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Interactive comment on "The response of stratospheric water vapor to climate change driven by different forcing agents" *by* Xun Wang and Andrew Emory Dessler

Anonymous Referee #1

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This paper analyzes the changes of the stratospheric water vapor simulated by an ensemble of climate models under different forcing agents. The water vapor response is separated into fast and slow components, and tropical lower stratosphere and polar lowermost stratospheric regions are considered. It is found that the SST-mediated slow response generally dominates over the fast response, and shows a consistency across different forcing. The fast response, on the other hand is found to be linked to the fast adjustment of the cold point temperature to the climate forcing. This study provides a key answer to the question of how the stratospheric water vapor feedbacks to climate changes. I recommend publication of the paper after the authors address my generally minor comments.

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Discussion paper

1. Why the latitudinal bands of 30-50 are left out? It covers a considerably large area, and may be more subjective to the horizontal mixing than the polar region. Even it may be messy and don't show an as good consistency among forcing agents and across models as the polar regions or the tropical region, it still worth reporting. Furthermore, the 50S-90S may not be a good representation of the Southern Hemisphere extratropics. This is because many models suffer a too strong southern polar vortex and hence the simulated southern polar stratosphere is too isolated. This can be hinted from Fig. 4a and Fig. S4, where a clear barrier is seen near 60S.

2. The regression method to get the equilibrium water vapor response seems to be unnecessarily complicate, especially the results are not too different from the simple average of the last 30 years. The authors first fit the radiative flux and water vapor time series with an exponential function, then regress the the last 30 years of the fitted function. All these fitting and regression have potential introduce artificial biases and uncertainties. Recent studies also show that the ECS from the Gregory method may not be a good estimate of the true ECS (e.g. Winton et al. 2020). In addition, without a sufficiently long simulation, one can not validate whether the "equilibrium" from the regression is the true equilibrium. It makes more sense to me to simply use the average of the last 30 years while acknowledging that the models have not fully reached the equilibrium.

3. It may be worth pointing out how the PDRMIP model ensembles relate to the CMIP5 ensembles. From Fig. 2b, it seems that all of these models except HadGEM3 are on the weaker side of the CMIP5 ECS estimation range. I am also surprised to see that these models do not show an more distinct efficacy among different forcing agents (Hansen et al. 2005).

4. The authors relate the slow response to the surface temperature and relate the fast response to the cold point temperature. I believe the slow response would also be regulated by the cold point temperature. It may be interesting to show that if the relationship between the stratospheric water vapor and the cold point temperature holds

from the fast adjustment to the slow response.

5. While Fig. 3 shows a consistent relationship between stratospheric water vapor and global mean surface temperature across various forcing, the temperature sensitivity does not seem to be so consistent in Fig. S4. Much more stratospheric moistening is seen in response to the solar forcing than others given the same surface temperature warming. This discrepancy needs to be resolved.

Other even more minor comments:

Line 85-86: How does the averaged of fixed SST with baseline atmosphere compare to the average of the coupled baseline simulations.

Line 96: y=c+abˆx -> y=c+abˆ(-x)

Line 101: Fig. S1 was not showing what is stated here. It seems the intended Fig. S1 is missing.

Line 147: Fig. S2-4. -> Fig. S1-3

Line 167: Fig. S5 -> Fig. S4

Line 191: Does the long wave effect of the tropospheric ozone also contribute?

References:

Hansen, J. M. and coauthors, 2005: Efficacy of climate forcings. J. Geophys. Res., 110, D18104, doi:10.1029/2005JD005776.

Winton, M. and coaturhors, 2020: Climate sensitivity of GFDL's CM4.0. Journal of Advances in Modeling Earth Systems, 12, e2019MS001838. https://doi.org/10.1029/2019MS001838

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