A COMBINED GOME AND SCIAMACHY GLOBAL WATER VAPOUR DATA SET

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ABSTRACT

A new version of the Air Mass Corrected Differential Optical Absorption Spectroscopy (AMC-DOAS) approach for the retrieval of water vapour total column amounts from measurements in the spectral region around 700 nm has been applied to measurements of the Global Ozone Monitoring Experiment (GOME) on ERS-2 and the SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY (SCIAMACHY) on-board the European environmental satellite ENVISAT. In this paper it is shown that GOME and SCIAMACHY water vapour data can be combined, resulting in a long-term time series covering already more than 10 years. Depending on the life time of SCIAMACHY this time series will continue further. In addition, the GOME-2 instruments on the series of operational meteorological satellites Metop will extend this data set, as first preliminary retrieval results confirm.

1. INTRODUCTION

Global water vapour total column amounts have been derived from measurements of the Global Ozone Monitoring Experiment (GOME, see e.g. [1]) on ERS-2 and the SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY (SCIAMACHY, see e.g. [2]) on-board the European environmental satellite ENVISAT. For this purpose, the Air Mass Corrected Differential Optical Absorption Spectroscopy (AMC-DOAS) approach (see e.g. [3, 4, 5] for details) has been applied to GOME and SCIAMACHY nadir measurements in the visible spectral region around 700 nm. Similar retrievals have been performed by other parties (see e.g. [6, 7, 8, 9, 10]). GOME and SCIAMACHY water vapour total column data are available over both ocean and land, but only measurements on the day side and under (almost) cloud free conditions can be used. The GOME and SCIAMACHY results do not rely on any other measurement data, thus providing a completely new and independent data set. As a first application of GOME water vapour data in the context of climatological trend analysis [11] shows, GOME-type instruments can lead to an additional, completely independent global water vapour data set suitable for climatological studies.

In this paper an updated version of the AMC-DOAS water vapour products for GOME and SCIAMACHY is presented. The derived GOME and SCIAMACHY water vapour columns are compared with previous versions and with each other, in order to show that a combination of the two data sets is possible and to verify similar investigations [12] which were based on the previous AMC-DOAS water vapour data set. Furthermore, a first comparison of SCIAMACHY water vapour columns with preliminary AMC-DOAS retrieval results using spectra measured by GOME-2 on Metop is performed.

2. GOME AND SCIAMACHY GLOBAL WATER VAPOUR DATA

GOME data are available since June 1995 until present, although with reduced coverage since June 2003. SCIAMACHY data are available since August 2002 until now. Recently, a complete reprocessing of GOME and SCIAMACHY water vapour data products has been performed involving an updated version of the AMC-DOAS retrieval program and – in the case of SCIAMACHY – also updated Level 1b data products. The resulting new data products have the version number 1.0. The main changes with respect to the previous AMC-DOAS version is that the radiative transfer data base used in the retrieval has been recalculated in order to consider changes in the HITRAN spectroscopic data [13]. For the SCIAMACHY water vapour retrieval data the following additional modifications apply:

- The water vapour data are mainly derived from the SCIAMACHY reprocessed Level 1b Version 5 data set. Gaps in this data set have been filled (as far as possible) by near-real-time (NRT) data of either Level 1b version 5 or (since May 2006) version 6.
- The SCIAMACHY retrieval is now based on (except for additive offsets) uncalibrated Earthshine radiance and solar irradiance data. More specifically, in the extraction of the Level 1b radiances only memory effect correction, dark current correction and wavelength calibration are applied. The irradiances are based on uncalibrated solar spectra derived from measurements involving the ASM (Azimuth Scanner Module) diffuser. When no actual ASM diffuser spectra were available (which is the case for 2002 data), the ASM diffuser spectrum of 9 April 2003 (also provided in the Level 1b product) was used.
- The Doppler shift for the solar reference spectrum is now read from the Level 1b product (earlier versions used a fixed value). This is however a minor change which has not much influence on the derived water vapour products.

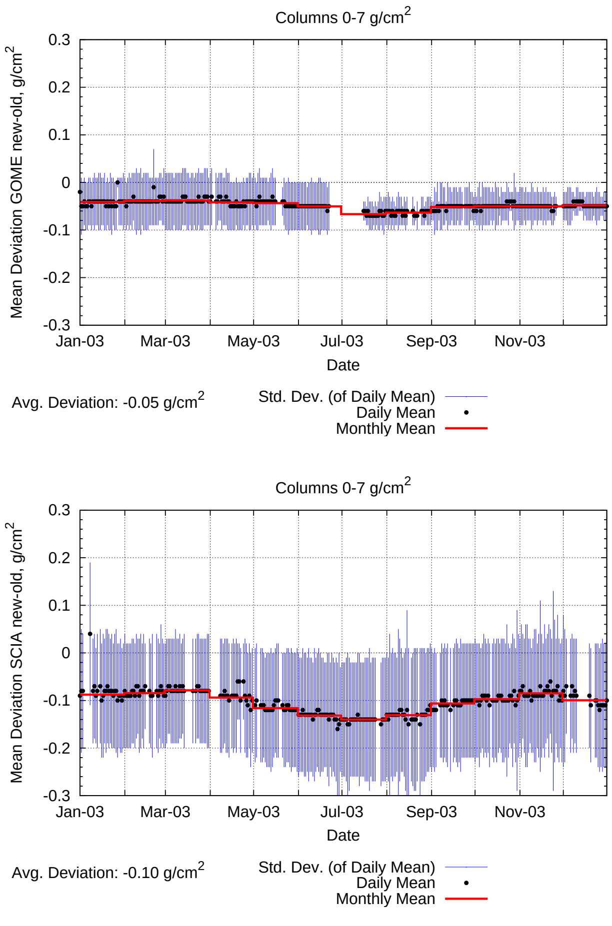

Figure 1. Comparisons of new (V1.0) and old AMC-DOAS water vapour products for the year 2003. Top: Globally averaged daily and monthly deviation of the different GOME water vapour product versions. Bottom: Similar plot for SCIAMACHY water vapour data.

The combination of the new HITRAN data base with the reprocessed Level 1b data results in typically smaller water vapour columns as in previous (0.x) versions. This is shown in Fig. 1 where the global daily and monthly mean deviation between old and new GOME and SCIAMACHY data sets are displayed as a function of time for the year 2003. For this comparison, all data sets have been put on a 0.5° × 0.5° latitude/longitude grid. As can be seen from this figure, the new GOME water vapour columns are systematically about 0.05 g/cm^2 lower than in the previous data product version. The SCIAMACHY V1.0 columns are on average about 0.1 g/cm^2 smaller than before, with some seasonal variation in the difference. The larger differences for SCIAMACHY data can be explained by the fact that for GOME data only the radiative transfer data base has been updated, whereas within the generation of the SCIAMACHY V1.0 products additionally updated Level 1 products have been used.

The SCIAMACHY water vapour data set is still somewhat limited by the amount of available SCIAMACHY Level 1b spectral data. Although this situation has largely improved since the generation of a re-processed Level 1b version 5 data set, the reprocessed data still contain some gaps which had to be filled by corresponding near-real-time (NRT) data. Furthermore, the SCIAMACHY Level 1 forward processing has been changed to version 6 in May 2006. The SCIAMACHY Level 1b data set used for the generation of the V1.0 AMC-DOAS water vapour columns is thus a combination of version 5 and version 6 data products which is – due to the inclusion of NRT data – not completely consolidated. However, recent investigations [14] have shown that there is no major difference between AMC-DOAS water vapour columns retrieved from SCIAMACHY version 5 and version 6 Level 1b data such that the different version numbers are considered to be less relevant. Latest after the completion of the Level 1b version 6 reprocessing also the consolidation issues should be solved.

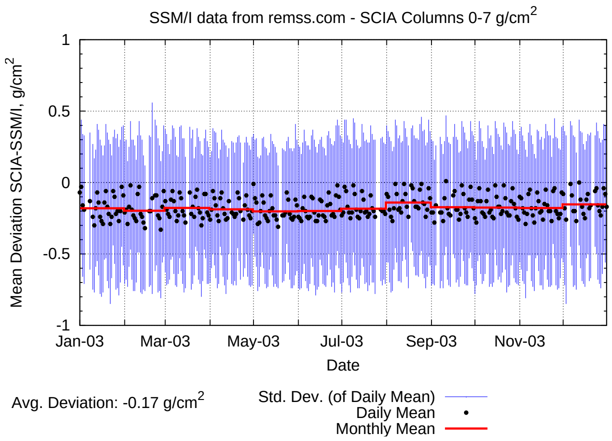

Figure 2. Comparisons of new (V1.0) SCIAMACHY water vapour columns with SSM/I data for the year 2003.

Fig. 2 shows a comparison between the new V1.0 AMC-DOAS water vapour product with vertical columns derived from measurements of the Special Sensor Microwave Imager (SSM/I) over ocean. For this purpose we selected data from the descending orbit part of the DMSP F-14 satellite, which has a dayside equatorial crossing time of about 08 00 LT, close to the ENVISAT dayside equatorial crossing time of 10 00 LT. In this intercomparison updated SSM/I data (version 6, derived based on an algorithm by Wentz [15], provided by Remote Sensing Systems) have been used. Both SSM/I and SCIAMACHY data have been spatially (re-)gridded to 0.5° × 0.5°). The time series of global average deviations between SSM/I and SCIAMACHY water vapour columns displayed in Fig. 2 results in an average offset between the two data sets of -0.17 g/cm^2 (with the SCIAMACHY data being lower than the SSM/I data). There is no seasonal trend visible in the deviations. The agreement between SCIAMACHY and SSM/I results is thus slightly better than for previous versions (see [5]). The scatter of the data is still considerably large, which can be attributed to the different spatial and temporal resolution and sampling of the instruments.

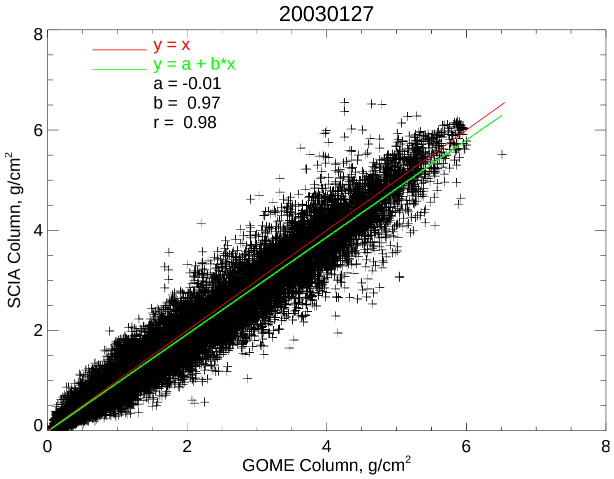

Figure 3. Example for a correlation between GOME and SCIAMACHY water vapour columns.

3. INTERCOMPARISON BETWEEN GOME AND SCIAMACHY WATER VAPOUR DATA

The comparison between GOME and SCIAMACHY water vapour data is limited by the availability of global data from both instruments. For the intercomparison between the derived GOME and SCIAMACHY water vapour data presented here the time interval from August 2002 until December 2003 has been chosen. This includes six months (January to June 2003) where both instruments were operating nominally. The SCIAMACHY water vapour data from 2002 are of slightly reduced quality because no actual ASM diffuser solar reference spectra are available for that time. On the other hand, GOME data after June 2003 have no longer global coverage due to a failure of the on-board tape recorder. For the comparison all data have been gridded to 0.5° × 0.5°.

As an example, Fig. 3 shows a scatter plot of gridded GOME and SCIAMACHY water vapour columns on 27 January 2003. Because of the similar orbits of ERS-2 and ENVISAT there are many collocations. The correlation between the two data sets is quite good (0.98), but there is a small bias of -0.02 g/cm^2 and a slope which deviates 3% from 1 such that overall the SCIAMACHY columns are slightly smaller at this day. This is in fact in contrast to what was found out for the previous version of water vapour data [12] where the correlation was slightly worse and the SCIAMACHY data were on average larger than the GOME data.

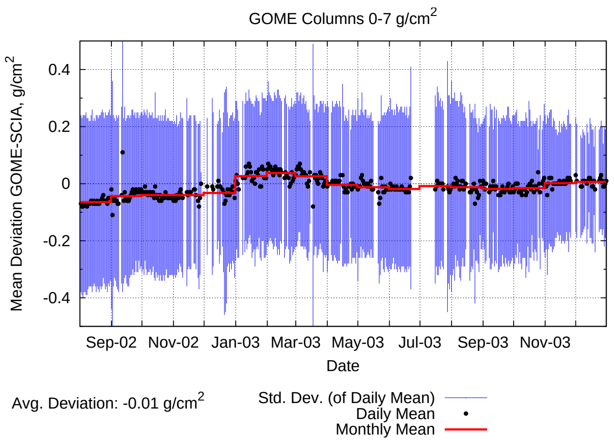

Figure 4. Deviation of GOME and SCIAMACHY water vapour columns as a function of time (August 2002 to December 2003).

The complete time series of global mean deviations shown in Fig. 4 reveals that the deviation between GOME and SCIAMACHY is in fact quite small without a distinct sign. In 2002 the SCIAMACHY data are typically larger than the GOME data (which may be related to the non-actual solar reference spectrum). Between January and April 2003 the SCIAMACHY data are on average smaller than the GOME data, for later times the mean difference is almost zero. The scatter of the data is about ±0.25 g/cm^2, smaller than e.g. when comparing SCIAMACHY and SSM/I data (see Fig. 2).

Fig. 5 shows the difference between GOME and SCIAMACHY water vapour columns as a function of geolocation for the months January to May 2003 where both instruments performed global measurements with non-reduced performance. For these plots, all monthly mean data have been re-gridded to 5°×5° spatial resolution to reduce the influence of the high variability of water vapour. However, there is still a lot of scatter visible in the plots. For most of the Earth differences between GOME and SCIAMACHY data are less than 0.3 g/cm^2. The shown absolute differences are typically lower at higher latitudes where water vapour columns are low. At a few places differences are larger, but these locations vary from month to month such that no typical regions of higher deviations can be clearly identified. This indicates that the differences are not caused by e.g. topography but by specific meteorological conditions, especially cloud statistics. The potential influence of different amplitudes of seasonal effects caused by the different spatial resolution of GOME and SCIAMACHY may also not be excluded. Considering these aspects, the GOME and SCIAMACHY water vapour columns fit quite well together, such that a combined water vapour set can be generated which then may be used for climatological studies. Nevertheless, any application should check the transition point between GOME and SCIAMACHY carefully for potential jumps in the time series.

4. FIRST PRELIMINARY WATER VAPOUR RETRIEVALS USING GOME-2/METOP DATA

On 19 October 2006 the Metop satellite was launched into low-earth orbit as the first of a series of European meteorological satellites. One instrument on-board of Metop is GOME-2, an enhanced version of GOME. Compared to the GOME instrument, GOME-2 has a higher spatial resolution (80 km × 40 km, comparable to the SCIAMACHY resolution of typically 60 km × 30 km) and a larger swath width of 1920 km, resulting in a daily coverage at mid-latitudes. The Metop orbit is – as the ERS-2 and ENVISAT orbit – sun-fixed with an equa-

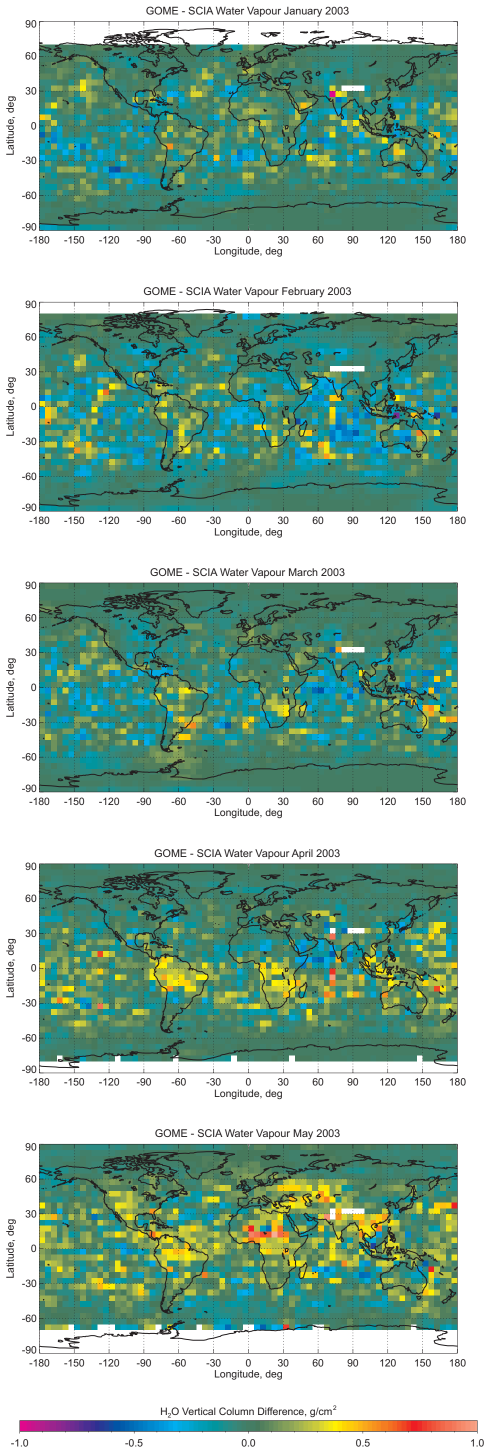

Figure 5. Deviation of GOME and SCIAMACHY water vapour columns as a function of geolocation. Top to bottom: January 2003 to May 2003.

tor crossing time of 09 30 LT (compared to 10 00 LT for ENVISAT and 10 30 LT for ERS-2). This small time difference facilitates the combination of the retrieval results. Currently, GOME-2 is still in its CalVal phase, therefore all GOME-2 data presented here are of preliminary nature.

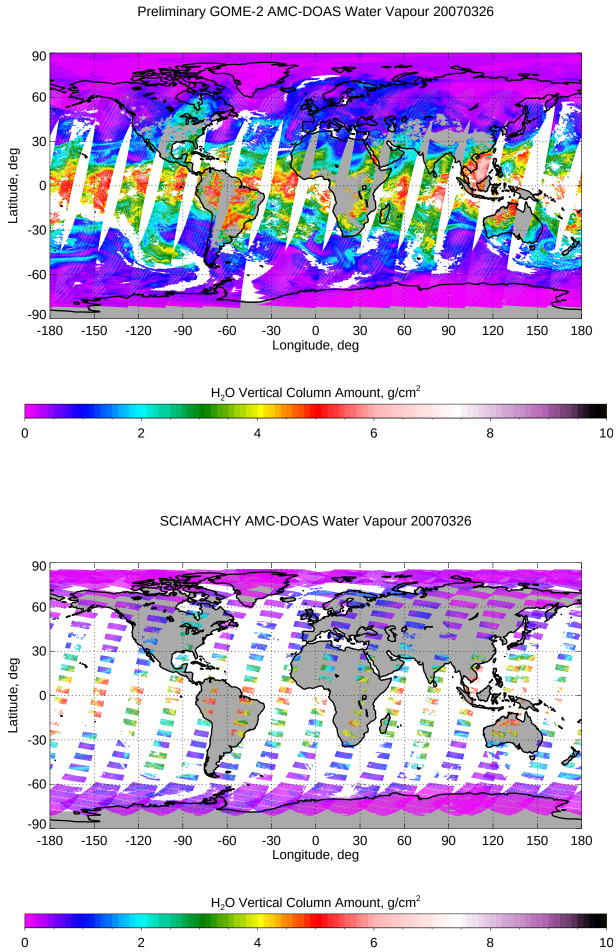

Figure 6. Top: Preliminary GOME-2 water vapour columns derived with the AMC-DOAS method for two orbits on 26 March 2007 (swath data). Bottom: SCIAMACHY water vapour columns for the same day (also swath data).

Because of the similarities between GOME-2 and GOME, the AMC-DOAS retrieval method can also be applied to GOME-2 data. Fig. 6 shows a map of preliminary GOME-2 water vapour columns derived using the AMC-DOAS method and the corresponding SCIAMACHY results for the same day (26 March 2007). The larger swath of GOME-2 is clearly visible. An eye inspection of these swath data already reveals that the observed water vapour structures agree quite well. This is confirmed by a more quantitative analysis for which all data are spatially gridded to $0.5° \times 0.5°$ and compared. A scatter plot of all resulting collocated data points of GOME-2 and SCIAMACHY for this day is shown in Fig. 7. The agreement between the two data sets is quite good; the linear correlation coefficient is 0.99, and a fitted straight line reveals a slope of 0.99 and a small bias of -0.01 g/cm^2. However, this is only a single day example for a comparison between GOME-2 and SCIAMACHY water vapour columns. A more extensive statistical analysis will be performed when more GOME-2 data are available.

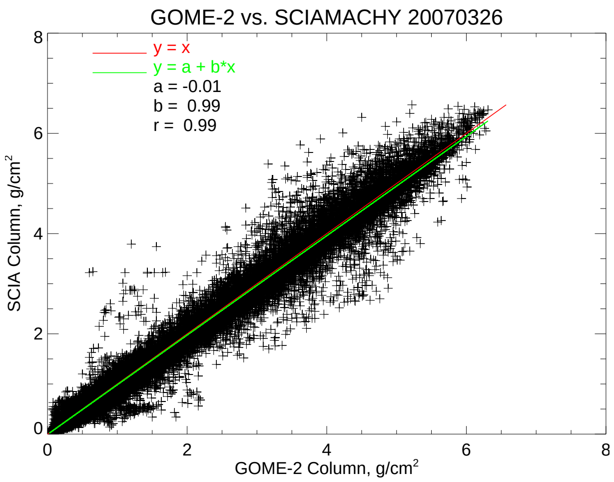

Figure 7. Comparison of water vapour columns derived from preliminary GOME-2 spectral data from 26 March 2007 with corresponding SCIAMACHY results.

5. CONCLUSIONS

A new version (1.0) of AMC-DOAS water vapour products has been generated based on GOME and SCIAMACHY measurements, taking into account an updated spectroscopic data base and (in the case of SCIAMACHY) re-processed Level 1b data products. The derived version 1.0 water vapour columns are systematically lower than the previous products by about 0.05 to 0.1 g/cm^2, but they still compare well with e.g. SSM/I data over ocean.

An intercomparison between GOME and SCIAMACHY data results in a good agreement. On global average there is no significant offset between GOME and SCIAMACHY water vapour columns, but there is a mean scatter of about $\pm$0.25 g/cm^2 and local deviations which potentially need to be taken into account when using the combined GOME and SCIAMACHY data set for e.g. climatological trend analysis. For illustration Fig. 8 shows the resulting annual means for the complete combined GOME and SCIAMACHY water vapour data.

First AMC-DOAS retrievals based on preliminary GOME-2 spectral data have been performed. A comparison with SCIAMACHY data shows an good agreement between the water vapour columns which gives confidence in the possibility to extend the GOME/SCIAMACHY water vapour time series by GOME-2 data.

ACKNOWLEDGMENTS

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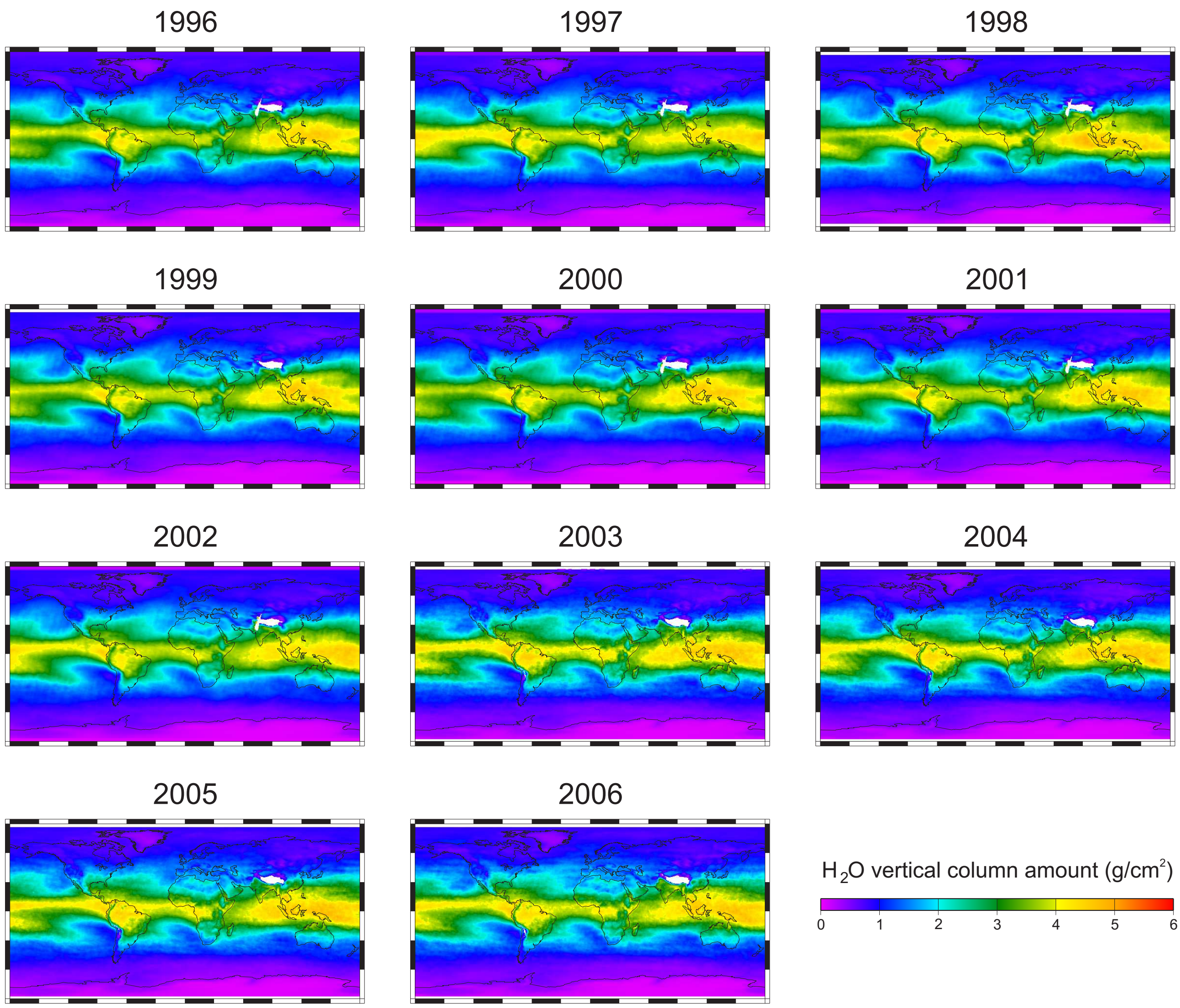

Figure 8. Annual mean water vapour total columns derived from GOME (1996–2002) and SCIAMACHY (2003–2006).

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