Winterwind
INTERNATIONAL WIND ENERGY CONFERENCE

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

Presented by: **Matthew Wadham-Gagnon**

At Winterwind 2014

Cédric Arbez, TechnoCentre éolien

Mathieu Boquet, Léosphère

Raghu Krishnamurthy, Léosphère

LEOSPHERE
Lidar Environmental Observations

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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


Lidar Measurement in Complex Terrain under Harsh Winter Conditions

E. Jeannotte[1], D. Faghani[2], M. Pelletier[1], M. Boquet[3], R. Dexter[2], B. Boucher[4], E. Osler[5], C. Masson[1]
[1]Ecole de technologie supérieure, [2]GL Garrad Hassan, [3]Leosphere SAS, [4]TechnoCentre Éolien, [5]NRG Systems

Abstract

A WINDCUBE® v2 LiDAR was sited in an operating wind farm in vegetated complex terrain in harsh cold climate. Following work presented in [1], flow simulations using MeteoDyn WT were used to investigate and confirm the low level of complex terrain bias observed. Encouraging results indicate potential of CFD in helping with LiDARs siting in complex terrain.

Objectives

- Gain insight into LiDAR bias in complex terrain;
- Evaluate in-house algorithm and MeteoDyn's LiDAR module to predict the bias; and
- Investigate efficacy of CFD in proper siting of LiDAR in complex terrain.

Methodology

Experimental Data:

A WINDCUBE®v2 LiDAR was sited on a 2.5-m high platform approximately 79 m South-West of an 80-m met mast (Fig. 1) located in an operating wind farm in a densely forested area in complex terrain and harsh winter conditions (Fig. 5) in Gaspe peninsula, Quebec, Canada. The LiDAR was commissioned on 7 Jan. 2011. Several measurement levels were available from this ongoing campaign but for this study, only data at 80 m (Lidar) and 79 m (mast) above ground level (agl) were compared between 16/02 and 28/03.

Fig. 1: Topographic Map.

Modeling LiDAR Behaviour in Complex Terrain:

It was previously shown [1] that despite terrain complexity no significant bias existed between the met mast and the LiDAR measurements (Fig. 2). In the work presented here, LiDAR bias & spatial flow variability were estimated using the non-linear MeteoDyn WT 4.2 CFD tool. First, LiDAR bias correction was investigated using both the commercial MeteoDyn LiDAR module and an in-house algorithm [2]. Then, spatial flow variability was investigated by comparing speed-up ratios predicted by MeteoDyn at LiDAR and met mast locations. Finally, the overall CFD predictions were used to compare "*corrected*" LiDAR measurements with mast measurements.

CFD Simulation Parameters:

Based on conclusions of [1], new MeteoDyn simulations were performed on a 2.5 km x 2.5 km domain with a nominal horizontal resolution of 5 m, using a spatial expansion rate of k = 1.1 outward from the LiDAR.

The experimental data at hand were from a met mast and a LiDAR measuring at the same altitude but with a significant spatial separation. On-site relative height surveys showed that precision of digital maps was no better that a few meters vertically. However, as depicted in Fig. 2, measurements showed that at about 80 agl, vertical uncertainties of up to a few meters entailed wind speed uncertainties well within measurement uncertainty limits, hence validating the use of digital maps.

Fig. 2: Lidar (76 m & 80 m) vs. mast (79 m)

Results and Discussion

Data Analysis & CFD Modeling:

Overall analysis of LiDAR/mast speed-up ratios in [1] suggested limited complex terrain (LiDAR bias & spatial flow variability) effects. Further sector-wise analysis of measured ratios in Fig. 3 confirms small deviations (typically 2-3%) from unity for the measured wind rose (Fig. 1).

CFD simulations remained within measurement uncertainty levels for most sectors where enough data samples were available and notably for wind sectors between 240 ° and 300°. Beyond, significant differences between CFD and measurements were observed (Fig. 3).

Using the CFD-calculated bias ratios, LiDAR time series were i) corrected for complex-terrain bias and ii) were spatially extrapolated to the met mast location.

Fig. 3: LiDAR/mast speed-up ratios: measured vs. simulated.

Fig. 4: CFD-corrected LiDAR/Mast speed-up ratios.

CFD-Corrected LiDAR Data:

Corrected LiDAR/mast ratios are shown in Fig. 4 using MeteoDyn/in-house and MeteoDyn/LiDAR module correction schemes. Complex-terrain bias correction was applied to 1-second LiDAR time series. Spatial separation correction was also applied to 1-second data except for MeteoDyn/LiDAR module where it was applied to 10-minute averages, notably based on 10-minute averages of wind direction, with potentially minor impacts on the end results.

In Fig. 4, deviations from the ideal unit value indicate shortcomings of the CFD model in specific directions. Overall, the two tested schemes show comparable performances. The table embedded in Fig. 4. shows that regression slopes are close to unity (no bias) and R^2 values are close to their uncorrected values (unchanged scatter/uncertainty, see Fig. 2).

Conclusions

- Despite terrain complexity, measurements show negligible bias on LiDAR data.
- CFD simulations provide comparable and relatively good results when modeling LiDAR behavior in the complex terrain under study.
- CFD simulations confirm that negligible bias is indeed expected given the measured wind rose.
- Further measurements/simulations are needed to isolate complex terrain bias under more *favorable* conditions to confirm efficacy of CFD predictions as a LiDAR siting tool in complex terrain.

Fig. 5: LiDAR on its 2.5-m high platform under more than 100 cm of snow.

References

The authors would like to acknowledge Cartier Wind Energy for providing access to the site as well as F. Pelletier and OSIsoft for providing access to met mast data through PI system.

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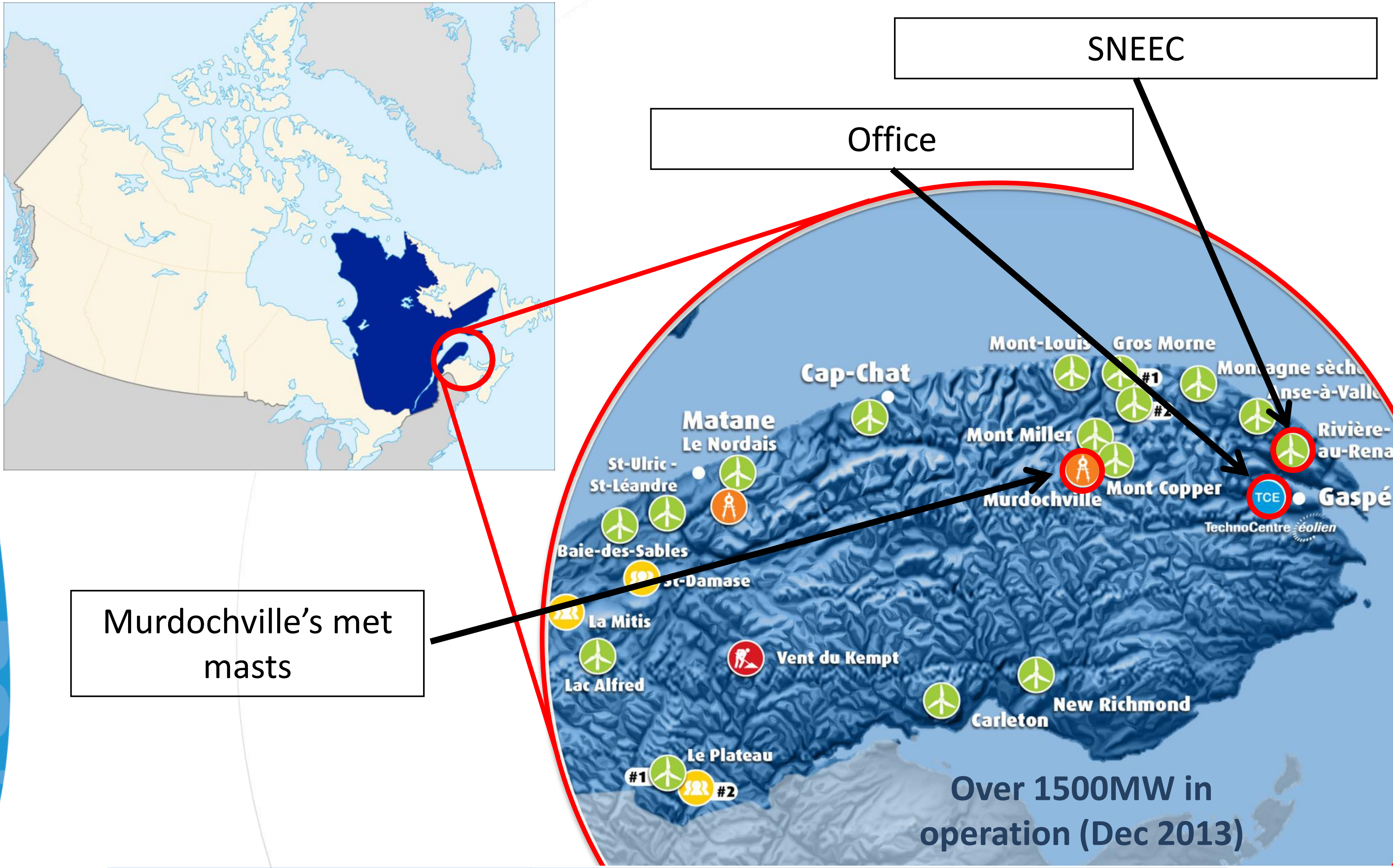

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SNEEC

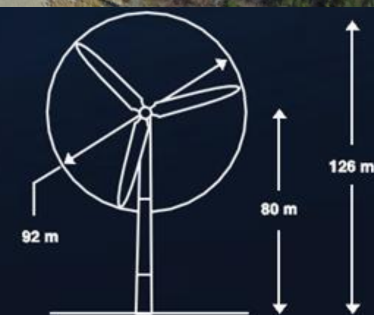
- Two 2.05 MW Repower MM92 CCV

REpower Systems

- Commissioned March 2010
- Icing & complex terrain
- R&D, technological transfer, technological validation, performance assessment.

OSIsoft

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



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

Met masts name	MMV2
Height (a.g.l.)	126 m
Altitude (at the base)	325 m
Tower type	Tripod permanent guyed wire CSA S37-01
Location	Rivière-au-Renard (QC)

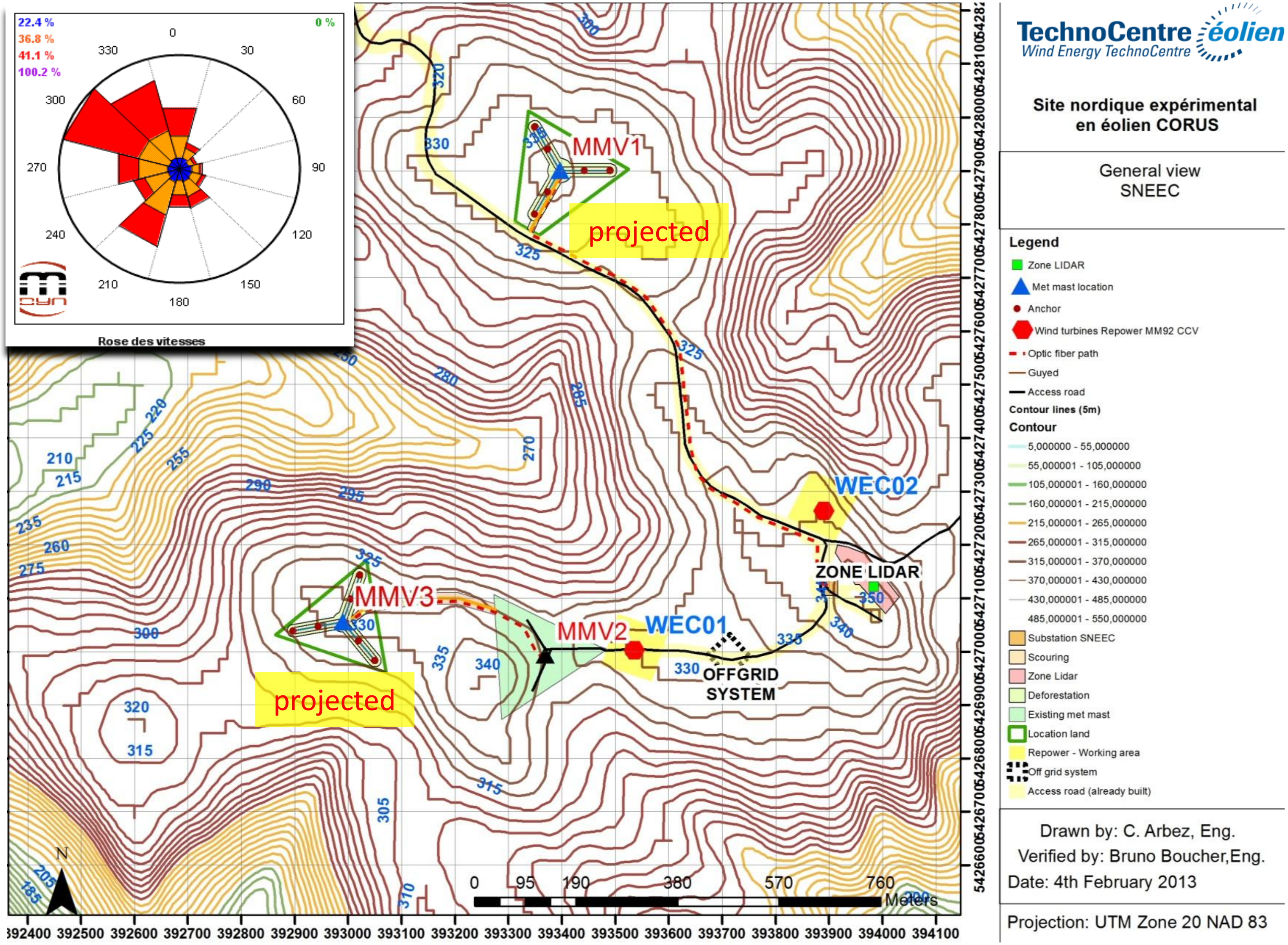
Sensors installed over 15 levels:

- 8 anemometers (heat/unheat)
- 5 wind vanes (heat/unheat)
- 5 thermometers
- 4 differential temperature probes

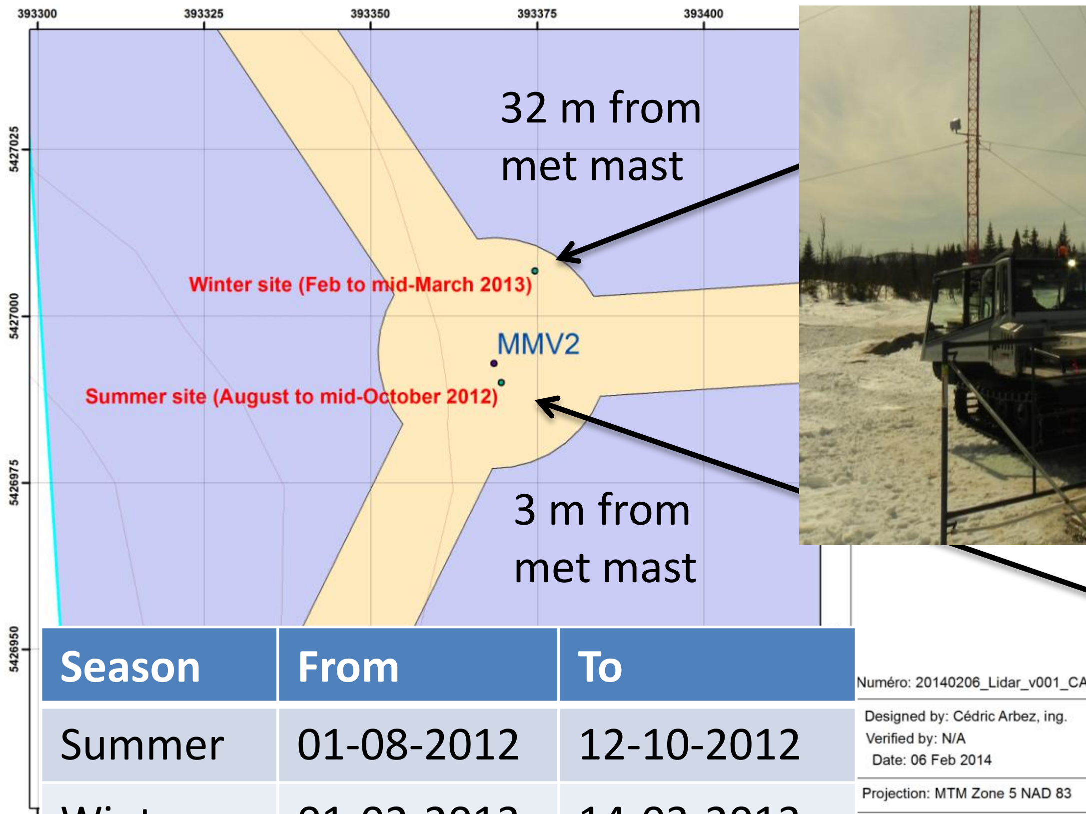
- Vertical anemometer
- Ceilometer
- Barometer
- Pyranometer
- Hygrometer
- Ice meter (detector)

Real-time data storage with Osisoft-PI

Introduction- Topographical layout SNEEC

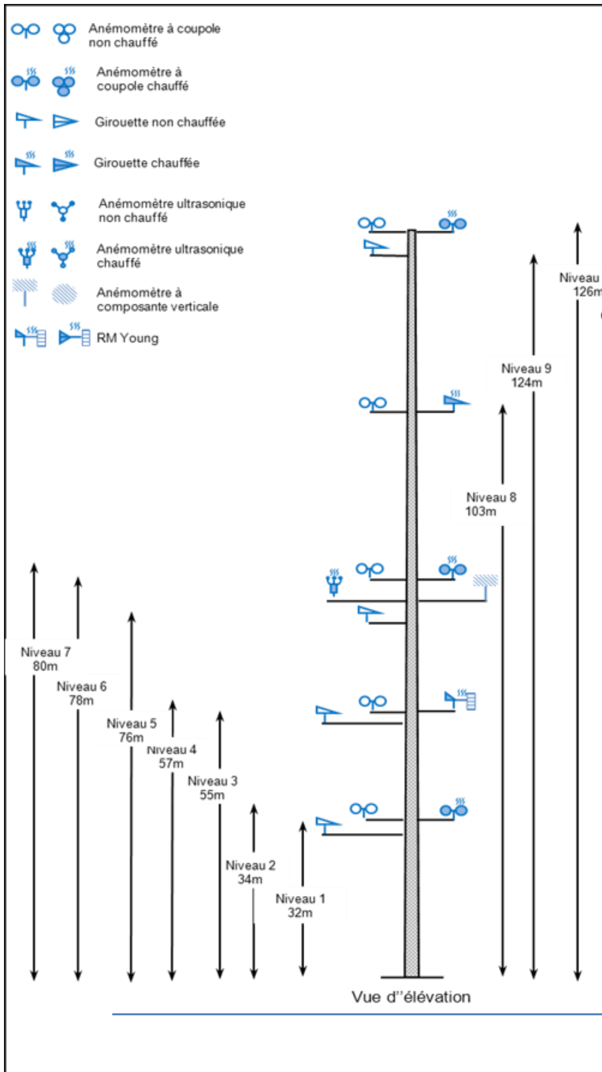


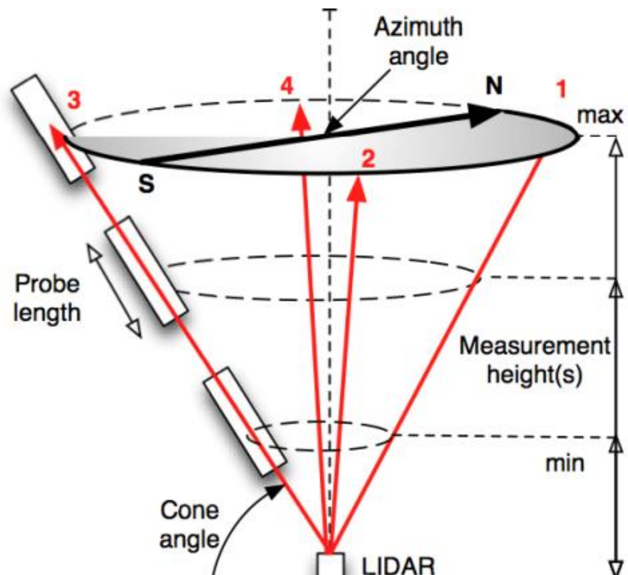
Infrastructure used for the study – WindCube Lidar v2 & acquisition period



Season	From	To
Summer	01-08-2012	12-10-2012
Winter	01-02-2013	14-03-2013
More than 4 months		

Infrastructure used for the study

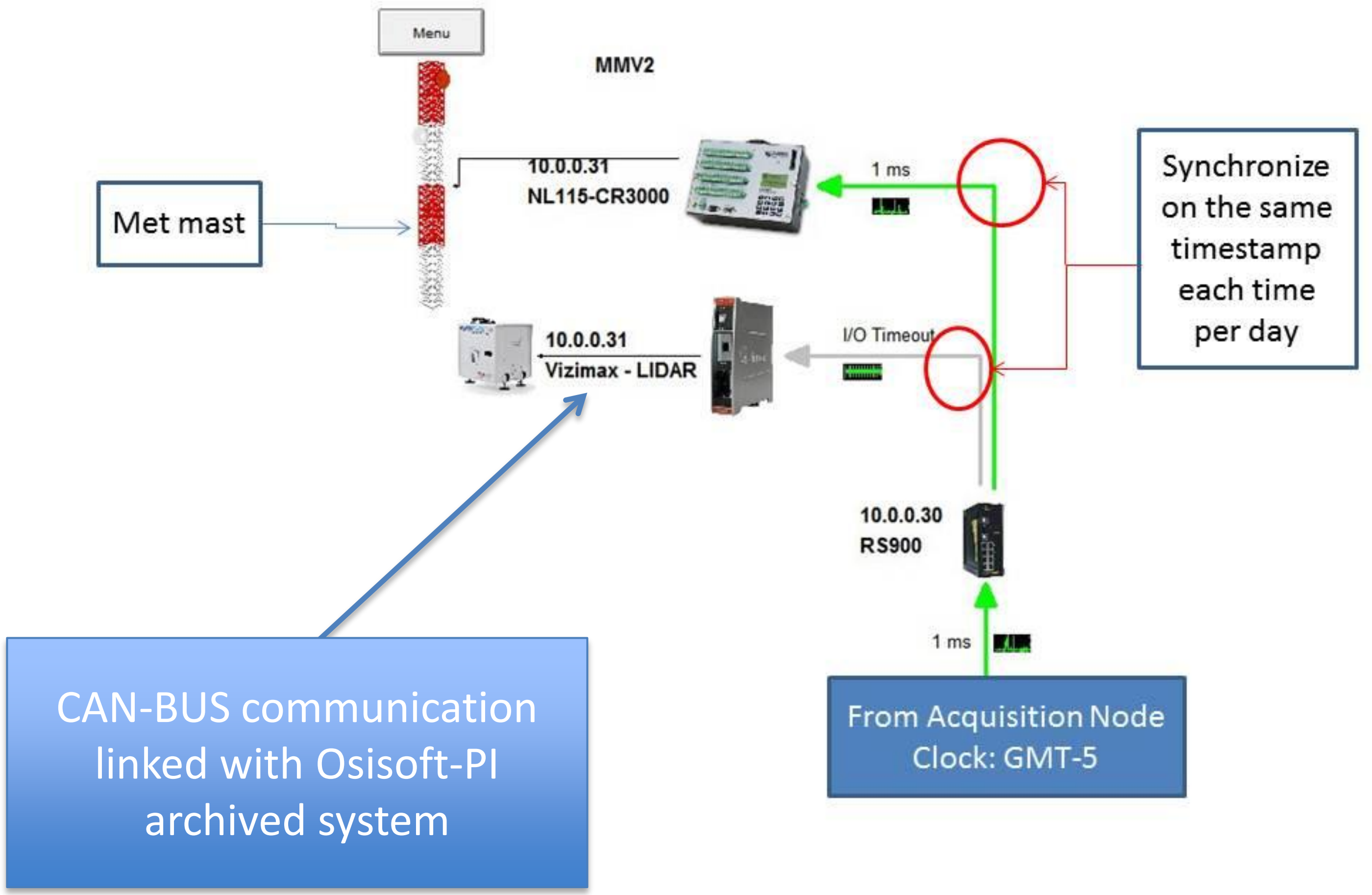




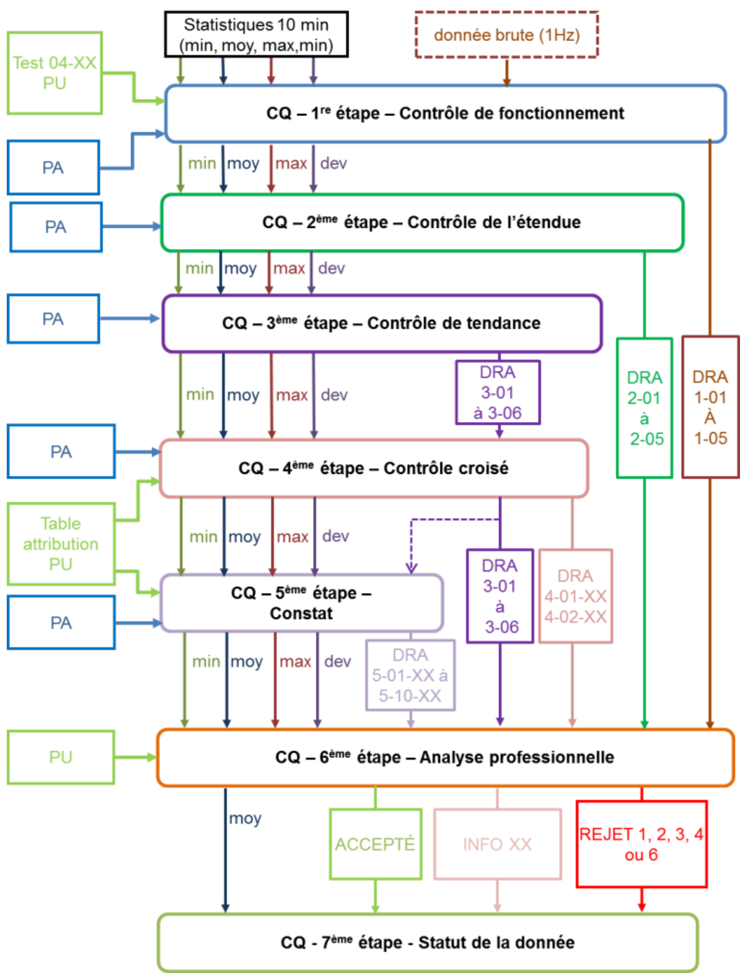
11 levels of measured provided from LIDAR:

- -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



Measurement campaign –QC



Quality control with more than 32 tests covering:

1- Functionnal check

2- Area check

3- Trend check

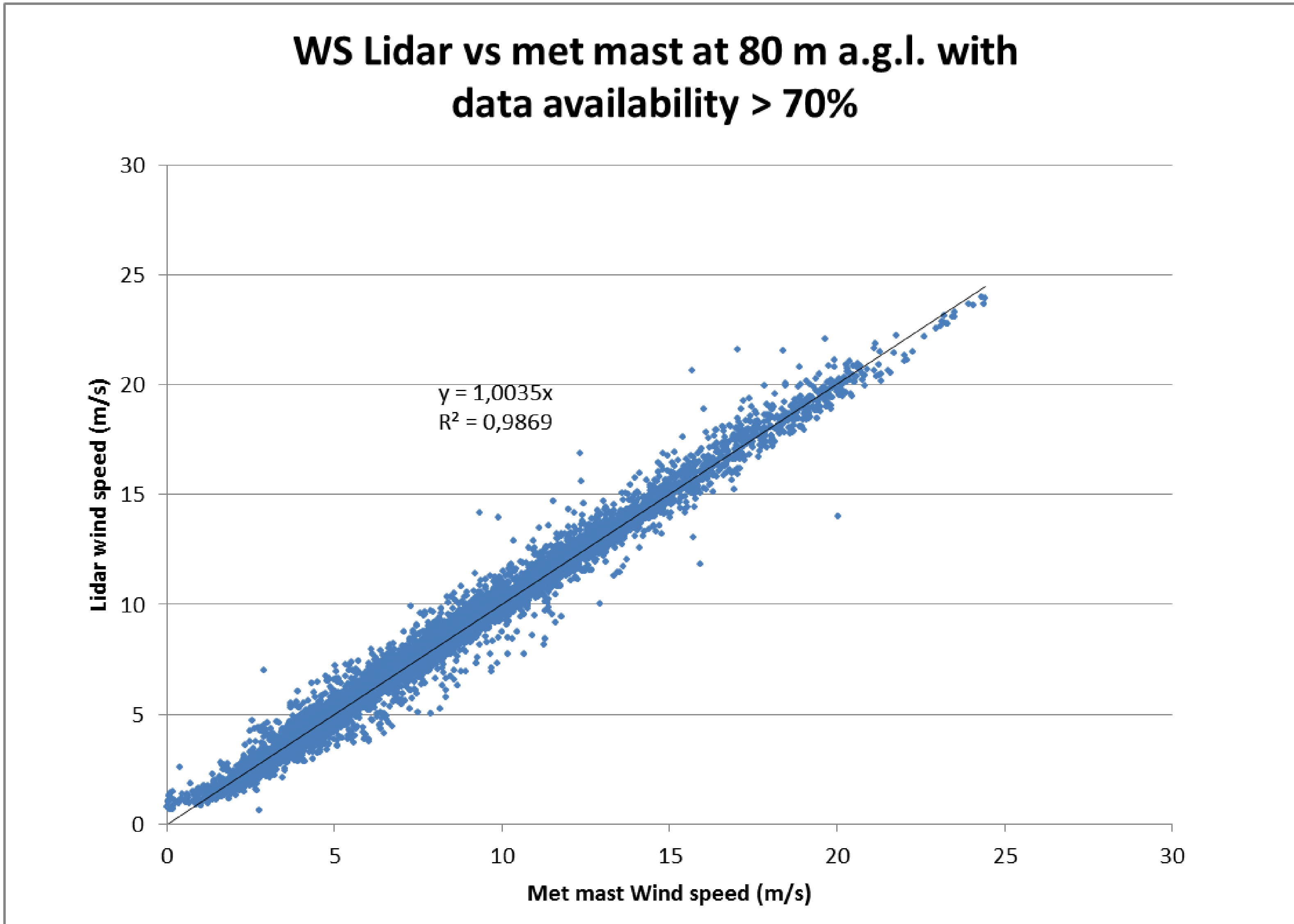
4- Cross comparison check

5- Status notification including special meteorologic detection (ex: icing, low temperature, no cloud)

Measurement campaign – site description

Characteristics	Units	Comments
Lowest temperature	-26,15 C	Site conform to GL Technical note 069
Highest wind speed	31,5 m/s	During the measurement campaign
Snow accumulation	1 meter height	
Remote area	At 7 km from the nearest village	Low CNR measured during the winter

Performance of the Lidar in CC & complex terrain



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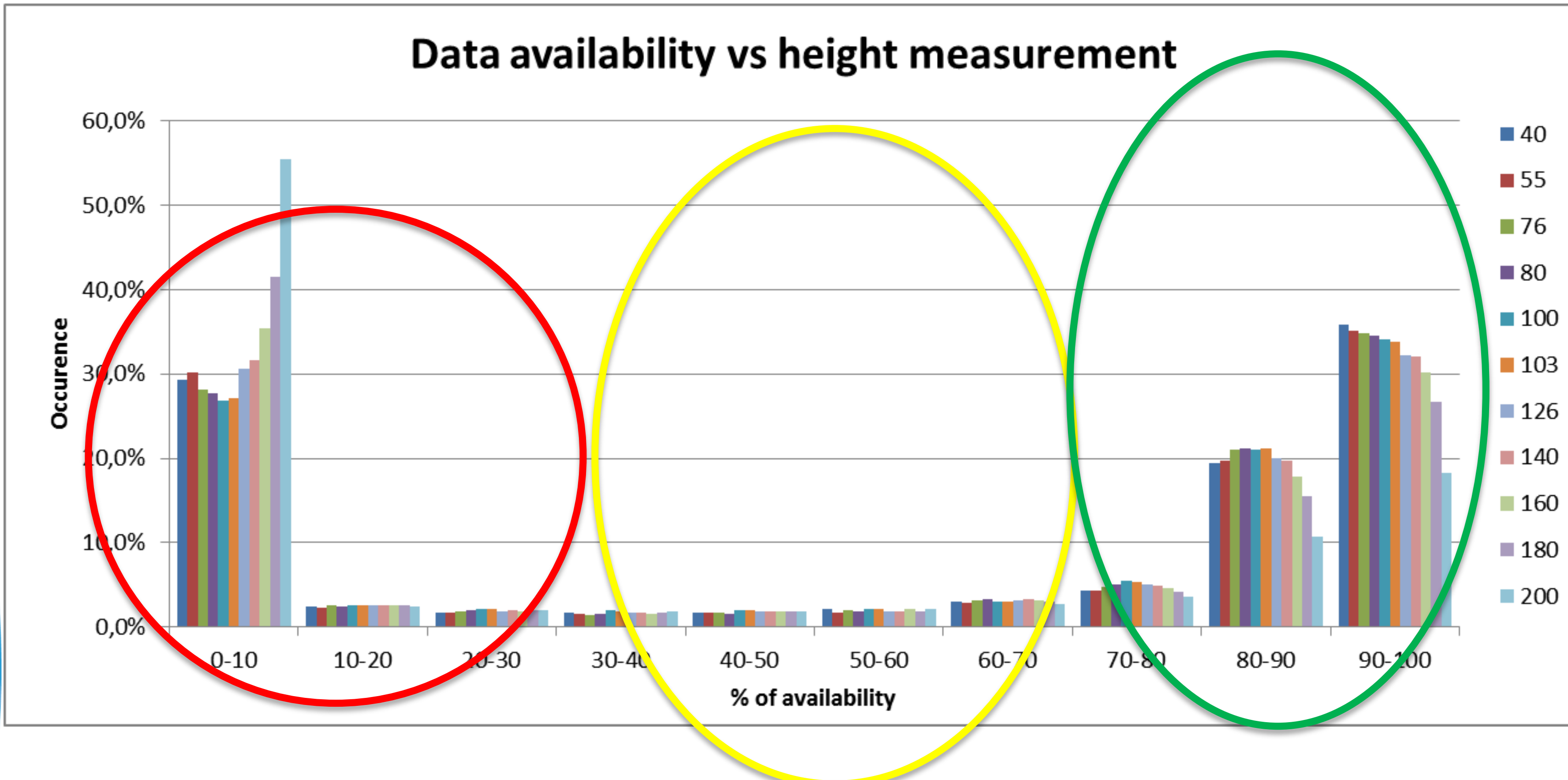
Performance of the Lidar in CC & complex terrain

R^2 table	All seasons	Summer	Winter
34 m	0,9848	0,9843	0,9836
80 m	0,9869	0,9883	0,9842
126 m	0,9848	0,9951	0,9932

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



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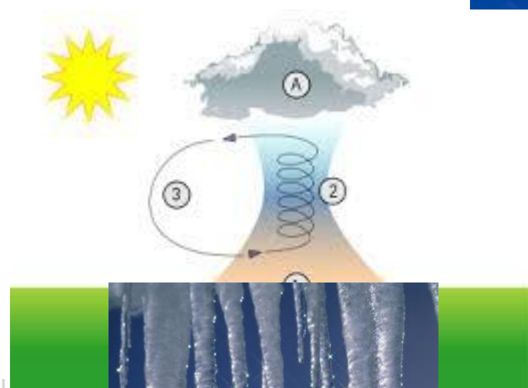
Data availability of Lidar– recovery rate

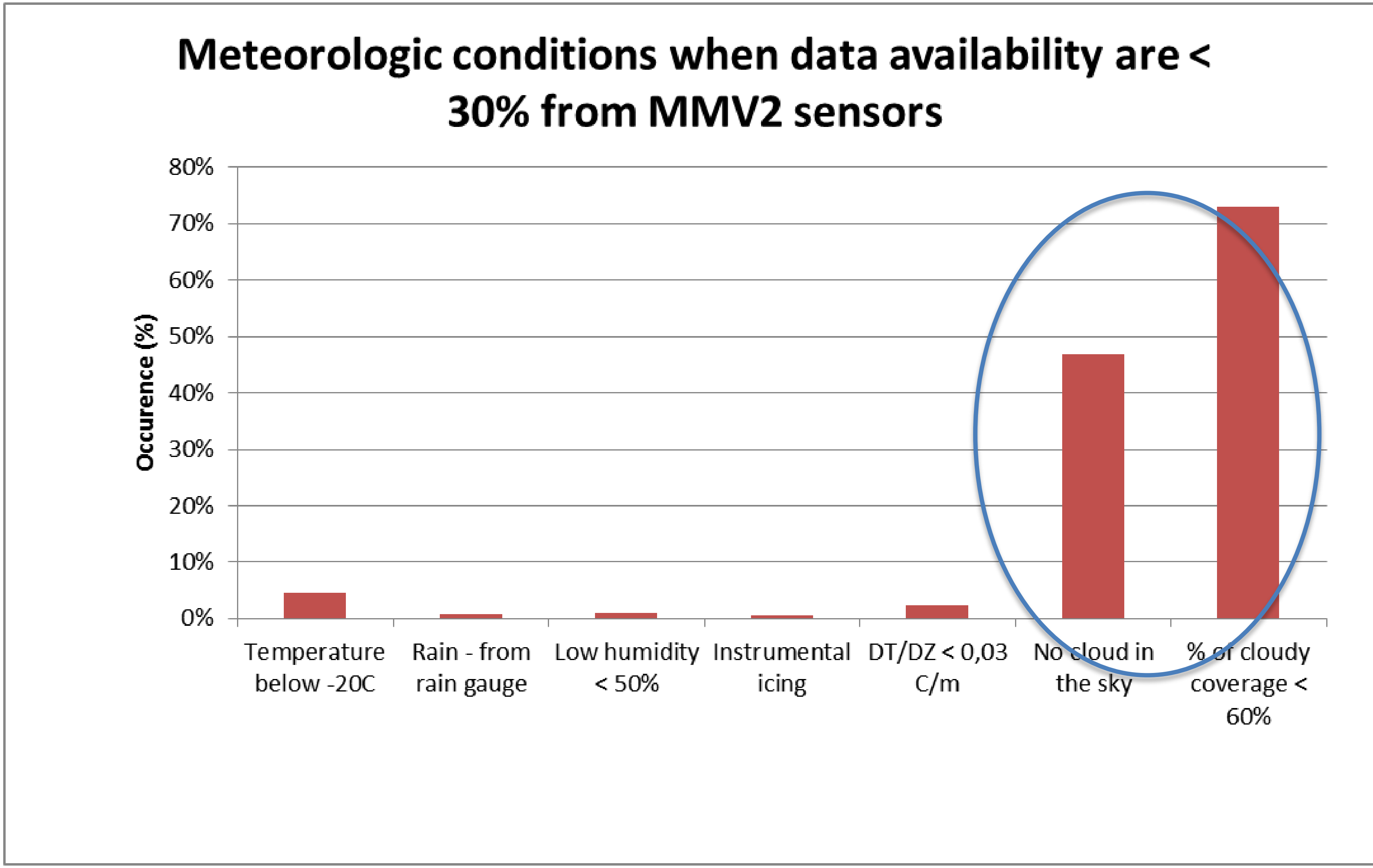
Height (m)	< 30%	30 to 70 %	> 70%
40	33,0%	7,9%	59,1%
55	33,9%	7,3%	58,8%
76	32,2%	7,7%	60,1%
80	31,7%	7,9%	60,5%
100	31,2%	8,6%	60,2%
103	31,5%	8,6%	59,9%
126	34,7%	8,3%	57,0%
140	35,7%	8,1%	56,2%
160	39,5%	8,3%	52,3%
180	45,8%	8,1%	46,1%
200	59,6%	8,2%	32,2%

Data availability of Lidar– recovery rate

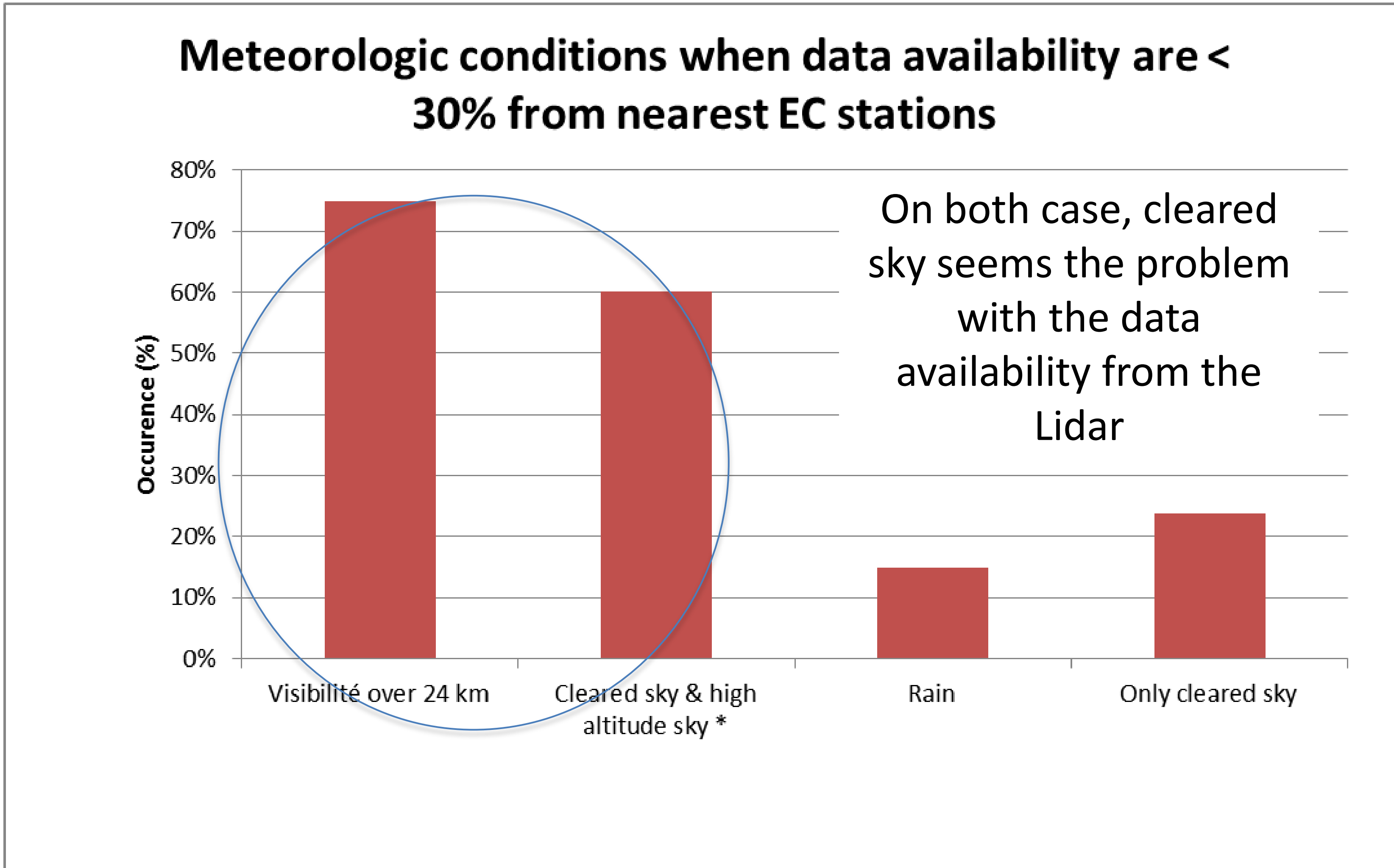
When did the Lidar lose data?



Data availability of Lidar– recovery rate



Data availability of Lidar– recovery rate



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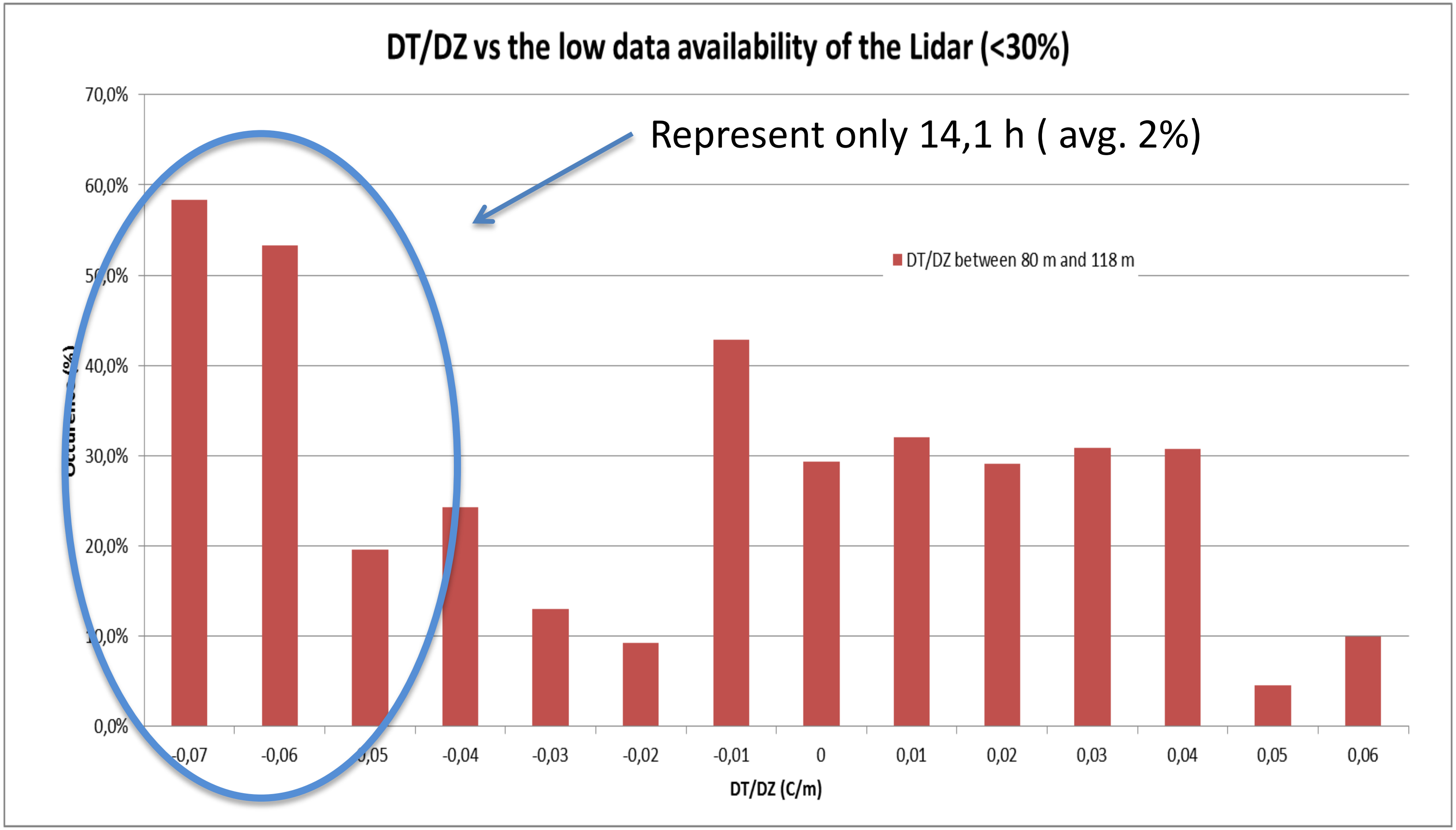
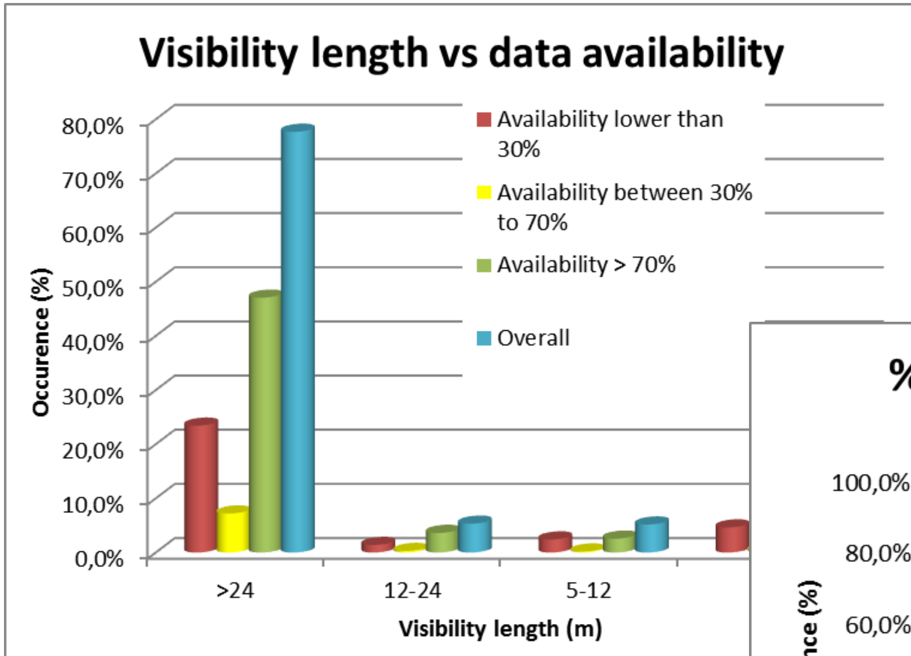
Data availability of Lidar– recovery rate



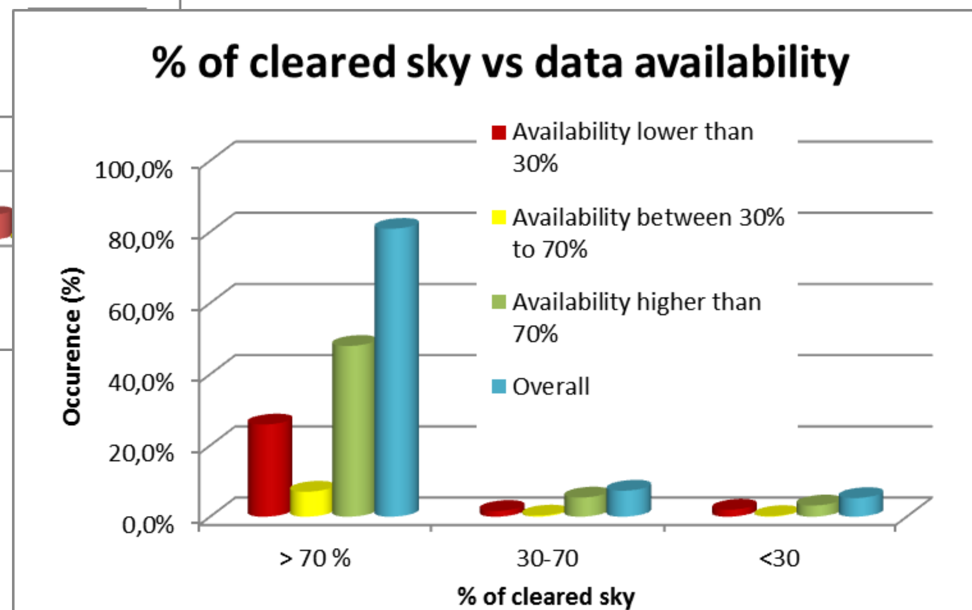
Data availability of Lidar– recovery rate

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



From met mast

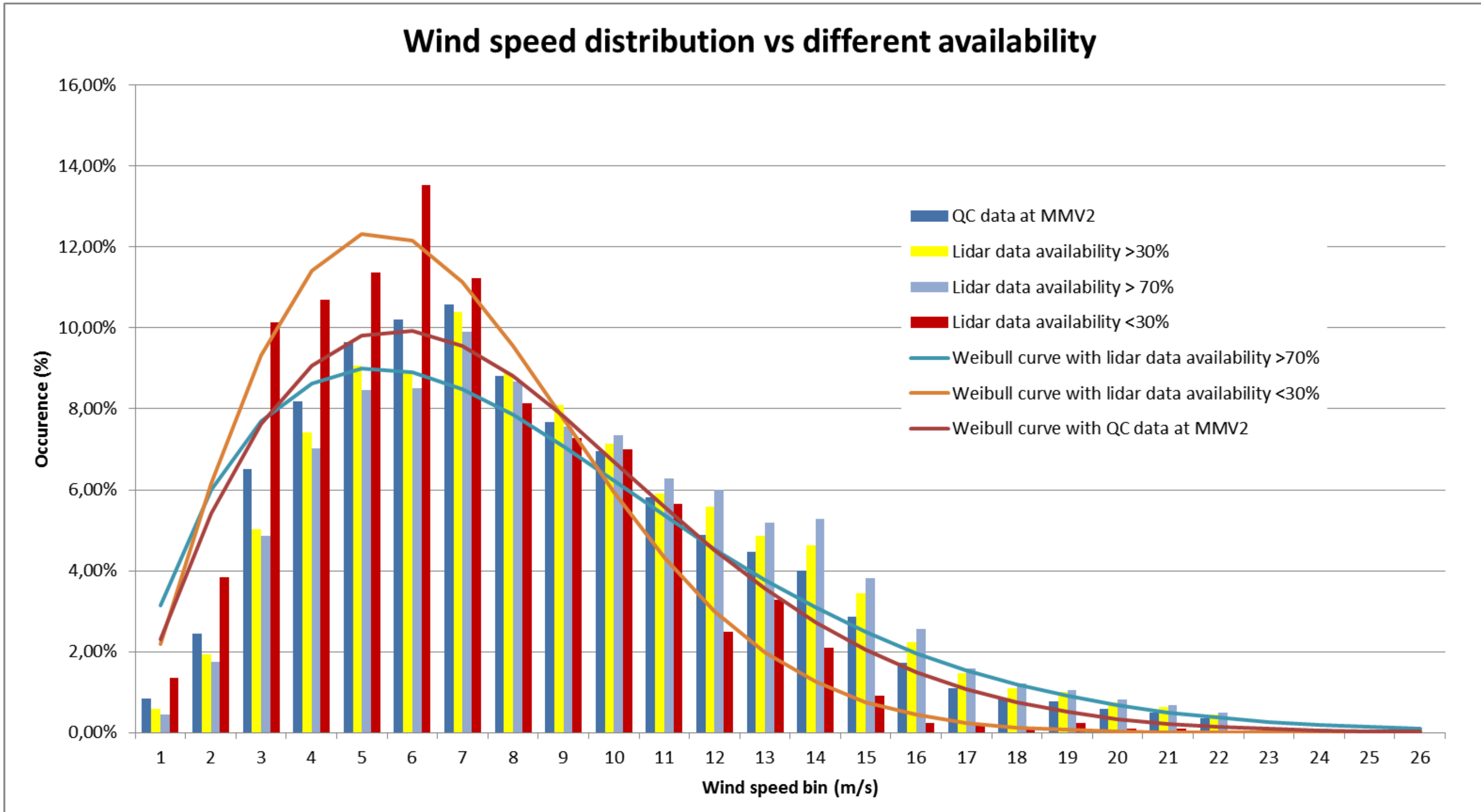
From EC station



The lidar lost data during approx. 1/3 of clear sky occurrences (or > 24 km)

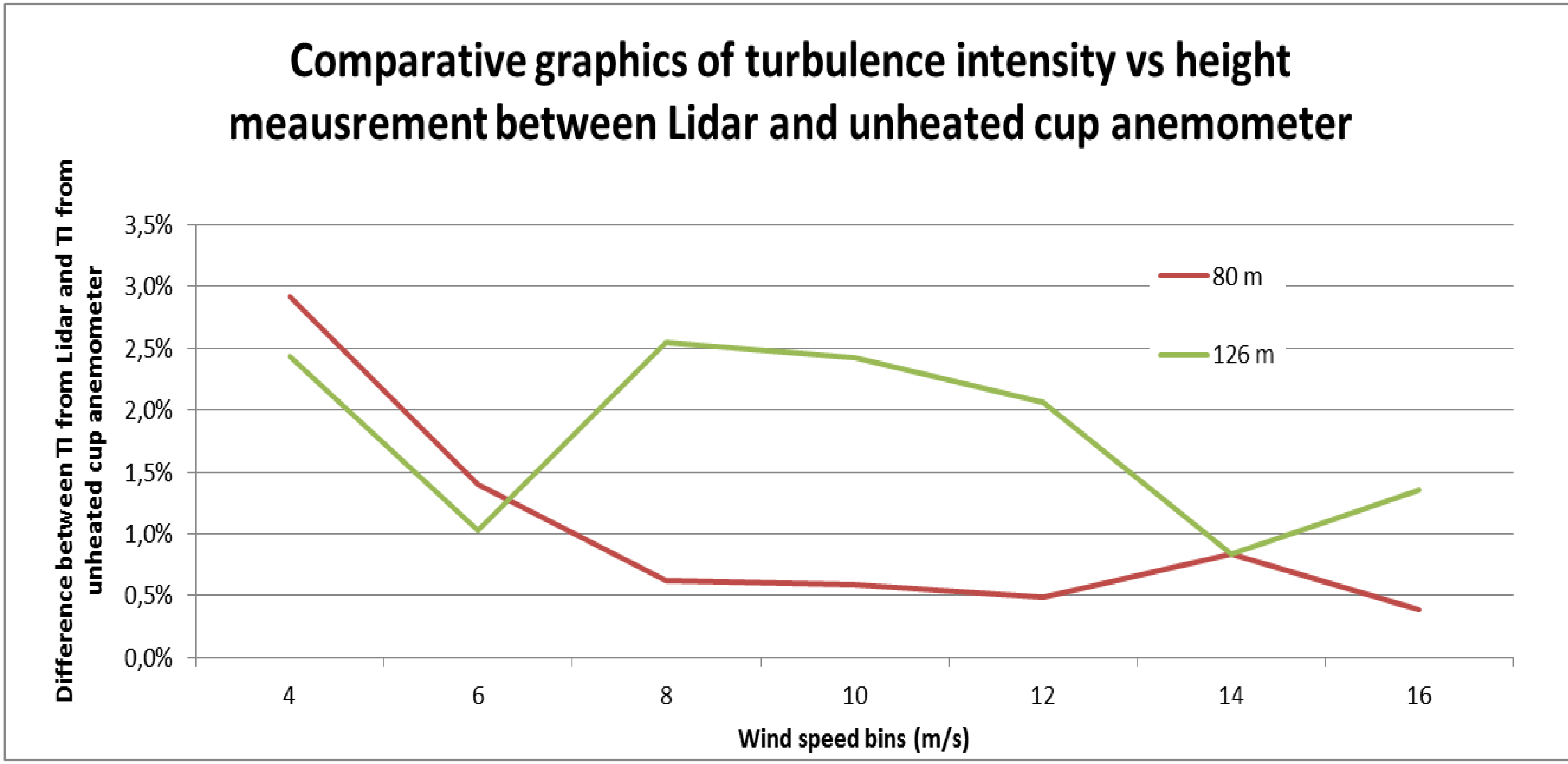
Data availability of Lidar– long term analysis

Did this lost of availability affect the long term wind speed bias?



Data availability of Lidar– long term analysis

- Turbulence intensity bins



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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 visibilty 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 availabilty of the Lidar during clear sky occurrences (or high visilibility) for remote areas
- Measure the wake effect of wind turbine in complex terrain with the Lidar (see zone lidar)

Cédric Arbez, Eng.
Project lead
carbez@eolien.qc.ca

70, rue Bolduc, Gaspé (Québec) G4X 1G2
Canada
Tél. : +1 418 368-6162 x237

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