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## Comment on acp-2020-1237

Anonymous Referee #1

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Referee comment on "Does the coupling of the semiannual oscillation with the quasi-biennial oscillation provide predictability of Antarctic sudden stratospheric warmings?" by Viktoria J. Nordström and Annika Seppälä, Atmos. Chem. Phys. Discuss., <https://doi.org/10.5194/acp-2020-1237-RC3>, 2021

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Review on:

"Does the coupling of the mesospheric semiannual oscillation with the quasi-biennial oscillation provide predictability of Antarctic sudden stratospheric warmings?", ACPD, 2021, by Nordström, V. J. and Seppälä, A..

In their paper, Nordström and Seppälä present a coupling of SAO and QBO phases that has occurred both during the 2002 and during the 2019 Antarctic SSW events. The authors describe some characteristics of the two wind phenomena that, in combination, were special in these two years and hence may be crucial for the generation of the SSW events. In other years of similar QBO and SAO phase combinations, some differences can always be pointed out, but the method of doing so is not convincing. The conclusions of the paper are all in all pretty vague, and I think they could, with little effort, be concretised such that a clear statement stands at the end of the paper. I think the study presents an interesting mechanism that has the potential to add a fair bit of understanding to the SSW phenomenon and I recommend publication in ACP. However, there are a couple of major and numerous minor points that I would like to see addressed beforehand and also the presentation quality requires some improvement, especially because the language is often too unprecise. Please consider the list of major, minor and technical issues below for that.

Major issues:

- I do not understand how it can be fair in this study to compare in Figs. 9-12 an average over several years with particular years. This way you can average out particular features of certain years or even create artefacts in the averages. The dates that are chosen appear rather arbitrary and not well defined. If they are specific for each year (which seems to be the case for the two SSW years), how can they fit to the averages over several years? I also did not really understand how it makes sense to put these particular years into one pot (the use of the 'streams'). I guess this requires some good explaining or serious revision of the method.

- In some of the additional years, the SAO-QBO interaction takes place, but then the signal is not moving down all the way. Too often in the paper, it is stated that eQBO and eSAO come together, but then this does not result in change in deposition of wave forcing/wind reversal/... (see 301-302 as example) but then, the reason for that is not discussed. This happens throughout the paper, it always leaves the reader behind puzzled with nothing in his hands. Some more analysis or discussion to at least point out the one or the other mechanism that could be responsible for this would be very helpful.

- In the analysis, gravity wave (GW) drag is completely missing. GWs can also largely contribute to the overall wind forcing in these areas. These data should be available from MERRA-2 as well. That should be added to the resolved wave drag and the contours should be plotted more nuanced. As is, the caption does not even provide information on the values of the drag and there is only one (or no) contour line. Possibly, clearer conclusions can be drawn on the wave activity statements with this done.

- The paper fails to make any quantitative statements about the events. In consideration of the few examples, it is clear that this cannot be made in detail. However, some more effort could be made to achieve something in that direction. One could maybe make statements about when it is too late in winter for the two signals to fall together for generating an SSW as seen from example years where this happened. Or the magnitude that is reached could be described better. For example, in L269-270 a 'large' eQBO and SAO is mentioned but not even stating what 'large' means. Is it the strength or the expansion of the easterly winds that matters? With statements that are a bit clearer, the conclusions of the paper could step up a little from what is now stamped by a conditional that reflects in the word "may" too often (see e.g. L316-). The mechanism that is described in the paper is quite clear and interesting, so it is a little disappointing that at the end the conclusions are so vague. I think this could be improved fairly easily for example by some statistical analyses.

Minor issues:

- L10: "these features". Please name them.
- L28: When did record keeping begin?
- L31-32: This is a bit oversimplified for my taste, please don't forget about PSC processes here. (below you mention it then) Moreover, use the common wording 'ozone depleting substances'. These substances are there, no matter if "trapped" or not. Please remove the word "trapped".
- L55: 'at higher altitudes' and 'at lower altitudes' in one sentence confuses me. Please rephrase.
- L61: Rephrase to: Hence, the dynamic situation in 2010 was unlike the situations in 2002 and 2019, because in the latter two years, rapid warmings and wind reversals occurred.
- L96: What does 'well' mean here? Realistically or at all or ...?
- L104-109: I do not think this kind of summary belongs here, rather state how the paper is structured at this point.
- For my taste, the introduction (and also the methods section) is too long. I do appreciate the detailed information, but I think the authors could try to somewhat compress it. Sometimes it is a bit of a back and forth and moreover, I am not sure if all the information is really needed for the paper.
- L136: Remove: 'in zonal winds'
- Fig. 3 caption: Denote the magnitude of the EPfc line!
- L160: cite here: Middle atmosphere dynamics, Andrews, David G and Holton, James R and Leovy, Conway B, 40, doi:10.1002/qj.49711548612, 1987, Academic press
- L195-196: "reverse further down than the mesosphere" I do not understand what you want to say here. Can you rephrase that please.
- L200-2005: Rephrase to: In Fig. 4, we average Fig. 3d according to the two geopotential anomaly patterns from Fig. 1, namely clockwise from 40..... This way, we find .... But actually, do you conclude anything from these figures? Or will you refer to this later on? If so, state it. If not, you can remove this bit, because it shows simply what you would expect.
- L206-209 and associated figure: That is a nice depiction too, but not needed for understanding. If no conclusions are drawn from this here, move it to where it is needed, or remove it. (but see below)
- L218-219: rephrase 'comes to lay' and please the entire sentence, it is very confusing
- L221: Rephrase to: Fig. 6d shows that the polar winds reverse between ...
- L223-225 If the purpose is to contrast Fig. 5 and Fig. 7, show the two figures together here and describe differences. Wouldn't it be interesting to extend these time series to when the SSWs happen to see the entire evolution? Or is not so much happening in these latitudes then?
- Remove subsection headers 3.3.1 and 3.3.2
- L235: Fig 8 is as.... remove the sentence
- Fig. 9-12: I cannot see any EP flux convergence contours in these plots (exception is 12b). I can hardly imagine that there is none anywhere there. So how come?
- L249: 'as before' What are you referring to exactly? Be precise.
- L256: How can you expect the timing to be so similar to 2002 or 2019, when even the timings of 2002 and 2019 are not really similar. How similar does it have to be?

- L273-275: 'smaller' and 'larger'. In what sense? Expansion, or strength, both? Be specific.
- L273: Rephrase to: ...QBO and SAO and the two patterns only occasionally interacted.... But actually, I do not like this statement at all. How can you summarise over whole decades, when each year is so specific and has its very own dynamics and each feature can be of importance. This refers to my main point, why I think the averaging over several years is not feasible in this study.
- L280: Do you mean: In both years, the SAO is in its easterly phase with winds extending into the SH above 1 hPa... ? (also L349)
- L287: The 'However' here confuses me. Do you want to express 'in contrast'? But I don't see how these two situations stand in contrast. Can you resolve this?
- L288: What does 'links across latitudes' mean?
- L308: I guess you mean stratospheric extreme events? As it appears like referring to troposphere. Better simply write SSWs.
- L317-320: The reason that SSWs are less common in the SH is not explained here! I reckon the eQBO and eSAO co-occur about as often in both hemispheres, and then the wave guide is changed similarly in both hemispheres. But what is different is the amount waves that then uses that waveguide and makes its way up to the mesosphere. In the SH there are generally much less/weaker waves and hence the perturbation in the upper atmosphere is weaker.

#### Technical issues:

- L30: What do you mean by 'descend' here? I guess a different word could be more suitable.
- L21: Change 'aftermath' to 'influence'
- L59: Change 'had' to 'included'
- L66: Change 'However' to 'In contrast'
- L67: remove 'flat' and change 'don't' to 'do not'
- L83: change 'a switching' to ' and 'alternation'
- L96: change 'found' to 'showed'
- L99: Do you mean forced QBO and SAO-like or forced QBO- and SAO-like or...?
- L101: change to: ... we are here following suggestions that the upper atmosphere may be key to understand the...
- L102: draw
- L104: In the present study, we analyze the interactions of the ...
- L114: change 'vertical levels' to 'levels in the vertical'
- L122: change 'were' to 'where'
- L124: remove one 'average'
- L133: Analogously
- L134: Rao et al. (2020)
- L136: ...by contrasting the zonal winds to sonde radiosonde measurements from Singapore...
- L154: MERRA-2
- L154: deposition
- L160: Change '\*' to '.'
- L166: ...correspond to the ...
- caption Fig. 1: ... at 2 hPa over ... and remove last sentence
- L183: In the austral winter of 2019, the QBO was in ...

- L189: 'comes to sit' □ 'remains'
- L198: form □ from
- L218: between 50 and 2 hPa
- L238 and L241: (Figure 8b)
- L245: ... for these years.
- L272: reversals
- L287: In 2002, the zonal mean....
- L305 ...was it necessary...
- L321 heed?
- L333-: Please move these links to the references or so.