Response to Anonymous Referee #1

General comments: Despite the moisture sources of the Tibetan Plateau (TP) have been basically revealed by several researches on the basis of different methods, the further study of the moisture sources over TP from various dataset is necessary. In this manuscript, the authors quantified the absolute and relative contributions of oceanic moisture sources over TP based on a moisture tracking model and the various atmospheric reanalysis products. The methods in the manuscript is generally effective, while the moisture tracking method in this study still have non-ignorable uncertainties and need proper evaluation. In science, the novel contribution of this study is not clear due to most of the conclusions have been revealed in previous studies. Therefore, I would recommend that the manuscript need major revision before accepted by HESS. Below are my specific comments.

Response: Thank you for your valuable comments and suggestions.

For the uncertainties of the moisture tacking method, in the revision, we further explained (1) why we chose the WAM-2layer model and (2) how we dealt with the uncertainties of this model. The clarifications have been strengthened in the revised manuscript. Please see our detailed response to your specific comment #1.

For the novelty of this study, in the revision, we more clearly pointed out the unique contributions of this paper by (1) summarizing knowledge gaps and (2) thoroughly comparing this study with existing moisture tracking studies in the TP (see Table AC1). Please see our detailed response to your specific comment #2.

Specific comments:

1. In this study, there are several approximation in the Eulerian moisture tracking method (Van der Ent et al., 2010; Van der Ent, 2014), which induce non-ignorable uncertainties of the moisture sources calculations. For example, it only can resolve two vertical layers in the model and does not consider all the water substances (water vapour, cloud droplets, cloud ice, rain, and snow) and all the physical processes that the moisture undergo in the model, eg. deep convection, shallow convection, cloud macrophysics, cloud microphysics, diffusion etc. It is not the best one. In fact, the detailed quantified moisture models have been developed. In the references in around line 70, I suggest the authors pertinently evaluate previous studies and properly evaluate Van der Ent' (2014) method in section 2.1. Also need indicate the uncertainties of this method in the manuscript.

Response: Thank you for the comment and suggestion. We would like to address your concern from the following two aspects.

(1) Why we chose to use the WAM-2layer model over the study area.

Firstly, the WAM (Water Accounting Model) has already been widely used in moisture tracking in the TP region, for example, in the central-western TP (*Zhang et al.*, 2017), in the Endorheic TP (*Li et al.*, 2019), between the southern and northern parts of the TP (*Zhang et al.*, 2019a), and in the entire TP (*Guo et al.*, 2019; *Zhang*, 2020). The quantified moisture tracking results with WAM are generally consistent with other commonly used models, such as FLEXPART, HYSPLIT, LAGRANTO, QIBT, and CAM (see Table AC1 for a detailed comparison). This cross-region, cross-model comparison showcases the reliability and robustness of WAM model for moisture tracking over the study area.

Table AC1. Summary of numerical moisture tracking studies in the TP region.

Reference	**Study area**	**Time period**	**Model**	**Data**	**Main conclusions**
Chen et al. (2012)	TP	2005–2009 (summer)	FLEXPART	NCEP/GFS	The ocean source could extend from the Arabian Sea to the Southern Hemisphere.
Sun and Wang (2014)	Grassland on eastern TP	2000–2009	FLEXPART	NCEP-CFSR	During the warm (cold) season, oceanic moisture is mainly from the Arabian Sea and Bay of Bengal (areas surrounding the Arabian Peninsula).
Zhang et al. (2017)	Central-western TP	1979–2013	WAM	ERA-I, NCEP-2	More than 21% of the moisture comes from oceans.
Huang et al. (2018)	Southeastern TP	1979–2016 (winter extreme precipitation)	LAGRANTO	ERA-I	About 18% of the moisture comes from oceans.
Pan et al. (2018)	Southern/northern TP	1982–2014	CAM	MERRA	During summer, the Indian Ocean supplies about 28.5% of the moisture to the southern TP.
Chen et al. (2019)	Four areas in TP	1980–2016 (May–August)	FLEXPART	ERA-I	The northwestern TP and northeastern TP are less affected by the Indian monsoon moisture.
Guo et al. (2019)	TP	1979–2015	WAM-2layers	ERA-I	Indian Ocean and Pacific Ocean account for 24% and 2% of the moisture contribution, respectively.
Li et al. (2019)	Endorheic TP	1979–2015	WAM-2layers	ERA-I, MERRA-2, JRA-55	24%–30% of the moisture comes from oceans.
Qiu et al. (2019)	Three areas in TP	1979–2016 (winter extreme precipitation)	LAGRANTO	ERA-I	Moisture contributions of the Arabian Sea to the intense precipitation in the western, south-central, and southeastern TP are 9.2%, 6.9%, and 1.1%, respectively.
Xu and Gao (2019)	Southeastern TP	1982–2011 (April–September)	QIBT	ERA-I	Only 2% of the moisture originates from the oceanic source.
Zhang et al. (2019a)	Southern/northern TP	1979–2016	WAM-2layers	ERA-I	Northwestern (southeastern) source contributes ~39% (~51%) of the moisture in the northern (southern) TP.
Zhang et al. (2019b)	Sanjiangyuan Region	1960–2017 (June–September)	HYSPLIT, HDBSCAN	NNR1	About 51% (54%) of the medium to heavy precipitation is influenced by the northwestern (southern) source.
Liu et al. (2020)	Western TP	1979–2018 (winter)	HYSPLIT	ERA-I	About 57% of the moisture comes from the Arabian Sea, Arabian Peninsula, and northern Indian Ocean.
Ma et al. (2020)	Seven areas in TP	1961–2015 (summer extreme event)	HYSPLIT	NCEP/NCAR	About 75% of the moisture for extreme precipitation in the southeastern TP comes from the Bay of Bengal.

Yang et al. (2020)	Southeastern TP	1980–2016 (June–September)	FLEXPART	ERA-I	30% of the moisture comes from oceans.
Zhang (2020)	TP	1998–2018	WAM-2layers	ERA-I, TRMM	The southeastern source from the TP to the western Indian Ocean accounts for 32% of the moisture contribution.
LI et al. (2022)	Seven basins in TP	1979–2015	WAM-2layers	ERA-I, MERRA-2, JRA-55	Oceanic moisture accounts for 24%–30% of the moisture in different basins of the TP.

Secondly, Lagrangian models (e.g., FLEXPART and HYSPLIT) concern the movement of ‘air particles’ in the atmosphere, thus, the identification of precipitation and evaporation events mainly relies on the dynamic humidity information of each air particle (*Tuinenburg and Staal*, 2020). The detailed methods have been introduced in *Sodemann et al.* (2008) (‘moisture source attribution’ method) and *Sun and Wang* (2014) (‘areal source–receptor attribution’ method). In comparison, Eulerian models (i.e., WAM-2layers) focus on the water balance of fixed grids, which enables us to track the precipitation and evaporation moisture separately based on the mass balance principle. This results in different computational costs for long-term studies. In Lagrangian models, researchers generally use a tracking period of about 10 days (the average residence time of moisture in the atmosphere) for a single release of air particles. For long-term experiments as in this work (1979–2020), Lagrangian methods can consume relatively higher computational resources if one continuous release particles from the target region during the period (or releasing a large amount of air particles from all potential source regions at once). Therefore, considering the need for long-term precipitation/evaporation moisture tracking, the WAM-2layer is more suitable in this study.

Thirdly, the model developers of the WAM-2layers have verified the availability of this model at both global and regional scales, by the comparisons with the ‘RCM-tag’ (MM5, the Fifth-Generation Mesoscale Model) model and the ‘3D-Trajectories’ (QIBT, quasi-isentropic back-trajectory) models (*Van der Ent et al.*, 2013). This comparison has suggested the reliability of WAM-2layers model in moisture tracking.

(2) How we dealt with the uncertainties of the model.

Firstly, as mentioned by the reviewer, the model contains only two layers. The two layers are set to adequately deal with the wind shear in the upper air, but this does not affect the accuracy in calculating the $\partial(S_k u))/\partial_x$ and $\partial(S_k u))/\partial_x$ in Equation (1) in the manuscript. In fact, a total of 17 layers of wind fields and specific humidity were used in the model to separate these two model layers. In addition, we also downloaded the total column moisture and vertically integrated moisture fluxes over all tracking areas to revise the calculations of moisture transport in the model.

Secondly, we have considered all possible phases of water in the atmosphere in ERA-Interim and MERRA-2, which contains water vapor, cloud liquid water, and cloud frozen water. One exception is JRA-55, for which we did not consider the cloud liquid/frozen water, as it is not available.

Thirdly, we totally agree with the reviewer that some physical processes, such as the deep convection, shallow convection, cloud macrophysics, cloud microphysics, and diffusions, are not considered in the model. However, the core function of the WAM-2layers is the dynamic reproduction of the moisture transport processes with the input datasets. An analysis at the original resolutions of the input datasets will largely limit uncertainties to input datasets themselves. We acknowledge that for analyses at a higher spatial-temporal resolution, more physically based models might be more accurate (e.g., WRF-WVT). In this work, all analyses were conducted at the original spatial resolution of the input datasets (1°×1°). To better capture the vertical exchanges due to convection, turbulence, and re-evaporation and minimize the water balance losses between different model layers in a higher temporal resolution in the WAM-2layers, the gross vertical flow is set to 4 times the vertical flow in the net flow direction and 3 times the vertical flow in the opposite direction according to the studies from *van der Ent et al.* (2014) and *Findell et al.* (2019).

Fourthly, to better demonstrate the reliability of our conclusions and potential uncertainties, we used three reanalysis products for moisture tracking over the study area. We have ensured that all relevant conclusions are supported by results using different reanalysis products.

Based on the above descriptions, we have strengthened the relevant advantages and uncertainties of the WAM-2layers model in Section 2.1 of our revised manuscript, and thoroughly evaluated previous studies in moisture tacking over the TP as Table S1 (i.e., Table AC1).

2. In science, the novel contribution of this study is not clear. The absolute and relative contributions of moisture sources, including oceanic source over TP have been quantitatively revealed. I suggest the authors focus on the comparisons of moisture sources evaluation based on the various atmospheric reanalysis products. The relationship between model oceanic source and isotope δ18O is interesting.

Response: Thanks for your suggestions. To highlight the novelty of this study, we re-summarized the scientific significances from the following two aspects:

(1) The pressing need to study the oceanic moisture contribution to the TP.

Firstly, the TP has been considered as a thermal "air pump" that attracts low-latitude oceanic evaporation to the region, particularly under recently altered land-sea thermal gradient between the TP and global oceans (meteorological records revealed that the atmospheric warming rate over the TP was twice that of the global mean). A quantitative, spatial and temporal evaluation of the oceanic moisture contribution to the TP could help better understand the changing hydrological cycle over the TP and its underlying mechanisms. This part is described in lines 28–46 in our revised manuscript.

Secondly, the interpretations of paleoclimate records in the TP, particularly the $\delta^{18}O$ and δD in the precipitation and ice-cores, largely rely on the understanding of different moisture sources for the TP. For example, the $\delta^{18}O$ and δD evaporated from oceans are relatively enriched in comparison with the other sources. Different oceanic contributions may link to different isotope values in different climate regions of the TP, which has not been thoroughly explored. This part is mentioned in lines 67–71 in our revised manuscript.

More specifically, we distinguished the moisture contribution of the Indian Ocean (IO) from that of the Western Oceans (WO) in our analyses. These two regions represent the source areas of the Indian summer monsoon and the mid-latitude westerlies (the two core circulation systems dominate the TP's climate), respectively. For example, by using numerous $\delta^{18}O$ measurements from precipitation and ice-core on the TP, Tian et al. (2007), Yao et al. (2013), and numerous isotope-related studies (Tian et al., 2001; Yu et al., 2008;

Hren et al., 2009; Zhao et al., 2012; Joswiak et al., 2013; Ren et al., 2021) empirically identified a line around the 34°–35°N to represent the northward extension of the Indian summer monsoon. In this context, we intend to provide a quantitative view of the region influenced by the Indian monsoon, from the perspective of moisture contributions. This part is included in lines 48–54 and 71–75 in our revised manuscript.

(2) The novelty of this study as compared with previous moisture tracking studies in the TP.

In comparison with the traditional synoptic and climatological analyses, the numerical moisture tracking method could quantitatively diagnose the moisture contribution to a target region. In Table AC1 above, we summarize existing studies using numerical moisture tracking in the TP published during the past two decades. Although these studies have quantified the oceanic moisture contribution to different parts of the TP in different seasons after the 1960s, nearly all of them only considered *regional averages* for specific target areas in the TP ('Study area' in Table AC1) with *backward* moisture tracking. The *spatial distribution* of oceanic moisture contribution to the vast TP, e.g., the transition gradient of the moisture transported from the Indian Ocean, is hitherto unclear. To fill this knowledge gap, in this study we leveraged a *forward* moisture tracking method and studied the *spatial distribution* of oceanic moisture contribution over the TP. This part is mentioned in lines 61–65 in our revised manuscript, and the Table AC1 is added as Table S1 in our revised Supplementary.

3. In line 147, I do not think the oceanic sources of the Mediterranean, the Red Sea, and the Persian Gulf, can compared to the Atlantic. They are too small. If say this, please give the quantitative tracking results.

Response: Thanks for pointing this out. Figure AC1 below shows the long-term mean contribution of moisture source to the TP precipitation in summer (Figures AC1a–c), in winter (Figures AC1d–f), and on an annual scale (Figures AC1 g–i). Although the spatial extent of the Mediterranean, the Red Sea, and the Persian Gulf is much smaller than that of the Atlantic, as pointed out by the reviewer, their relative contribution to TP precipitation is non-negligible. In fact, the summation of the contributions from these three regions can be greater than the contribution from the Atlantic (Table AC2 below summarizes the relative contributions of these four regions to summer, winter, and annual precipitation over the TP based on ERA-Interim dataset).

The Figures AC1a–f, Figures AC1g–i, and Table AC2 were shown as Figure S3, Figures S6a–c, and Table S3 in our revised Supplementary. Please see lines 179–184 in our revised manuscript for the justification.

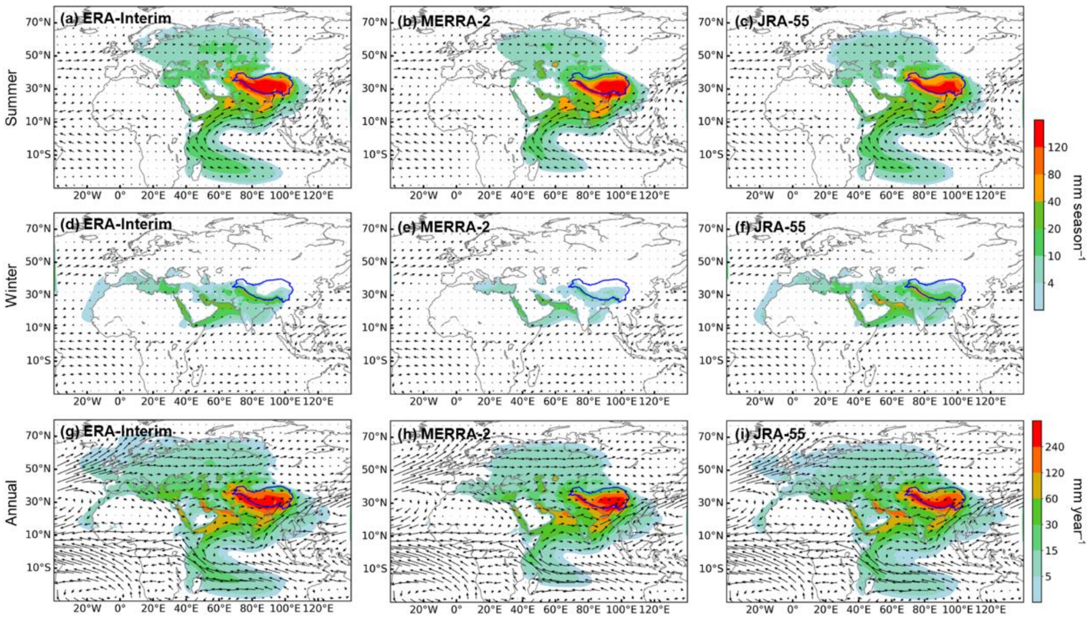

Figure AC1. Long-term mean moisture source of the TP precipitation in summer (a, b, and c), winter (d, e, and f), and on an annual scale (g, h, and i).

Table AC2. Relative moisture contribution to the TP from different oceans.

	The Atlantic	**The Mediterranean**	**The Red Sea**	**The Persian Gulf**
Summer	1.88%	1.05%	0.35%	0.82%
Winter	13.76%	8.43%	5.39%	4.42%
Annual	4.49%	2.75%	1.36%	1.57%

4. Please indicate the sub-figures when describe in around line 239.

Response: Thanks for the suggestion and sorry for the confusion. We have cited the sub-figures accordingly in the revised Lines 290–291: “Quantitatively, this geographical barrier of the monsoon system reflected in water isotope ratios closely aligns with the 10%–20% isoline of the relative contribution from IO (Figure 4h).”

References:

Chen, B., Xu, X. D., Yang, S., and Zhang, W.: On the origin and destination of atmospheric moisture and air mass over the Tibetan Plateau, Theor. Appl. Climatol., 110(3), 423-435, https://doi.org/:10.1007/s00704-012-0641-y 2012.

Chen, B., Zhang, W., Yang, S., and Xu, X. D.: Identifying and contrasting the sources of the water vapor reaching the subregions of the Tibetan Plateau during the wet season, Climate Dyn., 53(11), 6891-6907, https://doi.org/:10.1007/s00382-019-04963-2, 2019.

Findell, K. L., Keys, P. W., van der Ent, R. J., Lintner, B. R., Berg, A., and Krasting, J. P.: Rising Temperatures Increase Importance of Oceanic Evaporation as a Source for Continental Precipitation, J. Climate, 32(22), 7713-7726, https://doi.org/:10.1175/jcli-d-19-0145.1, 2019.

Guo, L., van der Ent, R. J., Klingaman, N. P., Demory, M.-E., Vidale, P. L., Turner, A. G., Stephan, C. C., and Chevuturi, A.: Moisture Sources for East Asian Precipitation: Mean Seasonal Cycle and Interannual Variability, J. Hydrometeorol., 20(4), 657-672, https://doi.org/:10.1175/jhm-d-18-0188.1, 2019.

Hren, M. T., Bookhagen, B., Blisniuk, P. M., Booth, A. L., and Chamberlain, C. P.: δ18O and δD of streamwaters across the Himalaya and Tibetan Plateau: Implications for moisture sources and paleoelevation reconstructions, Earth Planet. Sci. Lett., 288(1), 20-32, https://doi.org/:10.1016/j.epsl.2009.08.041, 2009.

Huang, W., Qiu, T., Yang, Z., Lin, D., Wright, J. S., Wang, B., and He, X.: On the formation mechanism for wintertime extreme precipitation events over the southeastern Tibetan Plateau, J. Geophys. Res.-Atmos., 123(22), 12,692-612,714, https://doi.org/:10.1029/2018JD028921 2018.

Joswiak, D. R., Yao, T., Wu, G., Tian, L., and Xu, B.: Ice-core evidence of westerly and monsoon moisture contributions in the central Tibetan Plateau, J. Glaciol., 59(213), 56-66, https://doi.org/:10.3189/2013JoG12J035 2013.

Li, Y., Su, F., Chen, D., and Tang, Q.: Atmospheric Water Transport to the Endorheic Tibetan Plateau and Its Effect on the Hydrological Status in the Region, J. Geophys. Res.-Atmos., 124(23), 12864-12881, https://doi.org/:10.1029/2019jd031297, 2019.

LI, Y., SU, F., TANG, Q., GAO, H., YAN, D., PENG, H., and XIAO, S.: Contributions of moisture sources to precipitation in the major drainage basins in the Tibetan Plateau, Sci. China-Earth Sci., 65(1674-7313), 1088, https://doi.org/:https://doi.org/10.1007/s11430-021-9890-6, 2022.

Liu, X., Liu, Y., Wang, X., and Wu, G.: Large-Scale Dynamics and Moisture Sources of the Precipitation Over the Western Tibetan Plateau in Boreal Winter, J. Geophys. Res.-Atmos., 125(9), e2019JD032133, https://doi.org/:10.1029/2019JD032133, 2020.

Ma, Y., Lu, M., Bracken, C., and Chen, H.: Spatially coherent clusters of summer precipitation extremes in the Tibetan Plateau: Where is the moisture from?, Atmos. Res., 237, 104841, https://doi.org/:10.1016/j.atmosres.2020.104841, 2020.

Pan, C., Zhu, B., Gao, J., Kang, H., and Zhu, T.: Quantitative identification of moisture sources over the Tibetan Plateau and the relationship between thermal forcing and moisture transport, Climate Dyn., 52(1-2), 181-196, https://doi.org/:10.1007/s00382-018-4130-6, 2018.

Qiu, T., Huang, W., Wright, J. S., Lin, Y., Lu, P., He, X., Yang, Z., Dong, W., Lu, H., and Wang, B.: Moisture Sources for Wintertime Intense Precipitation Events Over the Three Snowy Subregions of the Tibetan Plateau, J. Geophys. Res.-Atmos., 124(23), 12708-12725, https://doi.org/:10.1029/2019jd031110, 2019.

Ren, W., Tian, L., and Shao, L.: Regional moisture sources and Indian summer monsoon (ISM) moisture transport from simultaneous monitoring of precipitation isotopes on the southeastern and northeastern Tibetan Plateau, J. Hydrol., 601, 126836, https://doi.org/:10.1016/j.jhydrol.2021.126836, 2021.

Sodemann, H., Schwierz, C., and Wernli, H.: Interannual variability of Greenland winter precipitation sources: Lagrangian moisture diagnostic and North Atlantic Oscillation influence, J. Geophys. Res.-Atmos., 113(D3), D03107, https://doi.org/:10.1029/2007JD008503, 2008.

Sun, B., and Wang, H.: Moisture sources of semiarid grassland in China using the Lagrangian particle model FLEXPART, J. Climate, 27(6), 2457-2474, https://doi.org/:10.1175/JCLI-D-13-00517.1 2014.

Tian, L., Masson-Delmotte, V., Stievenard, M., Yao, T., and Jouzel, J.: Tibetan Plateau summer monsoon northward extent revealed by measurements of water stable isotopes, J. Geophys. Res.-Atmos., 106(D22), 28081-28088, https://doi.org/:10.1029/2001jd900186, 2001.

Tian, L., Yao, T., MacClune, K., White, J., Schilla, A., Vaughn, B., Vachon, R., and Ichiyanagi, K.: Stable isotopic variations in west China: a consideration of moisture sources, Journal of Geophysical Research: Atmospheres (1984–2012), 112(D10), D10112, https://doi.org/:10.1029/2006JD007718, 2007.

Tuinenburg, O. A., and Staal, A.: Tracking the global flows of atmospheric moisture and associated uncertainties, Hydrol. Earth Syst. Sci., 24(5), 2419-2435, https://doi.org/:10.5194/hess-24-2419-2020, 2020.

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, https://doi.org/:10.5194/hess-17-4869-2013, 2013.

van der Ent, R. J., Wang-Erlandsson, L., Keys, P. W., and Savenije, H. H. G.: Contrasting roles of interception and transpiration in the hydrological cycle – Part 2: Moisture recycling, Earth Syst. Dynam., 5(2), 471-489, https://doi.org/:10.5194/esd-5-471-2014, 2014.

Xu, Y., and Gao, Y.: Quantification of Evaporative Sources of Precipitation and Its Changes in the Southeastern Tibetan Plateau and Middle Yangtze River Basin, Atmosphere, 10(8), 428, https://doi.org/:10.3390/atmos10080428, 2019.

Yang, S., Zhang, W., Chen, B., Xu, X., and Zhao, R.: Remote moisture sources for 6-hour summer precipitation over the Southeastern Tibetan Plateau and its effects on precipitation intensity, Atmos. Res., 236, 104803, https://doi.org/:10.1016/j.atmosres.2019.104803, 2020.

Yao, T., Masson-Delmotte, V., Gao, J., Yu, W., Yang, X., Risi, C., Sturm, C., Werner, M., Zhao, H., and He, Y.: A review of climatic controls on δ18O in precipitation over the Tibetan Plateau: Observations and simulations, Rev. Geophys., 51(4), 525-548, https://doi.org/:10.1002/rog.20023, 2013.

Yu, W., Yao, T., Tian, L., Ma, Y., Ichiyanagi, K., Wang, Y., and Sun, W.: Relationships between δ18O in precipitation and air temperature and moisture origin on a south–north transect of the Tibetan Plateau, Atmos. Res., 87(2), 158-169, https://doi.org/:10.1016/j.atmosres.2007.08.004, 2008.

Zhang, C.: Moisture source assessment and the varying characteristics for the Tibetan Plateau precipitation using TRMM, Environ. Res. Lett., 15(10), 104003, https://doi.org/:10.1088/1748-9326/abac78, 2020.

Zhang, C., Tang, Q., and Chen, D.: Recent changes in the moisture source of precipitation over the Tibetan Plateau, J. Climate, 30(5), 1807-1819, https://doi.org/:10.1175/JCLI-D-15-0842.1, 2017.

Zhang, C., Tang, Q. H., Chen, D. L., van der Ent, R. J., Liu, X. C., Li, W. H., and Haile, G. G.: Moisture Source Changes Contributed to Different Precipitation Changes over the Northern and Southern Tibetan Plateau, J. Hydrometeorol., 20(2), 217-229, https://doi.org/:10.1175/Jhm-D-18-0094.1, 2019a.

Zhang, Y., Huang, W., and Zhong, D.: Major Moisture Pathways and Their Importance to Rainy Season Precipitation over the Sanjiangyuan Region of the Tibetan Plateau, J. Climate, 32(20), 6837-6857, https://doi.org/:10.1175/jcli-d-19-0196.1, 2019b.

Zhao, H. B., Xu, B. Q., Yao, T. D., Wu, G. J., Lin, S. B., Gao, J., and Wang, M.: Deuterium excess record in a southern Tibetan ice core and its potential climatic implications, Climate Dyn., 38(9-10), 1791-1803, https://doi.org/:10.1007/s00382-011-1161-7, 2012.

Response to Referee #2 (Ruud van der Ent):

General comments: The authors analyzed the moisture sources of the Tibetan Plateau using 3 different reanalysis products, a widely used moisture tracking method WAM2layers and additional stable isotope data.

English editing of the paper is absolutely necessary as there are many small mistakes, but this can easily be solved using and English editing service.

Scientifically, the paper is clear, but the whole analysis can also be considered rather straightforward meaning that the novelty is somewhat minor. Obviously not all papers have to be major breakthroughs, but it would be nice if the authors could indicate a bit more specific what we now know that we did not know before from other studies that analyzed the moisture sources of the Tibetan Plateau.

My major comment regards the analysis in subsection 3.3 and the conclusion that a decrease in oceanic moisture contribution resulted in reduced TP precipitation. I have strong reservations with this conclusion since as far as I can see the cause and effect could very well be the other way around. This needs more detailed investigation and possibly less strong conclusions.

I attach more specific comments as a supplement.

Response: We are very grateful for your thorough review and comments, which help improve our manuscript and provide guidance for our future research.

1. We are sorry for our grammatical issues in the first submission. We have thoroughly checked and corrected grammatical errors in the revised manuscript with the help of a native speaker. The English editing service will be adopted if there are still grammatical errors in this revision.

2. For the novelty of this work, in the revision, we have pointed out the unique contributions of this paper by (1) summarizing knowledge gaps in the field and (2) thoroughly comparing this study with existing moisture tracking studies in the TP (see Table AC1 in this response document). Please see our detailed response to specific comment #5.

3. For the analyses of oceanic moisture contribution and precipitation change over the TP in Section 3.3, we have thoroughly revised this section according to your specific comments #15, #16, #19, and #22. Please see our detailed response to specific comment #15.

Please see our responses to your specific comments below.

Specific comments:

1. In line 1 (*Title*).

Comments: In this way the title is 'imperative' which probably is not really intended.

Response: Thanks for pointing this out. Considering both reviewers' comments, we have changed the title to "Spatial Distribution of Oceanic Moisture Contribution to the Precipitation over the Tibetan Plateau". This title emphasizes the 'Spatial Distribution' which is the core novelty in comparison with previous studies in the TP (please see our detailed response to specific comment #5).

2. In line 11 (*Although recent accelerated global hydrological cycle*).

Comments: Incorrect English: probably meant: 'although the global hydrological cycle recently accelerated'. Contentwise: what does recently exactly mean?

Response: Thanks for pointing this out. We have carefully revised the language issues in our revision. By "recently" we meant in recent years. In this revision, this sentence has been revised to "Although the accelerated global hydrological cycle, the altered sea–land thermal contrast, and the amplified warming rate over the TP during the past several decades are known to have profound effects on the regional water balance, the spatial distribution of oceanic moisture contribution to the vast TP remains unclear." Please see lines 14–16 in our revised manuscript.

3. In lines 25–26 (*Van der Ent et al., 2010; Trenberth et al., 2011*).

Comments: Aren't there more recent estimates?

Response: Thanks for pointing this out. For the description "evaporation from oceans constitutes more than 80% of the global surface evaporation", the value "80%" is from *Trenberth et al.* (2011) which quantified the global oceanic evaporation and terrestrial evapotranspiration using six different reanalysis products (NCEP-NCAR R1/R2, CFSR, C20r, ERA-40, ERA-Interim, JRA-25, and MERRA). We considered this estimate robust and trustworthy.

For the description "evaporation from oceans contributes to about 60% of terrestrial precipitation", the value "60%" is from *Van der Ent et al.* (2010) (one of the earliest studies). Later on, this estimate was mentioned by *Van der Ent and Savenije* (2013). More recently, *Link et al.* (2020) released a dataset on the fate of land evaporation where the information on the sources of precipitation can be extracted based on WAM-2layers. In addition, *Tuinenburg et al.* (2020) released a high-resolution global atmospheric moisture connection dataset based on a Lagrangian moisture tracking model 'UTrack' (*Tuinenburg and Staal*, 2020). They concluded that about 43%–64% of the global terrestrial precipitation was evaporated from oceans.

In the revised manuscript (lines 28–30), this sentence has been changed to "Evaporation from oceans is one of the most important elements in the global hydrological cycle, which constitutes more than 80% of the global surface evaporation and contributes to about half of the terrestrial precipitation". We have also cited the three recent studies: *Gimeno et al.* (2020), *Link et al.* (2020), and *Tuinenburg et al.* (2020).

4. In line 28.

Comments: Insert "the".

Response: Thanks. We have corrected this in the revision (line 33 in the revised manuscript).

5. In lines 56–57 (*However, the spatial variation of the oceanic moisture contribution from the Himalayas to the inner TP and their historical changes have not been examined yet*).

Comments: It's unclear to me why the authors specifically highlight the oceanic moisture contribution here. In principle there have been several recent studies about the moisture sources of the TP (including the oceanic ones) that have been overlooked here:

Guo, L., van der Ent, R. J., Klingaman, N. P., Demory, M.-E., Vidale, P. L., Turner, A. G., Stephan, C. C., and Chevuturi, A.: Moisture Sources for East Asian Precipitation: Mean Seasonal Cycle and Interannual Variability, 20, 657–672, https://doi.org/10.1175/JHM-D-18-0188.1, 2019.

Zhang, C., Tang, Q., Chen, D., van der Ent, R. J., Liu, X., Li, W., and Haile, G. G.: Moisture Source Changes Contributed to Different Precipitation Changes over the Northern and Southern Tibetan Plateau, J. Hydrometeorol., 20, 217–229, https://doi.org/10.1175/JHM-D-18-0094.1, 2019.

Not only would a citation to these works be appropriate, but also: 1) How does this paper add to what we already know from the aforementioned papers? 2) How do the results from this paper compared to the findings of the aforementioned papers?

Response: Thanks for the comments. We would like to address your concern from the following two aspects:

(1) The pressing need to study the oceanic moisture contribution to the TP:

Firstly, the TP has been considered a thermal "air pump" that attracts low-latitude oceanic evaporation to the region, particularly considering the altered land-sea thermal gradient between the TP and global oceans in recent years (meteorological records revealed that the atmospheric warming rate over the TP was twice that of the global mean). A quantitative, spatiotemporal evaluation of the oceanic moisture contribution to the TP could help better understand the changing hydrological cycle over the TP and its underlying mechanisms. This part is described in lines 28–46 in our revised manuscript.

Secondly, the interpretations of paleoclimate records in the TP, particularly the $\delta^{18}O$ and δD in the precipitation and ice-cores, largely rely on the understanding of different moisture sources for the TP. For example, the $\delta^{18}O$ and δD evaporated from oceans are relatively enriched in comparison with the other sources, and the precipitation contains relatively low isotope values when strong convection activities occur along the moisture transport processes. Different oceanic contributions may link to different isotope values in different climate regions of the TP, which has not been thoroughly explored. This part is mentioned in lines 67–71 in our revised manuscript.

More specifically, we distinguished the moisture contribution to the TP precipitation from the Indian Ocean (IO) and the Western Oceans (WO). These two regions represent the source areas of the Indian summer monsoon and the mid-latitude westerlies (the two core circulation systems that dominate the TP's climate). For example, using $\delta^{18}O$ measurements from precipitation and ice-core on the TP, Tian et al. (2007), Yao et al. (2013), and numerous isotope-related studies (Tian et al., 2001; Yu et al., 2008; Hren et al., 2009; Zhao et al., 2012; Joswiak et al., 2013; Ren et al., 2021) empirically identified a line around the 34°–35°N to represent the northward extension of the Indian summer monsoon. In this context, we intend to provide a quantitative view of the region influenced by the Indian monsoon (from the perspective of moisture contributions). This part is included in lines 48–54 and 71–75 in our revised manuscript.

(2) The novelty of this study when compared with previous moisture tracking studies in the TP.

In comparison with the traditional synoptic and climatological analyses, the numerical moisture tracking method could quantitatively diagnose the moisture contribution to a target region. In Table AC1 below, we summarize existing studies using numerical moisture tracking in the TP published during the past two decades. Although these studies have quantified the oceanic moisture contribution to different parts of the TP in different seasons since the 1960s, nearly all of them only considered *regional averages* for specific target areas in the TP ('Study area' in Table AC1) with *backward* moisture tracking. The *spatial distribution* of oceanic moisture contribution to the vast TP, e.g., the transition gradient of the moisture transported from the Indian Ocean, is hitherto unclear. To fill this knowledge gap, in this study we leveraged the *forward* moisture tracking method and studied the *spatial distribution* of oceanic moisture contribution over the TP. This part is mentioned in lines 61–65 in our revised manuscript, and Table AC1 has been added as Table S1 in our revised Supplementary.

Table AC1. Summary of numerical moisture tracking studies in the TP region.

Reference	Study area	Time period	Model	Data	Main conclusions
Chen et al. (2012)	TP	2005–2009 (summer)	FLEXPART	NCEP/GFS	The ocean source could extend from the Arabian Sea to the Southern Hemisphere.
Sun and Wang (2014)	Grassland on eastern TP	2000–2009	FLEXPART	NCEP-CFSR	During the warm (cold) season, oceanic moisture is mainly from the Arabian Sea and Bay of Bengal (areas surrounding the Arabian Peninsula).
Zhang et al. (2017)	Central-western TP	1979–2013	WAM	ERA-I, NCEP-2	More than 21% of the moisture comes from oceans.
Huang et al. (2018)	Southeastern TP	1979–2016 (winter extreme precipitation)	LAGRANTO	ERA-I	About 18% of the moisture comes from oceans.
Pan et al. (2018)	Southern/northern TP	1982–2014	CAM	MERRA	During summer, the Indian Ocean supplies about 28.5% of the moisture to the southern TP.
Chen et al. (2019)	Four areas in TP	1980–2016 (May–August)	FLEXPART	ERA-I	The northwestern TP and northeastern TP are less affected by the Indian monsoon moisture.
Guo et al. (2019)	TP	1979–2015	WAM-2layers	ERA-I	The Indian Ocean and the Pacific Ocean account for 24% and 2% of the moisture contribution, respectively.
Li et al. (2019)	Endorheic TP	1979–2015	WAM-2layers	ERA-I, MERRA-2, JRA-55	24%–30% of the moisture comes from oceans.
Qiu et al. (2019)	Three areas in TP	1979–2016 (winter extreme precipitation)	LAGRANTO	ERA-I	Moisture contributions of the Arabian Sea to the intense precipitation in the western, south-central, and southeastern TP are 9.2%, 6.9%, and 1.1%, respectively.
Xu and Gao (2019)	Southeastern TP	1982–2011 (April–September)	QIBT	ERA-I	Only 2% of the moisture originates from the oceanic source.
Zhang et al. (2019a)	Southern/northern TP	1979–2016	WAM-2layers	ERA-I	Northwestern (southeastern) source contributes ~39% (~51%) of the moisture in the northern (southern) TP.

Zhang et al. (2019b)	Sanjiangyuan Region	1960–2017 (June–September)	HYSPLIT, HDBSCAN	NNR1	About 51% (54%) of the medium to heavy precipitation is influenced by the northwestern (southern) source.
Liu et al. (2020)	Western TP	1979–2018 (winter)	HYSPLIT	ERA-I	About 57% of the moisture comes from the Arabian Sea, the Arabian Peninsula, and the northern Indian Ocean.
Ma et al. (2020)	Seven areas in TP	1961–2015 (summer extreme event)	HYSPLIT	NCEP/NCAR	About 75% of the moisture for extreme precipitation in the southeastern TP comes from the Bay of Bengal.
Yang et al. (2020)	Southeastern TP	1980–2016 (June–September)	FLEXPART	ERA-I	30% of the moisture comes from oceans.
Zhang (2020)	TP	1998–2018	WAM-2layers	ERA-I, TRMM	The southeastern source from the TP to the western Indian Ocean accounts for 32% of the moisture contribution.
Li et al. (2022)	Seven basins in TP	1979–2015	WAM-2layers	ERA-I, MERRA-2, JRA-55	Oceanic moisture accounts for 24%–30% of the moisture in different basins of the TP.

6. In line 72.

Comments: Insert “the”.

Response: Thanks. We have corrected this in the revision (line 79 in the revised manuscript).

7. In lines 82–84 (*and in comparison with Lagrangian models (e.g., FLEXible PARTicle (FLEXPART) dispersion model and the Hybrid SingleParticle Lagrangian Integrated Trajectory (HYSPLIT) model), the Eulerian grids enable the model to excel in computation speed and to consider moisture budget from precipitation and evaporation separately(Van der Ent et al., 2013; Van der Ent, 2014)*).

Comments: This depends very much on what types of tracking runs are being done. Without going in depth in investigating this I would remove these claims entirely.

Response: Thank you for the suggestion. We have removed the inappropriate statement regarding computational cost, and revised this sentence as “In comparison with the commonly used Lagrangian models (e.g., the FLEXible PARTicle (FLEXPART) dispersion model and the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model) that identify precipitation and evaporation events mainly based on the dynamic humidity information of tracked air particles (Tuinenburg and Staal, 2020), Eulerian grids enable the WAM-2layers to consider moisture budget from precipitation and evaporation separately (Van der Ent et al., 2013; Van der Ent, 2014).” Please see lines 95–99 in our revised manuscript.

8. In line 86 (*Equation 1*).

Comments: There was an sign error in Van der Ent, 2014, better to write the equations as in Findell et al. (2019)

Findell, K. L., Keys, P. W., van der Ent, R. J., Lintner, B. R., Berg, A., and Krasting, J. P.: Rising Temperatures Increase Importance of Oceanic Evaporation as a Source for Continental Precipitation, J. Clim., 32, 7713–7726, https://doi.org/10.1175/JCLI-D-19-0145.1, 2019.

Response: Thanks for your reminder. The Equation (1) was corrected to $\frac{\partial \mathrm{S_{g,lower}}}{\partial \mathrm{t}} = -\frac{\partial(\mathrm{S_{g,lower}u})}{\partial \mathrm{x}} - \frac{\partial(\mathrm{S_{g,lower}v})}{\partial \mathrm{y}} + \mathrm{E_g} - \mathrm{P_g} \pm \mathrm{F_{v,g}}$ for forward moisture tracking in WAM-2layers in the lower layer. In addition, all the text description relevant to this equation has been revised. Please see lines 103–105 in our revised manuscript.

9. In lines 91–92 (*Due the existence of residual* ξ_k*, the closure of the model is defined by a ratio of residuals between the two layers, i.e.,* $\xi_{top}/S_{top} = \xi_{bottom}/S_{bottom}$).

Comments: That is not the definition of closure, but an assumption that is used in order to calculate the vertical flux (see: van der Ent et al., (2014), appendix B).

van der Ent, R. J., Wang-Erlandsson, L., Keys, P. W., and Savenije, H. H. G.: Contrasting roles of interception and transpiration in the hydrological cycle - Part 2: Moisture recycling, 5, 471–489, https://doi.org/10.5194/esd-5-471-2014, 2014.

Response: Thanks for pointing this out. We have thoroughly inspected all the incorrect or improper descriptions in the method section. Due to the modification of the water balance equation in forward moisture tracking (Equation 1), and according to the relevant descriptions in Van der Ent et al. (2013), van der Ent et al. (2014), and Findell et al. (2019), we revised this part to "The 'well-mixed' assumption is applied in this model, which means that the precipitation is assumed to be immediately removed from the atmosphere in the tracking process (i.e., $P_g/P = S_g/S$, where P and S are total precipitation and total column atmospheric moisture storage, respectively). The two vertical layers in the model are set to deal with the wind shear in the upper air. To better capture the vertical exchanges due to convection, turbulence, and re-evaporation and to minimize the water balance losses between the two layers, the gross vertical flow is set to 4 times the vertical flow in the net flow direction and 3 times the vertical flow in the opposite direction. Although this is a simplification of the turbulent moisture exchange, physically reasonable results have been obtained in previous studies, and the general tracking has been validated against online 3D tracking models (Van der Ent et al., 2013; van der Ent et al., 2014; Findell et al., 2019)." Please see lines 106–113 in our revised manuscript.

10. In line 94 (*1°×1°, and the time step is set as 0.25 h*).

Comments: This is at a higher resolution than Van der Ent et al. (2014), who used a 1.5 arcdegree resolution. Yet, the authors have chosen the same time step. This may lead to instable and spurious results at high latitudes or at least internal model corrections to maintain stability.

Response: Thanks for this comment. We have tested the sensitivity of our results to the selection of different time steps. Below is an example, which compares the results of two simulations using a 15-min time step (0.25 h) and a 10-min time step. As suggested in Figure AC1a and b, visually the results of the mean annual oceanic moisture contribution to the TP with different time steps are nearly identical. This is also confirmed by the differences between these two runs, as shown in Figure AC1c and d. Discrepancies in moisture tracking results induced by different time steps mainly appear in the western TP (Figure AC1c) but are very minor (~1 mm on the annual scale). The relative differences are below 1% in the TP on the annual scale (Figure AC1d). This suggests the stability of using different time steps in the study area. Please see lines 116–118 in our revised manuscript.

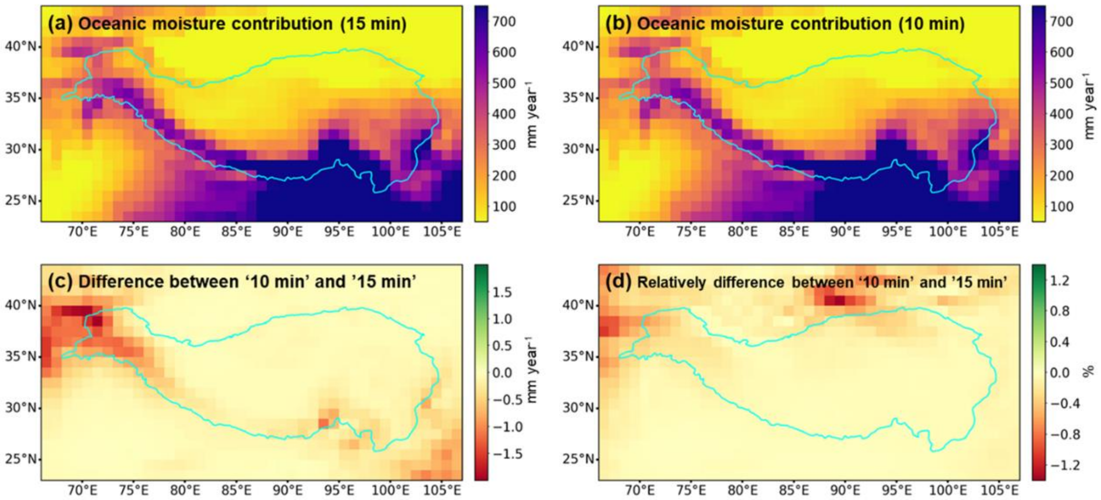

Figure AC1. Simulations of mean annual oceanic moisture contribution to the TP with (a) 0.25-h (15-min) time step and (b) 10-min time step, and (c) the absolute difference (mm year^{-1}) and (d) the relative difference (%) between these two simulations.

11. In line 95 (*as around 812 hPa*).

Comments: But varying with surface pressure?! This is a very important detail.

Response: We have revised this sentence as "the vertical separation between the two layers is prescribed as ~812 hPa at the normal atmospheric pressure (Van der Ent et al., 2013). Note that the atmospheric pressure of the vertical separation varies with different surface pressure (the "half-level" pressure in different reanalysis products is defined as $P_{k-1/2} = A_{k-1/2} + B_{k-1/2}P_s$, where P_s is surface pressure, k represents different model levels, and the values of $A_{k-1/2}$ and $B_{k-1/2}$ are defined independently for different reanalysis datasets)." Please see lines 119–122 in our revised manuscript.

12. In lines 102–103 (*The ocean and land distributions were defined according to the 1°×1° gridded land-sea mask from ERA-Interim*).

Comments: The land-sea mask of ERA-Interim considers lakes to be 'sea', but it does not makes sense to consider them 'ocean' in this tracking study in my opinion.

Response: Thanks for pointing this out. In our simulation, we removed all inland large lakes (considered as 'sea' in the ERA-Interim), for example, the Caspian Sea and the Black Sea. The final land-sea mask with the 1°×1° spatial resolution used in this work is shown in Figure AC2. In the revision, we have revised the description about the land-sea mask in lines 129–132, and added Figure AC2 to the Supplementary as Figure S2.

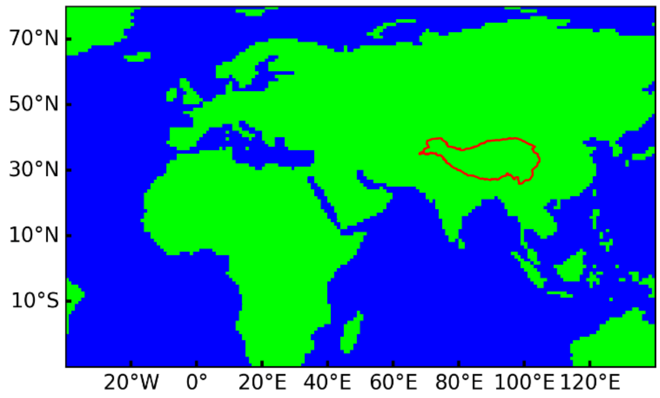

Figure AC2. The land-sea mask used in this study with 1°×1° spatial resolution (the blue area represents oceans).

13. In line 109 (*6h, 17 layers*).

Comments: What kind of layers?

Response: Table AC2 summarizes the selected 17 model layers in three reanalysis products used in this study. This table has been added to the Supplementary as Table S2 in our revised manuscript (lines 139–141).

Table AC2. Summary of the selected 17 model layers in three reanalysis products.

	Model layers (from the surface to the upper atmosphere)		
	ERA-Interim	MERRA-2	JRA-55
1	60	72	1
2	59	71	2
3	58	70	3
4	57	69	4
5	56	68	5
6	55	67	6
7	54	66	7
8	51	65	9
9	48	61	12
10	47	59	14
11	44	55	17
12	41	52	20
13	38	49	23
14	35	46	26
15	32	44	29
16	27	40	34
17	17	28	44

14. In line 123 (*in mm and %*).

Comments: mm per what? precipitation is a flux with dimension of length x Time-1, where x is 1,2 or 3; percent of what? of the total local evaporation or of the total sink precipitation or something else?

Response: Sorry for the confusion. The unit “mm” represents mm per year, per season, or per month in different parts of the study. The unit % represents the percentage of the total sink precipitation. These have been declared in our revision (lines 154–155), and all the ambiguous units have been corrected in figures or their captions in our revised manuscript. Nevertheless, the subplots of several figures (e.g., Figures 1, 3, and 4) use both mm year^{-1} and mm season^{-1} while sharing one colorbar. To avoid confusion, we have included their specific units in the captions of these figures but kept the unit mm in colorbars.

15. In line 187 (*Section 3.3*).

Comments: This seems to be one of the core results yet cause and effect could be entirely reversed, meaning precipitation on TP declines and as a consequence the oceanic contribution also drops, possibly keeping exactly the same ratio. However, it may also be that the evaporation of the ocean has dropped or that the source area has changed. Simply looking at similarities in Figure 5 is insufficient proof in my opinion. Moreover, this subsection discusses many results in the supplement, but if they are discussed at length they should be in the main text instead.

Response: Thanks for this comment. In this revision, we performed additional analyses and concluded that the decreased oceanic contribution is mainly induced by precipitation decrease over TP. We have thoroughly revised Section 3.3 to include new analyses and to improve the clarity, following the structure below:

a. Analyze the long-term trends of oceanic moisture contribution to the TP (Figure AC3), and point out that decreased oceanic moisture contribution was found mainly around the southeastern TP (i.e., the Brahmaputra Canyon region, which has long been considered the most important moisture transport channel for the TP (*Hren et al.*, 2009)). More specifically, the moisture contributions of both the monsoon-dominated Indian Ocean (IO) and the westerlies-dominated Western Oceans (WO) decreased over time around the southeastern TP (Figure AC4).

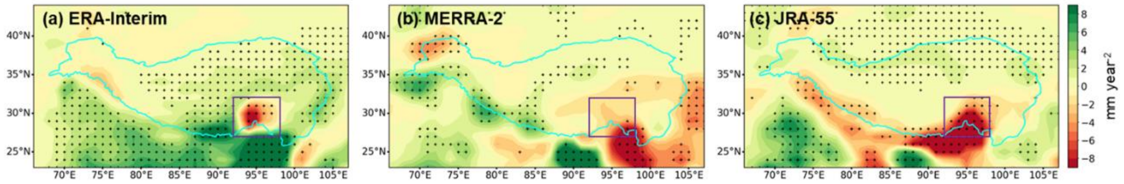

Figure AC3. Trends of oceanic moisture contribution to the TP region with (a) ERA-Interim (1979–2015), (b) MERRA-2 (1980–2015), and (c) JRA-55 (1979–2015).

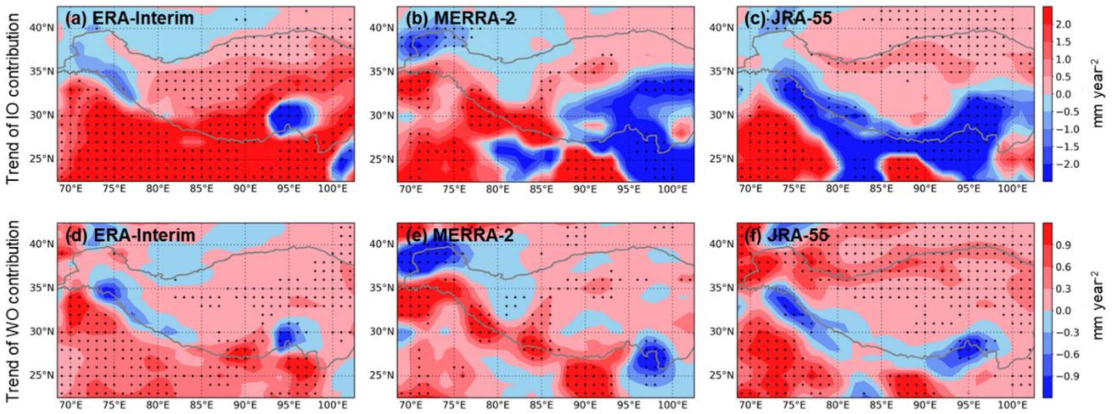

Figure AC4. Trends of oceanic moisture contribution to the TP region from the Indian Ocean (IO, a–c) and the western oceans (WO, d–f) with ERA-Interim (1979–2015), MERRA-2 (1980–2015), and JRA-55 (1979–2015).

b. Examine the trends of oceanic moisture contribution by detecting the changes in oceanic evaporation, precipitation, the horizontal wind fields, and the updraft around the TP region. According to the reviewer's suggestion, we calculated the long-term trends of global evaporation and precipitation during 1979–2015 (Figure AC5). Most of the oceanic sources exhibited *enhanced* evaporation, so the reduced oceanic evaporation is unlikely the cause. However, the enhanced oceanic moisture may still lose significantly before reaching the TP due to increased precipitation along the transport pathway, particularly when the moisture travels across the Indian Subcontinent and the Bay of Bengal (Figure AC5b). In addition, we analyzed the inter-annual trends of zonal (u) and meridional (v) wind at 700 hPa and 300 hPa and vertical velocity at 300 hPa (Figure AC6). Significantly weakened eastward and northward winds in the lower atmosphere (700 hPa) are found around the southeastern TP (the weakening of horizontal wind fields in the 300 hPa is not statistically significant in the region). This indicates decreased moisture transport to the region in the lower atmosphere. At the same time, significantly decreased upward motion in the higher atmosphere (300 hPa, Figure AC6e) was found in the southeastern TP. This further verifies the decreased condensation of moisture to form precipitation in this region.

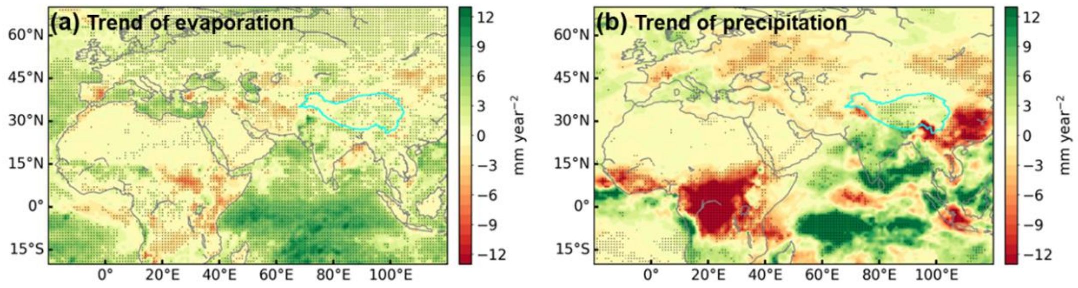

Figure AC5. Long-term trends of annual evaporation (a) and precipitation (b) over possible source regions during 1979–2015. Stippling indicates regions with statistically significant trends ($p < 0.05$)

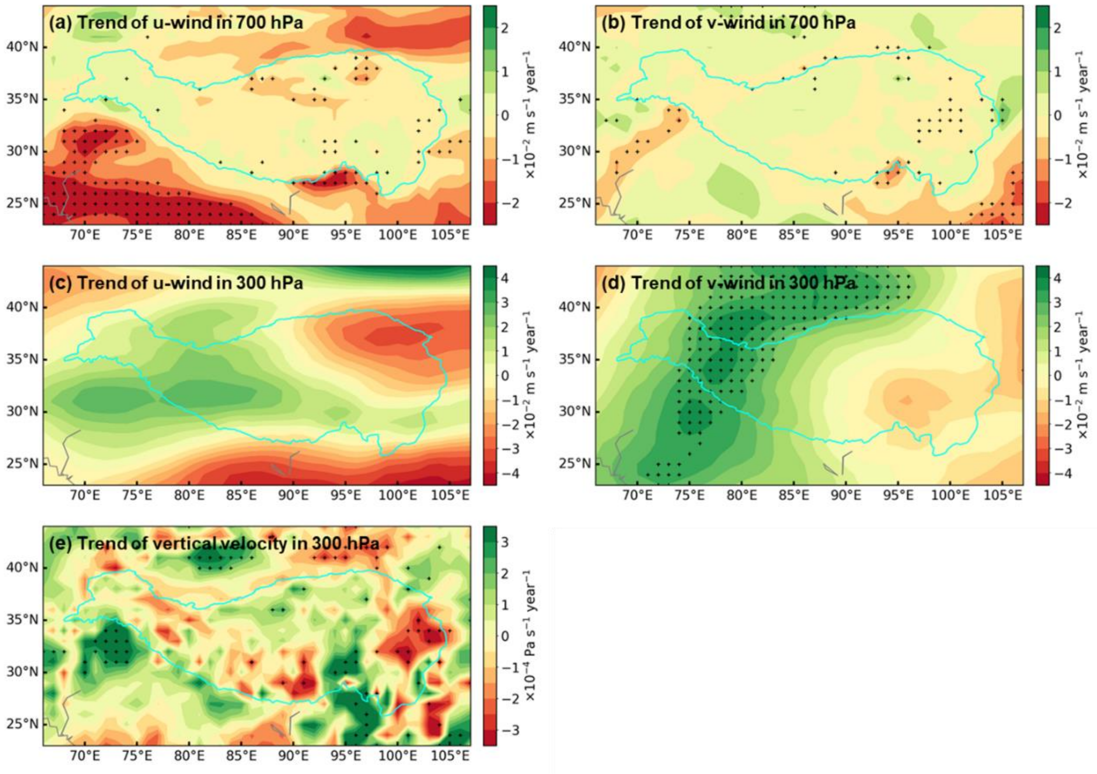

Figure AC6. Trends of (a) u-wind at 700 hPa (positive denotes enhanced eastward wind), (b) v-wind at 700 hPa (positive denotes enhanced northward wind), (c) u-wind at 300 hPa (positive denotes enhanced eastward wind), (d) v-wind at 300 hPa (positive denotes enhanced northward wind), and (e) vertical velocity at 300 hPa (positive denotes decreased upward motion) around the TP region during 1979–2015. Stippling indicates regions with statistically significant trends ($p < 0.05$).

c. The spatial patterns of the long-term trends in precipitation and oceanic moisture contribution over the TP are similar (Figures AC3 and AC5b). To further investigate whether the change in oceanic moisture contribution is due to precipitation change, we carried out additional backward moisture tracking over the southeastern TP (Figure AC7a). The southeastern TP (SETP) was defined as the purple rectangle in Figure AC3, where the oceanic moisture contribution and the precipitation both show decreasing trends during 1979–2015. The spatial distribution of the trends in moisture contributions to the SETP during the same period is shown in Figure AC7b.

As shown in Figure AC7b, the moisture contributions of both the westerlies-dominated western sources and the monsoon-dominated southern sources to the SETP decreased over time, and most source regions that experienced substantial decreases are over land. Meanwhile, only few areas in the southwestern slope of the Himalayas and the southwestern corner of the TP show increased moisture contribution to the SETP (Figure AC7b). Therefore, its inappropriate to conclude that the decreased oceanic moisture contribution dominate the precipitation change over the SETP, although they happen to have similar spatial patterns.

Please see lines 225–259 for the revised Section 3.3 in our revised manuscript. We have added additional figures relevant to our analysis in this section.

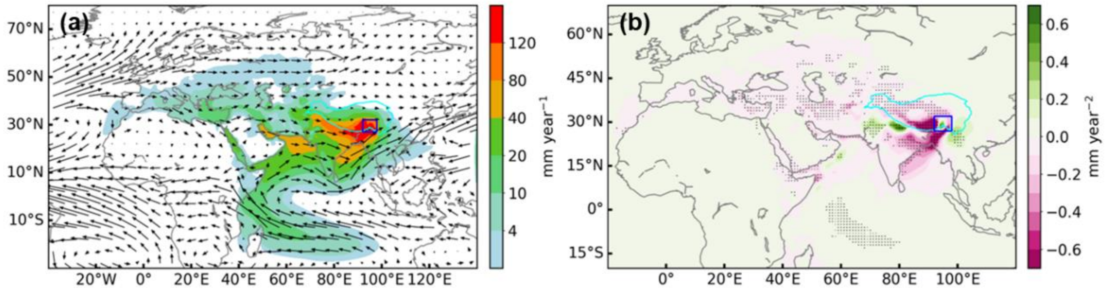

Figure AC7. (a) Long-term mean moisture source to precipitation in the SETP and (b) the relevant trends of moisture contributions during 1979–2015 simulated using WAM-2layers driven by ERA-Interim. The blue rectangles represent the SETP. Stippling indicates regions with statistically significant trends ($p <$ 0.05).

16. In line 212–213 (*Here we further reveal that this dipole pattern is driven by the changes in oceanic moisture contribution (particularly from IO)*).

Comments: As said before cause and effect may not be so easy to separate. Moreover, the authors should give an explanation of why the oceanic moisture contribution drops: which can be: less TP precipitation overall, less oceanic evaporation, changing pattern, ...

Response: Thanks for the comment. Based on our additional analyses above, we concluded that the spatial pattern of oceanic moisture contribution change is mainly due to precipitation change over the TP. These new analyses have been included in the thoroughly revised Section 3.3. Please see our response to comment #15 above for details.

17. In line 222 (*The strongest relationship is found between precipitation δ18O and relative oceanic moisture contribution from IO (Figure 6)*).

Comments: These are interesting plots, but these relationships should be quantified with at least a correlation metric.

Response: Thanks. Per your comments, we calculated the correlation coefficients between precipitation $\delta^{18}O$ and the relative oceanic moisture contribution of IO for the 19 stations on the TP (Table AC3). Note that the length of available isotope data for some stations is < 10 months. To ensure the robustness of correlations, we only calculated correlation coefficients for stations with available isotope data longer than 10 months. In Table AC3, nearly all precipitation $\delta^{18}O$ series are negatively correlated with the relative oceanic moisture contributions from IO, particularly for the westerlies-domain stations where all correlations are statistically significant ($p < 0.05$). These conclusions are consistent with our description in Section 3.4. Please see lines 271 in our revised manuscript (The Table AC3 has been added as Table S4 in the revised Supplementary).

Table AC3. Correlation coefficients between monthly precipitation $\delta^{18}O$ and the relative oceanic moisture contribution from IO for 19 stations (derived from ERA-Interim, MERRA-2, and JRA-55, respectively). '*' represents statistically significant correlation coefficients ($p < 0.05$).

	Model layers (from the surface to the upper atmosphere)		
	ERA-I	MERRA-2	JRA-55

Monsoon domain	1.Nyalam	–0.65*	–0.18	–0.51
	2.Zhangmu	-	-	-
	3.Dingri	-	-	-
	4.Larzi	-	-	-
	5.Baidi	–0.37	–0.42	–0.41
	6.Wengguo	-	-	-
	7.Dui	–0.38	–0.49	–0.33
	8.Lhasa	–0.62*	–0.44	–0.52
	9.Yangcun	-	-	-
	10.Nagqu	–0.39	–0.18	–0.05
	11.Lulang	–0.44	–0.12	–0.29
	12.Nuxia	-	-	-
	13.Bomi	–0.05	0.30	0.16
Transition domain	14.Shiquanhe	-	-	-
	15.Gaize	–0.73*	–0.52*	–0.36
	16.Tuotuohe	–0.80*	–0.63*	–0.36
	17.Yushu	–0.06*	0.04	0.32
Westerlies domain	18.Taxkorgen	–0.87*	–0.87*	–0.84*
	19.Delingha	–0.84*	–0.84*	–0.75*

18. In line 228–231 (*Note the mismatches between summer peaks of relative moisture from IO and low δ^{18}O values in autumn at Lulang, Nuxia, and Bomi near the Brahmaputra Canyon, which is likely attributable to the impact of moisture transported from southeast Asia or the Pacific Ocean driven by the trough embedded in the southern branch of the westerlies(Cai and Tian, 2020)*).

Comments: These could be investigated in more detail with moisture tracking rather than simply relying on the Cai and Tian (2020) study.

Response: Thanks. Per your suggestion, we conducted additional moisture tracking for monthly moisture sources of the SETP (blue rectangle in Figure AC8, which contains Lulang, Nuxia, and Bomi stations) near the Brahmaputra Canyon in Figure AC8. From June to September, moisture sources gradually extended to southeast Asia and the western Pacific Ocean. This is in line with the finding of *Cai and Tian* (2020). Please see lines 280–282 in our revised manuscript (Figure AC8 has been added as Figure S18 in the revised Supplementary).

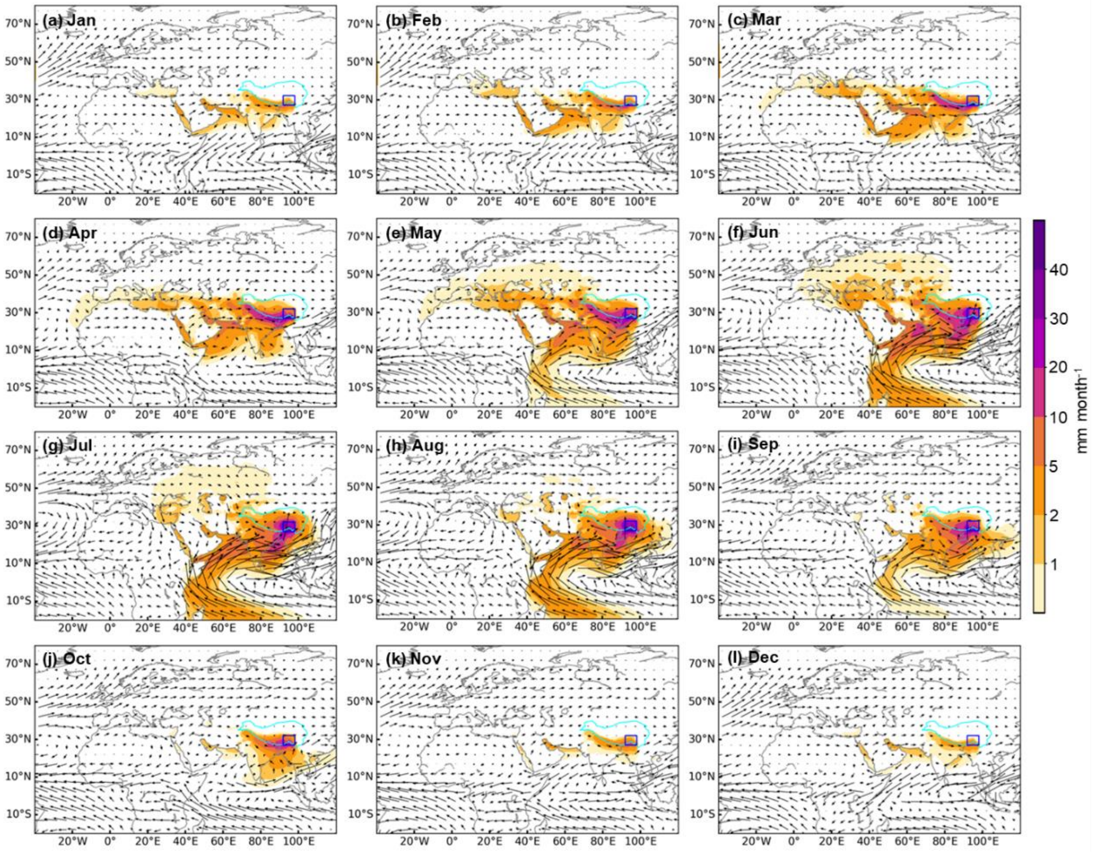

Figure AC8. Mean monthly moisture sources of precipitation in the SETP simulated using WAM-2layers driven by ERA-Interim (1979–2015). The blue rectangle represents the SETP.

19. In line 254 (*is more consistent with precipitation patterns*).

Comments: than what?

Response: Sorry for the confusion. We have revised this sentence as "… the absolute contribution of oceanic moisture, when compared with relative contribution, is more consistent with the precipitation patterns …". Please see Lines 304–305 in the revised manuscript.

20. In line 266 (*Data availability*).

Comments: In my understanding the authors should here nowadays provide links to where their data (to reproduce their figures) can be found.

The availability of the forcing data can be described in methods, acknowledgements and/or references.

Code availability of the original and adapted WAM2layers model is entirely missing.

Response: Thanks for the comments. Considering the size of the data, we will make the data that support the findings of this study available upon reasonable request. We have declared this in the Data Availability section. In addition, we have detailed the datasets and the code of WAM-2layers used in this work in the Data Availability section (lines 317–328 in the revised manuscript), and included them in the reference list:

The ERA-Interim dataset can be downloaded from the official website of the European

Centre for Medium-Range Weather Forecasts (ECMWF): https://www.ecmwf.int/en/forecasts/datasets/reanalysis-datasets/era-interim (ECMWF, 2017). The MERRA-2 dataset is available at https://gmao.gsfc.nasa.gov/reanalysis/MERRA-2/ (NASA Goddard Earth Sciences Data and Information Services Center, 2018), which is managed by the Goddard Earth Sciences Data and Information Services Center (GES DISC), National Aeronautics and Space Administration (NASA). The JRA-55 product was developed by the Japan Meteorological Agency and can be downloaded from https://jra.kishou.go.jp/ (Japan Meteorological Agency, 2018). The ERA5 dataset can be downloaded from the Copernicus Climate Change Service (C3S) Climate Date Store (CDS): https://cds.climate.copernicus.eu/ (Copernicus Climate Change Service CDS, 2021). The TNIP δ18O data can be downloaded from the National Tibetan Plateau/Third Pole Environment Data Center: http://data.tpdc.ac.cn (National Tibetan Plateau Data Center, 2021). The code of WAM-2layers (v2.4.08) is available at https://github.com/ruudvdent/WAM2layersPython (van der Ent, 2022). The data generated in this study are available from the corresponding authors upon reasonable request.

References added in this revision:

European Centre for Medium-Range Weather Forecast (ECMWF): The ERA-Interim reanalysis dataset, available at: https://apps.ecmwf.int/datasets/data/interim-full-daily/, last access: 16 May 2017.

NASA Goddard Earth Sciences Data and Information Services Center (GES DISC): Modern-Era Retrospective analysis for Research and Applications, Version 2, available at: https://disc.gsfc.nasa.gov/datasets?project=MERRA-2, last access: 19 June 2018.

Japan Meteorological Agency: JRA-55: Japanese 55-year Reanalysis, Daily 3-Hourly and 6-Hourly Data, Archived at the National Center for Atmospheric Research, Computational and Information Systems Laboratory, available at: https://rda.ucar.edu/datasets/ds628.0/, last access: 19 July 2018.

Copernicus Climate Change Service (C3S) Climate Date Store (CDS): The ERA5 monthly averages data on single levels from 1979 to present, avaible at: https://cds.climate.copernicus.eu/, last access: 11 November 2021.

National Tibetan Plateau Data Center: Data set of δ^{18}O stable Isotopes in Precipitation from Tibetan Network for Isotopes (1991–2008), available at: http://data.tpdc.ac.cn/en/, last access: 3 September 2021.

van der Ent, R. J.: WAM-2layers v2.4.08, available at: https://github.com/ruudvdent/WAM2layersPython, last access: 5 August 2022.

21. In line 426 (*Figure 2*).

Comments: mm/month. if the x-axis represents month than write the abbreviations of the months instead of 1 – 12

Response: Thanks. We have corrected this in our revised manuscript (line 511).

22. In line 447 (*Figure 5*).

Comments: It would be (more) relevant to look at trends in oceanic moisture contribution with respect to precipitation within the same reanalysis. I now think you're essentially comparing the different precipitation datasets, meaning these plots would have looked the same for total precipitation without any moisture tracking.

Response: Thanks. Per your comments #15, #16, #19, and #22, we have thoroughly revised Section 3.3, which includes the trends in oceanic moisture contribution and precipitation over the TP. Please see our detailed response to your comment #15 above.

References:

Cai, Z., and Tian, L.: What Causes the Postmonsoon 18O Depletion Over Bay of Bengal Head and Beyond?, Geophys. Res. Lett., 47(4), e2020GL086985, https://doi.org/10.1029/2020GL086985, 2020.

Chen, B., Xu, X. D., Yang, S., and Zhang, W.: On the origin and destination of atmospheric moisture and air mass over the Tibetan Plateau, Theor. Appl. Climatol., 110(3), 423-435, https://doi.org/10.1007/s00704-012-0641-y 2012.

Chen, B., Zhang, W., Yang, S., and Xu, X. D.: Identifying and contrasting the sources of the water vapor reaching the subregions of the Tibetan Plateau during the wet season, Climate Dyn., 53(11), 6891-6907, https://doi.org/10.1007/s00382-019-04963-2, 2019.

Findell, K. L., Keys, P. W., van der Ent, R. J., Lintner, B. R., Berg, A., and Krasting, J. P.: Rising Temperatures Increase Importance of Oceanic Evaporation as a Source for Continental Precipitation, J. Climate, 32(22), 7713-7726, https://doi.org/10.1175/jcli-d-19-0145.1, 2019.

Gimeno, L., Nieto, R., and Sori, R.: The growing importance of oceanic moisture sources for continental precipitation, Npj Climate and Atmospheric Science, 3(1), 27, https://doi.org/10.1038/s41612-020-00133-y, 2020.

Guo, L., van der Ent, R. J., Klingaman, N. P., Demory, M.-E., Vidale, P. L., Turner, A. G., Stephan, C. C., and Chevuturi, A.: Moisture Sources for East Asian Precipitation: Mean Seasonal Cycle and Interannual Variability, J. Hydrometeorol., 20(4), 657-672, https://doi.org/10.1175/jhm-d-18-0188.1, 2019.

Hren, M. T., Bookhagen, B., Blisniuk, P. M., Booth, A. L., and Chamberlain, C. P.: δ18O and δD of streamwaters across the Himalaya and Tibetan Plateau: Implications for moisture sources and paleoelevation reconstructions, Earth Planet. Sci. Lett., 288(1), 20-32, https://doi.org/10.1016/j.epsl.2009.08.041, 2009.

Huang, W., Qiu, T., Yang, Z., Lin, D., Wright, J. S., Wang, B., and He, X.: On the formation mechanism for wintertime extreme precipitation events over the southeastern Tibetan Plateau, J. Geophys. Res.-Atmos., 123(22), 12,692-612,714, https://doi.org/10.1029/2018JD028921 2018.

Joswiak, D. R., Yao, T., Wu, G., Tian, L., and Xu, B.: Ice-core evidence of westerly and monsoon moisture contributions in the central Tibetan Plateau, J. Glaciol., 59(213), 56-66, https://doi.org/10.3189/2013JoG12J035 2013.

Li, Y., Su, F., Chen, D., and Tang, Q.: Atmospheric Water Transport to the Endorheic Tibetan Plateau and Its Effect on the Hydrological Status in the Region, J. Geophys. Res.-Atmos., 124(23), 12864-12881, https://doi.org/10.1029/2019jd031297, 2019.

Li, Y., Su, F., Tang, Q., Gao, H., Yan, D., Peng, H., and Xiao, S.: Contributions of moisture sources to precipitation in the major drainage basins in the Tibetan Plateau, Sci. China-Earth Sci., 65(1674-7313), 1088, https://doi.org/https://doi.org/10.1007/s11430-021-9890-6, 2022.

Link, A., van der Ent, R., Berger, M., Eisner, S., and Finkbeiner, M.: The fate of land evaporation - a global dataset, Earth System Science Data, 12(3), 1897-1912, https://doi.org/10.5194/essd-12-1897-2020, 2020.

Liu, X., Liu, Y., Wang, X., and Wu, G.: Large-Scale Dynamics and Moisture Sources of the Precipitation Over the Western Tibetan Plateau in Boreal Winter, J. Geophys. Res.-Atmos., 125(9), e2019JD032133, https://doi.org/10.1029/2019JD032133, 2020.

Ma, Y., Lu, M., Bracken, C., and Chen, H.: Spatially coherent clusters of summer precipitation extremes in the Tibetan Plateau: Where is the moisture from?, Atmos. Res., 237, 104841, https://doi.org/10.1016/j.atmosres.2020.104841, 2020.

Pan, C., Zhu, B., Gao, J., Kang, H., and Zhu, T.: Quantitative identification of moisture sources over the Tibetan Plateau and the relationship between thermal forcing and moisture transport, Climate Dyn., 52(1-2), 181-196, https://doi.org/10.1007/s00382-018-4130-6, 2018.

Qiu, T., Huang, W., Wright, J. S., Lin, Y., Lu, P., He, X., Yang, Z., Dong, W., Lu, H., and Wang, B.: Moisture Sources for Wintertime Intense Precipitation Events Over the Three Snowy Subregions of the Tibetan Plateau, J. Geophys. Res.-Atmos., 124(23), 12708-12725, https://doi.org/10.1029/2019jd031110, 2019.

Ren, W., Tian, L., and Shao, L.: Regional moisture sources and Indian summer monsoon (ISM) moisture transport from simultaneous monitoring of precipitation isotopes on the southeastern and northeastern Tibetan Plateau, J. Hydrol., 601, 126836, https://doi.org/10.1016/j.jhydrol.2021.126836, 2021.

Sun, B., and Wang, H.: Moisture sources of semiarid grassland in China using the Lagrangian particle model FLEXPART, J. Climate, 27(6), 2457-2474, https://doi.org/10.1175/JCLI-D-13-00517.1 2014.

Tian, L., Masson-Delmotte, V., Stievenard, M., Yao, T., and Jouzel, J.: Tibetan Plateau summer monsoon northward extent revealed by measurements of water stable isotopes, J. Geophys. Res.-Atmos., 106(D22), 28081-28088, https://doi.org/10.1029/2001jd900186, 2001.

Tian, L., Yao, T., MacClune, K., White, J., Schilla, A., Vaughn, B., Vachon, R., and Ichiyanagi, K.: Stable isotopic variations in west China: a consideration of moisture sources, Journal of Geophysical Research: Atmospheres (1984–2012), 112(D10), D10112, https://doi.org/10.1029/2006JD007718, 2007.

Trenberth, K. E., Fasullo, J. T., and Mackaro, J.: Atmospheric Moisture Transports from Ocean to Land and Global Energy Flows in Reanalyses, J. Climate, 24(18), 4907-4924, https://doi.org/10.1175/2011JCLI4171.1, 2011.

Tuinenburg, O. A., and Staal, A.: Tracking the global flows of atmospheric moisture and associated uncertainties, Hydrol. Earth Syst. Sci., 24(5), 2419-2435, https://doi.org/10.5194/hess-24-2419-2020, 2020.

Tuinenburg, O. A., Theeuwen, J. J. E., and Staal, A.: High-resolution global atmospheric moisture connections from evaporation to precipitation, Earth Syst. Sci. Data, 12(4), 3177-3188, https://doi.org/10.5194/essd-12-3177-2020, 2020.

Van der Ent, R. J., and Savenije, H. H.: Oceanic sources of continental precipitation and the correlation with sea surface temperature, Water Resour. Res., 49(7), 3993-4004, https://doi.org/10.1002/wrcr.20296, 2013.

Van der Ent, R. J., Savenije, H. H., Schaefli, B., and Steele-Dunne, S. C.: Origin and fate of atmospheric moisture over continents, Water Resour. Res., 46(9), W09525, https://doi.org/10.1029/2010WR009127, 2010.

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, https://doi.org/10.5194/hess-17-4869-2013, 2013.

van der Ent, R. J., Wang-Erlandsson, L., Keys, P. W., and Savenije, H. H. G.: Contrasting roles of interception and transpiration in the hydrological cycle – Part 2: Moisture recycling, Earth Syst. Dynam., 5(2), 471-489, https://doi.org/10.5194/esd-5-471-2014, 2014.

Xu, Y., and Gao, Y.: Quantification of Evaporative Sources of Precipitation and Its Changes in the

Southeastern Tibetan Plateau and Middle Yangtze River Basin, Atmosphere, 10(8), 428, https://doi.org/10.3390/atmos10080428, 2019.

Yang, S., Zhang, W., Chen, B., Xu, X., and Zhao, R.: Remote moisture sources for 6-hour summer precipitation over the Southeastern Tibetan Plateau and its effects on precipitation intensity, Atmos. Res., 236, 104803, https://doi.org/10.1016/j.atmosres.2019.104803, 2020.

Yao, T., Masson-Delmotte, V., Gao, J., Yu, W., Yang, X., Risi, C., Sturm, C., Werner, M., Zhao, H., and He, Y.: A review of climatic controls on δ18O in precipitation over the Tibetan Plateau: Observations and simulations, Rev. Geophys., 51(4), 525-548, https://doi.org/10.1002/rog.20023, 2013.

Yu, W., Yao, T., Tian, L., Ma, Y., Ichiyanagi, K., Wang, Y., and Sun, W.: Relationships between δ18O in precipitation and air temperature and moisture origin on a south–north transect of the Tibetan Plateau, Atmos. Res., 87(2), 158-169, https://doi.org/10.1016/j.atmosres.2007.08.004, 2008.

Zhang, C.: Moisture source assessment and the varying characteristics for the Tibetan Plateau precipitation using TRMM, Environ. Res. Lett., 15(10), 104003, https://doi.org/10.1088/1748-9326/abac78, 2020.

Zhang, C., Tang, Q., and Chen, D.: Recent changes in the moisture source of precipitation over the Tibetan Plateau, J. Climate, 30(5), 1807-1819, https://doi.org/10.1175/JCLI-D-15-0842.1, 2017.

Zhang, C., Tang, Q. H., Chen, D. L., van der Ent, R. J., Liu, X. C., Li, W. H., and Haile, G. G.: Moisture Source Changes Contributed to Different Precipitation Changes over the Northern and Southern Tibetan Plateau, J. Hydrometeorol., 20(2), 217-229, https://doi.org/10.1175/Jhm-D-18-0094.1, 2019a.

Zhang, Y., Huang, W., and Zhong, D.: Major Moisture Pathways and Their Importance to Rainy Season Precipitation over the Sanjiangyuan Region of the Tibetan Plateau, J. Climate, 32(20), 6837-6857, https://doi.org/10.1175/jcli-d-19-0196.1, 2019b.

Zhao, H. B., Xu, B. Q., Yao, T. D., Wu, G. J., Lin, S. B., Gao, J., and Wang, M.: Deuterium excess record in a southern Tibetan ice core and its potential climatic implications, Climate Dyn., 38(9-10), 1791-1803, https://doi.org/10.1007/s00382-011-1161-7, 2012.