

Response to the Anonymous Referee #2

We wish to thank the reviewer for the insightful comments and suggestions. Below is a detailed response to your comments and questions. The response to each item is written in blue, and the modifications in the manuscript are written in bold.

Guillaume Gru,

on behalf of all the authors

Referee comments 2 - egusphere-2026-3611

This study is original, relevant, conducted using appropriate methods and written clearly. It was a pleasant and instructive reading.

I have a few comments and questions.

As reviewer #1, I find that the current title is misleading. "Sensitivity of time-lapse magnetic resonance sounding to vadose zone hydrodynamic parameters during an intense meteorological event" might be more convenient.

We thank the reviewer for raising this issue. The original title was indeed misleading. We will revise the title to your suggestion: **"Sensitivity of time-lapse magnetic resonance sounding to vadose zone hydrodynamic parameters during an intense meteorological event."**

Could you please explain how did you checked that the chosen warm-up period was long enough to satisfyingly dissipate the initial condition ? Were these initial parameters integrated to the GSA ?

We defined the warm-up period as the time required to get water contents and MRS signal independent of the initial conditions. This warm-up period avoids the conditioning of our GSA to the initial conditions. The warm-up period is parameter dependent. We checked the validity of our warm-up period by running simulations with the same parameter set but with different initial conditions. We did not check for all parameter sets, but we took a period significantly longer, long 'enough' to consider that warm-up period is appropriate.

Could you further investigate the interactions between parameters ? Detail of the interactions within pulses and during time would be instructive (regarding the relation between soil residual water content and the fraction of MRS undetectable water content in q1 for example).

Reviewer #1 also suggested to further investigate the interactions between parameters. Our response and the expansion of the discussions regarding parameter interactions should satisfyingly reply to your suggestion :

« We have expanded the discussion on parameter interactions to clarify their dependence on the pulse moment. We now explain why the interactions are relatively stronger for lower pulse

moments. This is because lower pulse moments investigate the unsaturated zone, where the non-linearities in the Mualem-Van Genuchten model induce interactions between parameters. However, our investigation of second-order Sobol indices reveals that these interactions are composed of many weak pairwise interactions. Specifically, the maximum pairwise interaction index is low ($S_{2,i,j} < 0.02$). Therefore, while these interactions are physically rooted in the unsaturated zone physics, they are negligible in terms of their contribution to the overall signal variance. »

The interactions between the soil residual water content and the fraction of MRS undetectable water content for q_1 are therefore negligible in terms of their effects on the MRS signal's variance. A perspective of this work is to verify if this results has an impact on the parameters' identifiability. The link between parameters could be further investigated by analyzing the correlation of the posterior distributions obtained from the inversion of time-lapse MRS experiment with Bayesian inference, for example.

To fully address your comment, we have added an explanation of the temporal evolution of the interactions between parameters.

Changes made :

L495-502 : *Finally, the sum of first-order Sobol indices is always close to unity, indicating that parameter interactions have a negligible contribution to the variance of the MRS signals. The interactions between parameters are stronger for the lower pulse values (q_1 and q_2) because the depths investigated by these pulses are unsaturated during most of the experiment **and are subjected to variations of saturation**, inducing interactions between Mualem-Van Genuchten parameters. **These interactions are enhanced during the hydrological event (fast rise of the water table and slower return to the initial state)**. As noted with the investigation of the second order Sobol indices, the contribution of interactions among parameters is composed of multiple weak pairwise interactions. These interactions are not physically meaningful in terms of variance contribution, as the maximum pairwise interaction index remains low ($S_{2,i,j} < 0.02$).*