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Radiative Transfer Modeling Within the Vegetation Based on Virtual Flux Decomposition

A. KALLEL
Tartu Obervatory, Tartuma, Estonia (abdelaziz@aai.ee/+3727410205)

The knowledge of vegetation density and structure at large scales is important for many applications related to global energy budget, carbon cycle, gross primary productivity, monitoring of land use change, hydrology, etc. The tools and methods allowing the acquisition of such information at regional to global scales are based on air- or spaceborne remote sensing data.

Many methods and algorithms have therefore been developed in order to understand the relationships between the vegetation features (namely amount and structure) and the amount of sunlight, through reflectance measurements in the optical and near- to middle-infrared spectral domains. On the one hand, passive optical remote sensing has shown good results in monitoring the changes in canopy structure. On the other hand, despite the long development process, many of the physically-based approaches (i.e., methods based on physical radiative transfer models) suffer from significant shortcomings, in particular considering hyperspectral and multiangular data.

Concerning the energy conservation, although the law of the conservation of radiative energy is one of the basement of the physically-based radiative transfer models, these latter tend to violate it frequently. This arises in particular when considering some finite size scattering elements (leaves or shoots) into equations originally describing a turbid medium (i.e. a medium having components with null size). This phenomenon, called the hot spot effect, is managed in classical radiative transfer model by increasing the reflectance due to the first collision of the solar irradiance calculated for turbid medium.

Recently, Kallel et al. (2008) proposed another formulation in terms of increase of the posterior probability of gap which could itself be viewed as a decreasing of the vegetation density called “the effective vegetation density”. Then, energy conservation is achieved using the same effective density to estimate the upward diffuse flux provided by the first collision of the solar irradiance (E_+^1) as well as the diffuse fluxes created by E_+^1 scattering. Finally, to solve the radiative transfer equations, E_+^1 is divided into virtual sub-fluxes having simple expressions, allowing the division of the radiative transfer problem into a finite number of sub-problems easily solved based on SAIL++ formalism. The simulation tests show that the proposed model conserves the energy with good accuracy, better than AddingSD (Kallel et al., 2008). Compared to 3-D models considered on RAMI database, our model shows similar performances. Finally, compared to AddingSD, the running time is drastically reduced from about 15 minutes to 0.05 seconds.