SCIAMACHY WATER VAPOUR RETRIEVAL USING AMC-DOAS

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ABSTRACT

Measurements of the SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY (SCIAMACHY) on ENVISAT have been used to derive global water vapour total column amounts over ocean and land. For this purpose, the Air Mass Corrected Differential Optical Absorption Spectroscopy (AMC-DOAS) approach, which has already been successfully used with GOME data, has been applied to SCIAMACHY's nadir measurements.

Whereas operational SCIAMACHY water vapour products are derived from measurements in the near-infrared (NIR), the AMC-DOAS algorithm is applied to the spectral region around 700 nm where both water vapour and molecular oxygen absorptions are present.

AMC-DOAS is an extension of the standard DOAS method. To be applicable to water vapour retrieval, it considers the non-linear relation between absorber amount and absorption depth (saturation effect). Furthermore, an air mass correction factor is derived from O_2 absorption features. This air mass correction factor not only compensates deviations of the modelled atmospheric conditions from reality, it also serves as an inherent quality check for the retrieval by which e.g. too cloudy scenes can be identified.

Comparisons of the SCIAMACHY total water vapour columns derived with the AMC-DOAS method with corresponding SSM/I and ECMWF water vapour measurements have been performed. Taking into account the large temporal and spatial variability of water vapour, the SCIAMACHY results agree well with these correlative data not only over ocean but also over land, thus showing the capability of SCIAMACHY to provide a new independent global water vapour data set.

1. INTRODUCTION

Water vapour is one of the most abundant atmospheric gases. More than 99% of it is located in troposphere, where it significantly contributes to atmospheric chemistry, weather and climate. Water vapour is highly variable in both space and time and thus a good tracer for tropospheric changes. Therefore, the knowledge of global water vapour distributions is especially essential for global atmospheric models aiming to predict weather or climate.

Current sources for global water vapour data are on the one hand in-situ measurements by radio sondes as well as ground-based and airborne measurements. On the other hand, information about global water vapour concentrations is obtained from space borne (near-)infrared ((N)IR) and microwave (MW) sensors like TOVS, SSM/I and MODIS, and from GPS observations. The MERIS instrument on ENVISAT contains also a dedicated NIR channel for water vapour retrieval, and first results look quite promising [1].

It has been shown by several parties that in addition to these data also measurements of the Global Ozone Monitoring Experiment (GOME, see e.g. [2]) and the SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY (SCIAMACHY, see e.g. [3]) in the visible spectral region may be used to derive global water vapour concentrations [4, 5, 6, 7, 8, 9, 10, 11].

The current paper presents recent results of the so-called 'Air Mass Corrected Differential Optical Absorption Spectroscopy' (AMC-DOAS) method which has been applied to SCIAMACHY nadir measurements in the spectral region at about 700 nm. Note that these are results of a scientific algorithm; they are not related to the (not yet available) operational SCIAMACHY water vapour data product which is based on measurements in the NIR.

2. THE AMC-DOAS RETRIEVAL METHOD

The AMC-DOAS method is based on the well-known DOAS (Differential Optical Absorption Spectroscopy) approach as it derives information about the amount of an atmospheric species from differential absorption structures in sun-normalised radiances. As usually all DOAS-type applications, AMC-DOAS is numerically fast and therefore well suited for operational data processing.

There are two main differences between AMC-DOAS

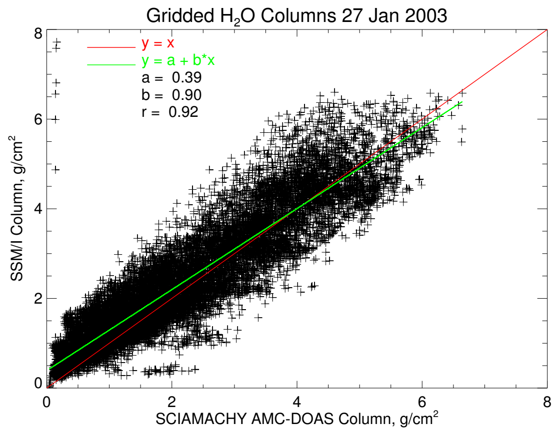

Figure 1. Comparison between SSM/I and SCIAMACHY AMC-DOAS water vapour columns for 27 January 2004. r is the Pearson's linear correlation coefficient.

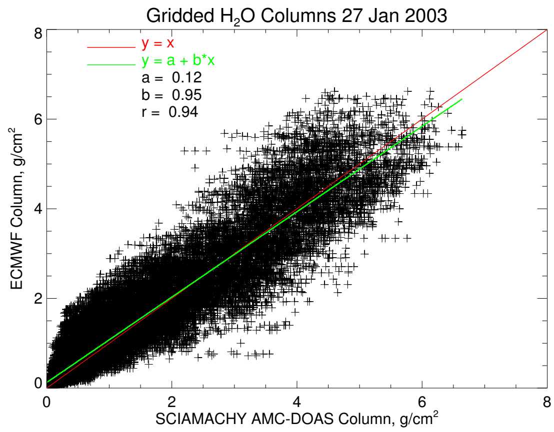

Figure 2. Comparison between ECMWF and SCIAMACHY AMC-DOAS water vapour columns for 27 January 2004. r is the Pearson's linear correlation coefficient.

and standard DOAS:

1) AMC-DOAS considers the non-linear dependence of the absorber amount from the absorption depth in the differential spectra, which results from the inability of the measuring instrument (SCIAMACHY) to resolve individual saturated and non-saturated absorption lines, as they are present for water vapour.

2) As the name implies, AMC-DOAS includes an Air Mass Factor (AMF) correction derived from O_2 absorption features in same spectral region as the water vapour absorption. This is in fact the reason why the fitting window for the retrieval has been chosen to be 688 nm to 700 nm: Both water vapour and molecular oxygen show absorptions of similar strength in this region.

Beside correcting the retrieved column, the derived AMF correction factor is also used as an inherent quality check for the retrieved data. Only results with an AMF correction factor larger than 0.8 have been taken into account, thus masking out e.g. too cloudy ground pixels. Currently, the AMC-DOAS retrieval is limited to solar zenith angles (SZAs) below 88°. All calculations have been performed assuming a cloud-free tropical background atmosphere. Details about the AMC-DOAS algorithm can be found in [6] and [12]. No additional scaling factor has been applied to the retrieved columns, therefore the AMC-DOAS results do not rely on e.g. comparisons with ground based radio sonde measurements.

3. RESULTS

For the present paper, the AMC-DOAS retrieval has been performed for all available SCIAMACHY nadir data for the year 2003, including both Level 1 near-real-time (NRT) and consolidated data products. The inclusion of unconsolidated data may influence the weighting of individual measurements in the statistical analysis. However, the unconsolidated data are required because the consolidated Level 1 data set for 2003 is not complete. Even after inclusion of the NRT data there are still larger data gaps, especially in November 2003. The known insufficient radiometric calibration of the current Level 1 data [13, 14] may also have an influence on the quality of the retrieved columns, although this is expected to be small because AMC-DOAS (as all DOAS-type methods) does not require absolutely calibrated data. Nevertheless, to prevent potential problems with the solar reference spectrum always the same (specially calibrated) solar reference spectrum (provided by J. Frerick, ESA) has been used in the retrieval.

The derived SCIAMACHY water vapour total vertical columns have been compared with corresponding SSM/I and ECMWF data.

The SSM/I data are taken from the Daily Gridded Integrated Water Vapour Product provided by the Global Hydrology Resource Center (GHRC) at the Global Hydrology and Climate Center, Huntsville, Alabama. Only data for the descending orbit part of the DMSP F-14 satellite (dayside equatorial crossing at about 0800 LT) have been used because these have been measured closest in time to the SCIAMACHY data (ENVISAT has a dayside equatorial crossing time of 1000 LT). Because SSM/I is a MW sensor, only data over ocean are available.

The European Centre for Medium-Range Weather Forecasts (ECMWF) water vapour columns used here are based on operational daily analysis data (geopotential height, temperature, pressure, and specific humidity). These assimilated meteorological fields are provided on a 1.5° × 1.5° spatial grid at 60 altitude levels every 6 hours. The 6-hourly values have been combined and integrated over height to derive the total vertical water vapour column. Afterwards, daily averages of the columns have been computed.

For the comparison all SCIAMACHY and ECMWF data have been (re-)gridded to the spatial resolution of the SSM/I data (0.5° × 0.5°).

As an example, Figs. 1 and 2 show comparisons of SCIAMACHY water vapour columns for 27 January 2004 with

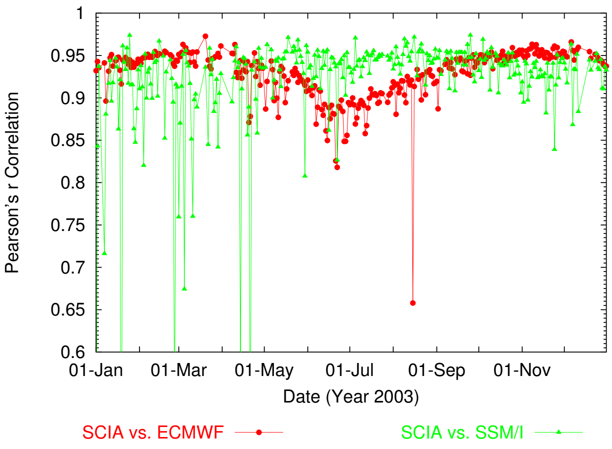

Figure 3. Correlation between SCIAMACHY and SSM/I (green) and SCIAMACHY and ECMWF (red) water vapour columns for the year 2003.

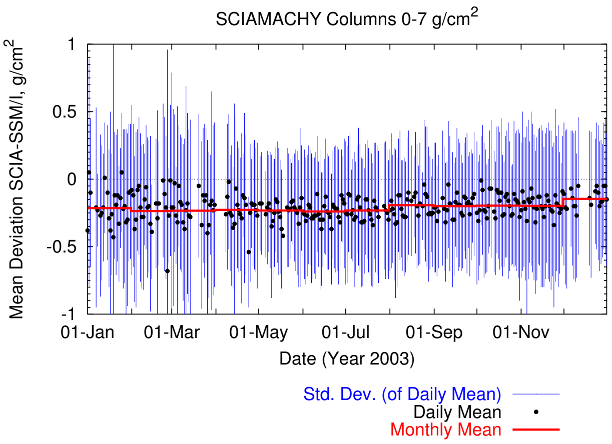

Figure 4. Mean deviation of SCIAMACHY and SSM/I water vapour columns for the year 2003.

corresponding SSM/I and ECMWF data.

As can be seen from these figures, the correlation with both SSM/I and ECMWF is quite good. The agreement between SCIAMACHY and ECMWF data seems to be slightly better than between SCIAMACHY and SSM/I. In general, the correlative data are smaller for lower SCIAMACHY columns, and higher for larger SCIAMACHY columns. However, a quantification of the deviations is not easy because of the large scatter of the data.

This scatter is mainly due to the high spatial and temporal variability of water vapour, which makes it difficult to compare individual measurements which are (initially) on different temporal and/or spatial scales. Because the scatter is not of statistical nature, it can not be significantly reduced by e.g. averaging more data (although the correlation and mean values may improve by this). This is a general problem for validation/verification of water vapour products for which there is no simple solution. The way we proceed in this study is that we just accept the scatter as it is and concentrate on the long-term analysis of correlation and mean values.

Fig. 3 shows the linear Pearson's r correlation between SCIAMACHY and both SSM/I and ECMWF water vapour total columns for the year 2003. In general, there is a good correlation of r=0.9 or higher over the whole year with both SSM/I and ECMWF data. Until about May 2003 the correlations with SSM/I show a large fluctuation and partly very low values. These low correlations are mainly due to a limited number of coincidences caused by missing SCIAMACHY data (especially over ocean) during this time. The correlation with ECMWF data is usually slightly higher than with SSM/I, except for summer 2003 where ECMWF correlations go down to about 0.8 in extreme cases. This reduced correlation with ECMWF data requires further investigation.

The mean deviation between SCIAMACHY and both SSM/I and ECMWF water vapour data over the year 2003 is shown in Figs. 4 and 5. The data displayed in these figures have been derived in the following way: For all SCIAMACHY columns up to 7 g/cm^2 (which is a typical global maximum value) of the same day the difference to the corresponding correlative data has been determined. Averaging these data results in the mean daily deviation (black circles) and the related standard deviation (blue vertical lines). The daily mean values are then averaged over a month, giving the monthly mean deviations (red line).

As can be seen from Figs. 4 and 5, the daily standard deviation (as a measure for the scatter of the data) is usually quite large (about 0.5 g/cm^2), somewhat higher for SSM/I data and at times where the correlation (Fig. 3) is lower, like for ECMWF data in summer 2003. The scatter of the mean values is smaller: about 0.1–0.2 g/cm^2 for the comparison with SSM/I data, and usually less than 0.1 g/cm^2 for the comparison with ECMWF results.

Looking at the monthly averages, the SCIAMACHY water vapour columns are in the order of 0.2 g/cm^2 lower than the corresponding SSM/I results. Within the scatter of the monthly averages, the SCIAMACHY data agree very well with ECMWF data throughout the year. The typical deviation between SCIAMACHY and ECMWF data is only -0.05 g/cm^2.

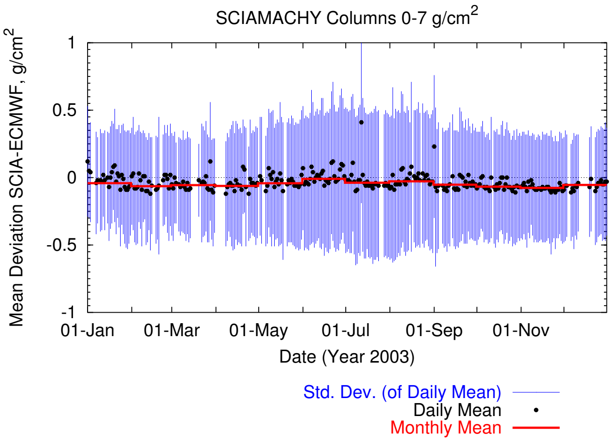

Figure 5. Mean deviation of SCIAMACHY and ECMWF water vapour columns for the year 2003.

4. CONCLUSIONS

SCIAMACHY "visible" H_2O columns agree well with correlative data. Correlations with SSM/I and ECMWF water vapour columns are typically in the range 0.9 - 0.95, except for a lower correlation with ECMWF data in summer 2003 which needs further investigation. The high scatter of about 0.5 g/cm^2 is mainly caused by atmospheric variability which in general makes a validation of water vapour columns more difficult. The mean SCIAMACHY AMC-DOAS water vapour columns are typically lower than correlative data. The mean deviation from SSM/I results is about 0.2 g/cm^2, but SCIAMACHY columns are typically only 0.05 g/cm^2 lower than ECMWF data. From these results, and because the AMC-DOAS method does not rely on a cross-calibration with other external water vapour measurements, it can be concluded that SCIAMACHY is able to provide a new independent global water vapour data set.

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