Journal of Global Change Data & Discovery. 2024, 8(2): 171-177
www.geodoi.ac.cn

Global Change Research Data Publishing & Repository

Dataset Development for Water Vapor Sources of Meiyu Season Precipitation in the Middle and Lower Reaches of the Yangtze River (26.5°N–33.5°N, 104.5°E–122.5°E, 1991–2020)

Zhang, C.

Key Laboratory of Land Surface Pattern and Simulation, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China

Abstract: Meiyu precipitation has significant impacts on drought and flood disasters, water resource management, and socioeconomic decision-making in the middle and lower reaches of the Yangtze River. Studying the sources of Meiyu precipitation in the middle and lower reaches of Yangtze River helps to manage and control Meiyu from its origin in the future. An atmospheric precipitation moisture tracking model was set up to trace the sources of precipitation in the middle and lower reaches of the Yangtze River during the Meiyu season (June & July) from 1991 to 2020, obtaining 30 years of data on the moisture sources for Meiyu precipitation in this region. The model's physical mechanisms are rigorous, and the driving data are based on actual measurements, ensuring the reliability of the simulation results. Furthermore, the amount of water vapor contribution from surface evapotranspiration traced through precipitation backtracking is comparable to the Meiyu precipitation amount. The dataset contents include: (1) boundary of the study area; (2) yearly precipitation moisture source during the Meiyu period, with spatial resolution of 1°×1°, and the unit is mm; (3) yearly surface precipitation during the Meiyu period. The dataset is archived in .nc, .shp, and .xlsx formats, consisting of 9 data files, with a total data size of 13.1 MB (compressed into 1 file, 10.7 MB). This dataset provides important data support for exploring the main moisture source region of precipitation in the Meiyu region, internal hydrological cycling, differences in sea and land moisture contributions, and attribution of Meiyu changes, among other applications.

Keywords: Meiyu; precipitation; moisture source; middle and lower reaches of the Yangtze River

DOI: https://doi.org/10.3974/geodp.2024.02.07

CSTR: https://cstr.escience.org.cn/CSTR:20146.14.2024.02.07

Received: 20-02-2024; **Accepted:** 16-05-2024; **Published:** 25-06-2024

Foundations: Ministry of Science and Technology of P. R. China (2023YFC3206603); National Natural Science Foundation of China (U2243226); China Scholarship Council (202310490002)

Author Information: Zhang, C., Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, zhangchi@igsnrr.ac.cn

Data Citation: [1] Zhang, C. Dataset development for water vapor sources of Meiyu Season precipitation in the middle and lower reaches of the Yangtze River (26.5°N–33.5°N, 104.5°E–122.5°E,1991–2020) [J]. *Journal of Global Change Data & Discovery*, 2024, 8(2): 171–177. https://doi.org/10.3974/geodp.2024.02.07. https://cstr.escience.org.cn/CSTR:20146.14.2024.02.07.

[2] Zhang, C., Huang, J. C., Tang, Q. H., *et al.* Precipitation moisture source dataset for the middle and lower reaches of the Yangtze River (26.5°N–33.5°N, 104.5°E–122.5°E) during the Meiyu Season of 1991–2020 [J/DB/OL]. *Digital Journal of Global Change Data Repository*, 2024. https://doi.org/10.3974/geodb.2024.07.04.V1. https://cstr.escience.org.cn/CSTR:20146.11.2024.07.04.V1.

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.2024.07.04.V1 or https://cstr.escience.org.cn/CSTR:20146.11.2024.07.04.V1.

1 Introduction

The term "Meiyu" (plum rain) refers to a period of persistent rainy weather that occurs in early summer (typically in June and July) in East Asian regions including eastern China, Japan, and Korea. This weather pattern is named after the plum ripening season which coincides with its occurrence[1]. Meiyu has a dual impact on regional ecosystems and economic development. On the positive side, it provides necessary moisture for crop growth and serves as an important period for water resource replenishment in many areas. However, variations in the intensity of Meiyu also bring significant challenges: excessive precipitation can lead to flooding disasters, while insufficient rainfall may cause water shortages, potentially resulting in severe droughts. These fluctuations in rainfall have profound effects on agricultural production, water resource management, and the overall socio-economic system[2,3].

It is noteworthy that the fluctuations in Meiyu precipitation are directly related to the strength of water input from surface evaporation[4]. By analyzing the evaporative sources of precipitation and the corresponding changes in water vapor circulation, we can gain a deeper understanding of the mechanisms behind Meiyu precipitation fluctuations. This in-depth understanding not only enhances our knowledge of the Meiyu phenomenon but also provides a theoretical foundation for potentially managing and regulating Meiyu intensity from the evaporation source in the future. Based on this, the present study uses numerical models to trace the water vapor sources of Meiyu season precipitation in the middle and lower reaches of the Yangtze River over the past 30 years, providing a spatial distribution dataset of surface moisture contributions to Meiyu at the grid scale. The application value of this dataset includes, but is not limited to: (1) identifying the main water vapor source region for Meiyu precipitation; (2) analyzing the interannual fluctuations of major boundaries; and (3) exploring the differences in precipitation sources during drought and wet years.

2 Metadata of the Dataset

Metadata of the Precipitation moisture source dataset for the middle and lower reaches of the Yangtze River during the Meiyu Season of 1991–2020 [5] is summarized in Table 1.

3 Methods

3.1 Model Driving Data

The model requires appropriate driving data, which consists of two main categories: atmospheric data and surface flux data. Atmospheric data uses ERA5[7], the new generation of reanalysis data from the European Centre for Medium-Range Weather Forecasts. It includes hourly wind speed and atmospheric humidity for 23 pressure levels from 200–1,000 hPa globally, as well as hourly surface atmospheric pressure, precipitable water, and horizontal water vapor flux. The spatial resolution is 1°×1°.

Surface data includes surface evapotranspiration and precipitation. For land evapotranspiration, the GLEAM (V3.5a) dataset's total evapotranspiration is used[8]. This data is based on remote sensing inversion algorithms and has been proven more accurate than other evapotranspiration products in multiple studies[9,10]. The GLEAM data used is monthly scale data with a spatial resolution of 0.25°×0.25°. For precipitation, the CN05.1 product is used[11]. This is a precipitation product developed by the China Meteorological

Administration based on interpolation of measured station data and is widely used in China. The CN05.1 data used is monthly scale data with a spatial resolution of 0.25°×0.25°.

Table 1 Metadata summary of the dataset

Items	Description		
Dataset full name	Precipitation moisture source dataset for the middle and lower reaches of the Yangtze River (26.5°N–33.5°N, 104.5°E–122.5°E) during the Meiyu season of 1991–2020		
Dataset short name	PrecSourceMLYangtzeRiver1991-2020		
Authors	Zhang, C., Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, zhangchi@igsnrr.ac.cn Huang, J. C., Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, huangjc@igsnrr.ac.cn Tang, Q. H., Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, tangqh@igsnrr.ac.cn Xu, X. M., Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, xuxm@igsnrr.ac.cn Gaffney, P. P. J., Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, gafppj@igsnrr.ac.cn Zhou, Y. Y., Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, zhouyy@igsnrr.ac.cn		
Geographical region	Middle and lower reaches of the Yangtze River		
Year	1991–2020		
Temporal resolution	Year	Spatial resolution	1°×1°
Data format	.nc, .xlsx, .shp		
Data size	10.7 MB (after compression)		
Data files	boundary of the middle and lower reaches of the Yangtze River		
Foundations	Ministry of Science and Technology of P. R. China (2023YFC3206603); 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 per cent 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[6]		
Communication and searchable system	DOI, CSTR, Crossref, DCI, CSCD, CNKI, SciEngine, WDS, GEOSS, PubScholar, CKRSC		

Additionally, ERA5 hourly global precipitation and evaporation data are used. Although this data has large errors over land surfaces[4], it contains diurnal variation information. By correcting it with GLEAM and CN05.1 monthly scale data, surface flux data with high temporal resolution and monthly values consistent with observational data can be obtained.

3.2 Data Preprocessing

The WAM2layers model is a two-layer model that divides the original atmosphere into two layers. According to the model settings[12], the division level is calculated as:

$$P_{\text{div}} = 74.38803 + 0.72879 \times P_{\text{surf}} \left(\text{hPa}\right) \tag{1}$$

where, the division pressure P_{div} varies dynamically with the surface atmospheric pressure P_{surf}. When P_{surf} = 1,013.25 hPa, the division pressure is 812.83 hPa. After calculation of the division pressure for the current grid point, the standard pressure level closest to this division pressure is selected from the 23 pressure levels. This level serves as the vertical boundary. The precipitable water and water vapor flux are then integrated separately from this layer to the top of the atmosphere and from this layer to the surface.

All data needs to be converted to the spatial and temporal resolution required for model input, which is 1°×1° and 15-minute intervals. For hourly instantaneous atmospheric data, such as precipitable water and water vapor flux, linear interpolation is used to obtain corresponding 15-minute interval data. For hourly cumulative flux data, such as evaporation and precipitation, the method of period averaging is used to obtain 15-minute interval data.

The CN05.1 precipitation and GLEAM evapotranspiration grid sizes are both 0.25°×0.25°. During conversion, spatial resampling is first used to calculate the weighted average of all 0.25° grid values falling within a 1° grid, thus obtaining precipitation/evaporation values representative of the 1° grid. These are then compared with the monthly values of ERA5 precipitation and evaporation, respectively. For each grid point and each month, a scaling parameter μ is obtained. The hourly ERA5 data for that grid point and month is multiplied by this parameter μ, then averaged to a 15-minute scale, resulting in high temporal resolution data with monthly values consistent with CN05.1 and GLEAM data after correction.

3.3 Model Algorithm

The WAM2layers water vapor tracking model is a numerical model based on an Eulerian coordinate framework. WAM2layers tracks the free movement of tagged water between upper and lower, inner and neighboring grid cells. The precipitation source tracing algorithm process is as follows.

Considering the inverse process of precipitation, the precipitation p_0 in a specific time step in the target area (i.e., the Meiyu area in the middle and lower reaches of the Yangtze River) is treated as tagged water vapor returning to the atmosphere, flowing back against the time axis and the direction of water vapor transport. When p_0 enters the atmosphere, there is an allocation rule: the amount of water vapor distributed to the upper and lower layers is proportional to the atmospheric precipitable water (W_{up} and W_{down}) in the upper and lower layers of the grid column. After entering the atmosphere, like diffusion, the marked water vapor continuously enters surrounding grid points through horizontal and vertical water vapor transport, fully mixing with the water vapor in the residing air layer.

At a specific time point, if there is evaporation *e* at grid point A, and the proportion of tagged water vapor to total water vapor in the lower layer is *r*, this means that *e*×*r* of the evaporated water vapor *e* entering the lower layer at point A will ultimately form direct precipitation in the target area. This part of the water vapor is then identified as the direct precipitation contribution from grid point A to the Meiyu area, successfully traced to its source. The tagged water in the lower layer needs to be reduced by this amount and continue its “recycling” process until almost all tagged water is traced to its source[13,14].

3.4 Data Postprocessing

As described in the previous algorithm, at any time step, *e*×*r* of the evaporation *e* will finally form direct precipitation in the target area. This can be expressed through Equation (2):

$$E_r(t,x,y) = E(t,x,y) \times \frac{W_{\text{r\_down}}(t,x,y)}{W_{\text{down}}(t,x,y)} \tag{2}$$

where W_{r_down}/W_{down} represents the proportion *r* of marked water vapor content in the lower atmosphere. By integrating and summing all *e*×*r*, we obtain the water vapor contribution from evaporation sources at the grid scale to the precipitation in the Meiyu area throughout the entire Meiyu season:

$$E_r(x,y) = \int_0^T E_r(t,x,y)\,dt \tag{3}$$

3.5 Technical Workflow

In summary, the technical workflow for the development of this dataset is shown in Figure 1.

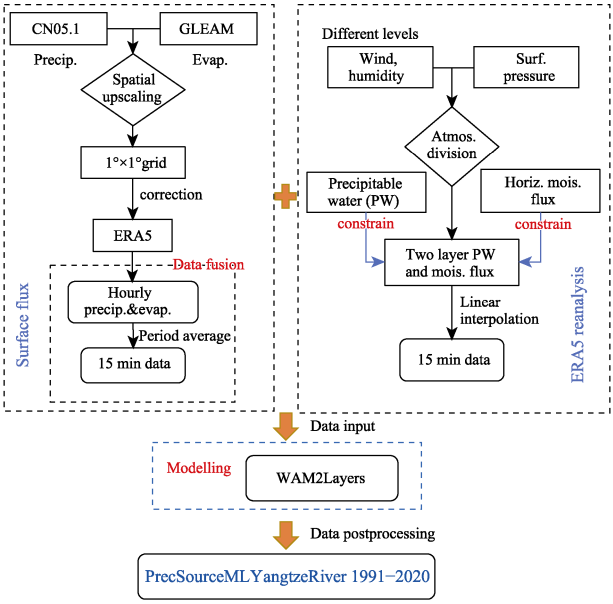

Figure 1 Technical workflow for the dataset development

4 Data Results and Validation

4.1 Data Composition

The dataset consists of 9 data files, including the location file of the Meiyu region in the middle and lower reaches of the Yangtze River (in .shp format), the precipitation amount (in mm, .xlsx format) for each Meiyu season from 1991 to 2020 in this region, and the corresponding moisture sources for Meiyu precipitation each year (1°×1°, in mm, .nc format).

4.2 Data Results

The Meiyu region in the middle and lower reaches of the Yangtze River, consists of totally 116 grid points of size 1°×1°, covering an area of about 1.24×10^6 km^2. The average precipitation is 413.9±70.0 mm, with the lowest precipitation of 321.2 mm in 2001 and the highest of 636.9 mm in 2020. Figure 2 shows the source tracing results of Meiyu precipitation for the 1st, 11th, 21st, and 30th years, presented at approximately ten-year intervals. Simple observation reveals that the precipitation in the Meiyu region mainly originates from the southwestern direction towards the Indian Ocean source region and the southeastern direction towards the tropical Pacific source region, with significant fluctuations between different years.

4.3 Data Validation

WAM2layers is constrained by strict physical processes and has been validated through model comparisons[15], making it highly credible and widely applied in moisture tracking simulations. For specific applications, on one hand, it is necessary to consider selecting appropriate driving data to reduce uncertainties brought by input data; on the other hand, it is essential to verify whether the model is functioning properly, that is, to confirm if the precipitation in the study area has been largely traced back to surface evaporative sources. By accumulating the contributions of each grid source to Meiyu precipitation and comparing it with the total Meiyu precipitation, the results are shown in Figure 3. On average, about 98.9% of Meiyu precipitation was tracked over the 30 years, with 2019 having the lowest tracking ratio of about 98.5%. This indicates that the vast majority of precipitation has been effectively identified and attributed to surface evaporative sources.

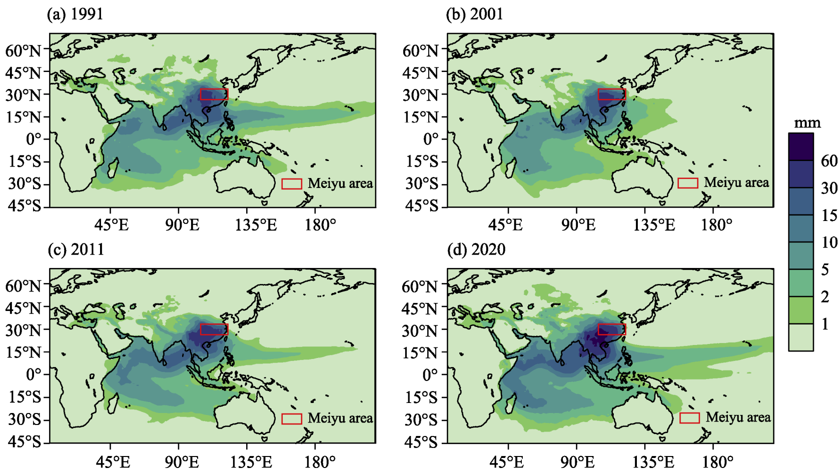

Figure 2 Moisture contribution maps of the Meiyu precipitation sources during 1991, 2001, 2011, and 2020, respectively

5 Discussion and Conclusion

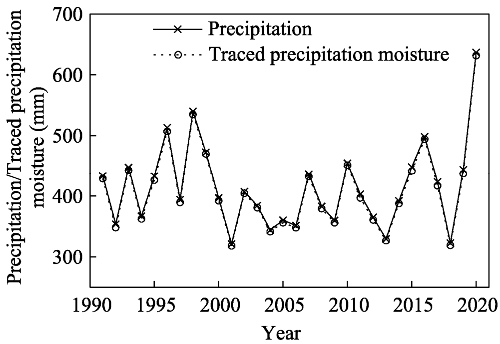

Figure 3 Annual Meiyu precipitation and traced precipitation moisture to the surface by the model from 1991 to 2020

This study traced the moisture sources of precipitation in the middle and lower reaches of the Yangtze River during the Meiyu season over the past 30 years using the numerical model WAM2Layers. It provides a spatial distribution dataset of surface evaporative sources' contribution to Meiyu at the grid scale. The dataset uses multi-source observational data as model inputs, including CN05.1 observational precipitation, GLEAM remote sensing evapotranspiration data, and atmospheric data of ERA5 reanalysis. The simulation is based on strict physical processes and water balance equations, calculated at a 15-minute time scale, ultimately providing global grid moisture contribution data at 1°×1° spatial resolution, with a high precipitation tracking ratio of 98.9% and high reliability.

Essentially, this dataset achieves an innovative data transformation, converting Meiyu precipitation into moisture contribution from surface evaporative sources, providing a new perspective for explaining changes in Meiyu precipitation. Preliminary analysis shows that in the drought year of 2001, precipitation in the Meiyu region mainly came from the Indian Ocean to its southwest and the South China Sea region to its south. In contrast, during the strong Meiyu period in 2020, the tropical Pacific region provided a significant increase in moisture contribution, becoming an important source of precipitation (Figure 2).

This dataset provides data support for exploring the main moisture source areas of precipitation in the Meiyu region, the fluctuation of source area boundaries, differences in sea and land moisture contributions, and differences and changes in internal and external moisture cycling in the middle and lower reaches of the Yangtze River. Future research can further combine data such as land use changes in terrestrial moisture source areas to deeply analyze the change mechanisms of terrestrial moisture contribution, thereby more comprehensively exploring the intrinsic dynamic processes of Meiyu precipitation changes. This multi-angle, multi-scale research approach will help improve our understanding of regional water cycle processes and provide scientific basis for water resource management and disaster prevention and mitigation in the context of climate change.

Conflicts of Interest

The author declares no conflicts of interest.

References

[1] Ding, Y., Liu, Y., Hu, Z. Z. The record-breaking Mei-yu in 2020 and associated atmospheric circulation and tropical SST anomalies [J]. *Advances in Atmospheric Sciences*, 2021, 38(12): 1980–1993.

[2] Zhang, L., Zhao, D., Zhou, T., *et al*. Moisture origins and transport processes for the 2020 Yangtze River Valley record-breaking Mei-yu rainfall [J]. *Advances in Atmospheric Sciences*, 2021, 38: 2125–2136.

[3] Hao, Z. X., Li, M. Q., Zheng, J. Y., *et al*. Relationship between the flood and drought and Meiyu in middle-lower reaches of Yangtze River [J]. *Progress in Natural Science*, 2009, 19(8): 877–882.

[4] Zhang, C., Tang, Q. H., Zhao, Y., *et al*. Moisture source differences between the 2020 and 1998 super Meiyu-flood events in the Yangtze River Valley [J]. *Weather and Climate Extremes*, 2024, 43: 100644. https://doi.org/10.1016/j.wace.2024.100644.

[5] Zhang, C. Precipitation moisture source dataset for the middle and lower reaches of the Yangtze River (26.5°N–33.5°N, 104.5°E–122.5°E) during the Meiyu Season of 1991–2020 [J/DB/OL]. *Digital Journal of Global Change Data Repository*, 2024. https://doi.org/10.3974/geodb.2024.07.04.V1.

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

[7] 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.

[8] 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.

[9] Forzieri, G., Alkama, R., Miralles, D. G., *et al*. Satellites reveal contrasting responses of regional climate to the widespread greening of Earth [J]. *Science*, 2017, 356(6343): 1180–1184.

[10] Li, X., Long, D., Han, Z., *et al*. Evapotranspiration estimation for Tibetan Plateau headwaters using conjoint terrestrial and atmospheric water balances and multisource remote sensing [J]. *Water Resources Research*, 2019, 55(11): 8608–8630.

[11] Wu, J., Gao, X. J. A gridded daily observation dataset over China region and comparison with the other datasets [J]. *Chinese Journal of Geophysics*, 2013, 56(4): 1102–1111.

[12] 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.

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

[14] 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. https://doi.org/10.1175/JHM-D-18-0094.1

[15] 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.