Response to the comment of Referee #1

This manuscript of Liu et al. presents and discusses decreases in summer precipitation over the Iberian Peninsula (IP) by analyzing the moisture sources. They applied WAM-2layers to track moisture sources that contribute to the summer precipitation. The moisture source region is divided into three sub-regions: western, IP, and eastern regions. Their findings show how moisture contribution changed from the three regions resulted in less precipitation over the IP.

The results showed by Liu et al. help to better understand what the changes and contributions of the three moisture sources are and how they affect the IP summer precipitation. The motivation is generally interesting, and the figures and text are clear. The method and analysis are clearly stated and explained. I have a few questions and recommend the manuscript for publication after a minor revision

We gratefully thank the reviewer for the time and effort spent making these constructive remarks and thoughtful comments. These comments can significantly enable us to improve the manuscript. Below, each of the reviewer's comments have been replied point by point.

Questions/comments:

1. About the identified west region, the moisture from this region was considered as a contribution from the circulation over the North Atlantic Ocean. North America is also included in this region. However, in Figure 4b it seems that North America is

not connected to the other moisture source regions (e.g., the eastern North Atlantic Ocean) when you consider the significant differences between wet and dry years. What are the physical mechanisms of moisture transport from North America? Is it reasonable to include North America in the west region?

Response: We are appreciative of this question raised by the reviewer. In this study, we include North America in the west region for the following reasons. Firstly, we do not think North America can be considered as a separate source region. It is true that due to the long distance of North America from the Iberian Peninsula, the climatological contribution of North America land evaporation to precipitation in the study region is much smaller compared to other regions (most areas contribute less than 0.2mm mon^{-1}, and a small part contribute 0.2-0.5 mm mon^{-1}, as shown in Figure4(a)) but still contributes (technically speaking, everywhere contributes although the region far away from Iberian Peninsula contributes much less). Therefore, it has not been considered as a main source of water vapor in the Iberian Peninsula in many studies or its contribution has not been considered enough to be discussed independently (Gimeno et al., 2010; Winschall et al., 2014).

Secondly, as we aimed to delineate a large enough precipitationshed to trace IP precipitation as completely as possible, a part of North America will, inevitably, be taken into consideration in our study. This part is influenced by the North Atlantic anticyclonic structure in terms of the mechanisms. Besides, it and the North Atlantic at similar latitude together form a relatively stable atmospheric basin in summer according

to the construction of global atmospheric moisture networks (Zhang et al., 2020). For these reasons, we believe that it is reasonable to include the contribution of North America in the west region in this study without ignoring it. And we will add these descriptions of the basis for sub-source division in the revision.

References:

Gimeno, L., Nieto, R., Trigo, R. M., Vicente-Serrano, S. M., and López-Moreno, J. I.: Where does the Iberian Peninsula moisture come from? An answer based on a Lagrangian approach, J. Hydrometeorol., 11, 421-436, https://doi.org/10.1175/2009JHM1182.1, 2010.

Winschall, A., Sodemann, H., Pfahl, S., and Wernli, H.: How important is intensified evaporation for Mediterranean precipitation extremes?, Journal of Geophysical Research: Atmospheres, 119, 5240-5256, https://doi.org/https://doi.org/10.1002/2013JD021175, 2014.

Zhang, Y., Huang, W., Zhang, M., Tian, Y., Wang, G., and Zhong, D.: Atmospheric Basins: Identification of Quasi-Independent Spatial Patterns in the Global Atmospheric Hydrological Cycle Via a Complex Network Approach, Journal of Geophysical Research: Atmospheres, 125, e2020JD032796, https://doi.org/https://doi.org/10.1029/2020JD032796, 2020.

2. As for the east region, it seems that it is at the downwind location of the circulation over the North Atlantic Ocean. It is not clear in the manuscript how the moisture from the east region contributes to the IP precipitation. It would be helpful if the authors could clarify the physical mechanism.

Response: Thank you for your comment. Normally, the east region sits downwind of the circulation. However, as the wind can blow everywhere due to pressure variation, the moisture transport trajectories are more complexed than the climate mean 2-

dimentional figure (Fig.4a) tells. Low pressures can form occasionally in the IP, which bring the moisture from the downwind east to the IP.

We will add these relevant explanations to the revision: The east region includes the Mediterranean Sea where the atmospheric moisture divergence is positive almost everywhere, indicating a net water flux from it to the atmosphere (Mariotti et al., 2002). The evaporation from the Mediterranean Sea moistens the air parcels and flows towards the surrounding land, and becomes the main short-term moisture source regions affecting the IP, especially the eastern IP (Gimeno et al., 2010; Vázquez et al., 2020). On the eastern peninsula, the most important pattern for producing precipitation extreme events is characterized by the presence of a cutoff low at mid-levels, mostly in autumn, together with an easterly moisture flow from the Mediterranean Sea, generating significant instability over the area (Merino et al., 2016). Although the eastern region is located downstream of the dominant wind direction, some of the large amount of evaporation it provides will contribute to precipitation over the adjacent IP land in a short time by the process of water vapor exchange, especially for the frequent convection precipitation in summer.

References:

Gimeno, L., Nieto, R., Trigo, R. M., Vicente-Serrano, S. M., and López-Moreno, J. I.: Where does the Iberian Peninsula moisture come from? An answer based on a Lagrangian approach, J. Hydrometeorol., 11, 421-436, https://doi.org/10.1175/2009JHM1182.1, 2010.

Mariotti, A., Struglia, M. V., Zeng, N., and Lau, K.-M.: The Hydrological Cycle in the Mediterranean Region and Implications for the Water Budget of the Mediterranean Sea, Journal of Climate, 15, 1674-1690, https://doi.org/10.1175/1520-0442(2002)015<1674:Thcitm>2.0.Co;2, 2002.

Merino A, Fernández-Vaquero M, López L, Fernández-González S, Hermida L, Sánchez JL, García-Ortega E, and Gascón E (2016) Large-scale patterns of daily precipitation extremes on the Iberian Peninsula. International Journal of Climatology 36

Vázquez, M., Nieto, R., Liberato, M. L. R., and Gimeno, L.: Atmospheric moisture sources associated with extreme precipitation during the peak precipitation month, Weather and Climate Extremes, 30, 100289, https://doi.org/https://doi.org/10.1016/j.wace.2020.100289, 2020.

3. Evaporation is used to explain the local moisture contribution. Although both have a decreasing trend, how does the annual evaporation (in Figure 9) correlate to the contributed P in Figure 6 in terms of interannual variability?

Response: Thanks for pointing this out. We agree that it is necessary to show correlations between local recycling and local evaporation. We will calculate the Pearson correlation coefficients between evaporation and locally contributed precipitation and its recycling ratio respectively, and add the result to show the correlations between these interannual variabilities.

4. Comments: The role of local recycling is stressed in the conclusion. However, looking at Figure 6a and Table 1, it seems to me that the changes in contribution from the west region have the most dominant effect. I think this should be made clear in the conclusions.

Response: Thanks for your rigorous consideration. Among the three subregions, the most dominant effect of the west region, as you mentioned, is more due to its wide coverage with a large number of grids, which makes the cumulative amount of the entire region the largest. We will rephrase conclusion appropriately to clearly emphasize the influence of the west region.

Technical corrections

1. The grey shading in Figures 2,6 is not defined in the captions.

Response: Thanks for your comment. We will add the explanations to the captions of Figure 2 and 6 in the revision. Due to the abrupt change in the summer precipitation sequence in 1997, the 40 years were divided into two periods in our study. In order to visually show the fluctuation and change of the whole 40 years and the two separated periods, we used different background colors in the figures. The white is for the period of 1980-1997, and the grey shading is for 1998-2019 period.