Assessing Vegetation Water Potential of Winter Wheat on Field Scale by Ground-Based L-Band Radiometry

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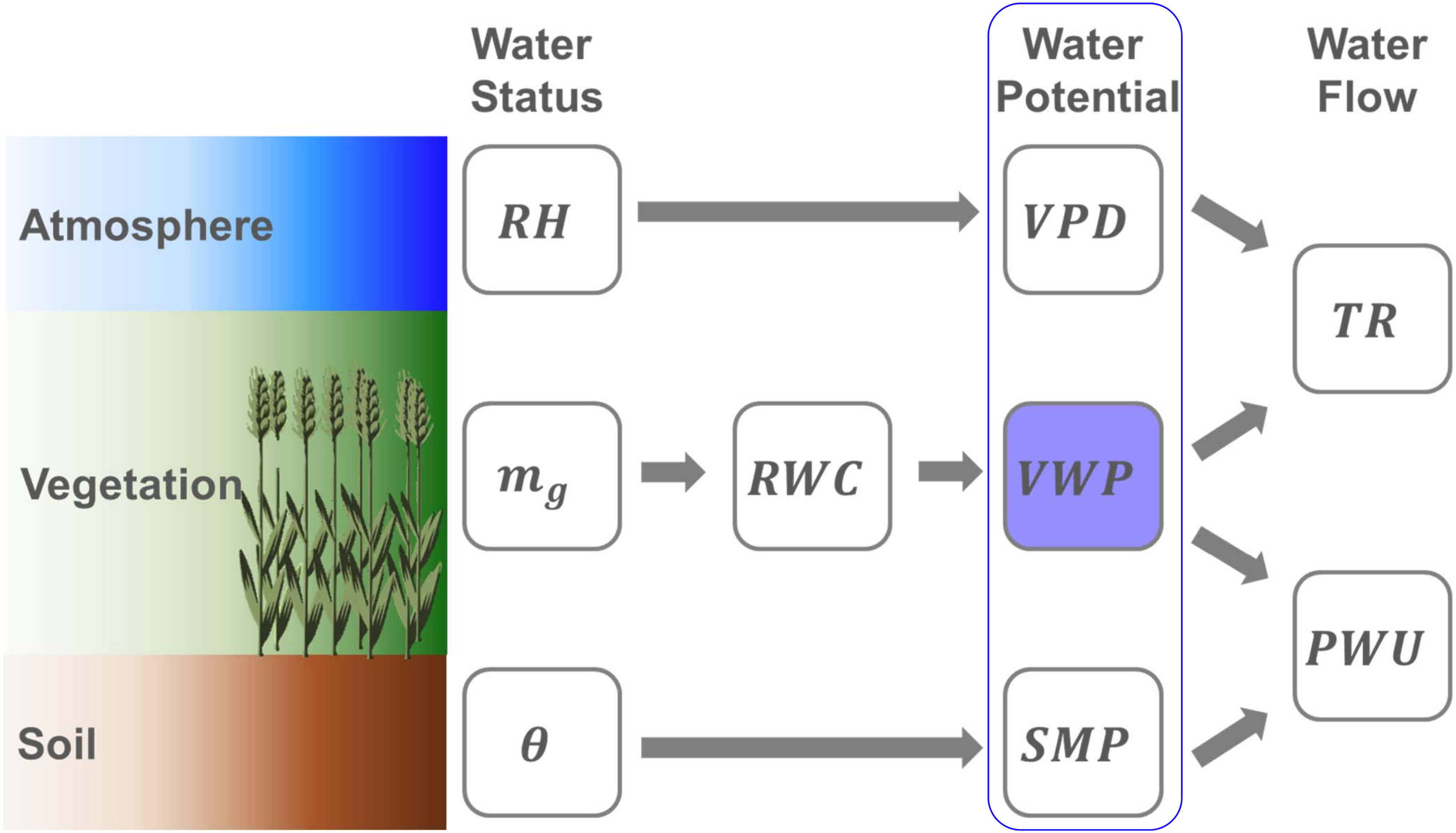
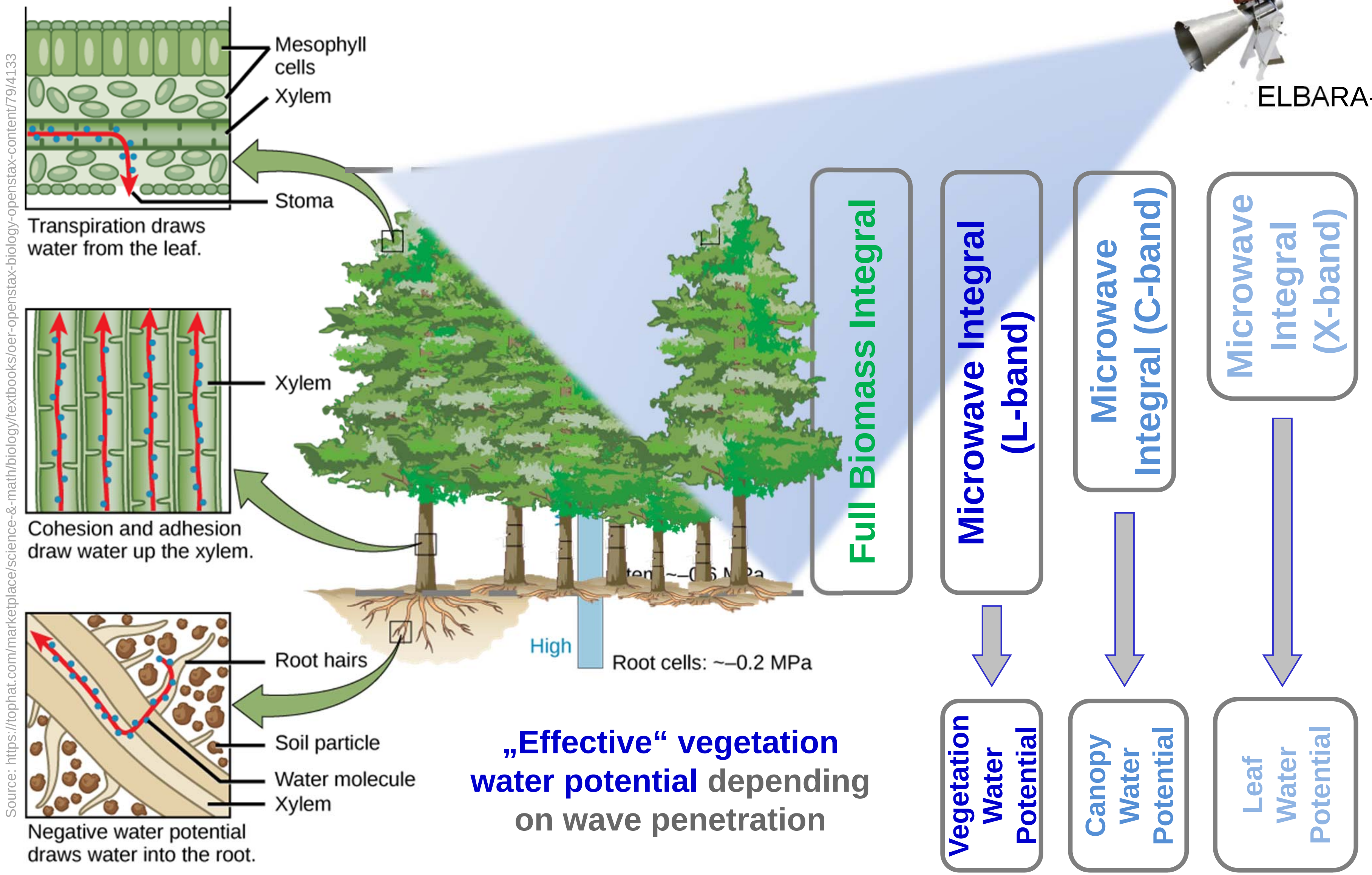
Water-Based Parameters in the Soil-Plant-Atmosphere System



Wheat graphic from: https://openclipart.org/image/800px/svg_to_png/276939/149

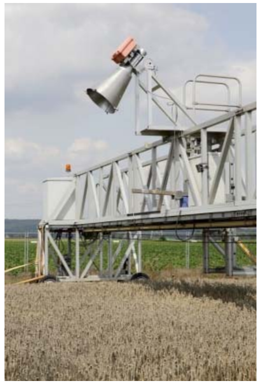
Vegetation Water Potential – A Remote Sensing Perspective

The Water Potential in Vegetation is a Pressure Gradient along Height.



„Effective“ vegetation water potential depending on wave penetration

Radiometer Sensing Field Laboratory @ Selhausen, Germany



ELBARA II

- L-Band radiometer
- Calibrated brightness temperature (accuracy ± 1K; sensitivity < 0.1 K)
- Dual-mode conical horn antenna (with 23° half-beamwidth at -3 dB)

Details in Meyer et al., 2018

DOY 100: Tillering

DOY 120: Stem

DOY 180: Fruit ripening

DOY 200: Early

remote sensing MDPI

Article

Vegetation Optical Depth and Soil Moisture Retrieved from L-Band Radiometry over the Growth Cycle of a Winter Wheat

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Received: 31 August 2018; Accepted: 13 October 2018; Published: 15 October 2018

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Abstract: L-band radiometer measurements were performed at the Selhausen remote sensing field laboratory (Germany) over the entire growing season of a winter wheat stand. L-band microwave observations were collected over two different footprints within a homogenous winter wheat stand in order to disentangle the emissions originating from the soil and from the vegetation. Based on brightness temperature (T_B) measurements performed over an area consisting of a soil surface covered by a reflector (i.e., to block the radiation from the soil surface), vegetation optical depth (τ) information was retrieved using the tau-omega (τ-ω) radiative transfer model. The retrieved τ appeared to be clearly polarization dependent, with lower values for horizontal (H) and higher values for vertical (V) polarization. Additionally, a strong dependency of τ on incidence angle for the V polarization was observed. Furthermore, τ indicated a bell-shaped temporal evolution, with lowest values during the tillering and senescence stages, and highest values during flowering of the wheat plants. The latter corresponded to the highest amounts of vegetation water content (VWC) and largest leaf area index (LAI). To show that the time, polarization, and angle dependence is also highly dependent on the observed vegetation species, white mustard was grown during a short experiment, and radiometer measurements were performed using the same experimental setup. These results showed that the mustard canopy is more isotropic compared to the wheat vegetation (i.e., the τ parameter is less dependent on incidence angle and polarization). In a next step, the relationship between τ and in situ measured vegetation properties (VWC, LAI, total of aboveground vegetation biomass, and vegetation height) was investigated, showing a strong correlation between τ over the entire growing season and the VWC as well as between τ and LAI. Finally, the soil moisture was retrieved from T_B observations over a second plot without a reflector on the ground. The retrievals were significantly improved compared to in situ measurements by using the time, polarization, and angle dependent τ as a priori information. This improvement can be explained by the better representation of the vegetation layer effect on the measured T_B.

Keywords: microwave remote sensing; vegetation optical depth; soil moisture; winter wheat; SMOS; SMAP; tower-based experiment; inverse modeling

1. Introduction

Soil surface moisture is a key variable in the hydrological cycle, and global information on soil moisture can improve our knowledge about heat and mass exchange at the land–atmosphere interface. Furthermore, information on vegetation properties is of great interest to characterize plant dynamics

Remote Sens. **2018**, *10*, 1637; doi:10.3390/rs10101637 www.mdpi.com/journal/remotesensing

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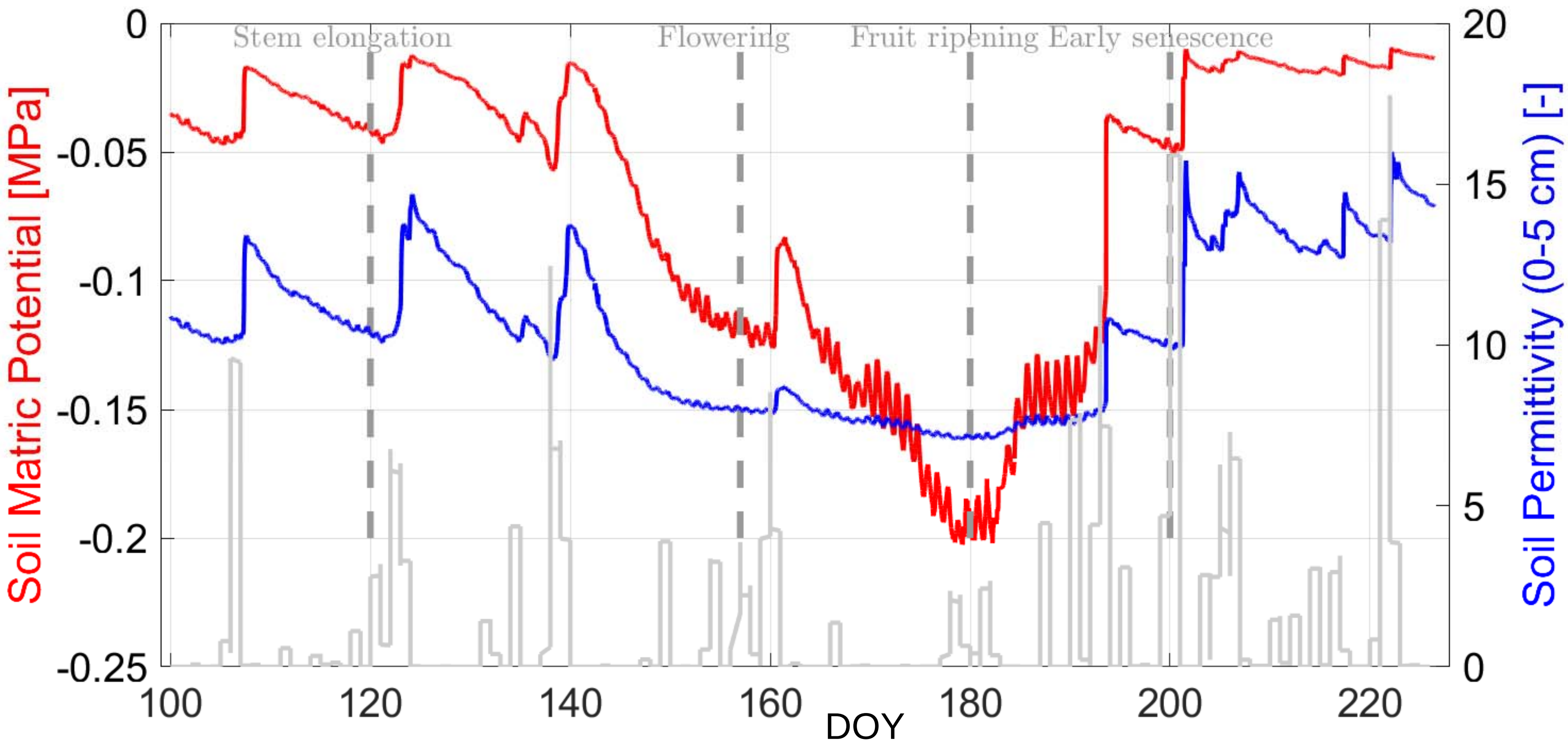
Soil Matric Potential Estimation from in situ Measurements



Calculated after Campbell, 1974

Clapp et al., 1978

in situ

$$\psi_{soil} = \left(\psi_s * \left(\frac{\theta}{n}\right)^{-b}\right)$$

ψ_s = saturation suction, θ = soil water content, n = soil porosity, b = empirical parameter

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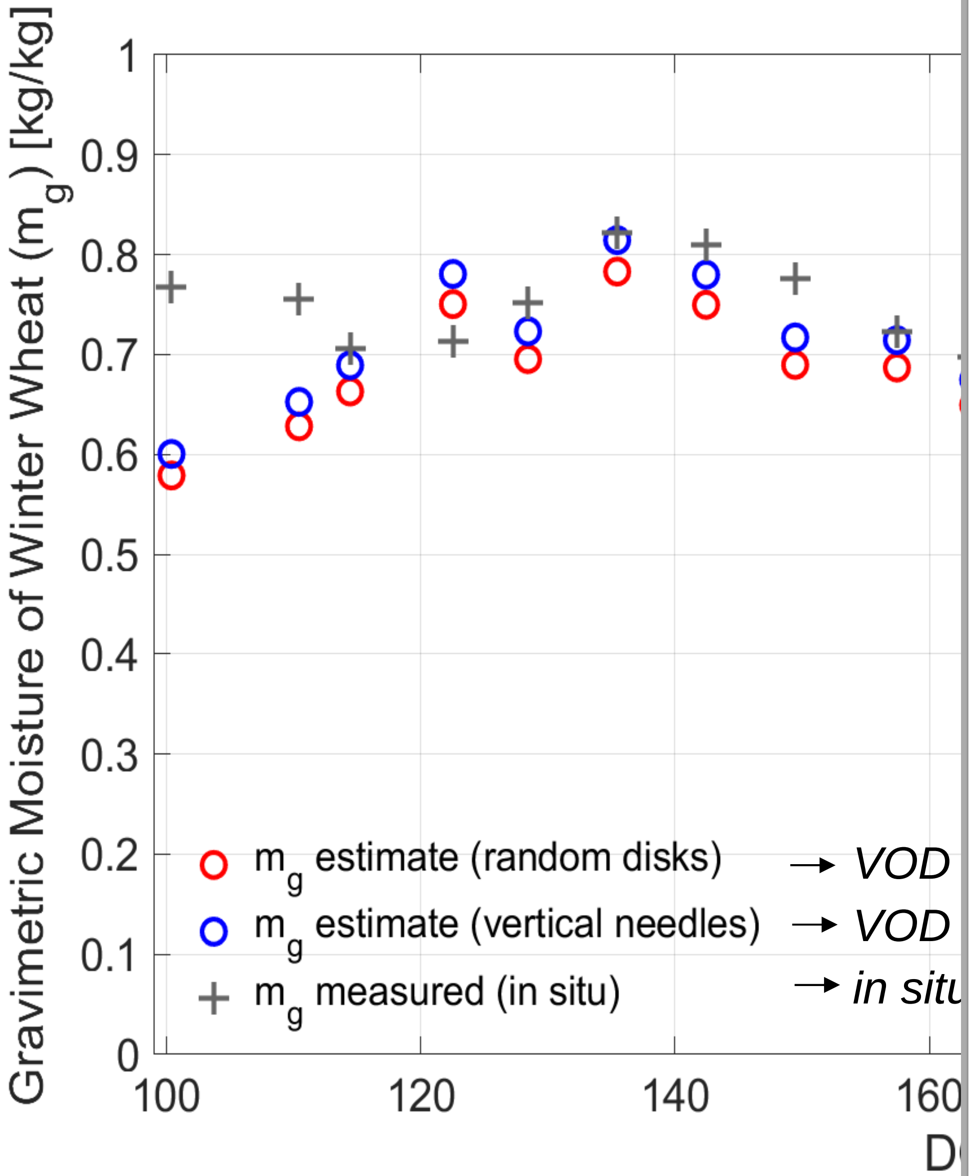
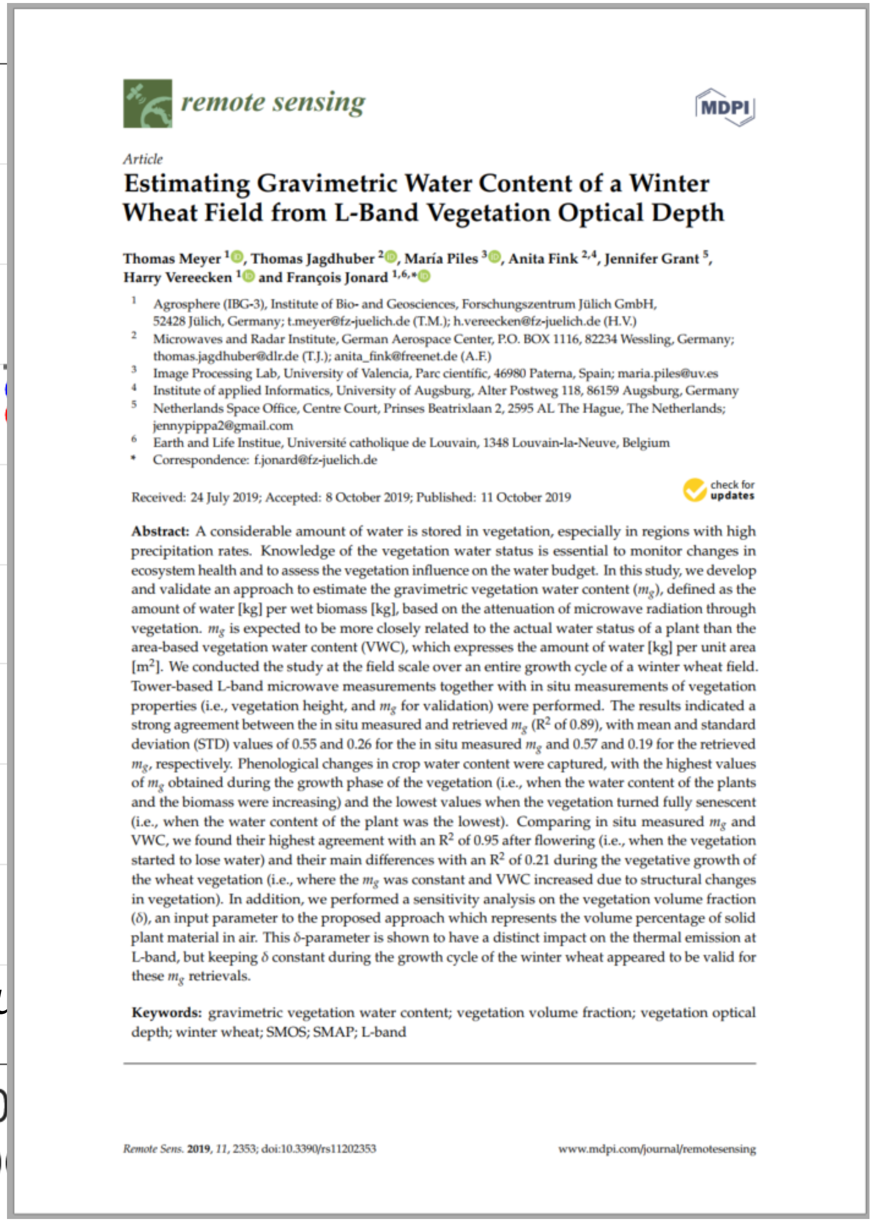
Gravimetric Vegetation Water Content m_g from in situ & L-band Radiometer-Derived L-Band VOD

Details in Meyer et al., 2019





remote sensing

MDPI

Article

Estimating Gravimetric Water Content of a Winter Wheat Field from L-Band Vegetation Optical Depth

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Received: 24 July 2019; Accepted: 8 October 2019; Published: 11 October 2019

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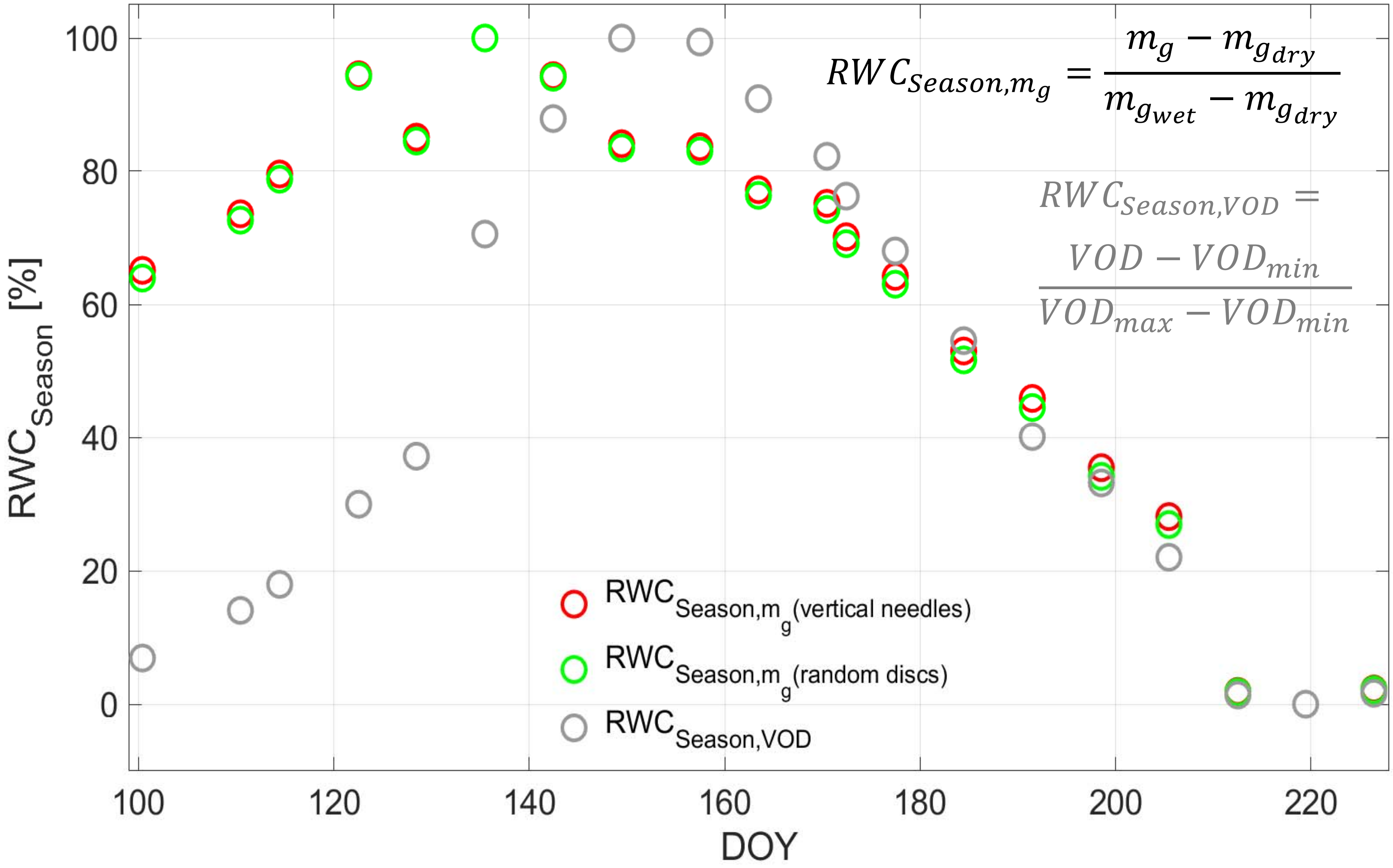
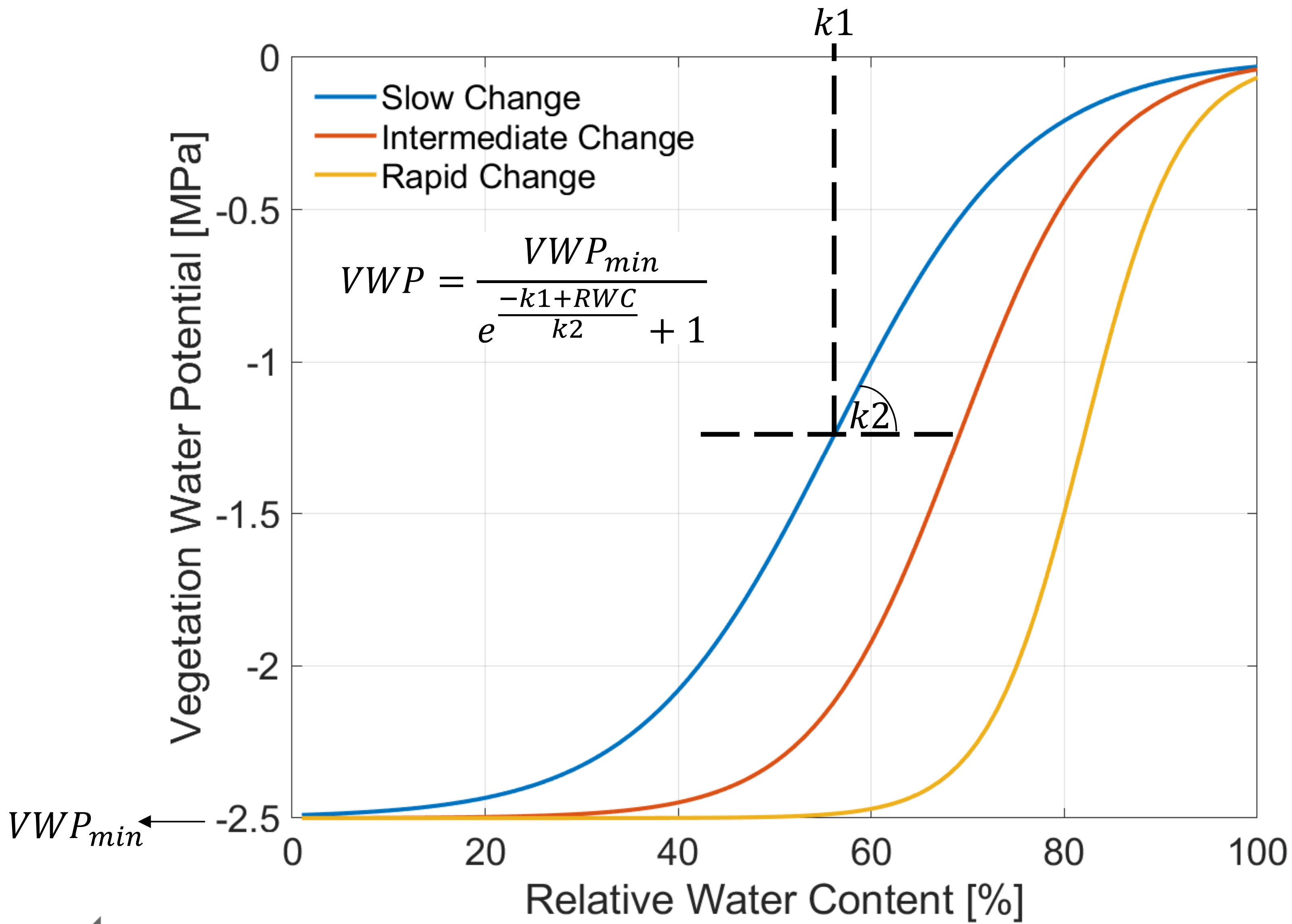
Abstract: A considerable amount of water is stored in vegetation, especially in regions with high precipitation rates. Knowledge of the vegetation water status is essential to monitor changes in ecosystem health and to assess the vegetation influence on the water budget. In this study, we develop and validate an approach to estimate the gravimetric vegetation water content (m_g), defined as the amount of water [kg] per wet biomass [kg], based on the attenuation of microwave radiation through vegetation. m_g is expected to be more closely related to the actual water status of a plant than the area-based vegetation water content (VWC), which expresses the amount of water [kg] per unit area [m^2]. We conducted the study at the field scale over an entire growth cycle of a winter wheat field. Tower-based L-band microwave measurements together with in situ measurements of vegetation properties (i.e., vegetation height, and m_g for validation) were performed. The results indicated a strong agreement between the in situ measured and retrieved m_g (R^2 of 0.89), with mean and standard deviation (STD) values of 0.55 and 0.26 for the in situ measured m_g and 0.57 and 0.19 for the retrieved m_g, respectively. Phenological changes in crop water content were captured, with the highest values of m_g obtained during the growth phase of the vegetation (i.e., when the water content of the plants and the biomass were increasing) and the lowest values when the vegetation turned fully senescent (i.e., when the water content of the plant was the lowest). Comparing in situ measured m_g and VWC, we found their highest agreement with an R^2 of 0.95 after flowering (i.e., when the vegetation started to lose water) and their main differences with an R^2 of 0.21 during the vegetative growth of the wheat vegetation (i.e., where the m_g was constant and VWC increased due to structural changes in vegetation). In addition, we performed a sensitivity analysis on the vegetation volume fraction (δ), an input parameter to the proposed approach which represents the volume percentage of solid plant material in air. This δ-parameter is shown to have a distinct impact on the thermal emission at L-band, but keeping δ constant during the growth cycle of the winter wheat appeared to be valid for these m_g retrievals.

Keywords: gravimetric vegetation water content; vegetation volume fraction; vegetation optical depth; winter wheat; SMOS; SMAP; L-band

Relative Water Content (RWC) from Vegetation Water Content (m_g) of VOD-Estimates



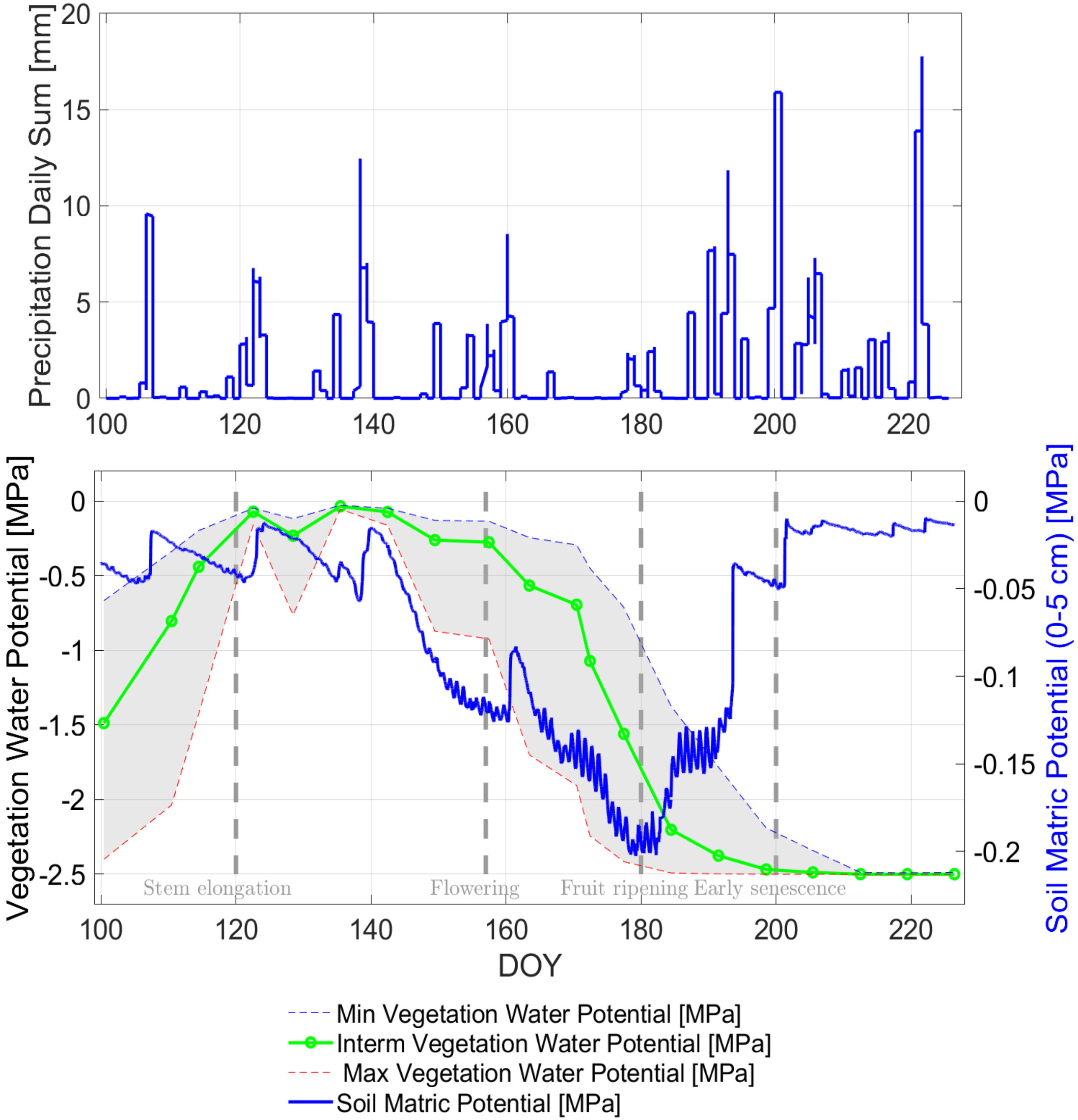
Conversion from Relative Water Content to Vegetation Water Potential for Winter Wheat *adopted from Zweifel et al., 2001*



Zweifel, R., Item, H., & Häsler, R. (2001). Link between diurnal stem radius changes and tree water relations. *Tree physiology*, *21*(12-13), 869-877.

DLR

Water Potential Estimates of Soil and Wheat Canopy



Summary and Conclusions

- ***Water potentials of soil & winter wheat were estimated for the field test site of FZJ in Selhausen (Germany) along the growing season (April to August 2017).***
- ***The assessment of the different potentials in the Soil-Plant-Atmosphere System (SPAS) was enabled by the combination of in situ-based soil measurement and L-band radiometer-based estimates of gravimetric vegetation moisture and relative water content (RWC).***
- ***RWC was converted into wheat canopy-scale vegetation water potential by a wheat-adopted model of Zweifel et al., 2001.***
- ***The retrieved water potential values of soil and wheat canopy follow precipitation input and each other in a reasonable manner and show a strong rise in potential magnitudes (large negative values) in a dryer period between DOY 160 and 180 (low rainfall, high evapo-transpiration, daily mean air temperature around 20 [°C]).***

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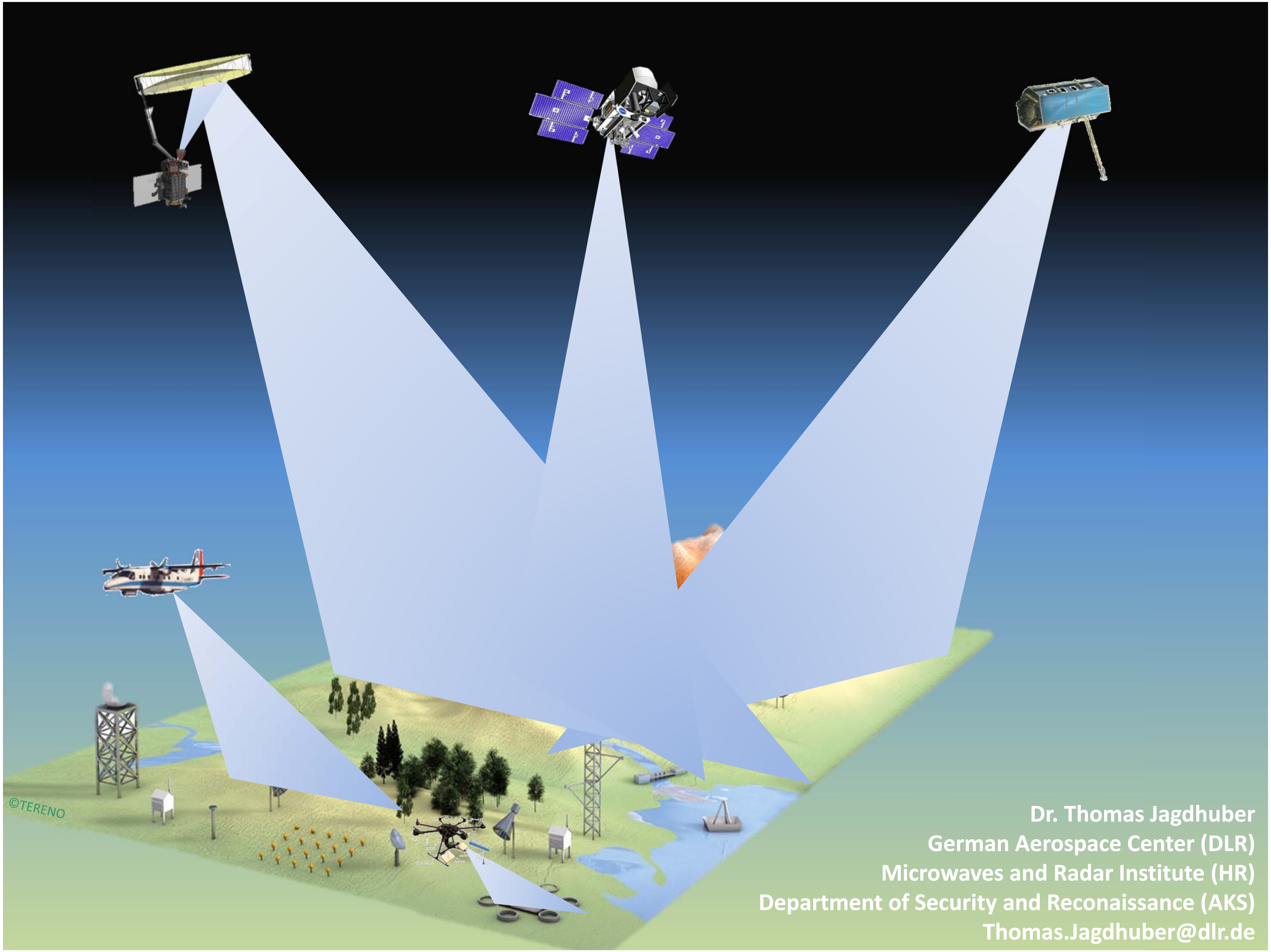

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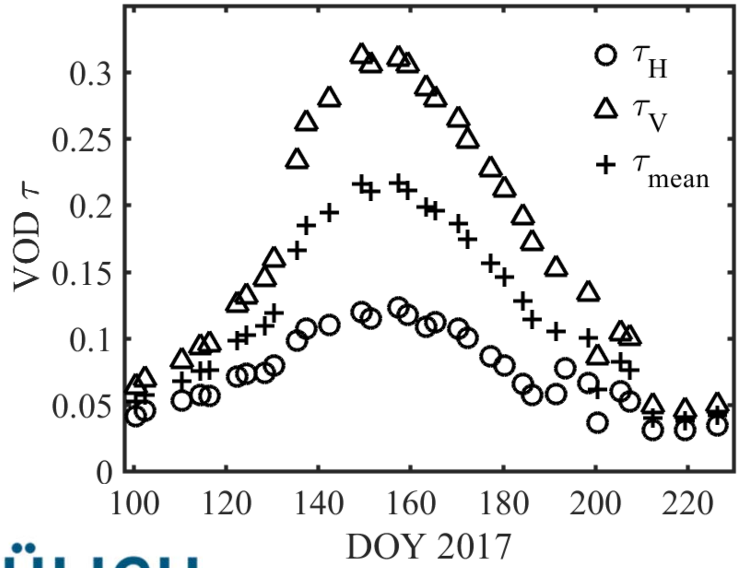
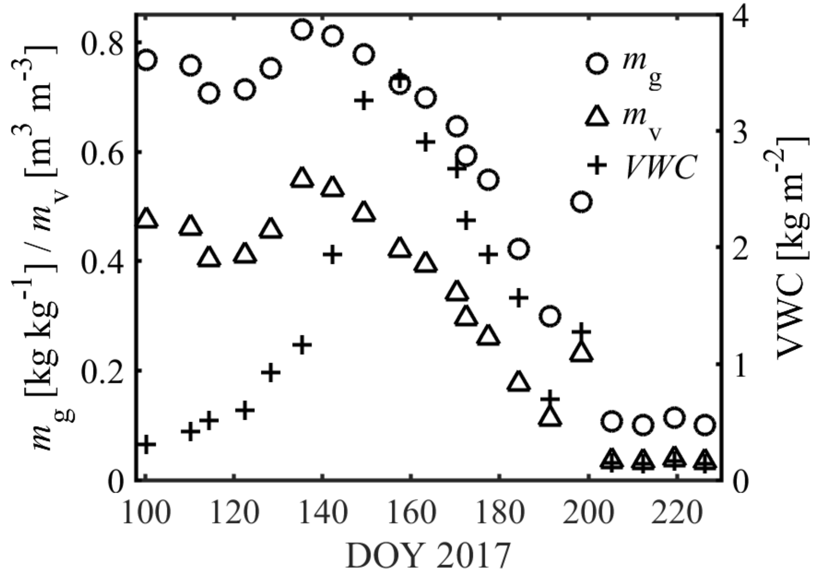
L-Band VOD Datasets & In Situ Measurements @ Selhausen

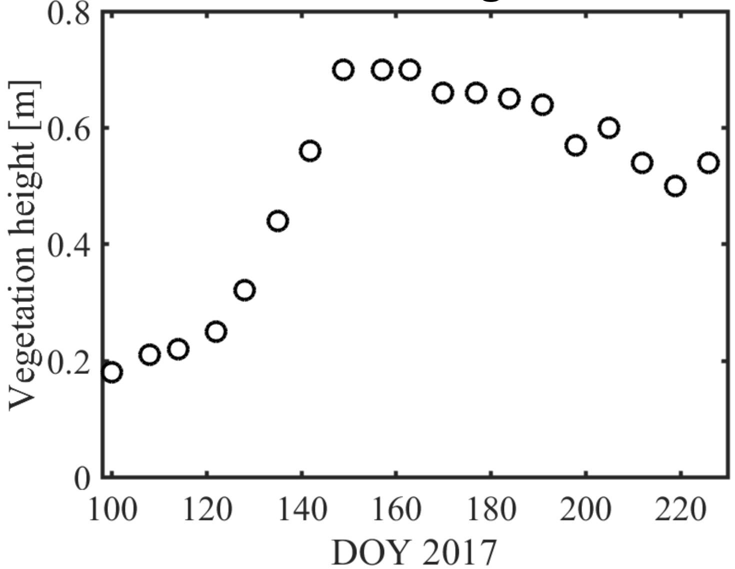
L-Band VOD (ELBARA)



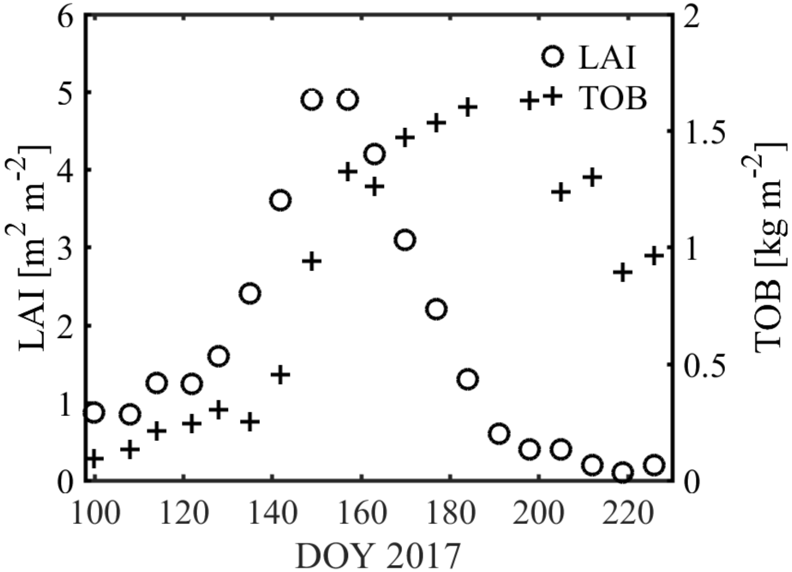
Plant Water Content



Plant Height



Above Ground Biomass



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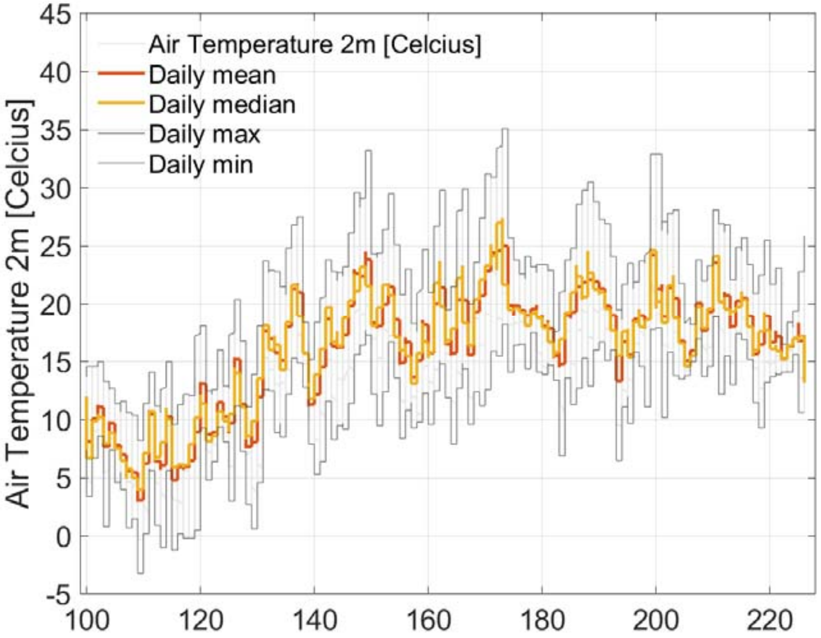
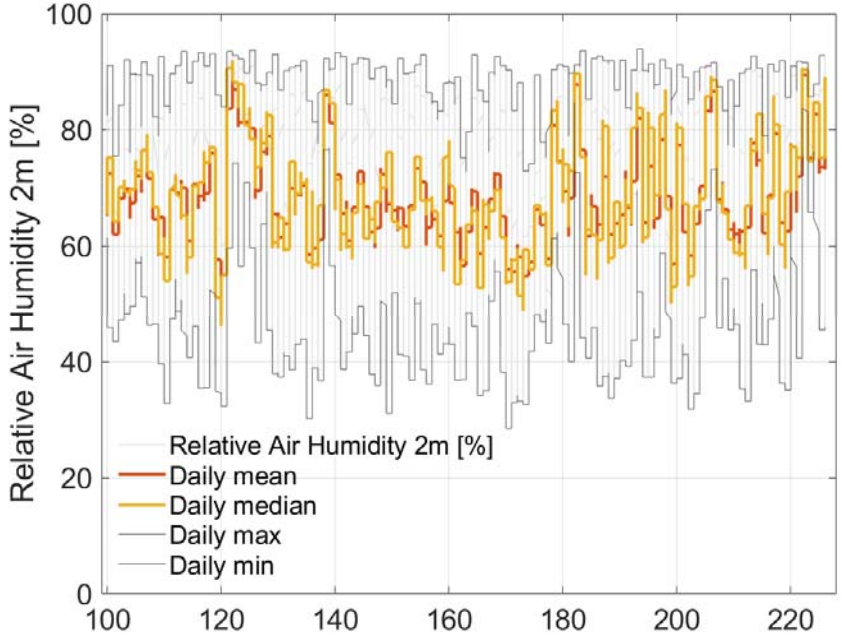
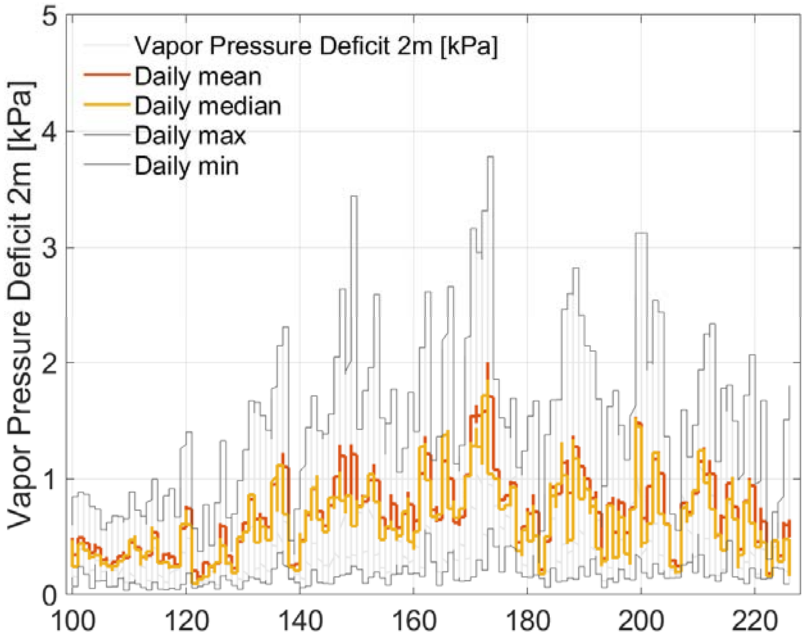
Air Temperature, Humidity & Vapor Pressure Deficit







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