# Multiangular imaging spectroscopy for separating the structural and biochemical reflectance signals of forests


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Imaging spectroscopy, or hyperspectral remote sensing has great potential in environmental monitoring. Among many potential applications, in can be used to investigate the status and functioning of forests at regional to global scales: the spectral reflectance properties of natural objects contain information about the physical properties and chemical composition of these objects.

Effecitve utilization of remote sensing in routine monitoring of vegetation is problematic. The inverse problem, or finding all biophysical variables describing the vegetation cover from remote sensing data alone, is ill-posed and underdetermined. For example, retrieving of the optical properties of elementary scatterers of a forest canopy(leaves, shoots or needles) is an important part of the inverse problem. However, vegetation canopies have three-dimensional internal structure and leaves with different spectral properties can produce similar forest reflectance spectra. Imaging spectroscopy provides a significant advantage over traditional multispectral instruments by making a large number of simultaneous reflectance measurements of the same target at slightly different wavelengths. Unfortunately, this may not suffice. An additional information source for tackling the inverse problem is the angular distribution of reflected radiation. That is, by measuring a vegetation canopy (or any other object with distinct threedimensional structure – also known as volume scatterers) from different viewing angles we obtain an additional tool to overcome the ill-posedness of the problem. However, when using more than one direction, describing and understanding the measurements becomes increasingly difficult.

We propose a novel approach: using multiangular remote sensing data, the reflectance signal of a scatterer with threedimensional structure (e.g., a forest) can be separated into first-order and diffuse components. The first-order component is similar to the signal provided by a reflecting solid surface: it is a linear function of the reflectance of the basic scattering element. This component can be treated as the biochemical reflectance signal, the signal component depending directly on leaf reflectance spectrum. The diffuse scattering is more affected by the 3D structure of the forest stand. Thus, we attempt to separate the structural and biochemical components of total forest reflectance using only basic physical and mathematical principles. As a case study, hemiboreal forest reflectance is separated into first- and higher-order scattering from multiangular remote measurements made by the CHRIS instrument on board ESA's experimental PROBA satellite. The first-order scattering component is shown to depend linearly on the single-scattering albedo of leaves.