

MONITORING CANOPY STRUCTURE ACROSS MULTIPLE SCALES FROM LEAVES TO CANOPIES AND STANDS

Yuri Knyazikhin¹, Mitchell A. Schull¹, Pauline Stenbæg², Miina Rautiainen³ and Matti Mõttus⁴

¹Department of Geography and Environment, Boston University, Boston, MA

²Department of Forest Resource Management, University of Helsinki, Finland

³Department of Forest Sciences, University of Helsinki, Finland

⁴Department of Geosciences and Geography, University of Helsinki, Finland

Project Abstract. The objective of the proposed research is to document the feasibility of deriving forest structural parameters – forest type composition, forest cover, tree density and crown shape – from multi-angle and hyperspectral data. The methodology is based on the novel idea of retrieving canopy spectral invariants – the recollision and escape probabilities – from optical remote sensing data. The recollision probability is a measure of the multi-level hierarchical structure in a vegetated pixel and can be obtained from hyperspectral data. The escape probability is sensitive to canopy geometrical properties such as forest cover, tree density and aspect ratio (crown diameter to crown height) and can be derived from multi-angle spectral data. The escape and recollision probabilities have the potential to separate forest types based on crown shape and the number of hierarchical levels within the landscape. We propose to develop this methodology and test it with experimental data using existing ground and aircraft-based remote sensing data from various sites in the USA, Finland and Estonia. This is a “Small proposals to contribute to non-NASA NEESPI and MAIRS project” type project.

CONTRIBUTION TO NON-NASA NATIONAL PROJECTS

ACADEMY OF FINLAND <i>Biosciences and Environment</i>	UNIVERSITY OF HELSINKI <i>Supports research in any field</i>	ESTONIAN SCIENCE FOUNDATION <i>Supports research in any field</i>	EMIL AALTONEN FOUNDATION (Private Foundation) <i>Supports Finnish speaking researchers in any field</i>
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BOREAL ECOSYSTEM: GROUND MEASUREMENTS, REMOTE SENSING, MODELS

CURRENT PROJECTS

Physically-based Remote Sensing Applications for Forest Ecosystems (2010-2015, Academy of Finland)
Seasonal Reflectance Changes of Boreal Forests (2010-2012, University of Helsinki)
Forest Reflectance Models and Optical Satellite Images in Change Detection (2009-2011, University of Helsinki)
Vegetation Structure and Functioning From Imaging Spectroscopy (2010-2012, University of Helsinki)
Remote Sensing of Optically Complex Natural Environments (2008-2013, Estonian Government project)
Forest Reflectance Models and Optical Satellite Images in Change Detection (2009-2011, Emil Aaltonen Foundation)
Monitoring Canopy Structure Across Multiple Scales From Leaves to Canopies and Stands (2009-2012, NASA)

PREVIOUS PROJECTS

Optical Remote Sensing of Northern European Forest Structure (2007-2009, AF)
Applicability of Hyperspectral and Multiangular Remotely Sensed Data for Estimating Forest Structure (2006-2009, ESF)
SPRINTER: Remote Sensing of Vegetation Based on Spectrally Invariant Structure Parameters (2006-2008, AF)
Scattering and Absorption of Radiation Energy in Natural and Cultivated Vegetation Canopies (2005-2008, ESF)
EOS MODIS and MISR LAI and FPAR Products: Algorithm Development, Implementation and Validation (1998-2008, NASA)

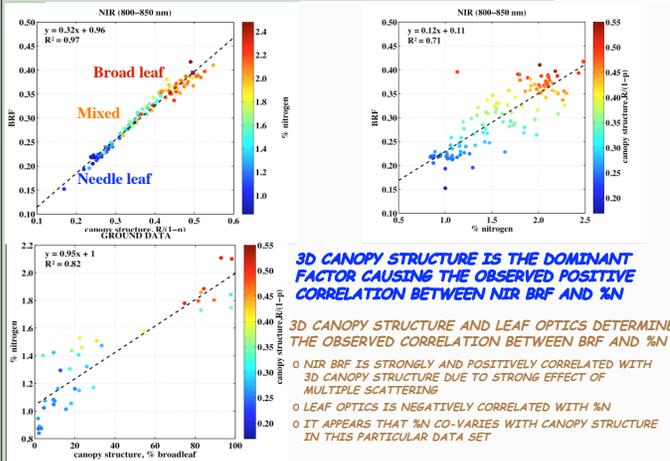
NETWORKS

Validation of Land European Remote Sensing Instruments (VALERI) network with sites Hirsikangas, Rovaniemi and Hyttälä
Land Product Validation subgroup/Committee on Earth Observation Satellites
Nordkalotten Satellite Evaluation co-operation Network (NorSEN) funded by European Regional Development Fund
Spectral sampling tools for vegetation Biophysical Parameters and Flux measurements in Europe funded by COST Action ES09093
Nordic network on "Physically-based remote sensing of forests" funded by Nordic Forest Research Cooperation Commit (SNS)

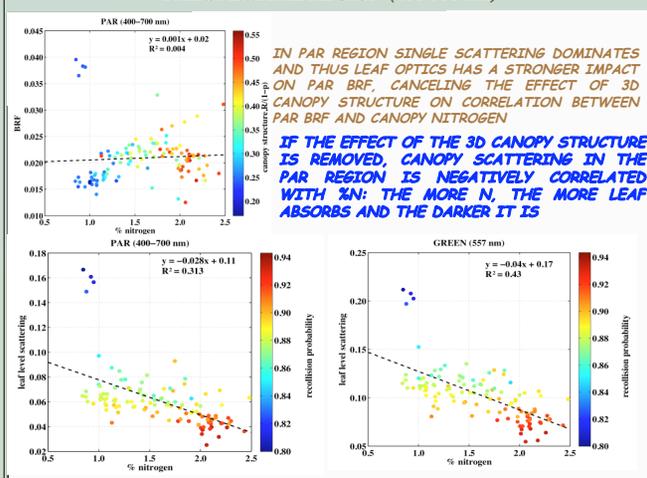
Our team has a history of successful collaborative research and field campaigns; has developed the spectral invariant concept and demonstrated its value for remote sensing and model applications. The current research activities are related to its application to monitor canopy structure across multiple scales.

FOREST REFLECTANCE, CANOPY STRUCTURE AND NITROGEN

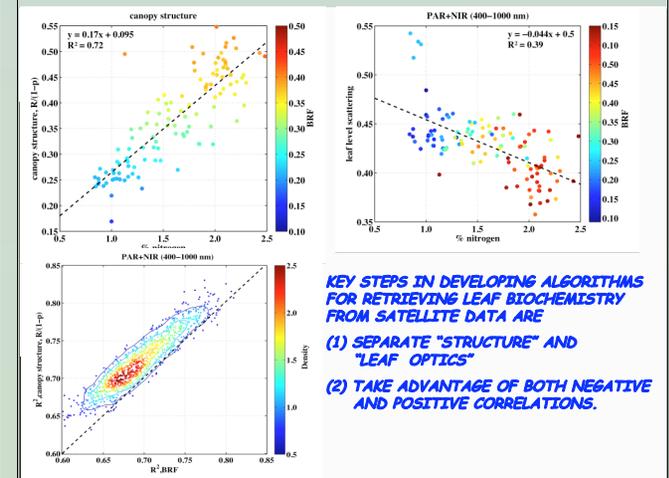
A high positive correlation between canopy nitrogen and NIR reflectance has recently been reported (Ollinger et al., 2008). Can we monitor canopy nitrogen from space? Our reanalysis of the same data has identified the following mechanism of the observed correlation (Schull et al., 2010b)



PAR SPECTRAL REGION (400-700 nm)



REMOTE SENSING OF NITROGEN FROM SPACE

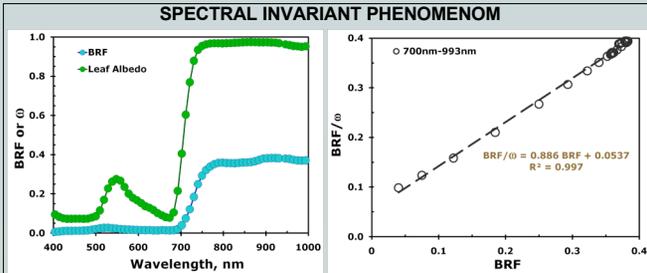


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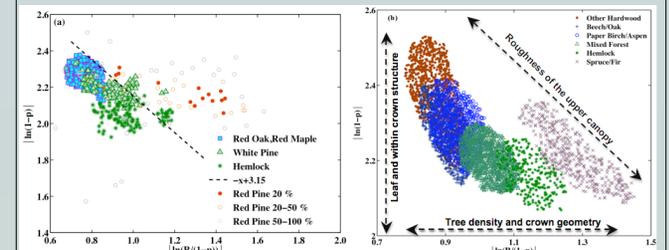
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Left Panel: spectra of canopy Bidirectional Reflectance Factor, BRF_λ, and leaf albedo, ω_{λ} . The BRF spectrum was derived from Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) data acquired over Bartlett Experimental Forest, New Hampshire, in the nadir direction. The AVIRIS sensor provides calibrated images of the up-welling spectral radiance in 224 contiguous spectral channels with wavelengths from 400 to 2500 nanometers at a spatial resolution of 3.3 m. ω_{λ} of an average leaf is shown here. **Right Panel:** by plotting values of the surface reflectance to leaf albedo ratio, $BRF_{\lambda}/\omega_{\lambda}$, versus BRF_λ values for a vegetated pixel, a linear relationship is obtained, where the slope, ρ , and intercept, R , give the recollision and directional escape factor, respectively. The latter depends on sun and view geometry. It follows from this relationship that BRF_λ spectra can accurately be approximated as $BRF_{\lambda} = R \omega_{\lambda} / (1 - \rho \omega_{\lambda})$. Physics behind this phenomenon is discussed in (Knyazikhin et al., 2010).

- Sensitivity to forest composition, crown geometry, tree density, within-crown foliage arrangement and the number of hierarchical levels in the pixel (e.g., the clumping of needles into shoots, shoots and leaves into crowns, etc.)
- Standardization to a single reference spectrum
- Decomposition of measured spectrum into structural and radiometric components

CLASSIFICATION OF FOREST TYPES FROM HYPERSPECTRAL DATA



Spectral invariant space for Harvard Forest, MA (Left Panel) and Bartlett Forest, NH (Right Panel) for nadir viewing direction. Distribution of points follows three simple rules (Schull et al., 2010a). **Rule A:** The roughness of the upper canopy determines the location of point on the anti-diagonal (-1:1 line); the upper left corner corresponds to smooth canopy boundary while the lower right corner to heterogeneous boundary. For example, in the mixed forest the coexisting broad leaf species (hardwoods) fill in the gaps, smoothing the resulting top of canopy topology. As a result, the mixed forest class occupies a space between broadleaf and needle leaf forests. This feature is evident at Bartlett. **Rule B:** Vertical variation is determined by within crown structure including leaf level structure. Leaf level structure refers to thin or thick leaf, shoot structure or flat leaf. Within crown structure means foliage distribution within tree crown, e.g., clumps, groups of branches and leaves, etc. **Rule C:** Tree density, ground cover and crown transparency are responsible for the horizontal shift. (Schull et al., 2010a).

Ability of the escape and recollision probabilities to discriminate between forest classes has been demonstrated