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Integration of GNSS-T VOD in Multi-scale Forest Structure Monitoring

Vegetation Optical Depth (VOD), derived from passive microwave remote sensing, is increasingly recognized as a valuable proxy for vegetation water content (VWC) and above-ground biomass (AGB). However, challenges remain in physically interpreting VOD signals due to the entangled influences of canopy structure and dynamic water content, especially across complex, heterogeneous forest landscapes. This project leverages a multi-scale approach integrating GNSS-Transmissometry (GNSS-T), airborne and ground-based LiDAR, DHP cameras, and in situ hydrological sensors to resolve the structural and hydrological components of VOD. Through analyzing field data across a network of established forest monitoring sites in Germany (VODnet) and and at a high-resolution experimental domain (~100 ha) across a variety of biomes, the study addresses three key objectives: (1) characterizing seasonal VOD variability due to canopy phenology and water loss, (2) mapping structural control over spatial VOD magnitude, and (3) developing a structure-aware surrogate VOD product using machine learning and remote sensing covariates. Additionally, derivation of a relative Live Fuel Moisture Content (LFMC) proxy by decoupling water-sensitive VOD residuals from a structure-based baseline, offers a scalable, non-destructive indicator for forest drought stress and fire risk. Together, these analyses advance the ecological relevance and spatial applicability of VOD for forest hydrology and disturbance monitoring.

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