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Development of a coupled Thermo-Hydro model and study of the evolution of a river-valley-talik system in the context of climate change

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

(1) CEA,/CNRS/UVSQ, LSCE, Gif sur Yvette, France (damien.regnier@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

Boreal regions have been subject to recent and intensive studies within the field of the impact of climate change. A vast number of the modeling approaches correspond to large scale modeling firstly oriented to thermal field and permafrost evolution.

We consider the evolution of smaller scale units of the landscape, in particular here the river-valley unit. In cold environments, we know that some rivers have at their bottoms a talik or a non frozen zone. Such systems have been poorly studied until now should it be as such or in relation with their surroundings, as major thermal conductors potentially impacting a larger portion of a region.

The present work is part of a more global study implying the Lena river (Siberia) evolution under climate change in collaboration with the IDES laboratory (Interaction et Dynamique des Environnements de Surface at Orsay University, see e.g. Costard and Gautier, 2007) where the study of the system involves a threefold approach including in situ field work (near Yakutsk), experimental modeling (in a cold room at Orsay University) and numerical modeling.

The river-valley system is a case where thermal evolution is coupled with water flow (hydrology and hydrogeology in the talik). The thermal field is impacted by and modifies the water flow conditions when freezing.

We first present the development of our numerical simulation procedure. A novel 2D-3D simulation approach was developed in the Cast3M code (www-cast3m.cea.fr/cast3m) with a mixed hybrid finite element approach. It couples Darcy equations for flow (permeability depending on temperature) with heat transfer equations (conductive, advective and phase change process) with a Picard iterations algorithm for coupling. Then we present the validation of the code against 1D analytical solutions (Stefan problem) and 2D cases issued from the literature (McKenzie et al. 2007, Bense et al. 2009).

We finally study by means of numeric simulations the installation of permafrost in an academic river-valley system subject to freezing cycles. Addressed are especially: conditions for the installation of permafrost, timescale involved, intensity of the temperature signal, geometry of the final system, extension of the talik. The impact of climate change in the final system is studied considering a global warming trend of the temperature cycles at multi-annual scale with special concern on the role played by the talik. Physical experiments in cold room will be carried out later and compared with the numerical simulations. Applications to the Lena river system within the context of its vulnerability to climate change will follow.

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