Workshop report

HYDRO-PERM: workshop to develop joint future permafrost hydrology research in Svalbard

The University Centre in Svalbard, UNIS, Longyearbyen, 24-26 October 2012

Workshop initiators/organizers:

Dr. Henk Kooi	Critical Zone Hydrology Group, Department of Earth Sciences, VU University Amsterdam (VUA)
Dr. Hanne H. Christiansen	Geology Department, The University Centre in Svalbard (UNIS) & Institute of Geography and Geology, University of Copenhagen

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Background

It is increasingly recognized that permafrost conditions and the associated groundwater hydrology are important, coupled components in the Arctic system which need to be better understood in light of climate change. Development of a comprehensive knowledge base in permafrost hydrology is a major task that can only be achieved through concerted efforts to collect dedicated field data that are currently largely missing, modeling and laboratory studies, and by collaboration across various disciplines. Additionally, observational systems are required to allow the monitoring of system change on various time scales. In the present workshop, it is investigated if such research may be initiated/developed in Svalbard.

Objectives

The main workshop objectives were to explore:

1. The potential for joint future permafrost hydrology research in Svalbard
2. The feasibility of intra- and sub-permafrost hydrological monitoring

Participants

Participants from 7 nations met in the workshop, representing 14 institutions, comprising 9 universities, 2 geological surveys, the Longyearbyen local water supply authority, SSF, and SIOS (Svalbard Integrated Arctic Earth Observing System). Scientific expertise in the participating group comprised permafrost and periglacial processes, hydrogeology, geomorphology, glaciology, geology and geophysics. Additionally, strengths in modeling, field investigation and monitoring were included.

Workshop participants at The University Centre in Svalbard, UNIS 26 October 2012.

Participant list:

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Main outcomes

Participants generally agreed there is a need for improved understanding of the role of groundwater in Arctic landscapes with permafrost. Key examples were presented of relevancy for Earth System research, but also for water supply security.

In Svalbard, there are ample indications of groundwater outflow (springs, pingos, icings, chemistry of subglacial discharge water and water seepage at the land surface) attesting to the presence of relatively deep sub-glacial and intra- and sub-permafrost groundwater flow. However, ideas regarding subsurface conditions are qualitative in nature and rapidly become more speculative with increasing depth (or distance underneath glaciers). Exceptional information on both artesian and extremely low hydraulic heads at about 150 m and 500 m depth, respectively, has been inferred for the lower reaches of the Adventdalen catchment from deep boreholes drilled within the framework of subsurface CO_2 sequestration studies at UNIS.

Compared to other key regions where permafrost research occurs, Svalbard offers special opportunities to study the groundwater hydrology of a high relief Arctic landscape within the continuous permafrost realm, including interactions with glaciers and the ocean. In Alaska and north-western Canada, for instance, permafrost research focuses predominantly on lowland areas and a large part of this research (~ 50% in Alaska) occurs in discontinuous permafrost settings. Hydrology research in Alaska and Canada would strongly benefit from an increased understanding of glacier-permafrost-hydrology interactions in Svalbard and of permafrost groundwater hydrology in general.

Svalbard is a suitable and potentially valuable region to study the impact of climate change on permafrost hydrology, as it hosts the warmest continuous permafrost in the high Arctic, which likely makes it relatively vulnerable to permafrost changes. More than 10 shallow (10 m) boreholes exist in different periglacial landforms incl. a pingo, enabling studies of the ground thermal regime, just as the cryostratigraphy is being studied recently, which will provide more detailed information on the ice content, type and its distribution in the top permafrost. Additionally, special climatic conditions, such as the relatively common rain-on-snow events in Svalbard can increase our understanding of how other places that do not currently experience such events may behave in the future.

Extensive parts of Svalbard are underlain by sedimentary rock, and relatively thick unconsolidated sediments occur in major valleys. These conditions are favorable for groundwater investigations due to the presence of porous (as opposed to fractured) aquifers below the permafrost. Groundwater flow in porous aquifers can be more readily constrained and studied through subsurface monitoring and groundwater flow modeling. Opportunities also exist for groundwater studies in karst aquifer systems.

K**ey scientific challenges** regarding the permafrost hydrology of Svalbard identified by the participants:

The overall Earth System Science level:

- Missing understanding of the present status/functioning of permafrost- groundwater systems in Svalbard.
- Missing understanding of the degree to which the present situation is in a transient state reflecting past climate, sea-level variation and/or landscape changes/developments.
- Missing understanding of the future development of the coupled hydrological -permafrost system under climate change (both on relatively short and long time scales).

Detailed level:

- Identification of recharge areas and recharge conditions.
- Identification of possible diffuse discharge (through permafrost, submarine).
- Improved understanding of pingo hydrodynamics.
- Improved understanding of age/residence time and flow paths of groundwater (e.g., presence of palaeo-groundwater).
- Improved understanding of subsurface processes determining water quality (reactive transport and microbiology).
- Identification of groundwater-glacier interaction (2-way coupling).
- Improved understanding of groundwater – surface water (including snow and icings) interaction (quality/quantify, active layer vs. deeper groundwater contributions).
- Improved understanding of active layer hydrology (e.g. ice-wedge polygon influences on water tables and drainage).

Some of the specific challenges listed above have been, or are being partially addressed, within existing research projects in Svalbard, albeit often indirectly and to a limited extent. In many of these projects, workshop participants are/were involved. However, there is no overall permafrost hydrology research project planned or occurring in Svalbard.

Among the participants, numerous **research methods/tools** were mentioned/proposed that are valuable or essential to address the inferred challenges. These methods include:

- Coupled permafrost-groundwater-(glacier) modeling; hydrochemical modeling.
- Borehole logging tools (temperature, DTS (Distributed Temperature Sensing using fibre optic cable), PFL (Posiva Flow Log quantifying groundwater flow rates, mainly fracture flow), SAMPO (an electromagnetic tool measuring apparent electrical resisitivity)
- Supra-, intra- and sub-permafrost borehole monitoring (water pressure, temperature, electrical conductivity (EC) and chemistry, using on in-situ techniques and sampling)
- Aquifer/reservoir testing methods
- Surface and airborne geophysics (ground penetrating radar (GPR), synthetic aperture radar (SAR, InSAR), automatic photographing, seismics, direct electical (DE) methods, electromagnetic (EM) methods, magnetic resonance sounding (MRS)
- Environmental tracer and age dating (hydrochem./isotopes/noble gases)
- Permafrost core studies.
- Seafloor seepage measurements.

This diverse set combines methods often used in different disciplines, demonstrating the great potential for collaborative research across disciplines.

Several presentations addressed borehole methods and results that are relevant to assess the **feasibility of intra- and sub-permafrost hydrological monitoring** in Svalbard, where 'hydrological' refers to water potentials (hydraulic heads/pressures), groundwater flow and groundwater quality. However, there was too little time to evaluate feasibility, notably technical aspects, in a comprehensive way. Feasibility of drilling boreholes through the permafrost has been demonstrated by the existing Longyearbyen CO_2 boreholes in Adventdalen. Repeated deployment of groundwater flow measurement devices, such as the PFL tool that is used in Greenland within the GAP project to constrain fracture flow, requires repeated borehole access to lower the device. Challenges associated with 'permanent' multi-level down hole monitoring instrumentation, ideally combined with the possibility for water sampling remain to be evaluated. Additionally, major feasibility issues are presently unresolved regarding use of drilling to access sub-glacier groundwater/permafrost/taliks (e.g. drilling though glacier or directional drilling).

Regarding **research funding** for future permafrost hydrology research the following considerations emerged:

- Applying for an Initial Training Netwerk (ITN) (People Programme; Marie Curie action of EU) will be considered. Ph.D's may be recruited for several (EU member and associate) universities, who conduct research and receive training in an integrated programme. Private sector participation is important (not trivial in this context). UNIS would be a suitable coordinating location for such a network.
- Non-European partners would have to look for other sources (e.g. NSF funding for US scientists to collaborate with international partners).
- SSF Arctic Field Grants can be used directly for students and minor research projects (pilots).
- Opportunities for borehole/drilling through The International Continental Drilling Program (ICDP) will be looked into.
- Large programme funding, for instance through Horizon 2020 , does not appear realistic at this stage because call contents are presently unknown. Moreover, coordination efforts and working with strict milestones, deliverables and deadlines is not optimal.

Conclusions and recommendations

There is large potential to develop comprehensive, joint permafrost hydrology research in Svalbard and particularly in the sedimentary landscape of Adventdalen, with its existing research infrastructure.

- Key scientific challenges have been identified linking existing permafrost, periglacial and geological studies and monitoring platforms, with the study of the subsurface hydrological regime. A research project with this theme in Svalbard would be unique and complement permafrost research elsewhere.
- There is broad interest and multidisciplinary expertise for collaborative research under this theme.
- The different researchers have a 'common language' allowing effective interaction/communication.
- A comprehensive set of methods exist that have been little or not yet used to address the challenges. And at least never been used together for this purpose.
- Svalbard is the only suitable field site for such research in Europe, hosting favorable geographical, geological and hydrological conditions.
- Svalbard can serve as an important proxy study site, generating key permafrost hydrological knowledge for other areas in the Arctic.
- The excellent accessibility, logistics and availability of very high-quality research facilities are unique for high Arctic settings, and extremely advantageous to conduct this type of Earth System research.

Preliminary assessment suggests intra- and sub-permafrost groundwater monitoring is feasible; however, this should be evaluated more comprehensively.

Part of what was identified as research challenges should be included in the **Svalbard Arctic Earth Observing System, SIOS**. It appears highly pertinent to establish an observational baseline allowing monitoring of the permafrost hydrological response to climate change. The knowledge center, which SIOS is suggesting to establish in the Svalbard Research Park, might also contain training possibilities for specific research methods, and as such relevant also for future permafrost hydrology research and education.

The workshop participants decided to jointly produce a review paper on permafrost groundwater hydrology in Svalbard as a step in the development of collaborative research.

A second workshop in 2013 is required to define and prioritize specific research projects and to further assess feasibility of sub-permafrost monitoring.

Individual collaborative research projects can/should already be started up where possible.

Detailed workshop agenda

Day 1 Wednesday Oct 24

09:55-13:55 SAS Airplane departure from Oslo airport Gardermoen, via Tromsø to Longyearbyen airport.

13:55-14:45 Pick-up in Longyearbyen airport and transfer to UNIS Guest House

15:30-16:00 Welcome with coffee/tea, food and cakes in UNIS canteen

16:00-19:00 Introduction to workshop and Svalbard permafrost hydrology characteristics (Chaired by Hanne Christiansen) in *auditorium Lassegrotta*

16:00-16:10	Welcome by the UNIS director, Ole A. Misund
16:10-16:20	Workshop idea and structure, Henk Kooi
16:20-16:35	Svalbard Science Forum presentation of Svalbard research infrastructure and their funding possibilities, Karoline Bælum
16:35-16:50	Subsurface groundwater systems in Svalbard, Sylvi Haldorsen
16:50-17:05	Longyearbyen water supply – problems and plans for the future, Håkan Eriksson
17:05-17:15	Break
17:15-17:30	Hydrology in Ny Ålesund, Christelle Marlin
17:30-17:45	Permafrost in Svalbard, Hanne H. Christiansen
17:45-18:00	Permafrost hydrology in Alaska, Anna Liljedahl
18:00-18:15	Permafrost hydrology in Canada, Brian Moorman
18:15-18:30	Tour of UNIS incl. preparations for field excursion Thursday

19:30 Dinner in UNIS canteen.

Day 2 Thursday Oct 25

Breakfast served at SAS hotel next to UNIS Guest House from 07:00

08:30-12:30 Field excursion to hydrology and permafrost monitoring sites in Adventdalen by cars and foot, **bring warm cloth and good boots**. Topics: Mining history of Longyearbyen area, overall geology and geomorphology of the Adventdalen area, visit to Longyearbyen CO2 research site with deep boreholes, visit to local watersupply dam, visit to pingo with waterflow. Visit one of the permafrost thermal monitoring sites, information on Svalbard snow conditions. Guides: Hanne H. Christiansen, Alvar Braathen, Ole Humlum, Karoline Bælum and Wesley Farnsworth.

13:00-13:30 Lunch in UNIS canteen

13:30-17:30 Identifying critical science issues that can be addressed in Svalbard (chaired by Henk Kooi) *in auditorium Lassegrotta*

- Each invited participant to give a presentation (~ 15 min.) addressing some of the following points:

- My research related to permafrost hydrology and what are the key scientific challenges? Is Svalbard a good/the best place to do this type of research and where in Svalbard?
- Which monitoring would be scientifically interesting to install in Svalbard?
- Technical issues concerning subsurface monitoring and environmental impact; feasibility issues.

13:30-15:15 Henk Kooi, Brian Moorman, Anna Liljedahl, Andy Hodson, Aga Nowak-Zwierz, Victor Bense

15:15-15:30 Break

15:30-17:30 Jon Engström, Andrew Frampton, Christelle Marlin, Sylvi Haldorsen, Björn Frengstad, Ole Humlum, Sara Cohen

19:00 Workshop dinner at the Huset Restaurant.

Day 3 Friday Oct 26

Breakfast served at SAS hotel next to UNIS Guest House, check out of UGH, bring luggage to UNIS.

9:00-12:00 Discussion & follow up activities (chaired by Henk Kooi) *in teaching room Kapp Schoultz*

Tentative schedule

9:00-9:15 Overview/inventory issues, requirements & feasibility

9:15-9:30 Svalbard Integrated Arctic Earth Observing System, SIOS – what is this and how could future permafrost hydrology monitoring be included in SIOS, Thorbjørn Gilberg

9:30-10:15 Discussion of project ideas (areas and methods) and (required) research collaboration

10:15-10:30 Data sharing from future permafrost hydrology observations in national and international databases, incl. the SIOS databases

10:30-10:45 Break

10:45-11:15 Funding options and discussion proposal development activities

11:15-12:00 Process of workshop reporting and participant involvement, discussion of potential joint (review) paper and associated writing responsibilities.

12:00-13:00 Lunch in UNIS canteen

13:30 Transfer to Longyearbyen Airport directly from UNIS.

14:45–19:00 SAS Airplane departure from Longyearbyen airport, via Tromsø to Oslo airport Gardermoen.

Workshop participants in the Adventelve river on excursion to visit research sites and infrastructure in the Adventdalen valley at -20˚C on 25 October 2012.