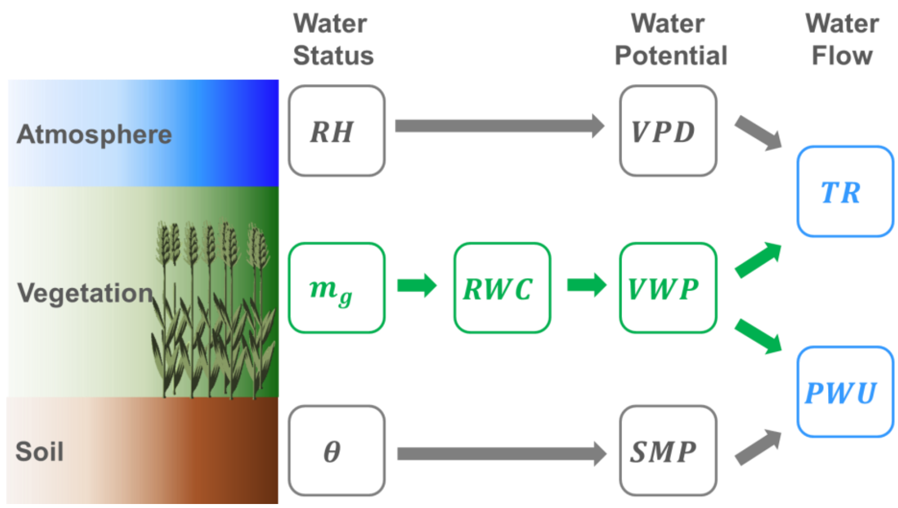
Response to Reviewer 1

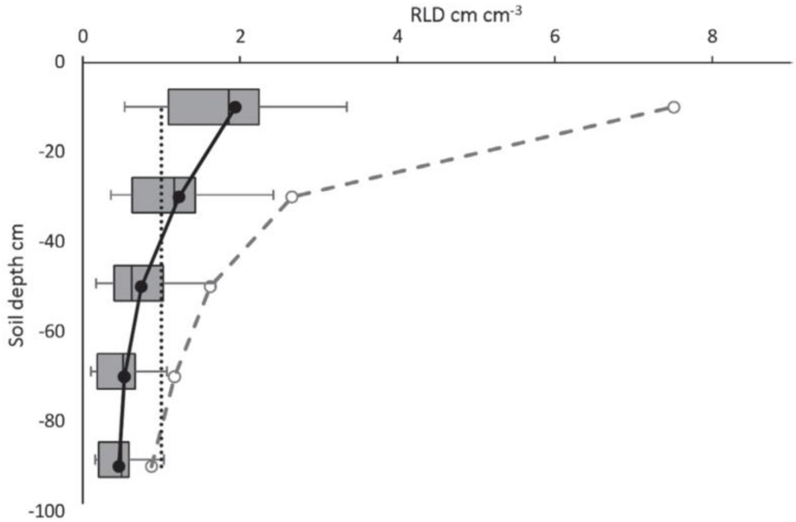
Towards Estimation of Seasonal Water Dynamics of Winter Wheat from Ground-Based L-Band Radiometry (Manuscript # BG-2021-71)

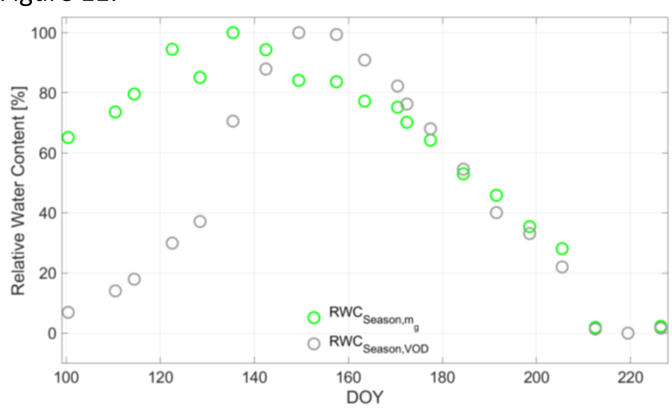
Comments	Responses/Actions
In this paper the authors seek to show that L-band radiometry can improve water dynamics estimation based on the Soil-Plant-Atmosphere System (SPAS). The methodology presented in the paper is relevant to the special issue and current L-band missions such as SMAP, and builds upon previous L-band research in Vegetation Optical Depth (VOD). While the method utilizing L-band radiometry and existing physical models to estimate wheat water dynamics is described in some detail, I have two major concerns:	Many thanks for confirming the relevance of the manuscript for the special issue. According to the reviewer comments, we will work on all raised issues with special focus on the two major comments: ▪ Validation of plant water dynamics ▪ Role of in situ measurements in the study.
1. The field data used does not contain in situ measurements for the target variables Transpiration Rate (TR) and Plant Water Uptake (PWU), leaving the authors to discuss results in vague terms of what 'might be a first indication to the feasibility' of their method without any validation. In the absence of any strong validation data, the paper could be a short communication rather than a full-length research paper.	Validation of plant water dynamics: We agree that the presented estimates of transpiration rate (TR) and plant water uptake (PWU) were not tracked by a set of in situ measurements from the dedicated field laboratory experiment along the growing season of 2017 (Meyer et al., 2018). The experiment was originally not designed for this purpose, but for estimating vegetation optical depth (VOD) and gravimetric plant water content from L-band microwave radiometry at the field scale and for one entire growing season of 2017 (Meyer et al., 2018; Meyer et al., 2019). One of the main innovations of the presented path finder research study is to elaborate a concept, foremost a methodology, to concert classical in situ measurements and VOD for finding a way to arrive synergistically (in situ with microwave remote-sensing combined) at estimated PWU and TR. This is a conceptual step forward in water dynamics estimation incorporating VOD in a field experimental setup leading to the projection of a future majorly remote sensing-based methodology to retrieve PWU and TR.

	We want to acknowledge this fact by adapting the title of our study and in this way preparing the reader for a concept-focused, rather than a validation-based, study. Suggestion for the new title is: "Towards Estimation of Seasonal Water Dynamics of Winter Wheat From Ground-Based L-Band Radiometry: A Concept Study". Moreover, note we explicitly stress in the manuscript (in Sections: Introduction (l.38-39), and Conclusions (l.638-639, 650-652)) that its scientific contribution is on the concept and methodology of estimating water dynamics by retrieving L-band radiometer-derived estimates and orchestrating them with on-site measurements for arriving at estimates of plant water dynamics. To our knowledge, this is the first time that an end-to-end SPAS analysis is conducted using mechanistic models and input data available from in-situ and remote sensors. We agree with the reviewer that this research study cannot serve as a validation study, meaning as a validation of an already existing methodology. Still, following the reviewer suggestion, we will consider different approaches with the aim of including an initial assessment of our estimated water potential and water dynamics (PWU, TR) with independently measured/derived entities of these variables in the revised version of the manuscript. To this end, we will investigate the following options: 1. Comparison with space-borne VOD from radiometer missions (e.g. SMAP or SMOS). 2. Comparison with evapotranspiration data from the remote sensing-based EcoSTRESS mission (starting from 2018): https://ecostress.jpl.nasa.gov/. 3. Comparison with Penman-Monteith-based calculus of evapotranspiration using on-site measurements (in situ & remote sensing). 4. Comparison with values of wheat water dynamics from literature.
2. If I understand correctly, m_g used in Figure 2 is derived from L-band retrieved VOD. While lines 130 through 132 mention that VWC was measured using destructive sampling during the study, there is no mention of sampled values being used in the processing workflow to derive later values outside of the comparison in Figure 10. Figures 13 and 14, therefore, appear to compare variables that are	Role of in situ measurements for m_g: In situ measured VWC was used to calculate in situ m_g. The details are described in Meyer et al., 2019 and read as follows: "Finally, to be able to compare our retrievals of m_g with a reference dataset, the in situ VWC was converted to m_g by calculating first the dry matter fraction (m_d) as defined by Mätzler, 1994 (i.e., m_d= *dry mass/ fresh mass*) and subtracting it afterwards from 1 (i.e., m_g= 1 - m_d). This calculated m_g will be called in situ measured m_g in our study." We will update the manuscript by including a description on how in situ m_g-values were calculated. These in situ m_g-values are used in Figure 10 to be compared against L-band radiometer-derived m_g-values. Both datasets are independent from each other and serve as a first validation effort. We will clarify this in the

both derived from L-band measurements, which results in a circular comparison and leaves the method unvalidated.	updated version of the manuscript. In Figure 2 the different variables are not assigned to certain acquisition techniques (in situ or remote sensing). Figure 2 introduces the general work flow to arrive from storage components to water fluxes. In order to make it more informative, we will update it by using different colors to indicate L-band radiometry-derived (green color), in-situ-derived (gray color) and jointly-derived variables (blue color).  Figure 2: Processing workflow for estimation of soil, vegetation and atmosphere water potentials (SMP= Soil Matric Potential, VWP = Vegetation Water Potential, VPD = Vapor Pressure Deficit) and water fluxes (PWU = Plant Water Uptake, TR = Transpiration Rate) from storage variables (θ = Soil Moisture, m_g = Vegetation Water Content (gravimetric), RH = Relative Air Humidity); Green variables are derived from radiometer observations, while gray ones are calculated from in situ measurements; Blue variables are derived jointly from radiometer and in situ observations. Finally, Figures 13 and 14 show estimates of plant water uptake and transpiration rate. They are jointly estimated from a combination of in situ measurements and L-band radiometry.
Without comparison to values derived from sampled VWC, the statement on line 569 that 'the presented results indicate the unique potential of using passive microwave observations with on-site information of soil and atmosphere to estimate seasonal water dynamics' remains	We will change the statement and clarify that in situ measured VWC was used to calculate in situ m_g. The details are described in Meyer et al., 2019 and read as follows: "Finally, to be able to compare our retrievals of m_g with a reference dataset, the in situ VWC was converted to m_g by calculating first the dry matter fraction (m_d) as defined by Mätzler, 1994 (i.e., m_d= *dry mass/ fresh mass*) and subtracting it afterwards from 1 (i.e., m_g= 1 - m_d). This calculated m_g will be called in situ measured m_g in our study." We will update the manuscript by including these details, especially how in situ m_g-values were calculated and used in our study.

unjustified and is based upon both target variables derived from L-band measurements that are 'overall concurrent and similar in trend' to their like derived counterparts.	
How, if at all, in-situ destructive measurements of VWC were used in the study.	The details about the on-site and in situ measurements are provided in Meyer et al., 2018. In situ measured VWC was used to calculate in situ m_g. The details are described in Meyer et al., 2019. From the reviewer comments, we realize this is an important point that needs to be further elaborated and clarified in the manuscript. We will update the manuscript accordingly.
If in-situ measurements were used, provide a more rigorous validation and comparison to L-band based results, instead of vague sentences such as on line 550 'VWP seems to be appropriate and fitting … '.	We will change the statement in line 550 to be more specific: "Nonetheless, VWP as a radiometer-based potential estimate shows considerable similarity in temporal dynamics to the on-site measurement-derived potentials of soil (SMP) and atmosphere (VPD)" Although the in situ data availability is limited for this concept-based path finder research, we will update the manuscript to include quantitative measures from comparison to in-situ data when possible. In this study, in situ -based gravimetric water content m_g is available and shown in Figure 10 together with its radiometer-based counterparts. However, validation using both (from in situ & from radiometry) was already done in Meyer et al., 2019 leading to a correlation of R^2=0.89.
Specific Comments	
Soil moisture measurements are only at 5cm and 30cm, however wheat root zone can go to 100cm (as mentioned on line 279). Additional justification is required to state how 5 and 30 cm is sufficient to capture seasonal water dynamics. This would presumably affect Soil Matric Potential and PWU estimates.	In situ soil moisture measurements were solely available at 5 cm and 30 cm depth during the growing season in 2017. Both measurements are included in the analysis and fully reported in the manuscript. Unfortunately, soil moisture below 30 cm depth and rooting depth of the wheat plants were not measured in situ. The root zone until 100 cm depth was adopted from literature. Interestingly, White et al. in (2015) showed in the Figure below that for winter wheat in 17 experiment, the soil depths of 10cm and 30cm (upper most two boxes) exhibited a median of the root length density (RLD) above the critical RLD of 1 cm cm^{-3} for wheat.

	 **Fig. 1.** Mean RLD (root length density; filled circles, full line) to 100 cm depth for winter wheat in 17 experiments across the UK from 2007 to 2013, compared with published reference values [from Gregory *et al*. (1978b) and Barraclough *et al*. (1989, 1991); open circles, dashed line]. The cRLD of 1 cm cm^{-3} for wheat is shown (dotted). The box and whisker plots at each soil depth show the median (mid-line), interquartile range (boxes), and the minimum and maximum ('whiskers'). Nonetheless, rooting behavior and resulting water uptake might be very much site dependent. Thus, the representativeness of the results in White et al., 2015 for the case in Selhausen might be quite limited. The reviewer comment made us realize, it is important to acknowledge this potentially limiting aspect for SMP and follow-on parameters (PWU) estimation. We will include a discussion on this in the updated version of the manuscript. In addition, we could have access to soil moisture (TDR) and soil matric potential (SMP) measurements from two rhizotron facilities next to the test field (facility 1 at 100 m distance to radiometer and facility 2 at 80 m distance to radiometer). The datasets are available from the responsible rhizotron-operator Prof. Dr. Andrea Schnepf, a direct and well-known colleague of Prof. Jonard (co-author). Although the relatively short distance to the radiometer should not lead to large differences in soil characteristics (e.g. texture, bulk density), this needs to be confirmed. The advantage of using this new data would be the availability of SMP and soil moisture at an hourly temporal resolution at three different plots and in six different depths (10, 20, 40, 60. 80, 120 cm). This may allow for a more detailed estimation of PWU from 10 cm to 120 cm depth. We plan to explore the feasibility of this option and update the manuscript accordingly.
Figure 11 and related discussion: Comparison of	The reason for presenting Figure 11 and including the statement at line 420 (see Figure and statement below) is to show that VOD carries

RWC$_{,season, VOD}$ and RWC$_{season,mg}$ seems to be superfluous and does not add to the paper. A statement on the shortcomings of directly calculating RWC from VOD (e.g. because plant biomass changes) would suffice.	influences from vegetation water content AND vegetation biomass & structure. Hence, we want to convey the message, especially to the readers with interest in vegetation water content estimation with remotely sensed VOD that $RWC_{Season,VOD}$, directly calculated with VOD from (9) carries a biomass imprint (gray curve in Figure 11), while $RWC_{Season,mg}$ does not, because m_g was extracted from VOD before RWC-calculus. We believe it is relevant to stress this fact, since VOD is increasingly being used as a direct indicator of either biomass or vegetation water content depending on the study focus (biomass: Malon et al., 2020; Rodriguez-Fernandez et al., 2018; Tian et al., 2016; vegetation water content: Xu et al., 2021; Holtzman et al., 2021). Figure 11 and associated text helps us convey this 'caution' message. Statement at line 420: "However, in periods of constant biomass, meaning times where only the water content in the plants would change, RWC_{Season} could be directly estimated from VOD (Rao et al., 2019; Holtzman et al., 2020)." Figure 11:  Figure 11: Seasonal Relative Water Content (RWC_{Season}) [%] calculated in (2) with radiometer-derived m_g (green circles) along growing season of 2017 in days of year (DOY) at the winter wheat field in Selhausen, Germany. The gray circles indicate RWC_{Season} calculated directly with the radiometer-derived vegetation optical depth (VOD) according to (9).
Figure 9 and related discussion: Figure 9 does not add to the paper. That soil permittivity varies with precipitation impulse is a given and neither permittivity nor Soil Matric Potential (SMP) are derived from L-band in this study. SMP as plotted in Figure 12 alongside	We will review section 4.1 (including Figure 9 and related text) on "water status in the soil" in order to update and shorten the content discarding redundant or trivial statements.

Vegetation Water Potential is sufficient.	
Lines 616-617: It is stated that wind speed can be remotely sensed by radar/scatterometers and radiometers. Please provide references for how to derive wind speed on land from these instruments.	We will revise the text paragraph and cancel the statement about satellite-based (radar, radiometer) sensed wind speed estimation, as retrievals are almost exclusively conducted over water and not over land. Land heterogeneity does not allow to easily isolate a clear wind-only signal contribution. Many thanks for pointing this out.
Lines 461-462: Please provide a reference and expand on the meaning of the statement 'Due to the onset of senescence … water availability is not the limiting factor any more'	In the late wheat development stages (onset of senescence), the water supply of the drying plants degrades in importance, as the fruit (grains) needs to ripen, meaning to decrease its content of liquid in the grains (Steduto et al.,2012; Sarto et al., 2017). We will further elaborate this point and include references.
Technical Corrections	
Multiple grammatical errors in this paper	We will correct the grammatical errors.
Line 84: 'microwave remote sensing techniques should be capable to obtain …'	We will revise this.
Line 265: 'Van den Honert in 1948 was one of the first realizing and showing …'	We will revise this.
Line 657: 'We advocate in future a fully remote sensing-based, wide area (up to global) SPAS assessment can be a major achievement …' as well as several typos.	We will revise this.
This paper would benefit from a thorough review by a copy editor.	We will conduct a thorough review.

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