Response to Anonymous Referee #2

Comment: *This paper studies the contribution of moisture sources to precipitation in the TGR region from 1979 through 2015. It does so by numerically tracking the moisture sources of annual and seasonal precipitation, by identifying the main sources that determine the interannual variability of precipitation and by analyzing the differences in moisture sources and their transport during extreme years over the region. The paper illustrates the trends in annual precipitation and the annual and seasonal variability very well over TGRR. To further look into the sources of moisture, the study divides the region into western and eastern parts and uses the moisture tracking method over the two domains to quantify the contribution from different regions. Contribution to the WP is thought to mainly come from the Indian monsoon system where as the EP comes from the EA monsoon system.*

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

Comment: *In this case how the region is divided into the two domains could influence the results, some more analysis of the domain extent could establish this relation further.*

Response: The division of two (sub)domains was mainly informed by the two major moisture transport pathways observed in Fig. 3 and the dipole patterns observed in Figs. 6, 7, 9, 11. Note that the two major pathways (see Fig. R2), from northern India Ocean to TGRR and from northwest Pacific Ocean to TGRR, have also been identified in previous studies in Yangtze River basin (e.g., Xu et al., 2014). We have tested the selection of different subdomain sizes, but the results and conclusions are consistent. For example, Fig. R1 and Table R1 below show the temporal variations of moisture contributions from subdomains with different sizes and their relationship with TGRR precipitation. Note that the WP and EP are defined in Section 3.1.

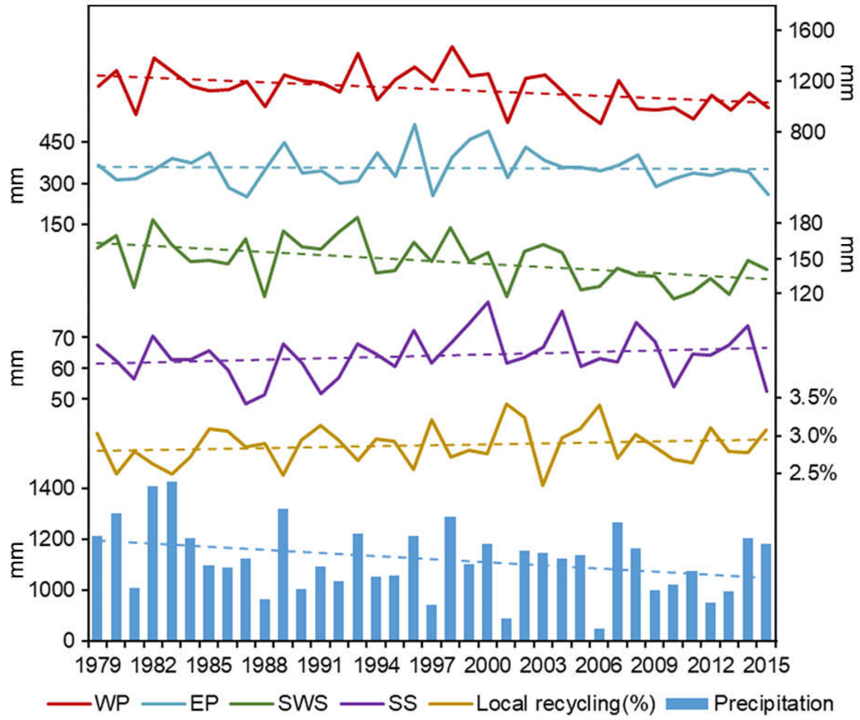

Figure R1: Temporal change of moisture (mm) from the WP, EP, SWS, SS and local recycling (%) to the annual precipitation (mm) in the TGRR. Dashed lines are linear regression fits to the data.

Table R1: 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 subdomain size we selected. We will add these analyses, Fig. R1, and Table R1 in the revision. In particular, Fig. 8 in the main text will be replaced by Fig. R1.

Comment: *Similarly, contribution from ocean, land and local recycling are also analyzed, showing land sources being dominant, these results are more convincing. The spatiotemporal* *trends of moisture sources on precipitation with decreasing trends of moisture contribution mainly come from Indian monsoon and with a marginally increasing trend of moisture contribution from local recycling - all good reasoning, however, correlating the annual TGRR precipitation to the different regional moisture sources is not enough to say that the variability in these moisture sources cause the changes in TGRR precipitation.*

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).

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 R2 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 R3 shows 800-hPa, 500-hPa, and 300-hPa wind fields and their trends over time.

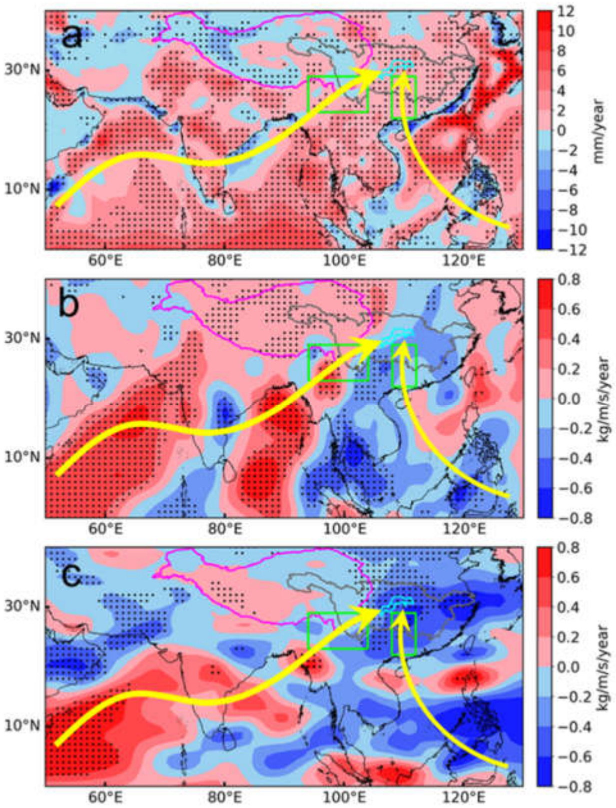

Figure R2: Trends of (a) evaporation, (b) vertical integrated moisture flux in the meridional direction (positive northward), and (c) vertical integrated moisture flux in the zonal direction (positive eastward) based on ERA-Interim during 1979–2015. Arrows in yellows show two major pathways of moisture 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. R2a). 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 R3, 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. R2b 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.

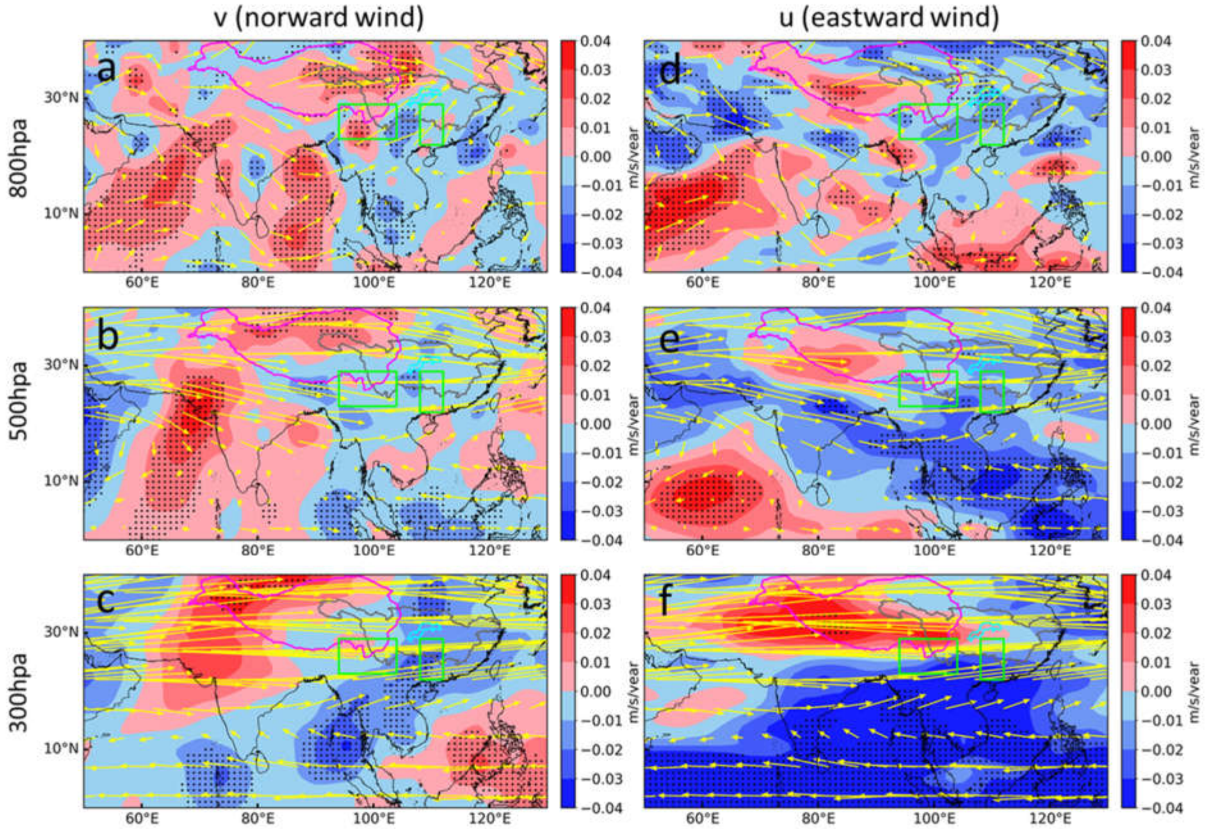

Figure R3: Trends of 800-hpa (top), 500-hpa (middle), and 300-hpa (bottom) wind in the (a, b, and c) meridional direction (positive northward) and (d, e, and f) zonal direction (positive eastward) based on ERA-Interim during 1979–2015, overlaid with wind vectors (yellow arrows).

We will add the above analysis and Fig. R2 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: *The analysis of extremes has just 3 sample years each for wet and dry conditions, can the sample size be increased?*

Response: Thank you for the suggestion. We selected three sample years because these years are the wettest/driest over the TGRR. In fact, the selection of wet/dry years only has marginal impacts on the results, and will not alter our conclusions. To illustrate this, here we increase the sample size from three to five. The five wet years are 1982, 1983, 1989, 1998, 2007, and the five dry years are 1988, 1997, 2001, 2006, 2012. Results of moisture contribution and flux change are shown in

Fig. R4. It is clear that the patterns in Fig. R4 are very similar to those shown in Fig. 9 (3 sample years): extra moisture from the southwest regions during wet years, with weak negative signals in part of the adjacent regions southeast of the TGRR. Therefore, our conclusions are robust. We will add this figure in supplementary in the revision.

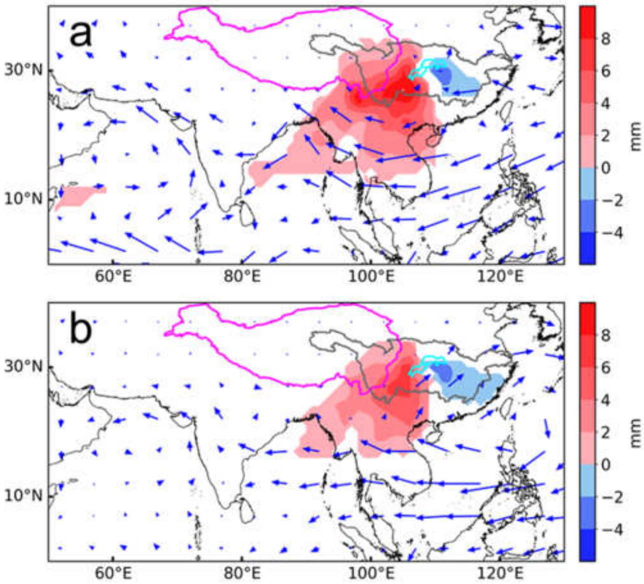

Figure R4: Difference in moisture (mm) contributing to annual (a) and summer (b) precipitation in the TGRR between five wet and five dry years (wet – dry), overlaid with the difference in vertical integrated moisture fluxes (blue arrows; wet – dry).

Comment: *The paper used the Water Accounting Model-2layers to simulate the moisture transport and to quantify and pinpoint the sources of moisture well, although the method has limitations it has been used quite effectively in this study.*

Response: Thanks again for all your comments and suggestions, which have substantially improved our manuscript.

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.