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

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1. General comments

The paper presents first results of the retrieval of water vapor (WV) total column fields from SCIAMACHY using two DOAS-type retrieval algorithms previously used for the retrieval of WV (Air Mass Corrected - Differential Optical Absorption Spectroscopy; AMC-DOAS) and WV and other trace gases (Weighting Function Modified - DOAS; WMF-DOAS) from GOME and SCIAMACHY (simulation studies). The retrievals have been applied to the weak branch (around 700 nm) of the WV 4ν-myriad. Retrievals of WV from the visible part of the spectrum are restricted by opaque cloud cover, but have the major advantage over retrievals from the IR and MW-regions that they are

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not restricted to ceratin surface types. Results for one day of SCIAMACHY data (14 orbits) have been compared to correlated results from the SSM/I instrument and the total water vapor column (WVC) field as given by the ECMWF data assimilation model.

It is remarkable that one of the first articles on the retrieval of scientific level 2 data from the SCIAMACHY instrument on ENVISAT (in orbit since March 2002) submitted to an peer-reviewed journal is on WV and not on O_3, NO_2, CH_4, CO_2, CO or other trace gases, which are at significantly higher priority from the list of SCIAMACHY level 2 products than WV.

This reflects the growing awareness in the remote sensing community of the importance of measurements of the tropospheric WV distribution from space. Being the major greenhouse gas and with respect to its important role in the direct effect (formation and deposition of aerosols), as well as the first and second indirect effect (formation of clouds), sources for data on the global distribution of WV, especially in remote regions over land, where little radiosonde measurements are available, are still sparse or often of limited quality. Inter-comparison studies between different type of data-assimilation models as well as between different remote sensing instruments frequently show large discrepancies in total column amounts, which is partly due to the strong spatial and temporal variability, as well as the complex spectroscopy of the water molecule.

Even though the retrieval algorithms employed for this paper are not new and have been published previously elsewhere, WV data from SCIAMACHY visible nadir, and hopefully in the future also from limb measurements, will make an important contribution to improve our knowledge about the three dimensional distribution of WV. WV data from SCIAMACHY and other instruments like MIPAS and MWR on ENVISAT, MODIS and AIRS on the EOS-AQOA platform, IASI (to be launched) and others will likely be used extensively in the future for inter-comparison with data from general circulation or chemical transport models and for the modeling of cloud and aerosol formation.

In order for the data to be used successfully for these purposes and for the article to

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be ready for publication in ACP - which serves as an adequate forum for the addressed topics - the authors should carefully address the four following questions in some detail, and perform other smaller revisions proposed and added at the end of this review.

2. Specific comments

1. In section 4.3 the authors state that for a comparison of the data with data from the ECMWF assimilation model a time average over the six-hourly ECMWF fields has been performed. The authors correctly state that the scattering in the intercomparison plots with ECMWF data may predominantly be related to the temporal and spatial variability of water vapor. Little can be done to improve the impact of the spatial resolution on the scatter due to instrument restrictions and gridding of data. The latter effect is adequately represented in Figure 7 and 8. However, the temporal overlap may be greatly improved by using six-hourly data from ECMWF for passes where the in-time overlap is largest (maximum plus minus three hours). The 4D-Var adjoint method employed by ECMWF transports the WV in space and time constrained by the measurements, i. e. on a physical basis. Averaging in time over such data will lead to a questionable temporal and spatial mean value, due to the strong variability of the data and the relatively small number (five) of points. Employing this kind of averaged data set is justified for performing a rough global comparison of the major patterns, like the impact of surface elevation and the position of the inter tropical convection zone, among others. For an appropriate estimate of the quality of the data, which is of much value to modelers, such comparison is not sufficient, because it does not reflect the real potential or lack of the data that could be assessed. All that can be stated is that there is a significant scatter around 0.5 $\mathrm{g/cm.}^2$ in the data (see conclusions), which is likely related to the temporal and spatial variability of the WV distribution. However, modelers should be able to make a good and easy to grasp

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judgement on the quality of level 2 data with respect to their individual needs. The possibility of easy to asses inter-comparisons between different products should therefore be one important goal of publications on level 2 data retrieval. For WV level 2 data validation, spatially correlated data with a maximum of two, at most three hours temporal overlap is a standard, which is already employed by most of the publications on WV retrieval in the literature. Even though the ECMWF comparison plots (Figure 12 and 13) exhibit a surprisingly small increase in scatter with respect to the SSM/I correlation plots (Figure 9 and 10) with better temporal overlap, the question arises how the temporal variability of the data affects the 0.5 g/cm^2 data quality estimate, especially for the regions over land where no SSM/I data is available.

2. In order to provide future data users with a good estimate of the quality of the data under specific atmospheric conditions and for specific measurement situations, a self-consistency error-budget study is required and either lacking from the paper, or results (quantities) from previous studies are not stated here (e.g., for WMF-DOAS). Apart from the validation with other data-sets each retrieval technique should provide error estimates of model parameter error, the forward model error, the retrieval noise, and, if available and applicable, the smoothing error. Forward model and parameter error impact studies may give especially important insights for modelers on the quality of the data under specific instrument viewing angles, for regions with significant atmospheric aerosol content and for different surface types (e.g., the land/ocean transition), which then can be accounted for with the use of data in models or with model comparisons. The error budget studies should either be included in the paper or derived estimates from previous publications should at least be stated and referenced.

3. In section 3.2 about WMF-DOAS the impact on the results of employing a too-high surface albedo is discussed. It is stated correctly that the surface albedo alters the relative depth of the absorption lines. This means that, also for DOAS-

type methods, the quality of the fit results depends on how well the broad band extinction effects, including the surface albedo, are modelled or retrieved under all conditions (i.e, via the pre-calculated quantities and the retrieved polynomial P). In contrast, in section 3.1 about AMC-DOAS it is stated that ’the choice of the model surface albedo is - like for most DOAS-type methods - rather uncritical’. Which is true? The authors should discuss in some detail how well the polynomial P represents the albedo among other broad band contributions. In fact, an impact study on the quality of the results with respect to changes in surface albedo (land/ocean transitions) is highly recommended in view of the fact that the retrieval of WVC above all surface types is one of the major selling points of these kind of retrievals.

4. The surface elevation is treated explicitly in WMF-DOAS via the precalculated RT reference spectra. It is by far not clear how this problem is treated in AMC-DOAS. It has been stated at the beginning of section 3.1 that the fitted AMF accounts for the altering of the light path due to clouds and to some extent to the ’insufficient knowledge of the background atmospheric and topographic characteristics’. The quantities b, c and τ_{O_2} have been calculated from radiative transfer calculations performed for ’different atmospheric conditions and solar zenith angles’. Later on it is stated that only ’one free tropical reference atmosphere’ has been used together with a fixed surface albedo of 5%. Assuming that this reference atmosphere has been used for the radiative transfer calculations to estimate b, c, τ_{O_2}, the retrieval of the Air Mass Factor (AMF) a should be quite sensitive to the surface elevation. In fact, most of the higher mountain chains, like the Andes and the Rocky Mountains, should suffer from a rejection of fit results. As has been pointed out in the discussion this is partly visible from Figure 4, for example, by the rejection of measurements over the Himalaya (not rejected in WFM-DOAS) due to the decrease in the AMF by surface elevation. The question arises if in case that a pixel comprising lower surface elevations is not rejected - like, for

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example, above the cloud-free Alps - a completely cloudy pixel over Munich may be considered as being cloud-free when both pixels have comparable effective elevation and cloud top scattering heights?

Therefore, a brief summary of the consequences on which pixels are rejected and which not by introducing the 0.8 AMF limit with respect to cloud cover fraction and surface elevation should at least be given by the authors. As an alternative, from a retrieval of the AMF from the O_2 absorption with AMC-DOAS an estimate of the effective scattering hight may be retrieved and then compared with an effective elevation height from a topological database, in order to, in turn, retrieve an estimate of the effective cloud top height values. The latter may then serve as an improved quality check criterium for rejecting or not rejecting the fitted total column C_v.

3. Additional comments

1. **Section 3.1, p. 5663, line 11f, and p. 5664, line 13f.** It is not very clear to the reader, who is not familiar in all details with previous publications, how b, c, τ_{O_2} are estimated from RT calculations as mentioned on page 5663, line 11f. Later on, at page 5664, line 13f, it is stated that only one reference atmosphere is used, presumably for the mentioned RT calculations. The authors should briefly explain how the effective quantities b, c, τ_{O_2} are calculated, preferably already at page 5663. For example, in which way does c 'contain' (and not 'is') an 'effective' reference spectrum apart from the applied sampling, i.e., which representative temperatures or pressures have been employed for the calculations of c. The different atmospheric conditions mentioned at p. 5663, line 11f, presumably refer to the calculation of τ_{O_2} and b for different WVC and solar zenith angles, but not for different surface elevations in the case of τ_{O_2}? How does this relate to the free

tropical reference atmosphere used and mentioned on p. 5664, line 13f? Please clarify.

2. **Section 3.1, p. 5664, line 15.** What happens in the case of an increased AMF pathlength correction by multiple scattering? Is there an upper limit employed as is the case for WFM-DOAS? Or are these cases suppressed by the general impact of surface elevation? Over the oceans, measurement situations with enhanced pathlengths with respect to the reference atmospheric geometry can be expected, especially at higher latitudes and above regions with high aerosol content.

3. **Section 3.2, p. 5666, line 10ff.** It makes the criteria limits employed by both methods for rejecting pixels due to large cloud fraction look quite *ad hoc* when both methods use different limit quantities without explaining in some detail why exactly these numbers are used. As mentioned before, it can be expected that an upper-limit criterium for rejecting pixels also applies to AMC-DOAS. But why employ a different lower limit for WFM-DOAS than for AMC-DOAS? A brief summary of how those limits are derived should therefore be given.

4. **Section 3.2, p. 5667, line 2f.** Here it is stated that 'all WFM-DOAS WVC discussed have been enhanced by 10%', whereas the explanation given for why such an scaling is required refers only to ocean pixels (p. 5666, line 17ff). If indeed *all* WFM-DOAS results are scaled, a more detailed discussion of this underestimation should be given, especially because it then cannot solely be referred to the highly variable surface albedo problem (p. 5666, line 19ff).

5. **Section 4.1, p. 5668, line 15ff.** The authors speculate on the reason for the systematic deviations between AMC-DOAS and WFM-DOAS as visible from the swath comparison plot (Figure 7). However, the reasons given should likely increase the scatter between both methods and should not be the reason for systematic deviations. The deviations look more like a result of treating the 'satura-

tion' problem differently, because the deviations seem to be smoothly dependent on the WVC.

6. **Section 4.3, p. 5669, line 15.** If indeed 'relative humidity' and not 'specific humidity' has been used for the calculations of total WVC from ECMWF, the authors must have a good reason for it. Significant errors may be introduced by converting relative humidity to specific humidity via biases in the temperature profile and the choice of the applied saturation pressure model (over water and over ice surfaces).

4. Technical corrections

1. **Abstract, line 6 and 7.** Differential *Optical* Absorption Spectroscopy.
2. **Section 3.2, p. 5665, line 16.** 'the derivatives refers', → 'the derivatives refer'
3. **Section 4.3, p. 5669, line 17.** 'each day', → 'the 27^{th} of January'.
4. **Section 4.3, p. 5669, line 25.** 'described here' → 'described in the following section'.
5. **Section 4.3, p. 5669, line 27.** 'are show' → 'are shown'.

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

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