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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Comparison of ECHAM5/MESSy Atmospheric Chemistry (EMAC) Simulations of the Arctic winter 2009/2010 and 2010/2011 with Envisat/MIPAS and Aura/MLS Observations" *by* Farahnaz Khosrawi et al.

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We thank reviewer 1 for the constructive, helpful criticism and the suggestion for revision. We followed the suggestions of reviewer 1 and revised the manuscript accordingly. Figures that we refer to in our answers to the referee comments are provided in the supplement to this reply.

General Comments
In this new study, Khosrawi et al. evaluate simulation results of the chemistry-climate model

EMAC for the Arctic winters in 2009/2010 and 2010/2011. Simulation results for temperature, HNO_3, and PSC volume density are compared with Envisat/MIPAS and Aura/MLS satellite observations. Overall, the study fits in the scope of ACP and the manuscript is well written. However, I have a number of general and specific comments, which I recommend to be addressed before the paper will be published.

1) In this paper you are not showing any evaluation results for stratospheric polar ozone. The fact that ozone data are available from the satellites for direct validation, but ozone simulation results are not discussed at all makes me wonder whether the simulated ozone distributions are far off reality (because the simulated PSC concentrations are too low by a factor of about 5 to 10)?
It is correct that the differences we find between the simulated PSCs and the ones observed by Envisat/MIPAS also affect the simulated O_3 distribution. Although we did not explicitly discuss other trace gases in the current paper, we have of course also evaluated some other gases. For example, for O_3 we find a generally good agreement between the EMAC simulations and Aura/MLS observations throughout the stratosphere (see Figure 1 and 3 in the supplement). Considering time series at 50 hPa (see Figure 2 and 4 in the supplement), we find at the beginning of the winter a very good agreement between EMAC and the Aura/MLS observations, but during the course of the winter when ozone destruction and descent become important, we find an increase of the differences, but these nevertheless do not exceed more than 20% (2009/2010) or 30% (2010/2011), respectively. We would like to keep the current study restricted to PSC volume density, temperature and HNO_3 since we presented already some (qualitative) comparisons of ozone simulated with EMAC to observations in Khosrawi et al. (2017). We referred to these comparisons presented in Khosrawi et al. (2017) in the introduction but repeat this now also in section 4 to remind the reader about this additional study.

2) MIPAS also provides measurements of long-lived tracers such as N_2O, CH_4, and

CFCs. Comparing simulation results for these tracers with the satellite observations may help to assess the proper representation of transport and mixing in EMAC.
We have also performed comparison between the N_2O distribution simulated by EMAC and observations from Aura/MLS and found (in agreement with previous studies) that descent is underestimated (see Figure 5 and 6 in the supplement, stronger downward transport of low N_2O mixing ratios is observed by Aura/MLS than is simulated with EMAC). To provide a thorough assessment of transport and mixing using several long-lived trace gases and adequate diagnostics for the assessment is quite complex and thus beyond the scope of this study. However, this will be the focus of future studies with EMAC.

3) The study finds good agreement between temperature distributions from EMAC and the satellite observations. However, the EMAC simulations have been nudged to ERA-Interim. From the paper I could not infer whether the nudging was rather weak or strong? Do the remaining temperature differences tell us something about the EMAC model or about the differences between the satellites and ERA-Interim?
In fact, the simulated temperatures are quite close to the ones derived from ERA-Interim since nudging is rather strong. Therefore, the differences found here tell us something about both the differences between the satellite observations and ERA-Interim as well as between the satellite observations and EMAC since both the model performance together with the data set used for nudging define the model results (see temperature comparisons between EMAC, ERA-Interim and satellite observations discussed in Jöckel et al. (2006) and Jöckel et al. (2016)). For example temperature fluctuations due to gravity waves are poorly resolved in the reanalysis data und thus the effect of gravity waves is underestimated in the model simulation but will be resolved by the satellite observations as e.g. MIPAS (Höpfner et al., 2006). When discussing the EMAC temperatures we added "nudged toward ECMWF ERA-Interim" to emphasize that these are nudged temperatures. Further, we added the following sentence in Sect. 4.1: *Note, due to the nudging the simulated temperatures are*

quite close to those from ERA-Interim but some differences remain (see comparisons between EMAC, ERA-Interim and satellite observations presented in Jöckel et al. (2006) and Jöckel et al. (2016)). The influence of gravity waves on temperature, which is measured by the satellites but still not fully resolved in the reanalyses data (and thus not reflected in the nudged model simulation), is e.g. one reason why differences between model simulations and observations are found, not only with regard to temperature but also with regard to PSCs, see Höpfner et al., (2006).

Specific Comments
p7, l3-8: MIPAS PSC measurements during the Arctic winter 2010/11 are also discussed in a new ACPD paper by Spang et al. (2017).
We added the following sentences referring to Spang et al. (2017) (now published in ACP) to this paragraph: *During the Arctic winter 2010/2011, the overall PSC occurrence frequency and area was exceptional for an Arctic winter as was shown by Manney et al. (2011) and confirmed in a recent study by Spang et al. (2018). The peak values of PSC area (in km^2) reached sizes comparable to June conditions in the Antarctic.*

p9, l14-16: The phrase saying "... PSC volume density is several orders of magnitude smaller..." is misleading. An order of magnitude refers to a change of a factor of 10. Several orders of magnitude may refer to change of a factor of 100, 1000, etc., but not to factors of 3 or 6-7 found here. This also needs to be fixed in other places.
Thanks for pointing this out. The relevant text phrases have been rewritten.

p12, l30-32: Additionally, there might be problems because the standard flux-form semi-Lagrangian transport scheme in EMAC may be too diffusive near the transport barriers (Hoppe et al., 2014).
This is correct, thanks for pointing this out. We added the following sentence referring to the study by Hoppe et al. (2014): *Furthermore, in a more recent study by Hoppe et al. (2014) it was shown that the standard flux-form semi Lagrangian scheme used in EMAC*

may be too diffusive near the transport barriers and that the results can be improved when a Lagrangian transport scheme is used instead.

Figs. 6 and 12: Adding curves for Envisat/MIPAS may help to put the differences between MLS and the model into context.
In fact, we had this in an earlier version of the paper and decided against it since it makes the discussion more complicated. Although the time series from Aura/MLS and Envisat/MIPAS are quite similar they are not the same. Using both satellites in the time series plots puts us in the need to discuss also the differences between the satellites which is however not the focus of this paper and distracts from what we actually want to discuss. However, due to a similar comment by reviewer 2 we added in the figure supplement to reviewer 2 a figure showing the time series from Aura/MLS vs Envisat/MIPAS for the Arctic winter 2010/2011. Further, in the manuscript we refer now to the study by Sheese et al. (2017) where a thorough comparison and discussion of the differences between MIPAS and MLS can be found.

Technical Corrections
p6, l2: "Arctic winter" → "Arctic winters"
p6, l14: "orographic waves" → "orographic gravity waves" (?)
p11, l25: "PSC seasons" → "PSC phases" (?)
Indeed, on p6, l14 it should read *orographic gravity waves* and on p11, l25 *PSC phases*. This has been corrected.

References
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Spang, R., Hoffmann, L., Müller, R., Grooß, J.-U., Tritscher, I., Höpfner, M., Pitts, M., Orr, A., and Riese, M.: A climatology of polar stratospheric cloud composition between 2002 and 2012 based on MIPAS/Envisat observations, Atmos. Chem. Phys., https://doi.org/10.5194/acp-18-5089-2018, 2018.

Please also note the supplement to this comment:
https://www.atmos-chem-phys-discuss.net/acp-2017-1190/acp-2017-1190-AC1-supplement.pdf

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