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Atmospheric Chemistry and Physics Discussions

Interactive comment on "CO at 40–80 km above Kiruna observed by the ground-based microwave radiometer KIMRA and simulated by the whole atmosphere community climate model" *by* C. G. Hoffmann et al.

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General comments

We would like to thank anonymous reviewer #3 for helpful comments on our manuscript. We answer the comments point by point below in the same order as given.

Answers to specific comments

- Page 563: All we intended to say here is that free-running WACCM and SD-WACCM share the same numerical code; the only difference between the two versions of the model is that, in SD-WACCM, the wind and temperature fields are relaxed towards values specified from an external dataset (in this case NASA's GEOS5 dataset).This is now explicitly stated in the revised paper.
- Page 566: The point we wanted to make is that the comparison is performed "on the shortest time scales currently simulated by the model." Stating instead specific numerical values would raise the question why we chose this resolution and not an even higher resolution to compare to a single point measurement. Therefore we have left this phrase as is.
- Page 567: While we agree that this might be an interesting exercise, it is beyond the scope of the paper. Furthermore, we are not even certain what the best approach to this question might be and so have not investigated whether a sophisticated assimilation technique might improve the comparison between SD-WACCM and observations. In any case, it is not clear to what extent a more sophisticated relaxation method might help, as the correlation between SD-WACCM and observations is already very good at low frequencies while, at high frequencies, discrepancies would appear to arise from the fact that small-scale, high-frequency motions (gravity waves) are not explicitly simulated but are instead parameterized in the model. As regards the specifics of how we use the GEOS-5 data, we simply interpolate linearly the GEOS-5 output to the spatial grid and time step of SD-WACCM. We now mention this last point explicitly in the revised paper, in Section 2.3.
- Page 567, line 12: GEOS-5 output is actually available through 80 km altitude. However, we do not believe these data are particularly reliable above the stratopause, so we use the latter altitude as the top of the domain over which relaxation is applied. We now mention this specifically in the revised paper.

- Page 568/569: We do not believe "double counting" is a problem at all because the ranges of wavelength and frequency characteristic of the gravity waves that must be parameterized do not overlap with those of the gravity waves (in general, inertia-gravity waves, including the tides) that are explicitly resolved by the model (or by the GEOS-5 reanalysis). The parametrized gravity waves are meso-scale (wavelengths ~ 100 km and frequencies in the tens of minutes); they are unresolvable by WACCM or any other chemistry-climate model given the moderate space and time resolution that can in practice be used in such models at present.

- Page 562: There is no comprehensive, published study of tides in WACCM, although we have looked into this subject before. In general, WACCM underestimates the amplitude of the diurnal and semidiurnal tides in the mesosphere and lower thermosphere, in places by as much as a factor of 2. However, the diurnal tide is not large at the latitude of Kiruna, and the semidiurnal tide, which *is* large at high latitudes, only becomes important above about 85-90 km, which is outside the range of altitude of interest in this paper. Therefore, we do not believe that a poor simulation of the tides contributes materially to any discrepancies between the simulations and observations discussed in this paper.

- Page 577 line 1: We have added a few more details about the profile shape deviation of KIMRA compared to MLS and SD-WACCM in the Conclusions section. This was kept very short here, since deviation was expected from the comparison to satellites presented by Hoffmann et al. (2011). However, we agree that the reader of the present manuscript needs some more information to make it more self-contained. Concerning the question whether it would be better to base the mean profile comparison on MLS instead of KIMRA, we agree that it would generally be interesting to repeat some of the comparisons based on MLS. However, most accurate comparisons MLS-SDWACCM require accounting for the MLS measurement characteristics (averaging kernels). Doing this would add another perspective to the paper ("CO seen through the glasses of

MLS"), and a careful separation of these perspectives in the discussion would be necessary. Switching between these perspectives might, however, be confusing and too much for a single manuscript. Therefore, we restricted ourselves to the KIMRA perspective, which has the lowest vertical resolution. After applying the KIMRA averaging kernels, all datasets are comparable from the KIMRA perspective. The only exception is the figure in the supplement (which will be included directly in the revised paper, see answers to reviewer Hugh Pumphrey), where a rough comparison MLS-SDWACCM indicates that the results obtained in the KIMRA perspective can be generalized to higher vertical resolution.

- General Comment: We have in fact compared free-running WACCM output to ACE CO_2 data and find good agreement. This is perhaps not too surprising because CO_2 is chemically a simple species, without very sharp spatial gradients, such that there are no major technical difficulties in modeling its chemistry or transport. The results of these comparisons have yet to be published; however, we note that, over the range of altitude where SD-WACCM, KIMRA and MLS are compared in this paper, the mixing ratio of CO_2 is practically constant, so CO_2 is not an important factor in the simulation of CO.

- Page 565: We are not sure whether we understand correctly the point of this question. The KIMRA retrieval depends on temperature profiles and SABER satellite measurements are used as input (Hoffmann et al., 2011). On the basis of this temperature information, among others, the CO profiles are retrieved from the microwave spectra. Thus, it is important that the temperature profiles used in the retrieval be close to the real atmospheric temperature during the time of the measurement. An error estimation, including the error of the temperature profiles, is included in Hoffmann et al. (2011). Once the CO profiles have been retrieved, this CO product is independent of temperature. Hence, KIMRA, MLS and WACCM CO can be reasonably compared stand-alone (without comparing also the temperatures of the respective datasets). If the question refers to a general

estimation of the quality of the SD-WACCM temperatures, Marsh (2011) states that SD-WACCM temperatures are in general agreement with SABER satellite observations. Comparing the temperatures is, however, not within the scope of this paper.

Answers to technical corrections

- Page 560, line 25: As far as we know, the noun “dynamics” can be used with either a singular or plural verb. We have used it consistently with a singular verb throughout the document, and are in favor of leaving it as is.
- Page 561, line 20: Corrected in the revised manuscript
- Page 561 line 26/27: Changed in the revised manuscript.

References

Hoffmann, C. G., Raffalski, U., Palm, M., Funke, B., Golchert, S. H. W., Hochschild, G., and Notholt, J.: Observation of strato-mesospheric CO above Kiruna with ground-based microwave radiometry – retrieval and satellite comparison, Atmos. Meas. Tech., 4, 2389–2408, doi:10.5194/amt-4-2389-2011, 2011.

Marsh, D.: Chemical-dynamical coupling in the mesosphere and lower thermosphere, in: Aeronomy of the Earth’s Atmosphere and Ionosphere, IAGA Special Sopron Book Series, vol. 2, 1st edn., Springer, Dordrecht, 3–17, 2011.

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