Reviewer #1

The paper of Zhang et al investigates quantifies the trends in rainfall decrease in Southwest China and investigates whether and how atmospheric circulation plays a role. The paper is easy to read and the figures generally support the text and vice versa. The study is novel in the sense that atmospheric tracking has not often been applied to trends in precipitation, but rather for climatologies or variability studies only.

A: Thanks for the comments. We truly appreciate it.

That being said, I have a few concerns with the manuscript, which I hope the authors can address in a revised version:

1. Units are not used consistently up to (what should be) the scientific standard. Precipitation should always be per a unit of time, thus mm mon^{-1} and never just mm. Trends should always be per unit of time squared, thus mm yr^{-2} or mm mon^{-1} $decade^{-1}$ and never just mm yr^{-1}. Same holds for moisture flux divergence (or in fact any flux). The sister journal of ACP, HESS, has a good guide: http://www.hydrology-and-earth-system-sciences.net/for_authors/manuscript_preparation.html under mathematical requirements.

A: Units have been changed to fit the standard of ACP in the revision. The trends are expressed as per unit of time squared. The fluxes including precipitation and moisture divergence are all expressed as per unit of time throughout the paper.

2. The water accounting model (WAM) has received several updates since van der Ent et al. (2010), and it is not clear whether the authors use the updated version with two vertical layers (van der Ent et al., 2014), which is apparently open source now (van der Ent, 2016). This may be very relevant due to the wind shear present in the area under investigation, which will lead to biases when vertically integrated fluxes are being used (van der Ent et al., 2013; Goessling and Reick, 2013).

A: The original version of WAM (WAM1), instead of the two vertical layer model (WAM2), was applied in this study. To address the concern of the reviewer about model versions, we tested the potential contribution of wind shear to moisture flux by *calculating the moisture flux shear factor following Eqs. (7-8) in van der Ent et al. (2013) in the target area (see Fig. r1). Lower value indicates stronger moisture flux shear. The areal-weighted shear factor at the zonal direction over summer (JAS) in study area SWC during 1979-2013 is 0.72, while it is 0.76 at the meridional direction. Taking the zonal shear factor as an example, a shear factor of 0.72 means that 86% of the water goes in one direction with 14% in the opposite direction. Because the dominant moisture flux has a high share of the overall flux, the moisture flux shear is not strong in this case.*

To further confirm that, we selected the year 1986 with the strongest moisture flux shear (The averaged zonal and meridional shear factor in summer 1986 is 0.71.) as a sample case and applied the WAM2 for comparison. The results (Fig. r2) show that the spatial patterns of moisture contribution match with each other between WAM1 and WAM2. This is not the case as in van der Ent et al. (2013), where WAM2 shew distinct spatial pattern with WAM1. Thus, WAM1 is considered suitable for this study. We have added the comparison of WAM versions into the discussion section.

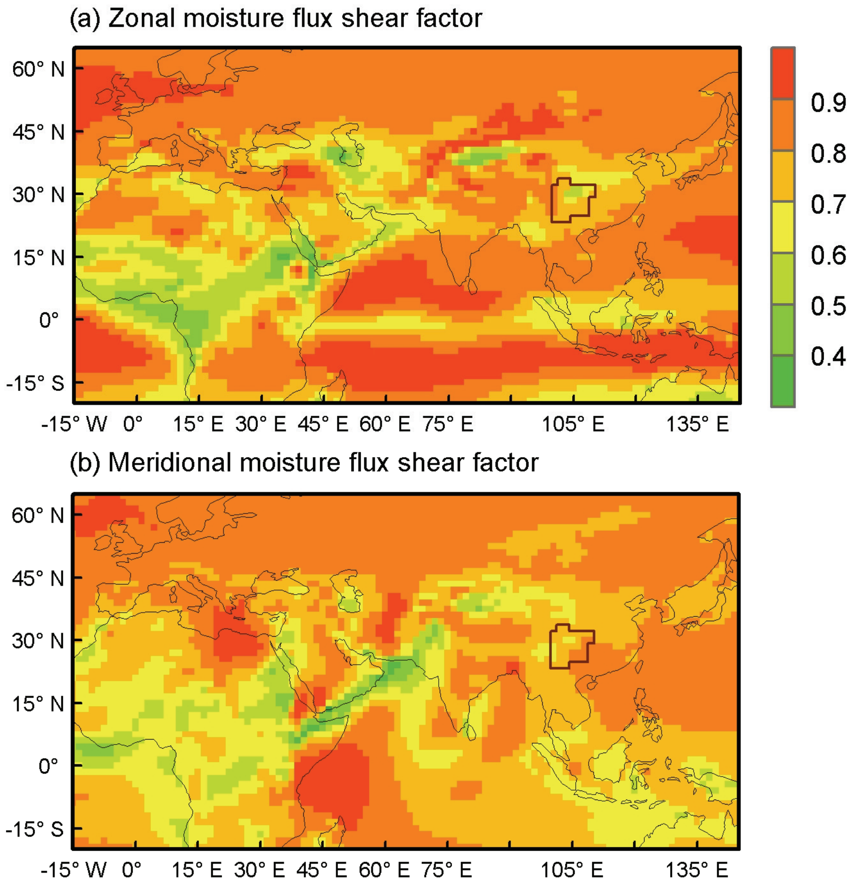

Fig. r1 Horizontal moisture flux shear factor in summer (JAS) averaged over 1979–2013 with ERA-I. (a) Zonal moisture flux shear factor, (b) meridional moisture flux shear factor.

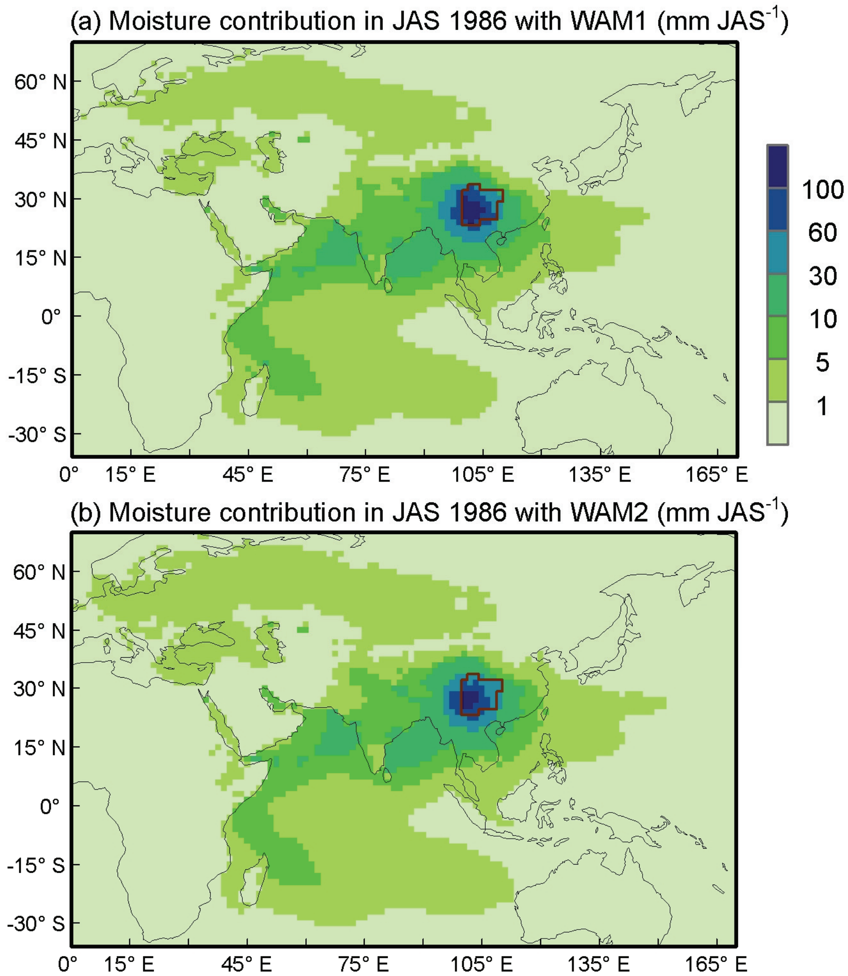

Fig. r2 Moisture contribution for JAS precipitation in 1986 SWC with WAM1 (a) and WAM2 (b).

3. There is limited background information on the ground-based precipitation dataset from CMA. It is always tricky to do trend analysis on interpolated data for which the stations on which the dataset is based might not be homogeneous. I suggest the authors give more information on the number of stations used, whether that is constant, are there data gaps, is it just stations or satellite information as well? And a reason why they think it is safe to apply trend analysis on this dataset.

A: The CMA (China Meteorological Administration) precipitation dataset is based on ground observations of ~2400 stations over China (Shen and Xiong, 2016). The stations within this study area are shown in Fig. r3. The data are quality controlled and released *by CMA. It is seen as one of the best ground-based precipitation products over China and it is widely used in many studies. In the revision, a brief discussion on the CMA dataset is provided.*

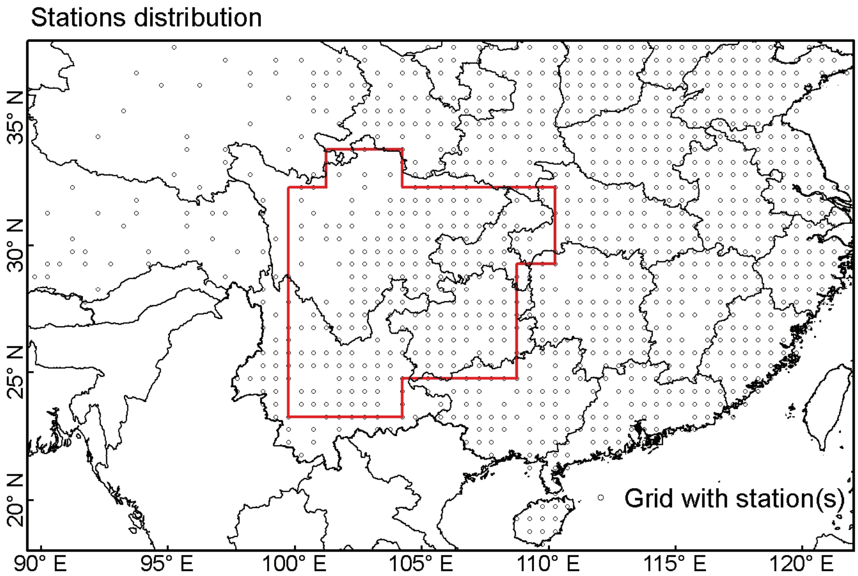

Fig. r3 Rain stations distribution. The circle represents the 0.5 ° grid with at least one rain station.

4. The decomposition of moisture transport is not well enough explained. The results seem relevant, but from the information in the paper I do not see how this could be easily reproduced.

A: Section "2.3 Decomposing moisture transport" has been revised by adding formulas to explain the decomposition of moisture transport. We have added a short paragraph to detail the analysis method. The decomposition process was described in detail in the references Li et al. (2013) and Seager et al. (2010). As it is a widely used procedure in the research field, it should not be difficult to reproduce following the guidance in the references.

5. P1, L19: "at a rate of -23.6 mm^{-1} decade" This is just one of the many examples what I mean with the wrong use of units. Because the unit is incorrect it leaves the reader wondering whether this is -23.6 mm per year per decade or -23.6 mm per decade per decade or -23.6 mm per month per decade or -23.6 mm per day per decade. Admittedly,

these mistakes can be found abundantly in the scientific literature, but it is no excuse, in my opinion, to take such issues lightly, rather I hope that the authors agree with me and start correcting themselves as well as others.

A: We agree with the reviewer on the unit issue. The units have been carefully checked and corrected in the revision.

6. P2, L27-28: "The ERA-I data have a spatial resolution of 1.5° × 1.5° grid cell" Apparently this is the resolution that the authors used (which is ok), but other (higher) resolution are also available, thus please rephrase this sentence.

A: There is ERA-I data with other resolutions, and the 1.5 degree data were used in this study. The sentence has been rephrased.

7. P2, L30-P3, L2: Here, the authors explain that they have replaced the evaporation and precipitation fields from ERA-I with CMA precipitation and GLDAS evaporation, because of existing "limitations in the reanalysis estimates". The claim about limitations is, however, not being backed up with a reference or figures and nor is any proof given that the alternative datasets are any better. I suggest the authors to back up this choice of data better.

A: It is well-known that the reanalysis data such as ERA-I have large biases on precipitation estimates, and so as the evaporation estimates (Trenberth et al., 2011; Tong et al., 2013). The CMA precipitation data is from ground-based observations and was released by CMA, the Administration which is responsible for meteorological observations in China (http://www.cma.gov.cn/en2014/). The GLDAS is forced with precipitation gauge observations among others (Rodell et al., 2004). Both datasets are observation-based and are better than the estimates in the reanalysis data. In the revision, we have provided the related references to back up the choice of data.

8. P3, L5: "backward in time" As far as I know backward tracking with WAM has been applied by Keys et al. (2012) for the first time.

A: We have corrected the citation and have added Keys et al. (2012) in the revision.

9. P3-P4: "Section 2.3 Decomposing moisture transport" This entire section could benefit from equations and figures to explain the concept behind decomposition.

A: This section has been revised by adding formulas to explain the decomposition method.

10. P4, L21-22: "As shown in Fig. 2, the farther away from the target region, the lower intensity of moisture is contributed to the target (Zhang C. et al., 2017)"

I think it is a bit misplaced to cite just an own paper here as there are literally dozens of other papers that used back-trajectory methods which have found this. Moreover, it is not even as simple as put here, because it naturally depends on the winds (otherwise we could just draws circles around the target region)

A: Thanks for your suggestions. More references have been added in the revision. In addition, the statement has been modified to reflect the key message, that is, the moisture contribution differs in different directions depends on the winds. As shown in the Fig. 2, for the study area, more moisture is from the south and less moisture from the north.

11. P4-P5, "Section 3.1 Moisture origin" I think previous literature is not sufficiently cited in relation to the findings of this paper. A few papers that have source region figures for China or sub-regions of China that for example could be of interest (Keys et al., 2014; Wei et al., 2012, 2016).

A: We have cited the references and compared the findings in the previous references and those in this study. The comparisons are generally consistent, although the focus areas are not the same. We have also emphasized that we focus more on the changes of the moisture contribution, rather than the climatological pattern in this study.

12. P7, L5: "the Asian monsoon regions" Which are exactly? Would it perhaps make sense to delineate them somewhere?

A: "The Asian monsoon regions" here means from the northern Indian Ocean to SWC *and from South China Sea to SWC. We have modified the statement and specified the exact regions in the revision.*

13. P7: "Data availability" What about the data availability of the CMA product? This section should be expanded according to the ACP guidelines: http://www.atmospheric-chemistry-and-physics.net/about/data_policy.html

A: The CMA product was released by CMA and was downloaded from the China Meteorological Data Service Center (CMDC, http://data.cma.cn/en, http://data.cma.cn/data/cdcdetail/dataCode/SURF_CLI_CHN_PRE_DAY_GRID_0.5.html). The site has been provided in the Data availability section in the revision.

14. The summer months appear to be July, August and September, whereas the meteorological summer for the northern hemisphere is generally regarded as June, July, August. Why the difference? The fact that JAS is considered should be 100% clear in all figure and table captions.

A: We focused on July, August and September because precipitation in these months shows large and significant trends over the study area. We agree that meteorological summer usually indicates June, July, and August. In the revision, we have added a note on the specification of "summer" in this study, The JAS represented summer is clarified throughout the paper.

15. Figure 2: the caption should include what the contribution to total precipitation the red boundary in Fig. 2a encompasses. I saw it mentioned in the text, but not in the figure caption itself.

A: The caption has been revised to include the information.

16. Figure 2: why is the Tibetan Plateau relevant?

A: The Tibetan Plateau situates in the upwind of SWC. Due to its high altitude, it is well-known that it will block the moisture from the west to SWC (Tian et al., 2007; Yu et al., 2008). It can be seen from Figure 2 that little moisture contribution from the west *of the Tibetan Plateau. However, the Tibetan Plateau itself may contribute moisture to SWC (Huang and Cui, 2015), which is also seen from Figure 2. Thus, it explains the moisture contribution pattern (relative high contribution from eastern Tibetan Plateau, but close to zero contribution from the western and west to the Tibetan Plateau) shown in Figure 2. It is an important finding regarding how the high altitude of the Tibetan Plateau affects moisture contribution pattern. These reasons have been clarified in the revision.*

17. Figure 2: There are multiple black lines (also the target region), which makes the caption confusing.

A: The line colors have been adjusted. The target region is changed to brown. The land outline is changed to gray. The division line between East and West is black.

18. Fig. 2b: The information between 0 and 1 and -1 and 0 seems quite relevant, could the authors add more colors?

A: The color bar has been modified following the suggestion.

19. Figure 2: Is the boundary between East and West expert judgement? The art of the modeler? Or is there some physical determining factor?

A: The boundary is based on the result (Fig. 2b) following the distinct opposite sign of the moisture trend. In the west side, the moisture contribution is decreasing while it is increasing in the east side. It has been clarified in the revision.

20. Figure S1: What do the colors mean? The color scale lacks units or explanation in the caption.

A: The colors represent the moisture divergence of the fluxes. The units have been added in the caption on the next page.

21. TECHNICAL CORRECTIONS

As mentioned before, units should be corrected throughout the paper.

A: The units have been corrected throughout the revised paper.

References

Huang, Y., and Cui, X.: Moisture Sources of Torrential Rainfall Events in the Sichuan Basin of China during Summers of 2009–13, J. Hydrometeor., 16, 1906–1917, doi: 10.1175/JHM-D-14-0220.1, 2015.

Li, L., Li, W., and Barros, A. P.: Atmospheric moisture budget and its regulation of the summer precipitation variability over the Southeastern United States., Clim. Dyn., 41(3-4), 613-631, 2013.

Rodell, M., Houser, P., Jambor, U., Gottschalck, J., Mitchell, K., Meng, C., Arsenault, K., Cosgrove, B., Radakovich, J., Bosilovich, M., Entin, J., Walker, J., Lohmann, D., and Toll D.: The Global Land Data Assimilation System, Bull. Amer. Meteor. Soc., 85, 381–394, 2004.

Seager, R., Naik, N., Vecchi, G. A.: Thermodynamic and dynamic mechanisms for large-scale changes in the hydrological cycle in response to global warming. J Clim 23:4651–4668, 2010.

Shen, Y., and Xiong, A.: Validation and comparison of a new gauge-based precipitation analysis over mainland China. Int. J. Climatol., 36(1), 252-265, 2016.

Tian, L., Yao, T., MacClune, K., White, J. W. C., Schilla, A., Vaughn, B., Vachon, R., and Ichiyanagi, K. Stable isotopic variations in west China: a consideration of moisture sources. J. Geophys. Res. Atmos., 112(D10), 2007.

Tong, K., Su, F., Yang, D., Zhang, L., and Hao, Z.: Tibetan Plateau precipitation as depicted by gauge observations, reanalyses and satellite retrievals. Int. J. Climatol., 34(2), 265-285, 2014.

van der Ent, R. J., Tuinenburg, O. A., Knoche, H. R., Kunstmann, H. and Savenije, H. H. G.: Should we use a simple or complex model for moisture recycling and atmospheric moisture tracking? Hydrol. Earth Syst. Sci., 17(12), 4869–4884, doi:10.5194/hess-17-4869-2013, 2013.

Yu, W., Yao, T., Tian, L., Ma, Y., Ichiyanagi, K., Wang, Y., and Sun, W.: Relationships between $\delta^{18}O$ in precipitation and air temperature and moisture origin on a south–north transect of the Tibetan Plateau. Atmos. Res., 87(2), 158-169, 2008.