Response to Reviewer 1 of manuscript "Mechanisms of hydrological responses to volcanic eruptions in the Asian monsoon and westerlies-dominated subregions" by Zhihong Zhuo et al.

We are very grateful to Fei Liu for your kind efforts and thoughtful comments, which are very helpful for enhancing the clarity and quality of the manuscript. We have revised the manuscript carefully according to the comments. The list of the reviewer's questions and comments (*in italic*) as well as our responses are listed below. The revised texts are shown in blue.

Comment on cp-2021-182

Fei Liu (Referee)

Referee comment on "Mechanisms of hydrological responses to volcanic eruptions in the Asian monsoon and westerlies-dominated subregions" by Zhihong Zhuo et al., Clim. Past Discuss., https://doi.org/10.5194/cp-2021-182-RC1, 2022

Review of ***"Mechanisms of hydrological responses to volcanic eruptions in the Asian monsoon and westerlies-dominated subregions****" by Zhuo et al*

Summary and recommendation

Understanding the regional hydrological responses to volcanic eruptions at different locations is important to predict the potential climate disasters after future eruptions. This work found a "wet get drier, drier gets wetter" response after the NHVAI, while a significant wetting effect after SHVAI. The relative effects of dynamic and thermodynamics were also investigated. The motivation and results are very interesting, and this manuscript is well organized. I would like to see this work to be published in CP, while before that some Minor revisions are needed.

Thanks for the positive feedback and comments regarding the study.

My major concern centers around the discussion on "wet response" or "dry response". This work mainly focused on the PDSI, which response is not only related to precipitation variation but also to temperature change. The increase of precipitation doesn't mean that the PDSI should be increased (Aiguo Dai 2013 Nature Climate Change). In the introduction and main text, the authors should be very carefully to avoid mixing the precipitation and PDSI change.

Thanks for the comment and the reference. After seeing the difference between the spatial pattern of precipitation and PDSI in Dai (2003), we realized it was inaccurate to conclude on a "wet gets drier, dry gets wetter" response patter based on the PDSI responses, thus we revised the description and discussion a lot regarding this concern. Below shows the revised text on describing the PDSI response to volcanic eruption.

"Figure 3 shows the hydrological response to two volcanic classifications in the Asian monsoon region. In the GNH volcanic classification, PDSI reduces significantly in the eruption year (year 0), and this reduction extends to three years after the eruption (year 3), indicating an intensified aridity after NHVAI. For the GSH classification, PDSI does not show strong changes, but positive PDSI emerges in year 2 and passed the significance test at the 99% confidence level, which indicates a weakened aridity after SHVAI.

Figure 4 further shows the spatial patterns of PDSI in the eruption year when it has the largest drying effect after NHVAI (Fig. 3). In the GNH classification (Fig. 4a), significantly reduced PDSI indicates an intensified aridity in a large part of the Asian monsoon region. The largest reduction of PDSI emerges in the southern part of the region (solid black box), while the largest increase of PDSI is concentrated in the south-western part of the region (dotted black box). This is exactly opposite to the climatological hydrological conditions in the areas where the RWA and RDA locate. In the GSH classification (Fig. 4b), different from that in the GNH classification, PDSI increases in the RWA, while a slight decrease emerges in the RDA.

The PDSI spatial patterns indicate distinct hydrological responses to NHVAI, with a reversed aridity pattern between the RDA and RWA to the climatological conditions. This is

also opposite to the "wet gets wetter, dry gets drier" precipitation response under global warming that is mainly caused by increased anthropogenic greenhouse gases (Schurer et al., 2020)."
The text about discussions on the mechanisms has also been revised, which can be seen in the answer to a following comment regarding line 250.

Line 14: You mainly focused on the three years after the eruption, which does not belong to the decadal prediction.

We have removed decadal, use near-term prediction instead.

Lines 38-40: What are the main results of these works? Are they consistent with your finding?

We have added some text on the main results of these works, with the revised text "A few studies focused on Asian summer monsoon response to volcanic eruptions, model simulations (Peng et al., 2010; Man et al., 2014; Man and Zhou, 2014) show a reduced precipitation due to a reduced land-sea thermal contrast that in favor of a weakened monsoon circulation, hydrological proxy reconstructions (Anchukaitis et al., 2010; Gao and Gao, 2018; Zhuo et al., 2014) generally agree on the temporal drying trend in the monsoon region, but discrepancies exist in spatial responses to volcanic classifications among different reconstruction data.". Similar to what written here, our findings show consistency on the temporal responses to volcanic eruption, but special responses are more complex, comparisons between model and proxy reconstruction data on these temporal and spatial similarities and discrepancies were investigated and discussed in our previously published paper (Zhuo et al., 2020).

Line 58: More details of this local cloud feedback are appreciated. Do you mean that the longwave radiation of the cloud will increase the convection?

We have added more details of this local cloud feedback with following revised text: "Spatial analyses were conducted in Zhuo et al. (2021) in order to understand the mechanism of precipitation responses to volcanic eruptions in the SASM region. Results indicate a dynamical response to VAI, with changed interhemispheric thermal contrast and land-sea thermal contrast, local cloud cover changes in different areas, this leads to subsequent physical feedback on local temperature response, together with the adjusted horizontal and vertical motion of local water vapor, leading to a decreased precipitation in the SASM region after NHVAI.". Zhuo et al. (2021) didn't focus on the longwave radiation of the clouds, instead indicated the physical feedback on shortwave radiation of the cloud. As different local cloud cover changes the local surface shortwave radiation, this contributes to different temperature responses in different areas, and adjust the local horizontal and vertical motion of water vapor and thus changes local precipitation.

Line 70: The dataset of Ammann et al. 2007 was used in IPSL model. Please check whether you used this model or not?

We used this model in our analysis, but it won't affect the results, as the Ammann et al. 2007 dataset used the same loading as Gao et al. 2008. This information is written in the volcanic forcing dataset used in the IPSL model simulation. The dataset is from Myriam Khodri who conducted the IPSL model simulation, after I contacted with Jean-Louis Dufresne, who is the corresponding author of the model reference paper. We would like to also express my appreciation to Jean-Louis Dufresne and Myriam Khodri here for their help and generous sharing of the forcing dataset.

Line 124: I don't know how the correlations are calculated. Did you calculate it among different eruptions or among the 11 selected years? More details are needed.

It's calculated among the 11 selected years. Maybe we did not write it clearly, we revised the text to "We calculate r in each grid between variables among the selected 11 years before and after the aerosol injection, and then calculated the average r value of the Asian monsoon region.".

Figure caption 3: Definition of the Asian monsoon region is necessary.

As suggested, the text has been revised to "…in the Asian monsoon region (8.75°S–56.25°N, 61.25°CE–143.75°E)" in the figure caption.

Lines 138-139: The reconstructed PDSI response of Asian monsoon to different eruptions was first discussed by Liu et al. 2016 SR. Comparison with this reconstruction analysis is necessary.

In the revised manuscript, we have added following discussion on the comparison of the PDSI response with Liu et al. (2016) paper: "The reduction of PDSI in the GNH classification agrees on a weakened Asian monsoon with Liu et al. (2016), which showed significant reduction of PDSI in the first year after tropical eruptions and the second year after NH volcanic eruptions. Due to limited aerosol magnitude in the GSH classification, slight increase of PDSI emerges after SHVAI and is only significant in year 2. This also agrees well with Liu et al. (2016), which showed an increased PDSI in the first year from SH volcanic eruptions, although without passing the significance tests.".

Figure 5: Definitions of these ASM land and ocean regions are needed.

As suggested, the text has been revised to "…in the Asian monsoon region (land and ocean part in 8.75°S–56.25°N, 61.25°CE–143.75°E)." in the figure caption.

Line 188: Figure 6 exhibits the temperature anomalies, not the PDSI.

The typo has been revised to figure 4.

Fig. 8: Significant test is needed in Figs. 8b and 8c.

The significance tests of IVT have been conducted and the test results have been added to the revised fig. 8.

Line 250: I don't think the mechanisms are totally the same. The change of PDSI include both precipitation and temperature related evaporation variations. Previous works mainly focus on the precipitation change.

We agree that the mechanisms are not totally the same, we thought it confirms these previous works that reflect part of the mechanisms shown in this study. Precious works mostly show that precipitation change can be explained only by the dynamical response, but mechanisms of the hydrological response relates to both precipitation and temperature, thus is related to both dynamical response and local physical feedbacks. In order to make the difference clearer, the discussion text has been revised to: "Previous studies explored the mechanisms of precipitation responses to volcanic eruptions (Peng et al., 2010; Man et al., 2014; Iles et al., 2013; Zhuo et al., 2021; Zuo et al., 2019a; 2019b). The reduction of monsoon precipitation results in the decreased land-sea thermal contrast and the subsequent weakening of summer monsoon circulation (Iles et al., 2013; Man et al., 2014; Zhuo et al., 2021; Zuo et al., 2019a). Our quantitative analysis confirms this on the dynamical response of the climate system to volcanic eruptions. The decrease of latent heat flux and evaporation over tropical oceans led to the reduction of the summer precipitation in eastern China (Peng et al., 2010). Zuo et al. (2019b) found a wetting response across arid regions, which is caused by the enhanced cross-equator flow after VAI in the other hemisphere and the monsoon-desert coupling mechanism after VAI in the same hemisphere. This is well reflected by the moisture transport from the adjacent area to the RDA (Fig. 8). Joseph and Zeng (2011) found less cooling in areas near the equator. The regional warming was suggested to be associated with the reduction of clouds, while less evaporation due to the less precipitation further contribute to the regional warming. This indicates that regional temperature and precipitation responses relate to changes of local clouds. Our findings, based on both temporal and spatial analyses, show the importance of both the dynamical response and the physical feedback on understanding the mechanisms of hydrological responses to NHVAI. The dynamical response changes the moisture transport and the formation of local clouds, the subsequent radiative effect and physical feedbacks result in different temperature and precipitation responses in different areas."

Line 295: The RDA region is actually located at central Asia.

The region is mostly located at central Asia, but the RDA region does not cover the whole part of central Asia, thus in order to not mix the definition, we used the self-defined RDA in the manuscript.