Observations of clouds by the MIPAS instrument on ENVISAT

J.J. Remedios, R. Spang, L. Kramer and A.M. Waterfall

Earth Observation Science, Dept. Physics and Astronomy, University of Leicester

MIPAS AND CLOUDS

The Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) on ENVISAT provides:

- five spectral channels covering a broad spectral region between 685 cm^{-1} and 2410 cm^{-1}.
- vertical profiles scanned from 6 km to 68 km with a vertical spacing of 3 km in the lower stratosphere commensurate with the vertical resolution of the instrument.

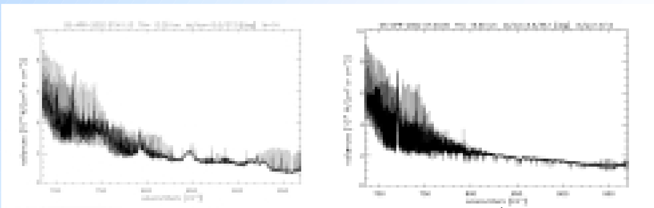
The broad spectral coverage of MIPAS at high resolution (nominally 0.035 cm^{-1} unapodised) is providing unprecedented emission spectra of trace gas and particle signatures. In particular, the new observations reveal exciting information on:

1. cirrus clouds in the upper troposphere
2. polar stratospheric clouds (PSCs) in the lower stratosphere.

Detection of such clouds and their characterisation will provide valuable data for studies of radiative forcing, water vapour distributions and ozone loss. The main attributes of MIPAS observations of clouds are described in this paper along with some first results.

MIPAS SPECTRA OF CLOUDS

• Figure 1 shows shows spectra (MIPAS band A) of tropical cirrus clouds at a tangent altitude of 13.5 km (Figure 1a) and 16.5 km (Figure 1b) respectively from orbit 504 on April 5th 2002 (4 minutes apart). Figure 2 shows corresponding effects for PSCs in the Antarctic vortex at 19.5km.



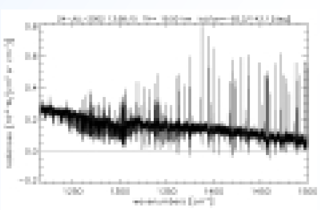
a b

Figure 1. MIPAS spectra of tropical cirrus clouds (a) at 13.5km, (b) at 16.5km. Spectra were recorded approx. 4 minutes apart.

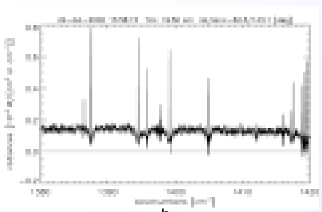
•The influence of clouds can be observed in unprecedented detail as:

- A distinct offset to the spectra of around 2 µW / cm^2 sr cm^{-1} (in brightness temperature such offsets can correspond to enhancement of up to 30 K from the local temperature).
- The appearance of gas absorption lines as well as emission lines from higher altitudes (Figure 1(b) and 2(a)). The absorption lines can originate either from a cold atmosphere above the cloud top or from upwelling tropospheric radiation scattered into the limb path. The presence of many weak H_2O lines indicates the latter explanation, a hypothesis confirmed by simplified radiative transfer calculations (see also the next point)
- The shapes of spectral lines involving scattering reveals a wide pressure-broadened absorption shape from tropospheric gas contributions whereas the sharp emission lines are a result of stratospheric contributions. The effect of the scattering is therefore complicated but revealing and depends on the height/location of the cloud along the line-of-sight, the temperature of the cloud and the mean size of the cloud particles.

Note also the differing gas contributions to the spectra. For example, Figure 1(a) shows emission lines from gases such as the very broad CFC-11 signature between 835 cm^{-1} and 855 cm^{-1}. In contrast, Figure 1b shows gas absorption lines with emission lines from high altitudes.



a



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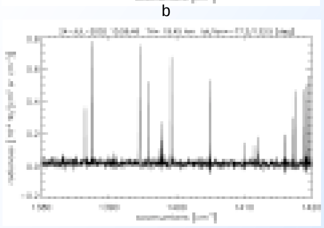

c

Figure 2: First spectrum of an Antarctic vortex PSC observed by the MIPAS on ENVISAT. Data are provided by the ESA and are preliminary but with expected calibration suitable for this purpose. (a) PSC at 19.5 km tangent height as observed in the MIPAS B band; (b) Detailed section of the same PSC spectrum near 1400 cm^{-1}; (c) "Clear sky" spectrum at 19.45 km for a nearby profile. Radiances are in units of µW/(cm^2 sr cm^{-1}).

Cloud detection for MIPAS

• A cloud detection system has been designed for MIPAS and implemented in the prototype processor (soon to be implemented in the operational processor).

•This is necessary not only to identify the clouds themselves but also to avoid problems of cloud contamination in the retrieved trace gas data (see below)

• Clouds are detected by a spectral ratio (colour ratio) test where the integrated radiance in two mesowindows are compared. Three different pairs of mesowindows have been identified: (Spang et al,2003)

•CI-A. MW1=788.20 – 796.25; MW2=832.3 – 834.4. Threshold=1.8; Alt range=10-45 km

•CI-B MW1=1246.3 – 1249.1; MW2=1232.3 - 1234.4. Threshold=1.2; Alt range=10-40 km

•CI-D. MW1=1929.0 – 1935.0; MW2=1973.0 – 1983.0. Threshold=1.8; Alt range=12-30 km

• Threshold values are chosen so as to minimise effects on MIPAS retrievals of trace gases. Hence cloud index values *less than* the threshold value indicate the presence of thick clouds (for example, see PSCs below). Cloud indices for Band A are shown in Figure 3.

•The effect on trace gas retrievals for CH_4 can be seen in Figure 4 below.

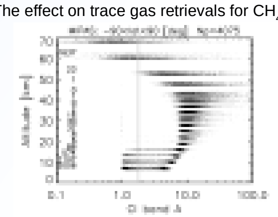

Figure 3. Cloud index values for Band A. Threshold values for clouds are shown by the grey vertical line. Numbers of observations below the cloud threshold are superimposed. Measurements from all latitudes between Sept 7 and 18, 2002

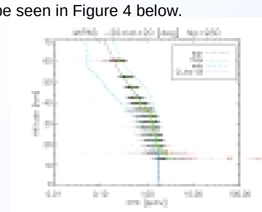

Figure 4: MIPAS tropical data for CH_4 in Sept 2002. Black and red dots are the non-cloudy and cloud affected (from CI-A) MIPAS retrieved data respectively, with the diamonds and crosses giving mean values; The tropical reference atmosphere is the dot-dashed line, with the dashes representing the expected extremes of the profile.

First Results for MIPAS Clouds

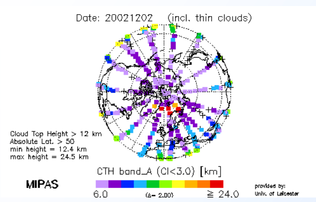

Figure 5

First strong PSCs observed in the Northern hemisphere on December 2nd 2002. (Spang et al, EGS 2003)

Tropospheric cloud occurrence frequencies for December 2002 from MIPAS

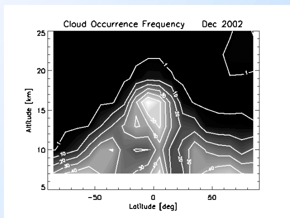

Figure 6

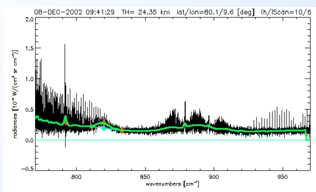

Figure 7

A spectral feature of PSCs observed at 820 cm^{-1} – this feature is believed to be NAT (green curve emphases broad structure due to PSC)

Conclusions

•The MIPAS instrument is providing unprecedented, high resolution, infra-red spectra of clouds from limb sounding

•Effects observed include spectrally varying offsets, unique spectral features (PSCs) and high resolution signatures due to the scattering of tropospheric radiation for particles of sufficient size.

• A cloud detection method has been designed for MIPAS based on colour ratios and leads to a considerable improvement in the quality of the retrieved MIPAS data (to be implemented in the MIPAS operational processor shortly).

• First results for PSCs include near real-time detection of PSCs through the Arctic winter of 2002/3 (as part of the Vintersol campaign) and probable observation of a NAT spectral feature. Near real-time cloud data from MIPAS can be viewed at http://www.leos.le.ac.uk/MAPSCORE/, under Data, Cloud top heights from MIPAS.

• Cloud occurrence frequencies for tropospheric cloud show high probabilities in the tropical upper troposphere (towards 50% for December 2002) and at 7 km in mid-latitudes. A large number of cloud free views occur even to the lowest tangent altitudes which provides considerable potential for measurements of tropospheric composition.

Address: EOS, Space Research Centre, University of Leicester, University Road, Leicester LE1 7RH, U.K
Email: John Remedios: jjr8@le.ac.uk, Reinhold Spang: r.spang@le.ac.uk
Web: www.leos.le.ac.uk/home

References: Spang, R, J.J. Remedios, and M.P. Barkley, Colour Indices for the Detection and Differentiation of Cloud Types in Infra-red Limb Emission Spectra, accepted for Adv. Space Res., 2003

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