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Concept of Canopy Spectral Invariants and its Application to Remote Sensing of 3D Canopy Structure and Leaf Physiology

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Interaction of solar radiation with the vegetation canopy is described by the three-dimensional radiative transfer equation. The interaction cross-section that appears in this equation is treated as wavelength independent considering the size of the scattering elements (leaves, branches, twigs, etc.) relative to the wavelength of solar radiation. Although the scattering and absorption processes are different at different wavelengths, the interaction probabilities for photons in vegetation media are determined by the structure of the canopy rather than photon frequency or the optics of the canopy. This feature results in a unique spectrally invariant behavior for a vegetation canopy bounded from below by a non-reflecting surface: simple algebraic combinations of the single-scattering albedo and canopy spectral transmittances and reflectances suppress their dependencies on wavelength through the specification of two spectrally invariant variables – the recollision and escape probabilities. These variables are determined by canopy structure such as tree spatial distribution, crown shape and size and within-crown foliage arrangement. The spectral invariants specify an accurate relationship between the spectral response of a vegetation canopy to incident solar radiation at the leaf and the canopy scales. This result allows for the separation of the structural and radiometric components of the measured signal. The former is a function of canopy structure while latter is a function of canopy biophysical behavior. Here we will discuss the physical basis of the concept and illustrate its application for monitoring canopy structure and leaf physiology from space.