

## ***Interactive comment on “The ASSET intercomparison of stratosphere and lower mesosphere humidity analyses” by H. E. Thornton et al.***

**H. E. Thornton et al.**

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We thank Referee 1 for their instructive comments. Please find below detailed comments on how we propose to address them.

1) The scientific motivations for the paper will be added into the abstract as:

In line 4 after ‘..(ASSET) project’ and before ‘With the availability.’ add: ‘Stratospheric water vapour plays an important role in many key atmospheric processes and therefore an improved understanding of its daily variability is desirable’

2) In line 3 prior to ‘Assimilation of Envisat Data’ add ‘EU funded framework V’

3) In line 29 on page 13511, after ‘for research.’ and before ‘The period of intercom-

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parison' add: 'A summary of the quality of MIPAS data is given in section 3.'

4) Prior to section 2.1 add: 'This section describes the different DA schemes used in the study. MIPAS data, as described in Section 3.1, were assimilated in all the assimilation systems. The selection of MIPAS data for each experiment was not identical, but depended on the quality control procedure used in each system'.

5) The analysis resolution is much less than the model resolution due to practicalities and cost implications, this is common in forecast models. To clarify, line 25 on page 13512 will be changed to:

'The assimilation scheme was incremental 4D-Var with a 12-h cycle. The model horizontal resolution is T511 ( 40km), but the assimilation is carried out at a horizontal resolution of T159 ( 125 km). There are 60 levels in the vertical up to 0.1hPa.'

6) At line 13, pg 13513 add after "The assimilation of Global Positioning System Radio Occultation (GPSRO) ... (Healy and Thepaut 2006)" (note the slight mod to location of GPSRO):

"Other observations included the usual set of conventional and aircraft observations, clear-sky radiances from the ATOVS instruments, AIRS, SSMI, and geostationary satellites, Atmospheric Motion Vectors from geostationary and polar satellites, scatterometer data, as well as ozone retrievals from the SBUV instrument onboard NOAA-16. All of these observations show little or no sensitivity to stratospheric humidity."

Next paragraph, add at the beginning: "In addition, ..."

7) Page 13514 Line 24, after 'simultaneously' and before 'as described..' add: 'with a 24 hour cycle,'

8) Page 13514 line 25 modify to read:

'The BASCOE background error spatial covariances are diagonal (i.e. all off-diagonal elements are set to zero) with a standard deviation equal to 20% of the background

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humidity field. Increments are spread in the horizontal due to the observation operator averaging points in and around the grid point in question. There are no cross-correlations between different analysis variables (see also the discussion in Errera et al., 2008, Sect. 4). Finally, BASCOE includes ...'

9) Start paragraph 2 of section 2.3 with the last two sentences of this paragraph, i.e. 'In this study,...in the analysis.'

10) in line 17 of page 13515 replace 'forecast error' with 'background error'

11) Line 19 on pg 13515, modify: '..and Chang (2000). The off-diagonal elements are the product of the square root of these variances and a correlation function that is flow-dependent and specified in terms of distance and PV (El Amraoui et al, 2004). PV is a quasi-conserved..."

4 lines later replace "(in distance and PV)" with "(as discussed above)".

12) On line 22 pg 13515 after 'short time scales' add '(i.e. a few days)'

13) Note for the referee: The representativeness errors include two types of errors: errors in the observation operator and errors arising from the fact that the model does not fully resolve the scales measured by the observations. Even if one assumes that the latter source of errors is not significant (which is not obvious with the model resolution of 100 km whereas limb data have a resolution of couple of hundreds of km), the former source cannot be totally negligible in our case, especially in the regions of strong gradients. Indeed, the interpolation of the state variable from the horizontal locations of the model grid points to the locations of the observations is a simple bilinear interpolation. To clarify we will add:

Pg 13515 line 25:

After '...model domain' add ', reflecting the error associated with interpolating to the observation location and resolution differences between the observations and model.'

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14) Prior to section 3.1 add:

'This section describes the observational data used in this study, including the MIPAS data assimilated, the independent observations used for validation and the climatology used to better visualise the biases. A description of both the instrument and its accuracy is given.'

15 - 17) Lines 11-20 pg 13519: Replace

'(<http://code916.gsfc.nasa.gov/Public/Analysis/UARS/urap/home.html>). The data selected are the extended HALOE/MLS dataset, which gives humidity profiles up to 0.1 hPa. A zonal monthly mean data field is available for the baseline period (April 1992 to March 1993) and an extended period (which includes the baseline period), 15 the latter is used here. A water vapour climatology field was created on the intercomparison grid, for every 6-h period over the intercomparison. This was done by linearly interpolating the monthly mean files in time, by assuming the UARS monthly mean files represent the 15th of every month. Polewards of 80 degrees in the stratosphere and polewards of 65 degrees in the mesosphere, horizontal extrapolation at a constant value extended the climatology.

With:

'(<http://code916.gsfc.nasa.gov/Public/Analysis/UARS/urap/home.html>). The data selected are the extended HALOE/MLS dataset, which gives humidity profiles up to 0.1 hPa, in the form of zonal monthly mean fields. A water vapour climatology field was created on the intercomparison grid (described in section 4), for every 6-h period over the intercomparison. This was done by linearly interpolating the monthly mean files in time, by assuming the UARS monthly mean files represent the 15th of every month. The UARS monthly mean fields are only available up to 80 degrees north/south in the stratosphere and to 65 degrees north/south in the mesosphere. MIPAS and the independent data are available at higher latitudes and consequently the climatology was extended horizontally at constant value. Although this assumption may modify the

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relative biases, it was felt justified to enable the higher latitudes to be analysed.'

18) - S4, P2, L1: Comment to Referee: This was done to enable the calculations of observation and analysis comparisons to be easier and more computationally efficient. We agree that it may have been better, with hindsight, to allow the vertical resolution of each observational dataset to have been retained, as the referee suggests. However, the sensitivity of the results (for ozone) to resolution was examined by Geer et al (2006). They show little sensitivity and we feel the same conclusions can be applied to water vapour. These arguments are already in the text so we feel there is no need to further alter the text here. However, we are aware that a different approach could be taken in future studies".

19) Line 7, pg 13520. Replace 'The observations that are...flagged as missing.' With:

'The observations that are used in the intercomparison have been quality controlled. For each profile, at each level, the observation must not be greater than the UARS climatology by more than 120%, otherwise it is flagged as missing. This has the impact of removing the observation profiles which are significantly different from the climatology, effectively removing outliers. None of the HALOE profiles were removed by this process, however 2%, 8% and 12% of MIPAS, SAGE II and POAM III profiles were removed respectively. The UARS climatology was made up of HALOE and MLS observations and therefore explains the good agreement between the HALOE data and the climatology. The removal of the other outlying observational profiles avoids poor data skewing the biases. For example, prior to the data consistency check, the extra SAGE II data produced very large biases in the southern hemisphere mid latitude lower stratosphere. The loss of data due to the quality control procedure is sufficiently small to avoid any significant loss of data coverage.'

20) Comment for the Referee:

The ozone intercomparison looked at the impact of changing the resolution of the common grid on the observation - model biases in different regions of the upper atmo-

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sphere. In high latitudes where the transport timescales can be shorter than the parameterization timescales, e.g. during the vortex break up, the mean differences were not found to be affected by grid resolution. In lower latitudes, the Brewer Dobson transport timescales are considerably shorter than water production by methane oxidation and again the impact of the grid resolution was minimal. In the UTLS, the temporal resolution was found to be most important and consequently a short temporal resolution of 6 hours was therefore chosen.

To clarify the text will be altered in the following form:

Page: 13520, line 15 after ' than 12hr.' and before 'Like ozone...' add:

'For example, in regions of rapid transport such as the polar vortex, or within the slow ascent of the tropics, the grid resolution had little impact on the mean differences. In the mid-latitude UTLS, the temporal resolution was found to be more important and therefore the comparison was completed every 6 hours.'

21) Comment for Referee: Unfortunately, such observations are not automatically blacklisted. We will add the following information to give more detail at line 2 pg 13521: after "...inflicting a wet bias in the specific humidity field down to about 0.5 hPa." Add:

"Some MIPAS partial columns were partially above the top of the ECMWF model, and for the part above the model top, the model humidity was erroneously taken to be zero."

and:

"... we will therefore discard the ECMWF analyses above 0.5 hPa. This limit was chosen on the basis of departure statistics for MIPAS retrievals and background error correlations."

22) Line 6 page 13521 replace ' to enable normalisation of the analyses.' with 'the relative difference in the biases with height to be seen.'

23) replace lines 22 on pg 13521 to the end of the paragraph with:

"The presence of a layer of dry ( 3ppmv - parts per million by volume) air around the 100-200 hPa suggests that some of the air coming into the stratosphere in the tropics may be being transported rapidly polewards. This is in agreement with previous observational studies (e.g. Jackson et al, 1998). There is also an indication of slow upward transport....Near the stratopause (near 1 hPa) the water vapour patterns are consistent with overturning of the stratospheric air related to a change in the pattern of the Brewer-Dobson circulation. This change implies the replacement of upward low latitude transport by poleward transport and associated downward transport at high latitudes of moist air from the upper stratosphere / lower mesosphere to lower levels. This pattern is most apparent in the winter high latitudes, where downward transport is stronger".

Reference is: Jackson DR, Burrage MD, Harries JE, Gray LJ, Russell JM (1998).The semi-annual oscillation in upper stratospheric and mesospheric water vapour as observed by HALOE. Quart J R Met Soc, 124, 2493-2515

24) Line 10 pg 13523 replace 'The tropical water 133;dehydrated the rising air.' with:

'As described by Kley et al (2000), the tropical water vapour minimum is generated around February, when the coldest tropopause temperatures have dehydrated the rising air.'

25) Line 23 on pg 13523 replace 'from 50-100hPa' with 'at 68hPa'

and replace lines 1-2 on pg 13524 with

'standard deviations of the analysis departures are approximately 15% for all three analyses (Fig. 6).'

26) PSC is already written out in full in paragraph 2.2.

27) lines 28-3 on pg 13524/5 replace with:

'ECMWF and BASCOE have larger dry biases of 20% and up to 60% respectively,

and standard deviations ranging between 10% and 40%. The BASCOE dry bias and standard deviation peak at 30hPa in the Southern Hemisphere high latitudes reaching 60% and 35% respectively. This large bias is likely to relate to the chemistry scheme applied in the BASCOE system and is discussed later in this section. Figure 7...'

28) Page 13528, line 14, after 'loading in 2003' and before ', which would not have..' Add:

'(due to the last major volcanic eruption occurring in 1991)'

29) At the end of line 23 pg 13529 add:

'Between 1-2hPa at most latitudes, there is a large dry bias of the analyses with respect to the SAGE II data, that is not seen when compared to the other observations. As discussed in section 3, the SAGE II data is found to be noisy in this region and gives wetter readings than the other satellite data. The poor quality of the SAGE II data in this region is therefore likely to be responsible for the large biases seen.'

30) Line 12-14 on pg 13530 Replace 'If a grid point ...similar increment' with 'Even if a grid point that is relatively far from a MIPAS observation has a similar PV value as found at the observation location, it will be given a similar water vapour increment.'

31) Comment to Referee: PV fields are well known to be patchy because PV is highly derived quantity. The question is not whether the PV fields are patchy but whether the dependency of the correlation function on PV is responsible for the patchy nature of the analysed H<sub>2</sub>O fields in MIMOSA. To address this, the text in the next point has been added.

32) Line 15 pg 13530 replace 'Consequently, although ...poor quality observations' with 'Consequently, although the MIMOSA analyses compare most favourably with the MIPAS observations, the smoother ECMWF and BASCOE stratospheric water vapour fields are closer to what one might expect from a water vapour field that is determined mainly by the large scale circulation, photochemistry and location specific dehydration

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(Kley et al., 2000). However, there is insufficient knowledge of the daily stratospheric water vapour field to assess whether the inhomogeneities of the MIMOSA analyses may in part be realistic.'

Line 7 pg 13530, after 'vapour field' add ' throughout the depth of the stratosphere'

33) Line 20 pg 13531 after 'continuity of the run.' Add 'Without this pre-imposed limit, after a couple of weeks of assimilation, due to unrealistically large humidity analysis increments, the stratospheric water vapour field reached significantly higher values and resulted in the failure of the run. The limit of 12 ppmv was chosen to ensure that the experiment ran without failure but also to allow plenty of scope for more realistic humidity analysis increments to be retained by the system.'

34) Line 21 pg 13531, replace 'The general Met....or parameterisations.' With:

'The Met Office bias with respect to the MIPAS observations shown in Fig. 12 can be seen after one 6-hr assimilation window, when starting from a realistic background. It is therefore clear that these biases relate directly to the assimilation scheme and its resultant humidity increments, rather than the model dynamics or parametrizations.'

35) Comment for Referee: Yes, although covariances will also have been developed for the other control variables. To clarify the following text will be added:

Line 8, pg 13532 change 'NMC covariances' to 'NMC temperature covariances'

36) Line 4 on pg 13534, after 'is very similar.' Add: 'It is not easy to apply the ECMWF covariances to the Met Office DA scheme, due to the different model formulations, however the use of ensembles to generate covariances is being further developed at the Met Office.'

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Interactive comment on Atmos. Chem. Phys. Discuss., 8, 13507, 2008.

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