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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Summertime stratospheric processes at northern mid-latitudes: comparisons between MANTRA balloon measurements and the Canadian Middle Atmosphere Model" *by* S. M. L. Melo et al.

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Interactive comment on: Summertime stratospheric processes at northern mid-latitudes: comparisons between MANTRA balloon measurements and the Canadian Middle Atmosphere Model

by S. M. L. Melo et al.

Reply to: Referee #1

We thank the referee for the careful review of the paper and for the clear comments contributing to improve the quality of the paper. We have deeply revised the text and redone part of the analysis following all the suggestions. In modifying the paper following the reviewer suggestions we enhanced the analysis and sharpened the discussions making the paper much more substantial.

The referee comments are in italic and our response follows right after in normal fonts.

GENERAL COMMENTS

This manuscript reports on the evaluation of modeling results obtained by Canadian Middle Atmosphere Model (CMAM). The evaluation relies mainly on comparisons with a large set of standard ozonesonde measurements of ozone and temperature profile and on profiles of 4 long-lived tracers measured by balloon-based Fourier Transform spectrometry during 4 late summer campaigns. The paper starts with clear and ambitious objectives. A main objective is to document current capabilities of CMAM to reproduce on an average ozone, temperature and tracers measurements obtained during the 4 MANTRA campaigns.

1 - The part addressing the value of the vertical diffusion coefficient is particularly sound and convincing. However, the presentation and discussion of CMAM/MANTRA comparison results lack of rigor. The main problem is that there are too many qualitative statements like "agree very well" and "very good agreement" without any quantitative statement, any reference and any further explanation on this high degree of satisfaction. E.g., in Section 4.2 (page 9), the authors state that "CMAM N2O agrees very well with MANTRA observations". Looking at Figure 5, we see up to 24km an agreement of about 4-9% which, if the 4% high bias of tropospheric N2O is taken into account, reduces to 0-5%. Is that fine for N2O? At higher altitudes, this agreement degrades to +25%. Is that still good? And what about +- 50% observed for HNO3 and +100% observed for CH4 and HCl, while recent ACE-FTS validation results show agreements better than 25% up to 50km for CH4 and 10% for HCl? Are there any fundamental differences between CMAM outputs and satellite measurements (e.g. ACE-FTS) that could explain such a large difference in agreement?

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R: We have deeply revised the analysis and the discussion in the paper using a more quantitative approach. Reference to the SCISAT ACE-FTS and the HALOE satellite measurements were included. Also reference to the recently published results from the SPIRALE balloon campaign was included.

Differences between model and measurement are discussed in terms of measurement error and using evidences from other experiments. We included the text: Because the measurements are single profiles, they are prone to sampling variability. Although the late summer is dynamically quiescent compared with the fall, winter and spring, as noted earlier, there are growing evidences that dynamically induced variability would still be present. For example, in a recent analysis Pendlebury et al, (2008) suggest the importance of day-to-day variability in the stratosphere associated with the 5-, 10- and 16-day Rossby normal modes which will induce variability in temperature and chemical fields. Their analysis show that all the three modes have maximum amplitudes near 50°N and that they could and likely would exist during the MANTRA campaign in late August and early September.

Two figures were included to support the comparison model-measurements of long-lived species. Discussions are supported by comparisons with other experiments available at the literature. The following text was included: The CH4 and N2O measurements are directly compared in Figure 6. As discussed in Fogal et al, 2006 the structure observed above about 25 km in the CH4 profile is co-located in altitude with a somehow less pronounced structure in the N2O profile. Structures in N2O and CH4 profiles occurring between 23 to 30 km at mid-latitude have been recently reported by Huret et all. (2006) as being present in the SPIRALE (Spectromètre Infra Rouge pour l’Etude de l’Atmosphère par Diodes Laser Embarquees) measurements conducted at Aire sur l’Adour launch base (France, 43.7 N, 0.3 W) on October 2, 2002.

The HNO3 differences are discussed in a quantitative manner and explained on the basis of measurement uncertainties. The following text was included: The HNO3 model and measurement profiles (Figure 8) show differences of the order of 10% at the peak altitude (about 24 km) increasing to about 20% for higher altitudes and to about 25% below the peak. Differences of about 50% are seen for altitudes above 30 km. HNO3 is the main constituent of the NOy family below about 25 km. Although the differences between model and measurements could suggest problems in the model NOy partitioning, those differences are within the measurement errors estimation. Therefore, we concluded that the model reproduces the measurements of HNO3 within the measurement error bars below about 30 km..

The comparison with HALOE measurements was strengthened by adding one figure (Figure 7) showing details of individual profiles over Vanscoy. The text was added: We show then in Figure 7 all the individual HALOE HCl profiles for August 28 at the latitude range of 45°N to 47°N corresponding to different longitudes. The presence of structures in HCl profiles above about 20 km is evident form the HALOE data. However, the structures are not as pronounced as observed in the MANTRA HCl measurement.

Comparisons between the ACE-FTS and HALOE measurements were introduced as support the assessment of the CMAM performance. The following text was added: Recent measurements of HCl and CH4 made by the ACE-FTS instrument on the Canadian satellite SCISAT were compared to HALOE measurements by McHugh et al (2005) showing that ACE-FTS HCl values are consistently higher than HALOE by 10-20% from 20-40 km altitude and CH4 values 10% higher than HALOE throughout. These results suggest then that the CMAM reproduces ACE-FTS measurements in a climatological mode, given confidence in the model.

2 - Could changing trends in HCl not play a role in the apparent disagreement between CMAM climatological results and real, punctual measurements?

R: We do not believe so. HALOE version 19 data is now available to the public at the HALOE data portal (http://haloedata.larc.nasa.gov/download/index.php). Individual profiles for the location close to Vanscoy on days close to August 24 1998 became available. While those measurements show structures in the HCl profiles that in somehow resemble the structure observed in MANTRA HCl profile, comparisons of climatological HALOE profiles with the SCISAT ACE-FTS satellite measurements conducted by McHugh et al (2005) found that ACE-FTS HCl values are higher then HALOE by 10-20% from 20-40 km altitude. Our understanding is that there is a rather large amount of day-to-day variability in chemical species at the stratosphere also in the late summer, which can be associated with transport. As shown in the item (1) above, the literature is more and more providing both measurements and model analysis evidences for such.

3 - References to other model studies, to relevant satellite validation papers, or at least a few lines of text, should be added to explain why the reported agreements are considered as good.

R: Again, as described above, the text has been revised to address this point. For example, references to the work by McHugh et al (2005) comparing ACE-FTS and HALOE measurements, to Huret et all. (2006) that analyses the results from the SPIRALE balloon measurements, and to the model analysis by Pendlebury at al (2008), and Eyring et al (2006) were included.

4 - The part on correlations among long-lived species (second objective) increases the confidence in the model, although the discussion of results is a little bit short.

R: The discussion was extended including the work by Huret et al. 2006 and further exploring the work with ATMOS data by Michelsen et al. (1998).

5 - In Section 5 (discussion), we would expect a discussion of results obtained in previous sections. Actually, there is only a short paragraph on the vertical diffusion coefficient, nearly nothing on CMAM/MANTRA comparisons and the tracers correlations, but a long discussion on the possibility to have observed "fossil" debris of the polar vortex. The latter discussion is based mainly on results published elsewhere. This review of existing literature is interesting to some point, but the CMAM/MANTRA results reported in this paper do not bring sufficient information to conclude on this subject.

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Figure 4 even show that CMAM is not able to reproduce this event satisfactorily.

R: We enhanced the analysis and the discussion on statistical analysis including a set of new figures as support. The features observed in the long-lived profiles are discussed in much deeper level of detail and the text includes now mention to different possible mechanisms. For example, it was included: The MANTRA campaign in 1998 measured nonmonotonic CH4 and N2O profile above about 25 km altitude. These structures are not collocated with O3 depleted layer discussed above suggesting they may be resulting from different mixing processes. MANTRA HCl profile show a pronounced depletion from 20 to 30 km altitude. Although less pronounced, we show here that similar structures at this altitude range are also present in the HALOE (v19) HCl profiles measured during late August 1998 at mid-latitudes…

6 - The general feeling that this paper gives is that excellent material is at the disposal of the authors, but that the presentation of the comparison results should be closer to scientific standards (more rigorous, more quantitative), and that discussion of the results needs to address more consistently the claimed objectives of the paper.

R: In modifying the paper following the reviewer suggestions we enhanced the analysis and sharpened the discussions making the paper much more substantial. We strengthened the point that this paper have the importance of adding to the growing evidence that the summertime stratosphere is rather dynamically disturbed, although at a lower level then during other seasons. The understanding of those variabilities is of particular important for trend analysis as likely they impact total column measurements and make difficult accessing bias and reconcile profiles measurement of constituents made at different years with different instruments.

7 - Finally, some sentences are somewhat long and sometimes difficult to understand at first glance.

R: the text was extensively revised.

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Interactive Discussion

Discussion Paper

8 - Section 1, line 2: I would suggest "anticipated" recovery of ozone.

R: changed.

9 - Section 1, paragraph 2, sentence 2: This sentence lacks of balance between the description of polar and mid-latitude ozone depletion. Polar loss estimates should be quantified and the trend character of mid-latitude depletion highlighted.

R: The text was revised. We introduced the sentence: In contrast to the large ozone loss observed in the Antarctic spring (up to 70%) and in the Arctic during cold winters (up to 30%), ozone long-term trend ozone depletion at mid-latitudes has been shown to be much smaller (3% to 6% since the 1970s) (WMO 2007).

10 - Section 2.2, sentence 3: Do the Canadian standards differ from WMO standards for ECC preparation and analysis? A reference or at least a description of details controlling the measurement error (manufacturer, sensing solution, pump efficiency correction type) would be appreciated.

R: Canada adopts the ECC preparation and analysis standards. This section of the paper has been expanded to include more details on the error analysis of ozonesondes measurements. References have been added accordingly.

11 - Section 2.2, sentence 5: Please write that ozonesondes "measure" in situ ozone rather than "produce". This misleading statement also appears in Section 4.2, paragraph 4, sentence 1.

R: Changed.

12 - Section 2.2, last sentence: 5% error estimate for ozone: Is this a systematic or random error? Instead of, or in addition to, Davies et al., 2000, please adopt as reference "Smit, H.G.J., and Straeter, W., Juelich ozone sonde intercomparison experiment 2000 (JOSIE-2000), World Meteorological Organization Global Atmospheric Watch (WMO-GAW), TD N. 1225, 2004." which is more complete, more general and more accessible to the widest community.

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R: We have revised the text here and included references to the recent papers describing the JOSIE and BESOS inter-comparisons (Smit et al., 2007 and Deshler et al., 2008).

13 - Section 2.2: Although used in the paper, there are no error estimates for RS-80 temperature measurements: precision of 0.1 K, and pressure-dependent accuracy: 0.2 K from the ground up to 50 hPa, 0.3 K from 50 to 15 hPa and 0.4 K below 15 hPa. Proposed reference (for RS-90, but including RS-80 results): "Luers, J., K.: Temperature Error of the Vaisala RS90 Radiosonde, Journal of Atmospheric and Oceanic Technology, 14(6), 1520-1532, 1997.

R: This reference has been added to the paper.

14 - Section 3, paragraph 1: Description of temporal characteristics of CMAM output is missing. Without this information, it is nearly impossible to understand what has been done in Paragraph 2 of Section 4.1 and subsequent discussion.

R: The model description was expanded to include: The CMAM data used here comprise years 28-48 from a timescale simulation representing conditions in the year 2000. Profiles are generated for the model grid point closest to Vanscoy, and at various solar zenith angles. For this run CMAM was sampled in approximately 10 minute increments, producing 144 profiles per model day.

15 - Section 3, paragraph 3: This paragraph would preferably start with a list of major factors generating inter-annual variability. This would help the reader understanding why CMAM might underestimate inter-annual variability.

R: We believe that the text we included in the paper properly addresses this point: In these simulations, climatological sea-surface temperatures are imposed which, although varying from month to month, are kept constant from year to year. Also, phenomena like the quasi-biennial oscillation and solar and aerosol variability, which are known to be significant factors affecting the inter-annual variability of the strato-

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sphere, are not included in the model version used here. As a consequence, the inter-annual variability in the model as reported here could be underestimated. However, a study by Wunch et al (2005), using both the National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) reanalysis and the United Kingdom Meteorological Office (MetO) analysis products, suggests that the CMAM appears to have a realistic level of dynamical variability for the time and location of the MANTRA measurements. This dynamical variability in CMAM is associated with Rossby normal modes, whose behaviour varies from year to year, and induces variability in ozone and long-lived chemical species (Pendlebury et al., 2008).

16 - Section 4.1: It is really hard to understand what has been done here. What does a "model day" mean?

R: A model day is calculated as the average of the 144 model profiles produced daily for ozone and temperature, for each year of the model run. This sentence was introduced in the text.

17 - Through suitable scheduling of the MANTRA campaigns, near the turnaround of stratospheric winds, great care is given to reduce dynamical sources of variability, thus comparison errors associated with spatial and temporal mismatch of the measured information. Moreover, ozonesonde data sets are averaged with a view to mimicking the climatological nature of the CMAM output. This is a strong point of the methodology. One could regret that such a care is not given here to vertical mismatch errors: ozonesonde data acquired at 100 m resolution are simply interpolated onto the CMAM grid points. This introduces likely large comparison errors that might explain the significant scatter observed in the comparison plots. Smoothing vertically ozonesonde data with a low pass filter close to the CMAM vertical resolution might help.

R: Good point. The ozonesonde measurements were smoothed to the model resolution following the referee suggestion. Indeed the smoothing removed some of the scattering, although not much. However, we agree that the smooth is needed to avoid

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spurious features in the data. We added to the text: In order to reconcile differences in altitude resolution between the model (˜ 1.3 km) and the measurements (˜ 0.2 km), the ozonesonde data are smoothed to the CMAM resolution.

18 - In paragraph 2 of Section 4.1, looking at T and O3 correlation plots in Figure 2, the authors conclude to a good overall consistency between model and measurements. Looking at the scatter of the correlation plots, which seems to me to exceed the ECC and RS-80 error estimates for O3 and T, I have some concerns with this conclusion. Maybe the authors could comment on this. They should include error budgets in the discussion in order to support their conclusion.

R: The analysis of the comparisons between the ozonesondes measurements and the model was enhanced and is much more rigorous now. In this specific point we added the text: Scatter about the 1:1 correlation line is expected because of day-to-day dynamical variability in both model and measurements… .

19 - The authors also note that temperatures above 20 km tend to be below the 1:1 line. I suggest that they rather write that CMAM overestimates or underestimates MANTRA observations, preferably with an estimate of this under/overestimation. Note that in Figure 2 the 1:1 line has a wrong position: it should not pass via (260:250).

R: The following text was added: The temperature plot in Figure 2 shows that points corresponding to altitudes above 25 km, that is, in the upper stratosphere, tend to be consistently located below the 1:1 correlation line suggesting the model overestimates the temperatures at this altitude range. This suggested warm bias in CMAM is consistent with the warm bias in the global-mean temperature which indicates a radiative bias in the model in the upper stratosphere (Pawson et al. 2000, Eyring et al., 2006). The axes in Figure 2 were revised.

20 - How do the authors justify the choice of the altitude ranges: 10-20 and 20-30 km? Is that an arbitrary choice, or is there something happening at 20km that justifies a separation of the results ?

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R: During the revision of the analysis of the data we had modified the choice of altitude range as: 6-15 km where mixing between tropospheric and stratospheric air are more likely to take place; 15-25 km, including the ozone pick; and above 25 km, the upper stratosphere.

21 - In Figure 5, horizontal scales for CH4, HNO3 and HCl are rather coarse: up to 100% and even 200%. This is fine to see large deviations pointing to real problems, but much too coarse to discuss the quantitative agreement with correlative data at altitudes where it reaches more classical values. A suggestion would be to add, for each species, on the right of existing graphics, the same results but now with a reduced scale allowing closer look at the quantitative results.

R: This figure was revised. We shortened the scale for the right side plots allowing better reading of the values making the differences clear at the region they are more reliable.

22 - Section 4.2, line 5: How many CMAM profiles are used in the calculation of daily averages?

R: We revised the text including more information on how the model is sampled and how a model day is build. In the first paragraph of Section 3, where the model is presented, we added the sentence: For this run CMAM was sampled in approximately 10 minute increments producing 144 profiles per model day. Then, in Section 4 we introduce the text: A model day is calculated as the average of the 144 model profiles produced daily for ozone and temperature, for each year of the model run. Thus, for each measurement point there are at least 20 corresponding model points (one for each model year)..

23 - Section 4.2, line 9: What does model variability mean? R: It represents the 1 sigma standard deviation using the ensemble of all the daily averaged profiles (for each specie) within the period of analysis (August to September). The text has been revised to make this clear.

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24 - Section 4.2, paragraph 2: Are the diffusion coefficient and the vertical resolution the sole changes between CMAM-WMO and CMAM-V7 that might have first-order effects on the tracer profiles?

R: Yes. For clarity we added the text: “Note that the diffusion coefficient and the slight reduced vertical resolution are the sole changes between CMAM V5 and CMAM-V7 that might have first-order effects on the constituents profiles.”

25 - Section 4.2 and 4.3: Please add relevant references to ACE-FTS, ATMOS and HALOE.

R: reference to McHugh et al (2005) analysis comparing ACE-FTS and HALOE was introduced. Also, reference to the recent work by Huret et al. (2006) was included. Huret et al. work reports on the analyses of measurements of long-lived species using the SPIRALE (French acronym for “Spectroscopie InfraRouge par Absorption de Lasers Embarqués”) instrument when launched in a balloon on October 2, 2002 from the Aire sur l’Adour launch base (France, 43.7° N, 0.3° W).

26 - Section 4.2: More details on the HALOE climatology would be needed to understand how far this data set can be suitable for the current study. E.g., are the first years of UARS operation (post-Pinatubo era) included in this climatology?

R: The climatology used here is the one available in the HALOE data portal (http://www.sp.ph.ic.ac.uk/haloe/userguide/uguide.html) and was built using version 18 retrieval. Detail information is publicly available throughout the UARS-HALOE data portal we refer to. The climatology has been calculated for the period December 1992 - February 1997 (prior to December 1992, the large quantities of Mount Pinatubo aerosol in the lower stratosphere gave rise to very large HALOE retrieval errors). The text was revised including this information.

27 - Section 4.2, paragraph 4, line 12: Please quantify this "very good agreement" with HALOE.

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R; The text has been revised to include a quantitative approach to the comparisons.

28 - Section 5: At the end of the paper, the reader would expect a conclusion, even short, recalling the three objectives of the paper and explaining to what extent they have been achieved.

R: This section was renamed to “Discussions and Summary” and was deeply revised.

——————————————&#8
TECHNICAL CORRECTIONS - Affiliations: wrong numerical position of affiliation indexes 7, 4 and 5. - Abstract: Sentence 1 is much too long. Please cut and rearrange. - Page 2, Section 1, paragraph 1, last sentence: please adapt standard reference format; complete reference should not appear in the text. - Page 3, paragraph 2, line 4: "reportED" - Page 7, paragraph 2, line 2: "measurementS" - Page 9, paragraph 1, last line: remove parenthesis - Page 11, paragraph 2, line 1: please remove "HAVE" - References, general: please review reference formats, adopt agreed standards (e.g. "Geophys. Res. Lett." And "Ann. Geophys.") and complete with right page numbers. - References, Avallone et al.: "Comparisons" instead of "Xomparisons" - References, Davies et al.: editor, page numbers? - References, Komhyr: remove accent in "Geophys." - References, Murcray et al.: character font is different. - References, Ross et al.: in 2007, a paper published in ACPD in 2004 should be either published in ACP or rejected. Please update reference. - References, Solomon et al., "temperatuRe" instead of "temperatuTe" - References, Tegtmeier et al., "anoMaLies" instead of "anoLaMies" - Figure 2: the 1:1 reference line should obviously not pass via (260:250). Please correct the abscissa range and the position of the 1:1 line.

All the suggested technical corrections were implemented.

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