Case study of Lidar in cold climate and complex terrain in Canada

Results of the 2012-2013 measurement campaign in Rivière-au-Renard (Québec) Canada

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At Winterwind 2014

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Topics

• Objectives of the measurement campaign
• Infrastructure used for the study
  – Met mast MMV2 – 126 m height & Lidar Léosphère Wincube v2
• Measurement campaign
  – Site description, acquisition period, QC, Communications features
• Performance of the Lidar in CC & complex terrain
• Data availability of the Lidar in Cold Climate & complex terrain
  – Recovery rate of the Lidar & Long term analysis
• Recommendations
• Future projects
Objectives of the measurement campaign

- Verify the long term data availability of the Lidar in complex terrain and cold climate;
- Gain insight into LiDAR bias in complex terrain;
- Continue the previous measurement campaign done in 2011-2012 at Anse-a-Valleau presented at CanWEA.
TechnoCentre éolien (TCE)

Over 1500MW in operation (Dec 2013)

Murdochville’s met masts
SNEEC

- Two 2.05 MW Repower MM92 CCV

- Commissioned March 2010

- Icing & complex terrain

- R&D, technological transfer, technological validation, performance assessment.

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of wind turbines</td>
<td>2</td>
</tr>
<tr>
<td>Model</td>
<td>REpower MM92 CCV</td>
</tr>
<tr>
<td>Rated power / Wind turbine</td>
<td>2.05 MW</td>
</tr>
<tr>
<td>Frequency</td>
<td>60 Hz</td>
</tr>
<tr>
<td>Rotation speed</td>
<td>7.8 – 15 RPM</td>
</tr>
<tr>
<td>Start-up speed</td>
<td>3 m/s (10.8 km/h)</td>
</tr>
<tr>
<td>Shut-down speed</td>
<td>24 m/s (86.4 km/h)</td>
</tr>
</tbody>
</table>

IEC wind class: 2
Annual average wind speed: 7.9 m/s
Topography: Complex site with high turbulence, near the sea
Temperature: -30°C to +30°C
Ice conditions: Up to 40 mm of ice
Infrastructure used for the study – MMV2

<table>
<thead>
<tr>
<th>Met masts name</th>
<th>MMV2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (a.g.l.)</td>
<td>126 m</td>
</tr>
<tr>
<td>Altitude (at the base)</td>
<td>325 m</td>
</tr>
<tr>
<td>Tower type</td>
<td>Tripod permanent guyed wire CSA S37-01</td>
</tr>
<tr>
<td>Location</td>
<td>Rivière-au-Renard (QC)</td>
</tr>
</tbody>
</table>

Sensors installed over 15 levels:
- 8 anemometers (heat/unheat)
- 5 wind vanes (heat/unheat)
- 5 thermometers
- 4 differential temperature probes
- Vertical anemometer
- Ceilometer
- Barometer
- Pyranometer
- Hygrometer
- Ice meter (detector)

Real-time data storage with Osisoft-PI
Introduction - Topographical layout SNEEC
Infrastructure used for the study –

WindCube Lidar v2 & acquisition period

<table>
<thead>
<tr>
<th>Season</th>
<th>From</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer</td>
<td>01-08-2012</td>
<td>12-10-2012</td>
</tr>
<tr>
<td>Winter</td>
<td>01-02-2013</td>
<td>14-03-2013</td>
</tr>
</tbody>
</table>

More than 4 months
Infrastructure used for the study

11 levels of measured provided from LIDAR:
- 40 m
- 55 m
- 76 m
- 80 m
- 100 m
- 103 m
- 126 m
- 140 m
- 160 m
- 180 m
- 200 m
Measurement campaign – data acquisition

CAN-BUS communication linked with Osisoft-PI archived system

From Acquisition Node Clock: GMT-5

Synchronize on the same timestamp each time per day
Measurement campaign – QC

Quality control with more than 32 tests covering:

1- Functionnal check

2- Area check

3- Trend check

4- Cross comparison check

5- Status notification including special meteorologic detection (ex: icing, low temperature, no cloud)
# Measurement campaign – site description

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Units</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowest temperature</td>
<td>-26.15 °C</td>
<td>Site conform to GL Technical note 069</td>
</tr>
<tr>
<td>Highest wind speed</td>
<td>31.5 m/s</td>
<td>During the measurement campaign</td>
</tr>
<tr>
<td>Snow accumulation</td>
<td>1 meter height</td>
<td></td>
</tr>
<tr>
<td>Remote area</td>
<td>At 7 km from the nearest village</td>
<td>Low CNR measured during the winter</td>
</tr>
</tbody>
</table>
Performance of the Lidar in CC & complex terrain

WS Lidar vs met mast at 80 m a.g.l. with data availability > 70%

\[
y = 1.0035x \\
R^2 = 0.9869
\]
Performance of the Lidar in CC & complex terrain

<table>
<thead>
<tr>
<th>R² table</th>
<th>All seasons</th>
<th>Summer</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>34 m</td>
<td>0.9848</td>
<td>0.9843</td>
<td>0.9836</td>
</tr>
<tr>
<td>80 m</td>
<td>0.9869</td>
<td>0.9883</td>
<td>0.9842</td>
</tr>
<tr>
<td>126 m</td>
<td>0.9848</td>
<td>0.9951</td>
<td>0.9932</td>
</tr>
</tbody>
</table>

All correlation overestimated lightly the wind compare to the met mast

(slope of relation around 1.003 to 1.04)
Data availability of Lidar– recovery rate

Data availability vs height measurement

% of availability

Occurrence
## Data availability of Lidar – recovery rate

<table>
<thead>
<tr>
<th>Height (m)</th>
<th>&lt; 30%</th>
<th>30 to 70%</th>
<th>&gt; 70%</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>33,0%</td>
<td>7,9%</td>
<td>59,1%</td>
</tr>
<tr>
<td>55</td>
<td>33,9%</td>
<td>7,3%</td>
<td>58,8%</td>
</tr>
<tr>
<td>76</td>
<td>32,2%</td>
<td>7,7%</td>
<td>60,1%</td>
</tr>
<tr>
<td>80</td>
<td>31,7%</td>
<td>7,9%</td>
<td>60,5%</td>
</tr>
<tr>
<td>100</td>
<td>31,2%</td>
<td>8,6%</td>
<td>60,2%</td>
</tr>
<tr>
<td>103</td>
<td>31,5%</td>
<td>8,6%</td>
<td>59,9%</td>
</tr>
<tr>
<td>126</td>
<td>34,7%</td>
<td>8,3%</td>
<td>57,0%</td>
</tr>
<tr>
<td>140</td>
<td>35,7%</td>
<td>8,1%</td>
<td>56,2%</td>
</tr>
<tr>
<td>160</td>
<td>39,5%</td>
<td>8,3%</td>
<td>52,3%</td>
</tr>
<tr>
<td>180</td>
<td>45,8%</td>
<td>8,1%</td>
<td>46,1%</td>
</tr>
<tr>
<td>200</td>
<td>59,6%</td>
<td>8,2%</td>
<td>32,2%</td>
</tr>
</tbody>
</table>
Data availability of Lidar—recovery rate

When did the Lidar lose data?
Data availability of Lidar—recovery rate

Meteorologic conditions when data availability are <30% from MMV2 sensors

- Temperature below -20°C
- Rain - from rain gauge
- Low humidity < 50%
- Instrumental icing
- DT/DZ < 0,03 C/m
- No cloud in the sky
- % of cloudy coverage < 60%
Data availability of Lidar—recovery rate

On both case, cleared sky seems the problem with the data availability from the Lidar.
Data availability of Lidar— recovery rate

Represent only 14.1 h (avg. 2%)
Data availability of Lidar– recovery rate

But, what represents the low availability due to clear sky compared to all the clear sky occurrences?

The lidar lost data during approx. 1/3 of clear sky occurrences (or > 24 km)
Data availability of Lidar—long term analysis

Did this lost of availability affect the long term wind speed bias?
Data availability of Lidar—long term analysis

- Turbulence intensity bins

Comparative graphics of turbulence intensity vs height measurement between Lidar and unheated cup anemometer
Recommandations

• Using the Lidar following the IEC61400-12-2 (in completion of met mast) is good practice

• The Lidar has a very good correlation with met mast in complex terrain and cold climate

• In remote areas (when aerosols are less present), check the general visibility or status from the nearest long term met station. (~1/3 rule)
Future work

- Public report with all the results of the current campaign

- Improve the data availability of the Lidar during clear sky occurrences (or high visibility) for remote areas

- Measure the wake effect of wind turbine in complex terrain with the Lidar (see zone lidar)
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References


[8] Wind energy handbook

[9] QC procedure from TCE, PRO-REC-003

[10] Users guide Léosphère