Interactive comment on "Accuracy assessment of water vapour measurements from in-situ and remote sensing techniques during the DEMEVAP 2011 campaign at OHP" by O. Bock et al.

Response to anonymous Referee #1

The authors would like to thank the reviewer for the constructive comments.

First, we would like to emphasize that the three main unexplained results contained in the first submission could be fixed during the time of the open discussion: (1) the drift in the IGN Raman lidar calibration factor, (2) the large biases in the SOPHIE spectrometer data, and (3) and the large biases in the SAOZ data. The explanations and correction measures taken are the following:

An in-depth investigation of the field operations reports from IGN lidar staff, house-keeping measurements from the lidar, completed with laboratory measurements that revealed significant unexpected sensitivity of the detected signals to positioning/orientation of the optics fibre, led us to the conclusion that the drift in the lidar calibration constant was due to successive optical re-alignments in detection system (mainly the optics fibre). The lidar house-keeping measurements were two N2 signals detected in the H2O and N2 channels using a common N2 filter. This procedure was described originally by Whiteman, et al., 1992, and is used in routine during the IGN lidar operations, at the beginning and end of each night of measurements. It allows monitoring the stability of the differential radiometric sensitivity of the H2O and N2 channels. As these measurements are only taken at beginning and end of each night, and not in between, they cannot be used for the correction of the calibration factor at high temporal resolution. So, no further correction is brought to the data in the revised manuscript, but the drift in the calibration is explained.

The bias in the SOPHIE spectrometer data appeared to be due to an overestimation of the convoluted H2O absorption cross section which was computed for a previous configuration of the spectrometer. The spectral resolution of the spectrometer was indeed significantly improved just before the DEMEVAP campaign and as a first step we did not re-compute the cross sections. The scale factor (1.34) and slope parameter (1.27) observed between GPS IWV and SOPHIE IWV data in the first submission suggested rapidly that the error was coming from the H2O cross sections. We recomputed the cross sections using several methods (NASA on line service, HITRAN online service via, homemade computations using HITRAN recommendations) and more adapted to OHP atmospheric condition (atmospheric pressure and temperature are important for H2O cross sections) showed that for very high resolution instrumentation, the H2O cross section used in the initial analysis was underestimated by 25%, generating values larger by the same amount, i.e. by a factor of 1.25. Note that the shape and broadening of individual structures in the cross section did not change significantly in the spectral range used here. Finally, using new cross sections our results decrease by 25% and are now in very good agreement with the GPS measurements.

The retrieval of H2O column from SAOZ measurements is new and the results presented in the first submission used a preliminary version of the algorithm. The retrieval algorithm has been improved to reduce the bias with the GPS IWV measurements. Two important modifications have been brought. First, the water vapour cross sections have been generated using HITRAN 2012 instead of HITRAN 2000 as in the first version. The relative amplitude of the two bands of interest (570 nm and 590 nm) is slightly different (<5%) and the error bars have been reduced with the new cross-sections. Second, we have introduced a colour index (CI) to distinguish between clear and cloudy days and use a Air Mass Factor (AMF) adapted to the measurement conditions. The CI is computed from the SAOZ individual spectrum by ratioing two fluxes at two different wavelengths (550 nm and 350 nm). Each single water vapour measurement has thus a correlative colour index. Four groups of CI values are considered and for each group a specific AMF is used to compute the H2O column at zenith. This modification of the algorithm has the larger effect and removes errors introduced by using a single AMF.

CI<1.1 Clear day, use the normalised AMF

1.1<CI<1.9 Limited broken clouds, the normalised AMF is reduced by 16%
1.9<CI<2.35 Broken clouds, the normalised AMF is reduced by 30%
CI>2.35 Full coverage, data are rejected

The reference AMF is calculated with a radiative transfer model using a single standard water vapour profile at mid-latitude on a clear day. This AMF is normalised so that the SAOZ measurements agrees with the GPS measurements. For the DEMEVAP campaign, we used data from 14 September 2011 to compute the reference AMF and normalised AMF. Note that the data can be used up to 80° solar zenith angle when CI<0.8 and 64° in all other cases. The data with CI>2.35 are rejected because it is impossible to calculate an accurate AMF, as the H2O profile is perturbed by clouds located at various altitudes.

Referee comment: "*The manuscript presents results from a field campaign which took place in Fall 2011.The campaign involved multiple instruments (2 lidars, 5 GPS, 3 radiosonde types, etc.) using multiple techniques (lidar, capacity sensors, frost-point, GPS, spectrometers). The most significant outcomes are on the behavior of the new radiosonde M10, the Snow-White FP hygrometer, and the range/accuracy of the IGN lidar. Unfortunately, very little could be learned from the low-elevation sensing capability of this scanning lidar (technical issues), from the OHP WV lidar (technical failure), and from the spectrometers (large biases). These results should be published after minor revisions. The list of suggested minor revisions is provided below.* "

Some information on the scanning capability of the scanning lidar have been added in the instrument description section (2.1.2). The technical failures experiences with the OHP lidar in September 2011 were "random emission time tagging" due to a change in the trigger/control hardware shortly before the experiment. The large biases in the spectrometers were fixed (see introductory remark above). The new results are presented in the corrected manuscript.

Page 3453, line 3: this sentence and the following have been clarified. Note that there are references quoted for more information.

Page 3457, line 20 %RH has been used to refer to the commonly used percent unit of relative humidity measurements, whereas % is used to refer to a general definition of a percentage, independent of the physical unit of the discussed variable. The whole manuscript has been checked.

Page 3459, line 15: wording changed to "resolution degrades"

Page 3460, lines 10-11: sentence has been modified to: "In the case of the NDACC-OHP lidar system, this error was estimated to be smaller than 2% (Sherlock et al., 1999b) and it is not corrected, but there are options available for implementing a routine correction (e.g. use of ECMWF model temperature profile)."

Page 3460, lines 19-20: There seems to be confusion in what we mean by « adjusting ». This consists in the traditional least-squares fitting of the lidar calibration constant to the reference source. In our case, we start with an a priori value for the constant, based on physical considerations and laboratory measurements as explained in the manuscript, and fit a correction factor to this a priori value instead of fitting directly the constant. The advantage of this is that the correction factor *f* is close to one and that the difference to 1 can be directly interpreted as the fractional change of the calibration constant (e.g. 0.9 means a decrease of 10%). Since we use a constant a priori value valid for the whole campaign there is no additional uncertainty due to variation of the a priori value. The text has been clarified in this respect.

Page 3461, lines 5-6: Sorry but there is a misunderstanding! The GPS IWV estimates are retrieved every 5 min from 30 sec measurements, the lidar IWV estimates (zenith and slant) are retrieved every 5 min from 20 sec measurements, and the PTU measurements are averaged over 10 min from 1 min measurements. All the raw data are saved at higher resolution than used in the analysis. Only the PTU measurements are used at a different averaging time. The latter could easily be changed to 5 min, but there is no significant difference in the RH measurements from this sensor between 5 min and 10 min sampling. Moreover, when used in comparison to the other sensors this sampling error is much smaller than noise in the other measurements. So there is no limitation in the present results due to averaging times. But we agree that it is important to specify consistent data logging schedule with all the participants before such an experiment.

Page 3468, lines 23-27: As suggested by the referee, we reprocessed the OHP Raman lidar data to retrieve a profile over the same 30 min time window as with the IGN lidar. The agreement with the Vaisala RS92 measurement is clearly improved (small variations in the profile are better captured with a shorter integration time). The RP2 calibration method was also reprocessed with the new SOPHIE measurements and its bias compared to RS92 is consequently reduced.

Page 3469, lines 3-5: The discussion of moist bias of the M2K2DC for this particular case (compared to the dry bias observed on average) has been removed in order not to confuse the reader. We just highlight the moist bias in the upper troposphere.

Page 3469, lines 11-15: The definition of RP1 and RP2 was given in the legend of Table 4. It is now included in the text of this paragraph. The text has been revised also.

Page 3472, lines 15-19: Figure 3 in Yoneyama et al., 2008, shows the diurnal evolution of the bias with a dry bias around 00 LST and 12 LST. Their paper is focused on the daytime radiative bias. They do not discuss the dry bias seen at night-time.

Figure 15: the corrected measurements from SOPHIE and SAOZ instruments were presented in this figure to highlight the good correlation with the other measurements in spite of the bias. The bias was quantified in Table 5.

Figure 16: the uncorrected data were used there.

Note that Figure 15, 16, and 17, and Table 5 have been updated with the new data from SOPHIE and SAOZ instruments. The text has been revised accordingly (Abstract, Sect. 4.3 and Discussion).