ANALYSIS OF WATER VAPOUR AND METHANE FROM THE MIPAS SATELLITE INSTRUMENT

Vivienne Payne, Anu Dudhia, and Chiara Piccolo

Atmospheric, Oceanic and Planetary Physics, Department of Physics, University of Oxford, Oxford, UK, e–mail: payne@atm.ox.ac.uk

ABSTRACT

Water vapour and methane are two of the target gases retrieved operationally in near–real–time (NRT) from the Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) on Envisat.

Water vapour and methane are chemically linked, since methane oxidation is the main source of water vapour in the stratosphere. The oxidation of methane eventually produces water vapour and molecular hydrogen such that the sum H_2+H_2O+2CH_4 is approximately constant with altitude. Assuming that the mixing ratio of molecular hydrogen is constant with altitude in the lower stratosphere, we would also expect the quantity H_2O + 2CH_4 to be reasonably constant in this region, providing a useful internal validation test.

Here we assess the quality of water vapour and methane profiles from the ESA NRT retrieval, based on MIPAS data from July 2002 until March 2004. Monthly means of MIPAS profiles are used to examine differences from climatology, and look for any biases or long-term trends. Comparisons are also made with measurements from the Halogen Occultation Experiment (HALOE) on the Upper Atmosphere Research Satellite (UARS).

Key words: MIPAS; water vapour, methane, Level 2.

1. INTRODUCTION

Monitoring of the Level 2 products has been performed routinely at the University of Oxford. Monthly mean profiles have been calculated for the MIPAS Near-Real-Time Level 2 products (temperature, H_2O, O_3, HNO_3, CH_4, N_2O and NO_2) from July 2002 until March 2004. Here we present the monthly mean profiles of H_2O and CH_4. The Level 2 profiles have been split into different latitude bands for the calculation of the means, and the monthly mean profiles for each of the products plotted as time–series. Some spike detection has been used in the averaging process, mostly excluding values of CH4 greater than 10ppmv and H2O greater than 1000ppmv. This examination of the time–series of the monthly means of the MIPAS H_2O and CH_4 is intended to give an overview of the quality of the data and of any persistent features in the profiles. The intention was also to try to identify any step changes in the data with time that might have resulted from changes in the data processing chain. Changes in processing for which we thought we might see changes in the monthly mean profiles were a Level 1 fringe count error correction in March 2003, the implementation of cloud detection in July 2003, and a number of improvements to the Level 1B processing that were implemented in November 2003.

In order to check whether the monthly mean profiles agree with what might be expected, we also compare them with reference climatologies, and with HALOE Level 3 data (1). The reference climatologies used in these comparisons are from the IG2 dataset (2) (used in the construction of the initial guess for MIPAS retrievals). Further details of the monitoring that has been taking place at Oxford can be found on the Oxford MIPAS Group web pages (3).

2. MONTHLY MEAN PROFILES

Here, the MIPAS data has been split into six latitude bands (90S–65S, 65S–20S, 20S–0, 0–20N, 20N–65N, 65N–90N) for the calculation of the means. These particular latitude bands were chosen because these are the bands into which the initial guess data for the MIPAS Near–Real–Time retrievals are split.

2.1 H_2O

Fig. 1 shows a contour plot of the MIPAS monthly mean H_2O profiles from July 2002 until March 2004. In general, the profiles show a minimum around the tropopause, with the volume mixing ratio (VMR) gradually increasing with height, as would be expected due to the oxidation of CH_4. Also, drier “tongues” of air can be seen propogating upwards from the tropical tropopause in the equatorial regions. This would appear to be consistent with the “tropical tape recorder effect” (4). However, there are some obvious problems with the MIPAS water vapour profiles. The profiles tend to show a reasonably sharp decrease at the highest retrieval altitude, which is not a feature expected in the real atmosphere. Also, values at the second–highest retrieval altitude seem rather larger than would be expected. There are also some unrealistically high values of H_2O VMR in the southern polar monthly means for the 2003 southern hemisphere winter. It is thought that this may have been due to polar stratospheric clouds, which would be consistent with the low temperatures observed for this time period, which could have caused difficulties in the MIPAS retrievals.

2.2 CH_4

Fig. 2 shows a plot of the time-series of the MIPAS monthly mean CH_4 profiles from July 2002 to March

2004. A strong seasonal cycle can be seen in polar regions, due to the general descending motion of the air at certain times of year. CH_4 is produced at the surface, is well-mixed in the troposphere, and broken down in the stratosphere by oxidation and photolysis. It is therefore expected that the CH_4 profiles should decrease monotonically with height. This is not the case for some of the equatorial monthly mean profiles. The MIPAS CH_4 in the equatorial latitude bands for some of the months shows a local minimum at around 15–18 km. The reason for this is not known, but it is thought that it may be due to the 3 km vertical resolution of MIPAS being unable to resolve temperature features around the tropopause region.

2.3 H_2O+2CH_4

Fig. 3 shows a plot of the time-series of the MIPAS monthly mean H_2O+2CH_4. This quantity is reassuringly mostly reasonably constant in the lower straosphere, apart from in polar regions, where it would not ne expected to be, due to the prevailing dynamics. Areas where there are problems are generally the problem areas that have been outlined for water vapour.

3. IG2 CLIMATOLOGY COMPARISONS

3.1 H_2O

Fig. 4 shows the percentage difference between the MIPAS monthly mean H_2O and the IG2 climatology profiles. The sharp decrease in MIPAS H_2O at the highest retrieval altitude, the otherwise large MIPAS H_2O values at the second–highest altitude and the problems in the southern polar regions in winter can be clearly seen in these difference plots. In addition, it appears that the MIPAS H_2O at the lowest retrieval altitude is generally much higher than would be expected from the climatology. It is thought that this may be due to a problem with the implementation of the cloud detection algorithm in the MIPAS retrieval. Cloud detection was supposed to have been implemented in July 2003, and we might have expected to see a step change in the monthly means around this time. However, it seems that there have been some problems in the implementation of the cloud detection in the Near–Real–Time processing. This is currently under investigation. It should, however, be noted that the cloud detection is working in the Off–Line processing (the results of which are not dealt with in this paper), but that there are difficulties there in distinguishing cloudy sweeps from those with very high water vapour amounts.

MIPAS H_2O is, in general, much higher than the IG2 climatology at the lowest retrieval altitude (12 km, or around 100 mbar), around 20% lower than the IG2 climatology in the lower stratosphere (below 10 mbar), higher than the IG2 by up to 40% between about 4 mbar and 1 mbar, and around 30–50% lower than the IG2 at the highest retrieval altitude.

3.2 CH_4

Fig. 5 shows the percentage difference between the MIPAS monthly mean CH_4 and the IG2 climatology profiles. As with the other gases, the MIPAS CH_4 at the lowest retrieval altitude seems unrealistically high when compared with climatological profiles. The problem with the local minimum in the equatorial tropopause region can be seen as blue regions in the equatorial plots. In general, MIPAS CH_4 is around 20% higher than would be expected over most of the stratosphere, for all latitude bands.

4. HALOE COMPARISONS

4.1 HALOE coverage

Monthly means were also calculated for HALOE from July 2002 until March 2004. As HALOE is an occultation instrument, the latitudinal coverage varies considerably from one month to the next. (For further details of the HALOE coverage, refer to the HALOE website (1).) The coverage of HALOE is illustrated to some extent by Fig. 6. Since the HALOE coverage is more sparse than that of MIPAS, it was necessary to use narrower latitude bands for the HALOE comparisons than for the IG2 comparison. Both sunrise and sunset occultation measurements were included in the HALOE monthly means. Here we only discuss the results of the comparisons in the 30–40S and 30–40N latitude bands, as they provide the most months with HALOE data.

4.2 H_2O

Fig. 7 shows the percentage differences between the HALOE and MIPAS H_2O monthly means at mid–latitudes from July 2002 until March 2004. The agreement is generally much better than with the IG2 climatology. We might have expected this, since the IG2 was designed only to represent some "average" state of the atmosphere, whereas the HALOE monthly means come from actual measurements of the atmospheric state for a particular month in a particular year. Agreement is within $\pm 20\%$ throughout most of the stratosphere. The plots in Fig. 7 are qualitatively very similar to the mid–latitude plots in Fig. 4. They show the MIPAS H_2O at the lowest retrieval altitude to be much higher than that of HALOE. The problems with the MIPAS H_2O at the highest altitudes is also apparent. There is not, however, an obvious bias in the lower stratosphere over the whole time period, as is suggested by the comparisons with the IG2 climatology, and as was suggested at the ACVE–2 meeting in May 2004. Obviously these monthly mean comparisons are quite rough, and a statistical study would provide a clearer answer to the question of a bias.

4.3 CH_4

Fig. 8 shows the percentage differences between the HALOE and MIPAS CH_4 monthly means at mid–latitudes from July 2002 until March 2004. As with H_2O, the agreement is much better than with the IG2 climatology. Agreement is within ±20% throughout most of the stratosphere. As in the IG2 comparisons, the MIPAS CH_4 at 12 km seems to be much too high. The MIPAS CH_4 is also generally higher than HALOE in the lower stratosphere. It was concluded at the ACVE-2 meeting in May 2004 that there was a high bias in the MIPAS methane in the lower stratosphere. This conclusion is borne out by the comparison with HALOE. However, there is much less of a bias than in the IG2 comparisons.

5. SUMMARY

The MIPAS H_2O and CH_4 monthly mean profiles show much better agreement with the HALOE monthly mean profiles than with the IG2 climatology. This is not altogether surprising, since the HALOE data represents the real state of the atmosphere at the time of measurement, whereas the IG2 climatology was constructed to represent some kind of "average" atmospheric state. Also, the IG2 atmospheres were based on data from the early 1990s, and we might expect there to have been changes in this "average" atmospheric state in the past 10–15 years.

The MIPAS H_2O appears to be much too high at 12 km (the lowest retrieval altitude) and shows persistent problems at the highest altitudes. Comparisons with HALOE monthly means do not show a low bias in the lower stratosphere, as has been previously suggested. The MIPAS CH_4 also appears to be much too high at 12 km, and shows a high bias in the lower stratosphere with respect to both HALOE and the IG2 climatology. However, the overall quality of the MIPAS H_2O and CH_4 seems good.

ACKNOWLEDGMENTS

We would like to acknowledge all of the MIPAS team, particularly those responsible for the development of the operational retrieval, and the MIPAS QWG for their input.

We are also very grateful to the HALOE team for the use of their data.

REFERENCES

http://haloedata.larc.nasa.gov

Remedios, J.J., Extreme atmospheric constituent profiles for MIPAS, Proceedings of the European Symposium on Atmospheric Measurements from Space, ESTEC, Noordwijk, Netherlands, 20-22 January, Vol 2, 779-783, 1999

http://www.atm.ox.ac.uk/group/mipas

Mote, P.W. et al, An atmospheric tape recorder: The imprint of tropical tropopase temperatures on stratospheric water vapour, J. Geophys. Res., 101, 3989-4006, 1996

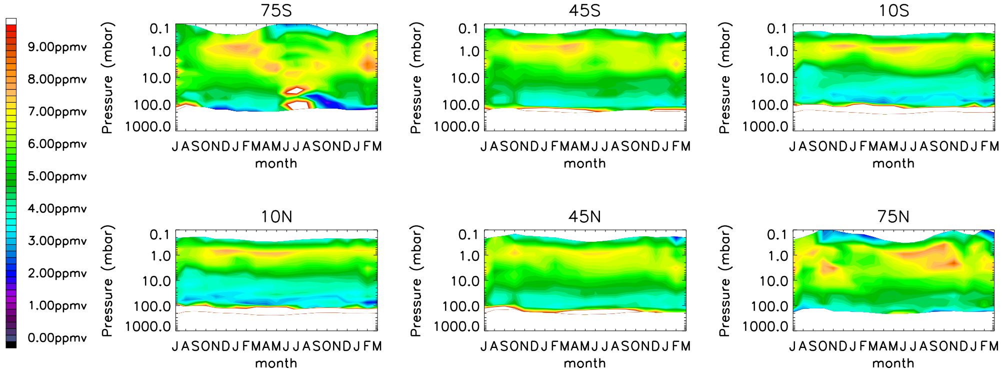

Figure 1. Time series of MIPAS near–real–time H_2O retrievals, from July 2002 to March 2004.

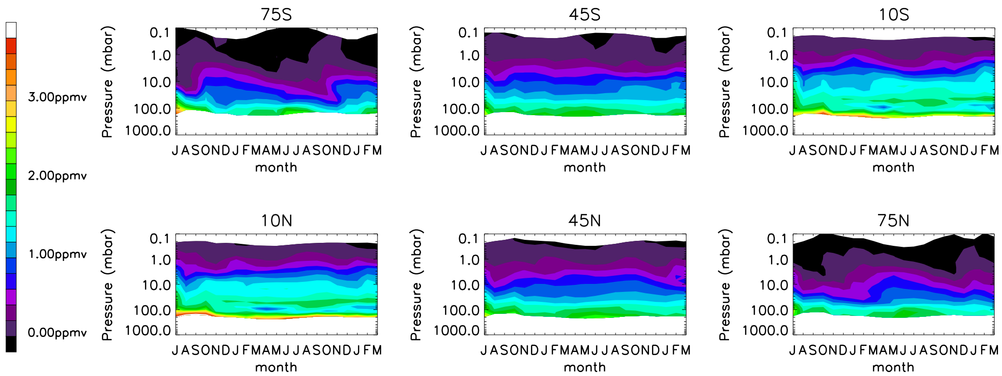

Figure 2. Time series of MIPAS near–real–time CH_4 retrievals, from July 2002 to March 2004.

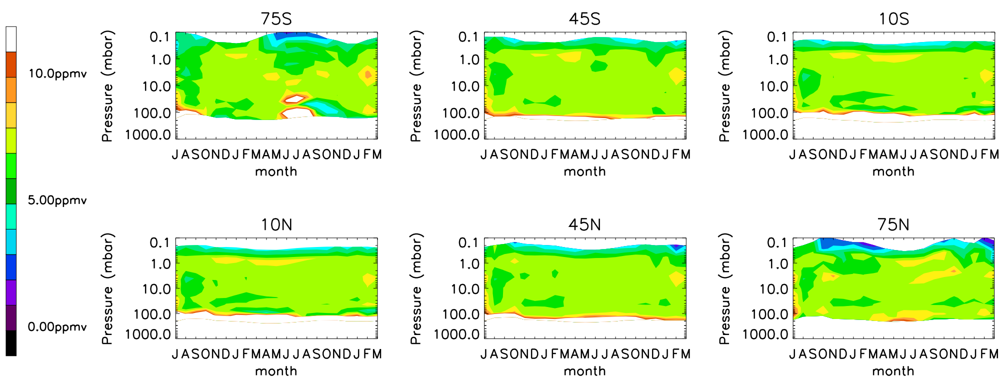

Figure 3. Time series of MIPAS H_2O+$2CH_4$, from July 2002 to March 2004.

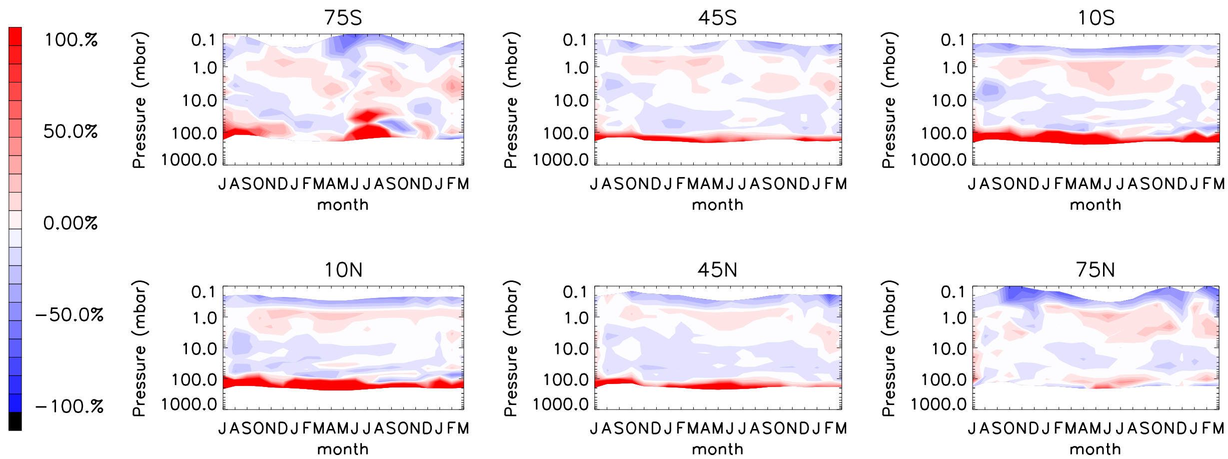

Figure 4. Time series of percentage difference of MIPAS near–real–time H_2O retrievals from the IG2 climatology, from July 2002 to March 2004. Plots show $\frac{MIPAS-IG2}{IG2} \times 100$. Red shows where MIPAS H_2O values are higher than the climatology and blue shows where MIPAS values are lower than the climatology.

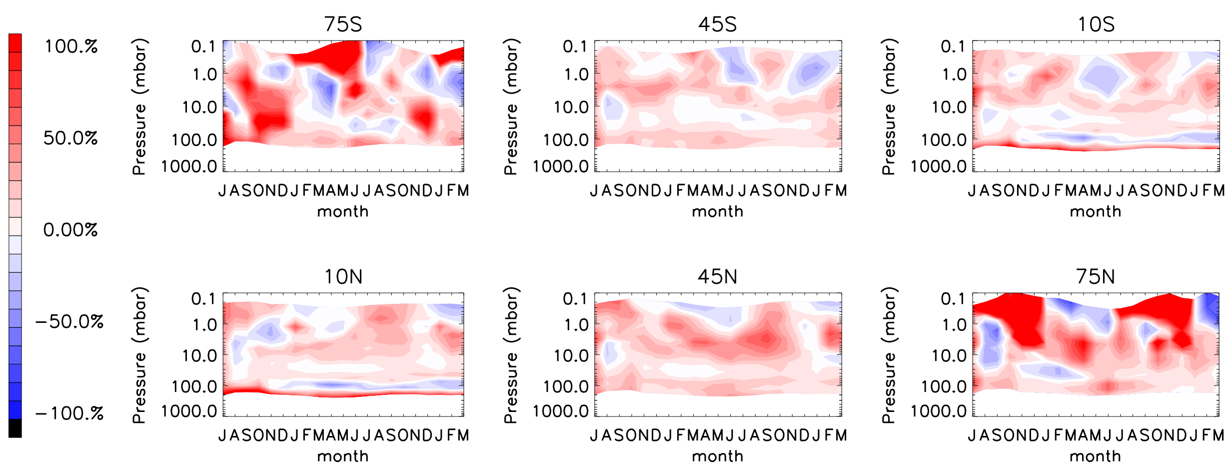

Figure 5. Time series of percentage difference of MIPAS near–real–time CH_4 retrievals from the IG2 climatology, from July 2002 to March 2004. Plots show $\frac{MIPAS-IG2}{IG2} \times 100$. Red shows where MIPAS H_2O values are higher than the climatology and blue shows where MIPAS values are lower than the climatology.

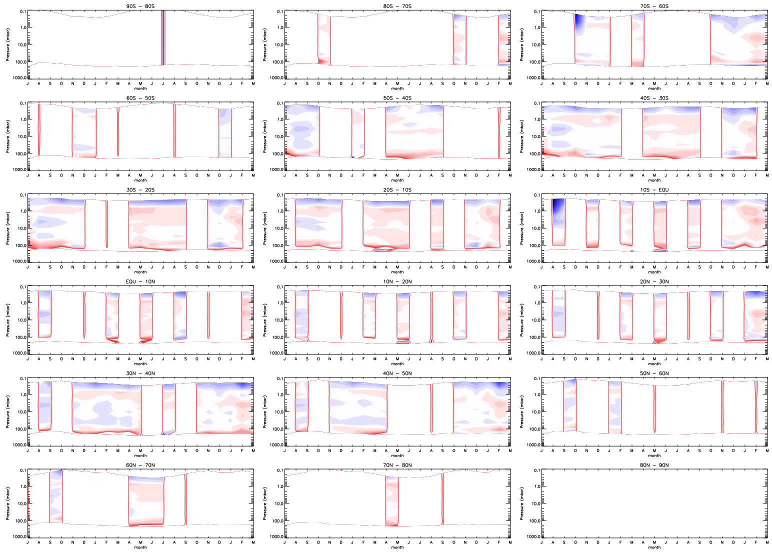

Figure 6. Difference plots of MIPAS-HALOE monthly mean H_2O, for eighteen 10 degree latitude bands. The purpose of this figure is really to show the coverage of HALOE in terms of months for the different latitude bands.

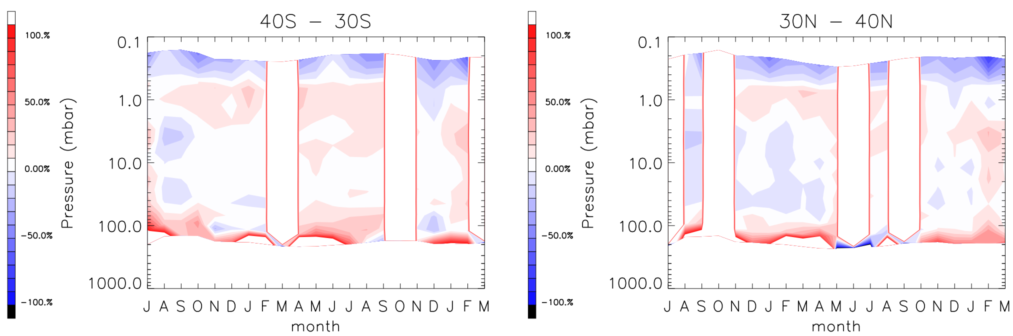

Figure 7. Percentage difference plots of (MIPAS-HALOE)/HALOE monthly mean H_2O, for 30–40S (left) and 30–40N (right)

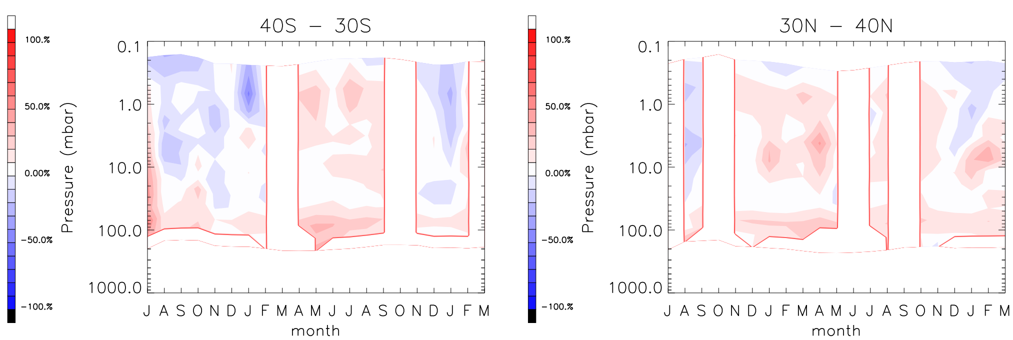

Figure 8. Percentage difference plots of (MIPAS-HALOE)/HALOE monthly mean CH_4, for 30–40S (left) and 30–40N (right)