LIMECS - LiDAR Measurement Campaign Sola

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LiDAR

An increase in nacelle height and rotor diameter of wind turbines in recent years have made measurements of wind profiles via meteorological masts difficult. In response LIDAR remote sensing has become increasingly important. With this technique, wind information at different heights is easily accessible and enables an analysis of boundary layer processes.

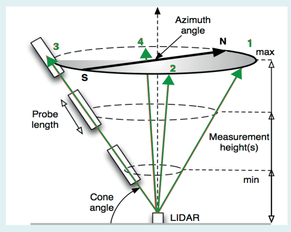


Figure 1: Measurement principal of the Doppler LIDAR WINDCUBE™ V1

WindCube v1

The WindCube v1 (figure 2) is a pulsed LiDAR system using the Doppler Beam Swing (DBS) technique to retrieve prevailing wind profiles. With 10 user defined altitudes the device can measure simultaneously up to a height of 200 m with a data accumulation time of 4 seconds.

Figure 2: WindCube v1 manufactured by Leosphere

WindCube 100S

The WindCube 100S (figure 3) is a scanning pulsed LiDAR system using Plan Position Indicator (PPI), Range Height Indicator (RHI) and DBS scanning techniques to picture 2D ambient flow fields, as well as wind profiles. With a range gate resolution of 50 m the device can measure to a distance of 3 km from the instrument.

Figure 3: WindCube 100S manufactured by Leosphere

Campaign & Methods

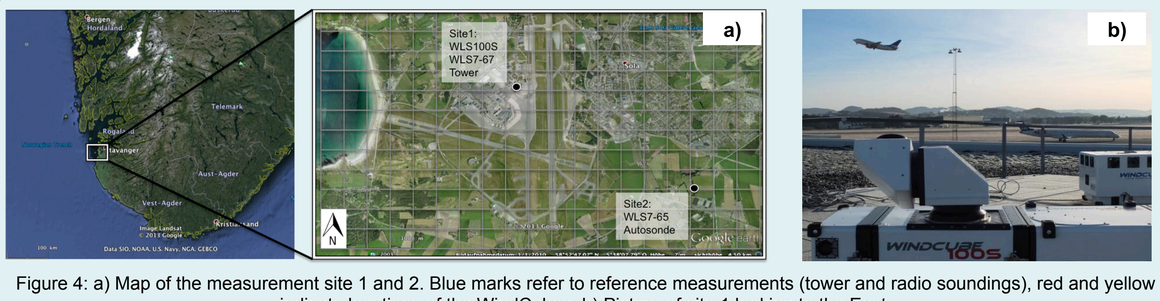


Figure 4: a) Map of the measurement site 1 and 2. Blue marks refer to reference measurements (tower and radio soundings), red and yellow indicate locations of the WindCubes. b) Picture of site 1 looking to the East.

Campaign

LIMECS was launched from beginning of March until mid of August 2013 at two different sites near the airport of Stavanger. The scanning WindCube 100S (WLS100S-8) and a WindCube v1 (WLS7-67) measured wind fields and profiles above the rooftop of the fire brigade building at Stavanger airport (site 1) respectively. At site 2, 2.3 km southeast of site 1, the other WindCube v1 (WLS7-65) measured wind profiles next to autosonde from the Norwegian Meteorological Institute (figure 4).

During the period of the campaign we temporarily increased the radiosonde launches from 2 to 4 releases per day. The two WindCubes v1 measured every 20 m from 40 to 200 m the three dimensional wind vector with a 4 second independent sampling rate, while the WindCube 100S measured at higher ranges between 150 and 3000 m, with a range gate of 75 m. In addition to wind profiles, the WindCube 100S also measured vertical and horizontal cross-sections of radial wind fields (figure 5), for a certain repetitive scanning pattern.

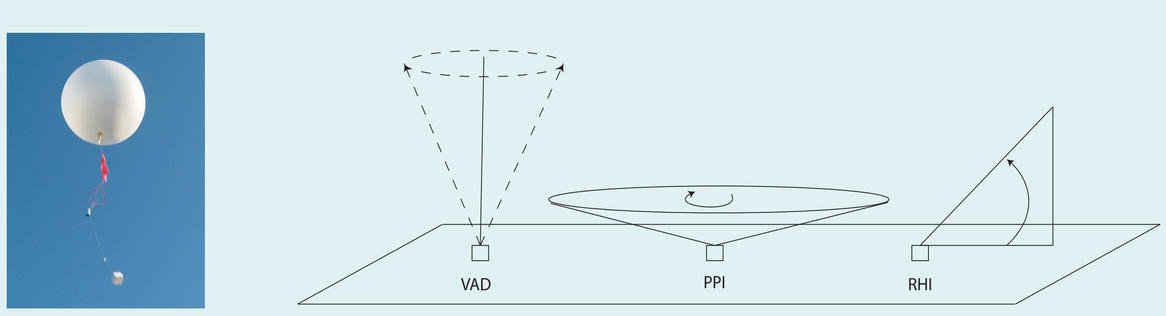
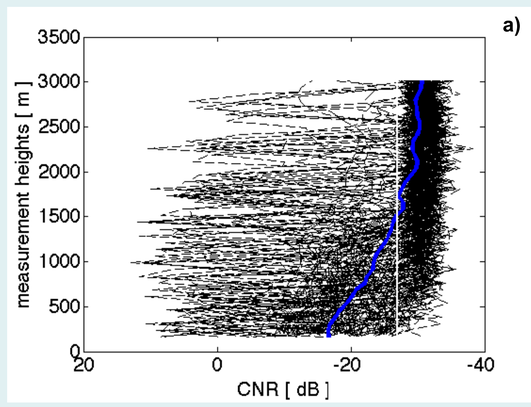


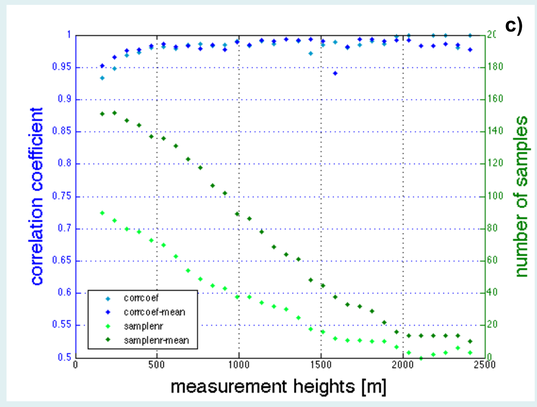
Figure 5: Picture of ascending radiosonde in a) and a sketch of possible scanning techniques with the WindCube 100S from left to right in b): Velocity Azimuth Display (VAD), PPI, RHI, leading to wind profiles, horizontal and vertical flow cross sections respectively.

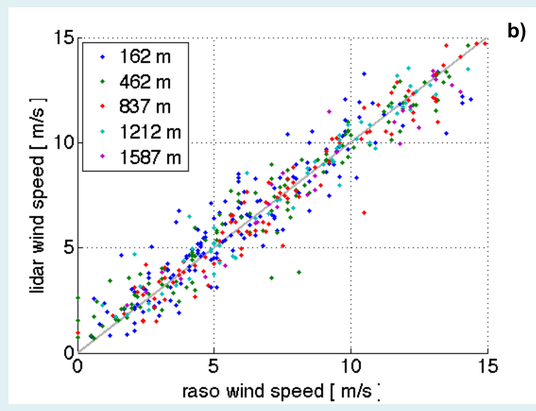
Methods

The collected LiDAR measurements are going to be compared among each other, as well as to wind data collected by radiosonde ascents of the Norwegian Meteorological Institute (figure 7). In order to compare LiDAR to radiosonde measurements, the closest LiDAR profile to the time of the radiosonde launch is picked and compared to an over the range gate averaged wind speed of the radiosonde.

Results







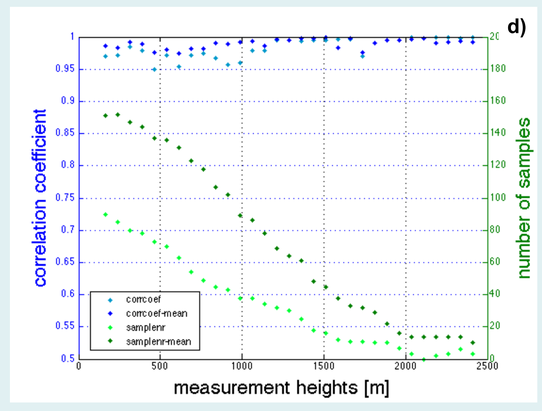


Figure 6: a) CNR profiles of the WindCube 100S for the period of comparison. The blue line indicates the average CNR profile and the white line shows the CNR threshold for data availability. b) Correlations of wind speeds of the same profiles to radiosonde wind measurements for different measurement heights. c) Correlation coefficients between WindCube 100S and radiosonde wind speeds as a function of height. In green the number of available measurements. d) Correlation coefficients between WindCube 100S and radiosonde wind directions as a function of height. In green the number of available measurements.

LiDAR-radiosonde comparison

First comparisons between 156 wind profiles measured by both, the LiDAR (WLS100S) and radiosonde show a correlation coefficient of 0.95 and 0.99 for wind speeds at measurement height of 162 m and above 500 m, respectively (figure 7). For wind direction the two measurement principles agree even a bit better, especially for 10 min averaged LiDAR wind directions.

During the analyzed period from mid March to mid July the average measurement range of the WindCube 100S was limited to around 1.5 km, as the data availability is dependent on weather conditions and aerosol concentrations.

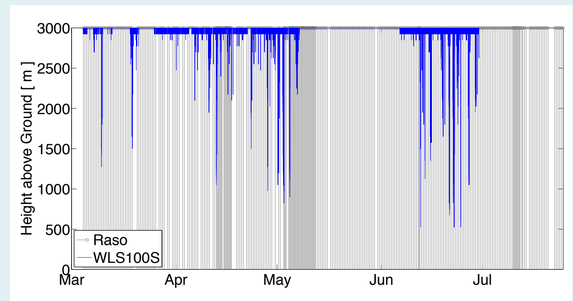


Figure 7: Data availability of WLS100S and radiosonde measurements over the whole measurement period. The blue lines indicate the maximal available measurement height.

Case study – Land breeze

Measurements show a case study of a land breeze circulation captured with the WindCube 100S on March 12th 2013. The surface near reversed flow layer is heading towards the sea with wind speeds of about 2 m/s and a depth of around 300 m (figure 6a).

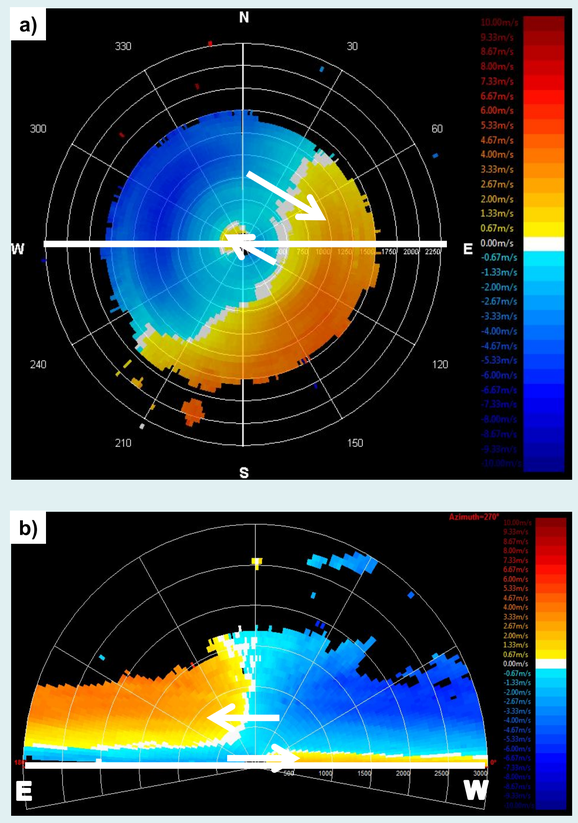


Figure 8: a) PPI scan of WLS100S on March 12th 2013 at 08:30 UTC. b) RHI scan of WLS100S on March 12th 2013 at 08:45 UTC. Red color indicate motion away from the LiDAR and blue towards the LiDAR.

Conclusions

- The compared WindCube 100S data is available on average until 1.5 km above ground level.
- Correlation coefficients between LiDAR and radiosonde wind measurements are height dependent and increase from 0.6 at 50 m to 0.99 at altitudes above 500 m.
- The WindCube 100S is able to capture costal boundary layer structures as shown in the case of a land breeze. Therefore it is a nice tool for boundary layer studies.

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