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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 #3

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Review on the paper : "The sudden stratospheric warming of the Arctic winter 2009/2010: Comparison to other recent warm winters", submitted by J. Kuttippurath and G. Nikulin.

The aim of this paper is to characterize winter 2009/2010 with respect to previous winters since 2003/2004. To do that they follow the evolution of several dynamical parameters such as: temperature, zonal wind, wave activity. The authors focus particularly on the stratospheric warming occurring during winter (date of arrival, intensity, type of waves. . .). This study is based on the analysis of operational data from ECMWF. In the last part they combine the evolution of several proxy over the 15 last years for quan-

tifying the ozone loss. The paper is well-written with a lot of references showing the scientific interest of this topic.

General comments: It is not sufficiently shown in the paper if the authors focus on 2009/2010 winter or if they want to characterize all the previous winter since 2003/2004. They show a lot of very sensitive dynamical parameters but do not use them with sufficient details. They describe some local characteristics of the plots and conclude. Because there is a lot of information not used in the graphs presented, it is not easy to be convinced about their concluding remarks. Perhaps adding several tables with the characteristics highlighted of the winters considered could give more clarity. There is no real link between the dynamical discussion in part 3,4 and 5 that allows them to define the proxy (mean zonal wind in January) they use in the last part to conclude on the ozone loss observed each winter since 1985. This last part appears to be another discussion. In its present form, paper objectives are not clearly defined. What's the link between the part on ozone loss and the dynamical study developed before, no link is provided by the authors between both.

Title The title is perhaps not well chosen. The authors characterize all 7 winters in the same way from 2003/2004 and do not focus their paper on the 2009/2010. The last part is on more than fifteen years of data. Abstract p. 7244 L6 : Suggestion in red : Âń . . .(SSW) by the reversal of winter westerlies in . . ." L9-11 : "The associated vortex split confined to altitudes below 10 hPa and hence, the major warming (MW) was a vortex displacement event" Comment : This is confusing since split and displacement events are different. I think this is more an altitude dependence : split below and displacement above but this must be better clarify.

General comment: I think it could be a bit confused for the reader between SSW and MW since in the abstract the difference or the link is not explained.

1. Introduction :

p.7245 L 4 : Reference needed: "In some extreme cases the temperature rise can be

as high as 50°C-60°C" L4 : "The accompanied zonal wind reversal displaces or splits the polar vortex toward mid-latitudes" Do you speak about the study of Charlton and Polvani (2007) ?

L13 : Comment: The authors have to define Major Warming before discuss about them, please invert the third part and the second part. L 21 : Comment: in the fourth part, the definition you use for your study to define MW has to be given in the part data and method. Comment: Reorganise the introduction defining first MW, SSW and the link between MW, SSW, Minor Warming.

p.7246 L 2,3,28 : add to N when you refere to latitude 60°.

Comment : Reference: In this introduction use the results of (Ayarzagüena, 2011) since it's also a 2009/2010 MW study and the paper of Orsolini et al., 2010 (JGR) since it's a last decade SSW study.

2. Data analyzes and methods

Equation (1): please denotes temperature by T and not by ïĄŚ, in equation (3) and (4) this symbol is used for "any function of entropy" after. 3 Synoptic evolution of winters

3.1 temperature and zonal wind

Comments: The figures 1 are not used in detail. There are a lot of differences in the evolution of temperature and zonal wind each winter but you do not describe them. For example : for the 2007/2008 it is never said that the temperature evolution at 90°N presents several important peaks (Jan-Feb) whereas other winters present just one major peak. Do you want to conclude in this part that all winters are very different regarding those parameters, or to find some general characteristics? Suggestion : Because 2004/2005 and 2006/2007 winters are really different comparing to other ones and because you do not consider them after, it could be better to help the reader plotting specific figures for these two winters, and as a consequence the figures will be more clear and analyses of the five others winters more easy. Figure 1 : The line for

2004/2005 is too thick.

3.1.1 The warming criterion at 10 hPa

Comment: The prolonged 2005/2006 warming seems very closed to the 2003/2004 one at 60°N and 90°N. It seems that the 2005/2006 warming "really" starts around the day -8 until the day +45 while the 2003/2004 starts the day -26 until the day +24.

3.1.2 Vertical development of the MWs

Figure 2: Are the magenta contours necessary? Comment : in the text and on the figure use a notation "2003/2004" and not just 2004 in order to be in agreement with your previous and following figures. p.7251 L 20, Comment: "In 2003/2004, relatively lower [. . .] in any other Arctic winters". I don't understand this statement/conclusion and I don't see the feature by comparison with the other winters.

3.2 Fluxes and waves

p. 7252 L 5 :The heat flux you report in the text for 2009/2010 during MW is really lower than 400 m Ks-1 in your figure. Comment: There is a lot of information in these figures. You do not describe them and compare them in detail. As in figure 1 you use just some characteristics, and do not explore all information you have. What is the conclusion of this part and the link with the next one?

-General Comment on part 3.1 and 3.2 : Perhaps a table could summarize your analysis and the different characteristics you have found to better compare the 2009/10 winters to other ones. In this table you could perhaps do the link with the part PV diagnostic by highlighting the characteristic you want to illustrate with PV maps.

3.3 PV diagnostic

p. 7253 L 21 : you have not a 3.3.2 part, the subtitle 3.3.1 is not justified.

Comment: The first paragraph is clear but the last one is very confused. p. 7254, L 19 : the date 5 January 2003/04 does not appear on maps. L13-L26 : In the first part of

the second paragraph, you do not refer in the text to 850 K or 475 K panels, this is a bit disturbing to follow the text with figures. More details would be expected on this last part which could be considerably improved.

-Comment : The dates you have chosen for PV maps are not sufficiently justified (p. 7253 L 16-18), you must use the previous figures to define the conditions of selected dates and why you have selected them. You have to find one or several parameters for justifying your choice. Otherwise your conclusions are not justified, because we do not know what you are comparing and what you want to show. For example : I have reported the date you have selected for PV map on the figure 2 and they do not correspond to the same conditions with respect to temperature evolution and wind evolution. They correspond to nothing in the low level you have presented before. Note that, the date can be different for each winter, but to compare each winter, you must qualify the period considered with respect to the Warming highlighted before: just after MW when circulation is Easterly, when circulation returns Westerly and before the FW, and when the FW is well established. You must really have a strategy clearly exposed for selecting the different dates to be able to compare the different winters. Perhaps zonal PV mean time evolution could help you to justify your choice?

-Comment : The conclusion of this part is that all winters are very different?

Figures 4 and 5 : Please mention at the top of the plate for each column the winter considered with the notation “2003/2004”.

5. SSW and ozone loss

In this part several proxys are used to identify sensitive parameters for quantifying ozone depletion from 1985 to 2010. Some of them are really well known as mentioned in the text (PSC area, temperatures. . .). The new information is the correlation between O3 and zonal wind (60°N-90°N) in January. The use of this parameter does not come from concluding remarks given in the previous parts. The feeling is that this parameter is use and it works, but not sufficiently justified by the paper. Is it the best one? This

part seems to be disconnected with the previous ones. How do the authors justify that ozone loss (an integrated variable on all stratospheric layers) is correlated with the zonal wind at the level 50 hPa? Is it the same at 10 hPa, 30 hPa? Why do you use only one level and this one? This is not clear. Please conclude previous each part and use the concluding remarks for justifying your new proxy otherwise it is just a hazard to discover this potential proxy. With this proxy it means that at the end of January you can predict the ozone loss, and this every year?

6. Discussion and conclusion

A lot of new studies are cited for the first time and too much new information is given. The discussion is not clear, and not well structured. This part must be improved by including subsection 6.1, 6.2. . . with a relevant title. p. 7260 L 3-7 : the sentence “each winter is different with respect to the chemical and dynamical processes associated with them.” is not well adapted and ask more questions than answers on the study you present. p. 7258 L25 : typo error 2008/09 and not 208/09

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