Response to reviewer 2

We thank the reviewer for the helpful comments. Please find below our responses (in blue).

Authors extended soil column to 10 m in depth, thus increase the inertia of heat transfer in simulation. Representation of bedrock additionally to strengthen this effect. However, it is not clear in which case the bedrock representation process is switched on or off?

The bedrock is switched on in all of the 'deep soil' simulations. This information is given in Table 2. However, to make it clearer we have now stated this explicitly in the text.

In Section 2.5 it now reads: "The simulations carried out are given in Table 2. This includes the standard JULES set-up (min4l), a higher-resolution soil column (min14l), a deeper soil column (minD), the effects of moss and organic soils both separately and in combination (minmossD, orgD, orgmossD), and finally the modified snow scheme (orgmossDS). **When deeper soil is added in minD, this includes both the extension of the soil column to 10m and the addition of a 50m bedrock column.**" (bold=new text)

Authors also mentioned no zero heat flux at the lower boundary of the soil column. Is it treat only the extended with bedrock column or to 10 m deep "ordinary soil column" as well as? If so, in spite of the reduction of the active layer thickness, produced by the improved JULES version the overestimated values of the active layer thickness comparing with active layer monitoring sites (Fig.3) could explained by this circumstances. How many layers the bedrock column contains?

There is a zero heat-flux condition at the deepest point of the soil column, which is the base of the ordinary soil column when bedrock is not used, and the base of the bedrock column when bedrock is used. There are 100 layers in the bedrock column of 0.5m thickness, so the total column is 50m (bedrock) + 10m ('ordinary' soil), making 60m in total.

It is unlikely that the bottom boundary will have an effect on the active layer in this case. We see the edge effects with a 3m soil column in Fig 9, but in fact they are not noticeable (i.e. the line for min14l coincides with minD) when we are closer to the surface, from about 2m away from the base of the column. This suggests that the bottom boundary effects on a 60m soil column will not make a significant difference to the active layers that are in the top 3m of soil. However it would be good to simulate the bottom of the permafrost as well as the top, and so in future work we would like to add the geothermal heat flux to make the model more realistic.

We have made the following addition to the text, which explains the requested details:

In Section 2.2.1: "The number and thickness of bedrock layers is set by the user when running the model. In this study, the bedrock column was run with 100 layers of 0.5 m each, making a 50 m column, thus bringing the total soil column up to 60 m. There is a zero heat-flux condition at the base of the bedrock column, which in future could be changed to a geothermal heat flux."

Figure 5 has no indexes a, b, c, referred in the text.

We have added these to the figure.

It is not clear for me what kind of modification to the snow scheme was done and how it is integrated with the soil column. It should be explained in text. How the snow properties are simulated? I think it is very important part of the manuscript, because near-surface permafrost strongly depend on snow pack and even sometimes snow defines does permafrost exist at some location or does not.

Thank you for this comment, we agree that there is not enough detail in the text. To address the first point (integrating the modification of the snow scheme), we have re-written Section 2.2.4 as follows:

“In the original multi-layer snow scheme, numerical stability requires that the layered snow is only used when the snow depth is 10 cm or greater, and the old, zero-layer snow scheme is used for shallower snow. The modification introduced in Chadburn et al. (2015) allows the multilayer snow scheme to run with arbitrarily thin layers, thus removing the zero-layer snow scheme from the model altogether.

In the zero-layer snow scheme the heat capacity of snow is neglected and melt water is passed directly to the soil model to be partitioned into infiltration and runoff. In the multilayer snow scheme the snow is treated as a separate layer with its own heat capacity, and a fraction of the mass in a snow layer can be retained as liquid water instead of passing straight into the soil model. This water will freeze if the layer temperature falls below 0°C. Thus the snow mass will be slightly different in the multilayer scheme, and in general the model’s behaviour is more realistic.”

We have also added the following into the JULES model description (Section 2.1) to answer the second point about how the snow properties are calculated:
“Snow in the zero-layer scheme has a constant thermal conductivity that is added in series to the conductivity of the top layer of soil. In the multi-layer snow model, thermal conductivity is parametrized as a function of snow density. Snow albedo is parametrized as a function of snow grain size (Best et al. 2011). ”