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Pore water pressure variations in Subpermafrost groundwater : Numerical modeling compared with experimental modeling

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Development and degradation of permafrost directly affect numerous hydrogeological processes such as thermal regime, exchange between river and groundwater, groundwater flows patterns and groundwater recharge (Michel, 1994).
Groundwater in permafrost area is subdivided into two zones: suprapermafrost and subpermafrost which are separated by permafrost. As a result of the volumetric expansion of water upon freezing and assuming ice lenses and frost heave do not form freezing in a saturated aquifer, the progressive formation of permafrost leads to the pressurization of the subpermafrost groundwater (Wang, 2006). Therefore disappearance or aggradation of permafrost modifies the confined or unconfined state of subpermafrost groundwater.
Our study focuses on modifications of pore water pressure of subpermafrost groundwater which could appear during thawing and freezing of soil.
Numerical simulation allows elucidation of some of these processes.

Our numerical model accounts for phase changes for coupled heat transport and variably saturated flow involving cycles of freezing and thawing.
The flow model is a combination of a one-dimensional channel flow model which uses Manning–Strickler equation and a two-dimensional vertically groundwater flow model using Richards equation.
Numerical simulation of heat transport consisted in a two dimensional model accounting for the effects of latent heat of phase change of water associated with melting/freezing cycles which incorporated the advection-diffusion equation describing heat-transfer in porous media.
The change of hydraulic conductivity and thermal conductivity are considered by our numerical model.

The model was evaluated by comparing predictions with data from laboratory freezing experiments.
Experimental design was undertaken at the Laboratory M2C (Univesité de Caen-Basse Normandie, CNRS, France). The device consisted of a Plexiglas box insulated on all sides except on the top.
Precipitation and ambient temperature are imposed. The Plexiglas box is filled with glass beads of which hydraulics and thermal parameters are known.
All parameters required for our numerical model are controlled and continuous monitoring of soil temperatures and pore water pressure are reported.

Our results of experimental model allow us to test the relevance of processes described by our numerical simulation and to quantify the impact of permafrost on pore water pressure of subpermafrost groundwater during a cycle of freezing and thawing.

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Wang, Chi-yuen and Manga, Michael and Hanna, Jeffrey C. 2006. Can freezing cause floods on Mars? Geophysical Research Letters, 33