Geophysical Research Abstracts
Vol. 13, EGU2011-6208, 2011
EGU General Assembly 2011

Impact of permafrost development on underground flow patterns: results from a numerical study considering freezing cycles on a 2D vertical cut through a river-plain system

Damien Régnier (1), Christophe Grenier (1), Philippe Davy (2), and Hakim Benabderrahmane (3)

(1) CNRS - CEA - UVSQ, LSCE, Gif sur Yvette Cedex, France (christophe.grenier@lsce.ipsl.fr), (2) Géosciences Rennes, UMR CNRS 6118, Université Rennes 1, 35042 Rennes Cedex, France, (3) ANDRA, Parc de la croix Blanche, 1-7 rue Jean Monnet, 92298 Châtenay-Malabry, France

Within the framework of nuclear waste storage in underground geological formations, the impact of long term surface conditions evolution on underground flow patterns is studied. We focus here on the impact of glaciation cycles on underground flows for the conditions encountered by the French nuclear storage agency, ANDRA, for the Meuse / Haute-Marne site in the eastern part of the Parisian Sedimentary Basin. Climatic conditions considered for the cold periods are steppic environment (dry climate without ice cap development).

In a first approach, freezing induces the development of permafrost leading to a stop of the recharge of the aquifers (Jost et al., 2007). Flow velocities are expected to be reduced, probably by a factor of two (e.g. Teles & Mouche, 2005; Teles et al., 2008). Nevertheless, some small scale features of the landscape can play a role to create local flow paths connecting deep horizons to the surface. Such a case is expected of instance below rivers or lakes where taliks (unfrozen zones) are observed at depth. This issue is studied for instance in the field under a lake in Greenland (Lehtinen et al., 2010).

We study here the evolution of smaller scale units of the landscape, in particular a river-plain system as found in the surroundings of the ANDRA site. The impact of a cycle of freezing and warming on permafrost development and consequent underground flow patterns evolution is studied by means of numerical modeling. The modeled 2D system is a simplified vertical cut through a homogeneous ground including river and plain at the surface. Associated questions are: conditions and time lag required to isolate the river from the depth of the aquifer through continuous permafrost, impact of heat convection and other terms of the heat transport equations, conditions leading to continuous or discontinuous permafrost, uncertainties associated with material properties and temperature signals. Sensitivity analysis to various parameters and forcing signals provides an overview of dominant phenomena.

The numerical model was developed in the Cast3M code (www-cast3m.cea.fr/cast3m, see Régnier et al., 2010). It involves coupled Thermo-Hydro equations similar to (McKenzie et al. 2007, Bense et al. 2009). It couples Darcy equations for flow (permeability depending on temperature) with heat transfer equations (advective, conductive, phase change) with a Picard algorithm. The perspective of a bench mark exercise on code validation, opened to the permafrost community, is presented in line with (McKenzie et al., 2007).

Bense VF, Ferguson G, Kooi H. Evolution of shallow groundwater flow systems in areas of degrading permafrost. GEOPHYSICAL RESEARCH LETTERS 36 (2009)

Jost, A., S. Violette, J. Gonçalvès, E. Ledoux, Y. Guyomard, F. Guillocheau, M.Kageyama, G. Ramstein & J.-P. Suc (2007) – Long-term hydrodynamic response induced by past climatic and geomorphologic forcing: the case of the Paris basin, France. Physics and Chemistry of the Earth, 32, 368-378, doi: 10.1016/j.pce.2006.02.053.

Lehtinen A., Claesson Liljedahl L., Näslund J-O. Ruskeeniemi T. Future glaciations and the challenges related to long time management of nuclear waste: the Greenland Analogue Project. Proceedings of EUCOP III, 13-17 June 2010, Svalbard, Norway

McKenzie Jeffrey M., Clifford I. Voss, Donald I. Siegel. Groundwater flow with energy transport and water–ice phase change: Numerical simulations, benchmarks, and application to freezing in peat bogs. Advances in Water

Resources, Volume 30, Issue 4, April 2007, Pages 966-983

Régnier D, Grenier C, Davy P, Benabderrahmane H. A coupled thermo-hydro model to study permafrost. Proceedings of EUCOP III, 13-17 June 2010, Svalbard, Norway

Teles et al. 2008. Modeling Permafrost Evolution and Impact on Hydrogeology at the Meuse/Haute-Marne Sedimentary Site (NE France) during the last 120 Ky. Proceedings of the NICOP conference, Fairbanks, Alaska

Teles & Mouche 2005. Analyse de sensibilité de la présence d'un pergélisol continu et discontinu sur l'hydrogéologie du secteur, Site MHM. Rapport Andra n° .RP.12CEA.05.001