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Discussions

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 2 for his/her review of the manuscript and for the fruitful comments.

2.1 [OVERVIEW The manuscript investigates the use of the Global Navigation Satellite System Interferometric ReïňĆectometry (GNSS-IR) technique for soil moisture retrieval. SpeciïňĄcally, one year of observations were acquired at a grassland site in France by using an antenna at 2 different heights (3.3 and 29.4 m). GNSS-IR data are compared with ground-based reference measurements and the effect of vegetation, litter water interception, sampling interval and antenna height is analysed on the ac-

curacy of the measurements. GENERALCOMMENTS GNSS-IR represents a new approach for measuring soil moisture and surely deserves to be investigated. SpeciïňĄcally, the potential of using GNSS-IR measurements for monitoring soil moisture over large areas might represent an important step forward in our capability of measuring soil moisture at ïňĄeld scale. The manuscript is well written and clear and, hence, I have no major comments to be addressed. I believe the paper might be published after considering the minor comment I reported below. 1) The same authors (nearly) published a paper in 2017 with a very similar purpose. I can see the differences between the two papers, and hence I believe this paper should be published. However, I strongly suggest to clearly underline the differences between the two papers and the main innovative aspects (e.g., antenna height, analysis of vegetation effect) of the current study.]

Response 2.1:

Yes. We will better describe the differences between the two studies throughout the manuscript.

In this study, both L2C and L5 signals were observed over a meadow during a rather long period of time of about 15 months using an AR10 antenna at contrasting heights (3.3 or 29.4 m) above the soil surface, while in Zhang et al. (2017) the L1 C/A signal was observed over a wheat field during a shorter period of about 7 months using an AS10 antenna at a constant height of 2.5 m above the soil surface.

A key difference between the two papers is related to the observed vegetation canopy. The studied grass and wheat (this study and Zhang et al. 2017, respectively) presented contrasting characteristics. While considered multi-species permanent grassland incorporated a litter composed of dead leaves, the wheat crop consisted of a single plant species with no litter. Another difference between the two canopies is that maximum height of the grass (about 0.3 m) was much lower than maximum height of the wheat (about 1 m). A large difference could also be noticed in maximum above-ground dry biomass values: less than 0.5 kg m-2 for grass, about 1 kg m-2 for wheat.

While VSM could not be retrieved by Zhang et al. (2017) after wheat tillering, i.e. for plant height larger than 0.2 m, we could retrieve scaled VSM values throughout time segments of the grass growing and senescence phases. However, retrieving VSM values in m3 m-3 was challenging and required a seasonal rescaling to account for vegetation effects (see Fig. 7).

2.2 [2) In the description of the study area, more details should be provided. At which depth are installed the surface measurements? How many rain gauges are available in the study area? How many soil moisture stations (I guess one)? Which model is used for simulating soil moisture? I suggest adding all these details in the revised manuscript.]

Response 2.2:

Three ThetaProbes measured VSM at a depth of 5 cm and were located within a few meters of each other (red star in Fig. 1). The mean value was derived from these three probes to represent the in situ VSM observations at 5 cm. One EC-5 Decagon VSM sensor was installed at 1 cm to measure VSM at 1 cm.

One rain gauge was available close to the in situ soil moisture sensors.

Moreover, VSM simulations for the top 1 cm were produced using the ISBA (Interactions between Soil, Biosphere, and Atmosphere) land surface model within the SURFEX (version 8.0) modeling platform (Masson et al., 2013). The ISBA model used the atmospheric forcing data produced by the SAFRAN atmospheric analysis of Météo-France. We used a model configuration corresponding to the C3 grassland plant functioning type and a multilayer representation of the soil hydrology. The model soil depth was 12 m, with 15 layers and the layer thickness increased from the top surface layer to the deepest layers (Decharme et al., 2011).

New reference:

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

2.3 [3) At Page 5, lines 17-20 it reads that only some satellite tracks are selected based on the comparison with in situ measurements. I was wondering how the authors will select the tracks if in situ soil moisture observations are not available, it should be clariïňĄed.]

Response 2.3:

Yes. This is a clear limitation of using high antenna heights. It must be noted that this limitation only affected measurements at a height of 29.4 m and was caused by the more complex experimental constraints in this configuration (e.g. possible parasitic signal reflection on buildings). For the low antenna configuration (3.3 m), this additional data sorting was not needed and all available satellite tracks with a complete elevation angle range (between 7 and 30°) were used.

We will clarify this in the revised manuscript.

2.4 [4) At Page 5, line 28, what is the “multipath interference pattern”. Please clarify.]

Response 2.4:

For a static receiver, the SNR is governed to a large extent by the interference pattern (IP). The IP is defined as the coherent summation of direct and reflected GNSS signals on the in-phase and quadrature space (Zavorotny et al., 2014). This coherent summation generates an IP where high and intermediate frequencies distinct from noise frequencies, are related to the difference of travelled distance between direct and reflected waves. The IP can be characterized with GNSS receivers using either (1) two antennas (e.g. Rodriguez-Alvarez et al., 2011) or (2) one antenna (e.g. Larson et al., 2008; Chew et al., 2014; Zhang et al., 2017). In this study we used the one-antenna

IP technique as illustrated by Fig. 1 in Larson et al. (2016) for a simple planar and horizontal ground reflection. We will clarify this in Section 2.

New reference:

Rodriguez-Alvarez, N., Vall-llossera, M., Camps, A., Bosch-Lluis, X., Monerris, A., Ramos-Perez, I., Valencia, E., Marchan-Hernandez, J.F., Martinez-Fernandez, J., Baroncini-Turricchia, G., Perez-Gutierrez, C., and Sanchez, N.: Land geophysical parameters retrieval using the interference pattern GNSS-R technique, IEEE Trans. Geosci. Remote Sens., 49, 71–84, https://doi.org/10.1109/TGRS.2010.2049023, 2011.

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