Retrieval of vertical columns of water vapour from SCIAMACHY/ENVISAT satellite data: Trend analysis results

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

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Summary

The complete GOME and SCIAMACHY spectral data from 1995 until end 2006 have been reprocessed using a new version of the AMC-DOAS retrieval program (Version 1.0), involving reprocessed SCIAMACHY level 1 data. A comparison of the resulting GOME and SCIAMACHY water vapour data shows good agreement, such that the data sets could be merged together. The resulting combined water vapour data set covers currently 11 years (January 1996 to December 2006) and has been used for a trend analysis. Special emphasis has been placed on the calculation of statistically significant trends, which reveals increasing and decreasing significant trends up to 5% per year distributed over the whole globe.

Introduction

H_2O is the most important greenhouse gas on Earth and plays an essential role in atmospheric chemistry. The H_2O content of the atmosphere significantly contributes to the future evolution of climate. Without H_2O the global mean temperature would be 18 ^oC below today's values as a result of its radiation absorbing characteristics and strong feedback mechanisms.

The H_2O amounts characterise the climate state of a region, e.g. whether it is dry or humid. H_2O trends can be interpreted as tracers following the climate state of a region. Hence, it is desperately necessary to detect such trends on a local and global scale. Additionally, the knowledge of the spatial distribution and temporal evolution of H_2O is of utmost importance to prove model results, which predict weather and climate.

Scientific activities

During the last year the AMC-DOAS algorithm [Noël et al., 1999, 2004] was optimised and applied to the reprocessed Version 5 and the new Version 6 of SCIAMACHY Level 1 data [Mieruch *et al.,* 2006]. New validation results between SCIAMACHY and SSM/I data are inline with previous studies and show in general a good agreement [Noël *et al.*, 2007]. Furthermore, a comparison of the overlapping GOME and SCIAMACHY data from August 2002 to December 2003 show small deviations and argue for the combination of the two data sets [Noël *et al.*, 2007].

A global trend analysis was performed for the combined data set using linear and non-linear methods from time series analysis and standard statistics. Several factors affecting the trends, such as the length of the data, the magnitude of the noise and the autocorrelation of the noise were investigated. Significant trends were observed distributed over the whole globe. The results have been presented at the EGU 2007 in Vienna (Austria) and at the CCMVal conference 2007 in Leeds (England) and are submitted for publication [Mieruch *et al.,* 2007].

Scientific results and highlights

Comparisons between GOME and SCIAMACHY water vapour columns

The combination of GOME and SCIAMACHY data is an essential prerequisite for the trend calculation. To assess whether the two datasets can be merged together a comparison has been performed for the time interval from August 2002 to December 2003, where both GOME and SCIAMACHY data are available (see Fig. 1).

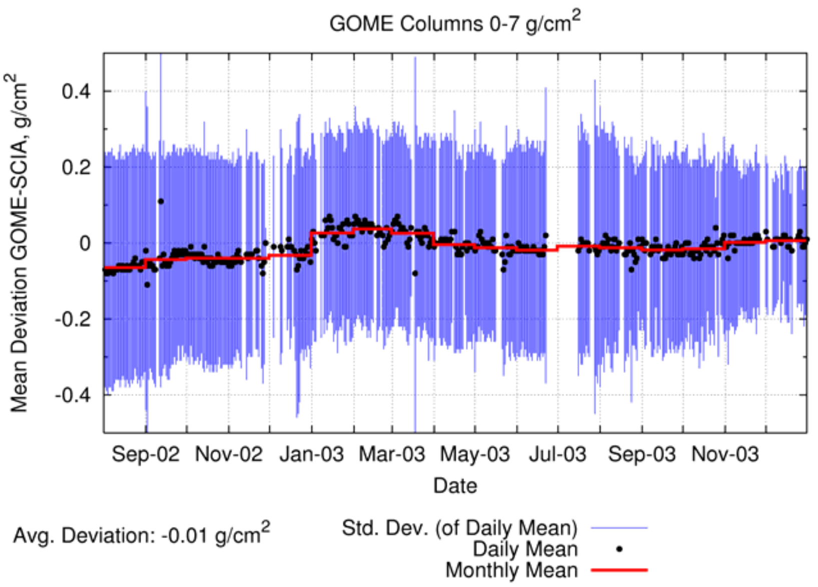

Figure 1: Comparison of globally averaged GOME and SCIAMACHY water vapour columns (August 2002 to December 2003).

Note that as a result of an onboard tape recorder failure in June 2003 no longer global coverage is provided by the GOME instrument, thus the comparison in Fig. 1 comprises the whole globe for the time from August 2002 to June 2003 and the reduced area from August 2003 to November 2003. Furthermore, the quality of the SCIAMACHY data in 2002 is reduced because of the non-availablity of an appropriate solar reference spectrum during that time. The black dots represent daily mean values for the respectively area, whereas the blue bars are the corresponding standard deviations. The monthly mean deviations are depicted by the red line. The average deviation between GOME and SCIAMACHY for the complete time interval is -0.01 g/cm², which is considerably small. However, the standard deviation for the full length of the comparison yields ±0.25 g/cm², which indicates that there are not negligible differences on a local scale. Under consideration of these local differences between the data sets a composition is possible to create an 11 years global H_2O record.

Trend estimation

A trend detection is difficult and depends on several factors such as the length of the time series, the containing noise, and the autocorrelation of the noise [Weatherhead *et al*., 1998]. Additionally, instrument changes (as it is the case for our H_2O data) during the measurement campaign introduce new uncertainties. In accordance with [Weatherhead *et al*., 1998] the trend model for a single H_2O time series is formulated as:

$$Y_t = \mu + S_t + \omega X_t + \delta U_t + N_t,$$

where Y_t contains the monthly mean data, μ is the offset, S_t describes the seasonal component as a Fourier-series and accounts for an amplitude change between the GOME and SCIAMACHY measurements. ω represents the trend and X_t contains the time. Furthermore, δ is the magnitude of a possible mean level shift at the interchange from GOME to SCIAMACHY and U_t presents a step function, which is zero before the changeover and unity after the changeover. The unexplained portion of the data, the noise N_t, is modelled as an autoregressive process of order 1 AR[1]. More details on the trend calculation can be found in [Mieruch *et al.,* 2007]. The applied trend model for a single time series is shown in Fig. 2 as an example for a grid pixel in the south-west Pacific at the island of Vanuatu.

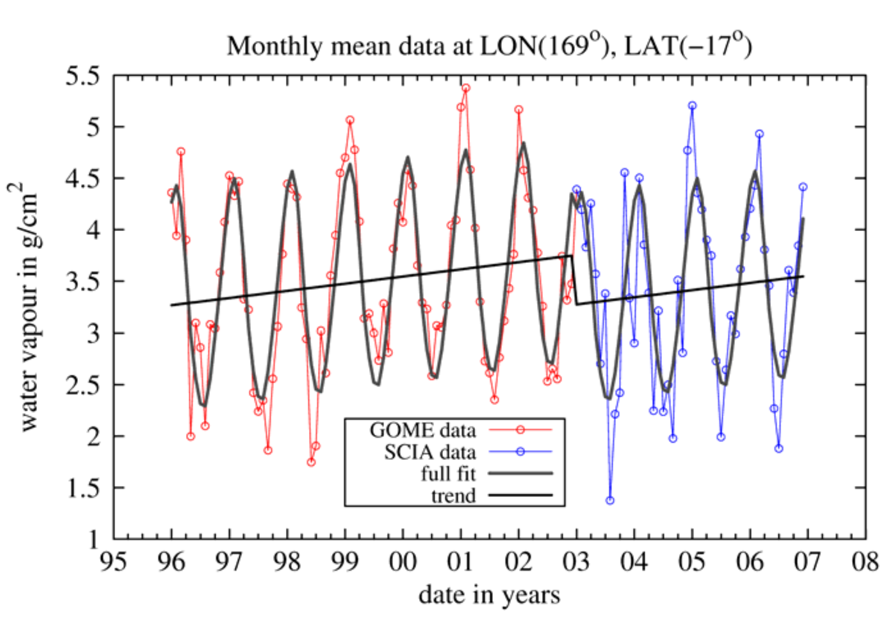

Figure 2: Application of the trend model to a single H_2O time series.

As can be seen in Fig. 2, the trend model (grey line) fits well to the data and an increasing trend (black line) of ω =0.07 g/cm² per year is observed, which corresponds to 2 % related to the offset μ =3.26 g/cm². The mean level shift is calculated to δ =-0.48 g/cm^2. In this case it is extremely important to consider the level shift, because the negligence would yield completely different results.

The trend calculation is performed for the whole globe, which is shown in Fig. 3 in the left panel, where the relative trends ω / μ in percent per year are coded by colours from violet over green to red. In the same way as [Weatherhead *et al.*, 1998] we claim that a trend is statistically significant if it is 2 times greater than its error. Additionally, we claim that time series have to contain at minimum 2/3 of the maximum data points to be significant as a quality criterion. The significant trends are plotted in the right panel of Fig. 3 which shows a patchy pattern. Increasing significant trends are found in Greenland, East Europe, Siberia and Oceania, whereas decreasing significant trends are found in the North-West USA, Central America, Amazonia, Central Africa, Antarctica and the Arabian Peninsular. The observed trends reach magnitudes up to 5 % per year.

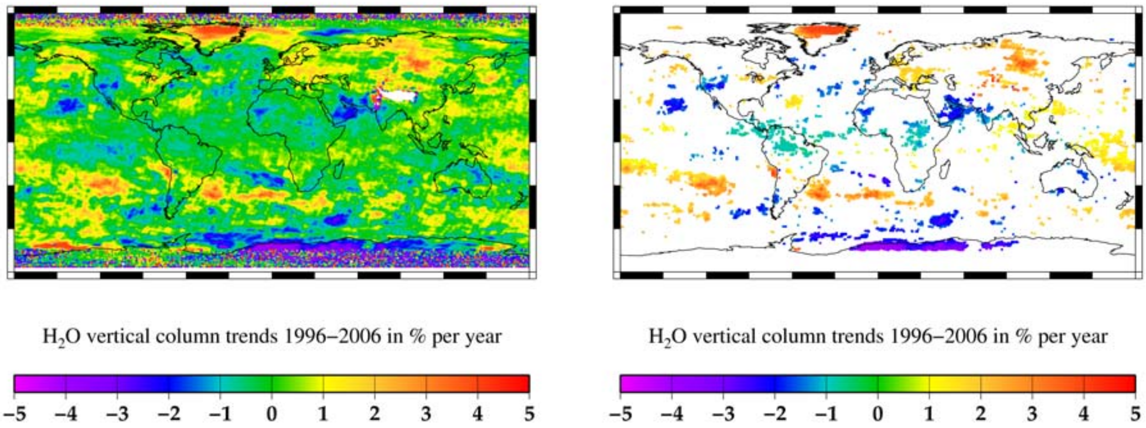

Figure 3: Left: Relative global trends. Right: Significant relative global trends.

Future outlook

The derived trends of global H_2O satellite measurements are important for climate models, thus a comparison of our observed trends with H_2O trends from climate-chemistry model (CCM) results is planned. A more precise analysis of the mean level shift between the two data sets is foreseen for a better understanding of the underlying processes. Another envisaged aspect is a correlation analysis between environmental data sets, such as surface temperature, precipitation, and clouds with our data. Furthermore, the AMC-DOAS method will be applied to measurements of the GOME-2 instrument on the series of meteorological satellites MetOp of which the first has been successfully launched in October 2006. First intercomparisons between GOME-2 and SCIAMACHY water vapour data are quite promising, which gives confidence into the possibility of extending the AMC-DOAS water vapour set until 2020.

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