

Interactive comment on “Measuring variations of $\delta^{18}\text{O}$ and $\delta^2\text{H}$ in atmospheric water vapour using laser spectroscopy: an instrument characterisation study” by F. Aemisegger et al.

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Replies to the comments from referee 1

The reviewer’s comments are repeated in normal case, our replies are given in italics. Specific comments are given for the printer-friendly version of the manuscript.

We would like to thank referee 1 for his/her constructive comments that helped to improve our paper. We address each comment point by point (see below) and performed structural changes in order to address the reviewer’s general comment on conciseness. The structure is now as follows: Abstract 1) Introduction 2) Instruments 3) Delta scale C1001

linearity 4) Water vapour mixing ratio calibration 5) Water concentration dependency of isotope measurements 6) Isotope measurement stability 7) Response time of the measurement systems 8) Comparative ambient air measurements 9) Conclusions For each instrument characteristic, the experiments, results and discussion parts are now described together in a dedicated section. We think that this allows a clearer and more succinct presentation of the individual experiments.

1) P. 1600 L. 13: The research instruments by Webster and Heymsfield, *Science* 302, 1742 (2003, see also refs therein), and Dyroff et al., *Appl. Phys. B* 98, 537 (2010) should be included in the list of references for completeness.

We added the two suggested references.

2) P. 1602 L. 17: change infrared to near infrared.

Corrected as suggested.

3) P 1603 L. 6: You state that “In both systems, the sample gas is drawn through a high finesse optical cavity,..”. Isn’t it that the finesse (F) of the WVIA cavity is actually low since the free spectral range (FSR) is made small by exciting the cavity with a beam that is coupled in off axis? ($F = \text{FSR}/\text{FWHM}$)

The cavity has a high finesse, for the detailed explanation we refer to comment 7 of referee 2. We removed the term “high finesse” to avoid confusion. Instead we mention that the mirrors are high reflectivity mirrors and this is in our opinion sufficient for the general understanding of the technique. We now write: “In both systems, the sample gas is drawn through an optical cavity, in which pressure and temperature are precisely regulated. Laser light is injected into the cavity through a semi-transparent mirror. A photodetector, placed behind another mirror, measures the light intensity leaking out of the cavity. In the WVIA spectrometer, the optical cavity consists of two slightly astigmatic high reflectivity mirrors and the laser beam is coupled into the cavity in an off-axis alignment.”

4) P 1603 L 10: change astigmatised to astigmatic.

Corrected as suggested.

5) P 1603 L 11: change introduced to coupled into the cavity.

Corrected as suggested.

6) P 1603 L 12: you state that the cavity “appears to be always resonant”. Isn’t it that the cavity is becoming rather non resonant due to the much lower FSR? Consider to refer to the Sayres 2009 paper you cited earlier.

The reference to Iannone, 2009 was changed to Paul, Lapson and Anderson, Appl. Opt. 40 (2011). For more details about the cavity resonant behaviour we refer to comment 7 of referee 2.

7) P 1603 L 15: You state “Laser light is injected in alignment with the mirror and the cavity mode structure requires frequency modulation of the electromagnetic signal using a piezoelectric actuator.” Please rephrase to make clear what is done. Is the length of the cavity adjusted by a Piezo electric transducer to keep the cavity modes at constant wavelengths?

The sentence now reads as follows: “Laser light is injected in alignment with the mirror. In order to obtain cavity frequencies that coincide with the source frequency, the cavity length is adjusted over short distances by a piezo-electric transducer.”

8) P 1603 L 21: Pressure and temperature control are not limited by the flow rate for any flow rate on the order of a few standard liters per minute! This is no technical problem.

We removed the end of the sentence: “which limits the exchange rate in the cell”.

9) P 1603 L 28: As far as I am aware, ringdown times are measured after the end of every laser scan in the LGR instruments. This would be a ringdown measurement at only one wavelength. The cited paper is an early work. I suggest getting back to the

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manufacturer to check this issue.

Ring down times are measured at 600 Hz after each laser scan at one wavelength. In the manuscript “at different wavelengths” was removed and the text adapted as follows: “Ring-down measurements are also done at regular intervals (600 Hz) in the WVIA system, in order to precisely monitor the mirror loss (Doug Baer, personal communication 2012).”

10) P 1608 L 7: What is a dry cell?

We replaced “dry cell” by “dried ambient air”

11) P 1612 L 22: You state “In the calibration experiment ten laboratory working standards of stable water isotopes were measured and calibrated with the two laser systems as well as with IRMS.” You calibrated your working standards with the laser spectrometers? Was it not the purpose of your experiments to characterize the instruments with known standards? Please clarify.

We measured a set of 10 working standards with IRMS and the Laser systems. We used the IAEA standards as reference standards in order to calibrate our internal standards in an independent way with the laser spectrometers. In the discussion version we presented IRMS measurements that were calibrated using two internal IRMS standards (WS 11 and WS 12). Following your comment and a similar one by referee 2 (comment 18), we measured the standards again with IRMS and used the IAEA standards to calibrate the measurements. We adapted the text and the results accordingly.

We use the IAEA Standards as reference standards because our internal standards in the delta linearity experiment span a large range of delta values, which can be well covered by the VSMOW-SLAP range. Furthermore the IAEA standards provide a direct link to the VSMOW-SLAP scale with a traceability chain that is as short as possible. With this experiment we can thus compare the measurements by IRMS and by the laser spectrometers in an independent way.

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This aspect will be clarified in the paper: Due to the revised structure of the paper the results will immediately follow a short presentation of the procedure. We will motivate our choice of procedure and explain why we used VSMOW and SLAP as reference standards for both the IRMS and the laser spectrometers.

12) P 1613 L 2: I am puzzled... Would it not be a good idea to use the SAME standard range to calibrate instruments that one wants to intercompare? Also here: mention again that you used WS11 and WS12 to calibrate the IRMS. Otherwise it takes a while to find it on Page 1607.

The procedure has changed, we now use the new IRMS measurements, see response to 11).

13) P 1618 L 7: I assume you refer to the spectral baseline?

Yes, "baseline" was changed to "spectral baseline".

14) P 1618 L 29: It is technically not difficult to dry ambient air to humidity < 5 ppmv using molecular sieve. Why is the residual humidity here so much higher?

With our setup we could not achieve better than 50 ppmv after 10 min of pumping ambient air through a molecular sieve and measuring the resulting air sample with the spectrometer.

15) P 1620 L 6: Change "...minimum, which is the optimum averaging time ($t_0 = 103$ s) and then..." to "...minimum, which is at the optimum averaging time ($t_0 = 103$ s), and then..."

Changed as suggested.

16) P 1620 L 10: The word "perfect" is misleading. Noise is never perfect as it is never wanted. Please rephrase to something like: "This indicates statistically independent measurements with a white frequency spectrum."

Rephrased as suggested: "This corresponds to statistically independent measure-

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ments with a white frequency spectrum, as shown by the solid line."

17) P 1620 L 25: Are 5 s averages not too long for flux measurements?

The sentence "For flux measurements high temporal resolution signals are needed..." was removed.

18) P 1621 L 19: Remove ", which are considered for the bias correction."

Corrected as suggested.

19) P 1623 L 5: Please state the humidity for which these precision values are valid (Fig. 6).

The text was changed as follows: "With such a calibration frequency at water vapour mixing ratios of around 15'700 ppmv the precision of the L1115-i signal averaged to 15 min is..."

20) P 1627 L 11: Rephrase "precision and accuracy in terms of short and long-term stability" to something like "the short and long-term precision and accuracy".

The text was changed as follows: "The main properties of the laser measurement systems investigated here were biases due to water concentration effects, the short and long-term precision and accuracy, and response times."

Interactive comment on Atmos. Meas. Tech. Discuss., 5, 1597, 2012.

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