

Detailed information about 12 GPP products

1. Light Use Efficiency (LUE) Models

(1) MODIS GPP

MOD17A2H is the standard Moderate Resolution Imaging Spectroradiometer (MODIS) GPP product at 500 m and 8-day resolution. It follows a radiation-use efficiency framework in which GPP equals absorbed photosynthetically active radiation (APAR) multiplied by a biome-specific maximum light-use efficiency, scaled by temperature and vapor pressure deficit (VPD) stress. Because of its long temporal coverage and global availability, MOD17A2H is one of the most widely adopted satellite-based GPP products and serves as a baseline reference in many intercomparison studies.

(2) GLASS GPP

Global Land Surface Satellite (GLASS) provides a satellite-derived GPP product based on the Eddy Covariance-Light Use Efficiency (EC-LUE) model. The framework integrates flux-tower data and estimates daily GPP from minimal inputs. The algorithm uses vegetation indices and meteorological factors such as the evaporative fraction as a soil-moisture proxy to adjust potential carbon uptake. GLASS GPP offers consistent long-term records and has been widely used to assess vegetation productivity dynamics across multiple biomes.

(3) VPM GPP

The Vegetation Photosynthesis Model (VPM) is an improved LUE framework that explicitly separates photosynthetically active vegetation from non-photosynthetic components using the Enhanced Vegetation Index (EVI) and the Land Surface Water Index (LSWI). By incorporating LSWI to represent canopy water stress and phenological transitions, VPM produces more realistic seasonal dynamics of GPP, particularly in evergreen forests and water-limited ecosystems. The VPM product has been extensively validated against eddy-covariance observations and is a representative second-generation LUE product.

(4) TL-LUE GPP

The Two-Leaf Light Use Efficiency (TL-LUE) model is an improved GPP framework that explicitly separates sunlit and shaded foliage. Using a two-leaf LUE scheme, it computes the photosynthetic rates of sunlit and shaded leaves separately, accounts for the canopy's nonlinear light response and differing saturation behaviors and thereby reduces the biases inherent in big-leaf LUE models. TL-LUE is particularly effective in capturing GPP under diffuse-radiation conditions and in structurally complex canopies.

2. Land Surface Models (LSMs)

(5) BEPS GPP

The Boreal Ecosystem Productivity Simulator (BEPS) is a process-based, remote-sensing-driven land surface model that couples canopy photosynthesis, energy balance, and water cycling. BEPS adopts a two-leaf approach and integrates satellite-derived LAI and clumping index to constrain canopy structure, enabling realistic simulation of GPP across diverse ecosystems. As one of the

most widely used remote-sensing-driven process-based LSMs, BEPS provides an important benchmark within the LSM category in our inter-comparison framework.

(6) CLASSIC GPP

The Canadian Land Surface Scheme Including Biogeochemical Cycles (CLASSIC) is a process-based land surface model that simulates coupled energy, water, and carbon cycles within the terrestrial biosphere. CLASSIC explicitly represents photosynthesis using a Farquhar-type biochemical scheme, dynamic vegetation processes, and soil carbon turnover, and has been widely used in the TRENDY ensemble for global carbon-cycle assessments. The CLASSIC GPP outputs are produced under the TRENDY v12 S3 protocol, in which climate, atmospheric CO₂, and land-use change vary over time according to historical reconstructions.

(7) O-CN GPP

O-CN is a process-based terrestrial biosphere model that extends the ORCHIDEE framework by incorporating a fully coupled nitrogen cycle alongside carbon and water dynamics. The model represents the interactions between leaf nitrogen, photosynthetic capacity, and stomatal conductance, allowing it to capture the influence of nutrient limitation on GPP. In this study, O-CN GPP outputs are taken from the TRENDY v12 S3 simulations, providing an LSM-based estimate that explicitly accounts for nitrogen constraints on terrestrial productivity.

(8) YIBs GPP

The Yale Interactive Terrestrial Biosphere (YIBs) model is a process-based vegetation model that simulates land carbon, water, and energy fluxes with dynamic vegetation phenology and interactive leaf area index. YIBs employs a Farquhar-Ball-Berry coupled photosynthesis-stomatal conductance scheme and explicitly accounts for the effects of ozone damage and diffuse radiation on canopy photosynthesis. The YIBs GPP product used here is provided by the TRENDY v12 S3 simulations under historical climate, CO₂, and land-use forcings.

3. Observation-constrained Products

(9) PML-V2 GPP

The Penman-Monteith-Leuning Version 2 (PML-V2) is a water-carbon coupled diagnostic model that estimates evapotranspiration (ET) and GPP simultaneously. Building on Penman-Monteith theory and Leuning's stomatal-conductance formulation, it links plant water use with carbon uptake through a shared canopy conductance, maintaining consistency between moisture fluxes and photosynthesis. The PML-V2 product is calibrated against global eddy-covariance observations and provides high-resolution, observation-constrained estimates of GPP and ET.

(10) FLUXCOM GPP

FLUXCOM is a data-driven GPP product based on the upscaling of FLUXNET eddy-covariance measurements using machine-learning methods. In this study we use the “RS+METEO” version, which relies on ERA5 meteorological forcings and applies a full-factorial combination of machine-learning algorithms and flux-partitioning schemes (Jung et al., 2020; Tramontana et al., 2016). This version is more independent of the MODIS GPP product than the RS-only version and provides observation-constrained estimates of spatial patterns and seasonal dynamics. Its sensitivity to long-

term trends, however, is limited because atmospheric CO₂ is not used as a predictor.

(11) GOSIF GPP

The Global OCO-2 SIF GPP (GOSIF) product uses satellite solar-induced chlorophyll fluorescence (SIF) as the core observation and constructs empirical SIF-GPP relationships at the global scale. The method integrates universal and biome-specific linear relations and applies ensemble averaging to enhance stability. Because SIF is a direct optical signal of canopy photosynthetic activity, GOSIF provides a relatively process-independent, observation-constrained estimate of GPP that complements LUE- and LSM-based products.

(12) VODCA2GPP

Vegetation Optical Depth Climate Archive to GPP version 1 (VODCA2GPP v1) is a global GPP dataset derived from a data-driven carbon-sink model. It uses microwave-based vegetation optical depth (VOD) to retrieve information on aboveground biomass and canopy water status, which is then used to estimate terrestrial carbon uptake and infer GPP. Because VOD signals are largely independent of visible/near-infrared optical inputs, VODCA2GPP provides an observation-constrained estimate of GPP that is structurally independent of the optically driven products evaluated in this study.

Table S1. Information on the 33 eddy-covariance flux-tower observations

Land cover	Station name (abbreviation)	Longitude / °E	Latitude / °N	Temporal resolution	Observation period	Reference
Cropland	Gucheng (GC)	115.67	39.13	30min	2020	L. Zhou et al., 2023
	Jinzhou (JZ)	121.20	41.15	30min	2005-2014	S. Zhang et al., 2023
	Jurong (JR)	119.22	31.81	30min	2015-2020	Y. Zhou et al., 2023
	Panjin Rice Field Station (PJC)	121.96	40.94	30min	2018-2020	Jia et al., 2023a
	Yucheng (YC)	116.57	36.83	30min	2003-2010	Zhao et al., 2021
	Changling Rice Field Station (CLC)	123.47	44.60	30min	2018-2020	Dong et al., 2023
Forest	Ailaoshan (ALS)	101.03	24.54	Monthly	2009-2013	Qi et al., 2021a
	Baotianman (BTM)	111.94	33.50	30min	2017-2018	Niu et al., 2023
	Danzhou Rubber Forest Station (DZRF)	109.48	19.55	Monthly	2010-2018	Yang et al., 2022
	Dinghushan (DHS)	112.53	23.17	30min	2003-2010	Li et al., 2021
	Huzhong (HZ)	121.02	51.78	30min	2014-2018	Yan et al., 2023
	Jinfoshan National Station (JFSN)	107.15	29.02	30min	2020	Tang et al., 2023
	Maoershan Ecosystem Research Station (MES)	127.40	45.25	30min	2016-2018	X. Wang et al., 2023
	PuDing (PD)	106.32	26.60	30min	2015-2019	Y. Wang et al., 2023
	Qianyanzhou (QYZ)	115.07	26.73	30min	2003-2010	Dai et al., 2021
	Xishuangbanna (XSBN)	101.21	21.96	Monthly	2003-2015	Qi et al., 2021c
	Xishuangbanna Rubber Forest Station (XSBNRF)	101.27	21.90	30min	2010-2014	Yu et al., 2021
	Xiaolangdi (XLD)	112.47	35.03	30min	2016-2017	Huang et al., 2023
	Yanshan artificial coniferous forest station (YSF)	116.66	40.42	30min	2020	Du et al., 2023
	Changbaishan (CBS)	128.10	42.40	30min	2003-2010	Wu et al., 2021
Grassland	Damao (DM)	110.33	41.64	30min	2015-2018	Jiaxin Song et al., 2022
	Dangxiong (DX)	91.08	30.85	30min	2004-2010	Chai et al., 2021
	Haibei Grassland Station (HBG)	101.31	37.61	30min	2015-2020	F. Zhang et al., 2023b
	Inner Mongolia (NMG)	116.40	43.33	30min	2003-2010	Hao et al., 2021
	Ruoergai (REG)	102.55	32.80	30min	2015-2020	Chen et al., 2023
	Three River Source Station (TRS)	100.70	35.25	30min	2012-2016	He et al., 2023
	Yuanjiang (YJ)	102.18	23.47	30min	2013-2015	Qi et al., 2021b
Shrubland	Haibei Shrubland Station (HBS)	101.33	37.67	30min	2003-2020	Zhang et al., 2021 F. Zhang et al., 2023a
	Yanchi Station (YCS)	107.23	37.71	30min	2012-2016	Han et al., 2023
	Yanshan Shrubland Station (YSS)	116.65	40.42	30min	2020	Du et al., 2023
Wetland	Haibei Wetland Station (HBW)	101.32	37.60	30min	2004-2009	Zhang et al., 2020
	Yellow River Delta Station (YRD)	118.98	37.77	30min	2011-2018	Wei et al., 2024
	Panjin Reed Wetland Station (PJRW)	121.96	40.93	30min	2018-2020	Jia et al., 2023b

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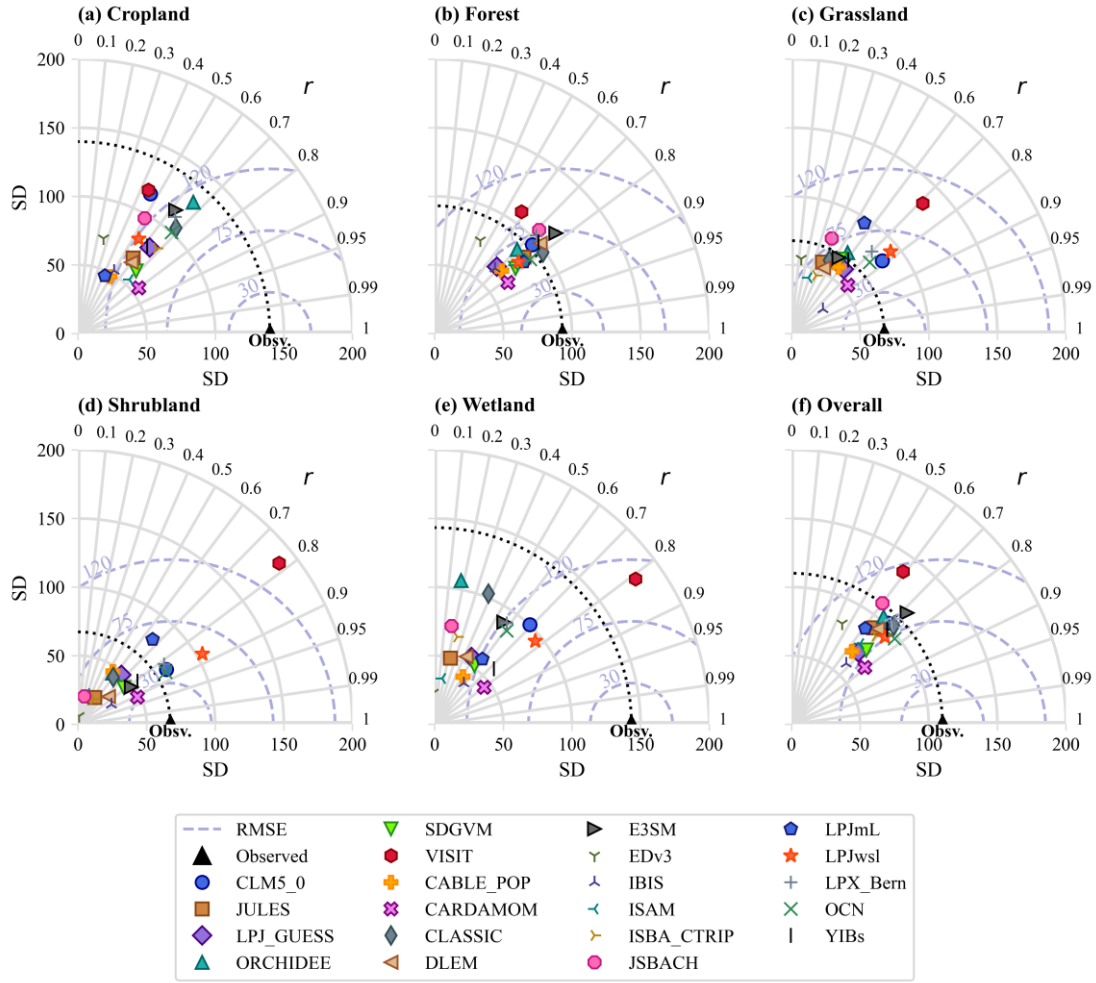


Fig. S1. Taylor diagrams showing the performance of TRENDY v12 models against eddy-covariance flux tower observations across China for (a) cropland, (b) forest, (c) grassland, (d) shrubland, (e) wetland, and (f) overall performance across all ecosystem types; displayed metrics include r , SD ($\text{g C m}^{-2} \text{ month}^{-1}$), and RMSE ($\text{g C m}^{-2} \text{ month}^{-1}$), where points near the observation indicate higher r , SD closer to the reference, and lower RMSE.