

The valuable comments given by the anonymous reviewer (Reviewer 1, <https://doi.org/10.5194/egusphere-2026-4731-RC1>) are highly appreciated. They are well-conceived and constructive, thus, contribute essentially to an improvement of the paper manuscript. Below the answers to each comment are given, where the answers are indicated in blue color, and the resulting changes in the manuscript are highlighted in green color.

Reviewer 1: <https://doi.org/10.5194/egusphere-2026-4731-RC1>

General comments

The paper is well written and structured. It addresses scientific questions well within the scope of AMT. It presents a new airborne lidar tool, that will be of interest for the atmospheric community. The concept is not novel, for it relies on a long heritage of former developments by the same team, but the improvement is well positioned within the state-of-the art, as well as compared to the precedent DLR lidar version. The paper claims are clearly expressed, and are demonstrated throughout the paper with sufficient details. It would have been nice to have also a validation of the lidar measurements compared to independent observations, but it is clearly explained that this will be part of future investigations and reports.

Thanks a lot for your thoughtful assessment, which summarizes the intention of our paper manuscript very precisely. As explained, a very concise HEDWIG performance characterization is currently performed based on a huge data set acquired during the NAWDIC campaign and will be presented in near future.

I would recommend only minor revision before publication, considering the specific comments below.

Specific comments

In Table 1, the relationship between τ_p in nanoseconds and τ_{pulse} in meters (not introduced in the text) should be clarified.

Correct. Actually, it is two times τ_p , just denoting the temporal as well as the spatial extend of the laser pulse. This is clarified in the manuscript by adapting the table accordingly and by adding the following explanation to the text:

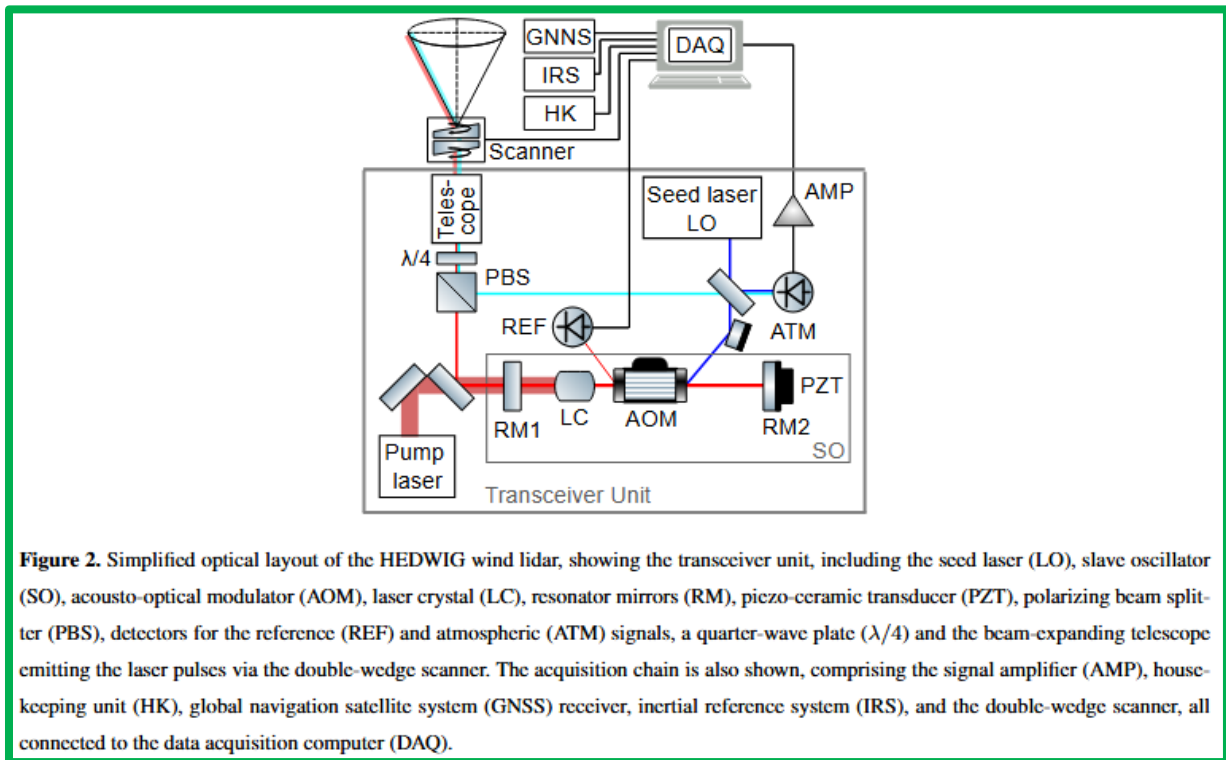
... τ_p is the laser pulse duration (full width at half maximum) in nanoseconds. The corresponding spatial pulse length in meters is obtained by converting τ_p from nanoseconds to seconds and multiplying it by the speed of light. The resulting physical resolution of the lidar measurements is finally $\tau_p/2$. The exponent α takes...

In section 2 around figure 1, it could be relevant to mention the size and weight of the presented structure.

This relevant information was indeed missing and is now added to the beginning of section 2. The text now reads: An overview of the HEDWIG instrument consisting of the airborne transceiver unit including the telescope and double-wedge scanner with the dimension of about 350 mm x 400 mm x 900 mm (excluding seat-rail adapters) and a total weight of 81 kg (right), and the data acquisition rack with the dimension of 650 mm x 550 mm x 1637 mm and a total weight of 118 kg (left) is provided in Fig 1. A schematic block diagram of the HEDWIG laser transceiver is shown in Fig. 2.

In Fig.2, the slave oscillator (SO) mentioned in caption should be shown in the drawing (or removed from caption). The label “housekeeping unit” is also unfamiliar (to me at least). I see the explanation is given in sect.2.3. Perhaps it could be given earlier as well.

The indication of the slave oscillator has been added to Fig. 2 which now looks as follows:



Regarding the housekeeping unit, no changes have been performed as the explaining text in line 191 says: “and a housekeeping (HK) unit responsible for time synchronization of all system components.” Do you think it needs more explanation than that?

Line 134: it is mentioned that a PBS is used for separating transmitted and received optical paths. I guess there is also a quarter-wave plate after emission (where exactly?) to rotate the polarization 90° between both paths?

Yes, this is true. There is a quarter-wave placed inside the transceiver before the beam expanding telescope. For clarification, this is now also indicated in Fig. 2 (as shown above). Further, the following paragraph was adapted and now also contains information about the quarter-wave plate:

The transmitted and received optical paths are separated by a polarizing beam splitter (PBS), which simultaneously protects the sensitive receiver from the high-energy outgoing laser pulse. A quarter-wave plate ($\lambda/4$) converts the laser beam to circular polarization, after which an on-axis telescope expands it to a diameter of approximately 11 cm. The beam then enters the double-wedge scanner, which enables arbitrary beam steering (see Sect. 2.2). Prior to entering the atmosphere, the beam passes a 400 mm diameter 35.6 mm thick fused silica window with anti-reflection coatings on both sides (Layertec GmbH) that is mounted in the fuselage of the aircraft.

Line 150: can you precise what is meant by “high dynamic performance”. How much time does it take for the scanner to go from conical-scan to nadir-pointing position, and how does it compare to the former 2 micron lidar version?

Correct, these details were indeed missing. Depending on the respective off-nadir pointing, the transition to nadir takes between 0.1 and 0.2 seconds. Compared to the 2-micron which used a belt drive motor, the transition took about 1 second, so an improvement of more than a factor of 5. To clarify this situation, the following was added to the manuscript:

The scanner, developed and built at DLR, is primarily operated in two measurement modes. During standard wind-vector observations, the beam is steered along a conical scan with a constant off-nadir angle, typically 20°, while the azimuth angle is varied in a step and stare procedure. This measurement geometry forms the basis for the retrieval of the horizontal wind vector using the VAD technique described in Sect. 3. Owing to the high dynamic performance of the scanner, the conical scans are regularly intermitted by short nadir-pointing periods, during which vertical wind profiles are acquired with substantially higher temporal resolution compared to vertical velocities obtained from the VAD retrieval. The rapid transition between these scan modes of 0.1 s to 0.2 s enables nearly simultaneous measurements of horizontal and vertical wind components without significantly reducing the sampling rate and precision of horizontal wind measurements. This transition time is more than five times shorter than that of the 2- μ m DWL, which used a belt drive motor and required approximately one second to switch between off-nadir and nadir pointing directions.

Line 220: it is mentioned that the laser performance can sometimes deviate from nominal behavior: can these deviations be compensated automatically (maybe partly), or does it rely entirely on the supervision and caution of the lidar operator to adjust the laser parameters? The laser “bad shots” are mentioned also lines 247-250, and can be suppressed at the processing level. As a rough order of magnitude, what fraction of data does this represent?

So far, the compensation has to be done by the operator. This is mainly needed when the laser experiences modifications that disturb the equilibrium or when equilibrium is not yet reached, e.g., at the beginning of the flight. During the campaign, it regularly happened that no adjustments were needed for hours, in cases where the aircraft was flying long legs on the same altitude without any maneuvers.

Regarding “bad shots”, this also depends on the particular situation, but in general, they are always in the low percentage range and below. For clarification, the following sentence was added to the manuscript:

pulse is not considered for accumulation. During normal laser operation, only very few individual laser shots are excluded, whereas this fraction can increase to a few percent under disturbed laser operating conditions, for example at the beginning of a flight, when the laser has not yet reached full thermal stabilization. Moreover, before accumulating

Line 237-238 and 269-274: From my understanding, the aircraft motion is obtained in the Earth frame by the GNSS sensor, while the Doppler velocity ν_D is obtained in the aircraft frame. Therefore I would have expected the coordinate transformation to apply only on ν_D (ν_{ac} subtracted after transformation) and not on $\nu_{LOS} = \nu_D - \nu_{ac}$ (ν_{ac} subtracted before transformation) as written line 269. Perhaps I misunderstood something there?

For our measurements, the situation is as follows. The IRS of the aircraft measures the aircraft attitude in the Earth frame. This is corrected. However, what is still needed, is the determination of the lidar installation position with respect to the aircraft frame. This is what we finally characterize by means of ground returns.

The aircraft velocity is measured by the Septentrio GNSS sensor.

Considering that, we do the following:

With the lidar, we measure the Doppler velocity along the actual viewing direction ν_D . This still contains the aircraft velocity projected onto this viewing direction. Hence, we have to subtract this contribution to obtain the actual line-of-sight speed. This is done for each nadir and off-nadir pointing direction (still in the lidar coordinate system), in order to obtain LOS wind speeds that can afterwards be used in the wind vector retrieval (without being “contaminated” by the ac-speed). This is also the stage where the LOS wind speed is converted to the Earth frame. So, I would argue that the explanation given in the text is so far correct.

Below figure 5: the random error is shown to be around 0.2 m/s over land surface. Could you add a few comments on this value? Is it limited by the transmitter FOM (hence a higher FOM would reduce the error), or by the signal processing / wind retrieval procedure cumulated uncertainties (hence improving the FOM would not change much the result)? Also, how does it compare to wind natural inhomogeneity at the scale of the instrument spatial resolution?

Ground returns provide signal with sufficiently high SNR and zero Doppler shift. So, the analysis of ground returns gives a hint on a properly working retrieval and corrections in case

the 0 m/s Doppler velocity are retrieved accordingly. On the other hand, the standard deviation of the ground return analysis provides an estimate of the random error that could be reached for wind speed measurements in high SNR situations. Hence, improving the FOM would likely not improve the random error for the ground returns, as they are already a result of high SNR measurements, but could improve the random error of wind measurements in lower SNR conditions. Hence, the 0.2 m/s random error are a best-estimate for the retrieved wind speeds. For further clarification, the following sentence was added to the manuscript:

...and therefore expected. Because the ground returns are characterized by high SNR, the standard deviation of the retrieved ground-return velocities provides an estimate of the random error under high-SNR conditions. This error is unlikely to be substantially reduced by increasing the transmitter FOM, as the ground-return measurements already have high SNRs. A higher FOM would, however, be expected to improve the precision of wind measurements under lower-SNR conditions by increasing the available signal strength. The observed standard deviations of approximately 0.2 m/s therefore provide an estimate of the retrieval precision achievable by HEDWIG under high-SNR conditions.

Technical corrections

line 36: the final s from “precises” should be taken off

Done.

line 48: remove space between “in” and “to”

Done.

line 89: probably a word is missing in “during the operating the airborne”

Correct. Changed sentence to: “Building on the experience gained during operating the airborne 2 μm Doppler wind lidar,...”

Figure 1: GNSS instead of GNNS (drawing)

Changed accordingly.

line 211: typo where the number 1.5 is repeated two times

Deleted one time.