Validation of Long Range Wind Lidar for Atmospheric Dynamics Studies in the LUAMI campaign

L. Sauvage, J.P. Cariou[1], S. Lolli[1,] R. Parmentier[1], M. Boquet[1]

[1]Leosphere, 76 Rue Monceau 75008 Paris, France (lsauvage@leosphere.fr)

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.

LEOSPHERE recently developed a new generation long range compact, eye safe and portable wind Lidar capable to fully determine the local the wind field in real time in the planetary boundary layer (PBL)

MEASUREMENT SET-UP

The WLS70 is a coherent Doppler wind Lidar developed for meteorological applications. The Lidar is derived from the commercial WindCube WLS7 as described in [1] with some major changes:

The optical set up, the pulse length and the number of averaged pulses have been modified to increase the range greater than 2000m in the PBL and greater than 4000 meters on clouds and however maintain wind velocity accuracy better than 0.2 m/s. The WLS70 has been integrated in the same compact casing of the WLS7 WindCube.

The WLS70 uses a 1.5µm pulsed fiber laser in MOPA configuration and a coherent detection, allowing the radial speed component to be measured at different distances along the line of sight. Wind velocity is derived from sequential lines of sight in North, East, West, and South respectively, along a cone with zenithal axis.

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Figure 1 WindCube WLS70 in Orsay, August 2009

Table 1 summarizes the WindCube WLS70 new parameters and Table 2 summarizes the parameters that are the same for both systems.

Parameter	WindCube WLS7	WindCube WLS70
Range	40-200m	100-4000m
Range resolution (FWHM)	20m	50m
Number of range gates	10	70
Measurement time	1.5s	15s

Table 1 Major difference between WLS7 and new long range WLS7

Parameter	WindCube WLS7 and WLS70
Horizontal speed and direction	Yes
Vertical speed	Yes
Velocity accuracy	0.2m/s
Wavelength	1540 nm
Casing	L80xl55xh65cm
Supply	24V – 120W
Remote control	Windows Remote deskstop
Data transfer	Ethernet or wireless GPRS

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 the 3-D 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, horizontal velocity and direction are coded in false colors. For vertical speed the color code varies 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.

First measurements were performed in Orsay, France in August 2008. Then the system took part of LUAMI campaign in Lindemberg, Germany, from November 2008 to January 2009

The objective of LUAMI campaign was to validate the performance and benchmark the new system against existing instruments for upper air measurements.

The lidar has been tested against meteorological masts, sonic sensors, radars and radiosounding. To estimate its performance in aerosol profiling, the WLS70 Lidar was placed close together also with an EZ Lidar™ ALS450 as shown on Figure 2.

Figure 2 Leosphere lidars WLS70 and ALS450

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.

During 62 days, the WLS70 Lidar retrieved 24/24 hours vertical profiles of the 3 wind components, putting in evidence wind shears and veers, as well as gusts and high frequency convective effects with the raise of the mixing layer or with incoming rain fronts. In-cloud and multilayer measurements are also available allowing a large range of additional investigations such as cloud-aerosol interactions or cloud droplet activation

LUAMI MEASUREMENT RESULTS

On 19th November 2008, the temporal plots of the Vertical Wind Speed, Horizontal Wind Speed, Direction and CNR are plotted respectively in Figure 3 , Figure 4, Figure 5 and Figure 6.

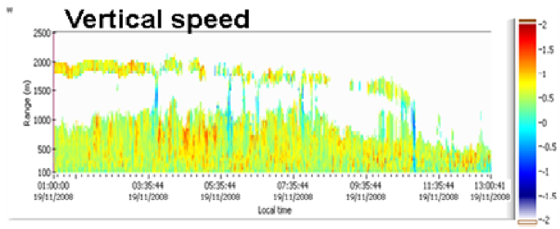

Figure 3: WLS70 Vertical Wind Speed relative backscatter (dB) on 19th November 2008 Lindenberg

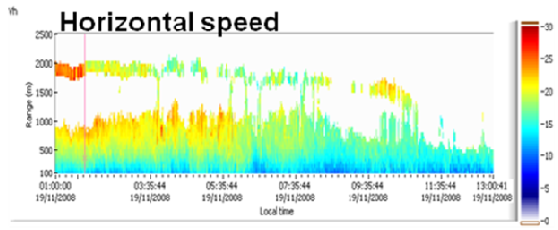

Figure 4 WLS70 Horizontal wind speed on 19th November 2008 in Lindenberg

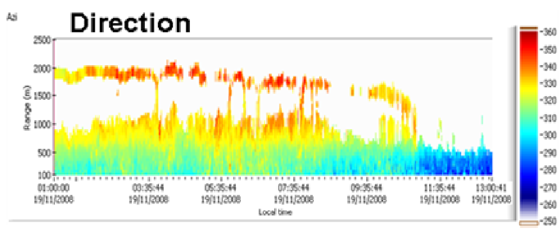

Figure 5: WLS70 Wind Direction on 19th November 2008 in Lindenberg

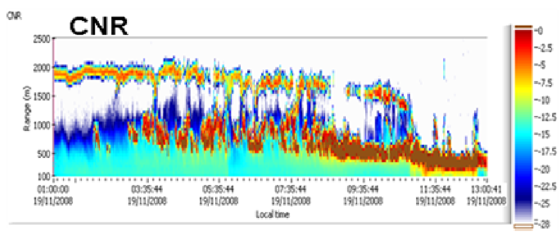

Figure 6: WLS70 CNR on 19th November 2008 in Lindenberg

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 we can observe the evolution of the PBL with the classical updrafts and downdrafts due to the convection. In Figure 4 and Figure 5 we can observe how both horizontal speed and direction vary respect to the altitude, putting in evidence shear and veer. Figure 6 makes possible through the CNR the detection of different layers in the atmosphere and the PBL height time evolution.

The WLS70 was validated also against a co-located wind profiler in Lindenberg. Preliminary results of 3 weeks measurement show a very good agreement between the two instruments. Radar data and Lidar data are compared at 500m altitude, with a temporal average on horizontal wind speed and direction of 10 minutes for the WLS70 and 30 minutes for the Radar. Results are showed in Figure 7.

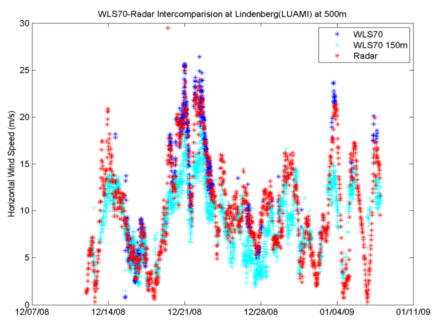

Figure 7 3 Weeks WLS70 and Radar Horizontal wind speed intercomparison during Luami campaign (Radar-red, WLS70-bleu, WLS70 at 150m cyan)

From December 20th to December 21st the agreement is particularly good, as depicted in Figure 8.

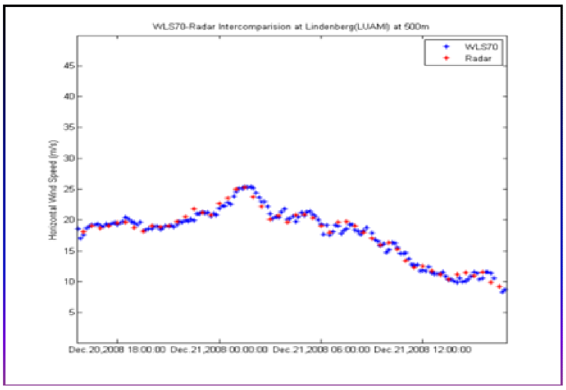

Figure 8 2 Days WLS70 and Radar Horizontal wind speed intercomparison during Luami campaign (Radar-red, WLS70-bleu)

On the same temporal period, at the same altitude are compared the wind directions retrieved from both instruments, as shown in Figure 9:

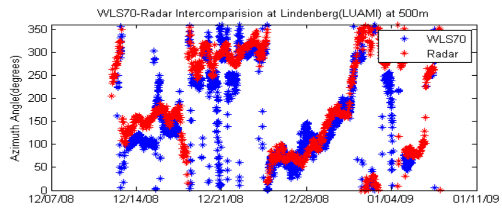

Figure 9 3 Weeks WLS70 and Radar wind angle direction intercomparison during Luami campaign (Radar-red, WLS70-bleu)

The agreement is overall good, with some discrepancies from Dec 14th to Dec 18th.

CONCLUSIONS

WindCube™ WLS70 is a new pulsed Doppler Lidar based on fiber-optic technology transferred from Onera (French Aerospace Lab) and has been experimentally tested and validated through EZ Lidar™ ALS450[2]. The system is 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 0.03 m/s , 50 m, and 15s 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 are now available on these lidars.

During the last intensive inter comparison campaigns, the WLS70 Wind Lidar was validated against lidars, radars, sodars and anemometers. The results show mostly a very good agreement between the instruments. Moreover, the measurements put in evidence both horizontal and vertical wind speed and wind direction vertical profiles and atmosphere structure (PBL height , clouds base) derived from Lidar data with good time resolution (15s/profile), good range resolution (50m from 100m to 2000m), and good velocity accuracy (<0.2m/s).

New measurements are on going at PNNL in Richland, Washington, and NASA Langley in Hampton, Virginia. These results are now processed and will bring a further proof on reliability and accuracy.

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