Retrieval of vertical columns of water vapour from SCIAMACHY/ENVISAT satellite data

- Final Report 2007/8 -

A contribution to ACCENT-TROPOSAT-2, Task Group 1

Stefan Noël and Sebastian Mieruch

Institute of Environmental Physics / Remote Sensing (iup/ife),
University of Bremen, FB 1, P.O. Box 330440, D-28334 Bremen, Germany

Summary

The so-called Air Mass Corrected Differential Optical Absorption Spectroscopy (AMC-DOAS) retrieval method to derive total columns of water vapour from nadir measurements in the spectral region around 700 nm (see e.g. [Noël *et al.*, 1999, 2004]) has been further improved. The currently available Version 1.0 of the AMC-DOAS algorithm has been applied to the Global Ozone Monitoring Experiment (GOME, see e.g. [Burrows *et al.*, 1999]) and SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY (SCIAMACHY, see e.g. [Bovensmann *et al.*, 1999]) data set, resulting in a completely new and independent water vapour climatology which already now covers more than 12 years. First trend analysis results based on the combined GOME/SCIAMACHY water vapour data set show the usefulness for climatological applications. Recently, the AMC-DOAS method has also been successfully applied to GOME-2/Metop measurements which supports a possible continuation of the AMC-DOAS water vapour data time series by further SCIAMACHY and GOME-2 measurements until 2020.

Introduction

Water vapour is the most important greenhouse gas and as such of key interest for climatological studies. By application of the AMC-DOAS retrieval method to spectral data measured by GOME-type instruments it is possible to derive a global total column water vapour climatology with the same algorithm for both land and ocean. This climatology is completely independent from other water vapour data sets and especially does not rely on an external calibration by radiosonde data.

Aims and activities

Within the framework of the ACCENT/TROPOSAT-2 programme the AMC-DOAS retrieval method has been further improved. The retrieval algorithm has been applied to the complete GOME data until 2004 and the complete SCIAMACHY data set since August 2002, taking into account reprocessed data sets. The AMC-DOAS algorithm has also been adapted for GOME-2. The resulting water vapour columns have been successfully compared with each other and with independent data from e.g. the Special Sensor Microwave Imager (SSM/I) and ECMWF model data. A close to real-time data processing system has been set up at IUP Bremen to continuously retrieve AMC-DOAS water vapour columns from SCIAMACHY and GOME-2 measurements. AMC-DOAS data have been discussed and compared with other water vapour results during the Satellite Water Vapour Retrieval Workshop (sponsored by ACCENT) in November 2007.

Results and highlights

The combined GOME and SCIAMACHY water vapour data set.

The derived GOME and SCIAMACHY water vapour columns agree well with independent data sets and with each other. Intercomparisons for the overlap period 2002/2003 of the two

data sets [Noël *et al.*, 2007] show that there is on average no offset between GOME and SCIAMACHY water vapour; however, there is a significant scatter in the order of 0.5 g/cm^2 which is regularly observed in water vapour comparisons of data sets with different spatial and temporal resolution and sampling. This scatter can be attributed to the large variability of water vapour, which makes validation of water vapour in general very difficult.

Trend analysis results

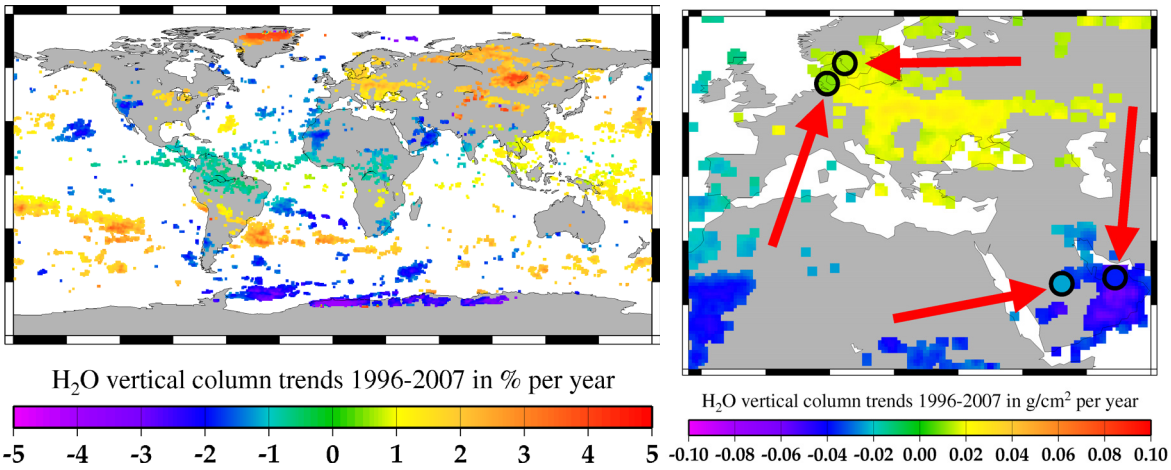

Figure 1. Left: Significant changes of water vapour columns 1996 to 2007 derived from the combined GOME-SCIAMACHY data set. Right: Significant GOME/SCIAMACHY trends with embedded significant trends (black circles) from radiosonde measurements.

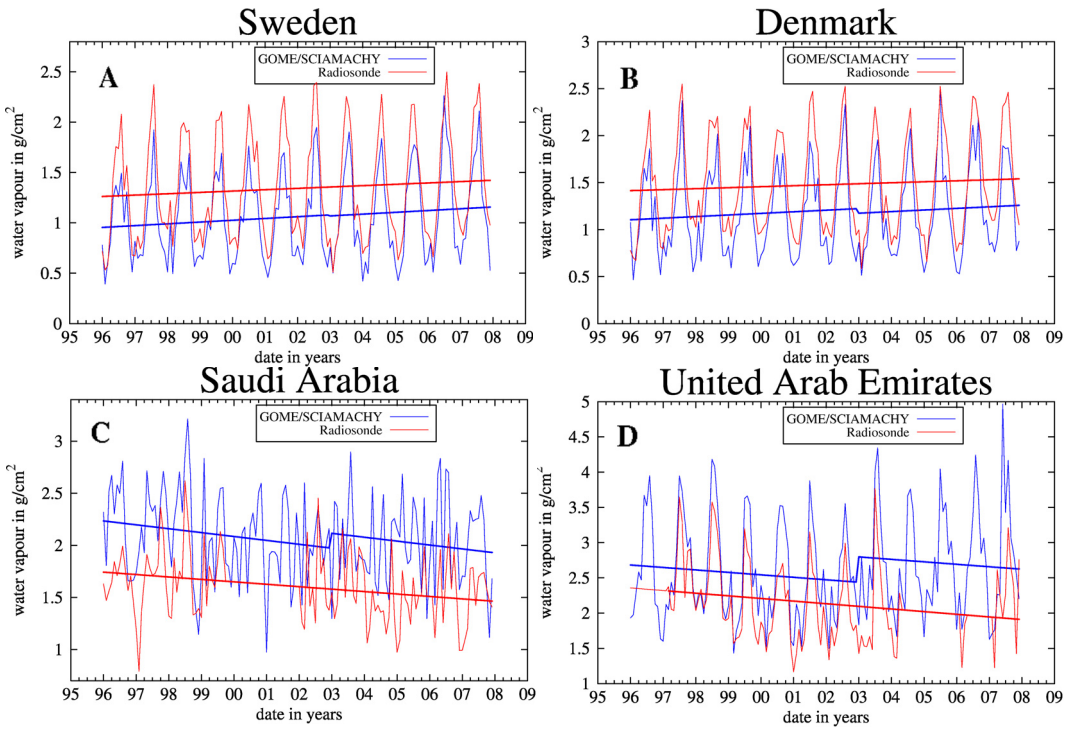

Figure 2. Time series of GOME/SCIAMACHY (blue) and radiosonde (red) water vapour with respective trends at four collocated locations where significant trends have been observed for both data sets.

The combined data set of GOME and SCIAMACHY has been used to determine changes in the water vapour total columns over the whole globe [Mieruch *et al.*, 2008]. Statistical methods have been applied to determine the significance of the derived (currently 12-year-)

trends. As Fig. 1 (left panel) shows, both positive and negative significant changes of up to 5%/year are observed at different locations on the Earth.

The trend analysis has also been applied to 187 globally distributed water vapour data sets for the same time interval (1996-2007) from radiosonde (RS) measurements provided by the German Weather Service (DWD). Altogether, 4 collocated locations could be found (shown in right part of Fig. 1), where both GOME/SCIAMACHY trends and radiosonde trends are statistically significant, i.e. the trends are greater than two times their errors. Figures 2 A-D show the corresponding time series. Here, excellent agreement of the trends between satellite and radiosonde data is observed. A significance analysis on the agreement, in a statistical sense, is under preparation.

First GOME-2 results

In October 2006 the GOME-2 instrument was launched on the operational meteorological satellite Metop. GOME-2 is from design very similar to GOME and SCIAMACHY, but it has an increased swath width of 1920 km and a spatial resolution of 40 km × 80 km (compared to 40 km × 320 km for GOME and typically 30 km × 60 km for SCIAMACHY. This increased swath width allows for a daily coverage at mid-latitudes. Because of the similarities between the instruments the AMC-DOAS algorithm could be easily ported to GOME-2; it was mainly necessary to adapt the spectral slit function. The comparison between GOME-2 and SCIAMACHY water vapour columns reveals a good agreement (see Fig. 3); the average deviation is almost zero with no significant seasonal variation. However, a closer look at the (globally averaged) daily means reveals a sinusoidal variation which is most likely related to scan angle dependencies (see [Noël *et al.*, 2008] for details).

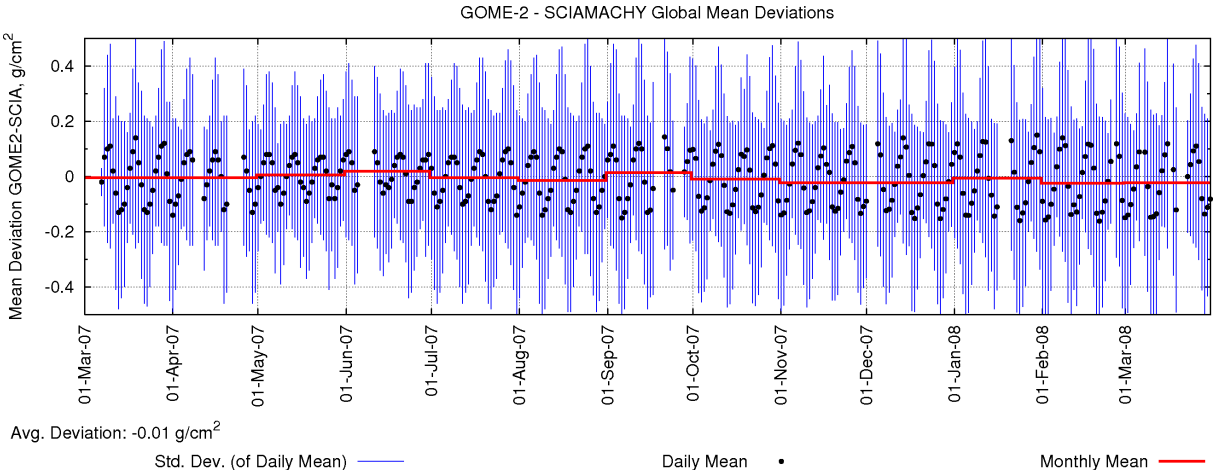

Figure 3. Comparison of GOME-2 and SCIAMACHY water vapour columns March 2007 to March 2008.

The increased swath width of GOME-2 has a large advantage especially at higher latitudes, where at a certain location several overpasses per day at different local times occur. Fig. 4 displays a time series of water vapour measurements over Ny Ålesund / Spitsbergen. In addition to GOME-2 and SCIAMACHY data this figure also shows corresponding 6-hourly ECMWF model data (on 1.5° latitude/longitude grid) for the same region. As can be seen from Fig. 4, the diurnal variation of water vapour described by the model is very well followed by both the retrieved SCIAMACHY and GOME-2 data. The agreement with the ECMWF data is especially good in spatially homogeneous situations (like 7 May 2008) whereas short-term fluctuations or sharp spatial gradients are better captured by the GOME-2 and SCIAMACHY measurements.

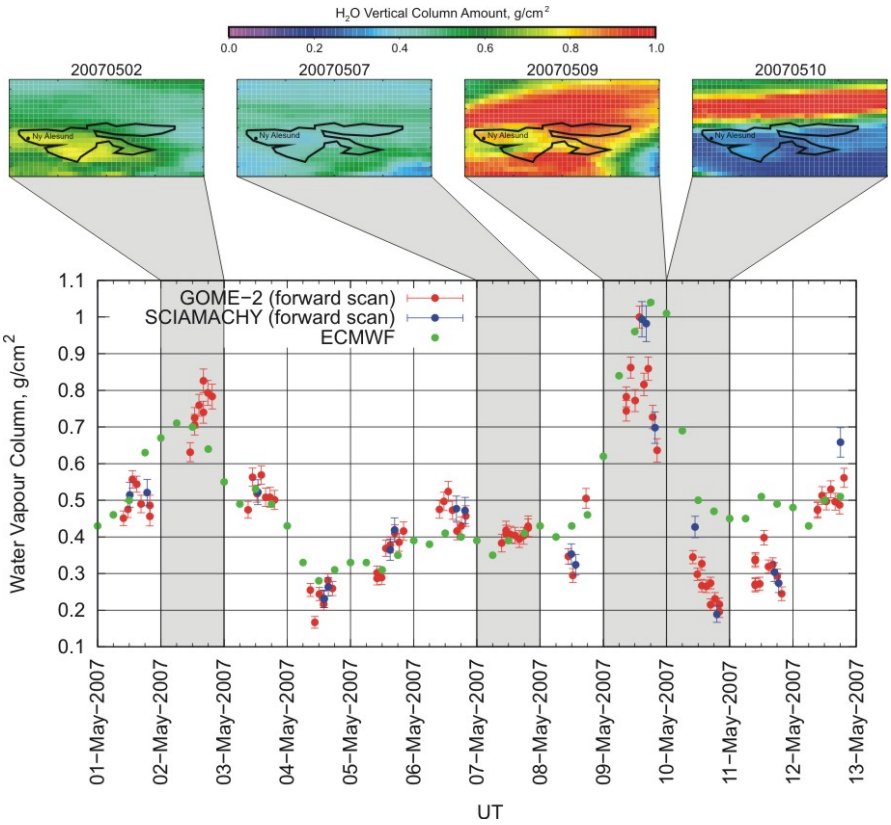

Figure 4. GOME-2 and SCIAMACHY water vapour columns over Ny Ålesund (from [Noël *et al.*, 2008]).

Achievements and future outlook

The retrieval of water vapour from GOME-type instruments using the AMC-DOAS method is ongoing. A new version of the retrieval algorithm, taking into account orographic information, is currently under development. The combined GOME and SCIAMACHY global water vapour data set derived with the AMC-DOAS method is available via the AMC-DOAS web site (http://www.iup.uni-bremen.de/amcdoas). A water vapour trend analysis based on this data set has been successfully performed; the results need to be confirmed by intercomparisons with other data sets and longer time series. First results for GOME-2 are quite promising, which gives confidence into the possibility of extending the AMC-DOAS water vapour set until 2020.

References

Bovensmann, H. , J. P. Burrows, M. Buchwitz, J. Frerick, S. Noël, V. V. Rozanov, K. V. Chance, and A. H. P. Goede, 1999, SCIAMACHY - Mission objectives and measurement modes, *J. Atmos. Sci.*, **56**, 127-150.

Burrows, J..P., M. Weber, M. Buchwitz, V. Rozanov, A. Ladstätter-Weißenmayer, A. Richter, R. de Beek, R. Hoogen, K. Bramstedt, K.-U. Eichmann, M. Eisinger and D. Perner, 1999, The Global Ozone Monitoring Experiment (GOME): Mission Concept and First Scientific Results, *J. Atmos. Sci.*, **56,** 151-175.

Mieruch, S., S. Noël, H. Bovensmann and J. P. Burrows, 2008, Analysis of global water vapour trends from satellite measurements in the visible spectral range, *Atmos. Chem. Phys.*, 8, 491-504.

Noël, S., M. Buchwitz, H. Bovensmann, and J. P. Burrows, 1999, Atmospheric water vapor amounts retrieved from GOME satellite data, *Geophys. Res. Lett.*, **26**(13) 1841-1844.

Noël, S., M. Buchwitz, and J. P. Burrows, 2004, First retrieval of global water vapour column amounts from SCIAMACHY measurements, *Atmos. Chem. Phys.*, **4,** 111-125.

Noël, S., S. Mieruch, H. Bovensmann, and J. P. Burrows, 2007, A combined GOME and SCIAMACHY global water vapour data set, Proc. ENVISAT Symp., Montreux, Switzerland, 23–27 April 2007 (ESA SP-636).

Noël, S., S. Mieruch, H. Bovensmann and J. P. Burrows, 2008, Preliminary results of GOME-2 water vapour retrievals and first applications in polar regions, *Atmos. Chem. Phys.*, 8, 1519-1529.

Recent publications related to AT2 work in the refereed literature

Mieruch, S., S. Noël, H. Bovensmann and J. P. Burrows, Analysis of global water vapour trends from satellite measurements in the visible spectral range, *Atmos. Chem. Phys.*, 8 (2008) 491-504.

Noël, S., S. Mieruch, H. Bovensmann and J. P. Burrows, Preliminary results of GOME-2 water vapour retrievals and first applications in polar regions, *Atmos. Chem. Phys.*, 8 (2008) 1519-1529.

Recent publications related to AT2 work in the conference literature

Mieruch, S., S. Noël, H. Bovensmann and J. P. Burrows, Verification of SCIAMACHY level 1 data by AMC-DOAS water vapour retrieval, in *Proc. Third Workshop on the Atmospheric Chemistry Validation of ENVISAT (ACVE-3), Frascati, Italy, 4-7 December, 2006* (2007).

Noël, S., S. Mieruch, H. Bovensmann, and J. P. Burrows, A combined GOME and SCIAMACHY global water vapour data set, Proc. ENVISAT Symp., Montreux, Switzerland, 23–27 April 2007 (ESA SP-636) (2007).

Theses related to AT2 work

Mieruch, Sebastian, Derivation and statistical analysis of water vapour trends, PhD Thesis, University of Bremen, Germany (ongoing work).