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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Increased water vapour lifetime due to global warming" *by* Øivind Hodnebrog et al.

Anonymous Referee #1

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The authors present a study of water vapour lifetime, defined as the ratio of IVW/P, from a series climate models for present and future climate. The main driving forces of an increase of the lifetime in a warmer climate are analysed by a range of sensitivity studies. In addition to some major comments, the overall writing can be substantially improved in some sections. I therefore recommend major revisions.

Major comments

1. Abstract: The abstract should be revised to better reflect the actual content of the manuscript.
2. Introduction: "The fact that water vapour content increases more than precipitation with rising surface temperatures implies an expected increase in the lifetime

(Douville et al., 2002; Held and Soden, 2006; Schneider et al., 2010), and hence a slowing down of the hydrological cycle. However, global-mean precipitation or evaporation fluxes are commonly referred to as the strength of the hydrological cycle, which, in contrast, implies an intensification or acceleration of the hydrological cycle with global warming. Douville et al. (2002) note that this conclusion is somewhat misleading because it suggests faster turnover of water, which is not the case. Hence, when the global hydrological cycle is said to intensify or accelerate with warming, it should be made clear that this refers to the fluxes and not the cycle as a whole"

The takeaway from this paragraph is rather confusing. If the fluxes intensify, what is the significance of the overall slowdown? The authors need to resolve the more fundamental underlying issue of explaining the meaning or significance of a residence time change. If what matters for the impact of climate change is the intensification of fluxes, what is the purpose of talking about a slowdown of the hydrological cycle? Maybe there is a clear answer, but it needs to be stated somewhere early on to motivate the reader to adopt the perspective of IWV/P rather than IWV and P individually.

3. Regarding the deep convective mass flux in the tropics: If the motivation of the study is to compare the convective mass flux between the different models, it may be relevant to consider additional quantities, such as convective vs. stratiform precipitation (noting that convective precipitation parameterisations have a large uncertainty and differ substantially between climate models), or the mass flux itself. As the study is designed presently, the mass flux and the implications thereof are rather implicit, and it remains unclear whether this quantity should be considered as an internal model variable or as the actual flux of mass as represented by climate models.
4. On pg. 3, L. 10 onward, the authors state that "understanding the WVL has the potential to contribute to improved quantification of the hydrological cycle and its

climate-induced changes", based on a previous paragraph about the potential use of isotope composition. However, if one were to investigate the implications of residence time for the stable isotope composition, it would be more meaningful to perform the study using isotope-enabled general circulation models, so it remains unclear how this motivation fits to the present study design. The connection between the cited literature and the topic of the study remain vague and would require further discussion. For example, the residence time definition in Aggarwal et al., 2012, yields values ranging from 1 to 100 days, which are in contrast to the magnitude of residence time changes discussed here. The study of Markle et al, 2018 addresses in particular multi-centennial time scales, and it is not obvious without further discussion if their findings are applicable to the presented sensitivity experiments.

5. Title: See major issue 2 above - what is the significance of the statement that the WVL is increasing? Is the ratio IWV/P an accurate and pointed description for how the hydrolocial cycle will be experienced in the future, given that fluxes will intensify? Consider that you possibly could ease the struggle of motivating this study at present by de-emphasizing the WVL aspects. By essentially reversing the study setup, you could talk about IWV and P changes and their sensitivities first, and finally concluding by discussing to what extend the WVL can provide additional information or be mistaken as a confusing message (which is now implicitly stated in the introduction).

6. Now it is very difficult to compare the results from individual models in Fig. 1. Consider plotting at least panel a on a horizontal scale that emphasizes the differences, rather than bars for example as a set of box and whisker plots. Regarding the large number of individual models in panels a-b, it may be more useful to present results as histograms and move the individual model perspective into a supplement figure.

7. Conclusions: "If emissions evolve according to a business-as-usual pathway, the WVL could increase by 25% by the end of the 21st century because of the large expected temperature changes, and despite the projected aerosol emission reductions leading to a lower water vapour lifetime sensitivity."

   What are the implications of that conclusion? Does it actually matter if the WVL increases by 25%, what would be the consequences? The question if the residence time is a useful indicator to measure aspects of climate models remains ultimately unanswered. What do the differences between model mean states and their sensitivities signify? Is there actual value in using the residence time over inspecting total column water and precipitation/evaporation separately? Maybe that (open) question should be put into the focus of the introduction and answered in the conclusions. This is also related to major issue 2 and 5.

   Furthermore, given that models and observational estimates of the residence time disagree substantially, even on the same magnitude as the absolute changes predicted here (Trenberth, 2011; van der Ent and Tuinenborg, 2017), what is the overall uncertainty of these predicted changes? How do we know that the differences only can be interpreted meaningfully?

8. Pg. 8, L. 19: "a longer WVL implies a higher heavy isotope ratio ... and in turn indicates a larger fraction of convective vs. stratiform" - This conclusion seems to be based now on (weak) correlations between a set of isotope measurements in surface precipitation and climate variables. I suggest that a reliable extrapolation to future climate be based on the underlying physical processes instead.

Minor comments

Sec. 3.2 should in part be within methods section.

Sec. 3.4 needs a transition sentence from previous section/paragraph.

Pg. 2, L. 24: "although some argue for a substantially shorter lifetime of 4-5 days" - I believe the discussion in the literature argues revolves around a consideration of whether IWV/P accurately represents how long water resides in the atmosphere - rephrase.

Pg. 3, L. 21: Some details to this long list of referenced studies should be given.

At numerous locations throughout the manuscript, the writing is unclear. The reasons are varied, but often two or more ideas and arguments are complied into one sentence. Sometimes, within one sentence it is referred to several figures for different aspects. Below I list some of the places were writing can be substantially improved by careful editing:

Pg. 3, L. 9

Pg. 5, L. 13

Pg. 5, L. 22

Pg. 6, L. 2

Pg. 6, L. 31

Pg. 7, L. 1

Pg. 7, L. 15-29

Pg. 8, L. 18-19

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