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The InterFrost benchmark of Thermo-Hydraulic codes for cold regions hydrology – first inter-comparison results

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The impacts of climate change in boreal regions has received considerable attention recently due to the warming trends that have been experienced in recent decades and are expected to intensify in the future. Large portions of these regions, corresponding to permafrost areas, are covered by water bodies (lakes, rivers) that interact with the surrounding permafrost. For example, the thermal state of the surrounding soil influences the energy and water budget of the surface water bodies. Also, these water bodies generate taliks (unfrozen zones below) that disturb the thermal regimes of permafrost and may play a key role in the context of climate change.

Recent field studies and modeling exercises indicate that a fully coupled 2D or 3D Thermo-Hydraulic (TH) approach is required to understand and model the past and future evolution of landscapes, rivers, lakes and associated groundwater systems in a changing climate. However, there is presently a paucity of 3D numerical studies of permafrost thaw and associated hydrological changes, and the lack of study can be partly attributed to the difficulty in verifying multi-dimensional results produced by numerical models.

Numerical approaches can only be validated against analytical solutions for a purely thermic 1D equation with phase change (e.g. Neumann, Lunardini). When it comes to the coupled TH system (coupling two highly non-linear equations), the only possible approach is to compare the results from different codes to provided test cases and/or to have controlled experiments for validation. Such inter-code comparisons can propel discussions to try to improve code performances.

A benchmark exercise was initialized in 2014 with a kick-off meeting in Paris in November. Participants from USA, Canada, Germany, Sweden and France convened, representing altogether 13 simulation codes. The benchmark exercises consist of several test cases inspired by existing literature (e.g. McKenzie et al., 2007) as well as new ones. They range from simpler, purely thermal cases (benchmark T1) to more complex, coupled 2D TH cases (benchmarks TH1, TH2, and TH3). Some experimental cases conducted in cold room complement the validation approach. A web site hosted by LSCE (Laboratoire des Sciences du Climat et de l'Environnement) is an interaction platform for the participants and hosts the test cases database at the following address: https://wiki.lsce.ipsl.fr/interfrost.

The results of the first stage of the benchmark exercise will be presented. We will mainly focus on the

inter-comparison of participant results for the coupled cases (TH1, TH2 & TH3).

Further perspectives of the exercise will also be presented. Extensions to more complex physical conditions (e.g. unsaturated conditions and geometrical deformations) are contemplated. In addition, 1D vertical cases of interest to the Climate Modeling community will be proposed.

Keywords: Permafrost; Numerical modeling; River-soil interaction; Arctic systems; soil freeze-thaw