VERIFICATION AND VALIDATION OF THE GOME-2 LEVEL-1 CLOUD PRODUCT

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Abstract

GOME-2 on MetOp will continue and improve the GOME data record, which started in 1995 for global monitoring of UV-visible trace gases, like ozone, NO_2, and BrO. One of the main problems in the detection of trace gases is the presence of clouds. Clouds affect trace gas retrievals in various ways: they shield the tropospheric trace gas column, but also cause increased path lengths for absorption. Detection of clouds and correction for their effects is therefore necessary to reduce errors in trace gas retrievals.

For GOME-2 the oxygen A-band around 760 nm can be used for the detection of clouds. The cloud algorithm used in the GOME-2 level-1 processor is FRESCO (Fast retrieval scheme for clouds in the O_2 A-band). FRESCO uses three 1-nm wide windows in and around the O_2 A-band, and assumes the cloud to be a Lambertian reflector. The cloud parameters retrieved by FRESCO are the effective cloud fraction and the cloud pressure. FRESCO is used extensively for GOME on ERS-2 and SCIAMACHY on Envisat for many years already, and has been validated for these instruments (see http://www.temis.nl).

We will analyse the FRESCO cloud parameters from GOME-2 in the following ways:
1. Verify the internal consistency of the GOME-2 cloud parameters, using our experience with the FRESCO algorithm.
2. Verify the quality of the GOME-2 cloud parameters, on the basis of comparison with statistics from the GOME and SCIAMACHY FRESCO cloud products, and other cloud climatologies.
3. Validate the GOME-2 cloud parameters by intercomparison with other colocated satellite cloud parameters, from imagers like SEVIRI on MSG and AVHRR on MetOp.
4. Validate the GOME-2 cloud parameters by comparison with groundbased measurements of clouds in Cabauw (NL), where lidar and radar instruments are operated continuously.

1. Introduction

In general, clouds have three effects on trace gas retrievals from UV-visible satellite observations:

- Shielding effect: tropospheric trace gases like NO_2 are shielded by clouds from observation by satellites (large effect)
- Albedo effect: reflection by clouds enhances the detection of trace gases above and between the clouds (large effect)
- In-cloud absorption effect: the photon path enhancement by scattering in the clouds enhances the depth of absorption lines of trace gases present inside the clouds (small effect).

These three effects are illustrated in Fig. 1.

To account for these effects accurately, one would have to model clouds in a detailed way, by using multiple cloud parameters (macrophysical and microphysical). This information on clouds is, however, generally not available from satellite. It is important to realize that the geometric (real) cloud fraction and the cloud albedo cannot be distinguished for the large pixels of GOME-2 (40x80 km^2). Therefore we use a simple cloud correction approach, using a Lambertian surface model for a cloud. The minimum required cloud information for sufficient cloud correction of trace gas retrievals, is at least: *effective cloud fraction c* and *cloud top pressure P*. Here the effective cloud fraction is the cloud fraction of a cloud with fixed albedo (say 0.8) yielding the same radiance as the clouds in the scene (which have an unknown albedo *and* unknown cloud fraction). We have:

$$\text{effective cloud fraction} = \text{geometric cloud fraction} \times \text{cloud albedo} / 0.8.$$

In the GOME-2 level-1 data product, cloud information is included, in order to help the users of the level-1 spectra with information on clouds. This cloud information comes from the FRESCO algorithm [6], [4]. The algorithm measures the amount of oxygen and thereby air pressure, since oxygen is a well-mixed gas.

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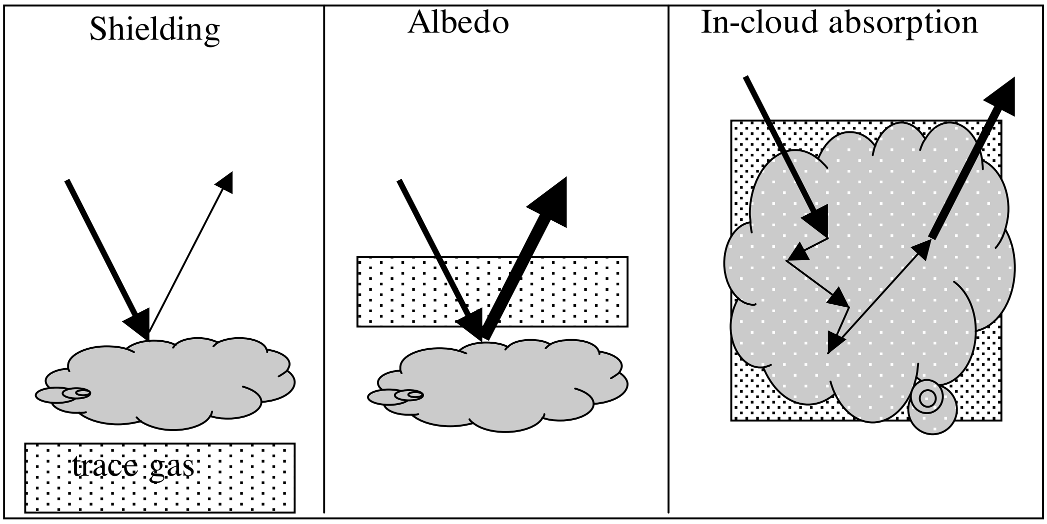

Fig. 1: Cloud effects on trace gas detection by satellites

2. FRESCO cloud algorithm for GOME-2

The principle of the FRESCO cloud algorithm [6] is the following. FRESCO fits a modelled Earth reflectance spectrum to the measured Earth reflectance spectrum in three 1-nm windows of the O_2 A-band (see Fig. 2), and produces an effective cloud fraction *c* and cloud pressure *P*.

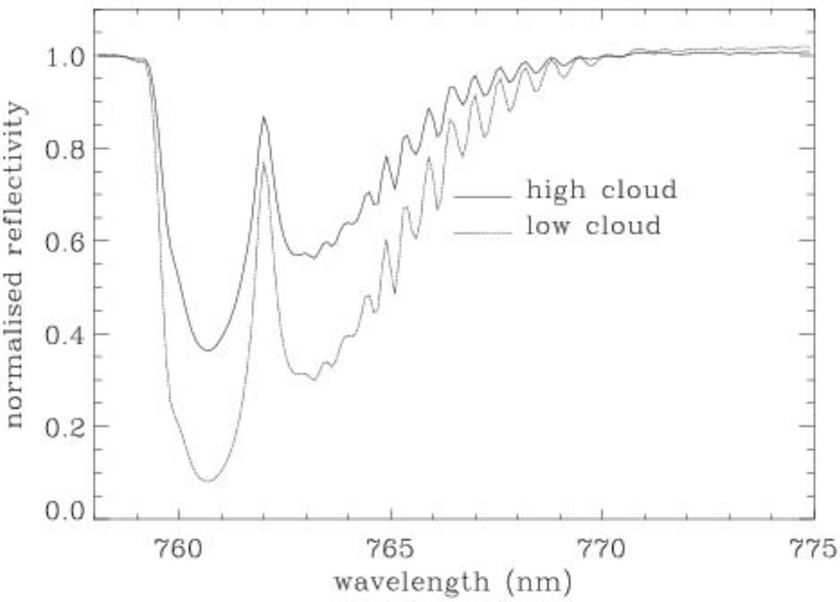

Fig. 2. Oxygen A-band as observed by GOME for a high and a low cloud. The FRESCO algorithm uses three 1-nm wide windows in this band, namely at 758, 760, and 765 nm.

The atmospheric model used in FRESCO is:

- Partly cloudy pixels are assumed to be covered by a bright Lambertian cloud (A_c=0.8) with an effective cloud fraction *c*.
- A fraction *1-c* is covered by the surface with albedo A_s, taken from the GOME surface albedo database [8], [3].
- The only process in the atmosphere is absorption by O_2.

The rationale of the Lambertian cloud model assumption in FRESCO, with albedo 0.8 ("thick cloud model"), is the following. From observations we know that the cloud reflectance is usually < 0.8. Furthermore, this approach allows a consistent simplicity in both the cloud retrieval algorithm and the cloud correction part of trace gas retrieval algorithms. The assumption A_c=0.8 produces the smallest errors in the cloud correction part of the retrieval of stratospheric trace gases like ozone [5] and tropospheric trace gases like NO_2 [9].

The O_2 A-band transmission database for FRESCO has been made by Fournier et al. [1] using the slit function information of GOME-2 (see Fig. 3).
FRESCO is used already in near-real-time for GOME and SCIAMACHY; see http://www.temis.nl. From regional and global validation using other satellites and groundbased observations we know that the effective cloud fraction can be much lower than real cloud fraction; as *effective* fraction it is accurate to ± 0.05. The cloud pressure is about 50-100 hPa larger than thermal-IR satellite cloud top pressure [7], [2], [4].

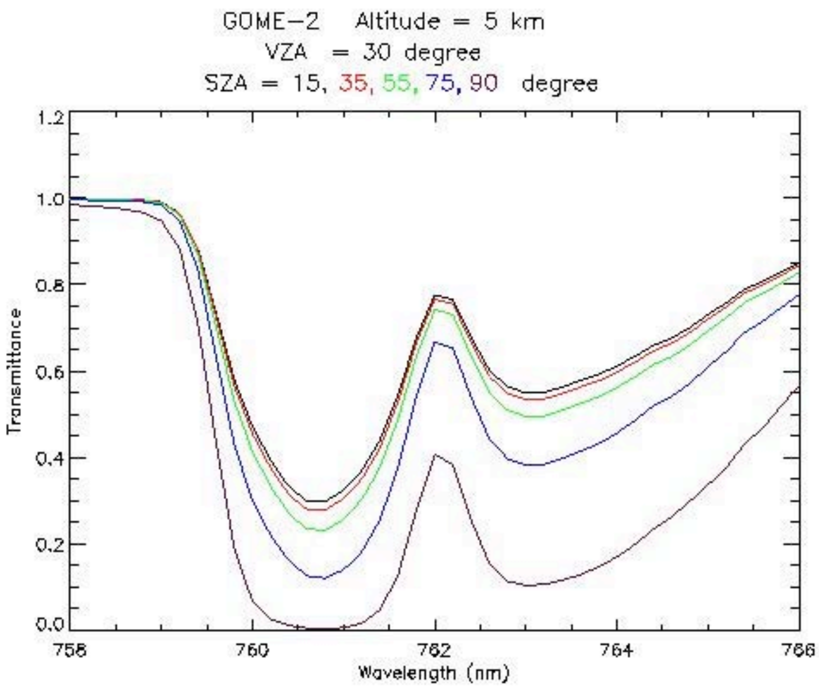

Fig. 3. Oxygen A-band simulations of the FRESCO transmission database for GOME-2.

3. Verification and validation plans of GOME-2 FRESCO cloud product

Our plans for verification of validation of the FRESCO cloud product, as part of the GOME-2 level-1 product validation, are as follows:

- Verify radiometric calibration around the O_2 A-band by comparing the GOME-2 reflectance with radiative transfer model results and/or reflectances from other satellite instruments.
- Verify the internal consistency of the cloud product.
- Compare with the known global mean effective cloud fraction and cloud pressure from GOME ($c \approx 0.30$, $P \approx 700$ hPa).
- Compare with the global cloud distribution functions from GOME.
- Compare qualitatively with colocated cloud imagery (AVHRR, SEVIRI).
- Compare quantitatively with colocated AVHRR/SEVIRI effective cloud fractions, which can be calculated from the geometric cloud fraction and the cloud optical thickness.
- Compare with groundbased radar/lidar cloud observations at Cloudnet and ARM sites.

The European Cloudnet sites (see: http://www.cloud-net.org) are:

- Chilbolton, U.K. (U. Reading, RAL)
- Paris, France (SIRTA, CNRS/IPSL)
- Cabauw, The Netherlands (KNMI, Cesar collaboration).

At the Cabauw site the following cloud remote sensing instruments are available:

- 35-GHz cloud radar
- 3.3-GHz FM-CW radar TARA (TU-Delft)
- 905 nm lidar ceilometer
- HATPRO microwave radiometer
- Total Sky Imager.

Especially, the synergy between radar and lidar is exploited for target classification at Cloudnet sites (see Fig. 4).

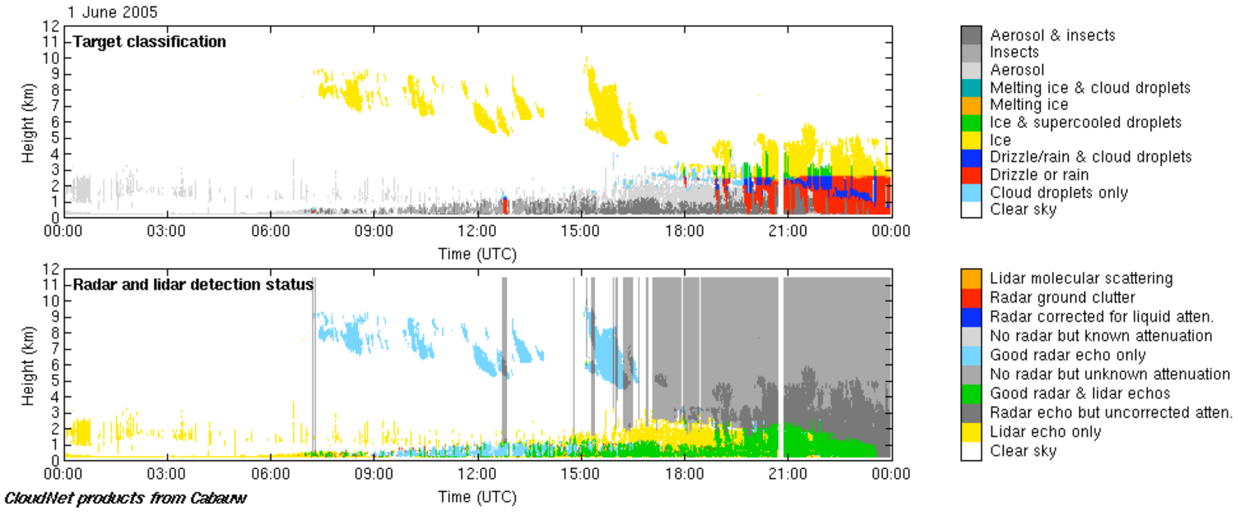

Fig. 4. Target classification from the radar and lidar observations at the Cabauw site (see http://www.cloud-net.org).

4. Summary

- The FRESCO cloud product from GOME-2 is needed for cloud correction of trace gases. It will be available in the L1 product.
- Verification of the cloud product will be performed on the basis of GOME/SCIAMACHY experience.
- Validation will be performed using colocated AVHRR/SEVIRI satellite data and Cloudnet groundbased observations.
- Note that FRESCO treats scattering aerosols as clouds, so it cannot be used directly in case of aerosol retrievals.
- The O_2 A-band provides a new view of clouds. GOME-2 can be used to continue monitoring of global variability and trends in cloud parameters from GOME and SCIAMACHY, to create a long term data set.

5. References

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