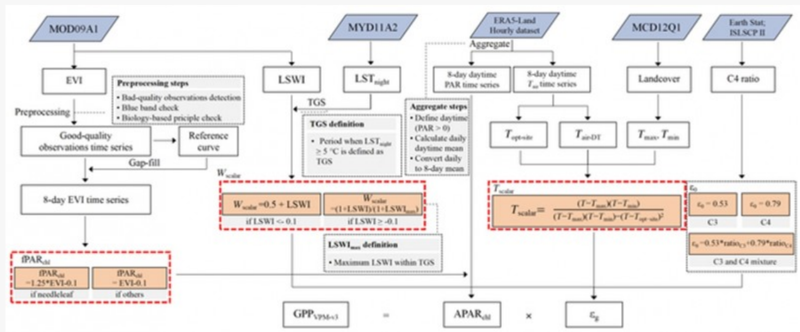
VPM 3.0: a leap forward in global GPP estimation

FAYETTEVILLE, GA, UNITED STATES, April 28, 2025 /EINPresswire.com/ -- A recent study has introduced the next-generation Vegetation Photosynthesis Model (VPM 3.0), delivering a major leap in the accuracy of global gross primary production (GPP) estimates.



Workflow and input data of VPM v3.0 to simulate global GPP (GPPVPM-v3).

Accurately estimating the gross primary production (GPP) of terrestrial vegetation is critical for assessing the global carbon cycle and its role in climate change. However, existing models struggle with discrepancies in GPP estimates and fail to fully account for site-specific environmental factors, leading to uncertainties in carbon flux predictions. These limitations create significant challenges for climate policy and ecosystem monitoring. Addressing these issues, researchers have developed a more precise and adaptable model to bridge these gaps.

Published (DOI: 10.34133/remotesensing.0471) on March 8, 2025, in the Journal of Remote Sensing, researchers from the University of Oklahoma and collaborating institutions unveiled VPM 3.0, a refined model designed to overcome critical weaknesses in existing GPP estimation methods. By integrating site-specific temperature optima, leaf-trait-based light absorption, and improved water stress calculations, VPM 3.0 delivers a more nuanced and accurate representation of vegetation productivity. The model leverages high-resolution MODIS satellite imagery and ERA5-Land climate data, providing a more precise tool for studying climate change and ecosystem dynamics on a global scale.

VPM 3.0 introduces three major advancements over its predecessor, VPM 2.0:

1. Site-specific photosynthesis temperature optima, allowing the model to adjust dynamically based on local climatic conditions.
2. Leaf-trait-based light absorption, improving accuracy in estimating how plants absorb and utilize sunlight.
3. Enhanced water stress estimation, refining predictions in arid regions where water availability

is a key limiting factor.

These improvements significantly enhance the model's accuracy and temporal consistency when compared to ground-based GPP measurements and satellite-derived solar-induced fluorescence (SIF) data. In extensive validation tests, VPM 3.0 demonstrated strong agreement with leading GPP products, such as BEPS and BESS, while outperforming previous models in capturing seasonal and spatial variations in vegetation productivity.

The research team validated VPM 3.0 using 205 eddy flux tower sites spanning 11 land cover types, totaling 1,658 site-years of data. The model achieved a slope of 0.97, an R^2 of 0.78, and an RMSE of 1.46 gC m^{-2} day^{-1} compared to direct GPP measurements—highlighting its exceptional accuracy. Additionally, over 55% of analyzed grid cells exhibited a correlation coefficient (r) above 0.8 when compared with TROPOMI SIF data, reinforcing the model's reliability across diverse ecosystems, from tropical rainforests to semi-arid landscapes.

"VPM 3.0 represents a major step forward in our ability to estimate global GPP with unprecedented accuracy," said Dr. Xiangming Xiao, the lead researcher. "This model not only enhances our understanding of the global carbon cycle but also provides a powerful tool for climate change studies and ecosystem monitoring."

The study leveraged MODIS surface reflectance data (MOD09A1) and ERA5-Land climate reanalysis data to drive its simulations. A novel approach was used to determine site-specific temperature optima based on EVI-Tair response curves, alongside an improved water stress estimation framework. To ensure high data accuracy, the researchers implemented a rigorous quality control process, filtering out low-quality observations and applying biology-based rules to minimize noise in time-series data.

With its enhanced accuracy and adaptability, VPM 3.0 opens new frontiers for global carbon cycle research and climate change mitigation strategies. Future applications could include incorporating CO_2 fertilization effects and utilizing solar-induced fluorescence (SIF) to further refine GPP estimates. By providing long-term, high-precision global GPP datasets, VPM 3.0 promises to be an invaluable asset in advancing our understanding of terrestrial ecosystems and their responses to environmental changes.

References
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