Thank you to the reviewer for your feedback and suggestions. Please find the response to your comments in blue.

Reviewer #1

The study applies the HydroBlocks model to simulate soil conditions in Finland, and the technical implementation appears thorough. However, I have significant concerns regarding the scientific novelty, methodological clarity, and overall focus of the paper. In its current form, the manuscript does not meet the standards for publication in this journal.

Below are my specific comments:

1. Lack of Clear Innovation and Advantage. The study appears to be a regional validation of the HydroBlocks model over Finland. However, the manuscript does not clearly articulate what specific advantages HydroBlocks offers compared to existing reanalysis products or other high-resolution models. Without a clear comparative analysis against established datasets (e.g., ERA5, satellite-derived SWE, in situ observations), it is difficult to assess the added value of this work.

Thank you for this valuable comment, we think this aspect of the paper needs to be improved. In the introduction, as a justification of using HydroBlocks, there is comparison with HydroBlocks to some other models used in research in Finland, for which are used only at a catchment and/or watershed scale such as Watershed Simulation and Forecasting System (WSFS), and HydroGeoSphere (HGS) models. Advantages with HydroBlocks are that it offers us the possibility to model multiple variables computationally efficiently but at a high-resolution scale at different depths across the whole country, and the model could possibly be used in other applications as well. We are presenting a hyper resolution simulation that can be validated with local observations of processes that take place in a field scale resolution.

In addition, in our paper, in the discussion sections, there is also discussion related to the possible problems with ERA5 Land air temperature and precipitation (smoothing of very low temperature and very high temperatures and over estimating precipitation) used global models, as well as differences between Finnish soil and with the Soil Grids soil data. The problem with global models, such as SWAT hydrological model, is the usage of synthetic soil representation, which lacks sufficient presentation of Finnish soil (such as till), which is a product of the latest glacial period. This issue was also brought up in our paper with our simulations. However, HydroBlocks offers us the opportunity to use different datasets for meteorology and soil data to improve the simulations. To strengthen our novelty, we suggest that in addition to presenting HydroBlocks model results for Finland using SoilGirds data (validated with in-situ observations), we would add to this paper HydroBlocks simulations using local soil data provided by the Geological Survey of Finland. This improved presentation of soil would highlight the advantages against other models.

In model validation, we used in-situ observations from six snow water equivalent stations at different latitudes and longitudes across Finland, and for soil temperature and soil water content, we had data from three soil stations. These in-situ observations are more reliable than satellite observations. Satellite-derived SWE could turn out to be valuable to “combine”/ use together with HydroBlocks model in the future, but just as a single dataset, we feel it would not increase the value in the validation.

1. Misdirected Introduction Focus. The introduction extensively discusses frost quakes, yet the manuscript does not directly address this phenomenon in the results or discussion. If the goal is to model soil conditions relevant to frost quakes, the connection should be

explicitly demonstrated. Otherwise, the lengthy background on frost quakes seems disconnected from the actual content.

This is a valuable comment, and we agree that the introduction focuses too much on frost quakes, and a shorter description of the phenomena is sufficient for this paper. The motivation of this work is to, in the future, be able to calculate thermal stress across Finland, but because it is a huge work, it will be done in a separate paper. The connection between frost quakes and soil conditions is achieved by introducing the thermal stress equation, which contains the soil temperature and frost depth that can be obtained as outputs from HydroBlocks. The goal of our paper is only to model soil conditions relevant to frost quakes; soil temperature and soil ice content, and for this reason some background on frost quakes and frost quake research is needed, but it will be made shorter.

1. Insufficient Model Performance Evaluation. While the authors note that HydroBlocks performs well in some respects, several KGE values are negative or low. For hydrological modeling, KGE > 0.5 is often considered acceptable for streamflow, but for other variables (e.g., soil moisture, temperature), benchmarks are less clear. The manuscript should include a systematic comparison with independent observational or reanalysis products (e.g., satellite SWE, soil moisture from SMAP or ERA5) to objectively demonstrate model superiority.

We agree that some of the values describing the model's performance, especially with soil water content, are not satisfactory. However, we have also discussed some possible reasons for this; the model's ability to describe Finnish soil is challenging due to the presence of glacial deposits such as till formations. In addition, as discussed in the discussion but will be expanded, for a model that covers the whole country, it is challenging to calibrate it to precisely represent each pixel with relatively low number of in-situ soil parameters. Further, soil water content is quite location specific and can change within a small spatial window. We also think that for model validation, satellite observations would not add value since we already have the in-situ observations. Additionally, we are mostly interested of the times when the soil is frozen, which the model can accomplish. The most important soil condition for us is the soil temperature, which the model can simulate well.

1. Unclear Purpose of Spatial Comparisons Across Years. The comparison of spatial patterns for specific days in different years (e.g., Fig. X) does not convincingly illustrate trends or model skill. Given interannual variability in meteorological conditions, such snapshots may not be representative. A more statistically robust analysis of temporal trends or climatological comparisons is needed.

The reasoning for showing certain days is that the background of the paper is in frost quake research and for this reason maps on the 6th of January 2016 and 2023 are shown for SWE and soil T, which are dates when frost quakes have been observed in other papers. The maps are there to visualize some of the outputs from HydroBlocks. The statistical analysis on model performance is included in tables 3-6. The focus of the paper is not to do analysis of trends.

1. Title and Focus Mismatch. The title promises an analysis of "temporal and spatial trends," but the manuscript lacks a dedicated trend analysis. The results are largely descriptive and do not systematically quantify or discuss long-term changes in soil conditions. This disconnect should be addressed.

Here, the word trend is meant to describe how, for example, the temperature profile behaves across time. Trend analysis was never the purpose. We realize now that the wording is misleading. Using wording such as “soil dynamics” would be better. The paper would benefit from a title with better working, and we suggest something along the following: “High resolution modelling of temporal and spatial dynamics in soil conditions in subarctic Finland using HydroBlocks model”.

1. Redundant Figures. Figures 10, 11, and 12 contain repeated subplots of meteorological and SWE time series, which adds little value and distracts from the key messages. These could be consolidated or moved to supplementary material.

The reason for leaving input air temperature and modelled snow water equivalent in the plots with soil temperature and soil water content is to show how the atmospheric and snow conditions directly relate to the modelled soil conditions. We agree that to save space, these figures should be combined to present air temperature, SWE, soil T and SWC only once in the same figure to reduce repetition.

1. Weak Scientific Narrative. The manuscript reads more like a technical report than a cohesive scientific paper. The focus is diffuse, shifting between frost quakes, model validation, and regional climatology without a clear central question. I recommend reframing the study to emphasize either (a) advancements in land surface modeling at high resolution, or (b) a focused investigation of frost quake drivers using HydroBlocks. The current version would benefit from substantial restructuring and refocusing before reconsideration.

The focus of the paper is in finding a way to estimate soil temperature and soil ice content with high spatial resolution across the multiple decades, to be able to, in the future, calculate thermal stress in Finland in a similar scale. We think this focus will become clearer after making changes suggested by the reviewers.