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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 #2

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A catalog of idealized climate model experiments to assess precipitation response to different radiative forcings is here exploited to investigate how the atmospheric lifetime of water vapor is affected. This is diagnosed as integrated water vapor divided by precipitation rate which effectively characterizes how long it would take to precipitate out all the water vapor in the atmospheric column. Although it is obvious, based on past research, that this lifetime should increase, since thermodynamic and energetic constraints cause water vapor to increase at a faster fractional rate than precipitation, this work provides a useful investigation into the differences in this response between forcing agents, relating to fast adjustments and slow response to temperature, and further explores regional contributions. The most novel aspect, in my view, may be demonstrating how water vapor adjustments and responses differ between forcing agents. I

recommend emphasizing this and I consider that this work merits publication following consideration of the suggestions below including the possibility of comparing with observed responses.

Specific points

1) p.1, L24-26: the first 2 lines do not make much sense to me in the abstract and have marginal relevance to the results. Something outlining what water vapor lifetime is and why it is important would be more useful I think.

2) p.1, L29: "projected" –> "simulated" (1986-2005 is not a projection)

3) p.1, L31: "slows down the hydrological cycle" - if precipitation is increasing, the hydrological cycle could be thought of as speeding up since water is fluxing between atmosphere and surface more quickly so I suggest removing this confusing terminology.

4) p.1, L34 - "fast responses" should be clarified

5) p.2, L18-20 - Is there a difference between water vapor residence time, lifetime and recycling rate (e.g. Li et al. 2011; Kao et al. 2018; van der Ent & Tuinenburg (2017); Allan & Zveryaev (2011) IJOC http://doi.org/10.1002/joc.2070). This could be clarified. Regional responses in water vapor lifetime may be misleading since the precipitation can result from transport of moisture from outside of the region and so not really reflect recycling rate within a box

6) p.4 L26 - RCP8.5 is a high emissions scenario but cannot simply be described as a business as usual pathway.

7) p.5, L15 - is an increase in WVL detectable in the historical period 1986-2005? Using trends from Allan et al. (2014) Surv. Geophys. http://doi.org/10.1007/s10712-012-9213-z for 1988-2008 and assuming WVL=8.9 days:

WVLS = WVL((1/IWV)(dIWV/dT) - (1/P)(dP/dT)) = 8.9x(0.064-0.028) = 0.32 days/K, which is smaller than simulated perhaps due to additional noise from internal variability (with a large uncertainty). Alternatively:

dWVL/dt=WVL((1/IWV)(dIWV/dt) - (1/P)(dP/dT)) = 8.9x(0.0084 - 0.0018) = 0.06 days/decade (rather small)

8) Fig.2 - additional annotation to show the meaning of dark/light bars in (a) and (b) would help the reader.

9) Fig.3 - it is not clear from the scattering aerosol bar how the light and dark part contribute. Perhaps the total can be distinguished as a thick horizontal line or symbol (at the top of most bars but at -0.01 for scattering aerosol).

10) Fig. 4 - it would be more informative for me to group all the WV, E and P lines into 3 separate plots so that they can be compared across forcing agents. Are zonal values calculated using zonal dT or global dT?

11) p.7, L4-6 seems an important result and some more mechanistic discussion of this would be useful. Is the SO4 slow response small due to forcing predominantly affecting land which has less moisture availability? Or does this relate to the vertical temperature changes and the temperature dependence of the Clausius Clapeyron equation? Does the low level relative humidity increase explain the large fast response in BCx10 and why? On the other hand is this all explained by land-ocean temperature responses as implied? This could be summarized in the conclusions along with implications (why do we care?).

12) p.7, L26 "small exception for SO4x5." Please be more explicit in what is meant.

13) P.7, L30 - there is very little mention of Figure 6. Either this can be removed or a little more discussion of the Figure panels included.

14) Fig.5 - dashed=Clausius Clapeyron in the legend would help. It is difficult to see dashed and solid in (b) so perhaps this can be replaced with a relative humidity change plot.

15) p.8 (Conclusions) - what is the significance of changes in water vapor lifetime above the differing fractional responses of P and IWV and implications for changes in the tropical circulation mass flux and precipitation intensity distribution, which is well known? Emphasizing what is novel will help increase the impact of this work.

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