Estimation of Terrestrial Biosphere Gross Primary Production Using Satellite Data and Climate Data

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1. Background
Gross Primary Production (GPP) defined as the amount of carbon uptake by vegetation through photosynthesis, constitutes a key area of climate change research. GPP is the starting point of the terrestrial carbon biogeochemical cycle and thus serves as the gateway for energy and carbon required for all ecosystem processes. There is thus a need to better understand the mechanisms that control terrestrial GPP, its accurate estimation, and the dynamics of carbon fluxes between the biosphere and atmosphere to help quantify potential changes resulting from global climate change. GPP is an important biophysical parameter of any ecosystem that plays a key role in the spatiotemporal dynamics of CO₂. As at a global scale, direct measurements of GPP do not exist, GPP prediction has become a key issue for ecologists and global climate change experts for quantifying global carbon cycles.

2. Data and Methods
MODIS LAI and fPAR Products: Leaf Area Index (LAI) and Fraction of Absorbed Photosynthetically Active Radiation (fPAR) depend on the canopy structure, vegetation element optical properties, atmospheric conditions, and angular configuration.

NOAA World Monthly Climate Data: Global gridding pressure, vapor pressure and sunshine hours were interpolated from approximately 2 000 surface data collection stations by using Kriging method. Pressure and vapor pressure were used to calculate photon flux, and sunshine hours were used to estimate photosynthetic time.

Estimation of leaf-internal CO₂ concentration: CO₂ concentration data is an important factor in GPP estimation, since CO₂ as the raw material directly participate in plants photosynthesis. The data in this study are global monthly CO₂ concentration data in 2014 captured by GOSAT, the world's first spacecraft to measure the concentrations of CO₂ from space.

Calculation of PAR photon flux density: It provides light and heat for the Earth and energy for photosynthesis. Solar insolation data are from National Aeronautics and Space Administration (NASA) Earth Observatory, based on The Fast Longwave And SHortwave Radiative Fluxes (FLASHFlux) data.

Acquisition of landcover component maps: Landcover is an important factor to global primary productivity estimates. If vegetation covers are different, Photosynthetic capacity will be different. The MODIS Land Cover Type product, MCD12Q1, provides data characterizing five global land cover classification systems.

Inversion of land daytime temperatures: Near-surface air temperature (T_air) is measured 1.5m above the ground level at official weather stations with sensors protected from radiation and adequately ventilated.

Estimation of GPP by terrestrial biosphere: As our photosynthesis model, used the Simple Biosphere Model (SiB), which is based on leaf- and canopy-level photosynthesis. SiB Model was originally developed by Piers Sellers in the mid-1980’s as an internally-consistent module to surface-atmosphere exchanges of radiation, heat, moisture, and momentum over land. Since that time it has been extended to improved treatment of carbon cycling, soils, snow, hydrology, stable isotopes, phenology, and crops.
3. Results

Fig. 1 shows that GPP in the Tropics is always higher than other areas (e.g., the Amazon Rainforest, Congo Rainforest, and Indonesia). Then it was followed by monsoonal subtropical regions (e.g., Southeastern Asia, Easternmost Australia), humid temperate regions in Eastern North America, and Western and Central Europe. The area of low GPP are always typical with adverse environments, such as high altitude regions (e.g., Tibetan Plateau) and high latitudes (e.g., Greenland, Northern Canada, Northern Russia) with a short growing season and low temperatures, or erg regions (e.g., Sahara, Taklamakan, Arabian) characterized by low precipitation, dry areas where the water availability limits the plant production. In addition, the results correctly capture the GPP pattern over the globe that boreal forests have a typical longitudinal gradient in Northern Eurasia with GPP decreasing toward the East as a consequence of increasingly continental climate; GPP over Africa shows a considerable latitudinal symmetrical distribution due to the lack of airflow barrier. Southern Africa is surrounded by ocean on three sides and far away from other continents, with richer precipitation than Northern Africa, thus GPP are larger than northern GPP; the pattern of GPP over North America shows notable East-West differences, basically due to precipitation distribution brought by ocean currents and winds; South America is a warm and humid continent, mainly in tropical climate type with relatively larger GPP, except the GPP over Andes in Western South America.

4. Discussion

In Fig. 2 the red dots represent the relationship between MODIS GPP Products and GPP from FLUXNET Dataset. The form of GPP from FLUXNET Dataset is measured by using site observed data. We utilized the measured GPP and MODIS GPP products in the same year and same location to draw the scatter relations plot. The MODIS GPP products of 2014 were utilized to set up the relationship with the estimated GPP in this study, as green dots. The version of the utilized MODIS GPP products is the same, to ensure that uncertainty and accuracy are consistent. We use MODIS products as the "Bridge" to compare the estimated GPP with the observed GPP. Red and green dashed lines are the relationship between observed data and MODIS data, estimated data and MODIS data, respectively. The red and green dashed line represent the linear relationship between MODIS GPP and measured GPP (y=1.1453x, p<0.001), MODIS GPP and estimated GPP (y=1.1157x, p<0.001), respectively.

Fig. 1 Global spatial distribution of estimated annual GPP.

Fig. 2 Relationship between estimated annual GPP and annual GPP from FLUXNET.