Atmos. Meas. Tech. Discuss., 5, C3894–C3904, 2013
www.atmos-meas-tech-discuss.net/5/C3894/2013/

Atmospheric Measurement Techniques Discussions

Interactive comment on "Raman Lidar for Meteorological Observations, RALMO – Part 2: Validation of water vapor measurements" *by* E. Brocard et al.

E. Brocard et al.

emmanuel.brocard@meteoswiss.ch

Received and published: 14 February 2013

Interactive comment on "Raman Lidar for Meteorological Observations, RALMO – Part 2: Validation of water vapor measurements" by E. Brocard et al. Answers to Anonymous Referee #1

We would like to thank anonymous referee #1 for the constructive comments, which have greatly helped us to improve the quality of the manuscript. We have carefully considered these comments. The point-by-point answers (A) are presented below.

Specific comments:

P6916 L25ff: Introduction: The state of the art of water vapour remote sensing and interrelated instrument intercomparisons needs to be discussed in more detail and cited more considerably. E.g., Intercomparison of microwave radiometer data (Bleisch et al. 2011, AMT); LUAMI Campaign 2008 (Wirth et. al, ISTP 2009, Deflt); IWV intercomparison FTIR vs Lidar (Vogelmann et al. 2011, AMT), MOHAVE Campaign (Leblanc et al. 2011, AMT).

(A) A brief discussion and references of the state of the art of water vapor remote sensing and related intercomparisons have been added in the introduction.

P 6918 L24f: The state of the art of water vapour profiling in the troposphere with lidar needs to be discussed an cited more considerably. There are other full operational Raman lidars around, e.g., Lindenberg (Reichardt et al., ILRC 2010), Cabauw (Apituley et al., ILRC 2012) and also some full daytime capable DIALs with short integration times, e.g., Hamburg (Bosenberg et al., 2002, ESPR), Zugspitze (Vogelmann et al. 2008, Appl. Opt.), DLR-Falcon (Wirth et al. 2009, Appl. Phys. B). This part should be moved into the introduction.

(A) The state of the art of water vapor profiling with lidar is discussed in the companion paper including an equivalent to all suggested references. See modifications in the introduction.

P6919 L16: I expect a more detailed description of the smoothing algorithm (gliding average or least square fit or other) and its vertical resolution as a function of altitude.

(A) More information on smoothing and vertical resolution has been added.

P6921 L22-23: The influence of different temporal and spatial matching needs to be discussed in more detail. The work of other groups on this topic should be cited. E.g., Sussmann et al., 2009, ACP; Schneider et al., 2010, AMT; Vogelmann et al. 2011, AMT

(A) Matching between lidar and radiosonde is discussed later on in Sect. 5.1, an example is provided (Fig.1), and the methodology is detailed at the end of Sect. 4.2. A reference to Sect. 5.1 has been given, and suggested references have been included in Sect. 5.1.

P6922 L5: Replace ”On the one hand” by ”First”.

(A) Done

P6922 L11: Replace ”On the other hand” by ”Second”.

(A) Done

P6922 L16ff: The impact of clouds, in particular of cirrus clouds, should be discussed here more detailed.

(A) We expect a very small influence of clouds since they have been filtered (clear-sky data). Cirrus cloud that have not been filtered by the algorithm (Apcada) are typically higher than 7-8km and would therefore only affect a few profiles.

P6922 L25: ”large part” should be reduced to ”large part of the tropospheric water vapour content”

(A) Done

P6924 L1-2: Could you give a quantification of the moon-light / cloud induced reduction of the altitude range? Is their a citation available?

(A) We did not investigate the effect of moon-light contamination and we consider it not relevant for this study. We are not aware of publications describing this phenomenon. Cloud-induced contamination must be small since low and mid-level clouds have been filtered.

P6923 L4-5: replace ”are” by ”were”

(A) Done

P6923 L 13: replace ”...in the form of...” by ”carried out by a comparison... just before

launch.”

(A) Done

P6923 L20: replace ”on the order of” by ”of the order of”.

(A) Done

P6923 L22: replace ”in the order of” by ”of the order of”.

(A) Done

P6923 L24: replace ”in Payerne” by ”at Payerne”.

(A) Done

P6924 L11ff: The HATPRO instrument should be specified more detailed. Some information about integration time, pointing geometry, field of view would be very creditable.

(A) Hatpro is pointing vertically, with a few degrees field of view (HPBW: 3.5°). The integration time is on the order of 1s averaged over 10min. This has been added to Sect. 4.3.

P6924 L15ff: To my knowledge, a lidar profile is presumably for the birds above the bottom edge of any cloud being hit by the laser beam at any time during the integration time because of potential signal induced noise after a signal overflow in the detection system. But it should be easy to detect this from the lidar data itself. Even clouds at higher altitudes beyond the vertical range are easily to detect with the lidar itself. Thus, it is not clear, why the author wants to distinguish between clear sky and not clear sky from an independent source. As long as there is no cloud in the field of view of the lidar detection system during the integration time it should not make any difference if there is clear sky around or not? I kindly ask the author to give an explanation and a motivation for using this clear-sky detection algorithm.

(A) Here we chose to use an independent source (APCADA) as it gives cloud-cover information of the whole sky and not just the fraction above the lidar. This is important as we want to ensure that both radiosonde (drifting) and lidar measure in the same cover conditions.

P6925 L1-3: Distinguishing between night and day profiles makes sense but what does the author mean with "valid assumption for more than 95%"? Are their cases where the zenith angle is greater than 95 degree and the sun is still above the horizon? Hard to believe. Please, explain this.

(A) For radiosondes launched at midday and midnight, knowing whether it is day or night is obvious. However, some radiosondes were launched at 06:00 and 18:00. It represents less than 5% of the total number. There, we took 95 degree sun zenith angle as the filter between night and day. At 95 degree zenith angle the lowest part of the atmosphere illuminated by the Sun is at approximately 24 km i.e below the background reference height of the lidar. However, there might be some light reaching the lidar through scattering.

P6925 L13-14: Either you refer to your example (Fig. 1), as indicated by the subsection header, or you make a general statement "A wet layer can move..." but with citations. Fast vertically moving layers can also be very dry (stratospheric intrusion). There have been many lidar observations of vertical dynamics in the troposphere (Stohl et al. and others). I suggest to delete the subsection header 5.1 and merge subsection 5.1 into subsection 5.2.

(A) This has been rephrased to refer to the example. Subsection 5.1 has been merged to subsection 5.2, as suggested.

P6925 L21: insert "horizontally" before "away".

(A) Done

P6925 L14ff: Regarding water vapour the effect of probing different volumes is definitely not negligible and should be dicussed significantly more extensive here. I see,

that it is very ambitious to quantify the influence of volume mismatch which is already beyond the scope of this paper. I suggest that at least an autocorrelation plot of the lidar data should be shown in contrast to the lidar-radiosonde correlation plot.

(A) We did some experiments but did not find any conclusive evidence. This would need further investigation, which is indeed beyond the scope of this paper.

P6925 L21-23: Quantify the positioning errors of the radiosonde, and, if of the same order as the field of view, the jitter of the lidar. If not possible, erase the statement about relevance.

(A) Comparison flights using the radiosonde used in this study and the GPS-equipped radiosondes have been carried out and show good agreement. However, as it is very difficult to properly quantify the positioning errors and the jitter of the lidar, this sentence has been removed.

P6926 L12-13: Explain how the altitude information from the radiosonde is retrieved. If it is retrieved by pressure, the information can be used for the calculation of relative humidity profiles from the lidar only with limits. If it is retrieved from GPS, specify the altitude uncertainty.

(A) The altitude information is retrieved from a water hypsometer with high-precision thermocouples. According to the specifications, boiling temperature is measured to about 0.01 K (accuracy: 0.05% in pressure or 0.5 hPa at 1000 hPa). The specifications can be found in Richner et al., JAtOT, 1996

P6926 L15: Write "...the difference between ...shows negative values of 5% to 10% up to 7.5 km".

(A) Done

P6925 L24ff and Fig. 7/8: I do not see the evidence of the left plots of Fig. 7 and 8. It does not tell us anything about the precision of the lidar what is suggested by the text. I would expect that the deviation between lidar an radiosonde is strongly influenced by different conditions (beyond day an night). Is their more information available? It would be of interest, how the deviations develop under certain conditions like "cold and dry" "warm and humid" and other combinations. I would prefer the profile of the standard deviation of differences between radiosonde and lidar as a curve. Same with error of mean value. Anyway, Fig. 8 or a new Fig. 8 should be cut of at 6km. Why doesn't the number of profiles have its maximum at the bottom? I would expect a constantly falling number of profiles with ascending altitude (there are some more ripples).

(A) Here we tried to illustrate the different behavior between day and night. As explained in the text, day and night offer very different measuring conditions. Characterizing the uncertainty as a function of conditions such as "cold and dry" "warm and humid" as not been done so far, and will be considered in future studies. It is noted, however, that this is not a trivial issue, since water vapor is highly variable in time, space, and altitude. A first hint at the lidar's performances under dry/humid conditions is given in Fig. 9.There, it seems that under high IWV content the lidar produces too high a value

(A) Fig. 8 has been cut at 6km.

(A) The signal-to-noise ratio increases with altitude below the altitude of full overlap. During day-time, the SNR close to the ground (partial overlap) is not good enough to retrieve water vapor with the required precision because the solar background is too strong compared to the backscatter signal.

P6927 L6ff: Explain how the correlation (Fig. 9) was calculated. Was the calculation done for one certain altitude or for several altitude layers? How were the values put together into the basic ensemble of the calculation?

(A) All altitude layers are used for this correlation plot, from the surface to the top of the lidar water vapor profile. It has been added to the caption of Fig. 9.

P6927 L10: Typo:"These"

(A) Done

P6927 L28ff - P6928 L10: Why was the IWV calculation from the radiosonde data not limited exactly to the vertical range of the lidar (range bottom to range top) for this intercomparison? This should be recalculated. For an intercomparison with the radiosonde an absolute IWV value is not necessary. For the intercomparison with GPS and the radiometer the IWV from the lidar should be completed by using the data from the radiosonde and not by extrapolating a 2m a.g.l. value which is presumably producing larger errors. Radiosonde data could also be used for altitudes above the lidar range.

(A) Several approaches have been tested such as cutting radiosonde profiles at the lidar profile's maximum height or combining lidar and radiosonde profiles. For this study, in order to compare the different instruments, we decided to use only lidar profiles reaching at least 8 km height, as stated in Section 5.3. As such, more than 99% of the water vapor column is taken into account. This allows comparisons with radiosonde measurements, but also the radiometer and GPS measurements. We think this is a valid approach.

(A) Taking the 2 meter-high value and extrapolating seems also valid to us. It is noted that the bottom point in the radiosonde profile is also taken as the same 2 meter-high operational value.

P6928 L18: The 1% difference was also observed in a recent intercomparison study (Lidar vs. FTIR, Vogelmann et al., 2011, AMT) and should be cited here. (A) The reference has been added

P6928 L24ff: As already mentioned above, I suggest a more sophisticated analysis regarding different conditions. If meaningful add one or even more plots.

(A) As mentioned above, (Comment P6925 L24ff), a first indication of the lidar's performance under high and low IWV is provided by Fig. 9. A more sophisticated analysis has not been done so far and will be considered in future work.

P6929 L17ff: A general explanation of the basics of measuring humidity with electronic sensors is credible, but, if doing so, I expect citations, and the error sources need to be specified in detail. Otherwise, the entire paragraph should be condensed to a subordinate clause.

(A) The reader is now referred to Miloshevich 2006 and the WMO Guide to Meteorological Instruments and Methods of Observations for a complete overview of the error sources on humidity sensors.

P6929 L26ff: I do not agree. In the context with the forgoing paragraph an explanation from the basics is appropriate: "The lidar's basic measurement principle is to measure backscattered light from molecules or particles as a function of time (distance, altitude). A Raman lidar or DIAL is measuring the intensity of inelastic backscatter from water molecules, or the specific absorption of (infrared) light by water molecules, respectively..."

(A) Yes, the sentence was not accurate. It has been modified according to the suggestion of the reviewer.

P6930 L3: Not so if using a DIAL. The statements should be clearly referred to the Raman technique.

(A) Done

P6930 L11ff: It is questionable, if it might be better to kick the comparison with GPS data out of the manuscript. It is known, that GPS data is not really suitable for such instrument validations (Sussmann et al. 2009, ACP). At least, I expect a statement about the reliability of GPS IWV data.

(A) We believe that the comparison with GPS measurements should be included in this paper. However, as suggested by the reviewer, a statement has been included: "although it is noted that IWV from GPS measurements are not always reliable for

Lidar validation (Sussmann [2009])."

P6932 L14: The Reference list is somewhat poor. There was recently many work done by others in the field of water vapour profiling with lidar and interrelated instrument intercomparisons (Whitman, Reichardt, Behrendt, Vogelmann, Leblanc, Wirth, Calpini, Apituley and others). This should be cited more complete.

(A) Thanks to the modification of the introduction, there are now more references.

P6936 Table2: What does the second column tell us? I suggest to specify non-clear-sky-day numbers instead.

(A) We think it is important to show the second column as it tells us what typical height is expected to be reached over a year, including days when a cloud layer limits the maximum height. Reaching out to potential customers interested in the data, these values are of prime interest.

P6941 Fig. 4: Replace this by a histogram plot.

(A) Histogram plot has been tested. It works out that this distribution is best seen with lines instead of bars.

P6944 Fig. 7 and P6945 Fig. 8: See above, it might be useful to plot this for different conditions including the mean horizontal distance. Standard deviation and errors of the mean value should be plotted as curve. The plot in Fig 8. should be cut of at 6km.

(A) Plotting mean horizontal distance vs lidar-sonde difference had been considered but did not produce any valuable information.

(A) We think this representation is more readable than having curves, especially in the lower part of the profile.

(A) Fig. 8 has been cut at 6km.

P6946 Fig. 9 caption: The altitude from were the values were taken must be specified, see above.

(A) The sentence “for all altitude levels” has been added to the caption.

P6947 Fig. 10: Scale the upper one higher to get a better spread.

(A) We do not understand this remark.

P6948 Fig. 11: Split this into 3 squared plots or merge it into one squared plot.

(A) Done

Interactive comment on Atmos. Meas. Tech. Discuss., 5, 6915, 2012.