

Interactive comment on “Combined wind measurements by two different lidar instruments in the Arctic middle atmosphere” by J. Hildebrand et al.

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major comment 1: mention in abstract that large part of the manuscript is related to RMR analysis; separated chapters for results of RMR lidar and combined measurements

We included in the abstract that analysis of RMR lidar data is also an important issue of the manuscript.

At the beginning of Sect. 4 we will mention that the first three subsections of this section will treat RMR lidar data only and the last three subsections are about the combined
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measurements.

major comment 2: include how to derive line-of-sight wind speed from Doppler ratio

We will include this at the end of Sect. 2.1 and put Fig. 5 (modeled Doppler ratio as function of wind speed and temperature) there. This will also improve the readability of Sect. 4.1.

abstract: clarify the term “common volume wind measurements”

We included altitude range of overlap in the abstract and mention that both lidars share the same receiving telescopes.

page 4124, line 21: include altitude range of radars

done

page 4125, line 10: additional references (e. g. Shen et al., 2009 or Xia et al., 2012)

done

page 4125, line 20 and line 25: include dates of joint campaigns

done

page 4126, line 2 and page 4129, line 3: why is the FOV of the Na lidar tilted against the FOV of the RMR lidar?

To avoid crosstalk/interference the focal optics are designed without a beam splitter. This makes it necessary to tilt the FOVs slightly against each other to separate the backscattered light.

page 4126, line 11: avoid term “point measurements”

done

page 4126, lines 20 to 25: conversion for MHz to m/s, wavelength of seed laser and stabilization to absorption line

We will include in the manuscript: “Both transmitting lasers are injection-seeded by one single seed laser, whose frequency is stabilized by iodine absorption spectroscopy at line 1109 ($\lambda = 532.260$ nm) (Baumgarten, 2010) to better than 6 MHz over three years (Fiedler et al., 2008), . . .”

will be included too: “A frequency offset of 1 MHz corresponds to a wind speed offset of 0.266 ms^{-1} .”

page 4127, line 1: method to monitor the power laser frequency offset

We will include in the manuscript: “This offset is monitored on single pulse basis for both lasers using an I_2 pulse spectrometer (Fiedler et al., 2008) and taken into account in the wind retrieval.”

page 4127, line 4 and line 9: why is FOV of receiver significantly larger than divergence of emitter?; divergence given as $\pm 2\sigma$ or $\pm 3\sigma$?

The FOV of the receiving telescope is larger than the beam divergence to ensure that the complete beam lies within the FOV. During long measurements the telescopes (on top of which the laser beams are emitted) are exposed to varying weather conditions (temperature and solar irradiation). This leads to changes in the beam pointing relative to the FOV. To correct this an automated beam stabilization system is used.

The beam divergence is calculated from data provided by the manufacturer of the power lasers.

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page 4128, line 9: reason for large difference in entrance ratio $E_{\text{telescope}}$ for both telescopes

Light received by both telescopes is coupled into one detection system. So, the two different optical axes of the telescope fibers need to be transferred to the optical axis of the detection system. This is done with a rotating segmented mirror (RFS). The light from the NWT passes through a hole in the mirror, while light from SET is reflected at the mirror. So, the alignment of the optical bench is easier for the NWT. Small misalignments of the RFS affect the optical path between RFS and detector, but only for SET, not for NWT.

page 4129, line 20: what is meant by “error” of the backscattered signal

The error of the backscattered signal is determined by photon noise plus uncertainty in determining the background signal.

page 4129, line 23: type of “thin clouds”

tropospheric, added to manuscript

page 4130, line 5: how to obtain the wind speed error; why different height ranges in Fig. 3

We take the error/measurement uncertainty from measured quantities (e.g., backscatter signal, frequency offset of power lasers) and perform error propagation during all calculations.

In the left panel of Fig. 3 we show the backscatter signal and its errors without restrictions, it is simply cut at 100 km altitude. In the right panel we show the Doppler ratio and its error restricted to the height range determined by the wind speed error. It is mentioned in Sect. 3 that we restrict wind speed to errors less than 20 ms^{-1} , this

C2005

can be seen in Fig. 6 which shows the wind speed corresponding to the Doppler ratio shown in Fig. 3.

page 4130, last abstract: number of measurements given in Tab. 1 and text (Sect. 3)

The two lines in Tab. 1 for 19 January are treated as single measurement (see also Tab. 2) since the break between both measurements is only one and a half hour.

Opposite pointing is used two times, we corrected the manuscript.

The two lines in Tab. 1 for 22/23 January are treated as one long measurement, it is listed twice since the pointing of SET changed.

page 4131, line 19: what is meant with “hypothetical”?

This Doppler ratio profile is calculated for zero wind speed using the measured temperature profile.

We revised this abstract.

page 4132, line 13: introduction of ECMWF

We will include in manuscript: “The European Center for Medium-Range Weather Forecasts (ECMWF) provides an operational forecast model (Integrated Forecast System, IFS) which assimilates real data. We use IFS version Cy35r1, T799, extracted for 69.28°N, 16.01°E.”

page 4133, line 26: use of fourth order polynomial

We tested various polynomials of different orders and found that fourth order represents the approximate background or undisturbed wind profile best. A fourth order polynomial

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as estimation for background wind profile was also used by Cot (1986) in a case study of wave-turbulence interaction in the stratosphere.

page 4134, Sect. 4.3: variation of entrance ratio only for SET; different profiles in Fig. 7

yes, only SET is affected (due to reflection at RFS); that NWT is not affected is noted now in the manuscript

We will provide a close-up of Fig. 7 for the altitude range where data of both lidars overlap (see figure below).

page 4139, line 15: time resolution of 1 h only; averaging time of previous studies

The time resolution of 1 h is mentioned in Sect. 3, end of first paragraph.

We included the averaging time of previous study in manuscript.

page 4139, conclusion: state, that validation and calibration applied for RMR lidar only

We revised this statement:

“For data of the RMR lidar we applied different validation and calibration methods using either two beams of the same lidar or a single vertical pointing beam.”

more appropriate term for “branches”

done (we use now “laser and telescopes”)

page 4126, line 9: delete “over the sky”

done

C2007

page 4128: move equation for $E_{\text{telescope}}$ from line 6 to line 5

done

page 4129, line 13: add tilting angle for clarification

done

page 4130, line 16: record length 33 s instead of 33 ms

done

avoid term “measurement runs”

we will use “observations of several hours” in the manuscript.

page 4131, line 11: include symbol for Doppler ratio

done

avoid “snapshot” for ECMWF data

done

page 4141, line 16: PhD or Master’s thesis

Master’s thesis; done

Fig. 1: colored numbers indicate diameters of sounding volumes

done

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Fig. 2: add “additional entrance after the RFS”

done

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C2009

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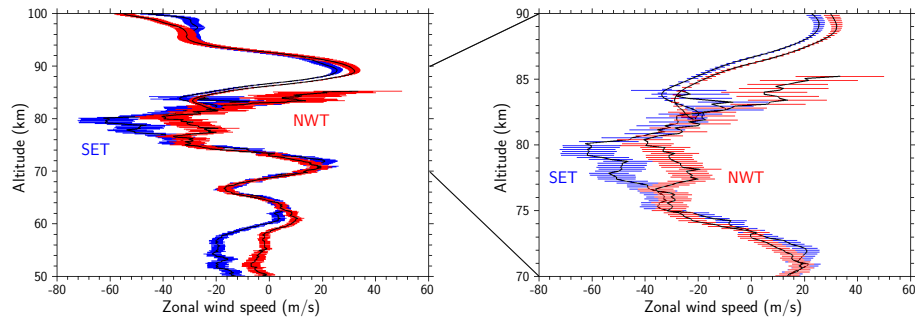


Fig. 1. Fig. 7 with additional close-up (between 80 and 85 km error bars are shown for each other data point only)