Comment on hess-2021-201
Anonymous Referee #1

Referee comment on "Using Machine Learning to Predict Optimal Electromagnetic Induction Instrument Configurations for Characterizing the Shallow Subsurface" by Kim Madsen van't Veen et al., Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2021-201-RC1, 2021

I very much appreciate to investigate the numerous options of ML for geophysical application and novel ideas related to this issue are of particular interest for HESS.

In this manuscript ML was intended to be used to improve a design optimization task for electromagnetical field mapping. The approach is interesting and especially the interpretation of the feature importance has an added value as this allows some enhanced interpretation. The manuscript holds a lot of interesting results however I suggest to rethink the focus of the manuscript. In the recent form of presenting the methods and results I cannot agree that “The result is an approach that can allow an EMI user with limited expertise to choose a better set of instrument configurations given their main survey goal and knowledge of the site conditions. (line 493/494)”.

One of my concerns is that the authors formulate as their main objective to present an approach to select sets of EMI configurations that are optimal given the specific survey goals and any independent knowledge of the subsurface electrical properties - with the aim to support users with limited expertise, see line 67-74. To fulfill this aim it would be more helpful to write a practical guideline than a scientific paper. In the recent form I have doubts that the manuscript can support users with limited expertise as the figures and way of recommendation needs to be simplified. Moreover the authors choose a rather arbitrary selection covering a very broad range of subsurface properties for the forward models. The chosen ECa range is rather high and from the practical point of view many field sites vary by a delta ECa not more than 20 mS/m which would cover only two classes (e.g., van Hebel 2018, McLachlan 2017, Robinet 2018, Reyes 2018).

Given the option of EMagPy it seems to me more convenient, even for an unexperienced user, to run a forward model with several instrument configurations (HCP, VCP, PRP and coil distances) for the specific application with some prior knowledge of texture, salinity etc..

Moreover I see a big challenge for unexperienced users to understand the dynamic aspects of the depth sensitivity of EMI depending on the subsurface EC distribution. In this manuscript this aspects was excluded as stated in line 58-59/line 120. I can understand to keep the situation in a first attempt simple in terms of using McNeill model, however I would strongly avoid to make decision on measurement configurations without keeping
this aspect in mind.

My suggestion would be either

- to focus on a very practical guide for users based on forward modelling that not only includes the instruments configuration but also EC of the subsurface and including a real world example to transfer knowledge into practice

- or to focus on the scientific value of the study and rather present and discuss your approach (and its advantages) compared to existing approaches/forward modelling having more room for a structured discussion (e.g. Table 2, Figure 4 and Figure 7) and advancing the way of presenting the results (Fig 7, 8). Especially for the results in chapter 4.4 I do not see the added value clearly.

Specific comments:

- in the title the root zone is explicitly mentioned however it doesn’t appear later on to be an issue

- in the introduction you use the formulation “near surface hydrogeologic structure”, later you switch to layered soils – maybe you can unify wording

- the introduction contains many information that are rather a methodological description of your work, e.g., line 57-58, 85-107, please address these issue in the methods chapter

- In order to simplify your discussion and figures the height above ground could be released in a first step, since the assumption the all option are in any case available is misleading, e.g., I don’t think its possible to carry an instrument with a coil distance of 4m at a height of 10 cm above ground along an agricultural or grassland transect. I completely understand that it is tempting to use all the information since ML is designed for big data, however for better understanding you could make use of Fig.2 in combination with some practical issues to reduce input heights.

- Do you have an idea why is the residuals in Fig 3 and 6 not evenly distributed? low EC values are overestimated and high EC values are underestimated - this aspect of heteroskedasticity needs to be discussed

- Fig. 4 I agree that a problematic condition for EMI is the thickness of a layer which is shown nicely for the thickness of A – the thickness of B should be even more challenging however this is not represented in the “outliers”

- the usage of an NRMSE is not clear to me if you intend to guide the user directly (l468)

