

## Postprint: Analysis of Spatiotemporal Dynamics of Evapotranspiration in China Using the PML-V2 Dataset

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### Abstract

Land evapotranspiration is a critical process in land-atmosphere water and heat exchange, representing an essential component of global water transport and energy conversion. Identifying the spatiotemporal dynamic characteristics of evapotranspiration holds significant importance for investigating regional water cycles and energy conversion. This study employs observational data from nine flux stations to comparatively analyze the applicability of three global evapotranspiration products (GLEAM, MOD16, and PML-V2) across China. Building upon this, the land surface evapotranspiration product demonstrating optimal applicability in China is selected to analyze the spatiotemporal dynamic characteristics of land surface evapotranspiration in China from 2003 to 2020. The results indicate: (1) The PML-V2 evapotranspiration product exhibits the best applicability in China. (2) Temporally, evapotranspiration in China displays an increasing trend during the study period; spatially, it demonstrates a general increasing gradient from northwest to southeast throughout the study period. (3) Based on Hurst exponent analysis, future evapotranspiration changes in China are expected to exhibit a trend opposite to historical patterns; that is, whereas evapotranspiration showed an overall increasing trend in the past, it is projected to decline in the future. This study, through analyzing the spatiotemporal dynamic characteristics of land surface evapotranspiration in China, aims to provide valuable references for regional water resource utilization and optimal allocation.

## Full Text

# Temporal and Spatial Dynamic Characteristics Analysis of Evapotranspiration in China Based on the PML-V2 Dataset

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## Abstract

Terrestrial evapotranspiration is a crucial process in land-atmosphere water and heat exchange and represents a vital component of global water migration and energy conversion. Identifying the spatiotemporal dynamic characteristics of evapotranspiration holds significant importance for studying regional water cycles and energy conversion. This research utilizes observational data to compare and analyze the suitability of three global evapotranspiration products (GLEAM, MOD16, and PML-V2) across China. Building upon this evaluation, we selected the most suitable terrestrial evapotranspiration product data for the Chinese region and analyzed its spatiotemporal dynamic characteristics. The results demonstrate: (1) The PML-V2 evapotranspiration product exhibits the best suitability for the Chinese region. (2) Temporally, China's evapotranspiration showed an increasing trend during the study period; spatially, evapotranspiration generally increased from northwest to southeast during the study timeframe. (3) According to Hurst index analysis of future evapotranspiration changes in China, the expected trend will oppose past performance—while evapotranspiration previously showed an overall increasing trend, future evapotranspiration is predicted to decline. This study analyzes the spatiotemporal dynamic characteristics of terrestrial evapotranspiration in China to provide a reference for regional water resource utilization and optimal allocation.

**Keywords:** evapotranspiration; suitability; dynamic characteristics; China

## 1. Introduction

Research on evapotranspiration is of great significance for rational water resource allocation, crop yield improvement, and regional climate dynamic analysis. Currently, direct measurement of evapotranspiration is generally limited to small scales using methods such as lysimeters, Bowen ratio systems, and eddy covariance towers, making it impractical to obtain actual measurements for large regional scales. However, with the development of remote sensing technology and empirical theoretical models, large-scale actual evapotranspiration estimation has become feasible. Presently, the main global and regional products with good fitting performance include MOD16 and GLEAM evapotranspiration products based on the Penman-Monteith equation.

The physical mechanisms of evapotranspiration are influenced by various surface parameters including climate and environmental factors. Analyzing the spatiotemporal dynamic characteristics of evapotranspiration across China enables macroscopic understanding of national climate evapotranspiration conditions and future changes, providing data sources and analytical foundations for drought early warning and water resource scheduling. Most scholars have primarily focused on regional-scale evapotranspiration analysis or potential evapotranspiration calculated through improved Penman-Monteith formulas, often neglecting product suitability when selecting evapotranspiration products for analysis. This study evaluates the suitability of three evapotranspiration products in China using flux station data from nine Chinese sites published in the FLUXNET2015 dataset, then analyzes the spatiotemporal dynamic characteristics of evapotranspiration across China using the most suitable product.

## 2. Study Area and Data

### 2.1 Study Area

China is located in southeastern Asia with an overall topography that is high in the west and low in the east, featuring diverse climate types. According to climate zoning data from the Resource and Environmental Science Data Center of the Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, the study area is divided into nine primary climate zones based on accumulated temperature during periods with daily average temperature  $\geq 10^{\circ}\text{C}$  and the multi-year average temperature of the coldest month or extreme minimum temperature as heat indices, and aridity index as a moisture indicator. The Nansha Islands are excluded from this study due to their small and dispersed area. The study area is illustrated in [Figure 1: see original paper].

### 2.2 Data Sources

**2.2.1 Flux Station Data** Due to the completeness of the FLUXNET2015 dataset (<https://fluxnet.org>) and its advanced methods for handling missing or anomalous values, this study selected nine flux stations from the dataset located in China (excluding one site with large errors) to evaluate the suitability of global evapotranspiration products in the region. The stations are DK-Sor, HK-WS1, CN-Qia, CN-HaM, CN-Dan, CN-Din, CN-Ha2, and CN-Du2. Station distribution is shown in [Figure 1: see original paper] and detailed information is provided in .

**2.2.2 GLEAM Evapotranspiration Product** The GLEAM (Global Land Evaporation Amsterdam Model) evapotranspiration product estimates actual terrestrial evapotranspiration and plant root zone soil water content from satellite remote sensing data. First released in 2011, the dataset has been revised and developed into the latest GLEAM v3 series. GLEAM v3 maintains roughly

consistent water fluxes with previous versions while improving correlation coefficients with soil moisture content from 28 soil moisture sensors across various layers. Data were downloaded from [www.GLEAM.eu](http://www.GLEAM.eu) at 0.25° resolution and daily temporal scale for the period matching flux station data, then aggregated to monthly means for suitability analysis.

**2.2.3 MOD16 Data** The MOD16 dataset is a global terrestrial evapotranspiration product produced by NASA using Terra satellite platform data through the Penman-Monteith algorithm. The dataset includes monthly evapotranspiration data at 500 m spatial resolution covering global land area ( $1.09 \times 10^8$  km<sup>2</sup>). MOD16 comprises three components: soil evaporation, wet canopy evaporation, and plant transpiration from dry canopy surfaces, calculating daytime and nighttime evapotranspiration separately before integrating to daily scale. Validation using AmeriFlux site data showed the improved algorithm effectively reduced mean absolute error from  $0.39 \text{ mm} \cdot \text{d}^{-1}$  to  $0.33 \text{ mm} \cdot \text{d}^{-1}$ . For this study, monthly data were downloaded from Google Earth Engine for the period matching flux station data.

**2.2.4 PML-V2 Data** The PML-V2 dataset, developed by the Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, uses Google Earth Engine platform with remote sensing data as drivers to calculate global terrestrial evapotranspiration based on the Penman-Monteith-Leuning model at 500 m spatial resolution and 8-day temporal scale. Validated using data from 95 globally distributed flux sites covering 11 vegetation types, the product effectively reduced root mean square error to  $0.69 \text{ mm} \cdot \text{d}^{-1}$  and bias to -1.8%. The dataset covers 2002-2017; this study selected all data for this period and aggregated to monthly means for analysis.

**2.2.5 Other Reference Data** SRTM v3 elevation data for China were obtained from NASA's Jet Propulsion Laboratory at 90 m resolution.

### 3. Methods

#### 3.1 Suitability Evaluation Method

To evaluate the suitability of evapotranspiration products in China, this study compared FLUXNET2015 flux station data with product data using Pearson correlation coefficient and root mean square error (RMSE) as primary metrics.

**Pearson Correlation Coefficient.** The Pearson correlation coefficient ( $r$ ) widely measures correlation strength between two variables. This study used correlation strength between observed and product data as an evaluation index, calculated as:

$$r = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^n (x_i - \bar{x})^2 \sum_{i=1}^n (y_i - \bar{y})^2}}$$

where  $x_i$  and  $y_i$  are sample values,  $\bar{x}$  and  $\bar{y}$  are means, and  $n$  is sample size.

**Root Mean Square Error.** RMSE measures differences between observed and simulated values, calculated as:

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^n (x_i - y_i)^2}{n}}$$

where  $x_i$  is observed data and  $y_i$  is simulated data.

**Taylor Diagram.** Taylor diagrams comprehensively visualize correlation coefficient, standard deviation, and RMSE, with observation points marked as black dots; closer proximity indicates better product performance.

### 3.2 Spatiotemporal Dynamic Characteristics Analysis

Spatiotemporal dynamic analysis employs various methods to examine temporal and spatial patterns and predict trends, providing references for water resource planning. Methods include:

- **Coefficient of Variation (CV):** Measures temporal stability, with larger CV indicating greater interannual dispersion.
- **Theil-Sen Median:** Robust non-parametric trend calculation; positive  $\beta$  indicates increasing trends, negative  $\beta$  indicates decreasing trends.
- **Mann-Kendall Test:** Non-parametric trend significance test; when  $|Z|$  exceeds critical values, trends are significant.
- **Hurst Index:** Measures long-term memory;  $H = 0.5$  indicates random series,  $H > 0.5$  indicates strong positive autocorrelation (future consistent with past),  $H < 0.5$  indicates strong negative autocorrelation (future opposite to past).

## 4. Results

### 4.1 Evapotranspiration Product Suitability Evaluation

Comparison of nine flux stations shows that except for the DK-Sor site, all products correlate well with observations, with generally consistent temporal trends. [Figure 2: see original paper] presents site fitting results, while [Figure 3: see original paper] shows Taylor diagrams. PML-V2 demonstrates superior performance across all metrics, with correlation coefficients, standard deviations, and RMSE values closest to observations. GLEAM and MOD16 perform less favorably. Overall, PML-V2 exhibits clear advantages in both temporal and

spatial fitting with station data, showing good suitability for China. Therefore, PML-V2 was selected for spatiotemporal dynamic analysis.

#### 4.2 Spatial Distribution Characteristics (2003–2020)

National multi-year average evapotranspiration was calculated from PML-V2 data. Evapotranspiration zones were classified as low ( $<200 \text{ mm} \cdot \text{a}^{-1}$ ), medium ( $200\text{--}400 \text{ mm} \cdot \text{a}^{-1}$ ), and high ( $>400 \text{ mm} \cdot \text{a}^{-1}$ ). Spatial distribution shows a clear increasing trend from northwest to southeast, with maximum values typically near water bodies. The coefficient of variation indicates low spatial variability in the north temperate zone, mid temperate zone, mid subtropical zone, south subtropical zone, and north tropical zone, while the mid temperate zone, south temperate zone, north subtropical zone, and plateau climate zone show high variability. Barren areas (sand, rock, soil) in northwest China exhibit low evapotranspiration due to climate and cover type. At the same latitude, different land cover types and climate zones produce varying evapotranspiration rates. Climate zoning shows good consistency with multi-year average evapotranspiration patterns, with maximum values increasing from northwest to southeast across zones [Figure 4: see original paper], [Figure 5: see original paper].

#### 4.3 Temporal Variation Characteristics (2003–2020)

Temporal variation coefficient spatial distribution [Figure 6: see original paper] and statistics reveal that the north temperate zone, mid temperate zone, south temperate zone, and plateau climate zone show relatively high temporal variation, with CV values of 0.18, 0.16, 0.15, and 0.15 respectively. Similar to spatial analysis, high temporal variability concentrates near basin-edge mountains and coastal cities.

National evapotranspiration shows slight fluctuations with an overall increasing trend at  $0.89 \text{ mm} \cdot \text{a}^{-1}$  [Figure 7: see original paper]. Linear regression for each zone follows the form  $Y = B_0 + B_1X$ , where  $X$  is year,  $B_0$  is constant, and  $B_1$  is coefficient. Theil-Sen median and Mann-Kendall analyses [Figure 8: see original paper], [Figure 9: see original paper] show that except for the north temperate zone, most regions exhibit low confidence levels, indicating non-significant trends. However, local areas show clear increasing or decreasing trends. Overall, both methods consistently indicate a growth trend across China.

#### 4.4 Future Prediction

Hurst index analysis [Figure 10: see original paper] reveals that north temperate, mid tropical, and plateau climate zones have  $H < 0.5$ , indicating future trends opposite to past trends (predicted decrease). Mid temperate and mid subtropical zones show inconsistent trends with low confidence, suggesting stable fluctuations. South temperate, north subtropical, south subtropical, and north tropical zones also have  $H < 0.5$ , indicating opposite future trends (slight

increase becoming slight decrease). China's overall Hurst index is  $<0.5$ , suggesting future evapotranspiration will oppose past growth trends and gradually decrease.

## 5. Discussion

Geoclimatic factors appear to be the primary drivers of large-scale regional evapotranspiration. The choice of research scale is critical for investigating heterogeneity and influencing factors, requiring deeper analysis across different scales and datasets. In water-scarce northern regions, temporal variation coefficients are generally larger, while southern humid regions show lower coefficients. Coastal cities and basin-edge mountains exhibit high temporal variability due to irregular local climate conditions. Maximum and minimum annual evapotranspiration timing varies across zones but correlates within adjacent regions.

## 6. Conclusion

This study evaluated three evapotranspiration products using Chinese flux station data, identifying PML-V2 as most suitable for China. Analysis of 2003–2020 data reveals: (1) Evapotranspiration increases from northwest to southeast, primarily influenced by geographic and meteorological factors. The mid temperate, south temperate, north subtropical, and plateau climate zones show high spatial variability due to heterogeneity, while other zones exhibit stable spatial patterns. (2) Temporal analysis shows small fluctuations across zones, with northern arid regions generally showing higher temporal variation coefficients than southern humid regions. Variation coefficients correlate with land cover type and geographic environment. (3) Trend analysis indicates overall growth, though mostly non-significant at the national scale, with significant local trends. (4) Hurst index prediction suggests future evapotranspiration will oppose past trends, likely decreasing overall. These findings provide valuable references for regional water resource management and ecological hydrology research in China.

## References

- [1] Mu Q Z, Zhao M S, Running S W. Improvements to a MODIS global terrestrial evapotranspiration algorithm[J]. *Remote Sensing of Environment*, 2011, 115(8): 1781-1800.
- [2] Zhang Y Q, Kong D D, Gan R, et al. Coupled estimation of 500 m and 8 day resolution global evapotranspiration and gross primary production in 2002–2017[J]. *Remote Sensing of Environment*, 2019, 222: 165-182.
- [3] 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.
- [4] Liu Changming, Zhang Dan. Temporal and spatial change analysis of the sensitivity of potential evapotranspiration to meteorological influencing factors

in China[J]. *Acta Geographica Sinica*, 2011, 66(5): 579-588.

[5] Zhang Qiaofeng, Liu Guixiang, Yu Hongbo, et al. Temporal and spatial dynamic of ET based on MOD16A2 in recent fourteen years in Xilingol Steppe[J]. *Acta Agrestia Sinica*, 2016, 24(2): 286-293.

[6] Deng Xingyao, Liu Yang, Liu Zhihui, et al. Temporal spatial dynamic change characteristics of evapotranspiration in arid region of northwest China[J]. *Acta Ecologica Sinica*, 2017, 37(9): 2994-3008.

[7] Zheng Defeng, Zhan Shiyao, Cao Yongqiang. Analysis of spatiotemporal dynamic characteristics on potential evapotranspiration and water budget in Hebei Province[J]. *Pearl River*, 2022, 43(3): 54-65.

[8] Zuo Daxing, Zang Chuanfu, Wang Lina. Temporal and spatial variation of potential evaporation and its influencing factors in Pearl River Basin from 1980 to 2019[J]. *Pearl River*, 2022, 43(10): 41-49.

[9] Pastorello G, Trotta C, Canfora E, et al. The FLUXNET2015 dataset and the ONEFlux processing pipeline for eddy covariance data[J]. *Scientific Data*, 2020, 7(1): 1-27.

[10] Zhu Binghai. *Climate of China*[M]. Beijing: Science Press, 1962: 147-150.

[11] Miralles D G, Holmes T R H, De Jeu R A M, et al. Global land surface evaporation estimated from satellite based observations[J]. *Hydrology and Earth System Sciences*, 2011, 15(2): 453-469.

[12] Miralles D G, Van Den Berg M J, Gash J H, et al. El Niño La Niña cycle and recent trends in continental evaporation[J]. *Nature Climate Change*, 2014, 4(2): 122-126.

[13] Running S W, Mu Q Z, Zhao M S, et al. MODIS global terrestrial evapotranspiration (ET) product (MOD16A2/A3 and year end gap filled MOD16A2GF/A3GF) NASA Earth Observing System MODIS Land Algorithm (for collection 6)[M]. Washington, DC, USA: National Aeronautics and Space Administration, 2019: 1-37.

[14] Farr T G, Rosen P A, Caro E, et al. The shuttle radar topography mission[J]. *Reviews of Geophysics*, 2007, 45(2): RG2004, doi: 10.1029/2005RG000183.

[15] Zhang Kun. *Parameter sensitivity analysis and optimization for remote sensing based evapotranspiration model*[D]. Lanzhou: Lanzhou University, 2018.

[16] Chen Long. *Comparison of estimated global gross primary productivity and evapotranspiration based on different remote sensing data*[D]. Beijing: China University of Mining and Technology, 2017.

[17] Xie Xuhong, Wu Lei, Wei Jianmei, et al. Applicability assessment of AET products in the alpine regions of northwestern China[J]. *Journal of Lanzhou University (Natural Sciences Edition)*, 2021, 57(4): 437-446.

- [18] Wang Shiwei. Spatial and temporal dynamics of drought in Inner Mongolia in recent 20 years and its response to seasonal climate and evapotranspiration[J]. Research of Soil and Water Conservation, 2022, 29(4): 231-239.
- [19] Zhang Peng, Zhang Shengwei, Xu Ran, et al. Spatiotemporal dynamics of evapotranspiration in Horqin Sandy Land based on remote sensing[J]. Research of Soil and Water Conservation, 2021, 28(3): 399-405, 414-415.
- [20] Zhang Xiang, Zhu Xiaoyu, Shen Beibei, et al. Analysis of temporal and spatial variation of vegetation evapotranspiration in Hulun Buir[J]. Chinese Journal of Agricultural Resources and Regional Planning, 2020, 41(4): 308-316.
- [21] Zhang Zhao, Chen Baorui, Xin Xiaoping. Variations of temperature and precipitation pattern in Hulunber grassland from 1960 to 2015[J]. Chinese Journal of Agricultural Resources and Regional Planning, 2018, 39(12): 121-128.
- [22] Gu Xue, Dong Guotao, Jiahe, et al. Effects of NDVI/land use on spatiotemporal changes of evapotranspiration in the Yellow River Basin[J]. Arid Land Geography, 2021, 44(1): 158-167.
- [23] Fensholt R, Langanke T, Rasmussen K, et al. Greenness in semi arid areas across the globe 1981–2007: An earth observing satellite based analysis of trends and drivers[J]. Remote Sensing of Environment, 2012, 121: 144-158.
- [24] Jiapaer G, Liang S L, Yi Q X, et al. Vegetation dynamics and responses to recent climate change in Xinjiang using leaf area index as an indicator[J]. Ecological Indicators, 2015, 58: 64-76.
- [25] Zhang H F, Shu Y T, Yang O. Estimation of Hurst parameter by variance time plots[C]//1997 IEEE Pacific Rim Conference on Communications, Computers and Signal Processing, PACRIM. 10 Years Networking the Pacific Rim, 1987–1997. Canada: IEEE, 1997, 2: 883-886.
- [26] Chen Yaoliang. Land use and land cover change and its impacts on evapotranspiration in inland river basin of arid region[D]. Hangzhou: Zhejiang University, 2018.
- [27] Zhan Mingyue. Effects of vegetation greening on land evapotranspiration in China based on model data[D]. Nanjing: Nanjing University of Information Science & Technology, 2022.
- [28] Yang Xiaohui, Yu Fengcun. Analysis of evapotranspiration and its influencing factors in reed wetland of Chaohu Lake[J]. Harnessing the Huaihe River, 2022(4): 21-23.

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