Planetary Boundary Layer dynamic measurements with new generation long range wind Lidar WINDCUBE™ WLS70

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ABSTRACT

The WINDCUBE™ WLS70 is a coherent wind lidar recently developed by LEOSPHERE to perform vertical wind speed and direction profile measurements in the boundary layer and upper clouds in the troposphere with high wind speed and spatial resolution (0.4 m/s and 50m). These measurement data play a key role in many meteorological applications, and can be used as input for forecast mathematical models.

This eye safe robust and portable lidar has been used up to now in its short range version under various latitudes and weather conditions for wind turbine site assessment. 3D wind data are delivered every second on the 10 range gates allowing both average values and turbulence to be measured. Special attention is done to fulfill all environmental conditions requirements, cold or hot temperature and rain. Data are automatically sent and stored for an unattended operation. The lidar has been successively demonstrated by independent institutes as RISOE and METEOFRANCE for continuous wind profiling during validation campaigns against calibrated cup anemometers and sodars.

Keywords: Planetary Boundary Layer dynamics, vertical wind speed, wind shear, coherent Lidar

INTRODUCTION

To fully understand atmospheric dynamics, climate studies, energy transfer, and weather prediction the wind field is one of the most important atmospheric state variables. Studies indicate that a global determination of the tropospheric wind field to an accuracy of 0.5 m/s is critical for improved numerical weather forecasting. Currently, mass (pressure-height) data derived from satellite temperature sounders is used to derive winds using the geostrophic relationship which assumes that the latitudinal dependent Coriolis force is balanced by the pressure gradient force. The dynamical balance relationships produce reasonable estimates for large horizontal scales and mid-latitudes. However, for small scales, good estimates are not obtained. In addition, in the tropical regions the Coriolis force is small and the geostrophic relationship breaks down. The need for direct wind observation in the tropics and over the oceans is emphasized since observations in these regions are sparse or not existent.

To answer to this need, LEOSPHERE recently developed a new generation long range compact, eye safe and transportable wind Lidar capable to fully determine locally the wind field in real time in the planetary boundary layer (PBL) and the free troposphere.

The Lidar is derived from the commercial Windcube ™ widely used by the wind industry and has been modified increasing the range up to several kilometers enabling the measurements in the PBL and up to the cirrus clouds. First results of the measurement campaign which took place in Cabauw (NL) in May 08 and Orsay (FR) in August 08 put in evidence both vertical wind speed and atmosphere structure (PBL height , clouds top and base) derived from Lidar data with good time resolution (30s per profile), good range resolution (50m from 100m to 4000m), and good velocity resolution (0.2m/s).

The lidar has been successively demonstrated by independent laboratories for continuous wind profiling during validation campaigns against calibrated cup anemometers [1]. It is now mass-produced and more than a dozen of WINDCUBEs is currently in operation all around the world, both offshore and onshore in flat and complex terrain.

In 2008, thanks to a more powerful laser, longer ranges can be reached and interesting atmospheric parameters can be monitored such as wind shears or wind vertical components under clouds. We report on results obtained during operational campaigns, as LUAMI'08 in Lindenberg (Ge) or EUCARII'08 in Cabauw (NL).

MEASUREMENT SET-UP

WindCube WLS70 was deployed in Orsay (48.7N 2.2W) in the beginning of August 2008. The WLS70 Lidar instrument was placed near by an EZ Lidar™ as Figure 1 shows.

EZ Lidar™, is a rugged and compact eye safe aerosol Lidar, that uses a tripled pulse laser source Nd:YAG at 355nm wavelength with an energy of 16mJ and pulse repetition frequency of 20 Hz. Both analog and photon counting detection is available. The Lidar system, validate through several measurement campaigns, provides a real time measurement of backscatter and extinction coefficients, Aerosol Optical Depth (AOD), and an automatic detection of the Planetary Boundary Layer (PBL) height and cloud base and top from 100m up to 20 km

The WindCube WLS70 is a wind Lidar developed for meteorological applications. System utilizes pulsed Erbium Doped Fiber Laser at 1.54µm wavelength and heterodyne detection. As the Doppler frequency shift is proportional to the radial component of the wind speed, the calculations are done in real time without need of calibration. 3D wind data are delivered every second on the 10 range gates allowing both average values and turbulence to be measured. Special attention is done to fulfill all environmental conditions requirements, cold or hot temperature and rain. Data are automatically sent and stored for an unattended operation. They can be sent to a remote server via GSM.

The Lidar is derived from the commercial WindCube™ WLS7 with some major changes:

Figure 1 Windcube WLS70 and EZ Lidar™ in Orsay, August 2008

- The conical scan has been removed for a sole measurement the vertical wind speed. The beam is then transmitted vertically in starring mode.
- The optical set up, the pulse length and the number of averaged pulses have been modified to increase the range greater than 4000 meters and however maintain vertical wind velocity resolution better than 0.4 m/s
- The WLS70 has been integrated in the same compact and waterproof casing than the WLS7 Windcube.

The table below summarizes the Windcube WLS70 new parameters

Parameter	Windcube WLS7	Windcube WLS70
Conical scan	Yes	No (under test)
Vertical speed	Yes	Yes
Horizontal speed and direction	Yes	Available Soon
Range	40-200m	100-8000m
Range resolution (FWHM)	20m	50m
Number of range gates	10	80
Velocity resolution	0.2m/s	0.4m/s
Nb of averaged shots/profile	10000	20000
Measurement time	1.5s	13s

Table 1 Respective characteristic of WLS7 and new long range WLS70

In table 2 are summarized the parameters that are the same for both systems.

Parameter	Windcube WLS7 and WLS70
Wavelength	1540 nm
Casing	L80xl55xh65cm
Supply	24V – 120W
Remote control	Windows Remote deskstop
Data transfer via GSM	FTP

Table 2 Invariant parameters for WLS7 WLS70

MEASUREMENT DATA

The WLS70 measures both the amplitude and spectral content of the backscattering signal. From raw data, the embedded signal processing software performs the computation of the aerosol backscattering coefficient and vertical wind speed profile.

The data are stacked in 2D arrays with horizontal axis corresponding to elapsed time and vertical axis corresponding to altitude. Carrier-to-Noise Ratio(CNR) and wind vertical velocity are coded in false colors, from blue for lower values (down) to red for higher values(up). CNR and velocity data are stored in binary files. WLS70 software transforms these data into ASCII format for further processing.

CET(Central European Time) time has been selected for timestamps. It can be change easily in the software for other areas.

Similarly, EZ Lidar™ data are plotted in 2D array, with horizontal axis corresponding to elapsed time and vertical axis to the altitude. The total normalized relative backscattering is coded in false colors. Red put in evidence a higher aerosol load.

MEASUREMENT RESULTS

On 1st August 08 in Orsay (FR), the temporal plots of the Radial Wind Speed and CNR are plotted respectively in Figure 2 and Figure 3, while in Figure 4 is represented the normalized relative backscattering (NRB) measured by EZ Lidar™ in the same spatial-temporal frame of Figure 2 and 3.

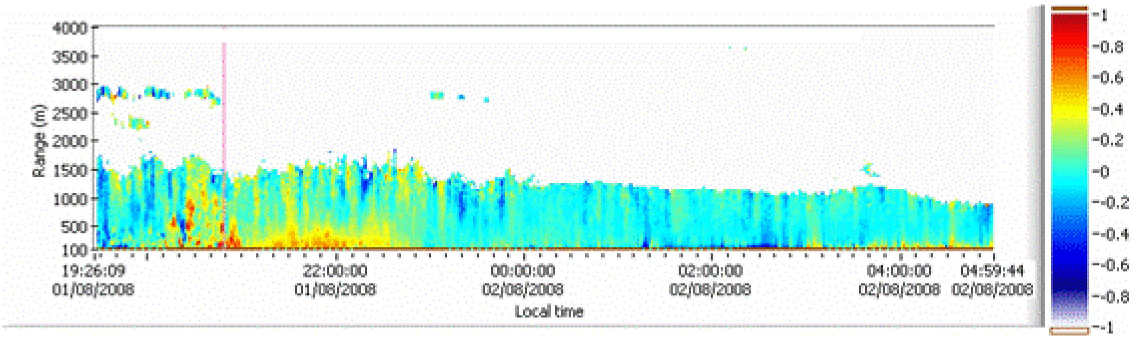

Figure 2 Vertical wind speed on 1st August 2008 in Orsay

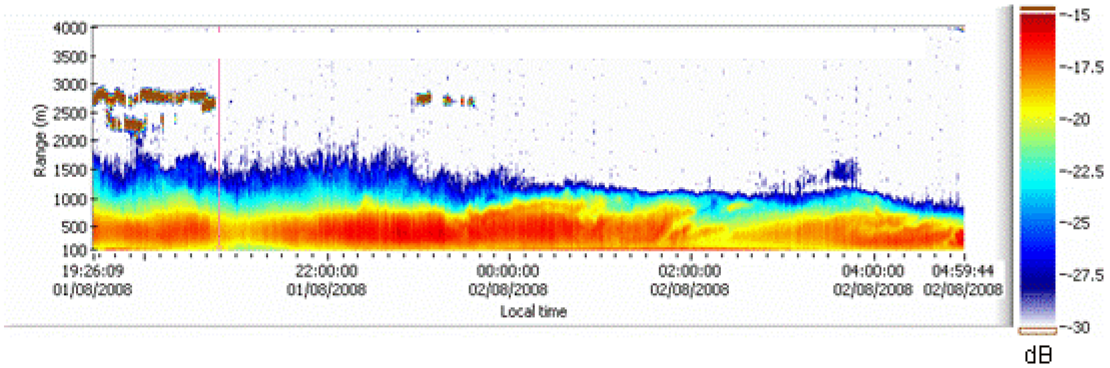

Figure 3 CNR on 1st August 2008 in Orsay

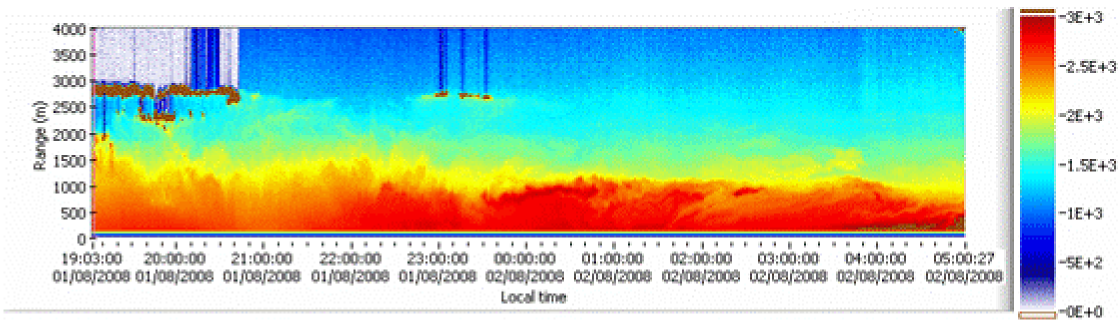

Figure 4 EZ Lidar™ NRB on 1st August 08 in Orsay. Range resolution is 15m and accumulation time is 30s.

Higher values of CNR are proportional to higher aerosol concentration. At 1540 nm, molecular scattering is negligible; it is then possible to directly retrieve the Planetary Boundary Layer height evolution observing the height at which the CNR drops drastically. In Figure 3 it can be observed the evolution of the PBL with the classical late afternoon decreasing of the residual layer to the stable layer in the night hours. Vertical wind speed (Figure 2) explains PBL dynamics. Strong vertical air motion and turbulence can be observed until late summer evening. The NRB profile retrieved with EZ Lidar™ put in evidence the same textures of Figure 3. The higher response to the aerosol load from 10pm showed in Figures 3 and 4 indicates a non turbulence layer with relative stability. In these conditions the pollutants do not disperse in the atmosphere but they stay increasing the level health risks. This is confirmed also from the wind measurement in Figure 2 where after 10pm the vertical wind is negligible.

On the second example shown below, taken on the 2nd of August 08, a front is in transit producing rain as can be noticed in Figure 5, when from 5am to about 6.30am ascending vertical wind speed indicates a lowering in pressure that gradually brings rain. The CNR in Figure 6 shows the same trend

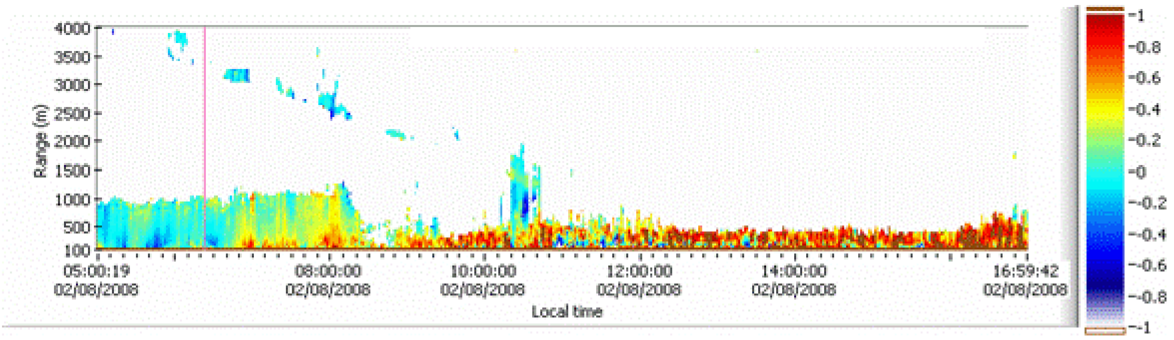

Figure 5 Vertical wind speed on 2nd August 2008 in Orsay

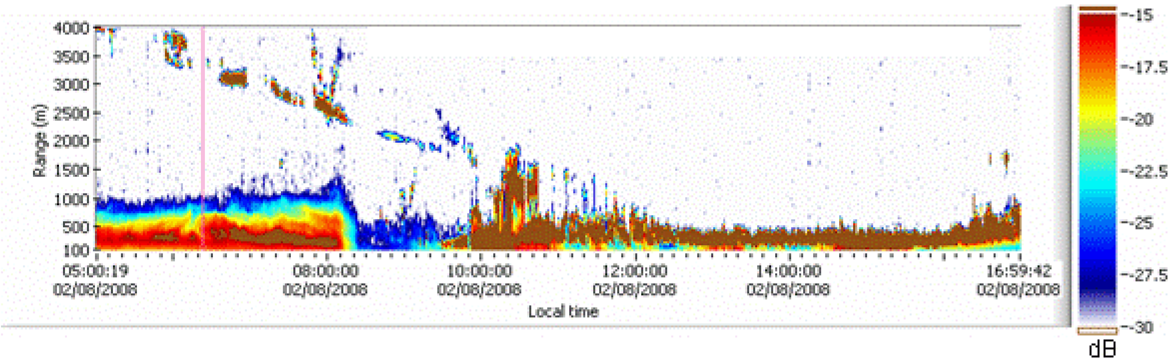

Figure 6 CNR on 1st August 2008 in Orsay

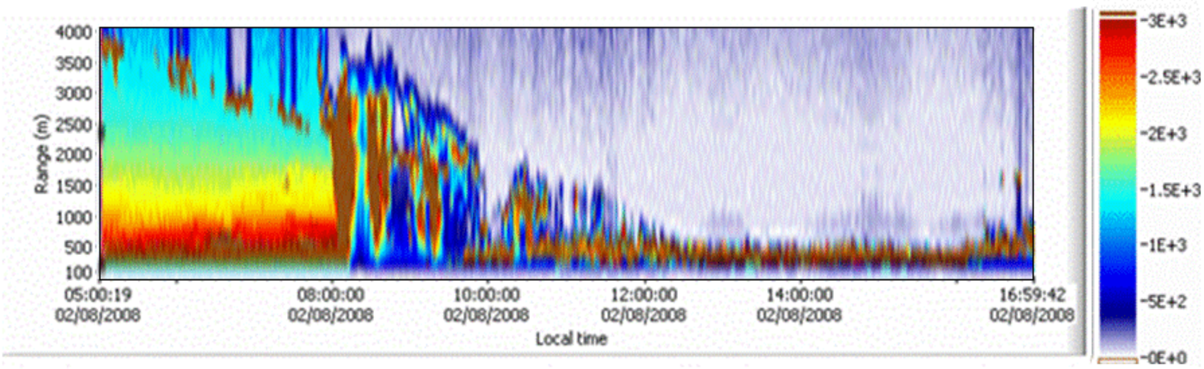

Figure 7 EZ Lidar™ NRB on 2nd August 08 in Orsay. Time is in UTC

5. CONCLUSIONS

WindCube WLS70 is a pulsed Doppler Lidar based on fiber-optic technology and has been experimentally tested and validated through EZ Lidar™ for PBL and Cloud height, and against sodars and RS for windspeed and direction. The system was designed for long-range, range-resolved, atmospheric wind measurements. Due to its robustness and fully transportability, together with velocity resolution, range and temporal resolutions of 0.4 m/s , 50 m, and 13s are potentially useful for a range of boundary layer meteorology applications where punctual measurements in the micro and mesoscale are required. Simultaneous horizontal speed and direction measurements will be soon available on this lidar that will be used in the coming LUAMI campaign in November 2008.

6. REFERENCES

[1] R. Parmentier, C. Aussibal, J.P. Cariou, WindCube™ pulsed compact wind profiler: Overview of 1 year of comparison campaigns with calibrated sensors, EGU 2008, Vienna.