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Characterization of Forest Ecosystems by combined Radiative Transfer Modeling for Imaging Spectrometer and LiDAR

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This research was motivated by the increased information dimensionality provided by current Earth Observation systems measuring the complex and dynamic medium of the vegetated surface of the Earth. Advanced and reliable algorithms that fully exploit this enhanced Earth Observation information are needed to deliver consistent data sets of the Earth vegetation condition describing its spatial distribution and change over time.

Spectral observation provided by imaging spectrometers and the waveform from large-footprint LiDAR are now available from space for forest ecosystem studies. The imaging spectrometer data contains information about the biochemical composition of the canopy foliage, and is widely used to estimate biophysical canopy parameters such as LAI and fractional cover. LiDAR responds to the vertical distribution of scatters and permits inferences about the plant structures required to supply water and mechanical support to those surfaces. Various canopy height indices derived from LiDAR waveform have been successfully used to infer forest above-ground biomass and the characterization of canopy structure. The structure parameters derived from LiDAR data can improve the accuracy and robustness of canopy parameter retrieval from imaging spectrometer by reducing uncertainties related to the canopy structure. The specific information content, inherent to the observations of imaging spectrometry and LIDAR, assesses thus different but complementary characteristics of the complex vegetation canopy. The combination of these two information dimensions offers a unique and reliable canopy characterization including information relevant to different aspects of the biochemical and biophysical properties and thus understanding of processes within forest ecosystems.

A comprehensive canopy characterization of a forest ecosystem is derived from the combined remote sensing signal of imaging spectrometry and large footprint LIDAR. The inversion of two linked physically based Radiative Transfer Models (RTM) provided the platform for synergistically exploiting the specific and independent information dimensions obtained by the two earth observation systems. The proposed research relies on a radiative transfer model adapted to imaging spectrometer data (GeoSAIL) and a LiDAR waveform model based on the same 3D canopy structure. Both the GeoSAIL and LiDAR waveform models have already been employed and validated to retrieve forest properties from Imaging Spectrometer and LiDAR data separately. As these models are based on the same basic physical concept and share common input parameters an interface between these models can be established, which allows for the generation of a Look Up Table (LUT) consisting of the simulated signatures of the Imaging Spectrometer and LiDAR as a function of a common forest stand parameterization.

In the presented approach, the specific information content inherent to the observations of the respective sensor was not only able to complement the canopy characterization, but also helped to solve the ill-posed problem of the RTM inversion. A comprehensive data set including EO and field data has been available for the validation of the proposed earth observation concept over a mixed hardwood and softwood forest part of the Northern Experimental Forest (NEF), Howland, Maine (45°15'N, 68°45'W). The Laser Vegetation Imaging Sensor (LVIS) acquired full waveform data over the site in the summer of 2003 as part of a NASA Terrestrial Ecology Program aircraft campaign. Further the Compact High Resolution Imaging Spectrometer (CHRIS) on the ESA platform Proba data acquired imaging spectrometer data in 2006-08. As reference data every tree in a 200m by 150m area was measured for its location, dbh, and species in 1990, and was re-measured in 2003-2004 and 2006. The field data has been complemented by hemispherical photographs characterizing the canopy structure as well as with field spectrometer measurements of the optical properties for relevant scatters and background. The presented approach provides robust estimates on forest canopy characteristics ranging from maximal tree height, fractional

cover (fcover), Leaf Area Index (LAI) to the foliage chlorophyll and water content.