Response to Reviewer 2

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

Comments	Responses/Actions
The manuscript presents a radio-meter based approach along with on-site measurements to estimate seasonal flux rates of water over a winter wheat field. The paper is well written, and the manuscript exhibits useful results. There are just a few aspects that need to be addressed before publication. First, the paper lacks other sources of data (e.g., satellite products and/or field laboratory data) to validate the employed empirical models and results. I'd suggest the authors at least include a few other observations to validate the overall utilized approach. Second, the paper requires some further modifications and/or clarifications in different parts. Based on these shortcomings, I recommend a minor revision. The authors should consider the following comments in their revision.	Dear Mostafa Momen, Many thanks for your encouraging and positive feedback, we are grateful you found this study useful and appropriate for this special issue and for the BG community. Concerning the aspects to address, we will closely follow your advice and include other sources of data to compare and validate the employed empirical models and results. Moreover, we will also incorporate further modifications and clarifications in response to your suggested major and minor comments.
Major Comments:	
Comment (1): Line 105: Q1: Why this particular plant has been selected for this study? Q2: What are the characteristics that distinguish it from other plants? Q3: How does selecting a plant and its hydraulic traits influence the final conclusions of the research? The authors need to comment on these.	We will add several text paragraphs to the manuscript to address the three issues (Q1-Q3) raised here. Please find our answers as follows: Q1: In 2017 winter wheat (*Triticum aestivum*) was grown in the crop rotation of the farmers at the Selhausen test site. We have access to this test field and the on-site measurements. The winter wheat at Selhausen grew well without too much care (no irrigation) or inputs (fertilizers). It was also not affected by diseases. Moreover, this wheat monoculture has the advantage, that growth stages between individual plants are nearly completely synchronized and the canopy is very homogenous. The benefit here is that measurements of individual plants are very likely representative for all other plants and can be scaled to the whole canopy. In a more complex study design, a direct comparison between remote sensing and in situ measurements would be even more difficult.

	The described experimental work, together with first estimations of VOD and the gravimetric water content of wheat (m_g) were the focus of previous research (Meyer et al., 2018; Meyer et al., 2019). We build on these results here and present a concept study for the estimation of water fluxes in the SPAS. Most notably, a main motivation for analyzing wheat comes from its importance for food production being one of the major crop types cultivated around the globe. A concise infographic of the FAO (Food and Agriculture Organization of the United Nations) summarizes the main impact of wheat as one of the top commercial crops: http://www.fao.org/assets/infographics/FAO-Infographic-wheat-en.pdf Q2: Key developmental stages of winter wheat (*Triticum aestivum*) are published by H. A. Bruns & L. I. Croy and indicate that this agricultural crop has a distinct phenological cycle in the yearly growing period. Detailed information on global distribution, botany, growth and physiology of winter wheat are presented in Curtis et al., 2002 (http://www.fao.org/3/y4011e/y4011e00.htm). These distinct growth stages are particularly interesting, since they allow us investigating whether and to what extent L-band radiometry is a technology suitable to capture them. Taking the other extreme, a tree in a system where nearly no change in biomass happens, would not allow conducting these analyses. We will add an introductory paragraph to the manuscript characterizing winter wheat as the investigated crop type of our study. Q3: We used a field-based measurement setup (including several in situ and radiometer observations) that monitored a winter wheat (*Triticum aestivum*) field at the Selhausen (Germany) test site of the FZ Jülich for the 2017 growing season. The final conclusions of our research study are bound to this setup as well as the selected plant type (winter wheat), its characteristics and traits. A transferability to another setup as well as to another plant type and its individual traits may not or only partially be possible. This will depend on the similarity between setups as well as phenotypes, phenological status and traits of the plant subject to study compared to the one used in the

	present study.
Comment (2): Equation 6: This model seems to have some empirical coefficients. Are these coefficients plant-type dependent? In Lynn and Carlson (1990), Fig. 16 is depicted for corn. How can that impact the used model in this study? The authors need to comment on these.	We will add a comment (text paragraph) on the revised manuscript specifying that the coefficients are empirically derived from a field study on corn, published in Lynn and Carlson (1990). We will acknowledge that the relationship for wheat may be different than that of corn, but that we adopted it due to its simplicity (linear correlation with LAI) that allows us to dynamize the root-xylem resistance along the growing season, while keeping the amount of needed input variables constant.
Comment (3): Figure 11 and Line 420: Something that perplexes me is that the LAI is changing nonlinearly in the whole duration of the measurements according to Figure 6 implying that the total biomass is changing. If this is true, the comparison shown in this study does not seem valid (based on Line 420) and does not add anything to the paper.	Above ground biomass is shown together with other in situ measurements (LAI, vegetation height & vegetation water content) in Figure 1. Figure 1 particularly illustrates how the total biomass changes across the growing season, as indicated by the reviewer. However, the reason for presenting Figure 11 and including the statement at line 420 (see Figure and statement below) is to show that VOD carries influences from both 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 by 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. This is especially important, since VOD is being increasingly 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). This is in line with the study in Momen et al., 2017, where the reviewer investigated water and biomass effects on VOD. We will add these references to the respective chapter in the manuscript. 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)."

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Figure 11:

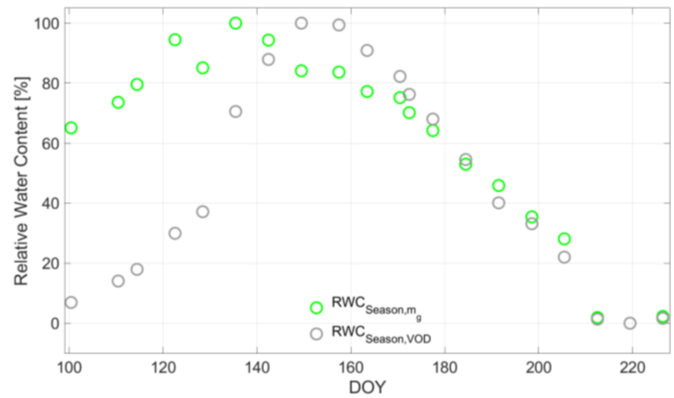

Figure 11: Seasonal Relative Water Content (RWC_{Season}) [$\%$] calculated in (2) with radiometer-derived m_g (green circles) along growing season of 2017 in days of year (DOY) at the winter wheat field in Selhausen, Germany. The gray circles indicate RWC_{Season} calculated directly with the radiometer-derived vegetation optical depth (VOD) according to (9).
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Comment (4): Figure 11, and a general comment: In general, one downside of the paper is that it does not compare the obtained results with other remote sensing products and/or laboratory analysis. This is significant for validation of the employed empirical models and results. In particular, authors can compare their derived RWCVOD (Fig. 11) or soil moisture with satellite products. Although the resolution might be different, it is expected to see generally a similar trend that can further validate the employed methods.
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As suggested by the reviewer, we will investigate the best way to compare and validate our obtained results with other available remote sensing products and/or laboratory analysis, despite the given inconsistencies in spatial and temporal resolutions of the different approaches and sensors. We plan to compare our water potential estimates and the water dynamics (PWU, TR) with independently measured/derived entities of these variables, considering the following approaches:

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.

However, we would like to note that this research study cannot contain a thorough validation study of the proposed concept. This will be subject of future research in which we plan to design dedicated measurement campaigns to validate and explore the practical application of the here introduced methodology for a wider range of vegetation types and climate conditions.
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Comment (5): Line 560: How can such water flow estimations be done solely using remote sensing data? The authors could add some discussions on this and the deficiencies of remote sensing approaches to fully capture the water flow dynamics. I noticed that this has been somewhat discussed in lines 610-620 but more discussions focusing on the limitations and deficiencies of such remote sensing data would be useful especially for large-scale studies.	In order to discuss possible limitations and challenges on the use of large-scale remote sensing for fully capturing the water flow dynamics, we will add the following text paragraph to the discussion section, connected to lines 610-620: "…This would enable a wide-area (up to global) assessment of the SPAS in the end." However, this comes with the limitations in spatio-temporal as well as spectral coverage of remote sensing systems, no matter if active (e.g. lidar, radar) or passive (e.g. spectrometer, radiometer) systems are used. Moreover, it has to be acknowledged that remote sensing acquisitions do not purely sense one variable of the Earth system, but normally a mixture of variables (e.g. combination of soil and vegetation variables). Hence, the quality of retrieved Earth system variables (e.g. soil or plant moisture), extracted from remotely sensed observations, depends directly on the sophistication of the signal-to-variable conversion by the established retrieval algorithm. Moreover, L-band radiometry does not measure fluxes per se. Hence, we need valid estimates of the water reservoirs (soil moisture, plant moisture and relative humidity of atmosphere). Afterwards, we need performant estimates of the water potentials. In the end, we need to transit to the water fluxes, here the essential auxiliaries are the flow resistances of the soil, vegetation and atmosphere. These resistances are challenging to assess with remote sensing due to multi-factorial (inter-)dependencies. For these reasons, in order to retrieve exact water flow dynamics, the most plausible solution will probably come from the combination of Earth system/vegetation growth models and high spatio-temporal resolution remote sensing data from multiple instruments. This multi-source approach will be key for applications needing quantitative estimates of water fluxes and will be the subject of further research.
Minor Comments:	
Comment (1): Line 125: How far is the climate station from the measurement site?	The used climate stations are located directly next to the test field (60 m from radiometer) and on a neighboring field (about 400 m from the radiometer). The second station is used only for assessing wind speed and net radiation as measurements of the closer station would be biased by interfering man-made infrastructure and measurement devices, which are located close by. We will add an informative sentence to the section 2 (test site and experimental data) to report this on-site

	setup.
Comment (2): Figure 1: How much is VWC correlated with LAI?	We calculated the Pearson's correlation coefficient R between the in situ measured vegetation water content (VWC) and leaf area index (LAI) along the growing season at the wheat field (see Figure 1 for individual data sets). It amounts to R=0.94. We will add a statement close to the description of Figure 1.

References

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