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# Extended global evapotranspiration and gross primary production dataset for 1981–2024

**Zhenwu Xu** and **Yongqiang Zhang**

*Key Laboratory of Water Cycle and Related Land Surface Processes, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China*

*Email:* xuzhenwu@igsnrr.ac.cn

**Abstract:** The Penman–Monteith–Leuning (PML) model is a remote-sensing-based diagnostic framework that provides physically consistent and coupled estimates of terrestrial evapotranspiration (ET) and gross primary production (GPP). Through two major version updates, Zhang et al. (2019) released the first globally comprehensive dataset of coupled ET and GPP at 500 m, 8-day resolution for 2003–2019, which has been cited over 700 times and is used by approximately 200 international organizations and regional water management agencies, including the World Meteorological Organization (WMO), for hydrological and ecological assessments. Nevertheless, there is an increasing demand for datasets that extend to the most recent years (to 2024 onwards) as well as to the pre-2000 period, as the absence of such long-term records constrains the ability to detect multi-decadal trends and attribute recent anomalies in a broader temporal context.

Here, we present the latest updates to the PML-V2 model, which extends the dataset to 1981–2024 through improved parameterization and bias correction with basin-scale water balance constraints. Key updates are as follows: (1) On the basis of PML-V2.2a — a 500 m, 8-day product based on MODIS LAI and albedo data for 2000-2024 and updated annually for nearest applications, we additionally release PML-V2.2b, derived from AVHRR LAI and albedo data, providing 0.1° bimonthly estimates for 1981–2020 to support long-term historical analyses. (2) Model calibration and evaluation are strengthened by expanding the eddy covariance network from 102 to around 400 globally distributed sites, integrating FLUXNET2015 with recent AmeriFlux, OzFlux, and ChinaFlux observations from a bottom-up perspective. (3) An additional multi-forcing framework has been implemented by incorporating the high-resolution MSWEP precipitation dataset together with three independent climate reanalysis products (ERA5-Land, MSWX, and MERRA-2) for the other variables. This enables inter-forcing comparison, uncertainty quantification, and improved robustness by leveraging differences among climate drivers. (4) Basin-scale water balance datasets are further applied in post-processing bias-correction to enhance hydrological consistency at large-basin and regional scales from a top-down perspective.

Cross-validation across the expanded flux tower network shows that the updated calibration substantially improves model performance. Compared to the previous version, site-level ET estimation accuracy improved, showing a noticeable reduction in RMSE and a corresponding increase in NSE, particularly for plant functional types with previously limited sites and lower cross-validation robustness. The incorporation of basin-scale water balance constraints further reduced systematic biases, leading to consistent reductions in RMSE and gains in NSE in large-basin evaluations. These improvements are evident across diverse climatic and biome zones, demonstrating the combined benefits of bottom-up calibration and top-down hydrological correction.

The two new products address different scientific and operational needs. The high-resolution PML-V2.2a (500 m, 8-day, 2000-2024) is suitable for near-real-time applications and fine-scale analyses, including assessing ET and GPP time series impacted by climate change and land surface changes, such as vegetation greening, land use and land cover change, wildfires. In comparison, the long-term PML-V2.2b (0.1°, bimonthly, 1981-2020) enables reproducible large-scale ecohydrological and climate attribution studies over four decades, such as identifying multi-decadal water and carbon cycle trends or placing recent anomalies in a historical context.

By integrating extended satellite records, multi-forcing climate inputs, and a substantially expanded observational network, PML-V2.2 provides a robust, four-decade-long dataset for monitoring and understanding coupled water–carbon processes under global environmental change. This bridges the gap between near-real-time monitoring and long-term historical analysis, thereby supporting both research and operational water management. Future efforts will focus on reconciling differences between AVHRR- and MODIS-based inputs, improving model structure, and further reducing uncertainty.

***Keywords:*** *Evapotranspiration, gross primary production, Penman-Monteith Leuning model, AVHRR, MODIS*

***References***

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