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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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We would like to thank the Anonymous Referee #1 for useful comments and suggestions. We considered all of them and added all the necessary edits to the revised manuscript. Our answers are given after double slashes (//) below.

Line 50. SSW, major and minor, do also occur in the Southern hemisphere, e.g., https://doi.org/10.3390/atmos11101063

// In the revised text the phrase is modified as "the middle atmosphere during winter"

L. 64. "studied for the first time". Further in the text, authors cite other papers on the

same subject, so this work is not the first of its kind. May be the "first time with this model"?

// The phrase is modified " . . . studied for the first time at altitudes up to the lower thermosphere." We did not find similar previous studies for so high altitudes in the literature.

L. 93. How the normal modes were included? By adding additional disturbances at the lower boundary? Or they were generated by the model in response to daily variations of the solar flux?

// The MUAM involves NM parameterization by adding terms to the heat balance equation in the troposphere, which have forms of time-dependent sinusoidal components with zonal wavenumbers m = 1 or m =2. For setting the latitude structures of NM components, the parameterization uses respective Hough functions. Periods of NMs are equal to the resonant periods of atmospheric reaction to the wave forcing at low (about 5, 10 for m = 1 AND 4, 7 days m = 2). We added respective discussion to the revised text.

L. 95-96. That is, at 50, but not 30 km? This is unclear from the text. Formulas (3) and (4). For me they look precisely equal to (1) and (2). Are they just another form of the latter, or am I missing something?

// We replaced the text by ". . .were frequently detected not at pressure level of 10 hPa (near 30 km altitude), but at higher altitudes up to 50 km . . .". In the revised text, we also replaced the abbreviation SW by HSW (high stratospheric warming) for such high-altitude stratospheric warming events. Eq. (3) and (4) are just other forms of eq. (1) and (2), which were used in our calculations.

L. 206. "Increased downward ... velocities". As follows from Fig. 2b, the downward velocities between 20 and 60 km weaken during SSW. Is it a typo? L. 208. Again, if the downward velocities are weaker over high latitudes, they cannot help with heating the atmosphere.

// In Fig. 2b2 at altitudes 20-40 km near the North Pole, one can see negative add-ons to the background downward vertical velocity shown in Fig. 2a2. This corresponds to increasing adiabatic heating of in the high-latitude stratosphere during SWs. We clarified this in the revised text.

L. 214. "Parcels" rather than "particles" is more suitable word for gas elements.

// Corrected.

L. 216. "For short time intervals". Here it would be appropriate to give the characteristic chemical lifetime of ozone at these heights in comparison with 11-day intervals of interest.

// Photochemical lifetime of ozone exceeds 30 - 50 days below 30 km altitude (Jacob, 1999), which is larger than considered 11-day intervals. Above 30 km, the lifetime decreases, and our calculations there are in the nature of a rough estimate, and rather reflect changes in the fluxes of conservative impurities. The discussion is added to the revised text.

L. 217. Specify what data the MUAM ozone model is based on.

// The MUAM ozone model is described by (Suvorova and Pogoreltsev, 2011; Suvorova et al., 2017). It includes a three-dimensional distribution of the ozone mixing ratio that takes into account long-term climatic longitudinal inhomogeneities. The model combines information from three databases: the ERA_40 project of the European Center for Medium-Range Weather Forecasting (ECMWF, Uppala et al., 2005) for pressure levels between 1000 and 30 hPa, GOME data (Global Ozone Monitoring Experiment, 1995) between 10 and 0.3 hPa, and the "BerlinOzoneModel" (Fortuin & Langematz, 1995) between 0.3 and 0.003 hPa. Between 30 and 10 hPa, the ozone mixing ratio is interpolated between the ECMWF and GOME data. At 0.3 hPa, the ozone ratio is calculated as the average between the GOME and BerlinOzoneModel values. Suvorova

and Pogoreltsev (2011) tested the ozone distribution used in the MUAM by comparing it with the empirical model of Randel and Wu (2007). The used ozone distribution is also consistent with databases Hassler et al. (2008) and Cionni et al. (2011). We added this information to the revised text.

L. 214. Is that really "monthly-mean" ozone? How good is to use monthly means for such rapid events as SSW? Or some sort of time interpolation was used?

// The ozone model used in MUAM gives climatological monthly-mean ozone mixing ratio. Below 30 km altitude, photochemical ozone lifetime exceeds one month and approximation of constant ozone mixing ratio makes sense. Dynamical variability during SSWs leads to variations in atmospheric density and winds, which cause changes in ozone fluxes shown in the paper. Above 30 km, the results of the paper may be referred to RMC fluxes of conservative atmospheric admixtures. Respective discussion is added to the revised text.

L. 245. Ozone fluxes enhance the residual circulation? They just reflect it. A rewording is needed.

// The rewording is made.

L. 248-250. I would recommend to move reservations concerning the fixed ozone distribution to the beginning of the section. Readers would then understand from the beginning that this is just a rough estimate.

// We added necessary discussion to the beginning of the section.

L. 266. Aren't the fluxes decrease at this location, as Fig. 2b shows?

// As was shown in Fig. 2b2, at altitudes 20-40 km near the North Pole, one can see increase in the downward vertical velocity during SW. Accordingly, the estimated ozone fluxes in this region are also enhanced.

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