Response to Anonymous Referee #1

Comment: *This paper has addressed an important scientific question regarding the moisture sources contribution to the change in precipitation over the Three Gorges Reservoir Region. Title and abstract reflect the content of the paper clearly. This paper has outlined the details about the data, model and methodology clearly. My main concern is about the conclusions derived from the results. In general, this geographic region (TGRR) is influenced by the south-west monsoon (mainly in summer) which brings moisture from the Arabian Sea and Bay of Bengal, as is suggested by figures 3 and 4. Results also suggest (as is expected) the influence of westerlies system on the moisture source region. Then, the authors claim that the decreased precipitation over the TGRR during 1979-2015 is mainly due to the decreased moisture contribution from the source regions which span over the southwest of the TGRR, especially around the southeastern tip of the Tibetan Plateau.*

Response: Thank you for your constructive comments and suggestions. Please see our responses below.

Comment: *In order to establish the above-mentioned causation, authors presented trend analyses (figures 6, 7) and the time series (figure 8), which suggest the association between the SWS region and the TGRR. No physical mechanism is provided to explain how the decreasing moisture contribution from the SWS region (including the southeastern tip of the Tibetan Plateau) leads to the decreasing precipitation over the TGRR. In other words, it is not clear what is the pathway of this causation.*

Response: Thank you for your comment. First of all, we would like to point out that the WAM-2layers model we used in this study is a moisture tracking model that numerically determines the moisture origin based on mass balance (see, e.g., van der Ent et al., 2013). We drew this conclusion mainly because, among all source regions with decreasing trends in annual and seasonal moisture contribution (Figs. 6 and 7, cf. Figs. 3 and 4), most are concentrated within SWS. In contrast, SS mainly experienced increasing trends in moisture contribution (although statistically insignificant). We then used the correlation results in Fig. 8 to show the relationship between variations of annual precipitation and moisture contributions.

Per your comment, we will further elaborate on the underlying mechanisms of this causal relationship in the revision. We will discuss this based on evaporation, vertical integrated moisture flux in the zonal direction, and vertical integrated moisture flux in the meridional direction based on reanalysis data. Figure R1 below shows the changes (trends) of these three fields in 1979–2015 and the two major pathways of moisture transport toward the target region (arrows in yellow). These two major pathways (from northern India Ocean to TGRR and from northwest Pacific Ocean to TGRR) are primarily based on Fig. 3, which have been identified in previous studies in Yangtze River basin (e.g., Xu et al., 2014). Note that the two key source regions, SWS and SS, are located along these two pathways and are critical to the moisture transport. Figure R2 shows 800-hPa, 500-hPa, and 300-hPa wind fields and their trends over time.

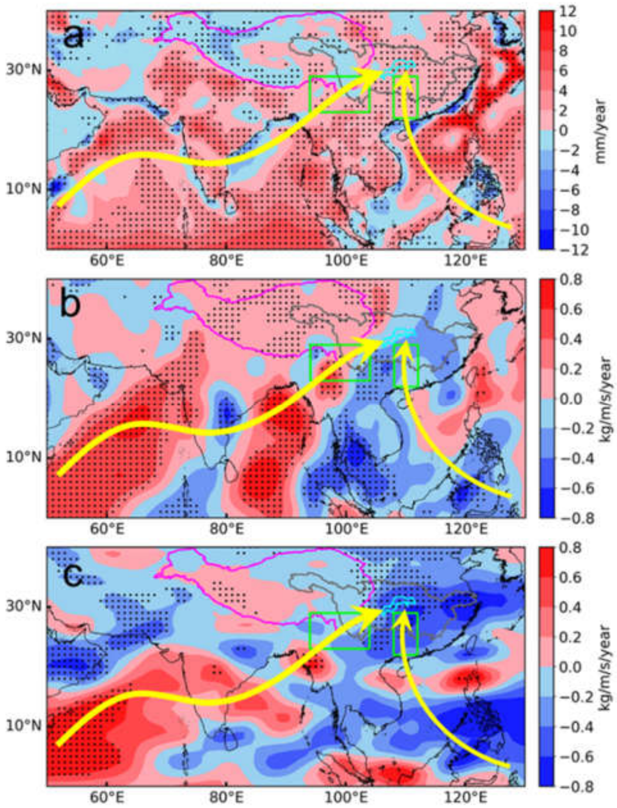

Figure R1: Trends of (a) evaporation, (b) vertical integrated moisture flux in the meridional direction (positive northward), and (c) vertical integrated moisture flux in the zonal direction (positive eastward) based on ERA-Interim during 1979–2015. Arrows in yellows show two major pathways of moisture transport toward the target region.

It is clear that the vast majority of all possible source regions experienced increased evaporation during the study period, despite a small portion of the SWS region with statistically insignificant decreased evaporation (Fig. R1a). Therefore, the enhanced evaporation increase over the SWS is unlikely the major cause of decreased precipitation in the TGRR. We then turn to vertical integrated moisture fluxes. As shown in Figs. 3 and R2, the two major pathways of moisture transport are controlled by winds at different pressure heights. The southwest pathway (from northern Indian Ocean) is mainly controlled by winds at relatively lower levels, while the southeast pathways (from northwest Pacific Ocean) is mainly controlled by winds at relatively higher levels. For the southwest pathway (from northern Indian Ocean), northward and eastward vertical integrated moisture fluxes in general enhanced along the pathway before reaching the SWS region (Fig. R1b and c). However, the further transport of moisture toward the TGRR is largely dampened by the decreased northward and eastward moisture flux over the eastern part of the SWS region, which contributes to the decreased precipitation in the TGRR. For the southeast pathway (from northwest Pacific Ocean), largely decreased eastward moisture flux over the northwest Pacific Ocean and South China Sea indicates an increased westward moisture contribution to the target region. But this enhancement is partly offset by the decreased northward moisture flux along the pathway (especially over the SS region), which results in statistically insignificant trends as observed in Figs. 6 and 7.

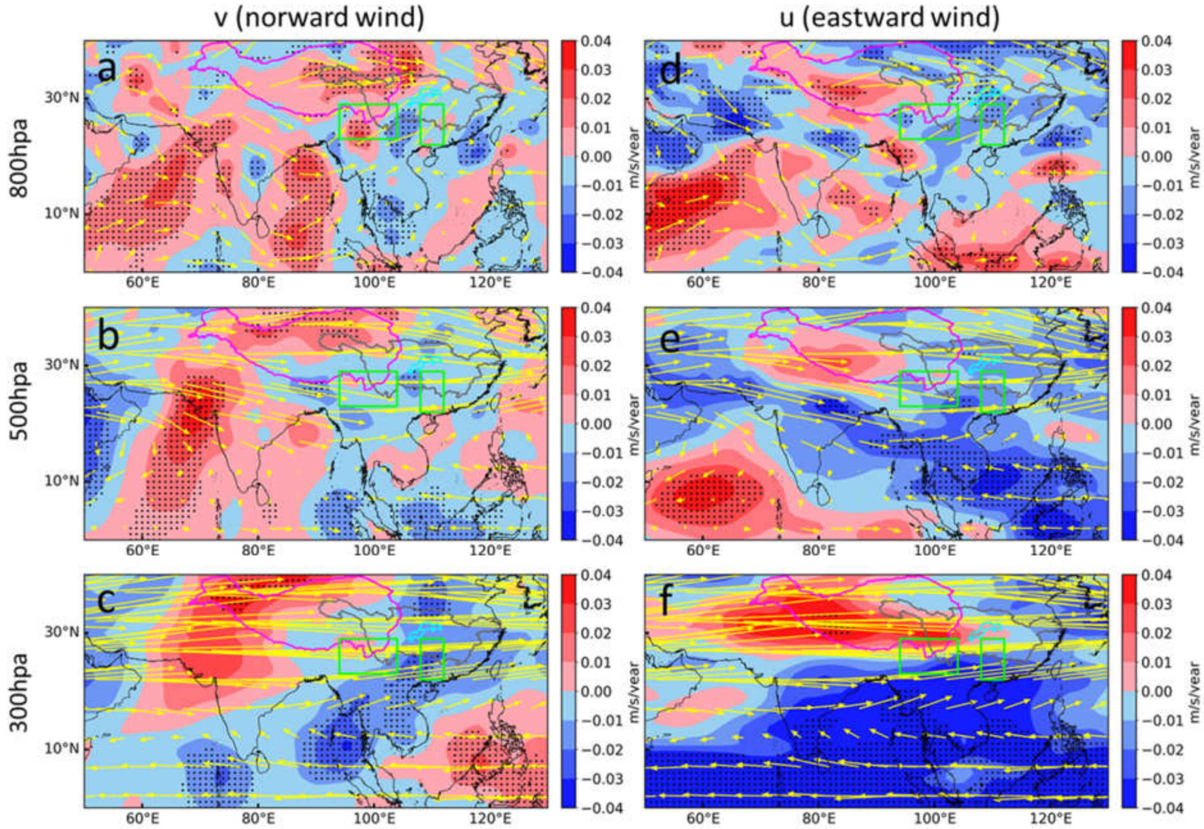

Figure R2: Trends of 800-hpa (top), 500-hpa (middle), and 300-hpa (bottom) wind in the (a, b, and c) meridional direction (positive northward) and (d, e, and f) zonal direction (positive eastward) based on ERA-Interim during 1979–2015, overlaid with wind vectors (yellow arrows).

We will add the above analysis and Fig. R1 in the revision. Nevertheless, our understanding can be partly limited by the moisture tracking model as well as our selected reanalysis dataset used in this study. We will rely on more sophisticated models to investigate the dynamics of specific systems (e.g., monsoon system) for the same period in future study.

Comment: *Furthermore, is this the case only for summer? How does this conclusion hold true during the winter and spring when the westerlies influence is strong? This part is not clear as well.*

Response: Thank you for the question. We have analyzed seasonal trends. The annual and seasonal trends of moisture contributions and TGRR precipitation are summarized in Table R1. As mentioned in our original submission, the decreasing trend in annual precipitation is consistent with decreased moisture contribution from the SWS region. Similar consistency is observed also for summer, autumn, and winter, although statistically significant trends ($p < 0.05$) only occur in summer. The weak relationship between precipitation and SWS moisture contribution in spring, autumn, and winter are likely due to the absence (or marginal influence) of the Indian monsoon, during which the westerlies influence is stronger. We will add these seasonal analyses and Table R1 in the revision.

Table R1: Trends of precipitation over the TGRR and moisture contribution from SWS, SS, and local recycling, on annual and seasonal scales during 1979–2015. '*' represents statistically significant trends ($p < 0.05$).

	Precipitation (mm/decade)	SWS (mm/decade)	SS (mm/decade)	Local recycling (%/decade)
Annual	–40.81*	–9.16*	1.45	0.04
Spring	5.60	–2.22	0.21	0.02
Summer	–35.67*	–3.41*	0.95	0.14
Autumn	–7.90	–2.26	0.46	–0.06
Winter	–2.83	–1.27	–0.17	0.08

Comment: *Authors have selected two boxes to identify two source regions, i.e., SWS and SS. The result of figure 8 depends a lot on how the box is defined. What do we know about the general variability and trend in moisture over the SWS region?*

Response: This is a good question. The two key regions are defined because (1) they experienced most significant changes in moisture contribution as shown in Fig. 6, and (2) they are located along the two major pathways as shown in Fig. R1 (will be added in the revision) and Fig. 3. To test the potential uncertainties induced by the selection of the bounding boxes, we further quantified the trends of moisture contribution from WP and EP (defined in Section 3.1) and their relationships with precipitation in TGRR. Results are shown in Fig. R3 and Table R2.

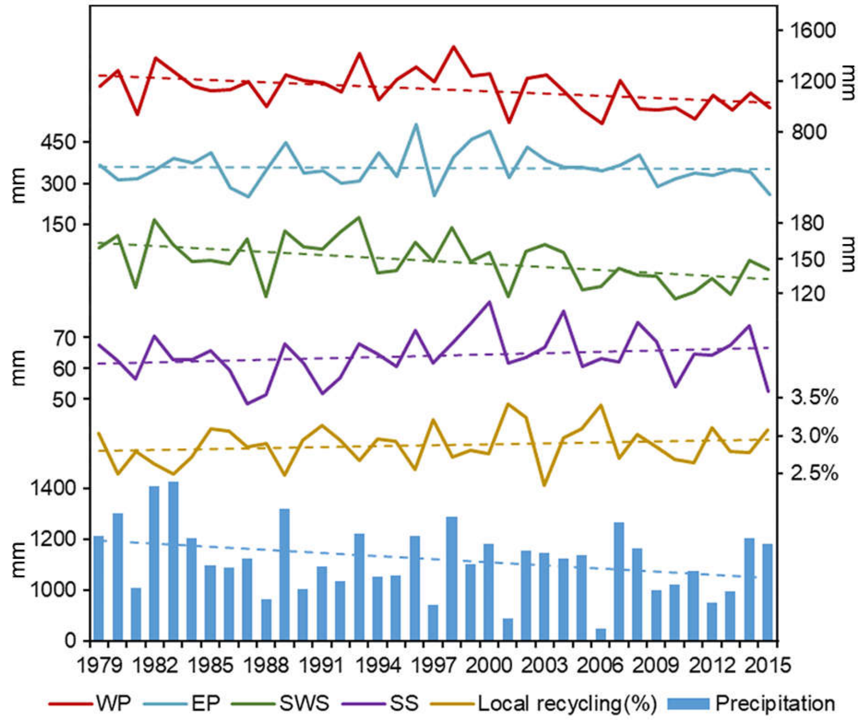

Figure R3: Temporal change of moisture (mm) from the WP, EP, SWS, SS and local recycling (%) to the annual precipitation (mm) in the TGRR. Dashed lines are linear regression fits to the data.

Table R2: Trends of moisture contributions and correlation coefficients between annual TGRR precipitation and moisture contributions in 1979–2015. '*' represents statistically significant ($p < 0.05$).

	Precipitation (mm/decade)	WP (mm/decade)	EP (mm/decade)	SWS (mm/decade)	SS (mm/decade)	Local recycling (%/decade)
Trend	–40.81*	–60.33*	–2.37	–9.16*	1.45	0.04
Correlation coefficient	—	0.69*	0.34*	0.68*	0.28	–0.64*

It is clear that the increasing moisture contribution over the WP is consistent with that over SWS, while contributions from both EP and SS regions show very marginal and statistically insignificant changes. Our conclusions are therefore not affected by the boxes we selected. We will add these analyses, Fig. R3, and Table R2 in the revision. In particular, Fig. 8 in the main text will be replaced by Fig. R3.

Please refer to our previous response (Fig. R1) for the changes of moisture flux and evaporation over the SWS region.

Comment: *Some form of visualization/analysis on a large-scale map (focusing TGRR) would help the readers in later section.*

Response: Thank you for the suggestion. We have tried large-scale maps focusing on TGRR, but due to the coarse resolution of the moisture tracking model (as determined by numerical stability and computational cost, see Section 2.1), large-scale maps do not show any additional details. We will rely on other moisture tracking models (e.g., Lagrangian ones) to refine our simulations in the future.

Comment: *In summary, the use of moisture tracking model in identifying the dominant source regions of moisture is useful. Hence, the first part of the conclusions is convincing and clear. But another key point of the conclusions associated with the role of specific geographic region as a source of moisture in increasing/decreasing the precipitation over the TGRR is not clear.*

Response: Thank you for your valuable feedback. We will discuss the physical mechanisms of the role that SWS region plays in TGRR precipitation change in the revision (please refer to our responses above).

References

van der Ent, R. J., Tuinenburg, O. A., Knoche, H. R., Kunstmann, H., & Savenije, H. H. G. (2013). Should we use a simple or complex model for moisture recycling and atmospheric moisture tracking?. Hydrology and Earth System Sciences, 17(12), 4869-4884.

Xu, X., Chen, L., Wang, X., Miao, Q., & Tao, S. (2004). Moisture transport source/sink structure of the Meiyu rain belt along the Yangtze River valley. Chinese Science Bulletin, 49(2), 181-188.