Long range off-shore wind assessment by high power scanning Lidars

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Abstract: A specific and world-première set-up for evaluating the potential of long-range scanning Doppler Lidar to serve wind energy applications has been organized by the CarbonTrust (UK) in the Dublin bay, Ireland. In this experiment the scanning Lidars are located on the Dublin bay shore and measure over the sea. Leosphere has deployed 2 scanning Lidars: the standard WINDCUBE 400S product and a prototype that is designed to considerably increase the measurement range. Additionally 3 vertical profiler WINDCUBE Lidars are located at ranges from 6 to 14km from the scanning Lidars, offering the possibility to wind speed measurement accuracy comparison. In this paper we propose to show the different Lidars performances in term of measurement ranges and wind speed accuracy, and analyze the specific atmospheric conditions that contributes to the different performances between the standard product and the prototype scanning Lidar.

Keywords: Coherent Wind Doppler Lidar, offshore wind assessment

1. Introduction

From several years now the wind energy industry is targeting the development of offshore wind farms, in part because of the possibility to build larger wind farms with higher and more stable winds available than onshore. This ambition requires developing specific methods to harness the energy resource available offshore: for instance platforms equipped with met masts, floating buoy mounted with Lidar and long-range scanning Lidar deployed on the cost. This latter option has raised the interest of several offshore wind energy players because the solution presents several economic and operational advantages.

Therefore, the UK based consultancy Company the Carbon Trust leading the Offshore Wind Accelerator program has launched a specific project aiming at evaluating the potential of long-range scanning Lidars to accurately and safely harness the offshore wind resource from the shore. LEOSPHERE and Lockheed Martin Technology have proposed their Lidar technologies in the project, which have been deployed and operated in the Dublin Bay by the UK Wind farm developer and consultancy RES.

In this paper, the LEOSPHERE long-range scanning Lidar technology, WINDCUBE 400S, is presented along with the project set-up and initial results if the measurement campaign which started early January 2016 to finish end of May 2016.

2. WINDCUBE Lidar Technology

Leosphere is developing pulsed fiber Doppler lidars for more than 10 years, based on a technology formerly developed at ONERA ([1], [2] and [3]). The core technology is using EDFA (Erbium Doped

Fiber Amplifiers) operating around 1,55µm in the telecom C band, and an all-fiber architecture. The high pulse repetition frequency (PRF) efficiently compensates the relative low pulse energy. Moreover, the MOPA architecture flexibility in terms of pulse duration allows fulfilling a large variety of requirements, enabling the design of high spatial resolution or long range systems.

The next figure describes the architecture of LEOSPHERE pulsed fibered lidars.

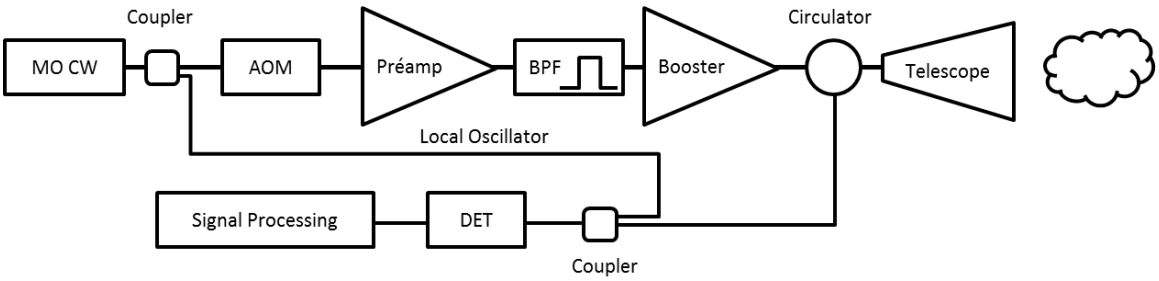

Figure 1 Architecture of fibered pulsed lidars

An endless rotation scanning head steers the beam in the full hemisphere, for either fixed line of sight, DBS, PPI, RHI, or customized scanning patterns.

Besides commercial products, Leosphere is testing new architectures to improve the Lidar performances. The RTA prototype integrates new features such as: increased energy and lower temporal ASE thanks to a larger LMA fiber, new generation circulator and optimized telescope, new fast scanning head. The max operational range is increased up to 14km, limited by the ambiguity distance associated with the high PRF.

Table 1. Lidar characteristics

Parameter	WINDCUBE400S	Proto RTA
Wavelength	1.54µm	1.54µm
PRF	10kHz	10kHz
Pulse duration	800ns	800ns
Energy	160µJ	240µJ
Telscope aperture	120mm	120mm
Recommended integration time	0.5 to 2s	0.15 to 1s
Max Acquisition Range	15km	15km
Recommended range resolution	200m	200m
Velocity range	-30m/s to +30m/s	-30m/s to +30m/s
Recommended scanning velocity	1 to 6°/s	1 to 18°/s

3. Campaign set-up

The campaign took place in the Dublin Bay, Ireland because the specific location has offered the possibility to locate several scanning Lidars on the cost as well as vertical profiler Lidars used for the validation offshore. The map below indicates the locations of the Lidars:

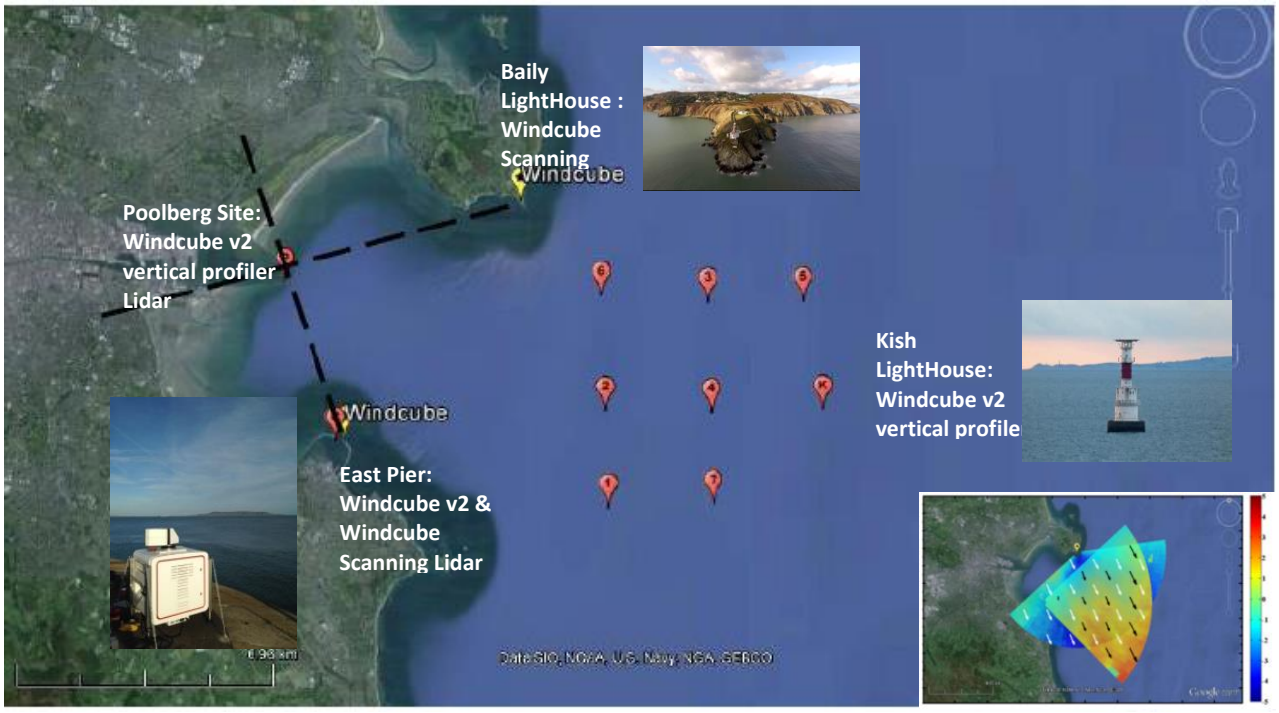

Figure 2 Measurement campaign set-up with locations of Lidars

The scanning scenarios of the Windcube 400S and prototype RTA have been defined such as horizontal wind speeds and directions could be derived from the raw measurements at selected locations and heights. Those locations comprise:

- The validation points where reference Windcube vertical profiler Lidars are deployed, ie. respectively ~10km and 13km from the scanning Lidar for the further one
- The demonstration points (indicated with red dots on the maps above)
- 2 measurement heights have been targeted: 100m and 150m above mean sea level

4. Preliminary observations

The long-range scanning Lidars have been evaluate for both their data availability at long distances (above 10km) and their capacity to accurately retrieve 10min averaged horizontal wind speeds and directions at those high distances. The graphs below respectively show the Lidars data availability over the campaign (60% of data availability at 10km is observed for the Windcube 400S, increased to 82% for the prototype scanning Lidar), and the 10min averaged wind speed and direction time series that are calculated from the raw Lidar data, using the dedicated LaserCup algorithm.

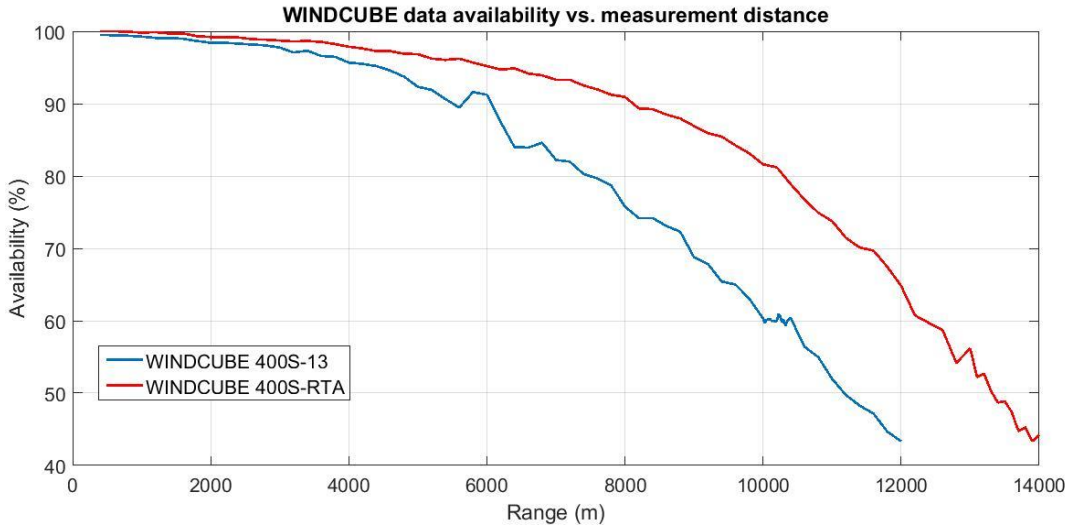

Figure 3 WINDCUBE 400S-13 data availability vs. measurement distance for the entire data set

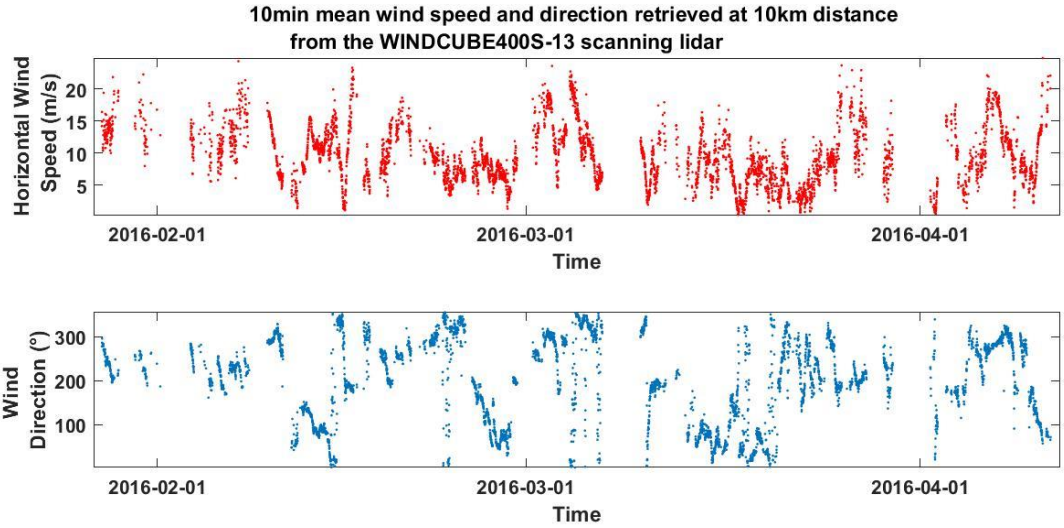

Figure 4 WINDCUBE 400S-13 calculated 10min averaged wind speed and direction at 10km distance from the Lidar

The wind data derived from the long-range scanning Lidars may then be used to evaluate the wind resource map over the sea area, covering around 200km^2 with wind speed and direction information. The evaluation of the wind variations over the area and going further from the coast into the sea is a crucial piece of information for wind farm developers.

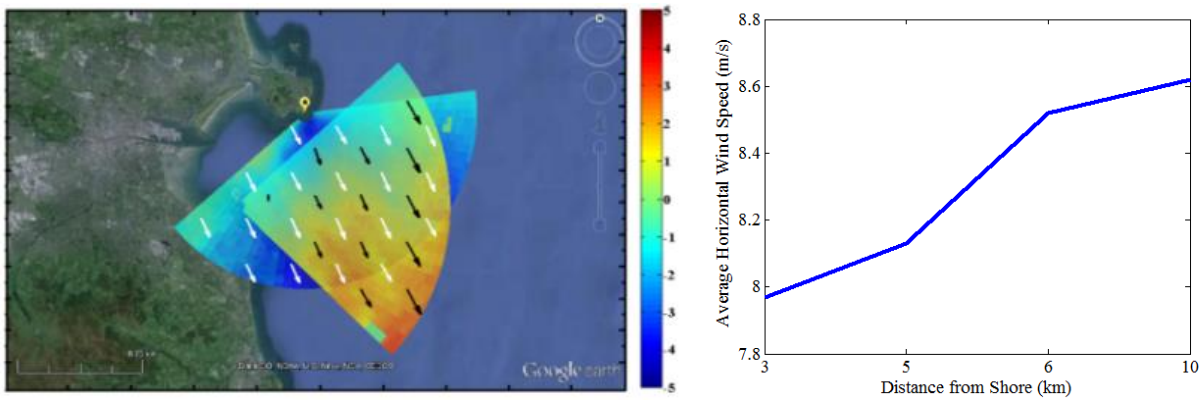

Figure 5 Wind speed map over the area and wind speed variation with distance from the shore.

5. Conclusions and perspectives

Long-range scanning wind Lidar are finding an interesting application in the wind energy industry: measuring the wind resource offshore from the shore. Although the concept is relatively new, it is gaining a lot of attraction because of the operational and economic advantages it may offer. For the industry to accept such instruments in the development of future wind farms, it is key to first validate their real capacity in terms of data availability and accuracy. This is the objective of the Carbon Trust funded project involving the Windcube 400S and its evolution prototype, for which a 5 months measurement campaign in the Dublin Bay has been performed. Up to day, the operational results are over expectations with almost 100% availability of the instruments through the entire measurement campaign, while preliminary assessment of the data availability above 10km range is looking very promising, as well as the initial verification of the retrieved wind data.

6. References

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