SCIENTIFIC REPORT

1

ACTION: ES1303 TOPROF
STSM: COST-STSM-ES1303-33730
TOPIC: Leosphere WindCube characterisation
VENUE: Reykjavik, Iceland
PERIOD: 4 to 8 April 2016

Host: Guðrún Nína Petersen (Icelandic Meteorological Office, Iceland)

Applicant: Jana Preißler (National University of Ireland Galway, Ireland)

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Contribution by: Jana Preißler (National University of Ireland Galway, Ireland), Guðrún Nína Petersen (Icelandic Meteorological Office, Iceland), Ewan O'Connor (Finnish Meteorological Institute, Finland), Ludovic Thobois (Leosphere, France)

Introduction

The STSM from 4 to 8 April 2016 was hosted by Guðrún Nína Petersen at the Icelandic Meteorological Office in Reykjavik, Iceland. Further participants were Ewan O'Connor from the Finnish Meteorological Institute in Helsinki, Finland and Ludovic Thobois from the lidar manufacturer Leosphere in France.

The STSM was dedicated to characterising the performance of Leosphere scanning WindCube Doppler lidar systems. Understanding the system performance and uncertainties in the basic measurements of radial Doppler velocity and signal-to-noise ratio is vital for providing reliable products. The uncertainties in the raw measurements can then be propagated through to the higher-level products that are created, like wind speed and direction, and turbulent properties. The measurement setup, scan selection and processing chain was evaluated with the objective of providing harmonised retrievals so that Leosphere systems can fit within an emerging European Doppler lidar network capable of providing reliable wind products and turbulent parameters in the boundary-layer.

The work plan included:

- outline of current operating procedures, scan selection and instrument performance
- describe current processing chains for Leosphere instruments
- highlight actual and potential instrument issues
- perform specific scans and evaluate results
- characterise performance: velocity uncertainty, signal uncertainty, background correction
- identify additional processing steps required
- begin definition of tests and processing tools necessary to harmonise Leosphere Doppler lidar data
- using the results previously obtained to begin optimisation of scan strategy
- update current processing chains where necessary
- begin writing Standard Operating Procedures document for Leosphere systems

There are two WindCube 200S with depolarisation capability in Iceland (one at Keflavik airport and one mobile), and currently one WindCube 200S without depolarisation capability at Mace Head in Ireland.

Results

The software

Wind lidars of Halo Photonics are deployed by a number of TOPROF members and tools exist for data processing and analysis for these instruments. A homogenised processing of wind lidar data across Europe is desirable for a number of reasons. Data standards can facilitate data sharing and the use in data assimilation into models. One objective of the STSM was to convert the output of the Leosphere WindCube Doppler lidars to a common netcdf format.

1

During the STSM, existing Python (2.7) scripts for conversion, plotting and analysis of WindCube data were adapted to output the common netcdf format. With the new netcdf output, the WindCube data can now be used as input for tools developed for Halo wind lidars by other TOPROF participants. A flow chart of the Python scripts is shown in figure 1. A documentation of the Python package exists and can be used as starting point for a Standard Operating Procedures document for Leosphere systems.

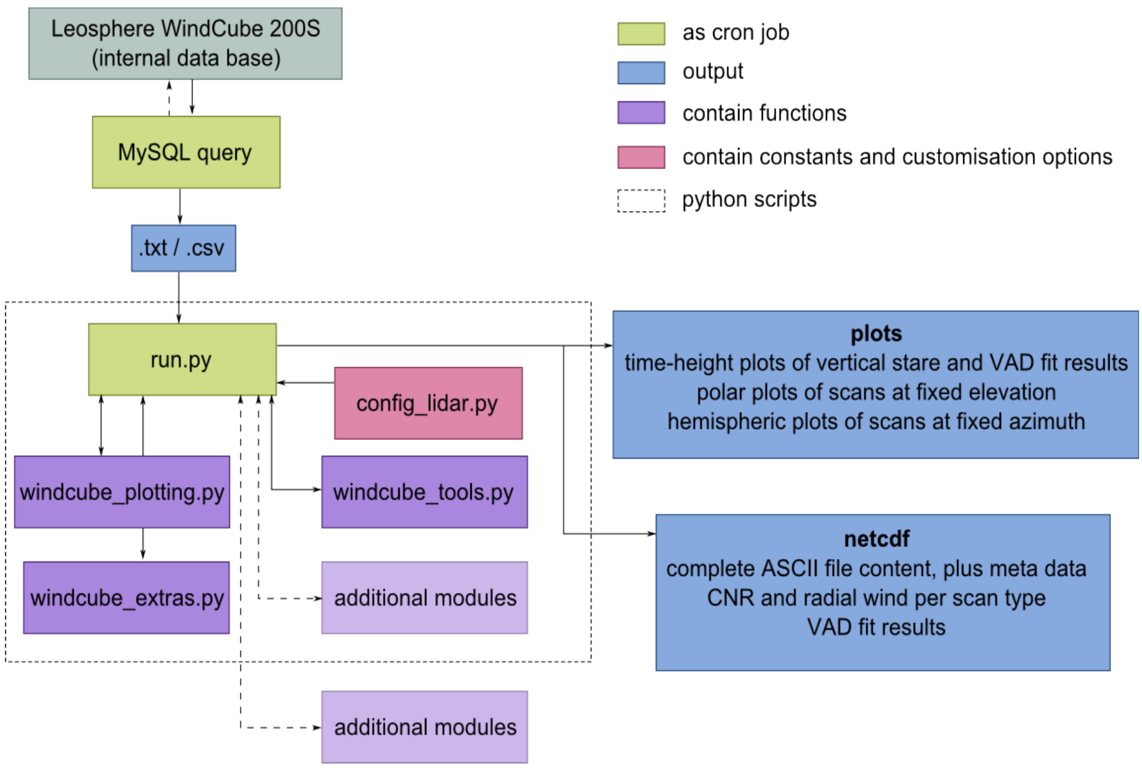

Figure 1 Flow chart of the Python scripts for conversion, plotting and analysis of WindCube data.

Those scripts also process VAD scans (velocity azimuth display = one full scan at fixed elevation angle) to obtain profiles of the horizontal wind speed and direction and the vertical wind speed. A least square fit of a sine function is done for each scan at each range bin (more on scans in the next section).

Automatic detection of aerosol and cloud layers and the PBL height, as well as calculation of the attenuated backscatter coefficient are performed by the WindCube. These products are provided by the instrument as additional output and were validated by Leosphere on limited datasets. However, they should be further validated on long term datasets in TOPROF in comparison with reference sensors or other algorithms.

The analysis tool SCUDA from Leosphere was used to calculate the instrument calibration function. A screen shot of the relevant part of the SCUDA interface is shown in figure 2. The calibration function is obtained by applying a Lorentzian fit to a measurement assuming homogeneous backscatter. This is best done for line of sight measurements at a low elevation angle or a low level scan over homogeneous terrain. At Mace Head, a scan at 3° elevation over the sea sector (210° to 330° azimuth) is repeated every hour.

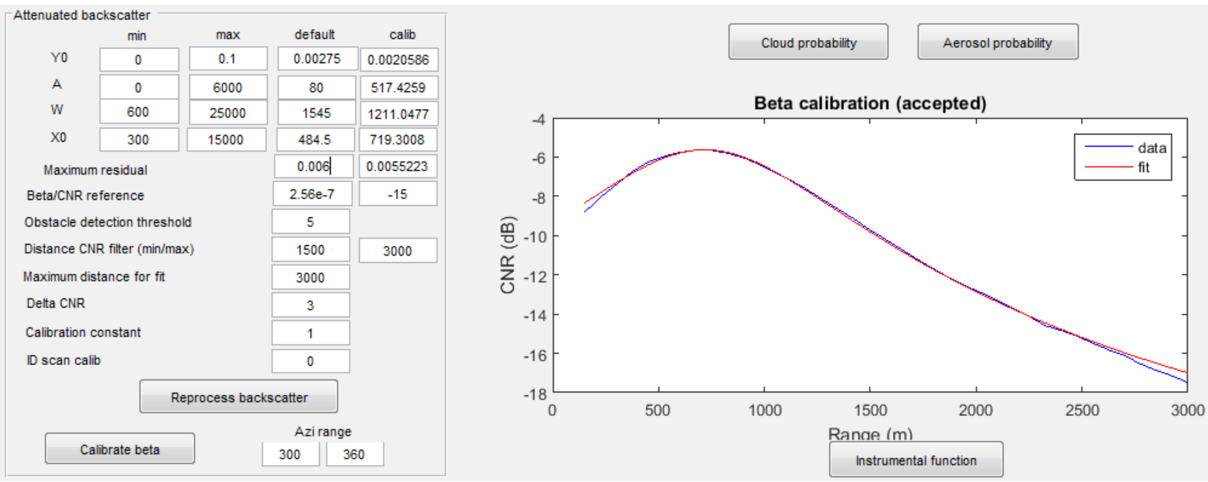

Figure 2 Screen shot of part of the SCUDA software and the instrumental function.

Scan recommendations

A scan schedule was set up and can be recommended to other users of scanning wind lidars. The recommended minimum scan pattern consists of two VAD scans at 15° and 75° elevation (75° and 15° off zenith, respectively) every 15 minutes, and a continuous vertical stare measurement (90° elevation, zenith) for at least 10 minutes in between the scans. The users can then add hourly or daily scans according to their specific requirements.

At Mace Head, VAD scans were performed as fast complete 360° scans (6°/s). This was changed to composites of 12 line-of-sight (LOS) measurements of 2 and 5 seconds averaging time per LOS at 15° and 75° elevation, respectively, to improve the signal threshold. Using these settings, the VAD scan at 15° elevation takes less than half a minute and the VAD scan at 75° elevation takes one minute. The composites LOS measurements by the Icelandic Met Office (IMO) at 15° and 75° elevation were both programmed to 5 seconds averaging time per LOS.

Figures 3 and 4 show the fit results of the VAD scans and illustrate the importance of the combination of both scans, especially in the low range. The first range bin is at 150 m, which at an elevation angle of 75° is 145 m altitude above ground level. However, at an elevation angle of 15° this detection limit is reduced to 39 m altitude above ground level. The same effect is true for the range of incomplete overlap of laser beam and receiver telescope. On the other hand, the higher elevation scan is more precise at higher altitude as the diameter of the scan circle is smaller and more representative of the profile. Therefore, a combination of two scans is recommended.

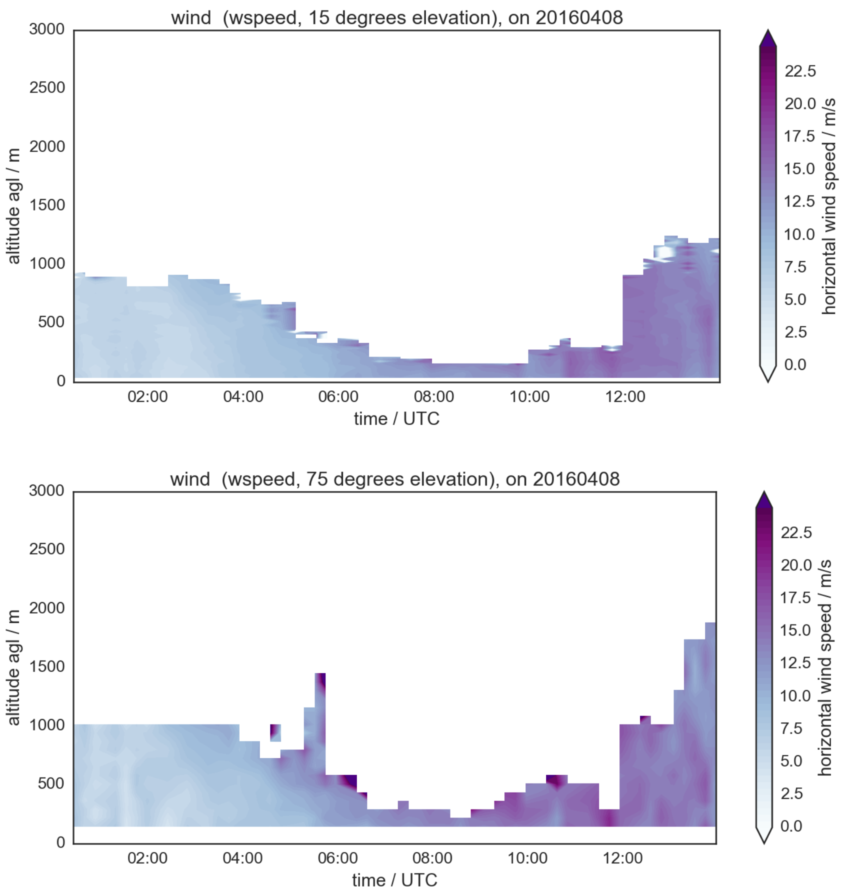

Figure 3 Time-height plots of the horizontal wind speed from VADs at 15° (top) and 75° (bottom) elevation.

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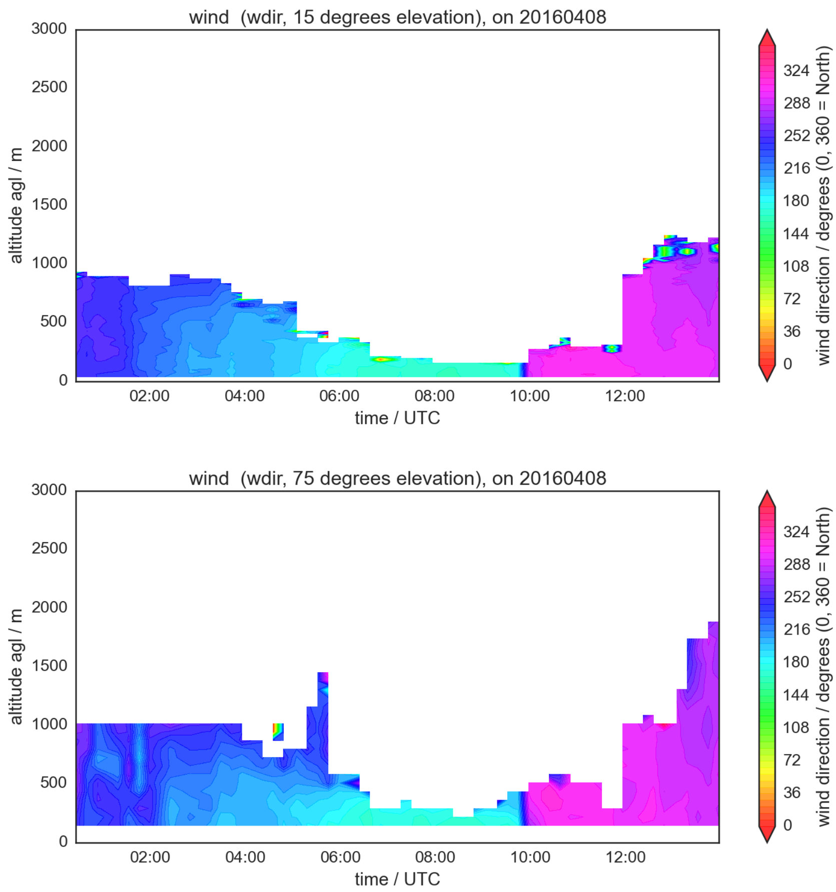

Figure 4 Time-height plots of the wind direction from VADs at 15° (top) and 75° (bottom) elevation.

The Leosphere WindCube systems also provide the possibility to perform Doppler beam swinging scans (DBS), which comprise of five LOS, one at zenith, and four at the same elevation angle but different azimuth angles. Similar to the VAD scans, those can provide horizontal and vertical wind at a high temporal resolution, but were not included in the scan schedule.

The vertical stare measurement should be done at a high temporal resolution of 0.5 or 1 second. This is important for the study of turbulence.

At Mace Head, a low level scan over the sea is done every hour for the retrieval of the calibration function. Additionally, a low level scan over the mountains is done twice a day to validate the pointing accuracy of the instrument and the radial wind retrieval. The mountains are used as a hard target, which should appear always at the same point in the scan, and should always have a radial velocity of 0 m/s. Also, the IMO lidar at Keflavik airport performs a low level scan (0.5°) once a day for the retrieval of the calibration function as well as to validate the pointing accuracy, using aircraft hangars as hard targets.

Instrumental issues

1. Hardware

One problem for both Icelandic and the Irish instruments was condensation on the inside of the telescope window. Desiccant is provided with the instrument, but doesn't seem to be sufficient. Also the recommended exchange periods of the desiccant containers are too long. This leads to heavy condensation inside the supposedly sealed housing, which leads to strong attenuation of the signal and might even cause damage to the detectors due to strong internal reflections. This behaviour is not common in the worldwide WindCube fleet, with instruments in tropical and marine areas. Leosphere proposes to resolve this problem during the next maintenance of the affected units.

The Icelandic instruments have additional problems with the depolarisation detection, due to a faulty mechanical element, which rotates the polariser.

2. Data

The background behaviour is of great concern in most atmospheric lidar applications as it is an indicator for possible malfunctions in signal detection or ill-adjusted data processing. In case of the three WindCube systems, the background behaviour generally seems to be good, which means there is a fairly constant background level with range and time. However, at times of strong attenuation due to condensation inside the system the background as well as the signal is strongly affected, as shown in figure 5. A day with strong condensation in the early morning hours between 4 and 9 UTC (4 to 9 am local time) is shown. The white lines show VAD scans, which cause gaps in the plotted zenith measurements.

In case of the Icelandic WindCubes, CNR values below a certain threshold are masked with a fill value, which is in the valid CNR range. This leads to difficulties when trying to tell fill values and actual CNR values apart.

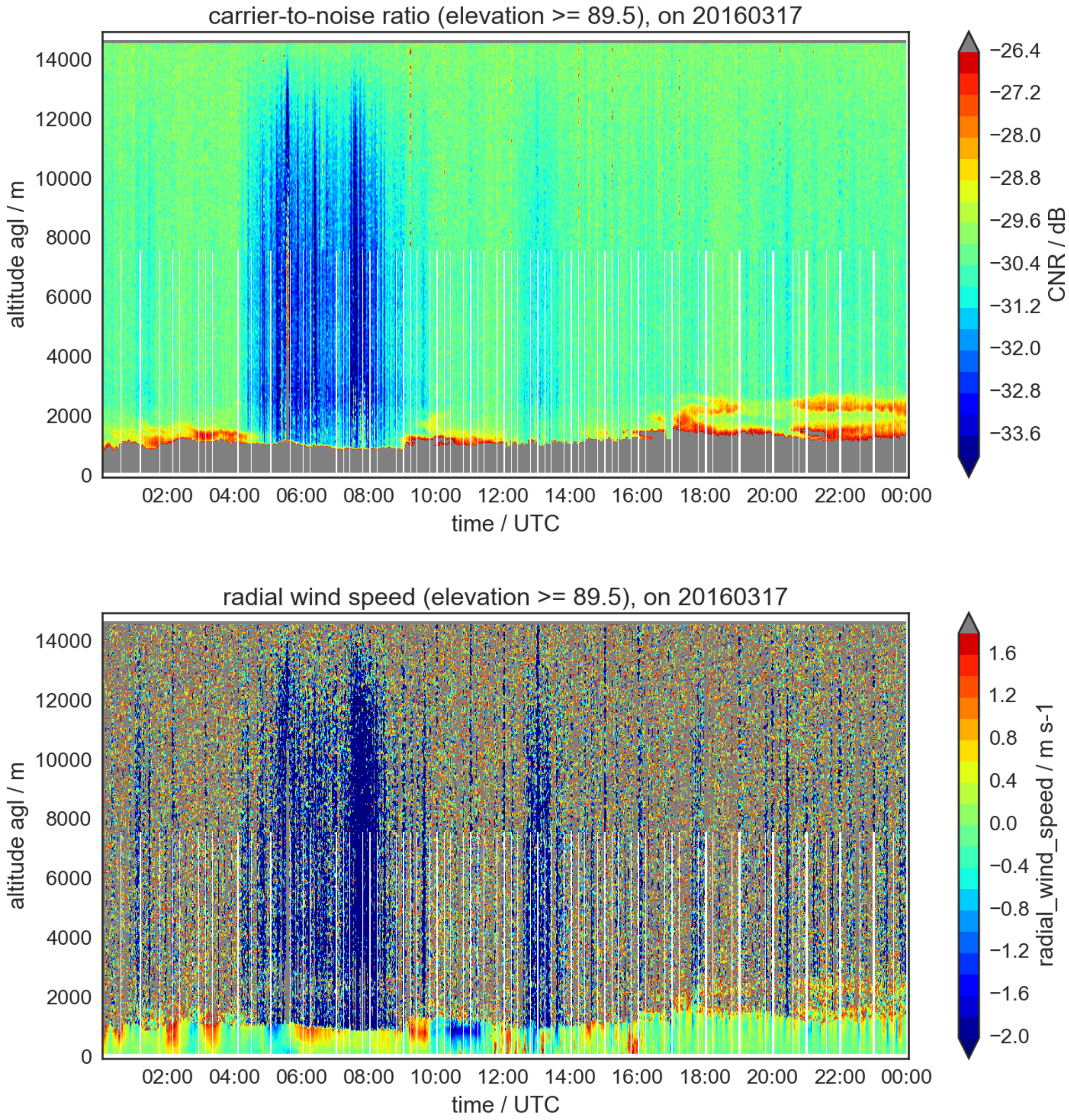

Figure 5 Time-height plot of the CNR (carrier-to-noise ratio, top, colour scale zoomed in to background) and radial wind (bottom) of line-of-sight measurements at 90° elevation.

Conclusions and future work

The STSM greatly improved our understanding of the Leosphere Doppler wind lidars. The Python processing scripts now provide a netcdf output format in common with the Halo systems in order to facilitate data sharing and use of existing algorithms. Different scan patterns were tested and scan recommendations are proposed. We identified some hardware and software related issues and discussed them with Ludovic Thobois, a representative of Leosphere.

The characterisation of the performance, incl. velocity uncertainty, signal uncertainty, and background correction was done by Ewan O'Connor and Ludovic Thobois. The results of their collaboration will be implemented in the processing chain shown in figure 1.

In the future, a systematic analysis of the backscatter calibration scans and the hard target scans is planned. This has been done for few test cases, but should be included in the automatic data quality monitoring. At Mace Head, more than one year of these scan data exist and the past performance of the instrument will be analysed in detail.

The Python software is made in a modular and flexible way. It is planned to implement already existing tools developed by other TOPROF groups in Python or other programming languages, e.g. for background correction, uncertainty estimation, boundary layer detection, backscatter calibration. The documentation of the software package will be updated and a Standard Operating Procedures document for the Leosphere WindCube lidars will be drafted following the results of this STSM.

The scientific report will be posted on the TOPROF website: www.toprof.eu.