MODELLING AND ASSIMILATION: EVALUATION OF MIPAS WATER VAPOUR DATA

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ABSTRACT/RESUME

At the 2nd Workshop of the Atmospheric Chemistry Validation of Envisat (ACVE-2), re-processed water vapour data from MIPAS (V 4.61) were evaluated using data assimilation models. The following groups participated: (i) the Data Assimilation Research Centre in collaboration with the Met Office, both UK; (ii) the European Centre for Medium-range Weather Forecasts; and (iii) the Belgian Institute for Space Aeronomy. This paper discusses issues concerning the assimilation of water vapour in the troposphere and stratosphere, and presents preliminary results from the evaluation of the re-processed MIPAS water vapour data. This evaluation exercise was done under the auspices of the Modelling and Assimilation (MA) validation subgroup of the Atmospheric Chemistry Validation Team (ACVT) for Envisat.

1. INTRODUCTION

The work carried out in this evaluation was as follows:

Group	Assimilation model	Work carried out	References
DARC/ Met Office	Troposphere-stratosphere global General Circulation Model (GCM)	Issues concerning assimilation of H_2O in troposphere-stratosphere	[1], [2], [3], [4]
ECMWF	Troposphere-stratosphere global GCM	Passive assimilation of re-processed MIPAS data	[5]
BIRA-IASB	Stratosphere global Chemistry Transport Model (CTM)	Active assimilation of Near-Real-Time (NRT) MIPAS data; comparison of analyses against re-processed MIPAS data	[6]

2. RESULTS

2.1 Met Office/DARC

The work from the Met Office (carried out as part of the EU-funded ASSET project, and in collaboration with DARC; http://darc.nerc.ac.uk/asset) focused on highlighting the problems associated with assimilating water vapour into a troposphere-stratosphere global GCM. The large variation in water vapour concentration between the troposphere and stratosphere (four orders of magnitude) and the almost discontinuous gradient in its concentration around the hygropause, make it difficult to assimilate water vapour. Note that these characteristics also make it difficult to retrieve water vapour in the neighbourhood of the hygropause.

A number of problems arise from these characteristics of the water vapour distribution. These are:

- Ill-conditioned vertical transform of the background error covariance matrix, **B**.
- Unrealistic stratospheric increments.

Besides the problems arising from the large variation of water vapour between the troposphere and stratosphere, there is an issue concerning what is the best control variable for assimilating water vapour: relative humidity (RH) or specific humidity. In the troposphere, RH provides a better representation of clouds and precipitation; in the stratosphere, RH has very low values, which makes specific humidity better suited. The choice of water vapour control variable is discussed in [7] and [8].

Two control variables were tested at the Met Office in 3d-var experiments run for one cycle. The results are summarised in Fig. 1.

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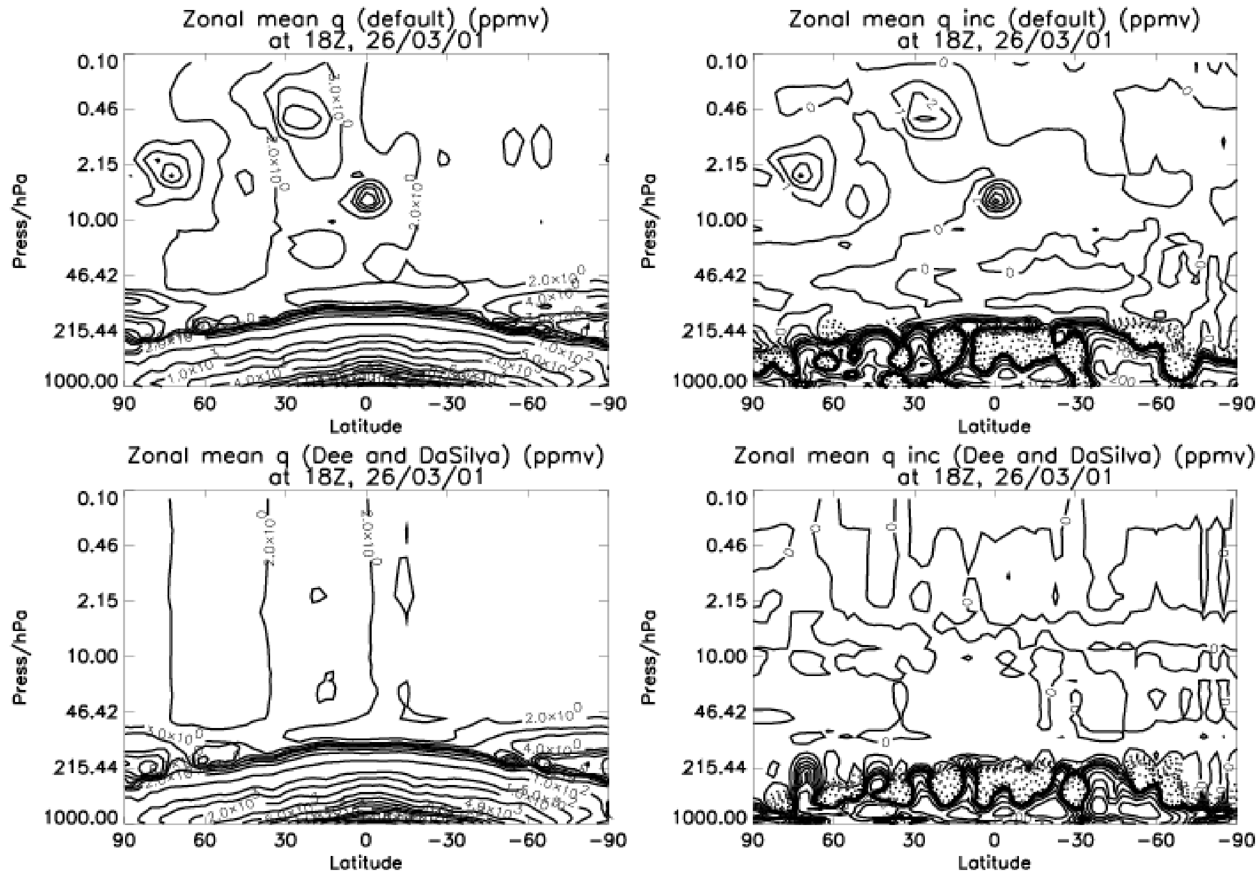

Fig. 1. Comparison of default (RH as control variable) and Dee and da Silva [8] (pseudo RH as control variable) water vapour assimilation approaches. Left hand plots: water vapour analyses; right hand plots: water vapour increments; top plots: default approach; bottom plots: Dee and da Silva approach. All units in parts per million by volume (ppmv).

As Fig. 1 shows, the Dee and da Silva approach gives better water vapour analyses and increments than the default approach. In particular, it avoids spuriously large analyses values and increments in the stratosphere.

Based on this work, an approach being investigated at the Met Office is to introduce a new humidity control variable that incorporates ideas from the work of [7] and [8]. As part of this work, the covariance code will be amended to modify the error variances and correlations, and the vertical weighting of the errors will be changed. In due course, the DARC will test and implement the approach developed by the Met Office.

2.2 ECMWF

In the current operational ECMWF analysis system no humidity observations are assimilated in the stratosphere. A simple parametrization of the upper-stratospheric moisture source due to methane oxidation is included to avoid an unrealistically drying of the stratosphere in the ECMWF model (Adrian Simmons, pers. comm.). Stratospheric humidity values from the 45-year ECMWF re-analysis project (ERA-40) are about 10-15% lower than Upper Atmosphere Research Satellite (UARS) Halogen Occultation Experiment (HALOE) retrievals in the upper stratosphere and lower mesosphere at high latitudes, where air moistened by methane oxidation has descended. Since ERA-40, the parametrization of methane oxidation has been modified to take into account a more recent climatology of methane, so that the dry bias of the current operational ECMWF model should be smaller than in ERA-40. In the lower stratosphere, the ECMWF water vapour field shows a too rapid upward progression of the annual cycle of drying and moistening in the tropics (the so-called “tape-recorder”).

MIPAS water vapour values are larger than ECMWF values in most of the stratosphere. The departures are around 40% in many areas. While the ECMWF model is known to have a dry bias, this bias should not be larger than 10-15%, and is hence not large enough to explain all of the departures. Even if the ECMWF dry bias is taken into account, MIPAS water vapour data still show a moist bias of over 20%. The moist bias has not been reduced in the re-processed MIPAS data. It is similar to, or even slightly larger than, the bias the operational NRT level 2 (L2) MIPAS retrievals showed relative to ECMWF values over the period 2002-2004.

Cloud contamination was a problem for operational NRT MIPAS L2 water vapour (and ozone) retrievals in the tropics over the period 2002-2004, and also over the South Pole in 2003 where Polar Stratospheric Clouds (PSCs) affect the retrieval from June to September 2003. This resulted in unrealistically large MIPAS water vapour (and ozone) values in the lower stratosphere. This problem is greatly reduced in the re-processed MIPAS data and hardly any unrealistically large values are seen in the September 2002 data. Fig. 2 illustrates this.

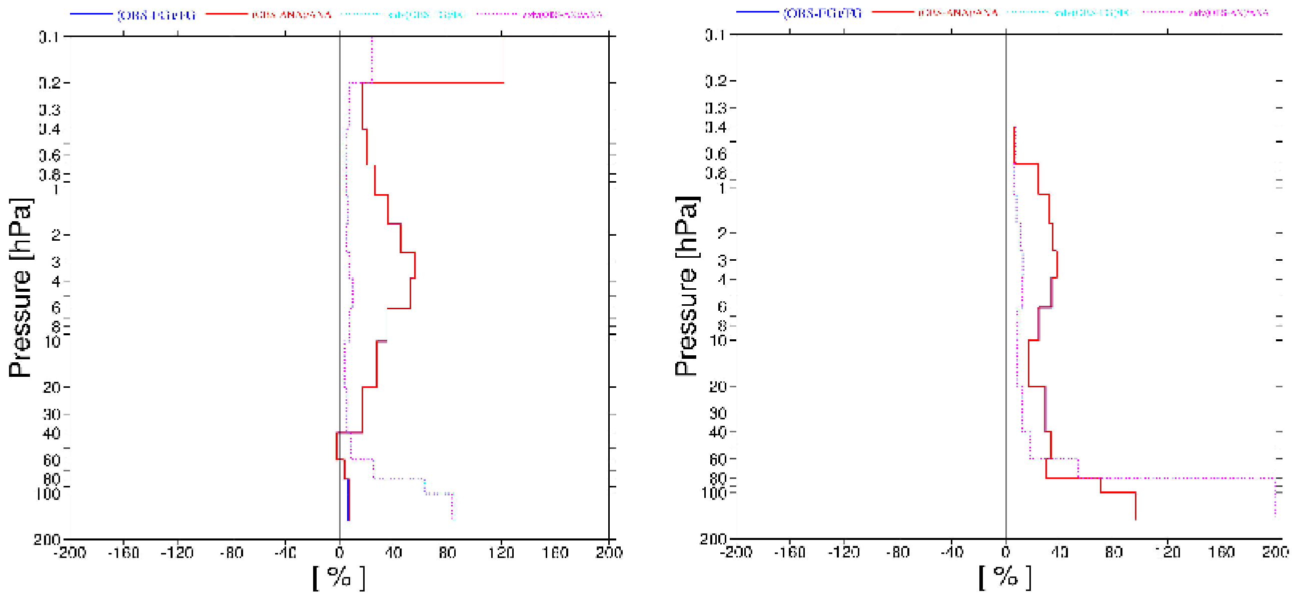

Fig. 2. Left-hand plot: Re-processed MIPAS data (12-28 September 2002; Equator-20^{o}N); right-hand plot: operational NRT MIPAS data (17 Feb – 30 May 2003; Equator-20^{o}N). The solid line depicts the bias of the O-A differences (observation minus analysis) normalised by the analyses: (O-A)/A. The dotted line depicts the standard deviation of the O-A differences normalised by the analyses: stdev(O-A)/A. In all cases, the statistics are calculated for the time periods and spatial extent indicated above. Y-axis is pressure from 0.1 hPa (top) to 200 hPa (bottom). Units are %.

2.3. BIRA-IASB

The strategy followed by BIRA-IASB was to first evaluate the water vapour analyses from the assimilation of NRT MIPAS water vapour into the Belgian Assimilation System of Chemical Observations from Envisat (BASCOE) with HALOE data. The comparison was made for sunrise and sunset events (HALOE is a solar occultation sounder). After establishing the quality of the NRT water vapour analyses, they were compared against the re-processed MIPAS water vapour data. This final comparison was then used to provide a qualitative evaluation of the re-processed MIPAS water vapour data.

Figs. 3-4 below show the following:

- The NRT MIPAS water vapour analyses are dry with respect to HALOE data for pressures lower than 1 hPa, and wet with respect to HALOE data for pressures higher than 1 hPa. Note that the sunrise comparison should be disregarded above 1 hPa, due to problems with HALOE data (Dominique Fonteyn, pers. comm.).
- The NRT MIPAS water vapour analyses are dry with respect to the re-processed MIPAS water vapour data.
- The re-processed MIPAS water vapour data are qualitatively similar to HALOE data.

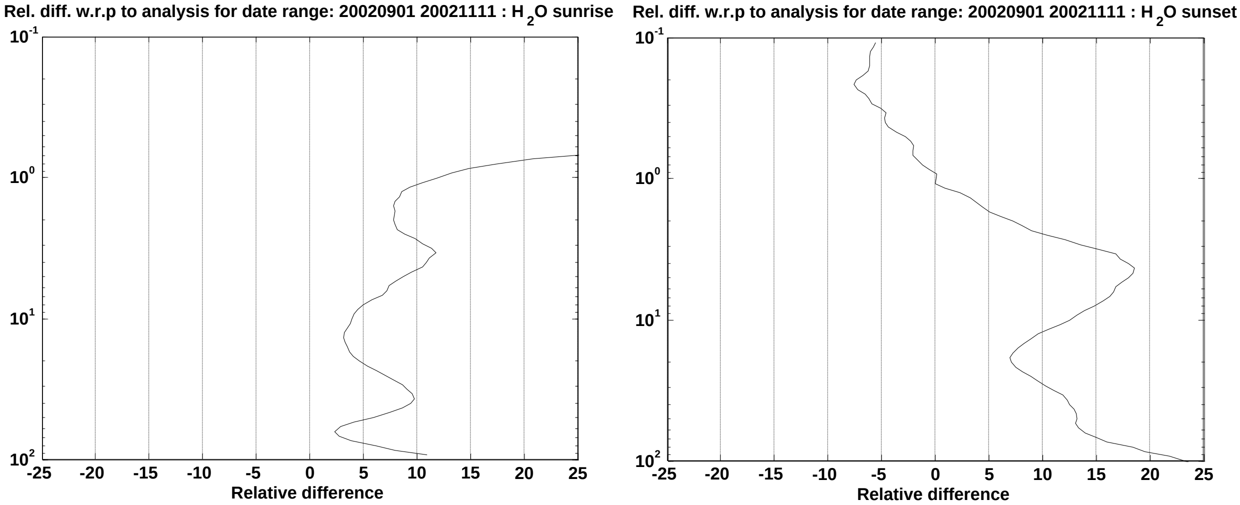

Fig. 3. Relative differences between HALOE (H) and NRT MIPAS analysed water vapour fields (A), normalised by the NRT analyses: (H-A)/A. Data is averaged over the period 1 September 2002 – 11 November 2002. Left-hand plot: sunrise comparison; right-hand plot: sunset comparison. Y-axis is pressure from 0.1 hPa (top) to 100 hPa (bottom). Units are %.

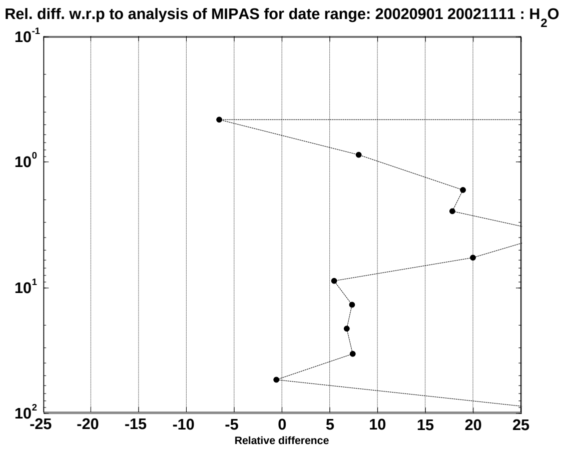

Fig. 4. Relative differences between re-processed MIPAS data (R) and NRT MIPAS analysed water vapour fields (A) normalised by the NRT analyses: (R-A)/A. Data is averaged over the period 1 September – 11 November 2002. Y-axis is pressure from 0.1 hPa (top) to 100 hPa (bottom). Units are %.

3. CONCLUSIONS

- There is a need to think what is the best control variable when assimilating water vapour in the troposphere-stratosphere. Work is ongoing at the Met Office and DARC (as well as at ECMWF) to address this issue. This issue is less important for BIRA-IASB, because they assimilate water vapour data into a stratosphere model.
- Re-processed MIPAS water vapour data have less cloud contamination in the tropics than the NRT MIPAS water vapour data.
- Based on the very preliminary studies presented, in the stratosphere (pressures 100 hPa –1 hPa) the re-processed MIPAS water vapour data show a wet bias against ECMWF analyses (of about 20%), but are qualitatively comparable to HALOE data. For levels in the mesosphere (pressures lower than 1 hPa), the re-processed data show a wet bias against HALOE data.

4. REFERENCES

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