Response to Reviewers 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 and the anonymous reviewer 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.

1. **Response to Reviewer #1**

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.

In the revised abstract: "It leads to an intensified aridity over the AMR after northern hemisphere VAI (NHVAI), spatially, a distinct inversed response pattern to the climatological conditions emerges, with an intensified aridity in the relatively wettest area (RWA) but an weakened aridity in the relatively driest area (RDA) of the AMR. After southern hemisphere VAI (SHVAI), it shows a weakened aridity over the AMR, but spatial response pattern is not that clear due to small aerosol magnitude."

In section 3.1: "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 may counteract the "wet gets wetter, dry gets drier" precipitation response to global warming that is mainly caused by increased anthropogenic greenhouse gases (Schurer et al., 2020)."

In the conclusion: "After the NHVAI, PDSI decreases significantly in the AMR in the eruption year and this reduction lasts to three years after the eruption. Regionally, it shows a weakened aridity in the southwestern part of the AMR while an intensified aridity are concentrated in the southern Asian summer monsoon region, where the relatively driest area (RDA) and the relatively wettest area (RWA) locate. The response pattern is distinctly inversed to the climatological conditions, which may counteract the "wet gets wetter, dry gets drier" precipitation response pattern under global warming (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 climate 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° E–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° E–143.75° E)." in the figure caption.

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

Here we want to compare the temperature anomalies in the GNH classification (Fig. 6a) with PDSI, but the text was confusing. We have adjusted the text order in the revised manuscript to "When comparing to the spatial pattern of PDSI, in the GNH classification (Fig. 6a),".

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.

2. Response to Reviewer #2

Comment on cp-2021-182

Anonymous Referee #2

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-RC2, 2022

This paper uses the PMIP3/CMIP5 past1000 ensemble to investigate how explosive volcanic eruptions affect surface climate in the Asian monsoon region. The paper provides a nice analysis of the hydrological response in different regions within this larger area, and also contrasts the response to predominantly Northern hemisphere eruptions and Southern hemisphere eruptions. The analysis is interesting and clearly described and as such is publishable in this journal. Before this occurs though I have two more major concerns which I would like to see addressed, in addition to some more minor comments.

Thanks for the positive feedback and comments regarding the study. We have considered the comments carefully and revised the manuscript carefully accordingly. The detailed answers can be seen under the specific comments.

As also mentioned by reviewer 1, care needs to be taken when talking about these results in the context of the "wet-gets-wetter, dry-gets-drier" paradigm. Schurer et al 2020 (in addition to a number of previous studies) analysed precipitation across the whole tropic and found a detectable response in the wettest and driest regions. I do not think that it is definitely the case that this will also apply when restricting the analysis to only the summer climate of the Asian monsoon region, and particularly not to PDSI over this region. Also the fact that you are analysing PDSI should be taken into account when discussing the link to temperature.

Thanks for the comment and the reference. After considering both of your comments, 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 problem. Below shows some revised text as revision examples.

In the revised abstract: "It leads to an intensified aridity over the AMR after northern hemisphere VAI (NHVAI), spatially, a distinct inversed response pattern to the climatological conditions emerges, with an intensified aridity in the relatively wettest area (RWA) but an weakened aridity in the relatively driest area (RDA) of the AMR. After southern hemisphere VAI (SHVAI), it shows a weakened aridity over the AMR, but spatial response pattern is not that clear due to small aerosol magnitude."

In section 3.1: "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 may counteract the "wet gets wetter, dry gets drier" precipitation response to global warming that is mainly caused by increased anthropogenic greenhouse gases (Schurer et al., 2020)."

In the conclusion: "After the NHVAI, PDSI decreases significantly in the AMR in the eruption year and this reduction lasts to three years after the eruption. Regionally, it shows a weakened aridity in the southwestern part of the AMR while an intensified aridity are 315 concentrated in the southern Asian summer monsoon region, where the relatively driest area (RDA) and the relatively wettest area (RWA) locate. The response pattern is distinctly inversed to the climatological conditions, which may counteract the "wet gets wetter, dry gets drier" precipitation response pattern under global warming (Schurer et al., 2020)."

The mechanisms relate to both dynamical response and physical feedback, which indicates the link of PDSI to both precipitation and temperature. In order to make the difference clearer, the text about the discussion on mechanism 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."

As correctly acknowledged by the authors, there have already been a number of other studies analysing the response to the monsoon regions to large volcanic eruption. Although many have been cited here (e.g. lines 38-41, 51-55) I think that the paper would really benefit with a more detailed description of what some of these key papers found, in particular highlighting what exactly is novel here.

Thanks for the comment, we added more detailed description on these studies. As suggested, more detailed descriptions have been added in order to better highlighting the novelty of our study.

Close to lines 38-41, the text has been revised to "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.".

Close to lines 51-55, the text has been revised to "The mechanisms of the hydrological responses in the AMR were roughly investigated. Precipitation can be reduced from a weakening of the summer monsoon after volcanic eruptions (Dogar and Sato, 2019; Liu et al., 2016; Man and Zhou, 2014; Man et al., 2014; Zhuo et al., 2021; Zuo et al., 2019a). This was generally based on qualitative analysis of the altered land-sea thermal contrast. ITCZ moving toward a warmer hemisphere with less volcanic aerosol loading leads to inversed climate impacts in two hemispheres (Colose et al., 2016; Haywood et al., 2013; Iles and Hegerl, 2014). These studies focused on mechanisms of instant precipitation response, which does not reflect the degree of dryness after volcanic eruptions. And the analysis was conducted holistically over the investigated region. Zuo et al. (2019b) adopted both precipitation and drought reconstruction data in their analysis, all of them showed wetter conditions in arid regions after all types of volcanic eruptions, which is due to an enhanced cross-equator flow and a monsoon-desert coupling mechanism after SHVAI and NHVAI. However, moisture budget analyses were also conducted holistically over the hemispheric arid regions in Zuo et al. (2019b). These cannot fully explain mechanisms of local hydrological responses to volcanic eruptions, as

regional responses and local feedback processes were not considered. 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 indicates 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. No spatial analysis is conducted in order to understand the mechanisms of hydrological responses to volcanic eruptions in areas of the AMR in different monsoon and westerlies-dominated subregions.
This study tries to fill in the gap to investigate mechanisms of local hydrological responses in monsoon and westerlies-dominated subregions of the AMR to different hemispheric VAI. We perform spatio-temporal analyses on multi model ensemble mean of last millennium (LM) experiment from the paleoclimate modelling intercomparison project phase 3 (PMIP3)/coupled model intercomparison project phase 5 (CMIP5).".

Minor comments:
In the abstract (and throughout) please ensure all acronyms are defined (e.g. RWA, RDA, EASM, SASM).

Accordingly, for RWA and RDA, the abstract has been revised to "with an intensified aridity in the relatively wettest area (RWA) but a weakened aridity in the relatively driest area (RDA) of the AMR.". For EASM and SASM, since it's not used again, we have replaced them with the full text as "…weakened East Asian summer monsoon and South Asian summer monsoon".

L13 – To avoid misunderstanding - I think it would help to clarify that effects of future volcanic eruptions will only be a temporary, e.g. "future volcanic eruptions may temporary alleviate..."

The text has been revised as suggested.

L17 – would it be possible to include in figure 1 – what the boundaries are for your definition of the, EASM, SASM. Although not strictly necessary, I think this could help many readers understand the results more quickly.

The boundaries of EASM and SASM can be different according to different definitions from previous studies, thus it's hard to draw the exact boundaries in the figure, but we wrote in the text that according to Chiang et al. (2017), in the monsoon-dominated region, the EASM and the SASM is usually separated by 100°E longitude.

L20 – how is the modern Asian summer monsoon limit defined (or alternatively give a citation where it is defined)

It's referenced from Chen et al. (2018) as cited at the end of this sentence, but based on this comment, the reference citation has been added right after here as "…the modern Asian summer monsoon limit (Chen et al., 2018)".

Section 2.1 – I think that the model selection section could be better explained. Was this entirely based on the work of Zhou et al 2020? If so this should be made clearer. The GRA forcing in GISS was implemented approximately twice as strong as it should have been, see e.g. errata and comments here: https://data.giss.nasa.gov/modelE/cmip5/ Could this be why the GRA MMM is more significant?

Yes, as understood, the model selection is entirely based on the work of Zhuo et al. (2020), in which the model data were firstly evaluated in comparison to proxy data. We have made it clearer with revised text as "The green box of figure 2 shows model ensemble members employed in the GRA-based MMEM, which are the same as in Zhuo et al. (2020)." This GISS double forcing problem was already discussed in Zhuo et al. (2020). The GRA MMM is more significant partly because of it, but also because GRA forcing is larger than CEA forcing, as in the reconstruction of CEA forcing, 2/3 power scaling was applied to all values greater than or equal to 0.200 AOD, considering the collisions between aerosol particles result in size increases, shortwave radiative forcing is reduced by the 2/3 power (Crowley et al., 2013), the smaller CEA forcing itself also contribute to less significant results when comparing to GRA MMM results.

Figure 2 – this should make it clear in the caption that this is just for the GRA dataset.

As suggested, the text has been revised to "classifications based on the GRA volcanic forcing." in the figure caption.

Section 2.2 – how were the SHVAI eruptions classified – was there a threshold? And are the NHVAI only defined based on a NH threshold? Does this necessarily mean that the NHVAI is larger than the SHVAI? More details and justification are needed for this section.

There is no threshold for the SHVAI classification, the definition is that all those eruptions that only have southern hemisphere volcanic aerosol injection were selected, as the number of events is limited and especially the magnitude of these events is quite small according to the GRA volcanic forcing, thus it is hard to apply the threshold as that in the NHVAI classification. Yes, the NHVAI is larger than SHVAI. As we wrote in the beginning that the classification is following Zhuo et al. (2020). We also noted in line 85-88 in the end of this paragraph on the potential limited climate impact of this much smaller aerosol magnitude, that's why we also noted in line 88-89 that the GSH classification is serve as a reference classification without NHVAI, and we mainly focused on the mechanisms of hydrological responses to NHVAI in section 3.3, and used a separate part (section 3.4) to fucus on the SHVAI, and their difference to the NHVAI.

Section 2.6 – did you mean Pearson correlation?

Yes, the typo has been revised.

Figure 3- Make it clear in the caption which region this refers to.

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

Can you explain why the SH eruptions seem to be significantly wet even before the eruption (e.g. year -3)? Given that the PDSI before the eruption seems so different between the GSH and GNH can you really be confident the value for the GSH in year +2 is significant, and due to the eruption?

Year -3 passed the significance test at the 95% confidence level, year 4 also passed at the 95% significance level, but year 2 passed at the 99% confidence level, so we only noted that year 2 is significantly wet, and we discussed, in line 150-152, the uncertainty that due to the limited magnitude of the classification shown in this study and also from previous studies lie Zuo et al. (2019b), but we also added discussed that this can be the case, as previous studies also showed the wetting effect after SH volcanic eruption, especially in Zhuo et al. (2021) study, which used the same Pinatubo strength for simulations, and their results reversed drying and wetting effect after the NH and SH eruption.

Figure 4 – can you describe what significance test you performed here? Is it also possible in this and subsequent figures to make the stippling clearer?

The significance test is based on Monte Carlo model test, the details are described in section 2.4, which is a method following Adams et al (2003) and has also been used in Zhuo et al. (2014, 2021). We added this method in the figure caption and revised the text to "The gray slashes and cross signs indicate significant results that passed the Monte Carlo model tests at the 95% and 99% confidence level". In order to make it clearer, the spatial figures have been replotted with pdf format, and also the stippling format has been changed to slashes and cross signs instead of dots and slashes.

Section 3.3 – says that the results will only discuss the NHVAI – yet go onto to also discuss the SHVAI.

At the beginning of section 3.3, it says that we focus on the GNH classification, not only discuss the NHVAI. We also discussed the SHVAI, in order to show the large difference clearly between GNH and GSH, this can contribute to better understand the significant impact of NHVAI and its potential mechanism. The section tittle reflects the main content well, as most discussions focus on the NHVAI, and section 3.3.3, the last part of this section summarized the mechanisms of the hydrological responses to NHVAI. However, to make it more accurate, we added in the text that "we mainly focus on the GNH classification…".

Figure 8 – What is the scale for the arrows? Is it the same in all figures? Also the caption should make it clear that the color scales are different.

The scale for the arrows shows in the green box at top-right corner of the figure, it's 100 in (a) REF at the top panel, but 10 in (b) GNH and (c) GSH at the bottom panel. We added in the caption that "The scale for the arrow shows in the green box at top-right corner of the subfigure. Note the scales of the colors and arrows are different between the top and bottom panel of the figure.

Figure 9 – why is the feature in figure b such a clear line – is this expected? In panel b why is there no effect at all in the NH (whereas there is in the SH in panel a) – is this expected given the definition of SHVAI?

This is the outgoing shortwave radiation in the clear sky, which reflects the direct radiative effect of volcanic aerosols, thus it's reasonable that it's quite uniform along the longitude, as the aerosols are considered to be quickly distributed across the globe and uniformly distributed along the longitude. We have doubled checked, the clear line is due to the scale of the color bar, they are all within the range of 4 to 8 W/m^2 at different longitudes, thus becomes a line in the figure. The limited effect in the NH in Panel b is due to the definition of SHVAI, as no aerosol injected into the NH based on GRA forcing, thus there's no direct radiative effect from volcanic aerosols in the NH.

Line 268 – should this refer to figure 3?

Yes, we revised it to figure 3.