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Dataset Development of Precipitation Moisture Sources of Five Grid Cells at the Boundary and Center of the Qinghai-Xizang Plateau

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Abstract: The climate of the Qinghai-Xizang Plateau is influenced by 3 major circulation systems: westerly circulation, monsoon systems, and local circulation. However, these circulation systems affect different regions of the plateau to varying degrees, resulting in specific precipitation distribution patterns. To reveal the evolutionary rule of circulation systems regarding their impact on plateau precipitation at a finer spatial scale, the team set up a grid network of 5 research grids across the plateau, selecting grid points at the east, west, south, north boundaries, and the center of the plateau, and conducted precipitation source tracking simulations at these grid points. The model uses ERA5 reanalysis data, GPCP precipitation, and GLEAM evaporation as driving data. Verification was performed through comparative experiments, ultimately generating monthly precipitation source data for the 5 grid points across the plateau. The dataset includes: the 5 research grid point locations; monthly precipitation moisture source data for each of the 5 grids from 2011–2020, with a spatial resolution of 1°×1°, unit: mm/mon; monthly precipitation data for each plateau grid from 2011–2020, unit: mm/mon. The dataset is archived in .nc, .tif, and .xlsx formats, consisting of 7 data files with a total data volume of 131 MB (compressed into 1 file, 98.8 MB).

Keywords: Qinghai-Xizang Plateau; precipitation; circulation influence; moisture source

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Dataset Availability Statement:

The dataset supporting this paper was published and is accessible through the *Digital Journal of Global Change Data Repository* at: https://doi.org/10.3974/geodb.2024.09.03.V1.

1 Introduction

Precipitation on the Qinghai-Xizang Plateau is primarily influenced by 3 circulation systems: the westerlies, monsoon systems, and local circulation patterns[1,2]. These systems exhibit significant spatial heterogeneity across different regions of the plateau, with variations not

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[2] Zhang, C., Zhang, X., Tang, Q. H., *et al*. Precipitation moisture sources simulating dataset for five grid cells at the boundary and center of Qingzang Plateau [J/DB/OL]. *Digital Journal of Global Change Data Repository*, 2024. https://doi.org/10.3974/geodb.2024.09.03.V1.

only in the dominant system but also in the influence intensity of each circulation[3,4]. Existing research has established the dominant role of westerlies in the northern Qinghai-Xizang Plateau and the control of monsoon systems in the southern regions[4,5]. However, in the transition zone where westerlies, monsoons, and local circulation systems deeply intertwine, the mechanism of circulation systems' modulation of precipitation and their spatial evolution characteristics remain an urgent scientific issue. Current research lacks a systematic analysis of moisture sources for precipitation across the entire Qinghai-Xizang Plateau.

The Qinghai-Xizang Plateau requires 258 grid points when filled with 1°×1° grids. Calculating and analyzing precipitation moisture sources for each grid point would consume excessive computational and storage resources. Moreover, different grid points within the same hydroclimatic region have similar moisture sources and circulation influences, making grid-by-grid precipitation source tracking unnecessary. To simply and effectively characterize the spatial differences in plateau moisture sources and reveal the spatial evolution of related circulation patterns over the plateau, this study selected 4 boundary grid points at the extreme east, west, north, and south, along with a central point (33°N, 92°E) as the center point, forming a grid network. The 3 latitudinal grid points (extreme west-center-extreme east) allow observation of the westerlies' influence changes from west to east across the plateau. The 3 longitudinal grid points (extreme south-center-extreme north) enable observation of the South Asian monsoon's progression in the north-south direction.

For the 5 representative grids on the plateau, ERA5 atmospheric reanalysis data, GPCP (Global Precipitation Climatology Project) precipitation, and GLEAM (Global Land Evaporation Amsterdam Model) evaporation (detailed in the data section) were used as driving data to track precipitation moisture sources using a numerical model. To ensure result reliability and accuracy, comparative experiments were designed for verification[6], ultimately generating monthly precipitation source data for the 5 plateau grid cells from 2011 to 2020. This dataset provides scientific evidence for revealing the spatial evolution patterns of circulation systems and delineating the dominant influence regions of different circulation systems on the plateau.

2 Metadata of the Dataset

The metadata of Precipitation moisture sources simulating dataset for five grid cells at the boundary and center of Qingzang Plateau[7] is summarized in Table 1. It includes the dataset full name, short name, authors, year of the dataset, temporal resolution, spatial resolution, data format, data size, data files, data publisher, etc.

3 Methods

3.1 Model

This study uses the Eulerian numerical model WAM2Layers (Water Accounting Model-2layers) to track moisture sources for precipitation at plateau grid cells. The model divides the atmosphere into 2 vertical layers, a design that effectively overcomes the tracking errors of the previous WAM model in case of vertical wind direction shear, significantly improving the accuracy of dynamic moisture tracking[9,10]. An extended version of the WAM2Layers model was used to process pressure level data from ERA5[11,12]. The model's basic equation is:

$$\frac{\partial W_k}{\partial t} + \frac{\partial (W_k u)}{\partial x} + \frac{\partial (W_k v)}{\partial y} = E_k - P_k \pm F_V + \alpha_k \tag{1}$$

where W represents atmospheric precipitable water (mm), k represents upper or lower atmospheric layer, u and v are horizontal wind speeds (m/s), E is surface evaporation (mm), P is precipitation (mm), F_V represents vertical moisture transport between layers (mm), and α is the residual term. Moisture from a specific source region Ω follows a similar atmospheric water balance equation:

$$\frac{\partial W_{k,\Omega}}{\partial t}+\frac{\partial\left(W_{k,\Omega}u\right)}{\partial x}+\frac{\partial\left(W_{k,\Omega}v\right)}{\partial y}=E_{k,\Omega}-P_{k,\Omega}\pm F_{V,\Omega}+\alpha_{k,\Omega} \quad (2)$$

Table 1 Metadata summary of MoistureSource5GridCellsQZP

Items	Description
Dataset full name	Precipitation moisture sources simulating dataset for five grid cells at the boundary and center of Qingzang Plateau
Dataset short name	MoistureSource5GridCellsQZP
Authors	Zhang, C., Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, zhangchi@igsnrr.ac.cn Zhang, X., Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, zhangxu246810@126.com Tang, Q. H., Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, tangqh@igsnrr.ac.cn Huang, J. C., Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, huangjc@igsnrr.ac.cn Zhou, Y. Y., Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, zhouyy@igsnrr.ac.cn Gaffney, P. P. J., Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, gafppj@igsnrr.ac.cn Xu, X. M., Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, xuxm@igsnrr.ac.cn
Geographical region	Qinghai-Xizang Plateau
Year	2011–2020
Temporal resolution	Monthly
Spatial resolution	1°×1°
Data format	.nc, .tif, .xlsx
Data size	98.8 MB（after compression）
Data files	Locations of 5 grid cells on the Qinghai-Xizang Plateau, monthly precipitation for these 5 grid cells during the 10 years, monthly moisture sources for precipitation of the 5 grids
Foundations	National Natural Science Foundation of China (U2243226); China Scholarship Council (202310490002)
Data publisher	Global Change Research Data Publishing & Repository, http://www.geodoi.ac.cn
Address	No. 11A, Datun Road, Chaoyang District, Beijing 100101, China
Data sharing policy	(1) *Data* are openly available and can be free downloaded via the Internet; (2) End users are encouraged to use *Data* subject to citation; (3) Users, who are by definition also value-added service providers, are welcome to redistribute *Data* subject to written permission from the GCdataPR Editorial Office and the issuance of a *Data* redistribution license; and (4) If *Data* are used to compile new datasets, the "ten percent principal" should be followed such that *Data* records utilized should not surpass 10% of the new dataset contents, while sources should be clearly noted in suitable places in the new dataset[8]
Communication and searchable system	DOI, CSTR, Crossref, DCI, CSCD, CNKI, SciEngine, WDS, GEOSS, PubScholar, CKRSC

3.2 Data Sources and Processing

Driving data consists of atmospheric data and land surface flux data. The atmospheric data uses ERA5[13], the new generation reanalysis data from the European Centre for Medium-Range Weather Forecasts, which includes hourly wind speed and atmospheric humidity across 23 pressure levels from 200–1,000 hPa globally, as well as hourly surface atmospheric pressure, precipitable water, and horizontal moisture flux. The spatial resolution is 1°×1°. These data are used to calculate variables in Equation 1, such as precipitable water and moisture flux in upper and lower atmospheric layers, and vertical moisture transport between the 2 layers. All hourly variables are converted to 15-minute intervals through linear interpolation or equal division methods for model input.

Since ERA5's evaporation and precipitation fluxes over the Qinghai-Xizang Plateau rely entirely on model output without assimilating any observation[13], there are significant uncertainties in the data. In view of this, this study adopted the remote sensing-based land evaporation product of the Global Land Evaporation Amsterdam Model (GLEAM, v3.5a)[14] and the merged satellite/gauge precipitation product of Global Precipitation Climatology Project One-Degree Daily (GPCP1DD, v1.3)[15] to improve data quality. GLEAM provides monthly-scale data with a spatial resolution of 0.25°×0.25°; GPCP1DD provides daily-scale data with a spatial resolution of 1°×1°. To maintain consistency with ERA5's spatial grid, the authors resampled GLEAM and GPCP data to ERA5's spatial resolution through bilinear interpolation and other methods. Subsequently, monthly ratio series for each grid point were calculated for the period 2011–2020 by dividing the monthly values of GLEAM and GPCP by corresponding ERA5 monthly values. Using these ratios, the authors corrected ERA5's hourly evaporation and precipitation data, creating a new high temporal resolution dataset. Finally, to meet model input requirements, we converted the corrected hourly data to 15-minute interval time series through equal division methods.

3.3 Simulation Experiment Description

After the numerical experiments, the simulation data needs to be processed. The experiment outputs the tagged water content for any time step and grid column. For the lower atmospheric layer, within the evaporation e at a time step, $e \times r$ of water vapor will eventually form direct precipitation in the target region, which can be expressed by the following formula:

$$E_{con}(t,x,y) = E(t,x,y) \times \frac{W_{\mathrm{r\_down}}(t,x,y)}{W_{\mathrm{down}}(t,x,y)} \tag{3}$$

where $W_{\mathrm{r\_down}}/W_{\mathrm{down}}$ represents the proportion r of tagged water content in the lower atmosphere. By integrating all $e \times r$, we obtain the monthly water vapor contribution from the grid-scale evaporation source to the precipitation sink in the plateau study grids:

$$E_{con}(x,y) = \int_{t1}^{t2} E_{con}(t,x,y)\,dt \tag{4}$$

where the unit of E_{con} is m^3/mon. Since this study traces the moisture sources of precipitation at grid scale, the units of precipitation moisture sources in the dataset are all converted to precipitation flux units for the study grid, i.e., mm/mon. Due to huge differences in precipitation amounts between different grids (for example, the annual precipitation comparison between the south and north plateau grids is 978 mm : 63 mm), there would be legend scale issues when directly displaying the numerical results of moisture sources. Therefore, it is standardized (Equation 5) and converted to the percentage of moisture contribution from different grids relative to the total moisture contribution from all grids, to highlight the relative impact of different source regions.

$$Ratio(x,y) = \frac{E_{con}(x,y)}{\sum_{x=1}^{360}\sum_{y=-90}^{90} E_{con}(x,y)} \times 100 \tag{5}$$

4 Data Results

4.1 Dataset Composition

The dataset consists of 7 data files, including: locations of 5 grid cells on the

Qinghai-Xizang Plateau (in .tif format); monthly precipitation for these 5 grid cells during 2011–2020 (mm/mon, in .xlsx format); monthly precipitation moisture sources for the 5 grids with a spatial resolution of 1°×1° (mm/mon, in .nc format).

4.2 Data Results

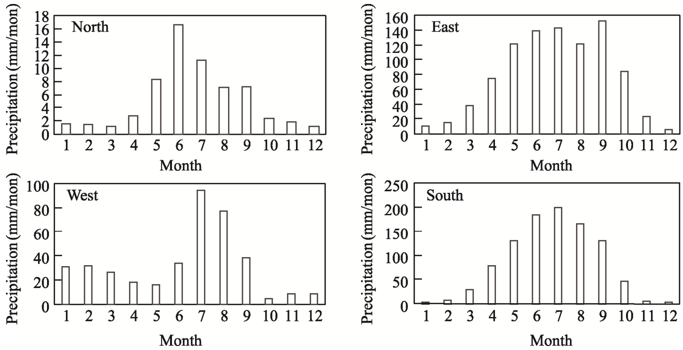

Figure 1 Average monthly precipitation at Qinghai-Xizang Plateau boundary grid cells (2011–2020)

The multi-year average monthly precipitation variation at plateau boundary grids (as shown in Figure 1) reveals unique precipitation characteristics under boundary-location environments. Analysis shows that while all 4 regions of the plateau display significant seasonal variations, each region has its own distinctive features. The southern and northern regions best exemplify the “rain and heat in same season” characteristic, with maximum precipitation in summer and minimum in winter. This pattern reflects typical monsoon climate features, not only suggesting significant influence from the South Asian monsoon system but also raising an intriguing question worth deeper investigation: whether the South Asian monsoon could potentially cross the plateau to affect such northernmost regions.

The east grid exhibits a double-peak pattern in monthly precipitation, occurring in July and September, with September precipitation even exceeding July’s. This phenomenon suggests that besides the South Asian monsoon, other weather systems might affect the eastern plateau after the South Asian monsoon retreats in August. This could be related to the East Asian monsoon or tropical cyclone systems, warranting further research.

The west grid also shows a double-peak pattern, but with peaks in February and July. This unique pattern reveals 2 distinctly different systems dominating precipitation in this region: the westerlies in winter and the South Asian monsoon in summer. Horizontal comparison shows that the extreme western region has significantly higher February precipitation than other regions, a phenomenon likely closely related to topographical factors. When westerly flows encounter the Qinghai-Xizang Plateau’s massive topographic barrier, they are forced to climb along the windward slope, promoting moisture condensation and bringing abundant rain and snow to this region. This mechanism highlights the plateau’s topography’s crucial role in regulating regional precipitation distribution.

Analysis of precipitation characteristics at plateau boundary grid cells shows that July is the significant peak period for plateau precipitation, providing an ideal time window to study moisture transport and water contribution from global evaporation sources to precipitation across different regions of the plateau. Figure 2 presents the normalized moisture source distribution for each boundary grid point, revealing significant differences in precipitation moisture sources across the four boundary positions of the plateau.

(1) Southernmost grid: The South Asian monsoon influence is most prominent in this region. The moisture sources show a distinct band-like distribution extending from the Bay of Bengal through the Arabian Sea to the western edge of the Indian Ocean, consistent with previously observed moisture source distribution patterns in the southern plateau[16].

(2) Northernmost grid: Precipitation moisture mainly originates from the northwestern plateau and Tianshan region, showing a pattern drastically different from the southernmost grid. The moisture contribution of monsoon from south of the plateau is minimal in this area, indicating that precipitation here is primarily controlled by westerly circulation rather than the monsoon system. While Zhang, *et al.* found that the monsoon region, despite its low

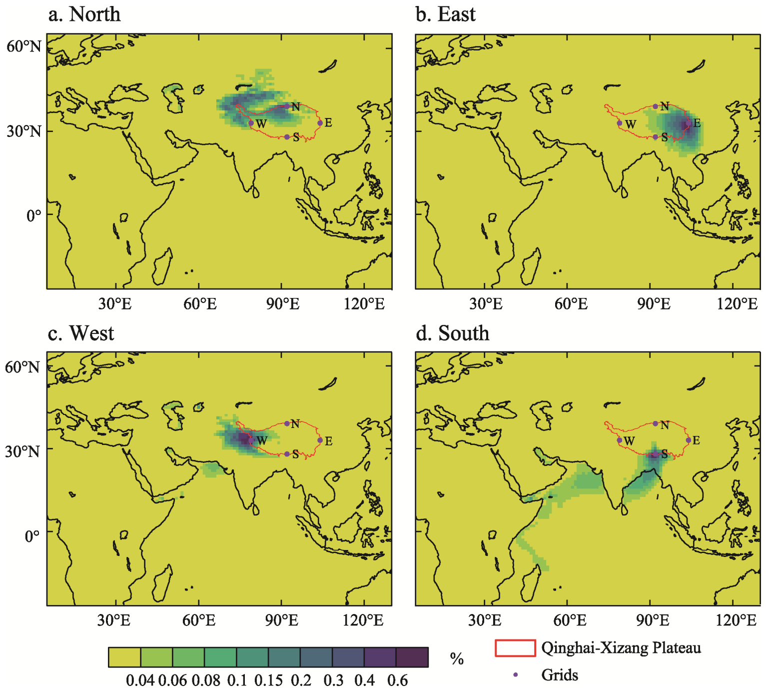

Figure 2 Distribution of average moisture contribution from surface evaporation sources to precipitation at Qinghai-Xizang Plateau boundary grid cells in July (Normalized)

contribution, was still an important moisture source when studying moisture sources in the northern plateau (north of 35°N)[16], this study further demonstrates that the influence of the monsoon system weakens as the plateau grid moves northward, becoming negligible in the northern regions.

(3) Easternmost grid: Located downstream of the westerlies on the plateau, its moisture sources exhibit complex dual characteristics. On one hand, the eastern plateau region makes significant contributions to this grid cell, reflecting the importance of local moisture circulation; on the other hand, with the prevalence of the East Asian monsoon, evaporated moisture from the southeast of the plateau also reaches this region through the East Asian monsoon transport system, forming another important moisture source. This composite pattern reveals the diversified characteristics of moisture transport in this region.

(4) Westernmost grid: The precipitation moisture sources are relatively concentrated, mainly distributed around the western plateau region. However, distant water bodies such as the Arabian Sea and the Caspian Sea also contribute to some extent to precipitation at this grid point. This distribution pattern reflects the combined effects of the westerlies and local moisture circulation, while also suggesting the potential importance of long-distance moisture transport in precipitation formation in this region.

5 Discussion and Conclusion

The circulations affecting Qinghai-Xizang Plateau precipitation vary spatially across the plateau. To reveal the spatial evolution of different circulation systems' influence over the plateau, the team selected representative study grid cells around the 4 edges and center of the plateau to form a distribution grid network, conducting precipitation source tracing at the grid scale. The study used ERA5 reanalysis data, GPCP precipitation, and GLEAM evaporation as the main model driving data, and designed and executed a series of comparative experiments to ensure the reliability and accuracy of model results[6]. The research successfully developed monthly-scale precipitation moisture source data for 5 grids across the eastern, western, southern, northern, and central Qinghai-Xizang Plateau, providing a solid foundation for scientifically assessing the evolution process of different circulation systems across various regions of the Qinghai-Xizang Plateau.

Through preliminary data analysis, we found that precipitation at plateau boundaries not only reflects the influence of large-scale atmospheric circulation systems (such as monsoons and westerlies) but also highlights the important role of topography in shaping local climate characteristics, such as windward slopes receiving more rain and snow in winter. Each region of the plateau has its unique moisture source distribution pattern—the eastern and southern regions are significantly influenced by monsoon systems, while the northern and western regions are more affected by westerly circulation. The moisture source distribution characteristics of different boundary grid cells not only reflect the differentiated influence of large-scale atmospheric circulation systems but also demonstrate the complex interactions between topography and local water cycles in shaping regional precipitation patterns. These findings provide important scientific basis for deeply understanding the Qinghai-Xizang Plateau's water cycle processes, assessing climate change impacts, and formulating regional water resource management strategies. Future research could further explore the seasonal variations of these moisture transport patterns and their long-term impacts on plateau ecosystems and water resource sustainability.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Zhang, C. Moisture source assessment and the varying characteristics for the Tibetan Plateau precipitation using TRMM [J]. *Environmental Research Letters*, 2020, 15(10): 104003.

[2] Zhao, Y., Zhou, T. Interannual variability of precipitation recycle ratio over the Tibetan Plateau [J]. *Journal of Geophysical Research*: *Atmospheres*, 2021, 126(2): e2020JD033733.

[3] Chen, B., Zhang, W., Yang, S., *et al*. Identifying and contrasting the sources of the water vapor reaching the subregions of the Tibetan Plateau during the wet season [J]. *Climate Dynamics*, 2019, 53: 6891–6907.

[4] Yao, T. D., Masson-Delmotte, V., Gao, J., *et al*. A review of climatic controls on $\delta^{18}O$ in precipitation over the Tibetan Plateau: observations and simulations [J]. *Reviews of Geophysics*, 2013, 51(4): 525–548.

[5] Zhang, C., Tang, Q. H., Chen, D. L., *et al*. Moisture source changes contributed to different precipitation changes over the northern and southern Tibetan Plateau [J]. *Journal of Hydrometeorology*, 2019, 20(2): 217–229.

[6] Zhang, C., Zhang, X., Tang, Q. H., *et al*. Quantifying precipitation moisture contributed by different atmospheric circulations across the Tibetan Plateau [J]. J*ournal of Hydrology*, 2024, 628: 130517.

[7] Zhang, C., Zhang, X., Tang, Q. H., *et al*. Precipitation moisture sources simulating dataset for five grid cells at the boundary and center of Qingzang Plateau [J/DB/OL]. *Digital Journal of Global Change Data Repository*, 2024. https://doi.org/10.3974/geodb.2024.09.03.V1.

[8] GCdataPR Editorial Office. GCdataPR data sharing policy [OL]. https://doi.org/10.3974/dp.policy.2014.05 (Updated 2017).

[9] van der Ent, R. J., Wang-Erlandsson, L., Keys, P. W., *et al*. Contrasting roles of interception and transpiration in the hydrological cycle–part 2: moisture recycling [J]. *Earth System Dynamics*, 2014, 5(2): 471–489.

[10] van der Ent, R. J., Tuinenburg, O. A., Knoche, H. R., *et al*. Should we use a simple or complex model for moisture recycling and atmospheric moisture tracking? [J] *Hydrology and Earth System Sciences*, 2013, 17(12): 4869–4884.

[11] Liu, Y., Garcia, M., Zhang, C., *et al*. Recent decrease in summer precipitation over the Iberian Peninsula closely links to reduction in local moisture recycling [J]. *Hydrology and Earth System Sciences*, 2022, 26(8): 1925–1936.

[12] Zhang, C., Chen, D. L., Tang, Q. H., *et al*. Fate and changes in moisture evaporated from the Tibetan Plateau (2000–2020) [J]. *Water Resources Research*, 2023, 59(11): e2022WR034165.

[13] Hersbach, H., Bell, B., Berrisford, P., *et al*. The ERA5 global reanalysis [J]. *Quarterly Journal of the Royal Meteorological Society*, 2020, 146(730): 1999–2049.

[14] Martens, B., Miralles, D. G., Lievens, H., *et al*. GLEAM v3: satellite-based land evaporation and root-zone soil moisture [J]. *Geoscientific Model Development*, 2017, 10(5): 1903–1925.

[15] Huffman, G. J., Adler, R. F., Morrissey, M. M., *et al*. Global precipitation at one-degree daily resolution from multisatellite observations [J]. *Journal of hydrometeorology*, 2001, 2(1): 36–50.

[16] Zhang, C., Tang, Q. H., Chen, D. L., *et al*. Moisture source changes contributed to different precipitation changes over the northern and southern Tibetan Plateau [J]. *Journal of Hydrometeorology*, 2019, 20(2): 217–229.