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Interactive comment on "Sensitivity of stratospheric water vapour to variability in tropical tropopause temperatures and large-scale transport" *by* Jacob W. Smith et al.

Jacob W. Smith et al.

jws52@cam.ac.uk

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Anonymous Referee #2

Reviewer comment (RC): General: This a very important and well-written paper and should be published by ACP. It de- scribes and uses the novel method of separation of transport and temperature histories on the formation of stratospheric water vapor. Although there are some limitations of this method (e.g. diabatic vertical velocities which are a part of transport strongly de- pend on temperatures), the obtained results are of great value. Similarly, the timescale- dependent analysis of Eulerian temperature variations give very interesting insights into their importance on stratospheric entry

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Discussion paper

values of water vapor. Thus, I have only few minor comments.

Author comment (AC): We thank the reviewer for their supportive and insightful comments which have improved the paper. Responses to specific comments are below. Small changes have been made to the text throughout.

Regarding responses: As a result of revising sections 2.1 and 3.1 for reviewer 1, figure 1 is now removed. So all figures 2,3...13 are instead number 1,2,...12 in the revised manuscript. All of the figure numbers mentioned below refer to the initial submission.

RC: Major points

Maybe one additional sentence in the abstract stressing the importance of the sampling effect of the Lagrangian dry point reconstruction which can lead to so different values and patterns of water vapor entering the stratosphere if compared with Eulerian estimates. . .

AC: This sentence has been added: “As with other aspects of dehydration, simple Eulerian measures of variability are not sufficient to quantify the implications for dehydration and the Lagrangian sampling of the variability must be taken into account. ”

RC: Minor comments:

P2L26 ...impact of water vapor on ozone is also related to the impact on the formation of the polar stratospheric clouds (PSCs)...more PSCs, more catalytic ozone de- pletion... maybe you can mention it

AC: PSCs are now mentioned.

RC: P4L122 The sentence starting with “This value could be regarded...” is very difficult to understand and probably not necessary. Fig 1, its caption and the other parts of text explain fully sufficient the applied method...Maybe you can replace “hot” by “warm” in the color bar of Fig 1 (hot TTL sounds strange for me).

AC: To address this and the comments of reviewer 1, this paragraph and figure 1 have been removed. Rather than referring to two timeseries, the method is presented as sensitivity experiment with replacement temperatures or replacement transport.

RC: P6L170 In the description of the UM-UKCA simulation it is not clear for me how the inter- annual variability was realized in the time-slice simulation. Because of the perpetual year 2000 boundary condition, it is not clear if you run year 2000 many times (perpetuum run) and get in this way an ensemble of "different" years 2000 which mimic the inter-annual variability of the real atmosphere?

AC: A sentence has been added to this paragraph to clarify what type of interannual variability is present in UM-UKCA. Also, to reflect the final figures presented in this paper, the statement that '49 years of data are used to calculate back trajectories' has been corrected to 12 years.

RC: P6L183 The 11 orange lines are obtained by using the transport of each particular year between 1999-2009 (11 cases) for all years between 1999 and 2009, isn't it?...maybe you would like to add this or a similar sentence to your text or to the caption of Fig 3a.

AC: Thanks, a more explicit description has been added to the caption of Fig3a.

RC: P7L193-203 To be honest I do not understand your explanation in this paragraph. For me every orange line in Fig 3a is calculated with always "true" temperature and "false" winds with exception of only one year when also the wind is correct (e.g. if you take the winds from 2003 for all other years between 1999 and 2009 than only for 2003 both temperature and winds are correct). Then, to get the purple line in Fig 4a you have to calculate the in-year average, i.e. an average over 10 orange lines from Fig 3a ....same with the orange line in Fig 4b resulting from 11 purple lines in Fig 3b. However, I do not understand why did you flip the colors? You also write in the caption of Fig 4 "....of (orange) time-shifted-temperatures and (purple) time-shifted-transport" Maybe you would like to clarify and reformulate this paragraph.

AC: Also in response to reviewer 1, this paragraph and related descriptions in the abstract and methods section have been reformulated to be more understandable. The phrases 'time-shifted temperatures' and 'time-shifted transport' have been replaced with 'replaced temperatures' and 'replaced transport' and described as sensitivity experiments. As part of reformulating the text, the colours in figure 4 have also been swapped. The description of the relationship between purple and orange lines has been removed as it is a subtlety that obscures the main results.

RC: P8L235 The results presented in 3.1 are very interesting and important. One additional point: In Fig 4b the positive anomalies of the purple line are always between late spring and fall indicating the also the summer monsoons and their dynamical interannual variability may be an important factor...

AC: Thanks, this is an important point across sections 3.1 and 3.2. It therefore included in the discussion.

RC: P8L249 The dry bias and reduced annual cycle amplitude due to non-linearity of the Clausius-Clapeyron equation with respect to temperature...

AC: This has been included.

RC: P9L255, Figure 5 In the caption you should shortly denote the red dotted line as an Eulerian esti- mation of the tropical H2O in the lower stratosphere..

AC: This has been rephrased to be clearer.

PHH: change 'a Eulerian estimate' to 'an Eulerian estimate'.

RC: P9283-288 Similar problem like in the previous chapter. I think that you repeat the transport of January for all month of a given year, the same for February, March, etc... and the same for temperature?

AC: This paragraph has been rephrased accordingly.

RC: P9L320 Section 3.2 is also very interesting and has very valuable results. Still two

re- marks (1) In boreal summer the monsoon circulations are very strong and unique. I also expect some influence on your results if compared with the winter transport, i.e. meridional “wide” (summer) versus meridional “narrow” (winter) tropics. (2) Vertical velocities, i.e. diabatic heating rates you are using depend strongly on the lowest temperatures in the TTL, i.e. cold TTL is related to a strong upwelling (winter) and warm TTL is related to a weak upwelling (summer). Because of this, the separation between transport and temperature has a clear limitation...

AC: The influence of tropical width will be part of the results described for Fig 6. It would be interesting to view the horizontal distribution of LDP events but is not presented here. For a limited view, see my thesis, Smith (2020) Fig 4.13, which may suggest that the summers of anomalous efficiency (1999, 2008) are connected to summers with a broader tropical region near the maritime continent. This is an interesting topic beyond the scope of this study but could be investigated in a further piece of work.

Such a separation between temperature and transport is inevitably artificial because in reality aspects of temperature and transport are to some extent coupled, but useful insight emerges. To reflect this, a sentence has been included to reflect this in section 2.1 and the second paragraph of section 5.

RC: P13L395 “Eulerian methods to estimate stratospheric water vapour”– in this context I can only imagine Eulerian methods to estimate temperature fluctuations which are compared here with the Lagrangian dry point estimation...how do you apply it for water vapor?... maybe you wish to clarify it

AC: This sentence was unclear and has been made more explicit.

RC: P13L420 You should mention here that the zonally averaged values are marked as stars in Fig 9.

AC: This has been included.

RC: P14L433 Why is the modeled tropical mean Eulerian water vapor (Fig 11 a, dotted

line) higher than the H2O obtained from the Lagrangian reconstruction? Is the transport scheme of the chemistry-climate model too diffusive?

AC: It could be because of differences in their respective transport schemes, such as diffusive climate model transport, or processes missing from the simple LDP calculation such as microphysics. This requires a careful investigation of the model transport scheme and we prefer not to speculate on this, so a general comment has been made in the first paragraph of section 4.1.

RC: P14L454 ...for which the LDP in the first month or two - something wrong with the sentence

AC: This sentence has been clarified.

RC: P14L558 “The seasonal variation of transport...” Do you mean the seasonal variation of vertical transport (different upwelling in winter and summer) or of horizontal trans- port (narrow tropics during winter and wider tropics including Asian and American monsoon during summer)?

AC: In the form of these sensitivity experiments, transport is general and referrs to both vertical and horizontal directions. This is now noted in section 3.1, and repeated in the summary section.

RC: P18L564 The general stronger role of transport during boreal summer and fall can be due to the inter-annual variability of monsoons

AC: This is now highlighted earlier in the paragraph, which helps to point out where vertical and horizontal aspects transport are considered.

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