Dear Reviewer,

Thank you very much for taking the time to review our work. We greatly appreciate your thoughtful comments that help improve the manuscript. Our responses to the comments and how we will revise the manuscript based on these comments are listed as follows.

RC #1.
All results are shown as time series and error plots. More insight is needed into the actual physical processes and system behavior, not just on 'dry' figures or plots showing errors. i.e. to answer WHY these processes are or are not important under these conditions.

AC #1.
We agree that there is room for more discussion of the processes and why results change these processes representations. We will add the following analyses in the text, and figures were added to the Supplement.

(1) Why models with cryosuction predict deeper thaw depth?

Essentially, cryosuction increases soil suction to attract more deep liquid water moving towards the frozen front during soil freezing. Thus, the real active layer formed due to the existence of cryosuction should be thicker than the cases in which cryosuction is assumed unimportant.

(2) Why Barrow site is more sensitive to the cryosuction process when estimating thaw depth and water content (Figure 8 of the manuscript)?

This is determined by both soil properties and climate conditions. The soil at Barrow has larger suction and is able to hold more water (Figure 2 of the manuscript), providing the possibility for cryosuction to make larger contributions. The principal difference between cryosuction and non-cryosuction representations is presented when temperature is below the freezing point (see Eq.(3) and Eq.(4) of the manuscript). Compared to Sag and Teller, Barrow has lower annual average temperature (Figure 1 of the manuscript), making the effect of cryosuction more pronounced.

(3) Why Sag and Teller sites are more sensitive to the cryosuction process when estimating temperature (Figure 9 of the manuscript)?

This is associated with the larger water present at these two sites. Soil freezes from ground surface downward and from the bottom of active layer upward during freezing, forming a liquid zone in between where the temperature approximates freezing point due to phase change (The following Figure S1(a) shows an example of the column model under Sag's condition at the 300th day of one year). Thus, this liquid zone isolates the upper permafrost from the soil surface temperature variations due to the weakened conductive heat transport the along soil depth. Besides, the released latent heat in this liquid zone may retard soil freezing, which also tends to reduce the thermal conduction. However, cryosuction process can speed up freezing and promote the attenuation of the liquid zone, and thus decrease the impact of the liquid zone (Figure S1(b) shows the ice saturation at the same time, i.e., 300th of one year, when the soil column still has large area no frozen). Hence, the influence of cryosuction is more significant with more soil water.

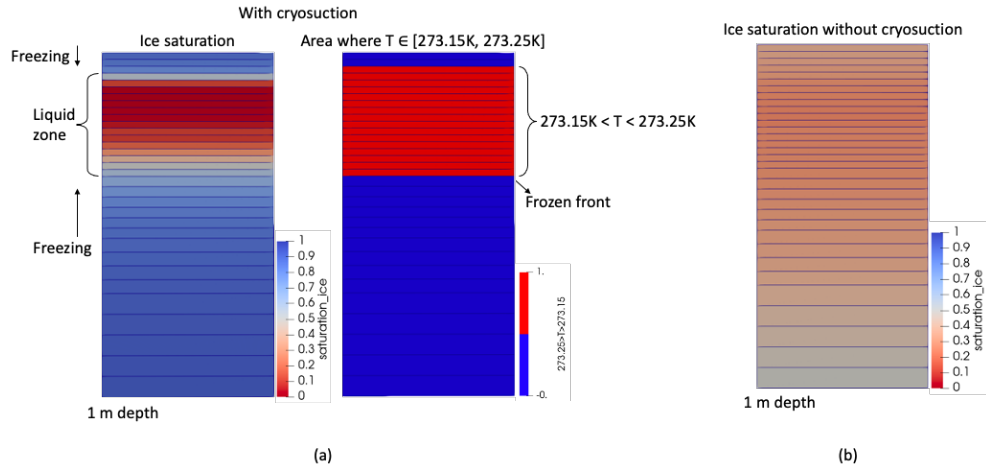

Figure S1. (a) Ice saturation and area where temperature is between 273.15K and 273.25K within the top 1 m depth of a column model under Sag's condition at DOY = 300, with cryosuction process in simulation (DOY is day of year); (b) Ice saturation within the top 1 m depth of a column model under Sag's condition at DOY = 300, without cryosuction process in simulation.

(4) Why advective heat transport is not significant in simulations under the assumed conditions of this paper?

Under the assumption of large-scale Arctic systems ignoring influence by localized groundwater flow features (e.g., ponds, gullies, etc.), the liquid water flux determines the advective heat transport in the subsurface. However, the flow velocity on average is quite low within the shallow active layer with limited thickness (see an example in Figure S2).

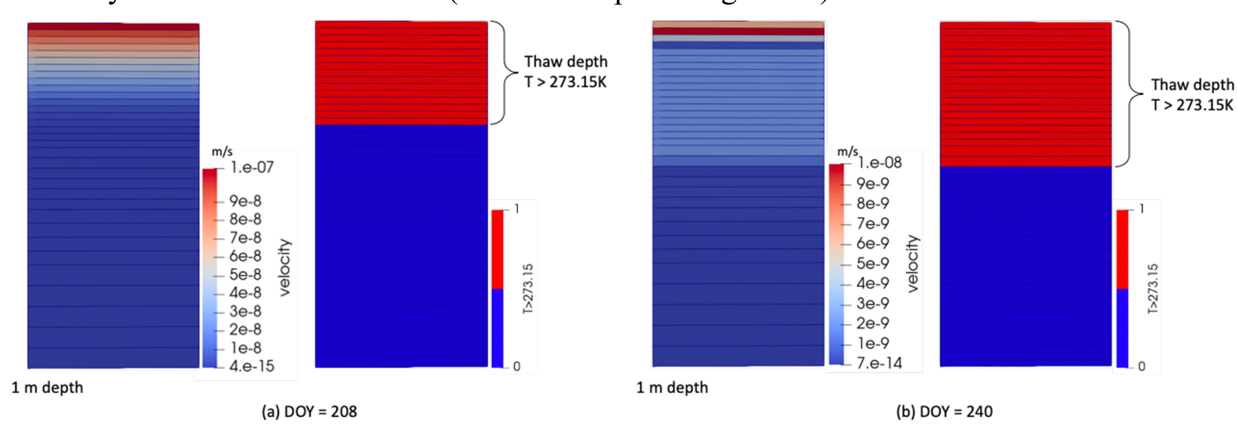

Figure S2. Vertical velocity distribution and thaw depth within the top 1m depth of a column model under Sag's condition at DOY = 208 and 240.

Figure S3 compares the absolute value of conductive and advective heat flux, at the 208th and 240th days, separately. The advective heat flux only shows a relatively larger value at top cells because of water flow inside of the active layer. The relatively larger advective heat flux is on the same order of magnitude with the smallest conductive heat flux (see Figure S3(a)) or even less than the smallest conductive heat flux (see Figure S3(b)).

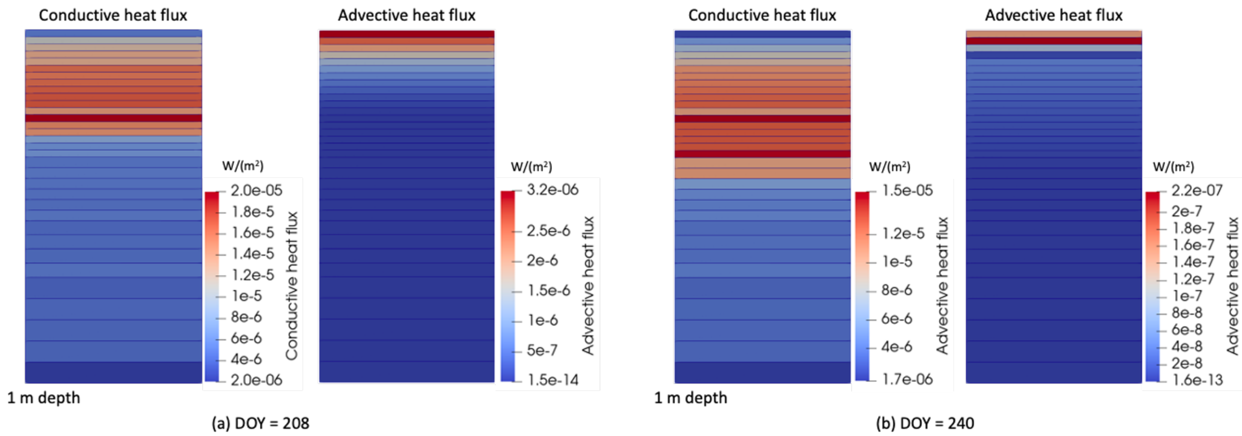

Figure S3. Absolute value of conductive and advective heat flux within the top 1m depth of a column model under Sag's condition at DOY = 208 and 240.

RC #2.

I did not find the comparison of computational efficiency very relevant. The authors seem to suggest if the computational cost of including advective heat transport is high, then it can be neglected. Computational cost should have little or no bearing on whether or not to include a process - if a process is important & relevant, it needs to be included, regardless of the computational cost.

AC #2.

We agree that the process distinction is by far the more interesting result, and we included the computational cost only as a sidenote, as it is of interest only to ATS users. We definitely did not intend to suggest that computational cost has any say in whether a process can be neglected or not. We agree with the reviewer that if a process is important and relevant, computational cost should not be a deciding factor. Considering the computational cost is analyzed just based on ATS code and primarily useful for ATS users, and this is a much smaller audience, we will move the discussions of the computational cost to the Appendix. The manuscript is probably clearer with their removal from the main text.

RC #3.

I found the results and conclusions were cast too strongly as being definitive in the general context. These results are specific for the conditions assumed (geometry, flow system, etc.).

AC #3.

We agree that the results are specific for the conditions considered, and tried to stress this in both the Introduction and Conclusions by noting clear exceptions in other geometries, such as thermo-erosion gullies, etc. (see Lines 118-128, Lines 608-609). We agree that it important to state the limitations of this study up front, however, and will add text at the beginning of the conclusions clarifying that "Here we investigated the influence of these simplified representations on modeling field-scale permafrost hydrology in set of simplified geometries commonly used in the permafrost hydrology literature with the Advanced Terrestrial Simulator (ATS v1.2). We note that these conclusions are specific to conditions similar to these geometries, and should not be applied in cases where focusing flow mechanisms may dominate." Additionally, in the Conclusions, we will also add "under the assumed conditions".

RC #4.
The paper refers a few times to 'a general Arctic system' (Line 27) or to '... a normal Arctic system' (Line 490) .... These should be replaced by, ex., 'a conceptual system'... or 'in these specific simplified cases'. There is no such thing as a 'general' or 'normal' Arctic system.

AC #4.
The "general/normal Arctic system" here does not mean "generalized" or "all" Arctic system, but refer to a large-scale Arctic system without apparent influence caused by localized groundwater flow features, such as taliks, thermal-erosion gullies etc., that mentioned in the Introduction. For a small area with these localized features, advective heat transport may play an important role. This paper does not focus on these localized features, but on a large-scale Arctic system where the influence of these features can be neglected. This will be clarified in the text.

RC #5.
Line 111: The Nixon (1975) paper is much too old to use for justifying this statement that 'it is commonly recognized that heat conduction predominates ...'.

AC #5.
This sentence was intended to lead to the introduction of the cases where advective heat transport plays an important role. It will be deleted in the text.

RC #6.
Line 156, 297: needs to be corrected to advection-dispersion (or advection-conduction). ('diffusion' is almost always used only in the context of mass transport).

AC #6.
This is clearly a difference of fields. Advection-diffusion is commonly used in the applied mathematics literature to describe the partial differential equation solved, though we are willing to consider that conduction may be the more commonly used term in the engineering community, and is typically more specifically used when referring to heat transport. The term "advection-diffusion" in the original manuscript (Line 156) will be revised to "advection-conduction". Section 2.3 focuses on advective heat transport and discusses the effect of including advective heat transport or not in permafrost models. Section 2.3 will remain the original heading "advective heat transport".

RC #7.
Table 6 (A summary of NNSEs of variables obtained through column model comparison): four significant digits is excessive here.

AC #7.
Four digits were used to avoid "NNSE = 1.000". This will be revised to three digits in the text.

RC #8.
Line 184: s_n *(saturation of n-phase) is usually capitalized.*

AC #8.
Lowercase "*s*" for saturation is used to differ from the function S_* for Van Genuchten model.