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Interactive comment on "Identification of the cloud base height over the central Himalayan region: Intercomparison of Ceilometer and Doppler Lidar" *by* K. K. Shukla et al.

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General comments

Reliable detection of cloud base height is a key parameter in several scientifically and societally important applications. Ceilometers were developed for this challenging task. Performance of ceilometers, and subsequently developed retrieval algorithms, to detect cloud base heights (CBH) has been intensively investigated by several research groups. Reliability of CBH detection depends on several factors, including, used detection algorithm (Martucci et al., 2010), type of cloud hydrometeors (Van Tricht et al., 2014), sensor wavelength and likely its sensitivity (Schween et al., 2014). It is true, however, that a published comparison of a Doppler lidar (wavelength of 1.5 micron)

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Discussion paper

and ceilometer (905 nm) is missing. This manuscript presents performance comparison of Vaisala CT25k ceilometer and Doppler lidar CBH detection which is well within scope of the Journal.

Response: We greatly appreciate the detailed review by referee #2. We have tried to address all the issues that they have raised to the maximum extent possible. These changes are implemented/modified here and also in the text. We hope these changes adequately address all the concerns raised.

Specific comments

A major disadvantage of the manuscript is related to the fact that sensor performance is compared by using two different data retrieval methods. In addition to presented results, the authors should apply only one method to data from both sensors in order to reliably compare performance of the two sensors. The second major comment is related to amount of data employed in statistical analysis (Fig. 10). In addition to six days of case studies, the authors should show statistical comparison covering the entire measurement campaign, and subsequently, add figure 11 displaying CBH comparison from Doppler lidar and ceilometer. This would significantly add value to the manuscript.

Response: It is to be noted that the visibility of the atmosphere cannot be measured by the Doppler Lidar (DL) and therefore it may not yield useful results if we use same methodology for both the instruments. The method used in the present manuscript is much robust and reliable for the Doppler Lidar and hence less affected by the false detection of the CBH.

“Although, the ARM site deployment was during June 2011 – March 2012, we do not have the Doppler Lidar data during the monsoon (June – September 2011) period because of washout of the aerosol particles. Moreover, we have both no/ less percentage of cloud coverage and less cloud residence time ($\sim$1-2 hours) during other seasons. Hence, we have particularly selected those cases where we have maximum cloud cov-

erage and residence times during the daytime boundary layer (05-10 UT) convection period. Also, another aspect for selecting these cases is the availability of simultaneous datasets with other instruments like Ceilometer (CM), Radiosonde and other meteorological instruments. Some of the cases are rejected because of sudden spikes and other consistency checks. These aspects are clearly mentioned in the revised version of the manuscript" (Page4, Lines:19-27).

Minor and technical comments

2.2 Doppler lidar Page 4, lines 14-24: Add a sentence to explain how you determined SNR threshold (-20 dB), and mention model and manufacturer of the Doppler lidar. A discussion on data quality should cite at least to work by Manninen et al. (2016). It is true, however, that in this case study corrections to signal-to-noise ratio as suggested by Manninen et al. (2016) would have limited, if any, impact to presented results.

Response: We have followed the methodology described in Lenschow et al. (2000) and Pearson et al., (2009) for the SNR threshold to remove outliers. We have also provided the technical details of Doppler Lidar in Table-1 and included Manninen et al (2016) reference in Doppler Lidar section in the revised manuscript (Page-5, Lines:25-30).

Pearson, G.N., Davies, F., Collier, C.: An analysis of the performance of the UFAM pulsed Doppler Lidar for observing the boundary layer. J. Atmos. Oceanic Technol., 26, 240-250, 2009.

Lenschow D.H., Wulfmeyer, V., Senff, C.:2000 Measuring Second- through Fourth-Order Moments in Noisy Data. J. Atmos. Oceanic Tech., 17, 1330-1347, 2000.

3.2 CBH retrieval using CM Add more information on CBH retrieval or state that standard output of Vaisala CT25k has been used.

Response: The CBH estimation by CT25k is done based on visibility threshold and yes, we have used the standard output of Vaisala CT25k and these things are now

added in the revised manuscript (Page-6, Lines:2-6).

4. Results and discussion Page 9, lines 1-2: 'It is interesting to note that the temporal evolution and duration of thin and opaque clouds in both the instruments are in reasonable agreement during all events'. Discuss more on this topic since it is the fundamental question behind your research, i.e. why temporal evolution would be different etc.

Response: We meant to say that TSI thin and opaque cloud coverage is exactly matching with DL and CM cloud patterns and now typo mistake has been rectified in the revised manuscript (Page-10, Lines:22-23).

Page 10, line 19: Table 1 does not show a detailed comparison of cloud base heights observed worldwide. In fact, I recommend removing Table 1 as it shows 8 single-day examples. To me main point of the current manuscript is not height of observed CBH, but rather, reliability of methods and sensors. Reconsider lines 15-33 on page 10.

Response: Our main aim behind giving Table-1 is to summarize all the observations related to cloud base heights at one place. For comparison, we have also included observations with the different locations latitude and longitude along with CBH. This table is just for comparison with our site. As pointed out by the reviewer, our main aim is to show the potential of Doppler Lidar in the estimation of cloud base height and reciprocate with other instruments as well and now we have focused mainly on these aspects in the revised manuscript (Page-11, Lines:6-9; Lines:24-27).

5. Summary and conclusions Discuss somewhere in the manuscript why you would expect, and in fact, present differences in CBHs from Doppler lidar and ceilometer.

Response: In general, they have reasonably good agreement in most of cases, however, differences in some cases between the CBH estimated by the DL & CM may be due to working principle, retrieval techniques and also the technical specification of different instruments with different methodologies. The retrieval of signal to noise ra-

tio with the Doppler Lidar (Hardesty et al., 1997) and backscatter from the Ceilometer (Heese et al., 2010) is also derived with different methodologies and these things are mentioned in the revised manuscript (Page-11, Lines:6-9; Lines:24-27).

Figures Page 20, Fig. 4: Explain interpretation of color scales in the figure caption for the journal readership.

Response: For better clarity, we have now explained clearly the caption of Figure 4 in the revised manuscript (Page-25, Lines:12-13).

References

Manninen A.J. et al.: A generalised background correction algorithm for a Halo Doppler lidar and its application to data from Finland, Atmos. Meas. Tech., 9, 817-827, 2016.

Martucci, G. et al.: Detection of Cloud-Base Height Using Jenoptik CHM15K and Vaisala CL31 Ceilometer, J. Atmos. Ocean. Tehcnol. 27, 305-318, 2010.

Schween, J. et al.: Mixing-layer height retrieval with ceilometer and Doppler lidar: from case studies to long-term assessment, Atmos. Meas. Tech., 7, 3685-3704, 2014.

Van Tricht, K. et al.: An improved algorithm for polar cloud-base detection by ceilometers over the ice sheets, Atmos. Meas. Tech., 7, 1153-1167, 2014.

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