SEEING THE FOREST FLOOR THROUGH THE TREES – an evaluation of SPL’s ability to measure ground elevation

Presented by Murray Woods on behalf of:

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Scott Charbonneau, Mapping and Geomatics Analytical Technician (A) (MNRF, Provincial Mapping)
Joanne White – Research Scientist - Canadian Forest Service — Peter Arbour, Melissa Vekeman Canadian wood fibre centre
Exploring the Innovation Potential of Single Photo LiDAR for enhancing Ontario's Forest Inventories

1. Characterizing terrain under varying forest types and canopy densities;

2. Quantifying the comparative performance of SPL in an area-based approach to forest inventory attributes & incremental advantages to supporting Individual Tree Approach inventories.

Co-Leads:
Dr. Joanne White – CFS
Murray Woods – MNRF (retired)
Melissa Vekeman – CWFC
Jordan MacMillan – CIF

Project Partners:
Annie Morin – CNL
David Belanger – CCMEO
Dr. Jili Li - FPinovations
Luxury of multiple LiDAR Datasets for PRF

Datasets chosen for comparison

<table>
<thead>
<tr>
<th>Collection Date</th>
<th>Sensor</th>
<th>Season</th>
<th>Altitude (m)</th>
<th>Vertical Datum</th>
</tr>
</thead>
<tbody>
<tr>
<td>31/05/2019</td>
<td>Leica SPL100</td>
<td>~Leaf-off</td>
<td>3,800</td>
<td>CGVD2013</td>
</tr>
<tr>
<td>31/05/2019</td>
<td>Leica SPL100</td>
<td>~Leaf-off</td>
<td>2,050</td>
<td>CGVD2013</td>
</tr>
<tr>
<td>02/07/2018</td>
<td>Leica SPL100</td>
<td>Leaf-on</td>
<td>3,800</td>
<td>CGVD2013</td>
</tr>
<tr>
<td>17/08/2012 – 20/08/2012</td>
<td>Riegle 680i</td>
<td>Leaf-on</td>
<td>750</td>
<td>CGVD28</td>
</tr>
</tbody>
</table>
Attractiveness of Single Photon LiDAR

- Acquisition faster at higher altitudes – 3800m vs 750m (LML)
- More cost effective for large capture areas
- Wider swath width captured
- Increased point density

Petawawa Research Forest / CNL Leaf-on 2018 LiDAR Characteristics

<table>
<thead>
<tr>
<th>Classification</th>
<th>Point Density</th>
<th>Point Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All Returns points /m²</td>
<td>Last Returns points /m²</td>
</tr>
<tr>
<td>Vegetation (3,4,5)</td>
<td>35.8</td>
<td>33.3</td>
</tr>
<tr>
<td>Ground (2)</td>
<td>4.2</td>
<td>4.2</td>
</tr>
<tr>
<td>All (2,3,4,5)</td>
<td>36.7</td>
<td>34.4</td>
</tr>
</tbody>
</table>
Canada Centre for Mapping and Earth Observation (CCMEO) Analysis – David Belanger

- Assessed the 2018 SPL LiDAR dataset on behalf of the Canadian Forest Service and the Canadian Wood Fibre Centre.
- Study included a vertical accuracy assessment based upon only 9 RTK survey points, none of which were in vegetated areas.
- Concerns noted about the relative low density of ground returns produced by SPL in some vegetated areas, in comparison to linear mode LiDAR.
- Recommended that further assessments be conducted in vegetated areas using a sufficient number of checkpoints.

<table>
<thead>
<tr>
<th>LiDAR Dataset</th>
<th>Ground Return Density% (&gt; 2 pts/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012 LML Leaf-on</td>
<td>34%</td>
</tr>
<tr>
<td>2018 SPL Leaf-on</td>
<td>31%</td>
</tr>
<tr>
<td>2019 SPL Leaf-off (3.8km)</td>
<td>-</td>
</tr>
<tr>
<td>2019 SPL Leaf-off (2km)</td>
<td>-</td>
</tr>
</tbody>
</table>

*Based on a 20 m raster where more than 2 ground returns/m² recorded

**Intersection of all dataset extents, minus water
## Ground Point Density of Survey Plots by Landcover*

<table>
<thead>
<tr>
<th>Landcover</th>
<th>Ground Point Density / m²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2019 SPL 2km</td>
</tr>
<tr>
<td>Black Spruce</td>
<td>4.3</td>
</tr>
<tr>
<td>Jack Pine</td>
<td>5.9</td>
</tr>
<tr>
<td>ConPlant</td>
<td>4.0</td>
</tr>
<tr>
<td>Red/White Pine</td>
<td>4.6</td>
</tr>
<tr>
<td>Intolerant Hardwood</td>
<td>15.4</td>
</tr>
<tr>
<td>Tolerant Hardwood</td>
<td>6.1</td>
</tr>
<tr>
<td>Mixedwood</td>
<td>5.4</td>
</tr>
<tr>
<td>Low Vegetation</td>
<td>4.3</td>
</tr>
<tr>
<td><strong>Average:</strong></td>
<td><strong>5.2</strong></td>
</tr>
</tbody>
</table>

* 2007 Inventory Polygons
Qualitative analysis to assess quality of the bare earth raster DTM

**Intent**
To ensure successful “downstream” use of the product to meet a range of business needs - such as:

- forestry operations
- hazard mapping and flood risk assessment
- wetland mapping,
- rural-urban planning.

**Evaluation Criteria Chosen**

- Point density of both last ground return points are homogenous, regularly spaced, and will meet user needs over a range of applications.

- Ground points have been correctly classified (no manmade structure or vegetation remains, no gaps except over water bodies).

- Ground surface is consistent and well defined, free from spurious errors, artifacts, and omissions across the landscape under a variety of land cover conditions and topographic areas including floodplains, river valleys and stream channels.

- No obvious anomalies due to sensor malfunction, aircraft fluctuations, or systematic processing are present (e.g., data voids, spikes, sinks, ridges, cornrows, hatching, etc.).
Qualitative analysis to assess quality of the bare earth raster DTM

Sample Sites Selected

- Site 1: Integrated wetland and stream areas
- Site 2: Deciduous forest
- Site 3: Coniferous forest
- Site 4: Stream valley lands
- Site 5: Black spruce wetland areas
- Site 6: Conifer plantations
- Site 7: Urban-like agricultural/rural areas
Site 1: Integrated wetland and stream areas
Site 1: Integrated wetland and stream areas

* Similar quality from both 2019 altitude acquisitions
Site 2: Deciduous Forest
Site 2: Deciduous Forest
Site 2: Deciduous Forest

2019 SPL Leaf-off
Site 5: Black Spruce – Intolerant Hardwoods
Site 5: Black Spruce – Intolerant Hardwoods
Site 5: Black Spruce – Intolerant Hardwoods
Site 5: Black Spruce – Intolerant Hardwoods
Project to quantify the comparative performance of SPL in characterizing terrain under varying forest types and canopy densities

Forest Types/Conditions

1. Tolerant Hardwood
2. Red/White Pine
3. Black Spruce
4. Mixedwood
5. Intolerant Hardwood
6. Conifer Plantations
7. Jack Pine
8. Low Vegetation
9. Open Areas
Single Photon Mission Required Accuracy Standards

The SPL dataset was produced to meet accuracy standards for Ontario Digital Geospatial Data for a 10-cm Vertical Accuracy Class equating to:

**Non-vegetated Vertical Accuracy (NVA) of** $\pm 19.6$-cm at 95% confidence level

**Vegetated Vertical Accuracy (VVA) of** $\pm 29.4$-cm at the 95% percentile.
Natural White & Red Pine Stand

2018 SPL Leaf-on  Ground Returns
Jack Pine Stand

Profile H1 - Jack Pine

Distance (m)

Elevation (m)

- 2012 Linear
- 2019 SPL 12k
- 2019 SPL 6k
- SPL 2018
- Survey

Ground Returns
Median absolute difference in elevation from reference (RTK)
Median; Box: 25%-75%; Whisker: Non-Outlier Range

- 2012 LML
- 2018 SPL
- 2019 SPL (1800 m)
- 2019 SPL (3800 m)
Testing against accuracy standards for a 10-cm Vertical Accuracy Class equating to:

**Non-vegetated Vertical Accuracy (NVA)** of +/- 19.6-cm at 95% CI

**Vegetated Vertical Accuracy (VVA)** of +/- 29.4-cm at the 95% Percentile

### Preliminary Results

<table>
<thead>
<tr>
<th>Category</th>
<th>Measure (cm)</th>
<th>2019 SPL 2-km Leaf-off (N)</th>
<th>2019 SPL 3.8-km Leaf-off (N)</th>
<th>2018 SPL Leaf-on (N)</th>
<th>2012 Linear Leaf-on (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Veg</td>
<td>NVA (95th Percentile)</td>
<td>14.1 (79)</td>
<td>16.3 (79)</td>
<td>13.8 (85)</td>
<td>17.3 (85)</td>
</tr>
<tr>
<td>Vegetated</td>
<td>VVA (95th Percentile)</td>
<td>14.5 (221)</td>
<td>16.9 (221)</td>
<td>23.4 (236)</td>
<td>18.7 (236)</td>
</tr>
</tbody>
</table>

### Classified (95th Percentile)

<table>
<thead>
<tr>
<th>Category</th>
<th>Measure (cm)</th>
<th>2019 SPL 2-km Leaf-off (N)</th>
<th>2019 SPL 3.8-km Leaf-off (N)</th>
<th>2018 SPL Leaf-on (N)</th>
<th>2012 Linear Leaf-on (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road</td>
<td>Gravel Road</td>
<td>14.8 (47)</td>
<td>18.6 (47)</td>
<td>10.8 (53)</td>
<td>18.3 (53)</td>
</tr>
<tr>
<td></td>
<td>Asphalt Road</td>
<td>13.7 (32)</td>
<td>12.4 (32)</td>
<td>15.1 (32)</td>
<td>16.2 (32)</td>
</tr>
<tr>
<td>Conifer</td>
<td>Black Spruce</td>
<td>13.8 (37)</td>
<td>15.0 (37)</td>
<td>29.5 (37)</td>
<td>18.8 (37)</td>
</tr>
<tr>
<td></td>
<td>Jack Pine</td>
<td>7.0 (15)</td>
<td>15.1 (15)</td>
<td>7.4 (15)</td>
<td>7.7 (15)</td>
</tr>
<tr>
<td></td>
<td>ConPlant</td>
<td>11.9 (21)</td>
<td>14.5 (21)</td>
<td>15.8 (36)</td>
<td>20.1 (36)</td>
</tr>
<tr>
<td></td>
<td>Red/White Pine</td>
<td>13.6 (27)</td>
<td>20.8 (27)</td>
<td>16.2 (27)</td>
<td>17.4 (27)</td>
</tr>
<tr>
<td>Hardwood</td>
<td>Hardwood</td>
<td>14.9 (37)</td>
<td>15.6 (37)</td>
<td>17.6 (37)</td>
<td>19.7 (37)</td>
</tr>
<tr>
<td></td>
<td>Tolerant</td>
<td>13.6 (35)</td>
<td>14.0 (35)</td>
<td>15.6 (35)</td>
<td>18.1 (35)</td>
</tr>
<tr>
<td></td>
<td>Intolerant</td>
<td>14.9 (37)</td>
<td>15.6 (37)</td>
<td>17.6 (37)</td>
<td>19.7 (37)</td>
</tr>
<tr>
<td>Other</td>
<td>Mixedwood</td>
<td>17.6 (34)</td>
<td>19.3 (34)</td>
<td>26.5 (34)</td>
<td>16.3 (34)</td>
</tr>
</tbody>
</table>

|          | Low Vegetation | 8.7 (15) | 5.0 (15) | 24.7 (15) | 23.4 (15) |

**Note:** All values in cm
Thank You & Thank You to the Project Team

- **Thomas Krahn**, Mapping and Geomatics Data Analyst (MNRF, Provincial Mapping)
- **Craig Onafrychuk**, Team Leader (MNRF, Provincial Mapping)
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