

Interactive comment on “Ground-based water vapor Raman lidar measurements up to the upper troposphere and lower stratosphere – Part 1: Instrument development, optimization, and validation” by I. S. McDermid et al.

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The authors wish to thank the two referees who provided very useful and constructive comments, which we have fully addressed. In particular and according to their suggestion, we merged the two manuscripts into one, and shortened what used to be part 1. Besides text itself, this includes the removal of several figures, and the merging of other figures together. Though it is loaded “in parallel” in the AMTD Peer-Review System (manuscripts #71 and #72), the present authors’ reply is common to both com-

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panion papers, and can be regarded as a single reply pertaining to our final, unique, merged manuscript. A point-by-point reply to all comments is provided below.

Referee #1, General comments:

On the manuscript length and number of figures (Part 1): We removed four figures that were in the original Part 1. We also merged figures at two occasions, resulting in a total number of 17 figures for both manuscripts merged together (instead of 23 for Part 1 and Part2).

On the calibration methods (Part 2): It is correct that there is no direct comparison between two or more calibration techniques. However, each calibration technique is tested for long-term stability. Because of the future application of our measurements (long-term), we think the real issue to be addressed is this stability rather than the calibration constant itself. On fig. 5 (formerly fig. 4 of Part 2), we indeed mention the mean value of the calibration constant for each calibration technique. The difference between the calculated mean values is well below the observed standard deviations, and because they are calculated from single coincident radiosonde profiles, they represent the worse case scenario as atmospheric variability cannot always be accounted for. A more quantitative comparison between the various methods will be done in the near future, once the statistics (using several years of routine data) will be sufficiently robust.

On the overlap function: As explained in section 3.1 we minimize the effect of the overlap function by re-aligning the laser beam and telescope field-of-view on a daily basis (computer assisted). Note that the lowest part of the profiles is obtained using our so-called “Near-range channels” which collects light by the use of a wide field-of-view telescope. Also, the comparisons with radiosonde and CFH (fig. 13 and 15, formerly fig. 6 and 8 of Part 2) show that the mean differences remain within 3% in the lower troposphere down to pressure levels of about 650 hPa (approx. 700 m above site). Below this altitude, there is an increasing positive bias, not exceeding

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10%. Because our primary target is the above the mid-troposphere, we have not tried to optimize the overlap function further down. None of the altitude bins below 3 km is used for calibration. An uncertainty term associated with an incomplete overlap function is included in the uncertainty budget.

On the science results in the abstract: As part of Part 1 and Part 2 merging process, the abstract was significantly revised. In particular, we added quantitative results in the 2nd and 3rd paragraphs.

Referee #1, Specific comments:

Page 5113, line 6-14: Fixed when merging Part 1 and Part 2.

Page 5117, line 9: We do not correct for aerosol extinction. This is reflected in our uncertainty budget assuming a low background aerosol loading. We detect aerosol layers with our Rayleigh channels (or other lidars). A study of the effect of thin clouds and aerosols on the retrieved water vapor profiles is among our high-priority investigations in the near future.

Page 5117, line 10: Fixed when merging Part 1 and Part 2.

Page 5119, line 27: We added the relevant references. 3% for radiosonde is indeed the most optimistic figure, assuming various a posteriori corrections (Miloshevich et al., 2009). The uncertainty in the uncorrected radiosondes measurements depends on altitude, and can reach 5% in the lower troposphere (please refer to fig. 2b of MOHAVE-2009 Campaign Review paper (Leblanc et al., 2011) as well as the results of (Hurst et al., 2011b), both papers in the same AMT(D) Special Issue on MOHAVE-2009).

Page 5123, line 14-18: The high variability at small temporal and spatial scales has been reported in a number of publications. It is one of the most prominent features of water vapor in the lower half of the troposphere. We added an explicit reference to fig. 8 of (Leblanc et al., 2011) in the same AMT(D) Special Issue.

Page 5125, line 1-10: Fixed when merging Part 1 and Part 2

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Page 5125, line 13: Actually, (Turner et al., 1999) and (Madonna et al., 2011) do not use GPS but microwave. However we introduced (Whiteman et al. 2006), who indeed reported lidar calibration using GPS IPW. As explained above, we are planning on performing a thorough comparison of the radiosonde/microwave/GPS calibration techniques once our statistics allows robust conclusion, i.e., after several years of routine measurements (though our radiosonde program started in 2005, our GPS and microwave data were not available until 2009)

Referee #1, Minor comments, part 1:

Page 5087, line 21: Unfortunately we do not have a larger dataset available. The CFH are very expensive instruments (>\$3000 each), which limits the possibilities for multiple launches. It is very rare indeed to find any validation or science articles using more than a few CFH at a time, and having used 30 CFH in 3 campaigns is actually quite an achievement. These things said, we will continue/extend validation work with any future Frost-Point hygrometer launches available to us.

Page 5088, line 7: No signal-induced-noise was identify with any of our receiver configurations. As far as saturation (pile-up) is concerned, the water vapor channels are not saturated because the overlap takes over before saturation level. As explained in the manuscript, fluorescence has been absent (or at least reduced to a non-detectable level) since the 2007 receiver upgrade.

Page 5089, line 3: Unfortunately we do not have a clear explanation as to where/how exactly signal magnitude was gained during the last receiver upgrade in summer 2009. Because we are focused on getting the right amount of signal, we were satisfied with the signals collected with the latest (2009) configuration and we did not try to investigate in details what had caused the signals deficiency before that.

Page 5090, line 9: The instrumental resolution (75 m) is mentioned at the end of section 3.2 of the merged manuscript, and the water vapor profile resolution is fully described in section 4.1 and fig. 2 and 3.

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Page 5091, line 2: All lidar profiles during the campaign were calibrated using the simultaneous and co-located radiosondes

Page 5091, line 15: This is addressed in (Leblanc et al., 2011), in particular their fig. 5 which takes 4 particular examples, with different time resolutions and atmospheric backgrounds.

Page 5092, line 9: We added “balloon-borne” research grade instruments to clarify

Page 5092, line 18: Fixed when merging Part 1 and Part 2

Page 5093, line 8: Reworded during the merging process

Page 5099, fig. 3: This figure was deleted during the merging process

Referee #1, Minor comments, part 2:

Page 5113, line 12: These are not estimates of an atmospheric variable, these are uncertainty estimates from our instrument.

Page 5115, line 12: We actually used “particulate” in order to include both aerosols and clouds.

Page 5117, line 2: The purpose here is to emphasize the fact that this part of the lidar data analysis is new, but builds upon experience acquired over the years with the other lidar systems. We do not think it is appropriate to enter into these technical details in our AMT manuscript.

Page 5118, line 21: we reworded this sentence

Page 5119, line 24: we replaced “instrument” by “radiometer”. Profiler usually refers to tropospheric profiling, which is not the case of all radiometers, like at TMF.

Page 5122, line 25: corrected

Page 5127, line 7: corrected

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Page 5127, line 10: corrected

Page 5145, Figure 10: We will make sure that both figure and caption are properly magnified to full page width

Referee #2:

On the technical novelty (Part 1): We understand that the fluorescence problems mentioned are not new, neither are the solutions provided, nor the technology upgrades described. However, we believe that the complete description, including the optimization, of the TMW instrument as it is presented now in the merged version, is an important contribution that will serve as a reference when future work using the TMW data is published. Unfortunately we do not have a clear explanation as to where/how exactly signal magnitude was gained during the last receiver upgrade in summer 2009, but we do not think it is critical point of the present paper.

On the manuscript length and number of figures (Part 1): We removed four figures that were in the original Part 1. We also merged figures at two occasions, resulting in a total number of 17 figures for both manuscripts merged together (instead of 23 for Part 1 and Part 2).

On “Additional Comments on the Hybrid Calibration” (Part 2): It is correct that the lamp mounted above the large telescope primary mirror is unlikely to characterize the illumination of the detector in a similar way as that of atmospheric returns. It is a caveat of the hybrid method, and using several lamps, or a scanning lamp has been proposed to mitigate the problem. However, as explained in (Leblanc and McDermid, 2008), the Hybrid method is not an absolute calibration technique, and the lamp serves essentially as a relative source of illumination which purpose is to detect calibration jumps between two campaigns of absolute calibration. In particular, it is explicitly written in (Leblanc and McDermid, 2008) and repeated in our AMT manuscript that absolute calibration using radiosonde (or any other available source) is required as soon as a change has been detected in the stability of the lamp ratio. Finally, it is also emphasized in both

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(Leblanc and McDermid, 2008), and our current AMT manuscript, that the lamp should remain untouched and at the same position between absolute calibration campaigns.

Interactive comment on Atmos. Meas. Tech. Discuss., 4, 5079, 2011.

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