GLOBAL LONG TERM DATA SETS OF THE ATMOSPHERIC H_2O COLUMN DERIVED FROM GOME AND SCIAMACHY - ANOMALIES DURING THE STRONG EL-NIÑO EVENT 1997/1998

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ABSTRACT

Global data sets of the total H_2O column are analysed from GOME and SCIAMACHY measurements. In contrast to other satellite instruments these observations have similar sensitivity over land and ocean. In addition, they are sensitive in particular for the surface near layers where most of the H_2O column is located. In this work we used the global H_2O data sets for the investigation of the global patterns of El-Niño induced anomalies. The positive and negative anomalies of the H_2O VCD are very similar to the anomalies of global precipitation patterns. We analysed first SCIAMACHY spectra using the same settings as used for GOME and found good agreement between both sensors. This will allow to extend the GOME H_2O data set into the future without discontinuities.

1. INTRODUCTION

Atmospheric water vapour is the most important greenhouse gas which is responsible for about 2/3 of the natural greenhouse effect, therefore changes in atmospheric water vapour in a changing climate is subject to intense debate. H_2O is also involved in many important reaction cycles of atmospheric chemistry, e.g. in the production of the OH radical. Thus, long time series of global H_2O data are highly required.

New UV/vis satellite sensors like GOME, SCIAMACHY or OMI are capable of measuring the total atmospheric H_2O column (including also the surface near concentrations). Thus these sensors allow to investigate the global long term evolution of H_2O and possibly also to identify a trend due to climate change. In this study we focus on the analysis of global water vapour anomalies during the strong El-Niño event 1997/98.

The El-Niño/Southern Oscillation (ENSO) phenomenon constitutes the strongest natural interannual climate variability [1-4]. It can be characterised as an irregular low frequency oscillation between a warm (El-Niño) and a cold (La-Niña) state. During ENSO large deviations of many atmospheric and ocean properties from their mean values appear. The most prominent quantities are the sea surface temperature (SST) as well as the atmospheric cloud cover and precipitation. Although many details of the feedback mechanisms between the ocean and the atmosphere have been discovered during the last decades, still a comprehensive theory is not available and the origin of ENSO is not fully understood. In particular, still coupled atmospheric and oceanic models have difficulties in correctly predicting ENSO events [5,6]. Of particular interest is also, to which extent the study of ENSO events may lead to a deeper insight into the mechanisms and consequences of climate change [7,8]. For example the strong deviations of atmospheric and oceanic parameters during ENSO allow to study the feedback mechanisms of the climate system and the response of the greenhouse effect to altered conditions [9,10]. In addition, a changed amplitude and/or frequency of ENSO might be seen as an indicator of global change [11,8].

Here we report on atmospheric observations of the global distribution of the total atmospheric water vapour column derived from the Global Ozone Monitoring Experiment (GOME) aboard the European research satellite ERS-2 [12,13]. So far only relatively few ENSO related studies on the H_2O VCD have been published [e.g. 14]. Also, many of these satellite studies cover only a restricted latitudinal range, typically centred around the tropics. Several studies are only sensitive to a limited altitude range (e.g. for upper tropopheric humidity).

In contrast to previous space borne observations of the atmospheric humidity like from TOVS and SSM/I [15-18 and references therein] our H_2O data set has three major advantages: First it covers the entire earth, including the continents (while SSM/I observations are only reliable over oceans) leading to a much more consistent picture of the global distribution of atmospheric humidity. Second, as the GOME H_2O analysis is performed in the visible spectral range it is very sensitive also to the surface near part of the H_2O profile which constitutes the major fraction of the total atmospheric column [19]. For example the sensitivity of TOVS H_2O observations is systematically decreased towards the surface. Third, in contrast most other algorithms our H_2O analysis does not rely on independent additional information or a-priori assumptions [19]. It is important to note that because of the fast decrease of the H_2O concentration with altitude the H_2O VCD is primarily a measure of the surface near H_2O concentration.

GOME observations were continuously conducted over eight years (from mid 1995 – mid 2003). Here we present observations covering the period Jan 1996 – July 2001. This period is of special interest because of two reasons: first, many of these years showed the hottest surface temperatures during the period of modern temperature records. Second, from 1997 to 1998 one of the strongest El-Niño events took place.

2. DATA ANALYSIS

Several algorithms for the retrieval of the vertical column density (VCD) of water vapor in the visible part of the spectrum from GOME and SCIAMACHY were developed during recent years [20-25]. Our DOAS analysis is performed in the wavelength interval 611-673 nm. It consists of three basic steps (described in detail in [19]), which will be only shortly described here: in the first step the spectral DOAS fitting is carried out, in which besides the H_2O cross section also those of O_2 and O_4 are included. From the DOAS analysis the H_2O slant column density (the concentration integrated along the light path) is derived. In the second step the H_2O SCD is corrected for the non-linearity arising from the fact that the fine structured H_2O absorption lines are not spectrally resolved by the GOME instrument. In the last step the corrected H_2O SCD is divided by a 'measured' air mass factor (AMF) which is derived from the simultaneously measured O_4 absorption. The AMF simply describes the ratio between the SCD and the VCD; it is usually derived from atmospheric radiative transfer modelling. However, for satellite observations of tropospheric species such model calculations have very large uncertainties, mainly because the lack of necessary input parameters like aerosol load, surface albedo and cloud properties. For the retrieval of our H_2O VCD we use an AMF directly extracted from the observation itself. Since the atmospheric O_2 concentration is almost constant the observed O_4 absorption directly yields a measured AMF, which is then applied to the H_2O SCD [19].

Our approach has several advantages:

- The DOAS method can be correctly applied to non resolved highly fine structured absorptions.
- A direct correction of the effects of aerosols, clouds, and the ground albedo is performed using simultaneously observed O_4 absorptions.
- No independent information (e.g. on the atmospheric state or loud fraction) is required.
- The method is very fast: the whole GOME data set of about 8 years (or about 80 Million spectra) can be analysed on a PC in about 8 days.

Since the atmospheric height profiles of the oxygen dimer O_4 and of water vapour have a similar basic structure, the observed O_4 and H_2O absorptions are affected by clouds in a similar way. Thus for most of the GOME observations our method using measured AMFs from simultaneous O_4 absorption is able to correct the cloud effects on the H_2O VCD. Nevertheless, especially in the case of high clouds and large cloud fraction the actual H_2O column can be still underestimated (see [19]).

Since during an El-Niño event in particular the atmospheric cloud cover changes strongly it is important to minimise the cloud effect on the H_2O VCD. For the characterisation and classification of the cloud cover we decided to use the absorption of O_2. Compared to the O_4 absorption it can be analysed with a much better signal to noise ratio and is much less affected by instrumental problems. Moreover, the O_2 absorption is mainly influenced by the shielding effect of clouds, which leads to a reduction of the observed absorption. In contrast, the O_4 absorption is often also affected by absorption enhancement due to multiple scattering. Thus many cloud covered GOME pixels could not unambiguously be classified as cloudy using a threshold based on the observed O_4 absorption. In contrast, for the O_2 absorption the presence of clouds is almost entirely characterised by significantly decreased absorptions. For the identification of a 'strong cloud influence' on the measurements we used a threshold for the O_2 absorption (70% of the maximum value) as a function of SZA.

3. RESULTS

Fig. 1 shows the global average H_2O VCD derived from GOME for January and February as well as the precipitation rate (from The Global Precipitation Climatology Project (GPCP), see http://cics.umd.edu/~yin/GPCP/main.html). The top panel shows data for the El-Niño year 1998, the bottom panel data for the 'normal year' 1996. Clear differences between both years can be identified in the H_2O and precipitation data. Over the central Pacific the H_2O are strongly enhanced for the El-Niño year according to the strongly enhanced sea surface temperatures. Also over the Indian ocean the H_2O VCD is significantly increased. Negative anomalies can be found in the subtropical Pacific. Over the Pacific the anomalies in the precipitation rate are in good agreement with those of the H_2O data. It is interesting to note that over the Indian ocean the precipitation rate is only slightly increased

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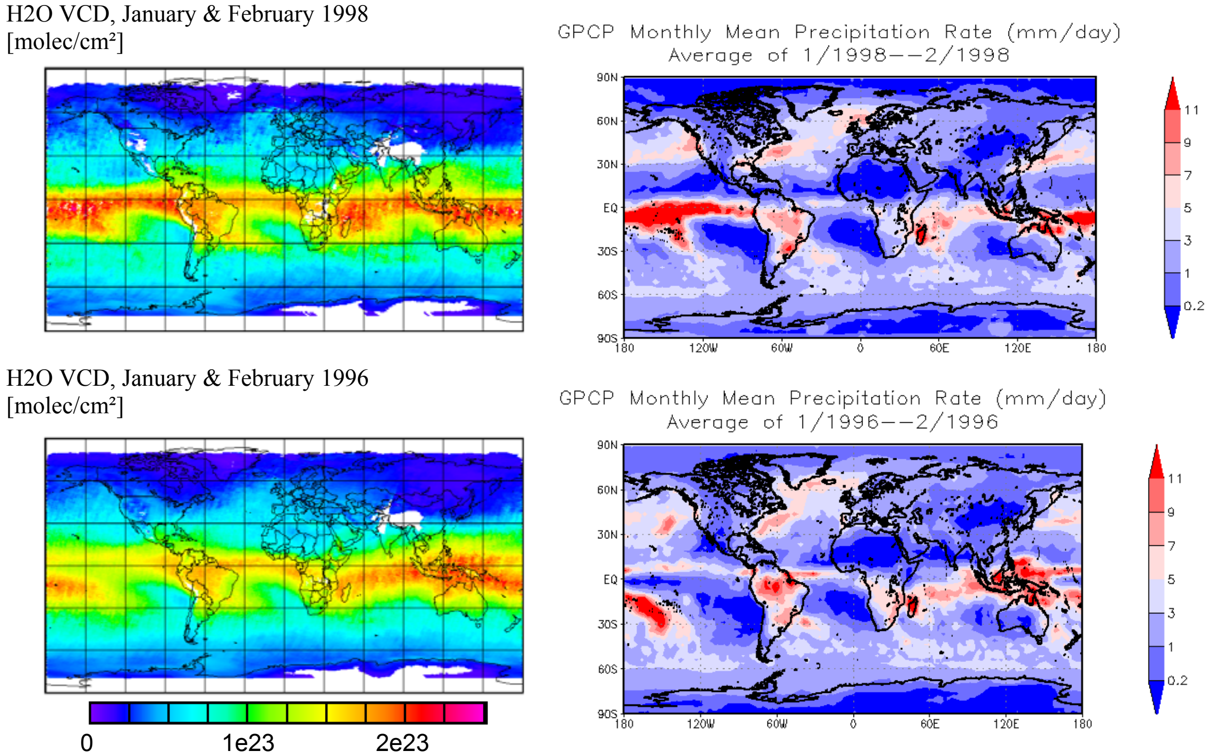

Fig. 1 Left: Average H_2O VCD (January and February) analysed from GOME spectra (see [19]) for the El-Niño year 1998 (top) and a 'normal year' 1996 (bottom). Right: Average precipitation rates for the same periods from GPCP (The Global Precipitation Climatology Project (GPCP), see http://cics.umd.edu/~yin/GPCP/main.html). The precipitation anomalies closely follow those of the atmospheric humidity.

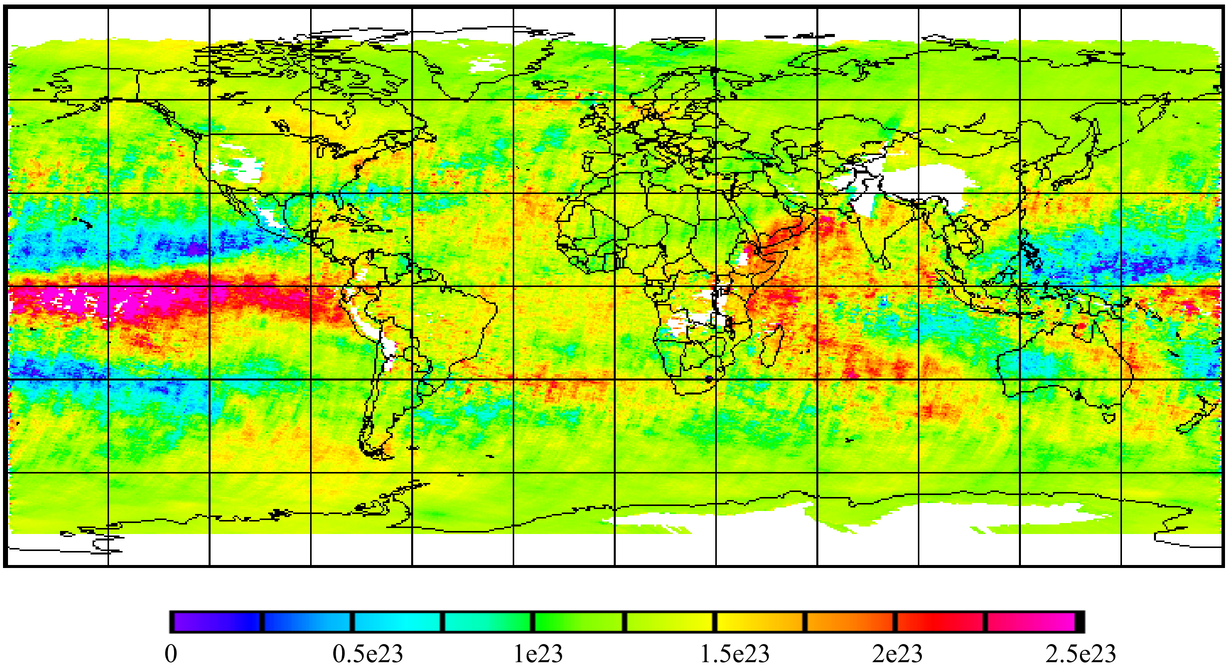

Fig. 2 Difference between the average H_2O VCDs (January and February) of 1998 and those of the 'normal years' 1996, 1997, 2000, 2001. Strong positive anomalies are found over the central Pacific and over the eastern Indian ocean. It is interesting to note that positive anomalies are also found over the continents, especially over western central Africa and the southern part of the Arabic peninsula. In contrast to other satellite sensors GOME observed the atmospheric H_2O VCD with similar sensitivity over land and ocean.

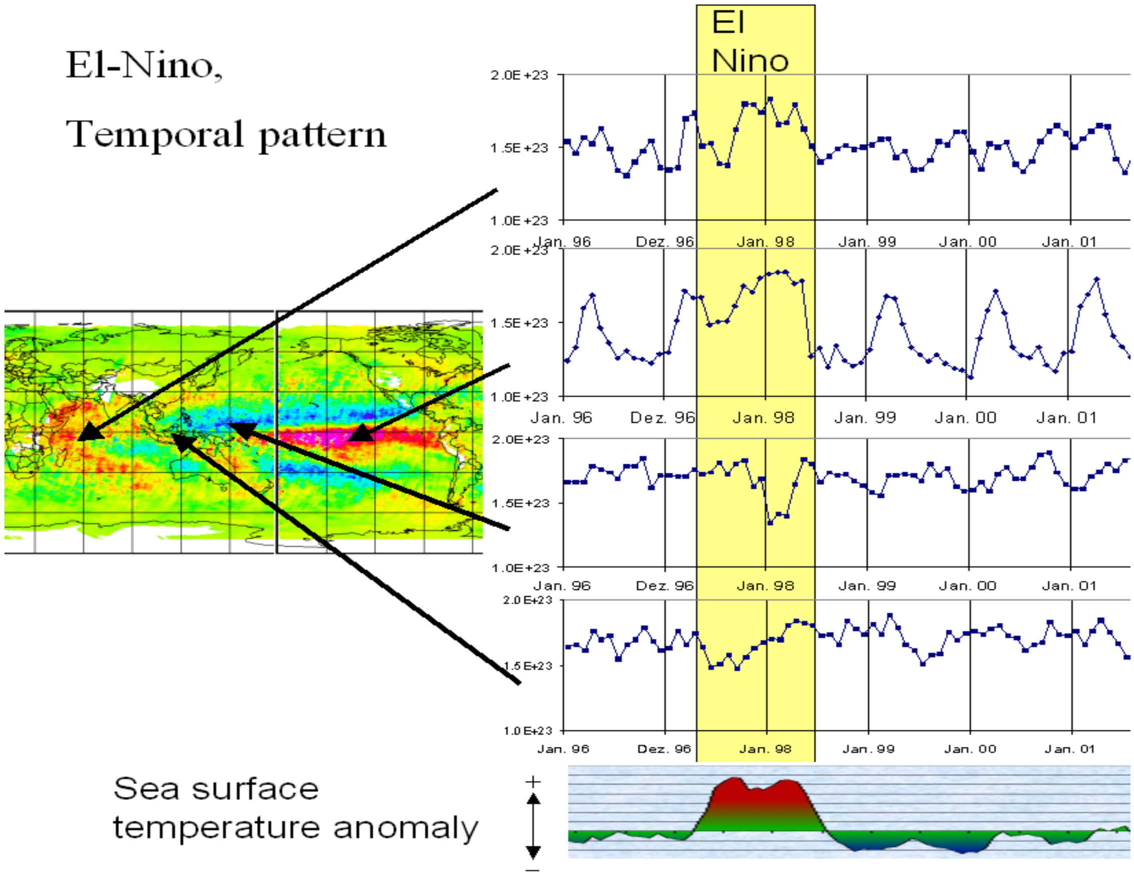

Fig. 3 Time series of the H_2O VCD (monthly means) over selected regions. Negative anomalies over Borneo occurred relatively early (June to October 1997) compared to the anomalies in other regions. The draught over Indonesia caused the strong biomass burning in September and October 1997.

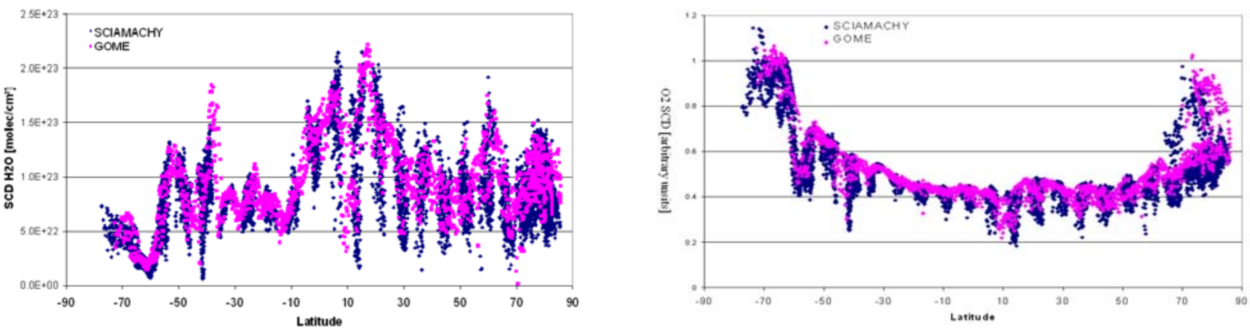

Fig. 4 Comparison of H_2O and O_2 SCDs analysed for quasi simultaneous GOME and SCIAMACHY orbits (23.08.2002, temporal difference about 40 min).

Fig. 2 shows the difference between the H_2O VCDs of 1998 and those of the 'normal years' 1996, 1997, 2000, 2001 (January and February). The strongest anomalies (positive and negative) are clearly centred around the central Pacific. Significant positive anomalies can also be found over the western Indian ocean and at the east coast of central Africa and the southern Arabic peninsula.

In Fig. 3 selected time series of different regions are shown. Over the central Pacific and over the eastern Indian Ocean significantly enhanced H_2O VCDs are found for several months during the El-Niño years 1997/98. Also strong negative anomalies can be found in several regions. North of Sumatra strongly decreased H_2O VCDs occur from January 1998 to April 1998. In contrast, over Borneo strong negative anomalies are found much earlier, from June to October 1997. The

resulting drought caused the strong biomass burning in September and October 1997.
In Fig. 4 SCDs of H_2O and O_2 are analysed for quasi simultaneous observations of GOME and SCIAMACHY. We find a very good overlap between both instruments, which will allow to merge the time series of SCIAMACHY with those of GOME without significant discontinuities.

4. CONCLUSIONS

We presented global data sets of the total water vapor column analysed from GOME and SCIAMACHY. In contrast to other satellite observations of H_2O the UV/vis observations have the advantage to be of similar sensitivity over both land and ocean. Our H_2O algorithm also makes no use of any a-priori or independent information. Thus it is very well suited also for trend studies.
Using GOME H_2O data we studied El-Niño induced anomalies during 1997/98. We found that strong positive and negative anomalies exist over the central Pacific region but also at other regions, e.g. the eastern Indian Ocean, western central Africa and the southern part of the Arabic peninsula. Significant negative anomalies were found over Borneo relatively early in 1997 (June – October) leading to the very strong biomass burning in September and October 1997. We also analysed first SCIAMACHY spectra using the same settings as used for GOME. A comparison during the one year overlap period showed very good agreement. This will allow to extend the GOME H_2O data set into the future without discontinuities.

5. ACKNOWLEDGESMENTS

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