Discussions for "Cirrus and water vapour transport in the tropical tropopause layer – Part 2: Roles of ice nucleation and sedimentation, cloud dynamics, and moisture conditions" – Reviewer A

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We would like to thank the reviewer for the encouraging comments for the manuscript. Please find below our responses to the reviewer's minor revision requests. We agree with all the reviewer's comments and have revised the manuscript accordingly.

1. ***Reviewer*** — Suggest adding either "cold cirrus clouds" or "Tropical Tropopause Layer" to the title because these simulations/conclusions do not necessarily hold true for warm cirrus clouds.

   Authors — The title has been changed to "Cirrus and water vapour transport in the tropical tropopause layer – Part 2: Roles of ice nucleation and sedimentation, cloud dynamics, and moisture conditions." Please see also our responses to Reviewer B for further explanation of this change in title of the manuscript.

2. ***Reviewer*** — P. 13304, Line 19: intepretations → interpretations.

   Authors — Thanks for spotting this spelling mistake. We have fixed it accordingly.

3. ***Reviewer*** — P. 13311, Lines 7-10 (Rather, of interest ...): What observations are you referring to in this sentence? Are there any observations to support your model simulations and conclusions? Although this is a theoretical study, quite a bit of observational work has been done to study these TTL processes. Can you link your results to these studies?

Authors — The reference to observations here is indeed confusing. We have deleted the second half of the sentence so that it now reads: "Rather, of interest here is the question to what extent the strongly simplified inf-sed calculation captures the dehydration induced by the cloud."

Please refer to our response to Comment 1 of Reviewer B for discussions comparing between model simulations and observations.

4. ***Reviewer*** — Figure 3: The q_v is averaged over the domain (correct?). What is the average cloud base/top height relative to the location of the hydrated/dehydrated layer for each scenario? In the text you mention that air passes through the cloud base is hydrated and the air that passes through the top is dehydrated. But in Fig. 3b for the all-phys dry case, the layer is hydrated at the top of the domain. I would be interested to see where the cloud top is relative to these simulations.

   Authors — The difference between the Eulerian and Lagrangian interpretations is quite interesting (but may be confusing). Figure 4 (originally Fig. 3) is indeed averaged over the domain (the Eulerian sense), and the change in water vapour here ($\triangle q_\mathrm{v}$) includes the advective tendencies. Conversely, the advective tendencies do not contribute to the change (δq_v) that the air parcels experience (because the parcels move with the air flow). Hence, we may have situations when, in the Eulerian sense hydration occurs ($\triangle q_\mathrm{v} > 0$), but in the Lagrangian sense dehydration occurs ($\delta q_\mathrm{v} < 0$).

   In Figure 5 of the revised manuscript, we show the domain average change in water vapour due to the source/sink terms associated with ice growth/sublimation only (i.e. the advective tendencies are excluded). Figure 5 shows that the domain average ice-to-vapour conversion is consistent with the change in water vapour along air parcels (the Lagrangian interpretation), with dehydration occurs always in the upper half of the cloud layer.

   We have added the following explanation for the differences between Fig. 4 and Fig. 5: "To separate the advective tendencies from the impacts on the moisture profiles of microphysical processes, we compute the accumulative mass of water associated with ice-to-vapour exchange during the model integration (Fig. 5). The exchange mass between vapour and condensates is recorded at the time and location when/where (de)hydration occurs (not at the end of the model integration). With the advective tendencies excluded, Fig. 5 shows that microphysical processes consistently lead to dehydration in the upper half of the cloud layer (in contrast to Fig. 4b where the advective tendencies result in hydration above 17.1 km in the all-phys simulation for the dry scenario)."

The cloud moves about both vertically and horizontally during the simulations. Please see the supplemental animations for illustration. We have added Fig. 6 which shows the location of the cloud at 3.5 d.

5. ***Reviewer*** — Figure 4: Is the conversion from ice to vapor or vapor to ice? Please clarify in the figure caption.

   Authors — The conversion is from ice to vapour. The caption (now Fig. 5) is revised as: "The profiles of accumulative mass exchange from ice to vapour over the model integration."

6. ***Reviewer*** — P. 13316, Lines 10–11 ("Of more interest ..."): I don't think I understand how you drew this conclusion. From your discussion, I thought that the inf-sed scenario did not produce much nucleation. Can you refer to the figure(s) to help make this statement more clear?

   Authors — This paragraph is indeed not clear. We rewrote it as: "The left panels in Fig. 8 compare the changes in specific humidity of air parcels in the inf-sed runs versus those in the all-phys runs for the dry (top panel) and moist (bottom panel) scenarios. The joint histograms (Fig. 8a and Fig. 8c) show a large number of air parcels for which the specific humidity is essentially unchanged in the inf-sed runs, but significant dehydration or hydration occurs in the all-phys runs. In addition, for dehydrated air parcels, δq_v is more negative in the all-phys than inf-sed calculations in both the dry and moist scenarios (the data for $\delta q_\mathrm{v} < 0$ lie above the one-to-one line in Fig. 8a and Fig. 8c). In other words, dehydrated parcels dehydrate more in the all-phys calculation. In the inf-sed runs, the immediate fallout of ice crystals limits dehydration to the saturation mixing ratio q_s at the nucleation time. Further dehydration does not occur in the same air parcels because the temperature never drops sufficiently low to bring the relative humidity above the nucleation threshold again. In the all-phys runs, dehydration continues after nucleation due to growth of ice crystals, and dehydration up to q_s at the minimum temperature of the Kelvin wave passage can be obtained."

   Please also note that we have rewritten a large part of Sect. 3.3, which is hopefully clearer and easier to read now.

7. ***Reviewer*** — P. 13316, Line 20: Figure 6c refers to the moist scenario. I

think you mean Fig 6b (not 6c).

Authors — Thanks! It is panel b indeed (the original Fig. 6 is now Fig. 8).

8. ***Reviewer*** — Figure 6: The scale is not defined for the histogram color bar, but I imagine it is number or counts. Please define in the caption.

   Authors — We added: "The colour bar shows the number of air parcel counts."