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Understanding the interaction of plant water status and vegetation optical depth from passive microwave satellite observations in Central African Forests

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Vegetation attenuates microwave radiation that is emitted or reflected by the Earth surface. The degree of attenuation derived from passive and active microwave satellite observations is commonly referred to as vegetation optical depth (VOD). While high-frequency bands such as the Ku-, X- and C-band retrieve information from the upper-most fraction of the canopy, low frequency bands (e.g.: L-band) are thought to convey information about the entire forest profile. Thus, different frequencies could be complementary for the study of plant-water interactions along the vertical vegetation profile. However, the fraction of the canopy that is detected within a given band is itself a function of water content, which challenges the interpretation and practical use of multi-channel VOD products. Understanding the VOD signal in tropical forests and how water dynamics might affect it is crucial, as microwave observations are one of the only reliable methods that can consistently measure tropical areas frequently covered by clouds.

Hydraulic capacitance in plants – the ratio between water content and water potential – is approximately constant within a physiologically non-damaging range of water potentials. Thus, during periods of minimal flux while systems are close to hydraulic equilibrium (e.g., predawn, drought), a linear relationship between predawn water potential and the total amount of water contained in the above ground biomass is expected. The deviation from a constant ratio between VOD bands under equilibrium conditions could thus be an indicator of 1) variation in penetration depth caused by the change in water content, 2) changes in surface moisture/interception, or 3) the transition over a physiological threshold, when hydraulic capacitance changes.

Here, we aim to exploit changes in ratios between VOD bands to understand the seasonality of the vegetation water status in Central African tropical forests within the framework of the CoForFunc international project. Specifically, we hypothesize that different forest structures might lead to varying seasonal responses to water availability and distinct plant phenologies detectable from satellite measurements of passive microwave radiation. To do so, we obtained night-time monthly VOD observations from the Ku-, X-, C-, and L-band from VODCA products between 2012 and 2018, and calculated the ratios between each pair of bands. Over forested pixels in Central Africa, we explored the variability of the VOD ratios in relation to precipitation and interception estimates

and other potential climatic predictors to tease out the seasonality of water availability and other confounding factors. We further tested the contribution of within-pixel land cover fractions and heterogeneity metrics on the variability of the VOD ratios.

Our results link physiological and biophysical understanding at the tissue-scale to the scale at which satellite observations provide information on water and biomass relations for land surface models. This will become particularly relevant as future missions such as the CIMR Copernicus Expansion Mission will ensure global daily multi-channel VOD products for continuous vegetation water monitoring. Understanding water-vegetation dynamics in tropical forests will further help the investigation and monitoring of such crucial but understudied areas.