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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Signatures of the two day wave and sudden stratospheric warmings in Arctic water vapour observed by ground-based microwave radiometry" *by* B. Tschanz and N. Kämpfer

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Response to Anonymous Referee #2

Dear Referee, your helpful and detailed comments and suggestions are highly appreciated and we thank you for investing your time. In the following we answer your comments and indicate changes in the manuscript. We summarise the main points of your general comments in italics and present the response.

We agree with the referee, there have been many studies investigating SSWs. Nevertheless, we think that extending the investigation of SSWs using new data is valuable for both understanding and categorising SSWs and for demonstrating the possibilities of ground-based measurements. We are aware that our contribution to research related to SSWs in this paper is a report of observations and we basically repeated a combination of the analysis used in Straub et al. (2012) and Scheiben et al. (2014) for two consecutive events with a water vapour dataset obtained at the same location.

In order to emphasise the Q2DW, we switch the sections in the text to match the order in the title with Q2DW first and SSW second. In addition, we are going to underline the Q2DW results in the abstract and discussion.

Comments:

page 373, lines 12 13: This sentence sounds somehow strange. Substituting "entering" with "the transport of this trace gas" could help. Besides that I would argue this transport is not the "main" source. For the middle atmosphere as a whole it is more like a 50-50 thing with the water vapour production from CH 4 and H 2 providing the other half.
We agree and changed the sentence to:
There are two major sources of middle atmospheric water vapour. The first one is vertical transport through the tropical transition layer. ...

page 373, line 14: I suggest to use the term "freeze-drying" instead of "dry-freezing". It is simply more common.
Done.

page 373, line 20: The horizontal gradients are sustained by the vortex edge. Otherwise the descending air would mix with mid-latitude air.
We added:
..., which are sustained by the vortex edge.

page 374, line 8: It should be "two days, ... " instead of of "two day, ...". And so on.
Done.

page 374, lines 25 - 28 & page 375, lines 1 - 3: There is a lot of doubling in these two sentences, like "this paper", "ground-based" or "radiometer", which makes a bit confusing. In addition, the phrase "illustrate the capability" appears to be too shy for the

potential of such observations.
Changed page 374, lines 23 - 28 & page 375, lines 1-3 to:
Measurements of the state of the atmosphere are essential for increasing the understanding of the dynamically variable Arctic winter atmosphere and help to improve the quality of models. In addition to satellites, ground-based instruments are used to monitor the atmosphere. They offer the benefit of being relatively easy to maintain and of a long lifetime compared to satellite instruments. In this paper water vapour data obtained with a microwave radiometer at the Arctic station of the Finnish Meteorological Institute FMI in Sodankylä in Northern Finland is used to demonstrate the capability of ground-based measurements at one station to monitor variations caused by Q2DW and SSWs.

The ground-based Middle Atmospheric WAter vapour RAdiometer for Campaigns (MIAWARA-C) measured in Sodankylä for 20 months from June 2011 to March 2013.
...

page 378, lines 27 - 28 & page 379, lines 1 - 3: I think the water vapour development here is even more complex than described. If you look at the lowermost mesosphere there appears to be a brief influx of former vortex air above Sodankylä just after the central SSW date. Shortly afterwards water vapour volume mixing ratios jump up again before a second weaker influx of former vortex air occurs. This happens within roughly 10 to 14 days after the central date of the SSW. Just at the 3 ppmv or 4 ppmv isopleth higher up in the middle mesosphere you see the steady descent in the aftermath of the SSW. Can you elaborate on that a bit? In that regard I think there are some inconsistencies to the message conveyed by the sentence in lines 18 - 20 on page 379.
We generally agree with your comment, the water vapour isopleths for VMR values around 5.5-6 ppmv show the behaviour as you describe in your comment: there seems to be an influx of former vortex air right after the central date. A confirmation can be found in the distance to the vortex edge. For the year 2013, there is a double peak

in distance to the vortex edge in the mesosphere an upper stratosphere. Calculation of Lagrangian 5day backward trajectories based on ECMWF operational data confirms that there have been different phases: 1) Just before the central date low-latitude air has been transported to Sodankylä. 2) Around the central date the origin of the air arriving at Sodankylä is in polar regions. 3) Afterwards, there is a second influx of low-latitudinal air.
In the revised manuscript we discuss the influx of former vortex air supported by the distance to the vortex edge and its effects seen in water vapour mainly for the 5.5-6 ppmv isopleths. The steady descent is only observed for VMR larger than 5 ppmv. Additionally, we have changed the order of the paragraphs.

page 379, lines 5 - 6: I would be a little bit more careful here. In the uppermost stratosphere the vortex air could already be dryer than non-vortex air. Some nice examples of this are shown in Nassar et al. (2005) and Lossow et al. (2009).
You are right. The transition from vortex air being more humid to being dryer compared to non-vortex air is located at approximately 40-45 km and does not coincide with the stratopause. We changed the sentence to: The descent above polar regions results in horizontal gradients of water vapour at the vortex edge. Inside the vortex, stratospheric air below 40-45 km is more humid than outside whereas the mesospheric vortex air is characterised as being dryer than non-vortex air.

page 380, lines 14 - 16: Something is fishy with the second part of the sentence. Should it be something like this: "... and only at high latitudes the Q2DW has been observed near winter solstice"?
Yes, thank you.

page 381, line 3: I would put here already a reference to Figure 6.
Done.

page 381, lines 11 & 12: There is certainly no amplitude peak at 2 days at 0.05 hPa in November. But there is one close by with a period of little less than 2 days that very likely can be attributed as Q2DW. The amplitude is just a little smaller than in the uppermost stratosphere. So, the message that there is no Q2DW in the upper mesosphere I would not support.
We assume that you are talking about the local maximum in amplitude at 1.5 days with an amplitude of 0.2 ppmv. Even though the amplitude is comparable to the one observed on 1 hPa with 2 days, it is much less defined if compared to neighboring periods. We had a look on figures showing period against time for 1.5 days for different altitudes and we do not see a clear maximum. Therefore, we do consider the small local maximum to be clearly related to the Q2DW.

page 381, lines 15 & 16: Here you could add a reference to Merkel et al. (2003) and Sonnemann et al. (2008).
We included the two references. We especially thank you for pointing out Sonnemann et al. (2008), it would have been a pity if we missed to mention their ground-based microwave work.

page 381, discussion of Figures 5 - 7: The figures are discussed to discern differences in the Q2DW in the mesosphere and stratosphere. I feel that this is a bit misleading. From Figure 4 I would make a separation between above and below 0.1 hPa, roughly.
You are right. We follow your suggestion and separate between above and below 0.1 hPa instead of mesosphere and stratosphere.

page 387, Figure 2 & page 388, Figure 3: I did bother a bit with the upper panel of these figures. I found that the overlaid distance to the vortex edge is covering up some details that I liked to look on. Could that be an idea to move the information to a separate panel?

Thank you for your suggestion. We added a forth panel to the figure.

Technical corrections:

page 377, line 21:"cause" should read "course". This happens again on page 379, line 24.
Done.

page 380, line 15: "hight" should read "high".
Done.

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Interactive comment on Atmos. Chem. Phys. Discuss., 15, 371, 2015.