

## ***Interactive comment on “Use of GNSS SNR data to retrieve soil moisture and vegetation variables over a wheat crop” by Sib0 Zhang et al.***

### **Anonymous Referee #2**

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#### General comments

This paper presents a case study applying GNSS signals, which were reflected on the ground surface (soil, vegetation surface) to derive soil moisture and vegetation height data over a wheat crop field. The GPS antenna was installed at a height of 2.51 m. Soil moisture was retrieved as long as the vegetation height was lower than  $\sim 20$  cm. However, with a further increase in plant height, it was not possible to retrieve soil moisture. Reaching a certain plant height, it was then possible to retrieve the vegetation height from the GNSS signals.

In general, the topic of this manuscript is interesting and worth to be published in HESS. The methods seem valid and transparent. However, before publishing, this manuscript has to undergo major revision as several points have to be clarified and described

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/ discussed better / more clearly. The manuscript should undergo an English spell check.

The following points should be improved in general:

- Please highlight in a more prominent way what is really new and what is the outcome and applicability of this approach.
- Please introduce and explain the so called 'dominant period' in more detail.
- Please clarify that the GNSS retrieval of soil moisture and / or vegetation variables, actually only vegetation height, is only valid for different temporal stages. Especially, at the beginning it is unclear / confusing that soil moisture and vegetation height were retrieved at different time periods (before and after vegetation significant growth in March).
- If the title contains 'vegetation variables' but only 'vegetation height' is retrieved, please change this in the title and at relevant parts of the manuscript.
- The structure of the paper is not always clear – especially the chapters 'Method', 'Results' and 'Discussion' should be structured better. Some results / discussions already appear in the methods part, some points of the discussion in the results part and some methods in the discussion part.
- In some parts, the methods are explained very well, but in some parts they are presented too extensively. The manuscript should be more focused on your applied method and should be shortened as many aspects are already published in literature and don't have to be repeated in this manuscript.
- Is it necessary to retrieve soil moisture before retrieving vegetation height? Please comment on this.
- Regarding the statistics, 7 or even only 5 (during the period you used to demonstrate vegetation height) in situ vegetation height samples are actually too low. Please

comment at least that during further studies more in situ data should be carried out.

- It is questionable if all information given in the supplement is needed. On the other hand, some figures (see specific comments below) would also be valuable within the manuscript itself and should be presented there.

Specific comments

Page 1 – Title

Please clarify that the retrieval of soil moisture and vegetation variables are actually only valid for different temporal stages (before and after vegetation significant growth in March). Moreover, it would be valuable to include that you use reflected GNSS signals in your approach as also other GNSS approaches exist on this topic.

Title suggestion: ‘Use of reflected GNSS SNR data to retrieve either soil moisture or vegetation height, depending on the vegetation phase of a wheat crop field,’

Page 1 – Abstract

General: The absolute length of the abstract seems fine, however, the information given here should be compressed or information should be combined more functionally. Additionally, it should be added why this approach is generally useful (1 sentence) and what is missing so far regarding the state of art (1 sentence)

p.1, l.15: ‘...numerical simulations of biomass...’

p.1, l. 18: describe in few words the ‘dominant period’

p.1, l. 18: ‘...SNR data, whereas changes in...’

p.1, l. 20: ‘...smaller than one wavelength (~19 cm).’ This should also be changed in the entire manuscript.

p.1, l. 22: dry biomass?

Page 1-3: 1. Introduction

General: The introduction is quite good, but it should be written more comprehensively, especially the parts where you describe already published techniques. However, the first part (p.1, l.27-p.2, l.2) where you introduce the necessity of this approach and the recent lack to monitor land surface variables at a local scale should be extended! Moreover, it should be written more clearly why GNSS reflectometry could be a solution.

p.2, l.7: The frequency of GPS L1-band is 1.57542 GHz. Please write 1.6 GHz instead of 1.5 GHz.

p.2, l.10: 'These properties have e.g. been...'

p.2, l.10-15: As you generally mention L-band active and passive remote sensing techniques, also other GNSS methods (besides reflectometry) aiming to derive soil moisture or vegetation parameters should be mentioned (e.g. GNSS methods using signal attenuation).

p.2, l.17: please specify, how these two antennas are mounted?

p.2, l.26: 'They are surrounded by sparse vegetation and are therefore not useful for vegetation studies.'

p.3, l.31/32: Better write 'lower and taller vegetation' as you are measuring the vegetation height and not their density.

Page 4-5: 2. Data

General: Actually this section already belongs to the 'Method' section.

p.4, l.4: Fig. S1: This figure is not really valuable to show where the test field is situated (present either a picture of the GNSS antenna in the field or a map where the field is situated)

p.4, l.14: '... , four GPS satellites of in total 32...'

p.4, l.18: refer to relevant figure

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p.4, l.1-2 and l.29: avoid repetitions

p.4, l.1ff: add information on the soil type and texture; moreover, the row spacing of the wheat crop would be interesting.

p.4, l.30/31: which satellite observations are meant? GNSS satellites or EO satellites?

p.5, l.2: 'soil moisture and vegetation height. . .'

p.5, l.5: Which soil moisture instruments did you use as reference, e.g. frequency domain probes?

p.5, l.8: add the vegetation height at the end of the season as well. Moreover, for each reference sample the measured height and the phenological status of the wheat crop would be interesting (e.g. listed in a table).

p.20, Fig. 1: Figure sub-captions (a-d) are not well structured; a legend in plot a) would be helpful (red and black line); please insert units if there are in y-axis of plot b) and plot d) and in the legend of plot c) (otherwise write []); the mentioned 128 to 1024 s are not shown in plot c –please mark or show tem additionally in a second x-axis; for more clarity in the manuscript, refer to Fig. 1a, 1b, 1c, 1d, not only to Fig. 1.

Page 5-9: Methods

General: This chapter should be written more comprehensively and precisely, especially the parts of already known methods.

p.6, l.8ff: How many soil moisture and vegetation height results per day did you get out of the 37 available satellite tracks? As of Table 1 and Table 3 it seems that you got 1 results for each day. Please clarify (short) already at this point the temporal resolution and the daily composition of your retrieved results.

p.7, l.3: Is there any S-value specific for L1 already available in literature? Or is the mentioned and an adjusted S-value for the first time applied for L1-band signals? Then this should be introduced more prominently in the manuscript!

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p.7, l.5: It seems more logical to introduce the adjusted S-value in this chapter instead in the 'Results' chapter.

p.7, l.6ff: Perhaps it also makes sense to introduce your experimental  $A_{norm}$  threshold of 0.88 within this chapter. Moreover, Fig 2 should be combined with / replaced by Fig. S7.

p.7,12/13: are GNSS data available for periods of bare soil (e.g. before the wheat crops reached a vegetation height of 10 cm before January 16th) – this would be valuable to improve the final soil moisture estimate.

p.7, l.21: 'see the Supplement' – which figure or part do you mean?

p. 8, l.9ff: 'One possible reason. . .' This part fits better to the 'Discussion' part.

p.9, l.8ff: In my opinion, the 'scores' don't have to be introduced with equations.

p.21, Fig. 2: Should/could be combined with Fig. S7.

Figure S3 and S4: Especially Fig. S4 is interesting. It should be demonstrated within the manuscript as it shows at which stages it is difficult to retrieve the results according to the dominant period.

Page 10-11: Results

p.10, l.3ff: Please insert also the mean soil moisture values of each method (for the entire observation period).

p.10, l. 3-24 and p.23, Fig. 4: Is it generally possible to compare these three methods one by one? The model simulates the first 10 cm; the reference measurements record at a soil depth of 5 cm and the GPS technique observes the soil surface. Perhaps the results with a S-value of  $S=0.0148$  are even more realistic!? Please state on this. The GPS retrieval seems to be slightly too low in this plot using a S-value of 0.0033; especially after soil freezing and at the end of the soil moisture retrieval period the correlation between GPS retrievals and observations / reference measurements is

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weaker.

p.10, l. 14: 'a priori'

p.11, l.6: delete '(not shown)'

p.11, l.10ff: Please insert also the vegetation height determined either by GNSS or manually for each date, instead only listing the deviations.

p.11, l.12: why do you use a 21 gliding window approach? Is this really necessary? Perhaps the vegetation height levels in Figure 6 make sense (e.g. due to meteorological events and plant growth spurts)?

p.11, l.26: Please state more on the overall possibility to compare dry biomass and vegetation height. Is this really possible? Are there some references available? Please state on this more detailed.

p.22/23, Fig. 3/4: for better comparability, in both Figures the y-axis should have the same scale; They could also be combined in one figure with sub-figures a) and b).

p.24, Fig. 5: How many dots are shown in this plot (N=47)? Please add this information in the figure capture.

p.25, Fig 6: You don't have to repeat the legend in the figure column.

Page 12-14: Discussion

General: The idea of asking questions is good. Please also insert a discussion section / further question on the potential future applicability and transferability (e.g. to other soils, other vegetation types, other GNSS signals etc.). What could be improved. . .

p.12, l.3ff: As important findings (regarding the discussion) are shown in Fig. S6, this figure should also be shown in the manuscript (not only the supplement). Moreover, this issue should be discussed in more detail.

p.12, l.9: Why did you increase this threshold exactly to the value 0.88? Is there any

reason for this value?

p.12, l.26: Re-formulate your question: 'Can other vegetation characteristic besides vegetation height be inferred from the wavelet analysis?'. Or formulate two questions: 'Can vegetation height be inferred from...?' and 'Is it possible to additionally retrieve other vegetation characteristics from...?'

p.12, l.27ff: The idea that you potentially also would like to retrieve the plant water content (or even other vegetation characteristics) should already be introduced earlier in the manuscript. Then an answer to this question would make more sense in the 'Discussion' part. Do you have reference data that show a decrease in plant water content?

p.13, l.22: What do you mean with STD?

p.13, l.17: The rainfall/meteorological and logging events could additionally be shown in the figure, e.g., as a subplot.

p.14, l.2-8: This actually belongs to the 'Method' chapter. It is a further method to compare your retrievals to a reference.

Page 14-15: Conclusions

General: Give also an outlook on potential applicability of this technique.

p.14, l.19: Please specify – is this a new algorithm you developed or do you mean at this point the algorithm of CH15 and others you applied for the wheat crop test field?

p.15, l.2: L5 is introduced here for the first time. It could be mentioned already earlier (e.g., in the 'Discussion').

Supplement

S p.1, Fig. S1: see comment above.

S p.2, Fig. S2: Applying the same time scale in the x-axis of the two plots would be

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better for comparability or it would even be more helpful if both plots would be combined in one figure (e.g. with two different colours).

S p.4, Fig. S3: a legend would be useful; it would be logical for comparison to combine Fig. S3 and Fig. S8

S p.5, Fig. S4: see comment above; insert a legend and units if needed.

S p.6, Fig. S5: see comment above; how many dots are shown in this plot (N=47)? Please add this information in the figure capture.

S p.7, Fig. S6: please add the black dots also to the legend; regarding the blue line / dots: use either dots or lines for all of the three plots.

S p.8, Fig. S7: see comment above.

S p.9, Fig. S8: see comment above.

S p.9, Fig. S9: This information could visually be combined with Fig. 2 / Fig S8.

S p. 11: Duveiller et al. 2011 should also be added to the references in the manuscript.

S p. 12: Please clarify the figure capture. Was is actually meant with ‘...the value retrieved 15 days before, ...’? The dates of flowering and ripening should also occur in the figure or at least in the figure capture.

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