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Reply on RC2

Xiangde Xu et al.

Author comment on "A vertical transport window of water vapor in the troposphere over the Tibetan Plateau with implications for global climate change" by Xiangde Xu et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2021-697-AC2, 2021

Reply to Referee 2

We are grateful to the referee for the encouraging comments and careful reviews which helped to improve the quality of our paper. In the followings we quoted each review question in the square brackets and presented our response after each paragraph.

[Review Comment: This paper investigates the effects of the Tibetan Plateau on the water vapor transport in the atmosphere and found that a summertime "hollow wet pool" and a vertical transport window exist in the troposphere over the Tibetan Plateau (TP) which have significant impacts on the global water vapor distribution. The results presented in this study are interesting and the content of the manuscript is well within the scope of ACP. However, the manuscript needs some revisions before it is accepted for publication in ACP.]

Reply: Thank you for the encouraging comments.

Major comments:

[My first concern is about the causal relationship. Based on the correlation analysis, the authors argued that the effect of TP's vertical transport window of tropospheric vapor have impacts on global water vapor distribution, even the remote regions like the Arctic, Antarctic. However, correlation analysis alone can not reveal the causal relationship. I would suggest a model simulation with a passive tracer released over the TP to verify transport pathways of water vapor over the TP as suggested by the correlation analysis.]

Reply:

Many thanks for the referee's suggestions. To verify transport pathways of water vapor over the TP as suggested by the correlation analysis, we have used the methods of composite analysis to further understand the AWT heat source driving and maintaining water vapor transport from the TP to the high-latitude regions like the Arctic, Antarctic with the global influence. In the revised manuscript (lines 149-170) we have added the following discussions and the added graphs can be seen in the supplement material:

"The strong anticyclone in the upper troposphere over the southeastern TP takes a significant part in the upward transport of water vapor in the troposphere and stratosphere (Garny, et al., 2016;Fu, et al., 2006). In order to understand the effect of the vertical transport window of troposphere over the TP on the global water vapor distribution from the perspective of the dynamic effect of anticyclone over the plateau driven by the heat sources, we presented the distributions of correlation coefficients between daily mean Q_1 in the TP and global water vapor flux in July from 2014 to 2016 at 300hPa (Fig. 3b.) Driven by the heat source of the TP, the anticyclone is formed in the upper troposphere over the TP and surrounding regions, which governed the water vapor transport form the TP not only to the surrounding area, but also extending to the north and south poles along the long-range transport channels (Fig. 3b), which indicates the vertical transport window effect of the TP on global water vapor transport, especially over high-latitude regions such as the Arctic and Antarctic. To further verify the global transport pathways of water vapor from the TP, we used the methods of composite analysis to characterize global distribution of water vapor transport fluxes at the 300hpa in the years to anomalously high and low Q_1 over the TP. The TP's anticyclone in the upper troposphere is often associated with deep convection in the troposphere □Garny, et al., 2016□. Fig. 3c shows that in years with higher Q_1, stronger anticyclone formed at the upper troposphere (Fig. 3b), which maintains the upward transport of water vapor to the upper troposphere, with strong transport of water vapor transport the arctic and antarctic (Fig. 3c), confirming the impact of the vertical transport in the troposphere driven by heat released within AWT in the TP on global water vapor transport especially to the polar regions."

[**Figure 3** (b) correlation vectors of the column Q_1 integrated vertically over the TP region (80-102^{o}E; 30-37.5^{o}N) with the 300hPa vapor transport flux in July of 2014-2016, The shaded area indicates the correlation coefficient passing the 90% confidence level□(c) the difference of specific humidity (shading, unit:kg/kg) at 300 hPa in summer in 1998 and 2007 with anomalously high Q_1 and in 1997 and 2003 with anomalously low Q_1 in the AWT. The black and orange arrows indicate respectively the anticyclonic circulations in the TP and water vapor transport pathways from the TP to the Arctic and Antarctic regions.]

[another issue is the role of the TP's thermal effect on the formation of the transport channel of the water vapor. It is proposed in the manuscript that the TP's thermal effect could make a strong warm wet vapor transport channel connecting the water vapor source in the low latitude tropical ocean. This conclusion is again drawn mostly from correlation analysis. Is it possible to do a few sensitivity experiments with a numerical model to verify that the proposed transport channel is indeed forced or maintained by the apparent heat source of the TP? Alternatively, it is better to perform a composite analysis with respect to high and low Q to see whether this transport channel will change with Q.]

Reply:

Following the referee's suggestion, FLEXPART trajectory model is used to prove the influence of the TP's Q1 on the water vapor transport channel connecting the TP to low latitude ocean moisture source, and composite analysis is employed to further verify this with adding two sub-graph as Figs. 3f and 3g which can be seen in the supplement material and the illustration as follows:

[Figure 3 (f) the backward trajectories of water vapor transport simulated with the model FLEXPART in July, 2009. (g) the difference of vapor transport flux at 500 hPa (vectors, unit:$gs^{-1}hPa^{-1}cm^{-1}$) and specific humidity (color contours, unit:kg/kg) between summers with anomalously high Q_1 in 1998, 2005, 2007, 2008 and 2009 and with anomalously low Q_1 in 1994, 1997, 2001, 2002 and 2003 over the TP]

"FLEXPART trajectory model (Stohl, et al., 2005;Reale,et al 2001; James, et al, 2004) was used to simulate the spatial and temporal changes of water vapor transport to the TRSR over the TP, driven with the ERA-Interim reanalysis data of meteorology with horizontal resolution of 0.75°×0.75° in July 2009. In the FLEXPART particle diffusion model, the 80000 particles was released at the TRSR (90°-102°E and 30°-35°N). In Figure 3f, it can be found that the water vapor in the TRSR was traced to water vapor source on the tropical Indian Ocean. The main water vapor from the central Indian Ocean in the southern hemisphere can be transported along the Somali jet flow through the Arabian Sea to the TP. The water vapor from the South China Sea and the Bay of Bengal was transported to the TP converging over the TRSR (Fig. 3f), characterizing the water vapor transport channel from the southern hemispheric and low latitude oceans to the TP.

Figure 3g shows the difference of vapor transport flux and specific humidity at 500hPa in summer between anomalously high and low Q_1. When the Q_1 in TRSR is anomalously high, large water vapor from the tropical oceans is transported across the Bay of Bengal and the Indian peninsula, and entered the TP from the southern edge, revealing the TP's thermal effect could make a strong vapor transport channel connecting the water vapor source in the low latitude tropical oceans.

References:

Stohl, A., Forster, C., Frank, A., et al.: Technical note: The Lagrangian particle dispersion model FLEXPART version 6.2. Atmos. Chem. Phys., 2005, 5, 2461–2474.

Reale, O., Feudale, L., Turato, B.: Evaporative moisture sources during a sequence of floods in the Mediter-ranean region. Geophys Res Lett, 2001, 28, 2085–2088.

James, P., Stohl, A., Spichtinger, N.: Climatological aspects of the extreme European rainfall of August 2002 and a trajectory method for estimating the associated evaporative source regions. Nat Hazards Earth Syst Sci, 2004, 4, 733–746."

minor comments:

[Title: 'global change' covers a relatively wide discipline. I would suggest change it to 'global climate change'.]

Reply: Following this comment, we have changed "global change" to "global climate change" in the revised manuscript.

[Line 41: 'The observed "CISK-like mechanism' may need a reference.]

Reply: In the revised manuscript, we have added a reference as follows:

"The observed "CISK-like mechanism" is an important mechanism sustaining the atmospheric "water tower" over the TP (Xu et al., 2014)

Xu, X, Zhao, T, Lu C., Guo, Y., Chen, B., Liu, R., Li, Y., and Shi, X. (2014).An important mechanism sustaining the atmospheric "water tower" over the Tibetan Plateau. Atmos. Chem. Phys.14: 11287-11295.https://doi.org/10.5194/acp-14-11287-2014"

[Line 65: 'not enough attention' >> 'inadequate attention']

Reply: We have changed to "inadequate attention" in the revised manuscript.

[Line 71: What is the meaning of 'special column constructor'?]

Reply: The 'special column constructor' means the vertical transport of water vapor in the troposphere constructed with the special column of apparent heat source in the AWT over the TP, which has been changed in the revised manuscript.

[Page 5: some letters and symbols in the text which are used in the formulas should be italics.]

Reply: Thanks for the careful review. They have been changed in the revised manuscript.

[Line 103: 'productions' >>'products']

Reply: We have corrected it in the revised manuscript.

[Line 134-135: which variable can represent 'convective cloud activities?]

Reply: we use the low cloud fraction to represent convective cloud activities based on the could characteristics observed in the TP, which has been added in the revised manuscript.

Please also note the supplement to this comment:
https://acp.copernicus.org/preprints/acp-2021-697/acp-2021-697-AC2-supplement.pdf