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Atmospheric Chemistry and Physics Discussions

Interactive comment on "4D-Var Assimilation of MIPAS chemical observations: ozone and nitrogen dioxide analyses" *by* Q. Errera et al.

Q. Errera et al.

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We thank A. Geer for his constructive comments. Our responses are preceded by A. Geer's comments given in italics.

Specific Comments

1 - p8011 l22: "for the first time" - this is probably the first time for a CTM with detailed chemistry, but Juckes (2007, ACP, "An annual cycle of long lived stratospheric gases from MIPAS") assimilated a year of MIPAS ozone, water vapour and methane with a nochemistry model. Juckes also compared MIPAS ozone with HALOE and POAM using assimilation as a transfer standard, so it would be worth mentioning his results in section 5.3.

Indeed Juckes (2007) should be mentioned. We also note that Juckes does not use

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the transfer standard method to compare MIPAS and independent data. In his study, assimilated fields of MIPAS are directly compared to independent data to derive cal/val information.

2 - p8012 l19: "The monitoring procedure ... optimal" - it might be better to explain what this is and why it is 'optimal', e.g. the observations are passively monitored within the assimilation system, using a model-to-observation operator, as is often done in NWP.

This has been clarified.

3 - p8014 l1: I'd be interested to know how this system is different or similar to the one evaluated in the ASSET intercomparison, and this information would also be useful when the ozonesonde results from that study are mentioned on p.8025.

The only difference between the two versions that affects the results is the data filter. As mentioned in sec 2.2, there are 44 days where the minimization is not attained. For those days, all observations for levels above 3 hPa and for latitudes poleward of $|\pm 50°|$ are now filtered out, allowing minimization to be attained for these days also. This filter was not implemented in the version discussed in Geer et al. This difference and its implication for the results of the old version are explained in the revised version of the paper.

4 - p8015 l28 "minimization is not attained" - in my experience, though in a very different system, when the M1QN3 fails to minimise the cost function, the 'analysis' state remains very close to the background state. Is that the case here? If so, that would suggest that for these 44 days your analyses are really just a free model run, and do not properly assimilate the MIPAS observations. If so, I'd be worried about keeping these days in the comparison with independent data (p8016 l13). Can you also reassure the reader that when the minimisation fails the analyses are left in a geophysically sensible state and not, for example, left in some kind of completely erroneous mess?

Indeed, when the minimization is not attained, the analysis corresponds to a CTM run

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initialized by the background state. This means that in any case, the analyses could not lead to "completely erroneous mess". On the other hand, we remind the referee that for this paper, the days without minimization are reassimilated with data above 3 hPa and poleward $|\pm 50°|$ are filtered out. So, in the end, all assimilated days produced a minimization.

5 - p8020 l19 I think this paragraph on the MIPAS observation error needs a bit more explanation, e.g. what is the total error, what is it based on, how does it differ from other kinds of error mentioned in the text, particularly the observation error used in the data assimilation scheme?

The MIPAS error is now described in more detail.

6 - p8020 l26 "MIPAS total errors .. are ... close to the total errors" - I'm confused! It seems you are using one name for two different concepts.

Indeed, this is confusing and the sentence has been replaced.

7 - p8021 l10 "A better filter..." - I can't see how this proposal would allow observations of enhanced NO2 coming from SPEs to be assimilated?

In the case of our study, data are filtered out if they are too far away from the background state which represents the reference state. A more appropriate choice of the reference state would improve the data filter. For example, for a domain of similar conditions, taking the median value of the observations would be a good reference state.

8 - p8021 Section 5.1 - It's worth making clear that comparing MIPAS analyses to MIPAS is basically a test of the quality of the assimilation algorithm, and an opportunity to demonstrate the areas where the data is of benefit to the system - not an independent verification.

Indeed, comparing the analyses with the assimilated observations is just a verification. The introductions of Sect. 5.1 and 6.1 has been amended to clarify this point.

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9 - p8022 Fig. 2 and MIPAS total error. Which "total error" is being shown? (See point 8).

The MIPAS total error is shown, i.e., the instrumental (random) error plus the systematic error.

10 - p8022 Fig. 2 and MIPAS total error. It's good to have a reference point by which to judge the size of the biases and standard deviations of (MIPAS - analysis) statistics, but can you justify using total error here? There are a number of things that worry me about this. First, if total error is made up of systematic and random components, surely you should be showing just the systematic part on the bias plots, and the random part on the standard deviation plots? But a still better measure of self-consistency of analysis, observation, observation error and background error would be to do something like the chi squared test, e.g. Menard et. al (2000, Mon. Weath. Rev, "Assimilation of Stratospheric Chemical Tracer Observations Using a Kalman Filter. Part II ...") who looked at observation minus first guess statistics. See Rodgers et. al. (2000, World Scientific, "Inverse Methods for Atmospheric Sounding") eq. 12.9 for the equivalent expected covariance matrix for observation minus analysis departures.

It is true that bias and standard deviation should be compared to systematic and random error, respectively. This has been corrected. The chi squared test (or the cost (J) weighted by the number of observation (p) test, which is an equivalent test under several assumptions, see: Talagrand, O.: A posteriori validation of assimilation algorithms, in: Data Assimilation for the Earth System, NATO ASI Series, edited by: Swinbank, R., Shutyaev, V., and Lahoz, W. A., Kluwer, 85-95, 2003c) allows one to check if errors are correctly specified. It is a necessary condition, not a sufficient condition. It also provides no indication about what is wrong if the test fails. Moreover, this test is usually based on assimilated data so it does not help to understand the impact of the data filter. Sect. 5.1 and 6.1 have been modified to take into account the referee's comment.

11 - p8023 l1 - would not the errors of MIPAS (e.g. when clouds influence the observa-

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tion) also be a factor in the troposphere?

Yes, this will be commented.

12 - p8024 l12 - why would extra model layers improve the photolysis calculations? Because the UV radiation reaching 0.5hPa would be more accurately modelled?

Tables of photolysis rates are computed offline by a UV radiative transfer model that starts at 120 km altitude, using five standard profiles of ozone. BASCOE then interpolates these tables as a function of the altitude, the solar zenith angle and the ozone column above each grid point. Since the ozone column is not known above the model lid, it is simply set to a constant value of 0.02 Dobson Units above 0.1 hPa. This approximation should have a negligible impact two or three levels below the lid, i.e. below 1 hPa. Adding extra model layers above 0.1 hPa would be a simple way to improve the photochemistry of short-lived constituents between 0.1 and 1 hPa.

13 - p8029 l14 - "rejected data are filtered out due to their variability and not because ...the conditions are not modelled". I don't understand how this statement is justified.

At the Poles (N and S), bias and standard deviation plots of stat1 and stat2 diagnostics are close to each other while the number of assimilated data are significantly lower than the total number of available observations. We conclude that the filter has worked correctly and that rejected data were probably outliers. The sentence has been reformulated.

14 - p8030 l7 - "this is due to the .. low amount of NO2" - but please remind us of the link between the low amount of NO2 and the fact that the observations are rejected.

Indeed, this sentence is confusing and has been removed.

Technical corrections

15 - p8015 l4 "background covariance" - it is the background ERROR covariance

16 - p8020 l23 "important" -> "high"

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This has been corrected.

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