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Atmospheric Chemistry and Physics Discussions

Interactive comment on "The sudden stratospheric warming of the Arctic winter 2009/2010: comparison to other recent warm winters" *by* J. Kuttippurath and G. Nikulin

Anonymous Referee #1

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General Comments:

The authors provide a convincing examination of the evolution of the sudden stratospheric warming (SSW) of 2009/2010 in comparison to other major warming (MW) events of the 2000s decade. The origin of the MW is analysed by diagnosing the temporal evolution in terms of wave fluxes (heat, momentum and Eliassen-Palm fluxes), and the relation to the interannual variability of stratospheric ozone during arctic winter is discussed. As far as I understand the aim of the paper is to provide a comparative study of the MWs of the 2000s decade and to contribute to the understanding of the origin and evolution of the MWs, which is still a challenging effort because – as

the authors show – each of the MWs was unique. From my point of view the paper gives new and important aspects for understanding the MWs during arctic winter of the 2000s decade and associated variability in stratospheric ozone. Overall the paper is well-written and worthwhile to be published in ACP. However, I have some few specific questions, and I recommend some few minor improvements before final publication.

Specific comments:

1) p. 7244, ll. 22-23, p. 7257, ll. 21-22, p. 7259, l. 21, and Figure 7: It is evident that a SSW, which is a phenomenon of stratospheric dynamics, has a strong impact on the ozone distribution by changing the tracer transport and temperature-dependent chemistry, therefore stratospheric ozone is a good indicator for what is going on during a SSW, and there might be also feedbacks of the changing ozone distribution on the occurrence rate of SSWs via radiative forcing; however, suggesting ozone loss "as a proxy for MWs" is not really a good idea because there are year-to-year changes in PSC-related ozone chemistry driven by anthropogenic emissions in addition to the effects of dynamics, which complicates an unequivocal definition of minor and major SSWs in terms of ozone distribution or ozone loss. From my point of view it would be more interesting to discuss whether the strong increase of the occurrence rate of MWs during the 2000s decade could have masked the PSC-related ozone loss due to anthropogenic emissions, i.e. whether the widely discussed ozone recovery since the mid-1990s could be primarily due to the increase in MWs and not to the restrictions in anthropogenic emissions of CFCs and some halons. Could you make a comment on this possibility?

2) p. 7250, ll. 6-8: Do you have an explanation for this "striking feature"? Usually the centre of the polar vortex does not coincidence with the geographic North Pole, but sometimes it does. Is the different behaviour of the temperature at 60°N and the 90°N during 2007/08 just related to the location of the polar vortex, i.e. to a weaker zonally asymmetric structure of the vortex than during other years?

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3) p. 7254, ll. 8-9: In Figure 5 (475K, 100128) the vortex is not really near the pole but the centre of the vortex is located over northern Siberia; over this region the vortex is found most frequently.

4) p. 7255, ll. 25-26: What do you mean exactly with “an advanced shift of 5-7 days”? It would be helpful to be somewhat more precisely at this point, because it is difficult to realize this feature based on the figures alone. For example, for the red line (2009/2010) I can identify 3 pronounced peaks in wave 1 EPz flux between mid December and mid January, and 3 pronounced peaks in wave 1 with a time lag of some days (similar for wave 2 between around 20 December and end of January). Do you mean here this kind of relationship?

5) p. 7256, ll. 4-6: It would be helpful to give some more few comments on these findings of the wave activity in the troposphere, because it could help to understand the processes initiating the SSW. For example, is it possible to formulate a link between the features shown in Figure 6 and the mentioned findings for tropospheric wave activity?

Technical corrections / Typing errors:

1) p. 7245, l. 1: As far as I know the term “vacillation” is usually used for short-term fluctuations, for example the regular vacillations during a winter period shown in Figure 1, 3 or 6. Therefore here the term “year-to-year variability” seems to be more appropriate.

2) p. 7245, ll. 15-16: It is not specified what you mean with “... induce heat ...”? For example, do you mean here adiabatic heating via changes in the Brewer-Dobson circulation, or heating of the cold polar vortex due to eddy mixing processes?

3) p. 7252, l. 9: What do you mean with the term “mountainous upward EP flux”? I see only pronounced negative values in EPz flux divergence during January, which is obviously related to the damping and reversal of zonal wind at 60°N, and a positive anomaly during early February.

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4) p. 7252, l. 11: Obviously it should be “geopotential wave 2 amplitude” and not “geopotential flux”.

5) p. 7258, l. 25: It is “2008/09” and not “208/09”.

6) Figure 3, figure caption: It is not specified that the dark contours denote the zonal mean westerlies.

7) Figure 6: It would be nice if the axes of total, wave 1 and wave 2 EPz fluxes are the same (e.g., -1 to 5); also for wave 1 and wave 2 (e.g., -10 to 40).

8) Figure 7: The ozone column loss is only given in relative units, but the reference state is not specified (presumably a long-term mean of ozone column).

Interactive comment on Atmos. Chem. Phys. Discuss., 12, 7243, 2012.