

Interactive comment on “Pole-to-pole validation of GOME WFDOAS total ozone with groundbased data” by M. Weber et al.

M. Weber et al.

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We thank anonymous reviewer 2 for his comments and suggestions to improve the paper.

Major comments:

1) A major concern was the uncertainty on how ozone temperature dependence of the ozone absorption is treated in the WOUDC station data. It is generally possible for both Brewer and Dobson to correct for the ozone temperature, however, most stations still use the standard retrieval according to WMO-GAW and therefore the cited error of +1.3%/K and +0.7%/K for Dobsons and Brewers, respectively, as cited in the text is still correct. We have added, however, in the manuscript after line 26, p. 6915: *In the standard retrieval, for both Brewer and Dobsons, the dependence of ozone cross-*

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section on temperature is not accounted unlike in the satellite retrieval. As discussed by Kerr (2002) temperature corrections can be applied to Brewer retrievals, but most of the stations participating in the groundbased network still rely on the standard retrieval. Also we added standard retrieval to sentence on page 6917, line 25, , where we cite percent errors per Kelvin, as follows: *...ozone change for Dobson and Brewer standard retrievals, respectively.* Furthermore, it is beyond the scope of this paper to go into every detail of the operation/practice at each individual stations. The main purpose here was to elucidate on the difference between Brewers and Dobsons and its impact on the comparison with satellite data. This is particularly important in view of the fact that many stations have changed or plan to change from Dobson to a more automated operation of a Brewer instrument. This may have implications for long-term trend monitoring. In the second paragraph in Section 3, the following information has been added: *Since the early eighties Brewer grating spectrometers have been installed at several stations (Kerr et al., 1985) and at many stations Dobson instruments have been replaced by Brewer spectrophotometers or are planned to be replaced.. Also: Particular advantage of the Brewer is its fully automated operation.*

2) It was also recommended to discuss the seasonal cycle in the WFDOAS differences to the ground data more rigorously. The ozone temperature is one issue as discussed in the Section on triple comparison, but other factors are also important. In the revised Section 5 we have added the following paragraph to the text: *The insignificant seasonal variation observed in the WFDOAS differences at low to mid latitudes is in contrast to the conclusion from the triple intercomparison involving collocated Brewer and Dobson data, where a distinct seasonal cycle signature is expected from the lack of ozone temperature correction in the ground based data retrieval. One should keep in mind that other factors influence Dobson results such as stray light errors (reduces retrieved total ozone) and environmental settings (affecting stray light levels) that may differ from station to station. As pointed out earlier, the ozone temperature correction is more important in direct sun measurements than for zenith sky measurements that are also included in the WOUDC data. An important result from this validation is, nev-*

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ertheless, that the seasonal dependence in the GOME-ground based data differences is quite small and gets smeared out when averaged over many stations. This is a large improvement compared to GDP V3 that shows a distinct seasonal signatures at mid latitudes that does not average out. Both retrievals, WFDOAS and GDP V3, use the TOMS V7 profile shape climatology (GDP V3 uses the climatology for airmass factor calculation). The big improvement in WFDOAS retrieval is that the TOMS V7 ozone profile shape climatology is also used to determine the varying ozone dependent contribution to the rotational Raman correction that is neglected in GDP V3.

3) The reviewer suggested to change "pole-to-pole" to "near-global", because the highest latitudes in the WOUDC data sets are 75 deg. (NH) and 78 deg. (SH). Polar stations are nevertheless involved in the comparison and we think, therefore, that the term pole-to-pole is well justified. One has to remember, that for dynamical reasons polar airmasses found at 90 deg will also be found at lower latitudes as well as airmasses in the polar night area will pass into the sunlit portion. Airmasses in the polar vortex will be circulated around the pole within a few days. Also all relevant solar zenith angles up to 90 deg, are covered in the comparison, so the polar region is covered well by the comparison. The reviewer also believed from Figs. 8 and 9, that there is significant solar zenith angle dependence in the WFDOAS differences to ground data. We have revised Figures 8 and 9 and replaced them by eight new figures (now Figs. 9 to 16) that show the significant improvement in dependence to retrieved total ozone and solar zenith angle as compared to the GDP V3. Nevertheless, the problem remains that we see a positive bias near the polar night period in the new GOME retrieval like in earlier versions, that to some extent also point at problems with ground data. The entire new Section 6 (Validation at polar latitudes) has been revised to make these points more clear.

Specific comments:

p. 6915, lines 19 to 16 and p. 6917, lines 26-27. We have added Kerr (2002) in Section 3 and made a remark on the potential to correct for ozone temperature in both Brewer

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and Dobson retrievals (see earlier comment).

p. 6918, Fig. 4. It was correctly noted by the reviewer that Resolute is a Brewer. Table 1 now contains the instrument type for each station that has been used in the validation. In the figure caption the following sentence has been added: *All station data are from Dobsons except for Resolute that are Brewer measurements.*

p. 6918, line 26, 27, and Fig. 4. Reviewer claims that every station except for Singapore shows a seasonal variation in the differences. A seasonal variation is observed, if a certain bias persists over many years. This is apparent in the polar data and Boulder as stated. For Commodoro Rivadavia, this is not the case, even though in selected years a seasonal bias may exist. We have modified one sentence as follows:

Outside the polar regions no significant seasonal signature in the differences is detectable with the exception of Boulder.

p. 6919, lines 1 to 3, and Fig. 4. The reviewer claims that there is no significant change in the seasonal signature of the satellite-ground differences for Boulder between 1996 and later years. We still stay with our view point that we see such a change that appears to be similar to the one observed with Hradec Kralove data, due to a change in the calibration settings of the Dobson that was recommended as a result from an international intercomparison campaign. In addition a jump of about 1% was observed in the long-term data series at several stations. For this reason, Hohenpeissenberg decided not to introduce the new calibration recommendation in order to ensure better consistency with the long-term TOMS data record (U. Köhler, Hohenpeissenberg, personal communication). This issue is still debated in the Dobson community, but we do not want to go into too much detail here. For this reason we will leave the text as is.

p. 6919, line 21. The reviewer suggests to introduce a new section or sub-section. We have rearranged the former section 4 and 5 and divided them into new sections, e.g. Section 4 (Comparison with individual WOUDC stations), Section 5 (Validation at low to middle latitudes) and Section 6 (Validation in polar regions). See also response to

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major comments by Reviewer 1.

p. 6920, lines 12-20. Disappearance of seasonal variation by including only European stations. See response to major comment above.

Fig. 8 and discussion. As mentioned earlier the comparison to polar data has been extended to 2003 and Figs. 8 and 9 have been replaced by eight new figures. A clear improvement in the polar region by WFDOAS as compared to GDP V3 is evident, although the positive bias near the polar night period remains. See major comment earlier.

p. 6921, last para. It was requested to make it more clear what the Fairbanks TOMS3-F campaign showed. This paragraph has been extended (now in Section 6) to make the points more clear and in view of the new figures that have been added. This comparison campaign showed that under high polar ozone condition like in Arctic spring 2001, the comparison between modified Brewer and Dobsons taking into account improved stray light corrections and accounting for the proper ozone temperature, showed a difference to the standard AD pair retrieval of the Fairbanks Dobson of about 3 to 4%. Looking at the new Fig. 11, we observe a bias of about 4% on average between WFDOAS and the results from the six polar stations (five Dobsons and Resolute Brewer) in March/April 2001 in line with the results from the TOMS3-F campaign. This points at the possibility that the WFDOAS bias observed can be at least in parts be explained by the shortcomings of the standard retrieval in groundbased instruments. The Brewers involved in the Fairbanks campaign were single and double monochromators (has been added in the text).

p. 6923, section 6, explaining again why WFDOAS shows a seasonal cycle signature in the differences to the groundbased data and in some cases not. The reasons should not be repeated again but has been discussed in detail before (see also major comment on seasonal variations). In light of the new figure that have been added, few changes were made in the Conclusion.

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All other specific comments have been agreed upon and changes were made as suggested.

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