CVPM 1.1: a flexible heat-transfer modeling system for permafrost
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This is the fundamental work describing in-depth modeling of the subsurface heat-flow in presence of permafrost that deserves to be published. The advantage of the CVPM model is that it is scalable from 1D to 3D and can be used in multiple coordinates including cartesian, radial and cylindrical. It accommodates diversity of the geologic settings for model setup and employs more physical approach for setting up the freezing depression point. Many existing permafrost models use empirically derived parameters to represent unfrozen water function, which is an important component responsible for correct temperature modeling and precision of the freeze/thaw moving boundary. However, from the current description is it not clear why and how the unfrozen water content used in CVPM is different from empirical derived unfrozen water coefficients, for example (a, b, and freezing point depression T*) used in GIPL model (Nicolsky et al, 2009; Jafarov et al., 2012). It is hard to clearly differentiate these two approaches without direct benchmark comparison of these models. In addition, CVPM uses empirically derived coefficients in equations (6) and (7), somewhat similar to GIPL. It would be nice to add an example of the modeled versus observed ground temperatures from one or multiple permafrost monitoring stations from North Slope, Alaska (Wang et al., 2018). Do the coefficients from Table 1 fulfil the whole range of subsurface complexity to represent observed ground temperatures?

Below I have minor suggestions aimed to improve the clarity of the manuscript.

Figure 1. I suggest to include two more plots: b) c_{pl} vs T(k), and c) c_{pi} vs T(k) as a subplots for Figure 1, where current plot is a). Add a line illustrating liquid-liquid critical temperatures. Line 7, most material fall within the range 630-870 J/kgK. I suggest to add a bar to the Figure 1A that represent that range.

What is the main advantage using equations (6) and (7) in oppose to apparent heat capacity formulation? Coefficients in Table 1, where are they come from?

P6. L5. L10. It would be nice to have visual representation of the porous media and unfrozen water redistribution for spherical and cubic packing.

Figure 2. It is not clear according to which formula phi_i is calculated. Equation (9) does not have d or T_f in it.

P7. L5. Pure water freezes at 273.15K. I am not sure where 273.16 and triple point pressure come from. Need a citation.

P9. Figure 3B. How the derivative was calculated (numerically or analytically)? I suggest to add an equation of the derivative.

P10. Eqn. 17, for consistency with eqn. 19, should it be k_{BM2}?

Table 5. It would be nice to list below the table the meaning of each notation mean.

An example shown on Figure 9. What was the time step?

Figure 10. Colorbar does not have notation.

Figure 13. What are the initial and boundary condition?

P24. L6-7. Need a citation.
Section 4.3. What are the initial (IC) and boundary condition (BC)? What type of ground material and layering was used?

P28. L10 “bulk thermal conductivity is found…”. Not clear, what does it mean “found”? Inversely estimated?

I felt that for all examples the domain setup including IC and BC was skipped. Since this the modeling paper, I suggest to add a bit more details on model setup, grid (mesh), thermal, hydrological and other parameters setup. What type of data do the model need for initialization? What is the model driver data? What is model subsurface setup (soil texture, layering, thermal conditions and so on).

References

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3. Wang, K., Jafarov, E., Schaefer, K., Overeem, I., Romanovsky, V., Clow, G., Urban, F., Cable, W., Piper, M., Schwalm, C., Zhang, T., Kholodov, A., Sousanes, P., Loso, M., and Hill, K.: A synthesis dataset of permafrost-affected soil thermal conditions for Alaska, USA, Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2018-54, in review, 2018.