Comparison of wind profiles of Skiron3D and Windcube 200s Doppler lidars

Tiemo Mathijssen[a] , Steven Knoop[a]
[a] Royal Netherlands Meteorological Institute (KNMI)
Utrechtseweg 297, 3731 GA, De Bilt, The Netherlands
Tiemo.Mathijssen@knmi.nl

Abstract: A Leonardo Skiron3D Doppler lidar has recently been acquired with the aim of providing wind measurement at Amsterdam Schiphol Airport for research purposes and operational services for aviation meteorology. As an initial step, the lidar is placed at the research site of Cabauw, the Netherlands for intercomparison with a WindCube 200s lidar and in-situ mast wind measurements. The Skiron3D is operated in velocity-azimuth display (VAD) mode, while the WindCube 200s uses a Doppler Beam Swing (DBS) strategy to provide vertical profiles of wind speed and direction. A nearby 213m high mast provides a platform for in-situ wind measurements using cup anemometers, wind vanes. This work presents the comparison of the vertical profiles of both lidars. The lowest measuring heights of the wind lidars are additionally compared with the in-situ measurements in the mast.

1. Introduction

Long range wind lidars have been providing valuable atmospheric wind measurements at airports [1,2]. The Royal Netherlands Meteorological Institute (KNMI) has acquired a Leonardo Skiron3D long-range Doppler wind lidar with the purpose to provide wind measurements at altitude and study the wind conditions for aviation at Amsterdam Schiphol Airport. Among others, it is foreseen to compare them to measurements with cup anemometers, to provide wind profiles, to study aircraft wake vortices, and measure glide slope wind conditions. The Skiron3D will be operated at several locations, in order to cover the entire airport and evaluate the representativeness of all currently operational cup anemometers for the runway wind conditions. The Skiron3D is placed on a movable trailer, making it possible to relocate it with relative ease, see figure 1.

Initial deployment of this lidar is done at the KNMI research site of Cabauw, the Netherlands. This location facilitates easy access to the lidar, which becomes more difficult once it is placed at Amsterdam Schiphol Airport, due to security issues. Moreover, a large number of measurements by other meteorological instruments are available at Cabauw in the framework of the Ruisdael Observatory atmospheric research program [3]. These other instruments provide the opportunity to validate measurements by the Skiron3D. One of the instruments at Cabauw is a Vaisala/Leosphere WindCube 200s wind lidar [4]. This manuscript describes a intercomparison of the Skiron3D wind lidar with the WindCube 200s, which is located only 70 m from the Skiron3D. Also a comparison with in-situ cup anemometers present in the nearby mast is presented.

Figure 1: Skiron3D on a trailer at Cabauw, the Netherlands

 https://doi.org/10.1051/epjconf/202636215002

2. Equipment

The Skiron3D is a scanning Doppler wind lidar with variable pulse length and maximum 20W laser output power. Compared to the WindCube 200s, the Skiron3D delivers a higher power, which allows for either a longer detectable range or faster scanning. A shutter blocks the laser beam periodically in case the scanner is not moving, in order to avoid exposure of the environment of dangerous levels of laser powers. A VAD scan with a scanning speed of 24 deg/s and an elevation angle of 15 degrees with respect to the zenith is configured, leading to a new profile of wind speed and direction every 15s. The selected pulse length of 200 ns allows for wind measurements with a 25m spatial range resolution and an azimuth resolution of 1 degree. The range is set to 14.1km, which captures the majority of the troposphere in the vicinity of the instrument, given a sufficient amount of aerosols present. A unique feature of the Skiron3D system is that it operates 4 individual lasers with slightly different laser frequencies, each at 4500 Hz concurrently. This makes it possible to operate the system with a high combined pulse repetition frequency (PRF) of 18 kHz, allowing high spatial resolution, while avoiding the issue of range ambiguity.

The WindCube 200s is located 70 m from the Skiron3D and scans using the same elevation angle of 15 degrees with respect to the zenith, but operates a DBS scan to generate profiles of wind speed and direction. Also this instrument creates a new profile approximately every 15s. It is operated using a 75m height resolution, for which the PRF is 10 kHz and a maximum height of 14.1km. These settings are configured in order to prevent range ambiguous signals.

The 213 m high mast, at 360m distance, hosts cup anemometers and wind vanes at 7 height levels: 2m, 10m, 20m 40m, 80m, 140m and 200m. At each height level, an anemometer is placed in 2 different azimuth directions to ensure undisturbed wind measurements [5]. Due the limited height of the mast and the blind range of the wind lidars, only a small overlap is present of the in-situ and lidar measurements.

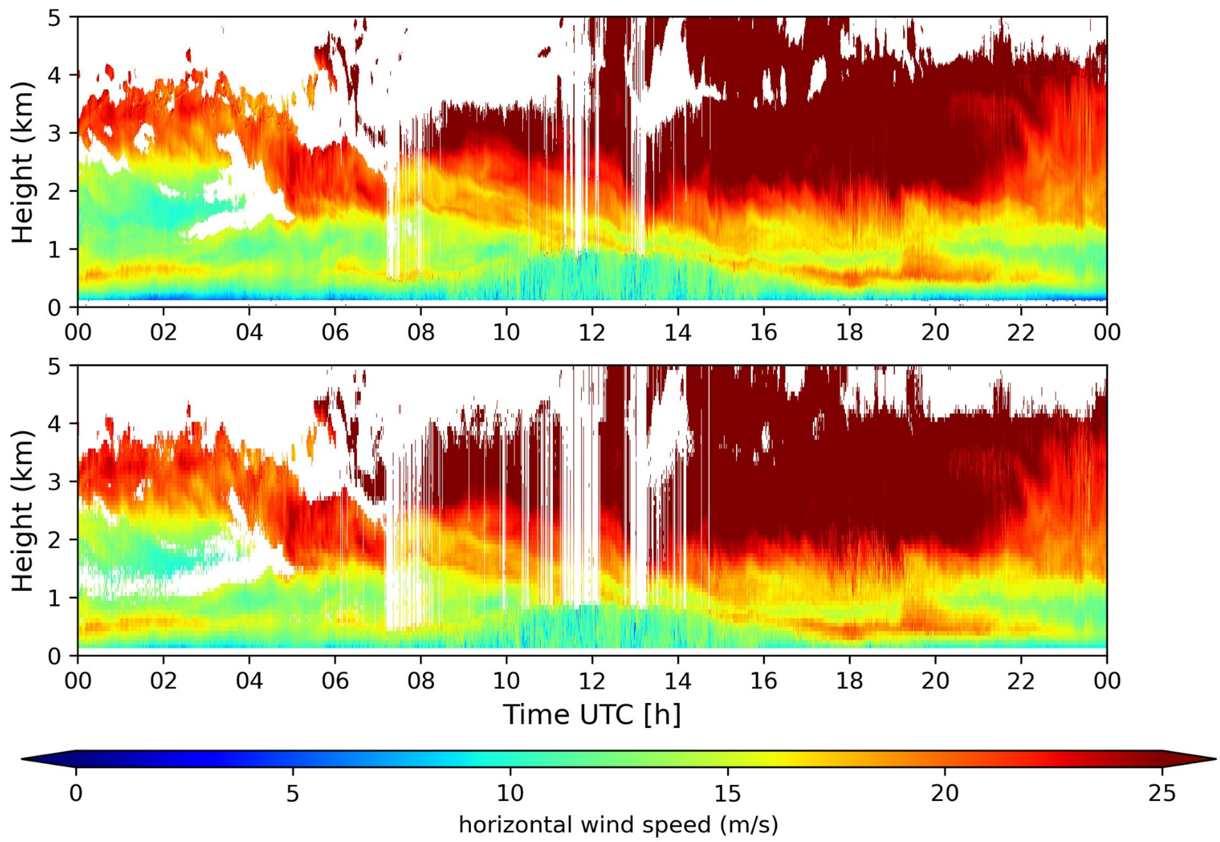

Figure 2: Density plot of the profile of horizontal wind speed of 7th of October 2023 from the Skiron3D (top image) and WindCube 200s (bottom image)

3. Preliminary results

The profiles of horizontal wind over time for a single day are displayed as density plots in figure 2 for both wind lidars. The plots show are remarkable similarity, but some differences are present. The difference in spatial resolution is detectible upon close inspection, and some differences are noticeable in certain time intervals between 7h and 15h UTC, in which measurements are sometimes limited to the height of the planetary boundary layer, and not above. This occurs more frequently for the WindCube 200s than for the Skiron3D.

Data from both wind lidars and the in-situ cup anemometers are averaged over 10-minute time intervals and compared. An example of the profile of the horizontal wind speed in such a 10-min interval is shown in figure 3. The smooth transition between the cup anemometer data in the mast with the two lidar systems provides confidence in the absolute value of the measured wind speed of the lidar systems. Both lidars profiles show little differences and capture the low level jet present at that time. Only at the higher altitude above 4km differences between the two system increase.

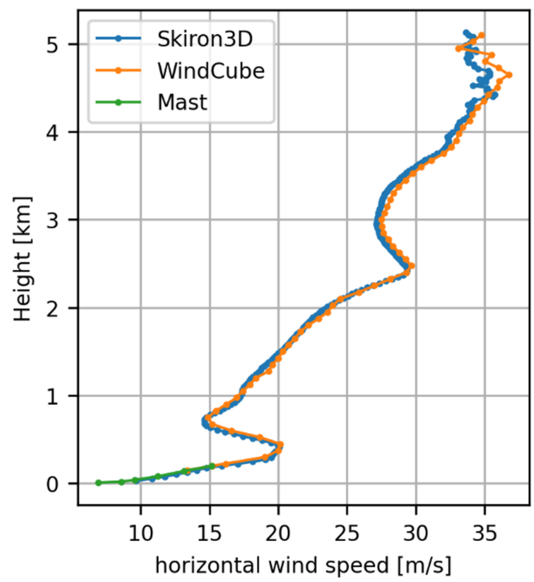

Figure 3: Profile of horizontal wind speed on 7th of October 2023 at 18:00h UTC of Skiron3D, WindCube 200s and cup anemometers in the mast.

4. Outlook

Preliminary results show a good agreement between the two lidars and mast data, which gives confidence in future measurements at Amsterdam Schiphol Airport. Data of the Skiron3D and WindCube 200s is collected over a period of several months. This dataset will be used to perform a statistical analysis of horizontal and vertical wind speed, as well as direction. This will provide an estimate of the achievable measurement uncertainty of such systems.

In the near future, the Skiron3D Doppler wind lidar will be relocated to Amsterdam Schiphol Airport to be used for a variety of experiments. It is foreseen to be used for measurements of airplane wake vortices, wind shear detection, and measurements of wind in the glide slope of aircraft. Also it will be used to compare with operational cup anemometers at the airport, and to evaluate the representativeness of these in-situ instruments for wind present at the runway. Validation of the Skiron3D with existing accurate measurements is therefore essential to ensure reliability in these proposed measurements.

5. References

[1] Thobois, L., Cariou, J.P. & Gultepe, I. “Review of Lidar-Based Applications for Aviation Weather”, Pure Appl. Geophys. 176, 1959–1976 (2019). https://doi.org/10.1007/s00024-018-2058-8

[2] Xia, H.; Chen, Y.; Yuan, J.; Su, L.; Yuan, Z.; Huang, S.; Zhao, D. “Windshear Detection in Rain Using a 30 km Radius Coherent Doppler Wind Lidar at Mega Airport in Plateau”, Remote Sens. 2024, 16, 924. https://doi.org/10.3390/rs16050924

[3] Bosveld, F.C., Baas, P., Beljaars, A.C.M. et al. “Fifty Years of Atmospheric Boundary-Layer Research at Cabauw Serving Weather, Air Quality and Climate”, Boundary-Layer Meteorol 177, 583–612 (2020). https://doi.org/10.1007/s10546-020-00541-w

[4] Knoop, S., “Scanning Doppler wind lidar at Ruisdael Observatory”, EGU General Assembly 2022, Vienna, Austria, 23–27 May 2022, EGU22-11985, https://doi.org/10.5194/egusphere-egu22-11985

[5] Bosveld, F. C., “The Cabauw In-situ Observational Program 2000 – Present: Instruments, Calibrations and Set-up”, KNMI, Technical Report, TR-384, available at: http://bibliotheek.knmi.nl/knmipubTR/TR384.pdf (last access: 13 January 2021), 2020.