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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Retrieval of global water vapour columns from GOME-2 and first applications in polar regions" *by* S. Noël et al.

S. Noël et al.

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Reply to referee 2

We thank the referee for the comments on the paper. We will consider them in the revised version. Our detailed answers are given below (referee comments in italics).

1. *I think it is worth to discuss a little more the impact of cloudiness on retrieved total water vapour columns especially over arctic regions. The authors don't say much about and even the cloud clearing algorithm applied is not mentioned. Since GOME-2 does not have channels in the infra-red, the cloud detection relies presumably on a combination of thresholds (contrasts) and O2 band absorption*

depths data. GOME-2 as well as similar UV/VIS sensors will miss clouds (especially cirrus clouds) and will be affected by bright surfaces in arctic regions which limits cloud detection. This will have an impact on retrieved total water vapour columns, even more over arctic regions when absolute columns are low.

We will include the following section in the revised paper which should explain these issues in more detail:

> Since the AMC-DOAS retrieval algorithm has been explained in detail before (see e.g. Noël et al., 2004) only a short summary of the main features of the method will be given here.
>
> As all DOAS-type applications the AMC-DOAS method uses only the differential absorption structures to derive total columns. All spectrally broadband contributions (e.g. from Rayleigh or aerosol scattering or surface reflectance) are approximated by a low-order polynomial which makes the DOAS retrievals very insensitive to these. Therefore the retrieval does not require any external information from e.g. albedo data bases.
>
> In addition to standard DOAS the AMC-DOAS method considers a non-linear relation between the absorber amount and the absorption depth, thus taking into account the effect of non-resolved saturated absorption lines. Furthermore, the AMC-DOAS method incorporates an air mass correction by which deviations between an assumed model atmosphere and the real conditions are handled. The radiative transfer data base used in the retrieval has been calulated for a tropical atmosphere assuming no clouds, a fixed surface albedo of 5%, no aerosols and a surface elevation of 0 km. Usually these assumptions are not fulfilled for the measurements. Any deviations from these assumptions in the "real" measurements are accounted for by the air mass correction factor. The air mass correction factor is determined from the O_2

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absorption within the fitting window (688–700 nm). Since the amount of atmospheric O_2 (as a well mixed gas in the troposphere) is known, a measured O_2 optical depth different from the modelled one can be interpreted as a different average light path or a different air mass factor. The underlying assumption for the air mass correction is, that this air mass factor difference can also be applied to the water vapour absorption, thus correcting the derived water vapour column. This assumption is justified because water vapour and O_2 absorptions overlap within the fitting window (i.e. the spectral range is very similar) and the absorptions are of similar strength.

Of course the air mass correction method produces better results for scenes where the atmospheric background and surface conditions do not differ much from the ones assumed in the radiative transfer calculations. Because of this only data with a retrieved air mass correction factor larger than 0.8 are taken into account. This value of 0.8 has shown to give a good compromise between the achieved data accuracy and the remaining amount of data. The most probable reason for low air mass correction factors is the presence of clouds in the atmosphere. Therefore the air mass correction factor limit removes too cloudy scenes such that the resulting AMC-DOAS water vapour data set is essentially cloud-cleared. However, not only too cloudy scenes are sorted out but also regions with too high surface elevation, like the Himalaya. Note that in contrast to e.g. cloud masks derived from imaging methods the AMC-DOAS cloud filter method is not very sensitive to bright scenes (e.g. ice in polar regions). Furthermore the AMC-DOAS retrieval is not based on external information (i.e. data from different spectral regions or from other sensors) which makes the resulting data set very independent.

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2. *It would be nice to see a comparison of GOME-2 results with ATOVS data (columns and error budget). This would allow estimating the quality of GOME-2 retrievals with respect to other satellite retrievals that are widely known and used. A comparison against model data is an asset but the satellite-satellite intercomparison tells more about the overall performance of GOME-2.*

   We agree with the referee that a comparison with ATOVS data (and also other independent data sets) would be very useful to validate the GOME-2 water vapour data. However, a complete validation is not the scope of the present paper. The main aim of this paper is to show the potential of GOME-2 as an additional source for water vapour information, especially in the polar regions. For this purpose we think a comparison with one validated product (in this case SCIAMACHY) is sufficient. We will include the need for further validation in the conclusions via the following paragraph, also mentioning the ATOVS instruments AMSU and HIRS:

   > For a full assessment of the quality of the GOME-2 AMC-DOAS water vapour product additional validation using other water vapour data products is required. Especially, comparisons with the results from other nadir viewing MetOp instruments (like the Advanced Microwave Sounding Units AMSU-A1 and AMSU-A2, the High-resolution Infrared Radiation Sounder HIRS/4, the Infrared Atmospheric Sounding Interferometer IASI, and the Microwave Humidity Sounder MHS) providing water vapour data at minimum temporal and spatial offsets will be very useful in this context.

3. *Daily courses of total water vapour columns based on a few data samples per day need to be discussed and justified. The authors speak about "short-term variations" in the abstract (should be called diurnal variation instead, as done view lines below) since it depends on the readers view-point what frequency is interpreted as "shortterm". Climatologists have certainly another time scale in*

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mind than e.g., people being interested in air chemistry and process studies. On p 17543, l9 the authors themselves speak about "the strong spatial and temporal variability of water vapour" but use the comparably low GOME-2 temporal sampling to discuss the diurnal cycle.

We agree with the referee and will replace "short-term variations" by "diurnal variation" in the paper to be more precise.

It is true that water vapour has a large spatial and temporal variability which makes the derivation of a daily cycle difficult, especially when only few data per day are available. This is why it is not possible to derive from GOME-2 the diurnal variation for each day, but as described in section 4 and shown in Fig. 7 b) it is possible to derive information about the average daily cycle on e.g. a monthly basis.

4. *The comparison of GOME-2 and SCIAMACHY water vapour data are obviously strongly influenced by viewing geometry and temporal differences between data acquisition over the same area. To some extent the different scattering regime (forward scatter/east, back-scatter/west) seems to affects the retrieval which could be due to surface BRDF effects (bright surfaces, strongly anisotropic scattering of snow and ice, large sun zenith angle) and atmospheric scattering. The authors could add some more explanations/details about the AMF computations here (e.g. treatment of surface reflection, which albedo model is used, which aerosol model is used ?). Even at the early stage of GOME-2 (cal/val phase products) it is however disappointing to have such artefact in the data which seriously limits the application of such combined data set for climatological studies. The question is then if the paper appears too early in the game. I appreciate the ambition to be the first on the market but there is a trade-off between being the first and the presentation of consolidated results. Maybe the title could be changed to something like "Preliminary results of GOME-2 water vapour retrievals and first applications in polar regions"*

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Since only differential absorption structures are analysed and due to the use of the air mass correction factor (see answer to comment 1) the influence of the AMC-DOAS results to geometrical issues as well as to surface albedo and aerosols is rather low. The reported East-West asymmetries in the results are a second order effect and in fact very low; as mentioned in the paper the remaining differences between GOME-2 and SCIAMACHY results are in the order of what is expected to be the accuracy of the AMC-DOAS water vapour product.

As requested by Referee # 1 we will add a section to the paper which ranks the discussed reasons for the observed discrepancies in order of probability. In our opinion, the most probable cause is a problem in the calibration of the GOME-2 data. However, for AMC-DOAS water vapour these are all second order effects, and we think especially climatological studies are not limited by these effects, because e.g. for a trend analysis systematic effects are less important as long as they are stable over time.

In the paper it is explicitly mentioned (end of section 2) that the GOME-2 results are preliminary. Nevertheless we agree to change the title as suggested by the referee to "Preliminary results of GOME-2 water vapour retrievals and first applications in polar regions" to make this more clear.

5. *p17543 "Related to the average global water vapour column of about 2 g/cm2 this variation is very small (∼ 6%)" Yes, that's true but the authors emphasize the retrieval of water vapour columns over polar regions where the total column is in the order of 0.5 gcm-2. The variation of 0.1-0.15 gcm-2 causes then an uncertainty of 20-30%. This should be added.*

The variation of 0.1–0.15 g/cm^2 is derived from globally averaged data; therefore this value should be related to the global average water vapour column of about 2 g/cm^2. In polar regions columns are much lower and also the deviations (of the gridded data) are smaller and less systematic due to more overlaps between the GOME-2 and SCIAMACHY swaths (and themselves) at one grid point. For

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latitudes larger than 60°N, for example, the sinusoidal variation is much less pronounced in the gridded data, and the amplitude is only about 0.01–0.02 g/cm^2. Related to a typical column of 0.5 g/cm^2 (as mentioned by the referee) the error of the daily gridded water vapour data related to the East-West effect is therefore only 2–4%. Thus, we think the number of 6% given in the paper is valid and even a conservative estimate for polar regions.

For clarification, we will add the following sentence in the revised paper:

> Note that in polar regions where both columns and deviations are smaller and instrumental swaths overlap more often the relative variation is less pronounced but of similar magnitude.

6. *Conclusion: On the one hand the enhanced GOME-2 swath is several times mentioned as improvement, making the instrument advantageous over GOME and SCIAMACHY. On the other hand it became obvious that it is especially the large swath that causes the problems when comparing the results to GOME and SCIAMACHY. I see that the authors are in a tricky situation here but I would prefer it to have a clear statement if the large swath is really an improvement over GOME/ERS-2.*

   We will add the following paragraph to the Conclusions section where this is clarified:

   > It should be made clear that from the perspective of water vapour retrieval despite of the observed systematic variations between GOME-2 and SCIAMACHY results the increased GOME-2 swath and the resulting increased spatial and temporal coverage is a clear advantage compared to GOME and SCIAMACHY. The periodical deviations of water vapour columns which may be related to a scan-angle dependency of the preliminary GOME-2 data are considered to be rather uncritical

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for the water vapour retrieval as they are very small and in the order of the assumed accuracy of the data product, especially compared to the scatter in the data which is mainly due to atmospheric variability.

7. *p 17549: DLR-Bonn -> DLR (Germany)*

   We will replace DLR-Bonn by DLR Space Agency (Germany) in the Acknowledgements section.

8. *Replace "concentration" by "total column", "atmospheric column" etc. in the text. It's not concentration what is retrieved from GOME-2.*

   Agreed, will be done.

Interactive comment on Atmos. Chem. Phys. Discuss., 7, 17537, 2007.