Atmos. Chem. Phys. Discuss., 5, S5211–S5217, 2005
www.atmos-chem-phys.org/acpd/5/S5211/
European Geosciences Union

Interactive comment on "Inter-comparison of stratospheric O_3 and NO_2 abundances retrieved from balloon borne direct sun observations and Envisat/SCIAMACHY limb measurements" *by* A. Butz et al.

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Received and published: 24 January 2006

We are grateful to the referee's overall positive comments and suggestions. Please find below our point-to-point reactions in italic.

Overall, I thought the paper was good to excellent. It was very well done and very thorough from when I first saw it. The quick review process was very successful in making the paper complete. However the paper became too long and I believe that very few people will read the entire paper, but many more could benefit from its results.

We concur with the referee's opinion that the paper is quite long. When editing the paper we considered to split the paper into two parts, where one part would treat the LPMA/DOAS comparison and one part the SCIAMACHY validation study. However, we decided not to split the paper, since in our opinion it is important to assess both, the quality of the validation data set and the validation itself, in a single paper. Nevertheless, we tried to choose the wording and the illustrations as concise as possible. We gratefully acknowledge the referee's feeling that we presented a paper, which is "very well done and very thorough". But in our opinion, there is no section which could be omitted without making the paper less comprehensive and less "thorough".
Moreover, we tried to structure the paper in a way that anybody who is interested in a single part only should be able to select the dedicated sections.

Therefore I think the paper could be improved if there was a table summarizing the results. A table that gave biases and precision of differences between balloon and satellite for slant columns and as function of altitude for both O3 and NO2 vertical amounts.

Fig. 2 and 3 and Fig. 7 and 8 summarize the LPMA/DOAS comparison on O_3 and NO_2 SCDs and the validation of SCIAMACHY O_3 and NO_2 vertical profiles, respectively. The overall agreement observed in these figures is summarized in abstract and conclusion where the LPMA/DOAS agreement is found 10% for O_3 and 20% for NO_2. SCIAMACHY and balloon borne O_3 and NO_2 vertical profiles agree within 20% between 20 km and 30 km and worse below 20 km. The biases and standard deviations between the data sets are indicated by solid and dashed vertical lines in Fig. 2, 3, 7 and 8, respectively.

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In our opinion a table listing the numbers illustrated in the figures mentioned above provides no new insight into the quality of the comparison studies. Rather, a table of numbers could prevent the reader from carefully looking at the illustrations and could lead to over-interpretation of the statistical comparisons. For example, the finding that SCIAMACHY O_3 profiles are systematically low around 26 km altitude cannot be inferred easily from any tabulated number.

Another table which would list the error contributions, such as cross section, pointing, fitting parameters, and the amount due remaining temporal and spatial differences in the tangent points would also be very instructive. This would illustrate whether our validation techniques are good enough, that is, do the component errors add up to the difference observed in the comparison data.

The section which discusses the error budget of the LPMA and DOAS measurements (p.10754,l.11ff and p.10775,l.25ff) is rewritten and supplemented by details and numbers on the different error contributions of both instruments. Since the number of contributions is limited an extra table is omitted. Fig. 7 and 8 are supplemented by the combined error bars of the satellite and balloon borne observations and the discussion in section 4.2.1 and 4.2.2 is extended accordingly.
Quantification of the remaining "temporal and spatial differences in the tangent points" is not an easy task since an exact treatment would require the knowledge of the true trace concentration as a function of location and time. We tried to asses the error due to unaccounted photochemical variation by sensitivity studies as described in Sect. 2.4. The resulting error estimates are part of the error bars attributed to the photochemically corrected NO_2 profiles. The impact of horizontal variations of the trace gas abundances strongly depends on the meteorological situation as outlined in the paper, but can be seen by comparing O_3 profiles inferred from balloon ascent and solar occulation measurements of the same balloon flight. While the high resolution

O_3 data from balloon ascent in Kiruna in 2004, Fig. 5e, excellently agree with the in-situ sonde data the corresponding solar occultation measurements, Fig. 5f, reveal some discrepancies with respect to the in-situ data below 20 km. This is a clear hint for sampling horizontally inhomogeneous air masses. However, we see no way how to quantitatively estimate this source of uncertainty. To put it another way, if it was possible to quantify the impact of horizontally inhomogeneous air masses on the validation study, we could possibly find a way how to correct for it.

The authors should quantify the corrections made to the spatial difference using the trajectory model and the time difference using the photochemical model. Did they help the comparison or not and how much? The authors point out that the modeling error is 10-20% while the modeling error for backward match is 30%. Therefore, are these models necessary for validation and how much value did they add to the comparison analysis?

The trajectory model is used for pre-flight planing to identify possible coincidences between the planned balloon and satellite borne observations and to optimize e. g. the launch time of the balloon. For post-flight analysis, the trajectory model identifies the coincidences actually observed according to the temporal and spatial coincidence criteria mentioned in the paper (p.10763) and calculates the corresponding air mass trajectories. No correction goes along with the trajectory model calculations. The temporal and spatial mismatch between the satellite and balloon borne observations is tabulated in Table 2. The need for a trajectory modell primarily resides in the identification of the satellite observations which are most suitable for validation.
The solar zenith angles calculated along the modeled air mass trajectories are then used as input for the photochemical model which calculates the photochemical weighting factors κ_{kj} (p.10765). Subsequently, the balloon borne NO_2 profiles are scaled by these weighting factors to yield the photochemically corrected profiles as

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described in detail in Sect. 2.4. The impact of photochemical scaling on the retrieved NO_2 profiles is illustrated in Fig. 6, where the uncorrected profiles are shown as gray diammonds and the corrected ones as black boxes or red triangles. In particular, for solar occultation measurements, Fig. 6a, c and f, the applied scaling is substantial. The added value of the photochemical model calculations is obvious from Fig. 6. Clearly, photochemical corrected balloon borne profiles agree better with the satellite data then the uncorrected profiles. The modeling error in the core range of the validation study between 20 km and 30 km ranges between $<$10% and 20%, which is in most cases less than the applied scaling. The modeling error is comprised in the error bars of the balloon borne profiles plotted in Fig. 6.

This paper is a benchmark for validation because of detail analyses included by the authors. Therefor are the results presented here the best that might be expected for validation? Where can improvements be made?

In our opinion we did our best to compare like with like by employing an air mass trajectory model to identify coincident air masses, by running a photochemical model to correct for the photochemical evolution of NO_2 and by smoothing the high resolution balloon borne data to match the altitude resolution of the satellite instrument. The validation strategy could be improved significantly if there was no need for meteorological or photochemical modeling, i. e. if the same air masse were sampled at the same time by the balloon and satellite borne instruments. Since solar occulation measurements have to be conducted close to sunset or sunrise, the LPMA/DOAS instrumental setup cannot provide such direct coincidences. This constraint could partly be overcome by a new small spectrometer developed by the DOAS-balloon division at IUP-Heidelberg (Weidner et al., 2005). The new spectrometer operates in limb scattering geometry similar to SCIAMACHY and can be deployed on various platforms. The conclusion is changed accordingly:

p.10777,l.7: Since the origin of the discrepancies observed at low altitudes cannot be unambiguously attributed to the satellite retrievals or the validation strategy, it is important for future studies to keep the spatial and temporal mismatch between satellite and validation measurements as small as possible.

Finally, a lot more value would be added to this paper if there were comments on the scientific impact of these results. I think validating ozone profiles to 10% is not good enough these days. We have seen comparisons with ground and satellite data approaching the 5% level (e.g SAGE and sondes). 10% is not likely good enough for trend monitoring. But possibly good enough for model verification. Much less is known about NO_2 climatology that 20% might be good for developing a climatology and providing some constraints to a 3D photochemical model, although having only NO2 may not be good enough. In this case the NO_2 data would compliment stratospheric profile data from Aura MLS and HIRDLS for model evaluation.

The paper is intended to compare O_3 and NO_2 abundances inferred from three different sensors, LPMA, DOAS and SCIAMACHY. As far as the balloon borne measurements are concerned there is a variety of publications where the retrieved trace gas abundances are compared to model calculations, e. g. Bösch et al. (2003), Dufour et al. (2005) and Dorf et al. (2005). Hence, the LPMA/DOAS data have clearly proven their importance for gaining new insights in stratospheric photochemistry.
The satellite retrievals, however, are in a preliminary stage and will require some updates in the future. The main purpose of the presented paper is to help to contribute to such updates and to improve the respective algorithms. Hence, we explicitly do not want to judge on the usefulness of the SCIAMACHY O_3 and NO_2 profiles. Rather, we leave the decision to the reader whether to use SCIAMACHY data or not after considering our validation results. Further, our paper is only one out of a suite of papers dedicated to SCIAMACHY validation. There are two special issues of ACP discussing various validation approaches for data retrieved from SCIAMACHY

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measurements. We feel that a statement on the usefulness of SCIAMACHY data based solely on our validation results would disregard the efforts of other authors. An overview of SCIAMACHY validation results is presented by Piters et al. (2005), although our results are not included.

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