Unified Optical-Thermal Modeling for Row-planted canopies

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Abstract:

To adequately exploit the information content of remote sensing data from visible to thermal infra-red (TIR) spectral domains, a unified optical-thermal radiation transfer model for row-planted canopies was constructed, and systematically compared against field data and a 3-D radiosity-graphics combined model (RGM, thermal infrared included).

This analytical row model was based on the radiation transfer (RT) equation, which represents the radiation energy balance for vegetative canopy. For the object of operational applications of the unified row crops model, the radiative transfer formulation takes the four-stream RT theory as a basis, and the row crop is abstracted as rectangular cross-section configuration, which is porous so that light beams can penetrate canopy rows through gaps within the row.

The unified row model capitalizes on the recent advance in modeling the transfer of radiation in a plant canopy, for example the hot spot effect for the first orders of scattering as well as a reasonable modeling of multiple scattering processes for row canopies, and the problem of numerical singularities in the calculation of directional reflectance by the original four-stream SAIL model.

Based on the unified row model, row effect, the radiative characteristic of row canopies, is discovered and properly explained in this study. The reasons for the forming of row effect in the visible, near infra-red, and thermal infra-red spectral bands are different. With the row model, the row effect can be quantitatively described as a collective results of row structure, leaf area index (LAI), leaf inclination distribution function (LIDF), leaf and soil spectral parameters, and leaf and soil temperatures (for TIR domains). Comparison between field measured winter wheat's optical and TIR radiation data with modeled results shows the row model has the ability to reproduce the angular distribution of the canopy radiative features as a whole. More systematic comparison of the output of the proposed row model against that of a 3-D computer simulation model (RGM) in three typical spectral bands (red, NIR and TIR) for several representative growth stages of row canopies shows generally very good agreements between these two models, and verifies the existence of row effect, which can be properly modeled by the proposed row model in this study.

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