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Interactive comment on "Modelling the residual mean meridional circulation at different stages of stratospheric warming events" *by* Andrey V. Koval et al.

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Reply to the Reviewer #3 of the paper by Koval et al. "Modelling the residual mean meridional circulation at different stages of stratospheric warming events"

We would like to thank the Anonymous Referee #3 for useful comments and suggestions. We considered all of them and added all the necessary edits to the revised manuscript. Our answers are given below in the italic font.

Question: The authors describe a numerical study on the change of the residual mean circulation during sudden stratospheric warmings (SSW). This is in principal an inter-

esting topic as SSW events cause important changes in the circulation for both the middle atmosphere dynamics and chemistry as well as for the troposphere. After the presentation of an overall agreement of the MUAM model with the MERRA reanalysis, the authors go on in calculating the EP Fluxes of the Ensemble members for the RMC and the ozone fluxes during several SSW events. They find a transitional behaviour of these fluxes and in general a weakening of fluxes after such events. I think, such an analysis makes sense in general but needs to be described more carefully. The motivation, why should one care about this, besides the usual academic curiosity? Please elaborate more on your motivation. Are there missing details in the description of the MA dynamics during SSWs where this method can improve or support the understanding?

Answer: We appreciate the reviewer for raising the helpful comments. Despite many studies, the mechanisms of SSW creation, evolution and their effects are not enough understood. In the revised text, we added discussions of variations of the stratopause height, zonal wind and eddy circulation produced by non-zonal wave motions. Combined with the analysis of the residual meridional circulation, this data allows us to analyze deeply some details of interactions of listed above characteristics at altitudes up to 100 km and their role in SSW formation, which we did not find in the literature. In addition, the residual and eddy circulation play an important role in the global transport of atmospheric tracers and conservative gas species. However, this transport is not the main goal of our paper and we concentrated on the fluxes of atmospheric mass, which are important for heat transport and adiabatic heating/cooling taking part in SSW formation and evolution.

Question: Are there important observed impacts of SSWs on the ozone distribution in the stratosphere that has not yet been understood so far? Are there dramatic changes in ozone distribution observed that need to be explained?

Answer: The ozone distribution is not the goal of our paper. We excluded ozone discussions from the paper and concentrated on considerations of the residual and eddy

fluxes of atmospheric mass. These fluxes may reflect the ozone transport at altitudes below 30 km, where the ozone photochemical lifetime exceeds 1 month. We made respective modifications in the revised text.

Question: The ensemble setup, how strong is the ensemble spread, e.g. in the 10 hPa wind?

Answer: We added Figure 1 showing zonal wind for the most intensive and smallest simulated SSWs. This Figure can give information about the ensemble wind spread.

Question: Does an SW event really appear in every member for every run?

Answer: No, the ensemble of 24 model runs contains 19 runs with stratospheric warming events during simulations for January-February conditions. This clarification is added to the revised text.

Question: Comparison with reanalysis. It is a really nice result that MUAM as a mechanistic model comes so close to the MERRA reanalysis in terms of the RMC analysis. This comparison should be extended to the fluxes during SSW events as well.

Answer: Yes, such comparison is a good idea. However, obtaining a composite SSW need many individual events observed throughout several decades years and requires filtering possible climate changes during this period. This is a big job, which cannot be made within the present paper. We added references to already published RMC studies examining the reanalysis data during SSW.

Question: Conclusions: what do we learn qualitatively about this changed circulation, what effect should be taken into account in future when studying such events?

Answer: The conclusion chapter is rewritten in the revised text to better summarize the findings of the paper.

Question: Finally, this might not apply to the current manuscript, however, I noticed, that the forcing of the SPWs at the lower atmosphere in MUAM comes from a relatively

old reanalysis from 1994. An update of this climatology or a change to MERRA or ERA5 or both would be desirable. It could even serve itself as a source of generating an ensemble by changing characteristics in these SPWs.

Answer: No, the old are only references describing existing reanalysis databases. The meteorological data required for preparation of background and initial data for simulations with the MUAM were taken from the UK Met Office and MERRA database for years up to 2011. We have added a clarification and new reference into the revised text.

Minor issues are:

L. 45: which ARE not compensated

// corrected

L. 51: reverseS its direction

// corrected

L. 70 ff. How many model levels has MUAM?

// 48 levels from the ground to 135 km. We added this information to the text.

L. 78 according to recent knowledge . . . this is relative as you quote papers from 1991 and 1994, which are already 30 years old.

// the rewording is made

L. 180 in Figures2c and may reflect (?)

// corrected

L. 205 which correspondS TO our results

// this part was rewritten

L. 214/215 Vertical transport . . . sentence is incomplete, please rephrase

// sentence is rephrased

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