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The revised manuscript entitled "Distinct drivers of recent seasonal precipitation increase over Central Asia: roles of anthropogenic aerosols and greenhouse gases" by Jianing Guo, Xiaoning Xie, Gunnar Myhre, Drew Shindell, Alf Kirkevåg, Trond Iversen, Apostolos Voulgarakis, Toshihiko Takemura, Ke Shang, Xinzhou Li, Zhengguo Shi, Yangang Liu, Xiaodong Liu, Hong Yan

We thank the ACP Handling Editor for their hard work and the three anonymous referees for their constructive comments, which have significantly improved our manuscript. We greatly appreciate the positive and helpful comments from all reviewers (Reviewer #1, Reviewer #2, and Reviewer #3) and have addressed the reviewers' concerns in the point-by-point responses provided below (reviewers comments' in black and our responses in blue). We have uploaded the file entitled "Response to reviewers.pdf".

Best wishes,
Xiaoning Xie

Response to Reviewer #3:

This work uses PDRMIP to investigate the impact of individual forcers on Central Asia (CA) precipitation. The authors found that greenhouse gases (GHGs) were the dominant driver of the wintertime precipitation response, while the summertime precipitation response was attributed to anthropogenic aerosols (AAs). AAs led to a regional northward shift of the westerly jet, resulting in a net increase of moisture inflow into CA. CMIP6 DAMIP simulations were then used to evaluate the cause of historical CA precipitation changes, and the corresponding conclusions were consistent with results obtained from PDRMIP. This work is clear and well-presented. However, I recommend the authors address the following questions:

1. This work would benefit from discussing the nonlinearity between different forcers, since the authors intend to attribute historical CA precipitation. PDRMIP simulations are an idealized tool that allows for a clean assessment of mechanisms, but previous work (e.g., Deng et al., 2020; Herbert et al., 2021) has shown the impact of nonlinearity among different forcers on regional precipitation.

Response: Thank the Review's positive and valuable comments on our manuscript. We have added corresponding description in Section 4 as "*This study is mainly based on the PDRMIP and DAMIP single-forcing sensitivity experiments to assess the historical precipitation changes in Central Asia, which makes it difficult to capture the potential impact of nonlinearity among different forcings on regional precipitation. Previous studies have shown that the nonlinear effects between CO_2 and anthropogenic aerosols can significantly influence the regional seasonal precipitation (Deng et al., 2020; Herbert et al., 2021). Further work is needed to assess how nonlinear effects impact seasonal precipitation in Central Asia.*"

2. In Section 3.3, the SSP scenarios include projected GHG and AA emissions. The response should be the result of the impact from both GHGs and AAs. The authors should be careful when stating the mechanism, such as in lines 285-290: "... the magnitude of these increasing trends is strongly dependent on the GHG emission levels...".

Response: We thank the reviewer for this important comment. We agree that the SSP scenarios represent combined forcings from both GHGs and anthropogenic aerosols. Across the three SSP scenarios, sulfate aerosol emissions decrease, especially in SSP3-70 and 5-85, while GHG concentrations increase from SSP2-45 to SSP5-85. Therefore, we suggest that the differences in precipitation trends among scenarios are likely associated with increasing GHG levels. In the revised manuscript, we have added descriptions of GHG and aerosol emission changes across the three scenarios and revised the corresponding descriptions in Section 3.3 by replacing "*strongly dependent*" with "*likely dependent*".

3. The curves and dots in Figure 6 would benefit from an explanation of the estimation method. The authors did not discuss these results in detail.

Response: Thanks for your suggestions. The dots represent the trends in regionally averaged precipitation from individual models. The previous description of 50 bins was inaccurate. The curves show kernel density estimates of the trend distribution, with the bandwidth selected using Scott's rule, which is used to illustrate the distribution of trends across all models. We have added an explanation of the dots and curves in Figure 6 caption as "*Dots represent the trends in regionally averaged precipitation from individual models, and curves show kernel density estimates of the trend distribution, with the bandwidth selected using Scott's rule.*" In Section 3.3, we have added corresponding description as "*In Figure 6, dots denote the trends in regionally averaged precipitation from individual models. Results from individual models show that most models exhibit increasing precipitation trends under hist-GHG forcing in winter and under hist-aer forcing in summer. These DAMIP results indicate recent increases in winter and summer precipitation over Central Asia and significant seasonal differences in precipitation drivers, which support the results of idealized sensitivity experiments in PDRMIP.*"

Reference

Herbert, R., Wilcox, L. J., Joshi, M., Highwood, E., and Frame, D.: Nonlinear response of Asian summer monsoon precipitation to emission reductions in South and East Asia, Environ. Res. Lett., 17, 014005, https://doi.org/10.1088/1748-9326/ac3b19, 2021.

Deng, J., Dai, A., and Xu, H.: Nonlinear climate responses to increasing CO_2 and anthropogenic aerosols simulated by CESM1, J. Clim., 33, 281–301, https://doi.org/10.1175/JCLI-D-19-0195.1, 2020.