

RC1

General comments:

The paper addresses research questions which are both important and relevant to the scope of HESS. Through comparing several modelling approaches with different types of data, this study presents novel ideas and data to demonstrate the importance of including lateral groundwater flow in models representing soil moisture, particularly when simulating saturated peatland conditions and lowland forest. These results are significant given many models do not currently include lateral groundwater flow, and the importance of accurate simulation of soil moisture. This is of particular importance for peatlands, given their role in mitigation of climate change impacts.

The paper is well-structured and written clearly and concisely. The abstract summarises the research well and the introduction reviews the current gaps in the literature, explaining the need for this research. Methods and assumptions are clearly defined, and the results support the conclusions with well-presented figures and analysis. Limitations to the study are well-described and supplementary materials clear.

I have a few specific comments, but otherwise an excellent paper.

We would like to thank the reviewer for the positive feedback on our work. Please find our replies to each specific comment in blue.

Specific comments:

Abstract - Could highlight why this research is needed within the first couple of sentences.

Good idea, the beginning of the abstract will be revised as: "Soil moisture plays a key role in soil nutrient and carbon cycling, plant productivity and in energy, water, and greenhouse gas exchanges between the land and the atmosphere. However, the knowledge on drivers of spatiotemporal soil moisture dynamics in subarctic landscape is limited. In this study, we used the Spatial Forest Hydrology (SpaFHy) model, in-situ soil moisture data and Sentinel-1 SAR-based soil moisture estimates to explore spatiotemporal controls of soil moisture in a subarctic headwater catchment in northwestern Finland."

Line 104: "at range" -> across/over a range

Thanks, this will be corrected.

Line 116: plant Latin names in italics normally?

Indeed, these will be changed to italic.

Figure 1. It's not very clear how a) fits into b) and the scale of b) compared to c). It would also be nice in figure 1a) to see which is the forest site and which is the mire site (perhaps clarify in the figure legend in brackets). Perhaps also add the river network over the top so this is clear.

Note that the catchment is very small (see the scale in Fig. 1a), and therefore it would not be at all visible if plotted in Fig. 1b. We will add scale or coordinates to Fig. 1b so that it can be better compared with Fig. 1c.

We are going to add (forest) and (open mire) either in the figure legend or in the caption.

Note that the stream network is shown in Fig. 2: streams. We are also going to add the stream network in Fig. 1.

Line 144: I assume the above-ground fluxes and state variables computed in the canopy submodel are the same for all 3 versions of SpaFHy? I would just add a sentence to make sure this is clear.

Yes, and this is already mentioned in the model parameterization section at L218. We will also add this earlier in the model description at L152: "The canopy and bucket submodels are common to all three SpaFHy versions."

Line 227: Did you do any sensitivity tests to confirm that depth-to-bedrock was not important? Or was 5m decided based on any other studies/references?

Reliable and high-resolution information on depth-to-bedrock or the quality of the bedrock (e.g. porosity) is very difficult to obtain. At Pallas, there are some, yet very limited measurements available. Hence, we opted for a pragmatic approach, to assign a general value of depth-to-bedrock that approximately corresponds to both the thickest peat layers of the catchment, and the shallowest mineral soil depths found in the uplands of the catchment. No sensitivity tests were conducted. We will add following texts and reference to a published groundwater model study by Autio et al. 2023, providing context for the selected depth-to-bedrock values.

L228: "Due to a lack of reliable data on the depth-to-bedrock, a uniform thickness of 5 m was assigned for the deep soil layer of the 2D groundwater module throughout the model domain. This estimate corresponds approximately to the thickest peat layers and the shallowest mineral soil depths at the catchment (Autio et al., 2023)."

L231: "No further calibration or sensitivity tests of any model parameters were conducted in this study."

Line 242/Figure 1: Not very clear which soil moisture sampling locations are those bi-weekly vs the 56 additional locations in the figure. I can also see there are locations labelled with m and l, but you don't explain what these two stand for.

The bi-weekly measurements are denoted with "i". The "l" and "m" correspond to those measurements that were only conducted twice (2021-06-17 and 2021-09-01). "l" measurements are conducted on a snow survey transect and "m" is an additional transect in different direction. These will be mentioned in the revised manuscript:

L242: "In particular, during snow-free seasons, biweekly manual measurements at 15 different points (denoted as "i" in Fig. 1) were conducted"

L244: "Additionally, we conducted two extended soil moisture measurement campaigns, including 56 additional locations (denoted as "l" and "m" in Fig. 1)"

Line 269: "of midday" -> at or for midday

Thanks, will be corrected.

Table 2: Figure legend above table rather than below

Legends of Table 1 and 2 will be shifted above the tables.

Figure 3: Please add in the figure legend for A) as observed (obs) and simulated (mod). In addition, there is no SWE in the figure. For B) and C) figure legend I think as you have specified what each parameter is in A, it makes sense to do so here too i.e. Air temperature (T)

These will be added in the figure caption.

Line 313: "groundwater recharge" -> groundwater recharge

This typo will be corrected.

Figure 5. figure legend – add "(obs)" for "in-situ measured"

This will be added.

Figure 6: as previous plots have low=dark blue, high = yellow, this should be consistent for canopy fraction too

Good point, the colormap will be reversed here.

Line 384: "follow mostly" -> mostly follow

This will be revised.

Line 508: I assume there was no groundwater level data to compare with model simulations.

We have compared the simulations to the groundwater level data in the Supplement (Fig. S7). This was mentioned at lines 344-346 in the manuscript. We will reiterate this at L509: "Even with these limitations, the modeled groundwater level dynamics were relatively close to the observed levels (Fig. S7)"