A Model for Instantaneous and Daily FAPAR Retrieval

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Abstract:

The Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) is the fraction of the incoming solar radiation in spectral range from 400 to 700 nanometers that is absorbed by plants. FAPAR can be derived from remote sensing measurements and a number of algorithms have been proposed to estimate this important environmental variable. However, most algorithms only consider parameters like normalized differential vegetation index (NDVI), leaf area index (LAI), leaf chlorophyll, and construct the empirical relationships between FAPAR and these parameters. It is known that the sun also affects the FAPAR, and thus a disadvantage for empirical method is that the relationship varies at different time of a day. To overcome this disadvantage, we present a model for FAPAR retrieval considering the solar zenith angle change besides some known parameters.

The model is derived by analyzing the interaction processes of photons and canopy. Along the light incoming path, we mathematically expressed the transmission (T_0) and directional reflectance ($\rho_{\theta v,\lambda}$) of canopy. Thus, the absorption of canopy along the incoming path can be calculated. Similarly, we calculated the absorption of canopy along the outgoing path of photons reflected from the background. The two parts of absorption constitute the FAPAR of single band and single direction ($FAPAR^{t}_{\theta v,\lambda}$). The FAPAR in the 2π space and the Photosynthetically Active Radiation (PAR) spectral region is the integral of $FAPAR^{t}_{\theta v,\lambda}$. The final formula is a function of Nilson parameter (λ_0), G function (G_s, G_v), solar zenith angle (θ_s), leaf area index (LAI), background reflectance (ρ_g), and bidirectional reflectance ($\rho_{\theta v,\lambda}$) of canopy. The daily FAPAR is calculated by the integral of instantaneous FAPAR with the weight of cosine value of solar zenith angle.

We conducted the Monte Carlo simulations of FAPAR and compared the results by model and by simulations. The FAPAR for different LAI, solar zenith angle, and leaf angle distribution (LAD) is calculated by the model and simulated by Monte Carlo method. We also analyzed the contribution of background to canopy FAPAR. Results show that canopy absorption along the outgoing path of photons reflected from the background cannot be neglected. The above model considers this contribution and the error is less than 2% compared with Monte Carlo simulation results.

We also further validate the algorithm with field data of daily FAPAR for some crops, such as wheat and corn. Results show that the algorithm, the Monte Carlo method, and the field data share the same daily change trend and similar scale. The error is small and acceptable, proving the feasibility of the proposed model.

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