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3DforestSIF - Understanding the solar-induced fluorescence signal of natural, complex tree canopies from the combined use of LiDAR and spatial high-resolution optical, and hyperspectral image data with 3D radiative transfer modelling

Measuring solar-induced chlorophyll fluorescence (SIF) is an innovative remote sensing technique, as the SIF signal is directly linked to the photosynthetic efficiency of plants. Remote sensing of SIF enables the monitoring of vegetation photosynthetic activity and related stress across a range of scales—from in-situ measurements to satellite observations. Recent advancement in airborne sensors, such as HyPlant, allows for high-resolution SIF mapping at meter-scale resolution. This bridges the gap between ground-based and satellite observations, allowing us to measure SIF across entire forest canopies.
SIF measured at the canopy level, however, differs from SIF emitted by leaves or photosystems due to confounding effects of illumination, scattering, and reabsorption. Therefore, it cannot be directly interpreted as a physiological signal that reflects the actual photosynthetic performance of plants.
The Helmholtz Imaging project “3DforestSIF” aims to deepen our understanding of how SIF interacts with the complex 3D structure of forest canopies. The project’s ultimate goal is to develop a novel SIF standardization method that scales the HyPlant SIF signal of the canopy observations down to the leaf and photosystem emissions. This downscaled SIF signal will serve as an indicator of forest photosynthetic activity and potentially act as an early warning signal of abiotic/biotic stress impacts.
To achieve this, canopy-level SIF will be normalized using canopy structural information derived from airborne high-resolution panchromatic imagery and LiDAR data integrated with 3D Discrete Anisotropic Radiative Transfer (DART) modeling. Top-of-canopy (TOC) SIF was derived from HyPlant FLUO airborne imagery using the Spectral Fitting Method extended with a Neural Network (SFMNN), developed in the Helmholtz AI project FLUOMAP. Forest leaf biochemical traits are being retrieved simultaneously from HyPlant DUAL TOC reflectance data using the hybrid approach that combines a machine learning regression with DART modeling.
In addition to HyPlant data, high-resolution panchromatic images are used for the segmentation of individual tree crowns. In a later project phase, the crowns’outlines will be used to divide their sunlit and shaded parts. Furthermore, airborne and terrestrial LiDAR data serve as inputs for reconstructing 3D forest scenes with realistic structural and biochemical characteristics. The 3D scenes will be used in DART environment to determine i) fraction of absorbed photosynthetically active radiation by chlorophyll and ii) the SIF escape probability from the leaf to the canopy level. Both parameters are critical for SIF normalization and their performance will also be compared with current index-based normalization approaches used by broad vegetation remote sensing community. Finally, the fluorescence quantum efficiency of the photosystem I and II will be retrieved from HyPlant data of the investigated forest stands through a DART inversion.

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