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Atmospheric Chemistry and Physics Discussions

Interactive comment on "First retrieval of global water vapour column amounts from SCIAMACHY measurements" *by* S. Noël et al.

S. Noël et al.

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General remark:

We thank the referee for his useful comments. Especially the suggestion to extend the error analysis (see point 2 below) motivated us to look deeper into the results of the algorithms. By this we could identify an error in the AMC-DOAS results. Within the context of the error studies it turned out that the AMC-DOAS results presented in the paper have been derived using inadequate pressure and temperature profiles. New calculations (with correct settings) have been performed, which indicate that the AMC-DOAS results systematically underestimate both the SSM/I and ECMWF columns, which is now consistent with the WFM-DOAS results. Therefore, the AMC-DOAS water vapour columns to be presented in the revised version of the paper will also been scaled by a factor of 1.1. Note that the correlation of the data sets is only hardly effected by this, and that the results of the study remain essentially unchanged. Possible reasons for

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this offset will be discussed in the revised version, and it is clear that this point needs to be investigated in further studies.

General comments:

In this section the referee explains (i) why he considers global water vapour total column measurements to be of high relevance for a number of scientific reasons, (ii) that SCIAMACHY is supposed to "make an important contribution to improve our knowledge about ... water vapor" and (iii) that ACP is an adequate forum to address this topic. Basically the referee gives a nice summary of our motivation to conduct the study presented in the paper.

Specific Comments:

1. The main aim of the paper is to shown that WV retrieval from SCIAMACHY measurements is possible on a global scale and produces reasonable results. A full validation of the derived products is not intended by the paper and is in fact limited by the amount of currently available data. 1-day averages of ECMWF data have been used to facilitate a comparison with SSM/I data. This average ECMWF data set is surely not optimal for a detailed assessment of data product quality, but it can be considered as a "worst case" data set. Therefore, it can be expected that the already good agreement between SCIAMACHY and ECMWF results will even improve if ECMWF data with less time difference to the SCIAMACHY measurements are used.

   However, we agree with the referee that further investigations are required to assess the quality of the SCIAMACHY WV product in more detail (i.e. by comparing directly with six-hourly EMWF data), but this will be the next step in developing an operational WV product from SCIAMACHY. The present paper is only the first step towards this, and in fact the results are quite promising.

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2. The present paper focuses on the application of existing WV retrieval algorithms on SCIAMACHY data. The algorithms themselves are described (incl. self-consistency checks, etc.) in previous publications which are already cited. The AMC-DOAS method has proven to be self-consistent within less than 1% (see Noël et al., 1999). However, for the revised version of the paper we intend to include the results of an AMC-DOAS error analysis showing the dependency of the retrieved columns on different atmospheric conditions and albedos.

   Similar remarks also apply to WFM-DOAS. In Buchwitz and Burrows (2003) a detailed error analysis is presented. That analysis, however, focuses on other gases derived from different spectral regions and, therefore, cannot easily be translated to the retrieval task discussed in this paper. A dedicated WFM-DOAS error analysis appropriate for this paper will be added in the revision of the paper.

3. In first order, the influence of the albedo is - as stated in the AMC-DOAS section - normally very small for DOAS type methods as the albedo effect is typically a broadband feature. This is true for both AMC-DOAS and WFM-DOAS. However, there are 2nd order effects of the albedo, which affect the differential absorption depth. The albedo sensitivity will be discussed in more detail in the revised version of the paper taking into account the (to be added) error analysis mentioned above.

   Nevertheless, the fact that the agreement of SCIAMACHY WV with SSM/I data obtained over ocean and ECMWF data over all types of surfaces is similarly good is an indication that the end-to-end albedo effect is low.

4. There seems to be one basic misunderstanding: The AMC-DOAS method does not determine an air mass factor, but an air mass *correction* factor. The “default” air mass factor is implicitly contained in the parameter c which is essentially the product of the “default” air mass factor and absorption cross section for the reference atmosphere used. Thus, an air mass correction factor a of e.g. 0.8 means

that the “real” air mass factor is 20% smaller than the “default” air mass factor.

There can be many reasons for the AMF correction factor being different from 1; clouds and surface elevation are probably the most important ones. Therefore, the AMC-DOAS results depend indeed on the actual cloud and surface properties (as it is stated in the text of the paper), but it is not required to distinguish between these effects, as the air mass correction factor takes care of this.

Obviously, the air mass correction is more reliable if the discrepancies between the model atmosphere and the real conditions are not too large, i.e. where the correction factor is close to 1. Therefore, we have to set a limit to “reliable” air mass correction factors. For AMC-DOAS, this limit has been set to 0.8, based on experience with GOME, but in fact this value is a more or less free parameter resulting from a trade-off between high product precision and rejection of not too many data.

Looking at the retrieval results it is indeed the case that by choosing a limit of 0.8 regions where discrepancies are expected (like high mountain areas) are correctly masked out; this gives confidence to the selection of the limit.

Additional Comments:

1. The explanation of the algorithms has been kept deliberately short, because detailed information can be found in previous publications.

   The term $c \cdot {C_V}^b$ is a parametrisation of the WV optical depth as a function of the vertical WV column. Thus, the parameter c has no direct physical meaning; as stated in the text it contains not only the reference cross section but also the air mass factor, both representative for the radiative transfer simulation used. Temperatures and pressures depend of course of the reference atmosphere used and vary along the light path.

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For the first applications of the AMC-DOAS algorithm (see e.g. Noël et al., 1999) the parameters b, c, and τ_{O_2} have been determined not only for different solar zenith angles but also for different atmospheric conditions (the six standard MODTRAN atmospheres). Later it turned out that it is sufficient to use only one (tropical) reference atmosphere (see Noël et al., 2000), this is why we used only this one in the present study. Different surface elevation has never been considered, although one could think about it in further studies to avoid data gaps over high mountain areas.

For clarification we suggest to add the following paragraph in the revised version of the paper:

"The term τ_{O_2} is the optical depth of O_2 and derived using radiative transfer calculations with and without O_2. The parameters b and c are determined from radiative transfer calculations assuming different water vapour columns C_V (see Noël et al., 1999, for further details)."

2. An increased AMF pathlength results in an air mass correction factor larger than 1. Currently, AMC-DOAS does not use an upper limit (like 1.2) for the air mass correction. The main reason is, that air mass correction factors larger than 1.2 do not occur very often, and we have checked that the exclusion of these measurements has no significant impact on the statistical results. However, it is true that these long pathlengths typically occur at higher latitudes, and one could think about introducing an upper limit for the air mass correction factor to improve the results at these regions, but this will be a subject of further studies.

3. As explained before, the limits for AMC-DOAS are based on experience with GOME data (reference is given in the text), and as the paper shows they seem to work also for SCIAMACHY data. These limits can not be derived from theory; as mentioned before, they are resulting from a trade-off between high product precision and rejection of not too many data. Similar remarks apply for WFM-DOAS.

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The limits for WFM-DOAS currently used and specified in the paper are more "an educated guess" based on experience of the authors with simulated retrievals (see, e.g., WFM-DOAS error analysis) rather than the result of a comprehensive study. WFM-DOAS and AMC-DOAS are different algorithms, therefore it is not required that the quality check method (and thus the limits) are the same.

4. An error analysis will be added for the revised version of the paper where the albedo sensitivity of the retrievals will be discussed. This error analysis will quantify how an error in albedo translate into an error of the retrieved column. If only a single albedo is used for the retrieval an error will occur. First order problems related to albedo are accounted for by the polynomial and by the air mass correction factor (AMC-DOAS) and by ratioing with the simultaneously retrieved O_2 column (WFM-DOAS), but some error will remain. As will be shown in the error analysis, a higher albedo typically results in a higher retrieved column. For AMC-DOAS the albedo induced error is expected to be smaller than 15%. This is the maximum error resulting from an albedo of 90%. More details will be given in the revised version of the paper. For WFM-DOAS, the error analysis will demonstrate that a 3-10% underestimation over ocean is expected. Over land only a small overestimation up to 3% is expected.

   For this study we have applied an overall correction of +10% mainly based on the comparison with SSM/I and because of the error analysis (see also general remark above). This might result in an overestimation over land surfaces. From our comparison with ECMWF data over land this expected overestimation has not been found. This, however, needs to be further looked at in future studies if more SCIAMACHY data are available and analysed.

5. We agree with the referee that the different treatment of saturation may be an additional explanation for the systematic deviations between the AMC-DOAS and WFM-DOAS swath data. We will add this in the revised version of the paper.

6. In fact, the specific humidity has been used to calculate the total water vapour column from ECMWF. This will be made clear in the revised version of the paper.

Technical corrections:

All technical corrections will be considered in the revised version of the paper.

Interactive comment on Atmos. Chem. Phys. Discuss., 3, 5659, 2003.