Proceeding of Paris 3rd InterFrost Workshop 22-23 Nov. 2017

(Ecole des Mines - Mines ParisTech)

Present: Victor Bense (Wageningen Univ.), François Costard (GEOPS, Univ. Paris Saclay), Sophie Dagenais (Univ. Laval), Michel Ferry (MFRDC), Christophe Grenier (LSCE, Univ. Paris Saclay), Emad Jahangir (Mines ParisTech), Anne Jost (METIS, Sorbonne Universités), Jeff McKenzie (McGill Univ.), John Molson (Univ. Laval), Laurent Orgogozo (GET, Observatoire Midi Pyrénées), Eric Pohl (LSCE, Univ. Paris Saclay), Agnès Rivière (Mines ParisTech), Johanna Scheidegger (BGS), Elise van Winden (Wageningen Univ.).

Present through videoconference: Andrew Frampton (Stockholm Univ.), Emma Johansson (SKB), Nicollo Turbini (Trente Univ.)

The pdfs of the presentations are appended.

The third InterFrost workshop meeting took place on the 22nd and 23rd of November 2017 at Ecole des Mines in Paris.

The discussions dealt with the different phases of InterFrost, the first being related to the inter-comparison phase and the paper submitted to ADWR, the second, ongoing, dealing with the Frozen Inclusion Experiment conducted at the GEOPS Laboratory and for which a discussion had to be carried on for a first evaluation of these results as well as the perspectives of modeling them with our coupled TH codes as a so-called validation exercise. Future possible phases of InterFrost were discussed as well in the direction of other experiments in the laboratory, field cases, or developments for unsaturated flow conditions.

Third InterFrost meeting program, 22 – 23 November 2017

Wednesday, November 22nd, 2017

***Mines Paris Tech**, Salle Chevalier - 60 Boulevard Saint-Michel, 75006 Paris*

9:00 *Welcome coffee*

9:30 Opening, overview of meeting aims and program (Christophe Grenier)

9:40 How far are we within the InterFrost project (CG)?

10:00 Presentation of the Frozen Inclusion experiment setup and results (François Costard)

10:30 Numerical modeling of the experiment with several models, toward a validation process?

11:00 *Coffee break*

11:30 Discussions period around the experiment and the simulations for validation

12:45 *Hosted lunch*

14:00 Preparation of future tasks considering new test cases: other laboratory experiment by CG and others, non-saturated media (an introduction by Laurent Orgogozo), applications to field sites with presentations by Eric Pohl about the Syrdakh river imprint study site in Yakutia and John Molson & Sophie Dagenais about the North Quebec Umiujaq study site)

16:30 *Coffee break*

17:00 Discussion period

20:00 *Dinner (at participants own expenses)*

Thursday, November 23rd, 2017

***Mines Paris Tech**, Salle Chevalier - 60 Boulevard Saint-Michel, 75006 Paris*

9:00 Sum up of previous day discussions

9:30 Presentation of the Greenland lake talik database (Emma Johansson) followed by discussion about site studies within InterFrost

10:30 Coffee break

11:00 Discussion and decisions on schedule for experiment simulation and preparation of other tasks. Discussion of other issues associated with the Cryohydrogeology domain.

12:30 End of the meeting

1. The InterFrost initial inter-comparison phase

The general introduction by Christophe Grenier reviewed the current state of InterFrost: a first phase (almost completed now) dealt with the intercomparison of coupled Thermo Hydrological codes on designed test cases. In spite of the challenges associated with the numerical simulation of the coupled set of non-linear equations with a sharp freeze/thaw interface, the intercomparison showed that simulation results analyzed based on a broad set of performance measures led to the consensus that simulation results were all converging. The minor discrepancies could be traced back to some deviations from the requirements (set of equations, parameter set and above all the freezing function).

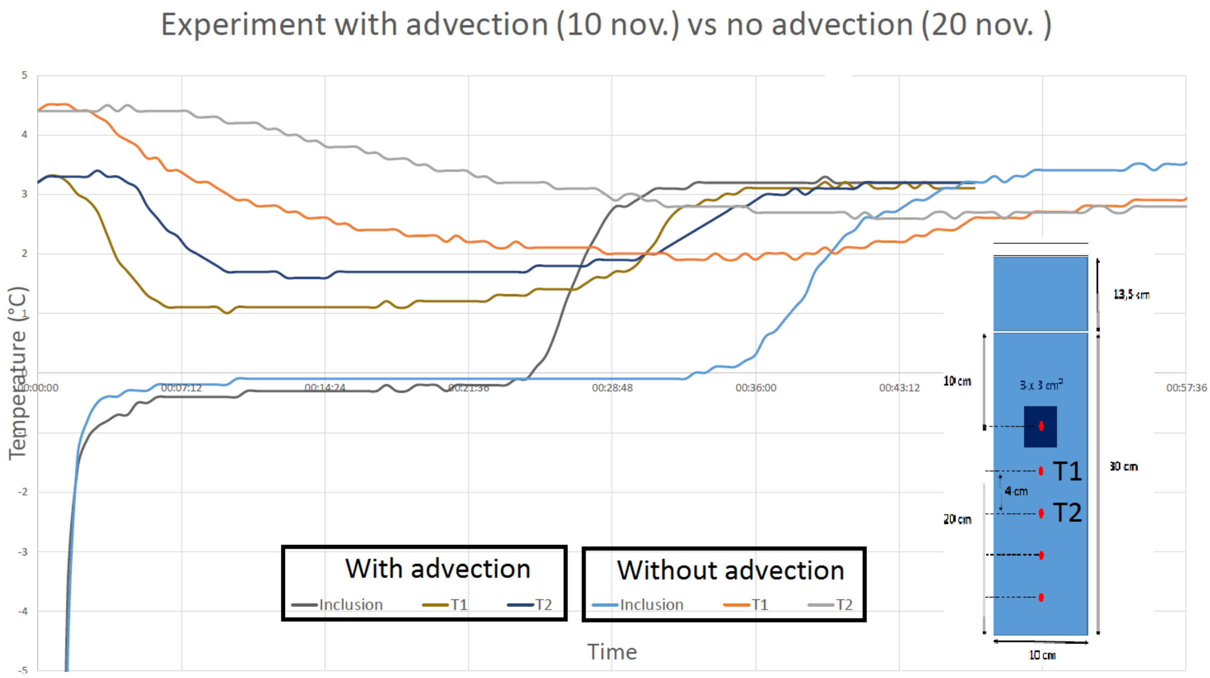
The state of our common inter-comparison paper was discussed. Submitted to ADWR, after review, the editor recommended minor corrections. The main difficulty in the points raised by the reviewers concern the significant length of the paper while another requirement is to discuss in more detail the causes of the discrepancies between code results. The discussion section has to be reorganized as well as some figures reprocessed. The present co-authors' decision reached during the workshop, in agreement with other comments already sent by email, is to keep our main message, conveying that our codes converge. The causes for some minor discrepancies will be have to be discussed at more length but strengthening the paper too far in this direction could add too much length while reducing the clarity of the main conclusion. The present phase of the InterFrost project dealing with experimental cases clearly shows that these discrepancies are very small compared with differences within the calibration phase or the comparison between numerical and analytical simulation results.

2. The InterFrost "validation" phase involving the Frozen Inclusion Experiment

The second phase of InterFrost, ongoing, deals with the validation of the set of equations using experimental data. A new experimental setup was developed at the GEOPS laboratory to address this issue. François Costard presented the implementation of the initial frozen inclusion, inspired from the TH2 test case as well as the monitoring results obtained so far. Temperature evolution is monitored within the inclusion and at 4 locations downstream of the inclusion. Air, input water and setup wall temperatures are monitored, and water flow rates exiting the system are also measured. Additional tests in the form of tracer test and involving a colored initial inclusion were also carried out. The general objective is to conduct complementary tests that should further constrain the parameter set used for numerical simulation if suggested. The implementation of an initial frozen inclusion into a positive temperature porous medium is very challenging. Although the setup has continuously undergone improvements, the initiation phase still requires roughly 2-3 minutes until through-flow is established. Due to the still moderate volume of the inclusion, this results in significant thaw of the initial inclusion before the flow is initiated. A further difficulty is in reproducing the initial 2D system. Although insulation was installed around the Plexiglas box, some lateral heat loss into the walls was observed. The option chosen is to document this by installing a thermal probe on the outer wall to monitor its temperature evolution and estimate such heat losses. Two types of experiments were conducted, with flow (for one single gradient) and without flow.

The ongoing simulation efforts associated with this experimental setup were presented by Christophe Grenier. Though very preliminary due to time constraints, the results showed the following points:

1. The initial phase of emplacing the inclusion has to be simulated,
2. The measuring (response) length of the thermal probes (5 mm roughly) had to be included,
3. Although sand properties are available, some level of calibration is required, especially for the freezing function (and including K and porosity),
4. The experiment without flow was considered first for calibration, then this parameter set was applied to simulate the experiments under dynamic flow conditions.
5. The flow rate included in the simulation does not match the experimental conditions so far.



These results provide some level of confidence that these experiments can reasonably be simulated with existing codes, building confidence in their models.

The subsequent discussion phase revealed some different opinions on this experimental setup. Some mentioned that the setup could be improved by complementary observations and in some cases should be modified (for a larger scale setup) where the creation of the initial inclusion would be obtained by a cooling coil running through the Plexiglas box. In the case of the latter redesigning option, the smaller setup should be replaced by a larger one requiring a longer schedule and some additional funding. Others were positive and were willing to directly simulate the experiments in their present phase, considering that experience can be gained on this and that the options in the experimental setup were already precise, carefully carried out and results mature enough.

A consensus was reached on the second day leading to the decision that interested participants will run the cases with the present setup. The idea is to have all modelers finding their own way to reproduce the experiments (one with advection, another without, with associated experimental precision bounds to be provided by the organizers). They will, in the end, report on the equation and level of complexity involved in the best fit obtained, as well as the associated parameters used in the models. The final outcome will be a table with the quality of fits, models and parameters associated to all participants, which could also include a sensitivity analysis. The issue of code validation will be addressed based on this. The global advancement can, however, be based on some iterative steps where modelers will provide some requirements for the experiments or vice versa. The idea of building a new and larger setup is not abandoned but would require a longer schedule and some additional funding. The process will show if a second setup is necessary and possibly what the added value could be. Some discussion also revolved around the interesting tracer tests and how they could be simulated. For example, the digital images of the tracer plumes could be processed to obtain relative concentrations which could be used for transport model validation.

The organizers will thus provide a set of experimental results and parameter database by the end of January 2018. The deadline for final simulation results is placed at mid-June, shortly before the EUCOP 2018 meeting where session 8 (Coupled heat transfer and fluid flow processes in permafrost regions co-chaired by Grenier, Kuzentsova, Bense) is organized and InterFrost results will be presented. Other contributions to this session from the InterFrost group would be particularly appreciated (deadline for abstract submission is soon, on the 15th of December 2017).

3. InterFrost perspectives

The prospects for a third phase of the InterFrost project were discussed. 3 directions were considered:

1. Work with **other experiments**. Experiments associated with pressure increases due to freezing front propagation in a saturated medium were presented (Agnès Rivière, Christophe Grenier). Another experiment associated with grouting under frozen conditions was also presented (Bastian Welsch and Wolfram Rühaak).
2. Work on **coupled TH processes involving unsaturated conditions**. The discussion was initiated by a presentation by Laurent Orgogozo documenting numerical challenges associated with a field study involving unsaturated flow conditions. The discussion showed that, although the InterFrost group could provide added value on this issue regarding theoretical challenges, modeling issues and confrontation with monitoring field cases in the active layer, the focus will first be put on the hydrogeological part of the issue of coupled TH processes in permafrost regions. Therefore, the unsaturated issue is postponed.
3. Work on **field monitoring cases** that can account for the full complexity of the real world. Presentations accounted for different sites
    a. Sophie Dagenais and John Molson presented the Umiujaq site involving coupled TH processes in a discontinuous permafrost setting. This site study and the associated simulation efforts raised a large interest in the audience. This exceptional case of groundwater flow and associated thawing of discontinuous permafrost pockets from below could be directly considered or further conceptualized to serve as a test case to be considered for a future phase of InterFrost. Moreover, additional field survey and modeling plans will include complementary geochemistry and transport issues.
    b. Eric Pohl presented the monitoring database associated with the Syrdakh site (Yakutia, Russia) where the thermal imprint of a river is being studied.
    c. Emma Johansson presented the Greenland site studies (GRASP and GAP), providing a very complete database addressing active layer evolution, ground temperatures, talik issues, supra and sub permafrost aquifers. The InterFrost group with its priority interest in groundwater flow would like to review in more detail the part of the Greenland site focusing on such issues.

4. Sum-up and decisions

The decision regarding the paper is to maintain the option to mainly convey the message that all code results converge for the test cases and performance metrics considered. The number of figures will be reduced and the discussion section reinforced.

Decisions regarding the experimental test cases (Frozen Inclusion Experiment):

a. The organizers will provide a database for the experiments by end of January 2018.
b. The interested modelers will run their codes considering this information and will be allowed to iterate with the experimental simulation to ask for setup improvements or complementary measurements. The deadline for the final results is the middle of June for preliminary results to be presented at the next EUCOP2018 meeting in Chamonix (France).
c. Another larger setup for the experiment considering the generation of the "initial" inclusion through a cooling coil could be considered next year if the present setup results prove inadequate for the purpose of model comparison.

Future tasks associated with InterFrost are not fixed yet. However a field case associated with the monitoring of permafrost evolution under the influence of groundwater raised great interest. It could be inspired by the North Québec conditions presented (Umiujaq Site) where further monitoring is being planned (water content, water levels, temperature profiles, heat fluxes, meteorological conditions, etc). This means that other experiments or the study of unsaturated flow conditions will probably not be considered in a near future.