Geophysical Research Abstracts
Vol. 15, EGU2013-7772, 2013
EGU General Assembly 2013

Estimating gross primary productivity (GPP) of forests across southern England at high spatial and temporal resolution using the FLIGHT model

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Forests and woodlands play an important role in CO_2 flux and in the storage of carbon, therefore it is important to be able to estimate gross primary productivity (GPP) and its change over time. The MODIS GPP product (MOD17) provides near-global GPP, but at relatively coarse spatial resolution (1km pixel size) and only every eight days. In order to study the dynamics of GPP over shorter time periods and over smaller areas it is necessary to make ground measurements or use a plant canopy model. The most reliable ground-based GPP data are those from the FLUXNET network, which comprises over 500 sites worldwide, each of which measures GPP using the eddy covariance method. Each FLUXNET measurement corresponds to GPP from an area around the sampling tower, the size and shape of which varies with weather conditions, notably wind speed and direction. The FLIGHT forest light simulation model (North, 1996) is a Monte Carlo based model to estimate the GPP from forest canopies, which does not take into account the spatial complexity of the site or the wind conditions at the time. Forests in southern England are small and embedded in a matrix of other land cover types (agriculture, urban etc.), so GPP estimated from FLIGHT needs to be adjusted to match that measured from a FLUXNET tower. The aim of this paper is to develop and test a method to adjust FLIGHT GPP so that it matches FLUXNET GPP. The advantage of this is that GPP can then be estimated over many other forests which do not possess FLUXNET sites.

The study was based on data from two mixed broadleaf forests in southern England (Wytham Woods and Alice Holt forest), both of which have FLUXNET sites located within them. The FLUXNET meteorological data were prepared for use in the FLIGHT model by converting broadband irradiance to photosynthetically active radiance (PAR) and estimating diffuse PAR, using methods developed in previous work by the authors. The standard FLIGHT model tended to overestimate GPP in the winter and spring period and under-estimate GPP in the summer months. Correction factors were computed based on the midday GPP for each month of the year.

The modified FLIGHT model was used to estimate GPP from each of the two forest sites at hourly intervals over a year. Both sites showed a strong linear relationship between GPP estimated from FLIGHT and GPP measured by FLUXNET (Alice Holt forest, R^2=0.96, RMSE = 2.39 μmol m^{-2} s^{-1}, MBE = 1.32 μmol m^{-2} s^{-1} , Wytham Wood R^2 = 0.97, RMSE = 1.42 μmol m^{-2} s^{-1}, MBE = 0.57 μmol m^{-2} s^{-1}).

The results suggest that the modified FLIGHT model could be used to estimate GPP at hourly intervals over non-instrumented forest sites across southern England, and thereby obtain regional estimates of GPP at high spatial and temporal resolution.

Reference

North, P. R. J. (1996). Three-Dimensional Forest Light Interaction Model Using a Monte Carlo Method. *IEEE Transactions on Geoscience and Remote Sensing, 34*(4), 946-956.