, Oregon

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Abstract

A 2,300 hectare forested watershed in the coastal mountain range of Oregon, USA is the subject of collaborative research with a principal objective of evaluating uses of lidar and other remotely sensed data for the development of detailed forest inventories. Panther Creek watershed (45° 18’ N, 123° 21’ W) is at an elevation of 100-700 m, about 57 km southeast of Portland. Major species are Douglas fir, western hemlock, western red cedar, grand fir, red alder and bigleaf maple; tree heights are up to 60 m. The Bureau of Land Management and other cooperators are using the watershed to test and develop methodology for detailed stand level forest inventories, the detailed mapping of soils and slope stability, and the assessment of other ecosystem functions.

Wall-to-wall discrete return lidar has been acquired under leaf-off conditions annually starting in 2007, and will continue through 2012. Leaf-on discrete return lidar was collected in 2007 and 2010 and will be collected in 2012. Surveys used Leica ALS50 Phase II or ALS60 lasers; pulse density is about 8 per m^2; in 2010 selected areas received multiple passes, raising the density up to 50 pulses per m^2. Return intensities are being corrected for power output and camera-to-target distances. Full waveform lidar leaf-on data was acquired in 2010, as was 4-band color-infrared imagery using a Leica ADS40 camera. Also in 2010, hyperspectral data from a Hymap sensor was acquired. Eighty-four cadastral-surveyed 0.08 ha stem-mapped permanent plots were installed, mostly in 2009; measurement will be repeated after the 2012 growing season. Several other imagery sources are available.

A project goal is to compare and evaluate methodologies. All data are available to research groups wanting to participate. Data are well documented and organized, and include cut-outs of the remotely sensed data at each of the plot locations.

Key words: crown delineation, fused data, cooperative research.

1. Introduction

Wall-to-wall lidar is increasingly available for large forested areas in the western United States. Acquisition is often funded by public agencies, though private companies are also funding some acquisition campaigns. The State of Oregon has recently been acquiring lidar data at a rate of over 100,000 ha. per year (Oregon Department of Geology and Mineral Industries, 2009). Current campaigns have lidar densities averaging eight pulses per m^2. The expense of acquiring the data can often be justified without considering the use of the data for intensive forest inventory. However, public agencies including the U.S. Bureau of Land Management (BLM) are using the lidar data for stand delineation and estimation of per hectare attributes. The later are typically based on analysis techniques similar to those described by Næsset (2002).

There is a common interest in exploiting the lidar data and fused imagery to obtain detailed forest inventories. Of particular interest are inventories with better information on species distribution and the mapping of dominant and co-dominant trees. Additionally, inferences related to habitat, fire risk, down woody debris and numerous other landscape feature are of interest. To research and evaluate suitable methods, the BLM, together with other governmental agencies and private parties have a cooperative research effort focusing on the Panther Creek watershed. The watershed has been the target of multiple efforts to collect remote sensing data, particularly airborne lidar data. In support of the inventory effort, stem-mapped forest plots have been measured, and will be remeasured after three years. The U.S. Environmental Protection Agency (EPA) is conducting an intensive soil survey of the area. Other data gathering efforts are ongoing, including the collection of terrestrial lidar data and meteorological data.

2. Panther Creek Watershed

The Panther Creek study area is a 2300 hectare forested watershed in the east side of the coastal mountain range of Oregon, USA. It is located 57 km southeast of Portland, Oregon, USA at 45° 18’ N, 123° 21’ W. The elevation ranges from 100 to 700 m. Annual precipitation is about 150 cm. The forests are mainly planted or natural stands of Douglas fir, with significant amounts of western hemlock, western red cedar, grand fir, red alder, bigleaf maple and several other species. Tree heights are up to 60 m. Management intensity throughout the watershed has been variable, with varying planting densities, and both thinned and unthinned regimes. The ecoregion classification is “Cascade mixed forest”(Bailey, 1995, p. 39-42).

3. Panther Creek Data

Much of the data for the Panther Creek project has already been collected. However, some data collection efforts, including soil sampling and meteorological data are ongoing, and other efforts are just getting started or are in the planning phase.

3.1 Lidar data

Six multi-point ALS data sets and one full waveform data set have already been collected (Table 1); two more lidar acquisitions are anticipated. All data acquisitions have similar requirements for off-nadir angle (± 14°), flight line overlap (100%), and pulse density (≥8 pulses /m^2). Ground densities average about 0.7 pulses per /m^2 in the leaf-off data sets, and 0.5 pulses per m^2 in the leaf-on data sets. Horizontal 1-sigma absolute accuracies for slopes < 20% are 30 cm or less. Line to line divergence is typically less than 10 cm. Additionally, the 2010.07.15 multi-point data set had some flight lines replicated so as to achieve very high pulse densities (≥ 50 pulses / m^2) for portions of the study area. The Leica ALS60 unit recorded data from the automatic gain control; these can be used to improve normalized intensities.

Table 1: Present lidar data sets for Panther Creek.

Season	Date	Type	Instrument
2007 Leaf-on	2007.09.03	1-4 pts	Leica ALS50 - Phase II
2007 Leaf-off	2007.12.08	1-4 pts	Leica ALS50 - Phase II.
2008 Leaf-off	2009.03.28	1-4 pts	Leica ALS50 - Phase II
2009 Leaf-off	2010.03.29	1-4 pts	Leica ALS50 - Phase II
2010 Leaf-on	2010.07.15	1-4 pts	Leica ALS60
2010 Leaf-on	2010.07.15	Full wave	Leica ALS50 - Phase II + Digitizer
2010 Leaf-off	2011.04.17	1-4 pts	Leica ALS60

3.2 Other remotely sensed data

The other remotely-sensed data sets include imagery from public sources and acquisitions specific to Panther Creek (Table 2). Three-band (RGB) natural color imagery from the National Agricultural Imagery Program (NAIP) for 2005 and 2009 is available. Resolution is 1 m; horizontal accuracy is quoted as ± 6 m to true ground. Quickbird Imagery in 2008 includes Panchromatic (blue visible - NIR) with 0.6 m pixels, and color with 2.4 m pixels. High resolution 4-band imagery was acquired in March, 2010 with a Leica ADS-40 camera at 30 cm ground sample distance (GSD); one image with 30 cm pixels was ortho-rectified to a 20 m bare earth DEM and another was ortho rectified to a 0.3 m canopy surface model derived from the lidar data; an accuracy assessment in comparison with common linear features identified in the lidar data indicates spatial accuracy of about 40 cm. Hyperspectral data were collected with an Integrated Spectronics Hymap sensor. Four 32-band spectrometers were used with all data collected at a 3 m GSD. The hyperspectral data was collected without extensive ground survey pre-marks; in comparison with the lidar data there is a mean positional error of 6.3 m and a standard deviation of 4.5 m. Four flat black landscape targets (15 m × 15 m) had been established under the canopy for establishing spectral signatures. GeoEye-1 satellite imagery was acquired in April, 2011 and July, 2011; the NIR image is 0.46 m GSD, and the RGB image is 1.9 m GSD; pixel size for the images is 0.5 m.

Table 2: Other remotely sensed data sets for Panther Creek.

Date	Type	Details
2005.06.28	RGB	NAIP, Leica ADS 40 (1 m pixel)
2008.06.29	NIR, RGB, pan	QuickBird (0.6 m panchromatic, 2.4 m color)
2009.06.23	RGB	NAIP, Leica ADS 40 (1 m pixel)
2010.03.19	NIR,RGB	Leica ADS 40 (30 cm GSD)
2010.07.30	Hyperspectral	Integrated Spectronics Hymap (3 m GSD)
2011.04.23	NIR, RGB, pan	GeoEye-1 (41 cm GSD pan, 165 cm GSD Color)
2011.07.06	NIR, RGB, pan	GeoEye-1 (41 cm GSD pan, 165 cm GSD Color)

3.3 Inventory sampling plan and tree measurements

An enhanced ability to create inventories is a project objective. However, the derivation of an inventory for Panther Creek is not a specific objective. Before starting to develop a sampling plan, the 2007 leaf-off lidar data and the 2005 NAIP imagery was used to delineate 144 stands. The primary ground data was to be a series of fixed-area stem-mapped plots. Sampling was to be limited to stands with cooperating public owners and cooperating large forestry landowners, excluding stands which had been recently clear-cut. There are 64 such stands with a combined area of 1451 ha. The 2007 leaf-off lidar data was used to derive several statistics for 30 m grid cells throughout the watershed; the grid cell statistics were aggregated to provide stand-level statistics. The statistics included HPCT90: the 90th percentile of the first returns above 2m; RH10: the ratio of HPCT10 to HPCT90; CC: the number of 1st returns greater than 2m divided by the total number of first returns. Additionally the NAIP photography was used to obtain a visual estimate of percentage of each stand in hardwood. The coniferous stands (> 80% conifer) were divided into three height groups with HPCT90 cut-points at 20.3 m and 31m. The tall stands (> 31 m) were further dived into three groups based on RH10, a measure related to depth of crown. The intermediate height stands (20.3 m - 31 m) were similarly sub-divided. The short stands were divided into three groups based on CC, a statistic assumed to be related to crown closure. Thus nine coniferous strata were defined.

A set of nine “modelling plots” was selected by choosing one stand in each of the nine strata, subjectively favoring the more extreme stratification statistics; within the nine selected stands, sample locations were randomly selected; the first location which had lidar statistics similar to those for the average statistics for the whole stand was accepted.

A design based sample was also created for the coniferous plots. Within each strata one stand was selected with probability proportional to area. Within each selected stand, three plot locations were randomly selected. Plots selected this way can be used to make valid statistical inferences, where as the “modelling plots” would not be suitable for that purpose. Additionally two plots locations were randomly selected within two of the non-conifer stands (< 80% conifer); and two plot locations were arbitrarily selected in riparian area.

Yet another set of thirty-six plots were installed in conjunction with the soil survey; the location of these plots was not dependent upon the forest conditions. Three more plots were established by subjectively finding locations on the ground that appeared to be challenging due to the multi-story nature of the location; one more was located in a patch of red cedar, and two more were selected to capture specific edge condition between adjacent stands. All together, some eighty-four plot locations were selected.

Plot centers were established using GPS. Exact locations were subsequently determined within 0.25 m with a cadastral survey. Plots are circular, with all trees whose face is within 16.05 m of the center being measured. Effective plot area is slightly greater than 0.08 ha. Each tree was numbered with paint. Measurements included tree location (azimuth and direction), species, diameter (DBH), total height, and height to base of live crown. Live/dead status, broken-tops and extreme lean were noted. A subset of the trees were bored to obtain 5-year increment, sapwood area, and breast-height age. Tree measurements for seventy-eight plots were taken in the latter half of the 2009 growing season, or after the end of that growing season. Measurements for the final six plots were taken before the start of the 2011 growing season.

3.4 Other field data

In the summer of 2011, downed woody debris is being measured on all plots; large piece sizes anywhere on the full plot are being recorded; smaller pieces are measured on a smaller central portion of the full plot. Additionally hemispherical photos have been taken and ocular estimates of vegetation cover will be made. Terrestrial lidar data are being obtained at a majority of the plots during the 2011 growing season.

The EPA is conducting an intensive soil survey at Panther Creek in conjunction with efforts to estimate aboveground and below-ground carbon, characterize the hydro geomorphology, conduct a systematic terrain analysis, and establish a network of weather and soil monitoring stations within Panther Creek. The analysis at Panther Creek will guide the development of a soil-landscape-climate model for the coast mountain range. Completed work includes the description and sampling of thirty-five pedons, with soil samples being analyzed for physical and chemical properties.

3.5 Analyses

Analyses directed towards improved inventories will rely heavily upon already-developed techniques, with an objective of comparing the quality of results obtained from various combinations of data sources and methodologies. The first-named author of this paper is collaborating with others to apply per unit area techniques and individual tree crown delineation methods to lidar and imagery data sets. Per unit area analyses are being undertaken with the Fusion Software (McGaughey, 2009). Crown delineation using both lidar data and imagery will be undertaken with ITC Suite (Gougeon, 2010). Another of the initial efforts will be three-dimensional crown segmentation of the full waveform data using techniques developed by

Reitberger *et al.* (2010). These segmentation efforts will be followed by efforts to better co-locate the various data sources and the field data, and to cross identify stem mapped trees and delineated crown segments. Automated object-based fusion is a possibility.

Individual crown based methods are generally not expected to outperform area based methods of estimation for yield statistics (Peuhkurinen *et al.*, 2011). Indeed individual crown methods can be seriously biased unless coupled with rigorous sampling methodology and models which account for the inability to correctly isolate all crowns (Flewelling, 2008). However, the individual crown based methods have the potential to improve species prediction, particularly in mixed species stands. Similarly individual crown methods have the potential of more fully utilizing high density lidar data fused with high resolution imagery. The multiple sources of remotely sensed data provide an opportunity to test many combinations of methods and fused data sources.

4. Cooperative Research and Data Sharing

The Panther Creek cooperative research project currently involves over forty researchers and land managers representing federal, state and local agencies, landowners, a lidar provider, universities, and consultants. The project is loosely organized but does have a formal operating policy, a policy committee and a science committee.

A data sharing agreement exists, under which all of the airborne lidar data, other remotely sensed data, the field measurements for the stem mapped plots, and other selected data will be freely shared with any researchers who choose to participate. Additionally, much of the data will be made publicly available later; those data might not include some of the imagery which was licensed to the BLM but is not owned by the BLM. Most of the data relevant to forest inventory, including the stem-mapped plot data, the airborne lidar data and other remotely sensed data are available for sharing now. The tree data will subsequently be enhanced by “growing” the trees forward or backward to the dates of the lidar acquisitions. The data sharing mechanism is a password-protected web site, supplemented by the mailing of portable disks.

Persons or organizations wishing to participate in the data sharing are invited to contact the authors of this paper. Participants will be encouraged - but not required - to share a statement of their research objectives; and hopefully to share various results. Research on crown segmentation, object-based fusion, and species imputation is especially encouraged.

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