Action Group:

The InterFrost Evaluation Platform

Date:

01 January 2016 to 31 December 2017 (2 years)

Action Group Contact:

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Short and descriptive text for the Action Group:

The purpose of this Action Group is to develop a common platform for testing and evaluating numerical models used within the rapidly evolving fields of cryohydrology and cryohydrogeology. Physically-based numerical models are vital tools, necessary for investigating coupled terrestrial cryotic-water-transport phenomena in complex, dynamic and highly variable permafrost environments. They are also important for their quantitative and predictive capabilities and play a prominent role in the integration of available knowledge. However, numerical model comparison and testing frameworks are currently lacking, including in particular suitable code benchmark test-cases and cryohydrological laboratory experiment set-ups appropriate for model evaluation. Such testing and evaluation platforms are necessary prerequisites for establishing robustness and reliability of model application to field scale investigations and predictive analysis.

The primary focus will be on hydrological and hydrogeological problems that require coupled Thermo-Hydrological (TH) treatment under cryotic conditions. Such problems (e.g., interface evolution) are particularly complex from a numerical perspective. While recently developed coupled TH codes provide qualitatively reasonable results, there is a dire need to establish independent quantitative assessments. This cannot be fully achieved using classical analytical solutions which typically rely on overly restrictive assumptions, generally leading to trivial model comparison cases. Here model comparison through suitably designed benchmarks and laboratory experiments can serve to provide more robust and realistic testing frame-works.

The platform developed in this Action Group will serve to enable an open forum for the permafrost and cold regions scientific community to test, validate and compare their codes, evaluate code robustness, reliability and efficiency, as well as discuss further strategic development needs considering real-world applications and field investigation needs. This will be achieved by providing a website with commonly developed test cases and experimental cryohydrological data, organizing workshops for inter-comparison and associated studies, including development of additional needed study cases, and disseminating and communicating outcomes to the broader scientific community through international meetings, conferences and journal publications.

<u>Objectives and scope of the Action Group:</u>

Background:

Cold regions environments are very sensitive to climate change because their hydrological and mechanical properties depend strongly on the ground thermal regime. In an effort to understand the evolution of high latitude environmental systems, numerical modelling is a necessary complement to field and laboratory studies. It has the unique potential of integrating information and processes to better study transient processes in a quantitatively accurate manner, evaluate hypotheses formed from field studies, and make predictive simulations.

This area of research is faced with daunting challenges since the present representation of permafrost environments is still predominantly focused on 1D, non-coupled phenomena (e.g. through large scale climate models). Landscape unit representations, (e.g., rivers, system of lakes, and entire catchments) are still very limited compared to lower latitude systems due to the unique, complex freeze-thaw processes occurring in cold regions. The present short-term changes in climate are superimposed on a longer, more general natural climate evolution, both having a long term influence on permafrost temperature and extent due to the large thermal inertia of frozen soil. Furthermore, the issue of homogenization of small scale processes in realistic heterogeneous environments is still in an infant state due, in particular to the numerical challenges of representing such complex systems.

The motivation behind the InterFrost project is to provide a platform to 1) validate existing and recently developed codes that provide qualitatively realistic results (analytical solutions, intercomparison on more complex test cases, develop associated laboratory experiments in cold room for validation), 2) evaluate the robustness and computational efficiency of the codes to identify best practices and avenues for improvements, 3) create a community of 3 researchers where major issues within this field can be discussed (e.g. supporting field and laboratory studies, upscaling and homogenization, coupling with remote sensing and geophysics, progress towards large-scale "climate" modelling approaches, massively parallel computation) and attract expertise around such major issues, 4) communicate in the scientific community.

The InterFrost project was founded and is led by Christophe Grenier (LSCE). The project as a whole provides a clear validation strategy which relies on well-defined test cases ranging from simple to complex, with some support by experiments in the cold room laboratory. These test cases, as well as current inter-comparison results, are published on the project web site (wiki.lsce.ipsl.fr/interfrost). Two specific workshops already took place (November 2014 and April 2015), which brought together experienced and young researchers from Europe (France, Sweden, UK, Germany, The Netherlands) and North America (USA and Canada). A total of 14 codes are represented in the present inter-comparison phase with a large diversity of numerical and implementation approaches. To date, the program includes coupled TH modelling for fully saturated water flow and idealized test cases (refer to wiki.lsce.ipsl.fr/interfrost web site).

Objectives:
The future needs and objectives of the project, which will be addressed by this Action Group, are 1) address the evolution of natural systems of interest (e.g. lake systems, water catchment profiles, taliks), 2) investigate the issue of system modelling in degraded numerical conditions (e.g. large systems with coarse spatial discretisation, strongly evolving systems over very large time scales implying coarse temporal discretization), 3) extend these issues to unsaturated water flow (Richards equations or multiphase flows).
This Action Group primarily aims to stimulate and improve cold regions modelling, which will benefit the scientific and engineering community reliant on the enhanced understanding and predictive power that numerical models can provide. In particular, findings from this ambitious project will help inform land use and water resource managers of potential hydrologic regime shifts in response to a warming climate. Improvements at this level will help inform the general public and policy makers and thus provide more effective management and legislation.

Outcomes:
Project outcomes include 1) the development of validation tests cases, 2) code intercomparison and associated laboratory test results and their communication (web site, publications and international conferences), 3) stimulation of the scientific community, and 4) inclusion of young researchers and attracting others to cold region issues. Project objectives and outcomes are ensured through the continued organization of workshops, and the earnest participation and enthusiasm which has already been shown through our initial workshop participants and conference activities.
The collaborative efforts for cryohydrological model evaluation and testing emerging through this Action Group will foster international scientific and engineering research in permafrost, and be achieved through regular meetings and workshops combined with a website portal for communication and result comparison. This relates primarily to IPA objectives 1-4 and 7. The expected model developments and improvements by participating scientists also contribute to objective 4.

Timeline:

The timeline spans two years (2016 – 2017):
2016
1. Publication of early-developed test cases (TH1, TH2, TH3) – early 2016
2. Inter-comparison & complementary studies (main results communication at ICOP2015, EGU2015 and AGU2015, through journal publication, and updates to InterFrost web site on test cases and new results) – Spring 2016
3. InterFrost meeting/workshop in the first half of 2016 to discuss ongoing laboratory cases and phase 2 of the project (further work on 'realistic' systems and poorly converged systems – time and spatial under-discretization)

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2017

1. Start phase 3 with a reassessment of coupled heat transfer theories including unsaturated water flow
2. Broaden the participation to the climate modelling community by considering 1D column experimental cases
3. Consider simple realistic field cases from monitored sites

<u>Deliverables:</u>

- The InterFrost website will be expanded to include:
  - Updated test case specifications and references in electronic format
  - Code inter-comparison results available to the public
  - Cold room experimental results and field monitoring data files available to the public
  - Guidelines for TH numerical simulations and directions for best practices
- Regular workshops, stand-alone and in conjunction with international permafrost confer-ences/meetings
- Improved numerical codes that can better simulate complex interactions between climate change, permafrost thaw, and hydrologic regime shifts.
- Publications in high impact scientific journals and other communication venues
- Broad findings will also be disseminated in multi-disciplinary journals for scientists and engineers who are not specialists in TH modeling or permafrost science.
- Presentations during international conferences (EGU, AGU, SIAM, ICOP2015) and regional conferences (e.g. Changing Cold Regions Network) in each country. Organisation of topic-specific sessions at international conferences.

<u>Other Action Group Members:</u>

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International dimension:

Several of our young researcher participants are also active members of PYRN. Therefore, our project has a strong collaborative link to the early career researcher community. We recognize that this connection to the next generation of researchers is critical to the continual improvement of numerical methods for coupled TH processes and for ongoing collaboration with the broader permafrost science community.