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Interactive comment on "Deriving surface soil moisture from reflected GNSS signal observations from a grassland site in southwestern France" *by* Sibo Zhang et al.

Sibo Zhang et al.

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The authors thank anonymous reviewer 1 for his/her review of the manuscript and for the fruitful comments.

1.1 [General comments: The authors utilize a geodetic-quality GNSS antenna (AR10 type) in a meadow to test out a soil moisture retrieval algorithm under different stages of natural grass cover growth. They ïňĄnd that their retrieval algorithm performs well and retrieves soil moisture compared to in situ with an RMSE less than 0.04 cm3 cm-3. They compare their results to a 'benchmark' algorithm and ïňĄnd that their algorithm performs better. They also vary the height of the antenna to see if antenna height af-

fects their results, and they also look at the effects from changing the sampling rate. They ïňĄnd that antenna height does not affect their retrievals, but sampling rate does. Overall, there are two major short comings of this study that must be addressed: *First, the 'benchmark' algorithm that the authors compare their own retrievals to should NOT be used for this type of antenna. The benchmark algorithm developed in Chew et al. (2016) was created solely for the antennas used in the Plate Boundary Observatory network (Trimble antennas). It is well known that the algorithm would need to be calibrated for use with a different antenna type. The authors should remove the portion of the paper (ïňĄgures and text) that compare their algorithm to that from Chew et al. (2016). This is a signiïňĄcant portion of the text and discussion that should be removed, but the paper is still worthwhile without it.]

Response 1.1:

Yes. We agree with Reviewer 1. Different GNSS receiving antennas and also various ground situations could affect the a priori S value used in the Chew et al. (2016) algorithm. We will remove the Chew et al. (2016) results from Figs. 4, 5 and 6 and from Tables 3 and 4, while noting that results very similar to those presented in the revised Fig. 5 can be obtained by multiplying by 0.6 the S value used by Chew et al. (2016).

1.2 [*Second, the fact that the authors' retrieval algorithm requires having in situ observations of maximum and minimum soil moisture (Eq. 3) detracts signiïňĄcantly from the usefulness of the algorithm. Of course their algorithm produces soil moisture retrievals within the bounds of the in situ probes–it is effectively scaled by the in situ observations. Furthermore, the authors state that they need min/max in situ observations from both vegetation growth and senescence periods, which then means that they need ancillary vegetation information in order for their algorithm to work. If you need vegetation data and in situ soil moisture probes in order for your algorithm to work, why use GNSS-IR at all? The authors should spend some time re-working their algorithm so that they don't need in situ soil moisture information. If the authors can

address the above two comments, then the paper will be technically correct and will make a more worthwhile contribution to the ïňĄeld of GNSS-IR in general. I know that these are harsh criticisms, and I don't want the authors/editors to think that I don't like the paper–overall, I enjoyed reading it. It is well organized and clearly written. I think reporting their retrieval results is worthwhile, and removing the comparison with the benchmark algorithm will not detract from the paper.]

Response 1.2:

Yes. Figure 7 clearly shows that using GNSS-IR to retrieve VSM values in m3 m-3 when significant changes in vegetation effects occur is challenging. The need to harmonize VSM retrievals from time segments 3 and 4 is related to the cutting of the grass when vegetation effects are pronounced (Anorm is lower than 0.78, see Fig. 1). This rather negative result is, still, technically correct. In the revised version of the paper, we will better emphasize that monitoring VSM using a GNSS network is difficult when vegetation effects are noticeable. However, we show that one may use the information from Anorm data to define time segments when scaled VSM time series can be used: grass cutting can be detected from the rapid rise in Anorm value. This is an encouraging result. In this study, we used independent VSM in situ observations to harmonize the VSM time series across time segments 3 and 4. Since in situ observations are not extensively available, this technique is not readily applicable at other sites. In practice, one could possibly use a data assimilation framework able to integrate the VSM retrievals into model VSM simulations such as those produced by the ISBA land surface model (Albergel et al., 2017). In such Land Data Assimilation Systems (LDAS), a complex seasonal rescaling of VSM observations is needed when the observations are not properly decontaminated from vegetation effects (Stoffelen et al., 2017). LDAS are usually used for satellite observations but can also integrate ground observations. Proposing a complete protocol to apply this method to local GNSS antennas is out of the scope of this work. Observations at a large number of sites would be needed. It can be concluded that more research is needed to use GNSS-IR in densely vegetated

areas. These considerations will be included in the Discussion and in the Conclusion Sections.

New references:

Albergel, C., S. Munier, D. J. Leroux, H. Dewaele, D. Fairbairn, A. L. Barbu, E. Gelati, W. Dorigo, S. Faroux, C. Meurey, P. Le Moigne, B. Decharme, J.-F. Mahfouf, J.-C. Calvet: Sequential assimilation of satellite-derived vegetation and soil moisture products using SURFEX_v8.0: LDAS-Monde assessment over the Euro-Mediterranean area, Geosci. Model Dev., Geosci. Model Dev., 10, 3889–3912, https://doi.org/10.5194/gmd-10-3889-2017, 2017.

Stoffelen, A., S. Aaboe, J.-C. Calvet, J. Cotton, G. De Chiara, J. Figua-Saldana, A. A. Mouche, M. Portabella, K. Scipal, W. Wagner: Scientific developments and the EPS-SG scatterometer, IEEE J. Sel. Topics Appl. Earth Obs. Remote Sens., 10 (5), 2086-2097, https://doi.org/10.1109/JSTARS.2017.2696424, 2017.

1.3 [SpeciïňĄc comments: Page 2, line 5: You should make it clear that GNSS-IR is not used for spaceborne applications, as you reference in the Camps et al. (2008) paper. The spaceborne technique is very different from GNSS-IR.]

Response 1.3:

Yes, this is confusing, we agree. We will delete this sentence.

1.4 [Page 8, line 9: Isn't another way of saying this, is that the sensing depth of GNSS-IR is less than 5 cm? This has been found in previous studies for GNSS-IR (Chew et al., 2014) and for L-band microwave remote sensing in general (Shellito et al., 2016, GRL). The comparison with the land surface model is a bit rushed and perhaps not needed. As you know, there are a variety of different land surface models, each with their own parameterizations of the land surface. There aren't enough details provided about the land surface model for readers to understand its advantages and shortcomings. Was it parameterized for this particular ïňĄeld? What is the spatial resolution of the model?

The authors do not spend much time with comparing their results to the model output, so it would be easy to remove this part of the paper.]

Response 1.4:

We agree that more details about the model simulations need to be provided, in particular on the soil modeling part. This will be done in the revised version of the manuscript. The model version we use has been designed for generic country-scale simulations over France at a spatial resolution of 8 km x 8 km. Sub-grid vegetation types are represented and soil moisture and soil temperature profiles are simulated for each vegetation type, independently of other vegetation types. In this study, the C3 grassland plant functioning type and a multilayer representation of the soil hydrology are considered. The model soil depth is 12 m, with 15 layers and the layer thickness increases from the top surface layer to the deepest layers (Decharme et al., 2011). It must be noted that the SAFRAN precipitation forcing is based on ground observations and is quite realistic (Quintana-Segui et al., 2008). Model simulations are useful to assess the litter interception effect (Fig. 8). We also agree that the sensing depth of GNSS-IR is not sufficiently discussed in Section 5.3. We will include the suggested references accordingly (in particular Shellito et al., 2016). We will make clear that the better agreement with scaled model VSM simulations is probably due to compensating errors triggered by the lack of representation in the model of a litter layer above the soil surface.

New references:

Decharme, B., Boone, A., Delire, C., and Noilhan, J.: Local evaluation of the Interaction between Soil Biosphere Atmosphere soil multilayer diffusion scheme using four pedotransfer functions, J. Geophys. Res., 116, D20126, https://doi.org/10.1029/2011JD016002, 2011.

Quintana-Segui, P., Lemoigne, P., Durand, Y., Martin, E., Habets, F., Baillon, M., Canellas, C., Franchisteguy, L., and Morel, S.: Analysis of near surface atmospheric variables: Validation of the SAFRAN analysis over France, J. Appl. Meteorol. Clim., 47,

92–107, https://doi.org/10.1175/2007JAMC1636.1, 2008.

Shellito, P. J., Small, E. E., Colliander, A., Bindlish, R., Cosh, M. H., Berg, A. A., Bosch, D. D., Caldwell, T. G., Goodrich, D. C., McNairn, H., Prueger, J. H., Starks, P. J., van der Velde, R., and Walker, J. P.: SMAP soil moisture drying more rapid than observed in situ following rainfall events, Geophys. Res. Lett., 43, 8068–8075, https://doi.org/10.1002/2016GL069946, 2016.

1.5 [With regards to the sampling rate discussion–are you not just exploring effects of sampling lower than the required Nyquist sampling frequency for a given antenna height?]

Response 1.5:

No. In the examples shown in Figs. 9, 10 and 11, the SNR frequency is lower than the Nyquist frequency (half of the sampling frequency). This will be indicated in the revised version of the paper.

1.6 [Technical corrections: Figure 2 needs a second y-axis for Anorm. I understand they are scaled between 0-1 just like you have your biomass values, but it's a bit confusing without an extra label.]

Response 1.6:

Yes. We will add a second y-axis for Anorm.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2017-597, 2017.