Case Studies for the Investigation of Cloud Sensitive Parameters as Measured by GOME

A contribution to subproject TROPOSAT

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Summary

This project focuses on the determination of cloud properties (like geometric cloud fraction and average cloud to height, etc.) from satellite observations and on the quantification of the corresponding cloud influence on tropospheric trace gas products derived from satellites. The investigations first concentrate on GOME and will later also be applied to SCIAMACHY on ENVISAT.

The most dominant effects of clouds are (a) that they shield the atmosphere below the cloud cover and (b) that their albedo is typically significantly larger compared to the earth's surface. Because of these effects the determination of quantitative tropospheric trace gas products depends strongly on the knowledge of cloud properties.

Already existing cloud algorithms are based on spatially resolved intensity measurements (Polarisation measurement devices, PMD, see ESA (1995)) as well as on the determination of the optical depth of the O_2-A-band (see e.g. Kuce and Chance (1994), Kjoelemeijer and Stammes, 1999). However, both quantities show important shortcomings, especially over snow and ice surfaces, which strongly limit their applicability.

In this study we investigate a large variety of cloud sensitive parameters measured by GOME. Besides the 'traditional' cloud sensitive parameters mentioned above we also make use of the polarisation of the measured light and in particular of various absorption bands of the oxygen dimer O_4 (at 360, 380, 477, 577, and 630 nm (Greenblatt et al., 1990)) as well as the filling-in of the solar Fraunhofer lines by inelastic Raman scattering (Ring effect (Grainger and Ring, 1962; Joiner and Barthia, 1995)). We demonstrate that several of these quantities are well suited for the characterisation of clouds, especially over snow and ice surfaces.

Table 1 Overview over cloud sensitive parameters and their dependencies on different scattering processes.

Cloud sensitive Parameter	Depending on
O_4-absorption 630 nm	Clear view down to the ground
O_4-absorption 360 nm	Clear view down to the ground ground albedo
Colour Index	Ratio of Rayleigh-scattered light to Mie-scattering and ground reflection
Polarisation	Ratio of single Rayleigh scattered light to total intensity
Ring effect	Ratio of Raman scattered light to total intensity
O_2-absorption 630 & 760 nm	Clear view down to the ground

Aim of the work

Already existing cloud algorithms (like ICFA, CRAG, PCRA, OCRA, FRESCO, etc., see ESA (2000) and references therein) are based on the analysis of the PMD measurements and the analysis of the O_2-A absorption (or a combination of both). However, while PMD-algorithms become insensitive over snow and ice surfaces, the O_2-A-band absorption is also affected by saturation effects. In particular, in polar regions no useful cloud data are available so far, which are strongly required for the interpretation of tropospheric trace gas measurements by satellite instruments. In contrast to the highly resolved strong atmospheric O_2 absorption the broad O_4 bands show only weak absorptions in the atmosphere and are not affected by saturation. Thus they are well suited for the investigation of cloud properties. In addition, especially at larger wavelengths they show only a weak sensitivity towards changes of the ground albedo. The combination of O_4 absorptions at different wavelengths (e.g. at 360 and 630 nm) also allows to discriminate the effects of Rayleigh- and Mie-scattering. Another important cloud sensitive quantity is the strength of the Ring effect which is also in the focus of this study.

24.03.1996: GOME orbit over Scandinavia (center pixel)

04.09.1996: GOME orbit over Hurricane Fran (east pixel)

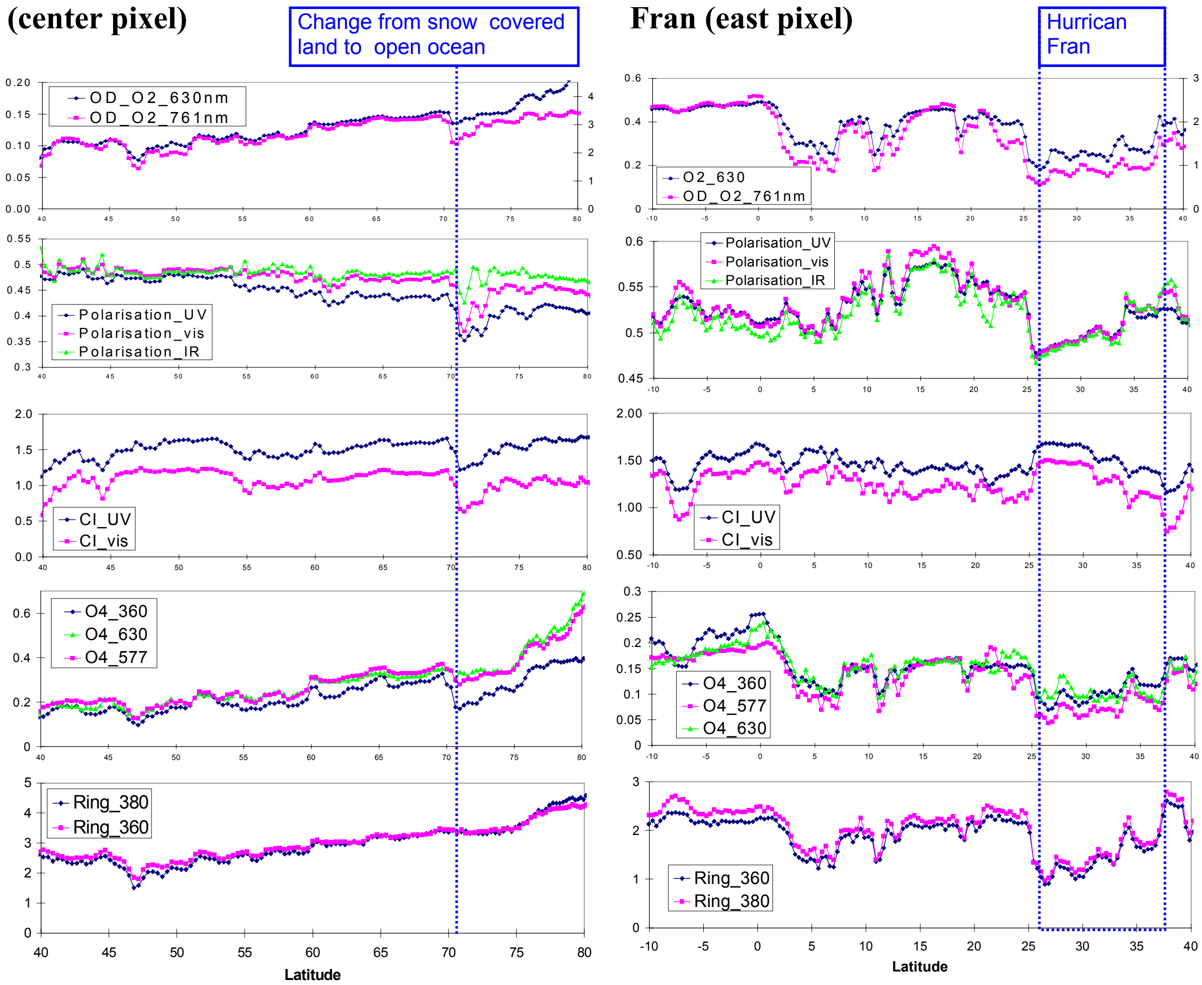

Figure 1 Dependence of different cloud sensitive quantities on the extended cloud of the tropical hurricane Fran (right) and on the strong change of the ground albedo from open ocean to snow covered ground (left, see also Fig. 2). All quantities show a strong sensitivity towards clouds. However, while several quantities are also sensitive to the ground albedo, in particular the Ring effect and the O_4 absorption at 630 nm show no dependence on the ground albedo.

Activities during the year

The activities of the first year of the project included the determination of O_4 absorption cross sections under atmospheric conditions (*Wagner et al.,* 2001) as well as the development and testing of O_4 algorithms from GOME measurements (*Klimm,* 2000). The O_4 absorptions derived from GOME were also compared to the results of the multiple scattering Monte-Carlo radiative transport model AMFTRAN (*Marquard et al.,* 2000).

During the last year we developed further algorithms for the determination of the Ring-effect, Colour indices and polarisation from GOME observations. We investigated the behaviour of all these quantities for two selected atmospheric scenes, which allowed us to discriminate the effects of clouds and those of the (potentially white) surface. In addition we developed an algorithm for the determination of the earth's coverage with ice and snow based on the GOME PMD data (*Klimm*, 2000). Table 1 shows an overview over the investigated cloud sensitive quantities.

Principal scientific results

Figure 1 shows the dependence of several cloud sensitive parameters derived from GOME observations on clouds (right) or snow and ice (left). The 'traditional' quantities (the observed intensity and the O_2 absorption) strongly depend on both, clouds and surface brightness. In contrast, some of the new quantities (like the O_4 absorption at 630 nm and the Ring effect) are only strongly affected by clouds, but not by the change of the ground albedo (see also Fig. 2).

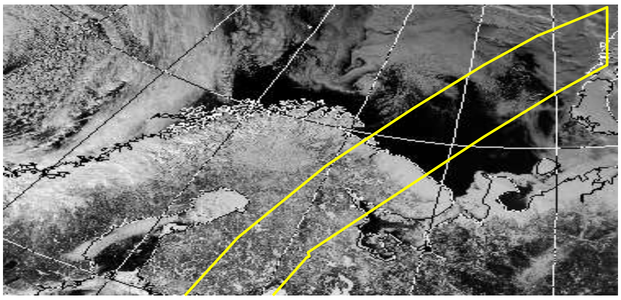

Figure 2 Satellite image of northern Scandinavia on 24.03.1996, 10:51. The satellite track (indicated by lines) crossed the cost where the albedo strongly changed from about 5% (over the ocean) to about 80% (over the snow). This case was investigated in Fig. 1, left.
The images are obtained via the Dundee Satellite Receiving Station, Dundee University, Scotland (http://www.sat.dundee.ac.uk/).

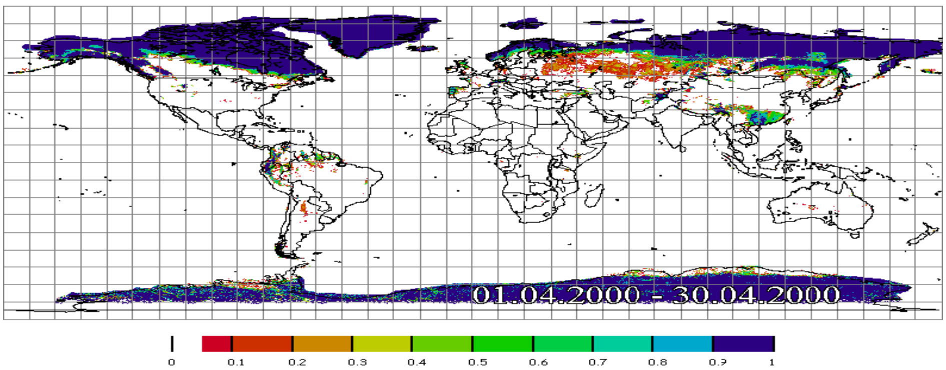

Figure 3 Snow cover derived from the new PMD algorithm for April 2000 (Klimm, 2001).

In Figure 3 a result of our new snow/ice algorithm is shown, which is based on image sequence techniques using GOME PMD data. The algorithm utilises the different time scales of the variability of clouds and snow; it is in particular insensitive to possibly erroneous GOME measurements.

Main conclusions

We demonstrated that several additional cloud sensitive parameters are well suited to yield cloud properties even over snow and ice surfaces. It will thus in the future be possible to analyse tropospheric trace gas measurements from satellite for polar regions in a quantitative way. This is of special importance for the interpretation of events of high boundary layer concentrations of BrO during polar spring.

Aims for the coming year

So far the new cloud products are partly analysed on a prototype basis. During the next year We will improve these algorithms, characterise and test them in order to use them on a routine basis. In addition, we will compare the cloud sensitive quantities with model results under specific atmospheric conditions. Finally we will combine selected quantities (most probably the O_4 absorptions at 360 and 630 nm, the O_2 absorption at 630 nm, and the Ring effect in the UV) for the determination of an operational cloud product for polar conditions.

List of publications in 2001

Wagner, T, C. von Friedeburg, M. Wenig, C. Otten, and U. Platt, UV/vis observations of atmospheric O_4 absorptions using direct moon light and zenith scattered sunlight under clear and cloudy sky conditions, *J. Geophys. Res,* revised, 2001.

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