Wang

This is a very interesting paper that is well written with a clear story line. I have a few minor comments, and I hope those will help polishing the paper toward final publication.

Comments on paper ACPD-15-22013-2015 entitled “Variability of water vapour in the Arctic stratosphere”

For years the topic of stratospheric water vapor in high-latitudes was indeed less reported. That’s why I was immediately intrigued by this interesting topic (also because I have seen similar results from our trajectory model). Unlike other simulations that mainly based on cold-point temperature regulations (e.g., Fueglistaler et al., [2005]; Schoeberl et al., [2002]; Wang et al., [2015]), the FinRose model has interactive chemistry included over the polar region, which makes this research more valuable to the UTLS and stratosphere community. However, I have a few comments to the authors and I hope those can help polishing the entire story.

We thank Dr. T.Wang for the encouraging review which we found very helpful indeed. We have revised the manuscript to address all the comments.

1. There should be more details to the model description. For example, besides implicit chemistry and circulation from ERA interim, is there any mixing considered? How about wave activity? Also, I am confused at the relations between “tropospheric concentrations” and the “boundary conditions” mean. What does “boundary conditions” mean in this paper?
The tropopause height is calculated at every time step using potential vorticity as defining parameter. Model levels below +-2 PVU are considered to be in the troposphere. Close to the tropics the 380 K potential temperature level is further used to define the tropopause. The tropopause is thus changing with time along meteorological conditions. The tropospheric concentrations of the chemical species are not calculated in the model but prescribed via model boundary conditions. These details are added to the revised manuscript.

2. About the description of (using) ERA interim water vapor field. This mainly occurs on P22021/L8-10, which is quite misleading. The authors mentioned about the improvement on ERA interim H2O after adopting the new linear scheme for stratospheric methane, but this was only limited to the experiments conducted on year 2000 (Monge-Sanz et al., [2013]). Therefore, the boundary condition water vapor (if I understand it correct) used in FinROSE model is still the official H2O field available on ERA interim. Be noted that ERA interim doesn’t assimilate H2O at the altitude range covered in this paper, so humidity field might primarily reflect the model simulation, and therefore comparison to observations is itself less meaningful. I mean, how much credibility should we lay on its range?
Please note that we state in P22021/L8-10 of the manuscript that ‘*The description of stratospheric H2O in the ECMWF model is however simplified (Monge-Sanz et al., 2013)…*’, therefore we believe there is nothing misleading in theses lines. We are aware about limitations imposed by using ERA-Interim. In the revised manuscript we specifically add that biases in ERA-Interim water vapour affect our simulations (see below). However it provides continuous and global coverage needed for initializing transport models, which is not available from observations. That is why it is used in ours as well as in other papers such as Schoeberl et al. (2012). The Reviewers concern about ‘how much credibility should we lay on its range’ is partly addressed in the manuscript by evaluating FinROSE simulations against observations from satellites (MLS) and soundings. We show that in many cases FinROSE

compares favorably to observations, which adds credibility to ours methodology. To further address Reviewers concern we add a note of cautious on the quality of ERA-Interim boundary conditions:
'The FinROSE-ctm has been run using ERA-Interim meteorology and ERA-Interim water vapour data as tropospheric boundary condition. Thus, the evolution of water vapour in the FinROSE model is strongly constrained by the water vapour at the ERA-Interim tropopause. Kunz et al (2014) recently compared Era-Interim water vapour in UTLS against independent sounding observations and found that while in the majority of the cases the agreement is satisfactory, in some cases the discrepancies between Era-Interim and observations are large. Thus one can expect that these biases would affect FinROSE simulations in the stratosphere. Nevertheless, since the description of stratospheric H2O in the ECMWF model is simplified (Monge-Sanz et al., 2013), the chemistry scheme in FinROSE produces a more realistic water vapour distribution, as we show in the manuscript.'

3. When comparing to MLS observations, did the authors apply averaging kernels? This might not be important since the focus is only on polar region that has lower reliance on H2O from below and upper levels (this could also be told from the figure below that applied AKs to the Fig. 4 in this paper), but it is worth to do a sanity check in order to do an apple-to-apple comparison.
MLS data used for Sodankylä were now changed to MLS overpass data figures 1, 2 and 4a. The area averages for figure 4 b-e are calculated from level 2 data, and are gridded without averaging kernels. Some text about the overpass-data have been inserted to the Water vapour and PSC measurements-section.

4. When comparing to MLS observations, please also pay attention to the cold-biases in ERA interim temperatures (Fueglistaler et al., [2011]), since those would affect the trajectory results tremendously (Schoeberl et al., [2012]).
We have commented on this in the original manuscript as follows: *'The dryness in the reanalysis data is likely a consequence of cold bias in the tropics in the ERA-Interim data (Schoeberl et al., 2012).'*

5. I hope the authors could also double check on Fig. 2b green line (ERA interim –MLS) around the tropopause. An eye-ball check, and also my own calculations a few years ago tells me that the difference should be at least around 10-14% at 100-hPa.
In the figure 2a there is water vapour from winter 2010 and in Fig 2b climatologies of the differences between MLS -sounding, MLS -ERA-Interim and MLS -FinROSE. The differences don't have to be the same in these figures. However, we have changed the MLS data to the overpass data and taken year 2014 along to the climatology. Now the difference between ERA interim –MLS is about 8+-6 % at 100 hpa.

6. Fig. 4 panels b–e show the anomalous H2O and the components due to transport and chemistry, which is basically what we saw in previous figure (Fig. 3) and the Fig. 6 in Schoeberl et al., [2012]. Here, in order to support the analysis in P22024- 22025, it is better to add MLS to those panels despite different time range. What the authors could do is to subtract the cycle covering the MLS period, and the results would be essentially the same but it adds more credibility to the model's performance. For reference, below is H2O from our trajectory model, driven by reanalysis and controlled by purely temperatures. Note that this figure demonstrates results from using GPS RO temperatures; but results from using reanalyses temperatures would be basically the same since reanalyses capture the interannual variability of cold-point tropopause over the tropics very well and therefore the *predictions are similar that essentially match with MLS observations (refer Fig. 8 Wang et al., [2015] for details). On the other hand, this, from another perspective, supports many arguments in this paper about the origin of stratospheric air.*

Figure. Arctic water vapor predicted from trajectories driven by MERRA (blue) and ERA interim (orange) circulation and GPS RO temperatures (refer Wang et al., 2015), compared to MLS observations. All trajectory results have been weighted by MLS averaging kernels.

Thanks for this comment and for sharing the results of your trajectory simulations not included into Wang et al. (2015). We have added MLS anomalies to the figure. We believe that this addition does improve the presentation of the results.

7. Discussions about the contributions to H2O from chemistry and transport (section 4) could be more easily understood by the H2O lifetimes (refer chap. 5 in the classic book by Brasseur and Solomon, [1986]).

Here the contribution from chemistry mainly refers to water vapour anomalies due to methane oxidation which takes place in the upper stratosphere. In the lower stratosphere where direct water vapour production from methane is negligible the variations arise from the transport of chemically produced water vapour from above. Therefore direct comparison of local chemical and transport life times of water vapour would not help much to understand contribution of these two sources to water vapour changes in the lower stratosphere. The rate of methane increases is more relevant here, as discussed in the paper. In the revised manuscript we specify what chemical contribution means as follows:
'*The chemical part (purple line), which is mainly due to the contribution of methane oxidation, has only a small positive trend …*'

8. Discussion in P22025/L17-23 is not exactly accurate. The stratospheric water vapor is more dominated by the Brewer-Dobson circulation instead of QBO. Please refer the multi-variate regression coefficients and the component time series in Dessler et al., [2013, 2014]). That's why the 2000-drop is believed to be related to the BDC (e.g., Randel et al., [2006]).

Following this and the related comments of R1 and R2 we have elaborated the discussion of the water vapour variability. We performed regression analysis following Dessler et al. (2014). We used three proxies: qbo index (QBO, equatorial winds at 50hPa), Brewer Dobson circulation index (BD, residual vertical winds at 70hPa averaged from 30S to 30N), and cold point temperature (CPT). Unlike Dessler et al. (2014) we found that the use of tropical temperatures at 500 hPa was not enough to explain the variability of the cold point temperature, and therefore used it as one of proxies. Although, there is some correlation between CPT and QBO (0.36) QBO also affect the transport of the water vapour not directly influenced by CPT; therefore the use of both proxies is justified. We apply multiple regression analysis with all three proxies to water vapour time series averaged north of 70N and at 82 hPa and 56 hPa. Cross-correlation analysis shows bread peaks at lags 6-12 months for the proxies. The maximum of the correlations of QBO and CPT with water vapour at 56 hPa is at about 10 months lag, and with 82 hPa is at 8-9 month lags, suggesting that propagation of the tropical anomalies in the lower stratosphere is faster than that in the middle stratosphere, likely due to more efficient mixing. We use 10 month lag for all proxies for regression at 56 hPa and 9 month lag for the regression at 82 hPa.

The individual correlation coefficients with our proxies are shown in the Table below. The main contribution to the polar water vapour variability is CTP, followed by QBO. We found very weak contribution of BD proxy to the variability of the water vapour. One reason is that the effect of BD contribution is accumulated over time and this is not well represented by the monthly proxy. The multiple regression coefficients are 0.57 and 0.51 at 82 hPa and at 56 hPa correspondingly, showing that our models only explain 25-30% of the variability. This is considerably less than that of Dessler et al. suggesting that different processes contribute to the polar water vapour variability in comparison to those in the tropics. Note that the regression somewhat explains the increase of the water vapour from 2005 to 2010, which is more clear at 82 hPa. However the peak of the water vapor during 2011-2013 is not explained by these proxies.

Table: Correlation coefficients

	CPT	QBO	BD	Multiple
56 hPa	0.454073	0.315499	-0.209597	0.51
82 hPa	0.518588	0.399678	-0.180337	0.57

9. Some comments on figs. 2, 4, and 6. This is a personal preference: I always add legends to the figures, so that when someone else uses those figures in their presentations they don't need to add legends manually. On the other hand, with legends the vast information is easy to be spotted on.

Thanks for comment. We added legends to the figures.

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