EVALUATION OF MIPAS AND SCIAMACHY DATA USING DATA ASSIMILATION

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ABSTRACT/RESUME

The evaluation of MIPAS and SCIAMACHY data using data assimilation carried out in the ASSET project is discussed. The EU-funded Assimilation of Envisat (ASSET) project involves assimilation of Envisat atmospheric chemistry and temperature data into several Numerical Weather Prediction and chemical transport models. Envisat was launched in 2002 and is one of the largest Earth Observing satellites ever built. It carries several sophisticated Earth observing instruments providing insights on chemistry and dynamics of the atmosphere.

1. INTRODUCTION

The ASSET project aims to provide analyses of atmospheric constituents based on the assimilation of observations from Envisat, and to develop chemical weather and UV forecasting capabilities. Data are assimilated into several data assimilation (DA) systems, including Chemical Transport Models (CTMs) with detailed chemistry or simple chemistry, and Numerical Weather Prediction (NWP) systems based on General Circulation Models (GCMs), either with simple chemistry, or coupled to detailed-chemistry CTMs. DA techniques (e.g. [1]) include three- and four-dimensional variational data assimilation (3D-Var and 4D-Var, respectively), and Kalman Filter (KF) methods. By confronting these various models and techniques with the newly available Envisat observations, it was possible to evaluate the MIPAS and SCIAMACHY data. In particular, the following tests were carried out: (i) self consistency tests to assess a posteriori error assumptions in the MIPAS data and the Met Office NWP model [2], and (ii) comparison of MIPAS and SCIAMACHY ozone analyses against independent data to estimate the accuracy and precision of the ozone analyses and the Envisat data, in the ASSET Intercomparison of ozone analyses project, ASSIC [3-4].

2. RESULTS

Eleven sets of analyses from seven different DA systems (2 NWP model systems based on GCMs and five chemical model systems based on CTMs) participated in the ASSIC project. The DA systems contain either linearized or detailed ozone chemistry, or no chemistry at all.

All but two of the analysis runs assimilate MIPAS height-resolved ozone data; the others assimilate SCIAMACHY total column ozone data. Both GCMs and CTMs are represented, and ozone chemistry may or may not be modelled. If included, it is done either by highly detailed photochemical schemes, or via a parametrization often known as a Cariolle scheme (e.g. [5]-[7]). The Cariolle scheme is a linearization of ozone photochemistry around an equilibrium state, using parameters derived from a more detailed chemical model.

Most of the analyses are focused on the stratosphere, but the scope of the ASSIC project spans from the troposphere to the mesosphere. Analyses are interpolated from their native resolution onto a common grid and then compared to independent ozone data from the Halogen Occultation Experiment, HALOE [8], ozonesondes [9-11] and TOMS [12], and to MIPAS [13-14]. More details of the quality of the MIPAS data are provided in [2-3, 15-16]. Most data, figures, and code are publicly available via the project website (http://darc.nerc.ac.uk/asset/assic).

The ASSIC project compared analyses produced for the period July – November 2003. This period was

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chosen because of the availability of high quality MIPAS ozone data [2]. Statistics were built up from the difference between analyses and observations (O-A differences). The statistics were binned into the following regions: 90ºS – 60ºS; 60ºS – 30ºS; 30ºS – 30ºN; 30ºN – 60ºN; 60ºN – 90ºN. Statistics were binned monthly; also for the entire period 18th August 2003 – 30th November 2003 (before 18th August 2003 one of analyses was not adequately spun up).

Because ozone amounts vary by orders of magnitude throughout the atmosphere, the statistics were normalized with respect to climatology due to Fortuin, Kelder and Logan (see [3] for further details) and displayed as a percentage. In this way, all regions in the atmosphere are given approximately equal weight.

The ASSIC project focused on various aspects of the statistics of the O-A differences (biases, standard deviations, and MIPAS evaluation), and on various regions of the atmosphere where chemistry plays an important role, or models and observations may be particularly challenged (upper stratosphere and mesosphere, the ozone hole, and the tropical tropopause). We focus on the overall results that provide a flavour of the ASSIC project, and refer the interested reader to [3] for more details.

Figure 2 shows that throughout the stratosphere (50 hPa – 1 hPa), O-A biases are usually within ±10% compared to the HALOE instrument. Figure 3 shows that throughout the stratosphere (50 hPa – 1 hPa) O-A standard deviaions are usually within 10% compared to the HALOE instrument. Similar results are found against ozonesondes for both the O-A biases and standard deviations (see [3]).

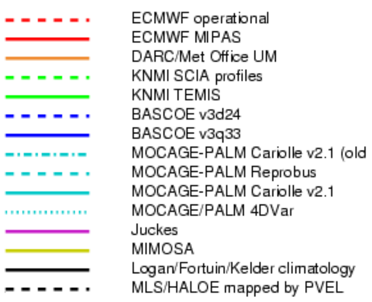

Figure1. Colour key for Figures 2 and 3. © ACP.

Biases and standard deviations in the O-A differences are larger in the upper troposphere / lower stratosphere, in the troposphere, the mesosphere, and the Antarctic ozone hole region. In these regions, some analyses do substantially better than others, and this is mostly due to model differences. At the tropical tropopause, many analyses show positive biases and excessive structure in the ozone fields, likely due to shortcomings in assimilated tropical wind fields and a degradation in MIPAS data at these levels. In the Antarctic ozone hole, only the analyses that correctly model heterogeneous ozone depletion are able to reproduce the ozone destruction over the South Pole [3-4]. In the upper stratosphere and mesosphere (levels above 5 hPa) some ozone photochemistry schemes caused large but easily remedied biases. The diurnal cycle of mesospheric ozone is not captured, except by the one system that includes a detailed treatment of mesospheric chemistry [3].

Using analyses as a transfer standard, and treating MIPAS observations as point retrievals, it is seen that MIPAS ozone is ~5% higher then HALOE ozone in the mid and upper stratosphere and mesosphere (levels above 30 hPa), and ~10% higher than ozonesonde and HALOE ozone in the lower stratosphere (100 hPa – 30 hPa), see Figure 4.

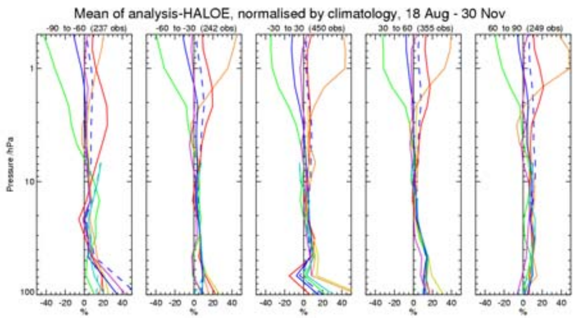

Figure 2. Mean of Analysis-HALOE differences, normalised by climatology, and averaged over 18th August – 30th November. The means are binned into five latitude bins: 90°S-60°S; 60°S-30°S; 30°S-30°N; 30°N-60°N; 60°N-90°N. Figure 1 gives the colour key for the curves. © ACP.

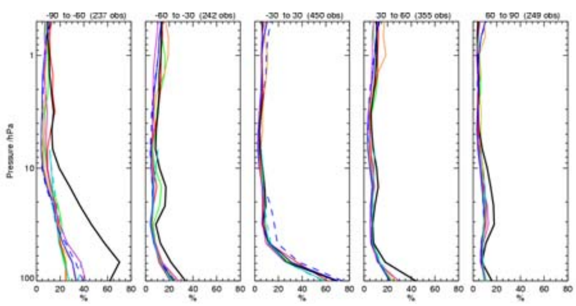

Figure 3. As Figure 2, but for the standard deviation of the Analysis-HALOE differences. Figure 1 gives the colour key. © ACP.

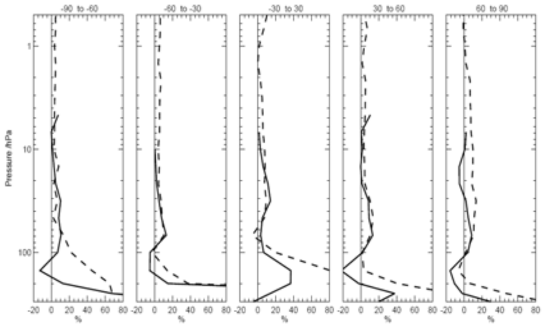

Figure 4. Estimates of the mean (MIPAS-HALOE; dashed line) and (MIPAS-sondes; solid line) using BASCOE v3q33 analyses as a transfer standard, and normalising by climatology, in latitude bands for the period 18 August – 30 November 2003. © ACP.

3. CONCLUSIONS

Based on the results from the ASSET analyses intercomparison project, the quality of MIPAS and SCIAMACHY analyses and data is as follows:

MIPAS (v4.61):

- The precision of MIPAS ozone analyses, based on the standard deviation of (O-A) (see [3]), is less than 10% versus HALOE and sondes between 50 hPa and 1 hPa. This provides an upper bound to the precision of the MIPAS ozone data.

- The accuracy of MIPAS ozone data, using BASCOE v3q33 analyses as a transfer standard (Figure 4), is ~+5% above 30 hPa and ~+10% between 100 hPa and 30 hPa.

- Based on results reported in [2], the assumption of Gaussian errors in the observations and model is justified for the stratosphere (100 hPa - 1 hPa).

SCIAMACHY (TOSOMI ozone columns; IFE v1.6 profiles):

- The precision of SCIAMACHY ozone analyses, using either total column ozone or ozone profiles, based on the standard deviation of (O-A) (see [3]), is less than 10% versus HALOE and sondes between 50 hPa and 1 hPa. This provides an upper bound to the precision of the SCIAMACHY total ozone column and ozone profile data.

- The accuracy of SCIAMACHY ozone analyses from SCIAMACHY total column ozone, based on the bias of (O-A) (see [3]), is ~+10% between 50 hPa and 5 hPa. Above 5 hPa the bias becomes negative and increases (in magnitude) with height.

- The accuracy of SCIAMACHY ozone analyses from SCIAMACHY ozone profiles, based on the bias of (O-A) (see [3]), is negative between 200 hPa and 30 hPa, with a largest (negative) bias of ~-20%. To estimate the accuracy of the SCIAMACHY data an estimate of the errors in the assimilation models is required. This is work in progress and outside the scope of this paper.

As shown by the ASSET project, DA is a valuable tool for evaluating observations. It is recommended that data assimilation be incorporated as a standard method for the evaluation of observations.

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