

A geometric model for scaling between needle and shoot spectral albedos

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Highlights: The spherically averaged shoot silhouette to total needle area ratio (STAR) can be used as a scaling parameter to link needle- and shoot-level spectral albedos in coniferous canopies.

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Spectral data convey information about the physiological processes and biochemical properties of plant leaves and canopies. Up- and downscaling spectral data between different plant architectural levels, such as from leaf-level to shoot- and canopy-levels, would allow to link spectral remote sensing data with leaf-level physiological processes. Such scaling has long been a challenge, especially in conifers. As the amount of data acquired through imaging spectroscopy, or hyperspectral remote sensing, is rapidly increasing, models for linking spectra measured at different scales are crucially needed in global modeling of plant productivity.

A key property of any scaling model is that the input parameters should have a physical interpretation – preferably an intuitive one –, and it should be possible to measure the parameters in the field or in a laboratory. The link between canopy structure and spectra can be modeled using a relatively recent development in canopy radiation physics: the spectral invariants theory. So far, the spectral invariant that has gained the most attention is the photon recollision probability, the probability by which a photon scattered from a leaf or needle in the canopy will interact within the canopy again. It is directly linked to the geometric structure of a canopy. Spectral invariants may prove useful in developing scaling methods which are as realistic as 3D models but as simple as 1D models, i.e., they offer an efficient way to describe the hierarchical structure of vegetation. Even though theoretical studies on the spectral invariants theory offer promising prospects, empirical observations are needed to validate the performance of these parameters.

In this study (Rautiainen et al. 2012), we tested empirically if it is possible to scale between the spectra of different plant structural levels using one of the spectral invariants, the recollision probability. We focused on two coniferous structures, needles and shoots, using Scots pine as our study species. The recollision probability was calculated directly from a plant structural parameter: the spherically averaged shoot silhouette to total needle area ratio (STAR). We measured both structural and spectral properties of the shoots and needles in laboratory conditions in the Remote Sensing Laboratories of University of Zurich. The hemispherical-bidirectional reflectance distribution functions of each shoot were measured using the LAGOS goniometer and an attached ASD spectroradiometer (350-2500 nm). The spectral albedos for needles were measured in a calibration laboratory using another spectroradiometer and an integrating sphere. The STAR of the shoots was calculated from digital photographs of shoot silhouettes.

We showed that it is possible to scale from needle albedo to shoot albedo using a model based on only one structural characteristic of the shoot, STAR. The upscaling model performed best in the visible and shortwave infrared wavelengths. From the perspective of further applications, we would like to investigate whether the spectral albedo of a whole tree crown (and furthermore, a stand) can be linked to the crown spherically averaged silhouette area through a simple relationship. In other words, can we upscale crown spectral albedo from shoot spectral albedo similarly?

LITERATURE CITED

Rautiainen, M., Möttöus, M., Yáñez-Rausell, L., Homolová, L., Malenovský, Z., Schaepman, ME. 2012. A note on upscaling coniferous needle spectra to shoot spectral albedo. *Remote Sensing of Environment* 17: 469-474.