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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Impact of meteorological analyses and chemical data assimilation on modelled long-term changes in stratospheric NO₂" *by* L. N. Gunn et al.

Anonymous Referee #1

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This study presents the results of several SLIMCAT runs from 1977 to 2003. One run is a free model simulation driven by the ECMWF ERA-40 reanalysis and the two other runs are based on the assimilation of HALOE observations (CH4, H2O, HCl and O3). HALOE CH4 data are also used to constrain N2O and NOy such that the tracer-tracer correlations in the model are preserved. The paper shows that the free model simulation is not able to capture the evolution of CH4, H2O and NO2 based on observations while the assimilation runs provide a much better agreement with these observations. The authors then argue that the lack of agreement of the free model simulation is due to errors in the ERA-40 dynamical fields.

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I found the focus of the study not very clear. It seems to be a continuation of Gil et al. (2008) but I don't see how the work of Gil et al. is extended here except that the datasets of three other ground-based stations are added. It also seems that the paper tries to evaluate the ERA-40 analyses, but this has already been done (Monge-Sanz et al., 2007; Meijer et al., 2004). Moreover, I do not believe that the method followed here is able to clearly identify that the model error mainly comes from ERA-40.

At this level, I see several shortcomings in the methodology as well as in the presentation which would make it difficult to upgrade the paper to ACP.

General comments

1. It is stated in the paper that the inability of the model (without assimilation) to reproduce the NO2 trend is attributed to the ERA-40 reanalyses. However, I see other sources of model error that are not discussed in the paper and which should be evaluated in comparison to the error introduced by ERA-40. First, uncertainties in the emission rates at the Earth's surface of CH4, N2O, CFCs are not discussed throughout the paper. Is this error negligible and is it quantified? Second, transport errors might be attributed to several other sources than the wind fields. For example, numerical diffusion of the advection scheme and the implementation of the wind fields in the model play also an important role. By wind implementation, I mean the way ERA-40 reanalyses are degraded to match the model grid as well as the error introduced by the time interpolation from the ERA-40 6-hourly analyses at the model time step.

2. Why did you use ERA-40 reanalyses in this paper instead of ERA-Interim? The latter is known to have solved most of the shortcomings found in ERA-40 and cover almost completely the period discussed in the paper (ERA-Interim starts in 1979 while the period studied in the paper starts in 1977). Moreover, I found the conclusions made in Sect. 3.4 a bit naïve as all the community already knows the issues of a CTM

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driven by ERA-40 (Monge-Sanz et al., 2007; Meijer et al., 2004). However, it would be interesting to make the same study using ERA-Interim to see if those wind fields are well suited to drive long CTM runs as those made by Feng et al. (2007).

3. In the paper, all observations are considered without error? The errors should be taken into account in the discussion, especially to assess if the bias between model runs and observations is significant.

4. Sect. 2 is confusing in some parts (mainly Sect. 2.2) and I would suggest the authors restructure it. Sect. 2.1 should describe the emission rates at the model surface as well as the setup of the aerosols (as this is a part of the model). Then I would include a new section (which should be Sect. 2.2) which describes the assimilation method (and the HALOE data). In the current manuscript, it is not very clear how assimilation of CH4 constrain NOy. Please clarify. Also, I did not understand how HCl constrains the other chlorine compounds. This should also be clarified. The new Sect. 2.3 (previously 2.2) should present the model experiments as done in the current manuscript but without the description of the assimilation method.

5. The analysis validation (Sect. 3.1) only uses two ATMOS profiles. These are far too few datasets to support the results in later sections. To improve the validation, other datasets must be used and the authors should also consider the comparison method discussed in Geer et al. (2006). Other datasets can come from the other ATMOS mission (as well as using the complete dataset of the November 1994 mission instead of two profiles), UARS MLS (1991-1997 for O3, H2O and HNO3), CRISTA (two short missions in November 1994 and August 1997, O3, CH4, N2O, HNO3, ClONO2, N2O5, CFCs), MIPAS (2002-2012, O3, CH4, N2O, H2O, NO2, HNO3, N2O5, ClONO2, CFCs) and ozonesondes. Moreover, why not compare model forecasts against HALOE? This is more a verification than a validation but it would be very interesting to see how SLIMCAT NO2 agrees with HALOE NO2.

6. There are several questions raised by figures 4 and 5 which have no answer in

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the text. First, it would be important to know if the runs that are compared to HALOE are the analyses or the forecasts (it should be the forecasts). Second, although run B agrees better with HALOE than run A, there are still some differences between run B and HALOE. For example, in Fig. 4, CH4 35N-60N at 3.2 hPa, there is a good agreement between run B and HALOE until 1995 while later, run B underestimates HALOE by around 0.05 ppmv. Ideally, assimilated data and analyses should agree within the error bars of the data. If this is not the case, this should be explained.

I would suggest the authors use the observation operator of the assimilation procedure to interpolate SLIMCAT at the HALOE location during the SLIMCAT run and save these values. This must also be done for run A even if HALOE data are not assimilated. Doing so, runs and data are averaged in the same way which removes the uncertainties that runs and data can be considered in different atmospheric conditions as, for example, if monthly average of HALOE data are compared to monthly average of SLIMCAT. It would also be useful to know what the assimilation time window is. In other words, do you update the model at every model time step when a HALOE profile is found or is this update done every day or month or for another time period? It is clear that the time difference between the observations and the assimilation should be reasonable in order to guarantee the fact that model and data are considered for the same atmospheric conditions.

Finally, section 3.2 is much more verification than a validation, as it compares the analyses against the assimilated data. Thus, I would place it before section 3.1.

7. The calculation of the differences between the NO2 observed total columns and the different runs seems to be done in a too simplistic way. As far as I understood, the comparisons given in Table 2 are based on the global means of the total column from the different datasets for the period 1992-2000. Instead, I would fit some parameters of a model to the different datasets. Then, I would verify that the fit is successful, i.e. the model is well chosen. And finally, I would compare the different parameters obtained by the different fits. I am not an expert on trend studies but I presume that the model to fit

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should include a periodic component and a linear component. A bibliographic research would certainly allow one to find the correct model to fit. Once this is done, it would be easy to detect any offset between the different datasets as well as to compare the value of the trend and the amplitude of the annual variation. Last but not least, I would use the fitted model to display the NO2 sunset-sunrise ratio in Fig. 8 instead of the data shown, as it would provide clearer information.

Specific comments

1. P12025 L7: For a report as here (WMO (2006)) or for books, please, provide also the section or chapter. Please, also correct for other WMO citations throughout the paper.

2. P12026 §1. It would be worth mentioning the review papers on chemical data assimilation written by Lahoz et al. (2007) or Lahoz and Errera (2010).

3. P12024 L17: replace "model-observation" by "model-minus-observation".

4. P12027 L21,23: Please, provide the chapter or section for the reference WMO (2002).

5. P12028, L6-8: "Our CTM also averages the ECMWF analyses (available as spectral coefficients) onto the particular model grid used in a method which reduces noise that can occur when interpolating grid point winds." Please, provide a reference or provide some information on this averaging method.

6. P12028 L16: Are you sure that the reference here is Chipperfield (2003) and not Chipperfield (2002). The former reference seems not to discuss data assimilation. Please, check.

7. P12028 L25: " . . . to correct for any model transport errors." What about errors in

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the chemical scheme of SLIMCAT or in the emission rates?

8. P12028 L25-26: What do you mean by ". . . overwritten at the surface . . ."?

9. P12029 L5-8. I do not understand what you mean about (1) the limit on Cly and (2) how this impacts the configuration of the assimilation of HCl.

10. P12029-30: An introduction on ATMOS should be given.

11. P12031 L7: ". . . in run A reflect changes in the model transport . . ." What about the change in the emission rates of CH4?

12. P12031 L20: replace "transport error" by "model error".

13. P12032 L11-12: "Moreover, the modelled NO2 trend over this period agrees with the observations." To write this sentence, you should make a proper estimation of the NO2 trend from the observations as well as from the runs. See also my general comment above.

14. P12032 L26-28: "While the model . . ." How can you explain that the observations at Jungfraujoch are lower than at Issyk-Kul?

15. P12033 L7-9: "This indicates that . . ." It is difficult to support this fact as the paper does not properly evaluate O3 from the different runs. See also my general comment about the validation.

16. P12033 L24-P12034 L2: "Figure 8 . . ." Why only show the period 1997-1998?

17. P12034 L21-23: "Overall . . ." As mentioned in the general comments, I think there are other sources of model error than ERA-40.

18. P12034 L26: Add "done" between "This can be" and "via".

19. The fontsize of the figures is too small. Please, increase them. Also increase the size of figures 1 and 2.

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