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Atmospheric Measurement Techniques Discussions

Interactive comment on "Intercomparison of atmospheric water vapor soundings from the differential absorption lidar (DIAL) and the solar FTIR system on Mt. Zugspitze" *by* H. Vogelmann et al.

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Answer to comments from Referee 1:

Dear referee

Thank you very much for your comments which helped to improve significantly our manuscript.

1. First and only. . .
Thank you for this comment, our statement in the introduction referred only to ground-based DIAL systems. The word "ground-based" will be added and the airborne approach will be cited (Ehret93, Browell96 (ILRC), Bruneau2001).

2. Reprocessing DIAL results with spectral data from HITRAN2008. . .
We comply with the very constructive suggestion to reprocess the DIAL results with the alternative set of line parameters from the HITRAN 2008 database. Within this approach we decided to refine the spectral resolution of the numerical calculation of the cross sections from $[10^{-3}]cm^{-1}$ to $[10^{-4}]cm^{-1}$ in order to minimize artifacts. The results using both sets of line parameters will be shown in the revised Fig. 2: There are no major differences, but the parameter set of Ponsardin (1997) appears to be the better choice. Numbers from the HITRAN 2008 intercomparison will be added to a new column within Table 2.

3. Averaging times
The averaging times are given in Table 1.

4. Outliers
The two outlier criteria will be explained in the manuscript in more detail:

1. Detection of a receiver overdriving in the beginning of the far-field range:
This type of overdriving can produce signal induced errors within the entire far field range. Even if the region where this overdrive occurs is also covered by the near-field channel which is not overexposed, these measurements had to be discarded. Overdriving of the far-field channel under clear-sky conditions was observed during strong Saharan dust events or during heavy winter storms with windblown snow at altitudes above 3300 m a.s.l. See also answer to referee 2.

2. In the case of very dry layers below 4 km measurements have been discarded if the column value from the FTIR was larger than the DIAL value by more than factor of 2. This is because the retrieval of the FTIR is not able to resolve structures which strongly differ from the a-priori profiles on fine vertical scales below one kilometer. The exact criteria for the two types of outliers will be explained more clearly in the manuscript.

5. Vertical range
Definition of the vertical range: The field of view of the near-field receiver is 2.5 mrad x 8 mrad in zenith-view whereat the 8-mrad-aperture has the orientation of the bistatic parallax. The laser beam is emitted at a horizontal distance of 0.7 m from the receiver's optical axis. Thus, the laser beam enters the field of view already at a vertical distance of 185 m, at an altitude of 2860m a.s.l. Because of both DIAL-wavelengths are emitted by the same laser with the same optical path and the self-calibrating principle of the DIAL-retrieval, the overlap function does not have a significant impact. From the experience with pure backscatter lidars with similar bistatic receiver alignments we know that after the descent of the lidar return to the half of its peak value the impact of the overlap function can be assumed to be negligible. For the Zugspitze DIAL this point is reached at a distance of 300 m, 2975 m a.s.l. This is a very conservative estimate for the Zugspitze DIAL because of its a single path laser geometry.

Under normal conditions the upper end of the range of the DIAL (for this intercomparison) is fixed to an altitude of 12 km a.s.l. If an $H_2$2O absorption line with a reasonable cross section is used, there is still enough signal at this altitude. Over Central Europe this altitude range usually covers the entire troposphere above 3 km. Of course, exceptions had to be made for several reasons:

- Tropopause is above 12 km.
- Perturbations exceeding the sensitivity limit for the tropopause region.
- Unexpected disruption by contrails (overdrive in the receiver).

If exceptions were necessary, they where manually set and reviewed in each case. The limits of the vertical range will be explained in more detail in the manuscript and the explanation of the vertical range will be moved to the subsection "2.2 DIAL".

6. Azimuth interval
Choice of the azimuth interval $210° \pm 6°$: $210°$ is the azimuth of best volume matching of the FTIR instrument and the DIAL. An interval of $\pm 6°$ was chosen because it scarcely provides enough pairs for statistical analysis at short intervals of coincidence. Larger intervals (as $\pm 10°$, see Fig. 3) already blur the sharp bounded minimum of the standard deviation of differences associated with a perfect volume matching. This can also be seen in Fig. 3. The lower (red curve) has one node marked with "9". This is exactly the point of 9 coincidences within an interval of 18 min within an azimuth of $210° \pm 6°$. Due to the suggestion of referee 2, the 9 pairs of the subset will be highlighted in Fig. 2.

7. Stratospheric water vapor
Thank you for this very good comment. In fact, the stratospheric fraction of water vapor above Mt. Zugspitze if calculated from the atmospheric model LOWTRAN5 is much smaller than presumed before, only 0.3% in summer and 1.5% in winter. This being said, we point to the fact, that the bias of the DIAL-FTIR intercomparison is now, only 1.6%, after recalculating the cross sections in the context with the testing the spectral data from HITRAN 2008. In the manuscript this passage will be changed and the statement about the role of stratospheric water vapor for the bias will be weakened. Same in the conclusions.

8. Seasonal distribution of the measurements and "early afternoon"
The measurements were gathered throughout the whole year with an average sun position equivalent with the sun-position of March 24 which is near the equinox. The early afternoon as mentioned in Fig. 1 just means sun azimuths around $210°$ which is, depending on the season, around 2pm local time (1pm UTC). Information about

the seasonal distribution will be added, ”early afternoon” is already in context with the azimuth.

9. Typo P5413
Corrected

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