

ESF Exploratory Workshop on
**GEOMICROBIOLOGY IN GLACIAL
SYSTEMS**

Sogndal (Norway), 7-10 August 2012

Convened by:
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SCIENTIFIC REPORT

1. Executive summary

The *ESF LESC Exploratory Workshop on Geomicrobiology in Glacial Systems* was held in Sogndal, central Norway over four days (7-10 August 2012). Fifteen participants from 10 countries contributed to make the workshop a scientifically and socially memorable event.

In summary, the main objective of the workshop was to accelerate an ongoing paradigm shift within glacial research towards [including microbiology and linking this field to classical glaciology and geology](#) by getting together leading researchers with a wide variety of disciplinary backgrounds in the field. The workshop should initiate collaboration that will lead to innovative breakthroughs both by [linking supraglacial, subglacial and proglacial environmental studies](#) and by introducing new unifying, multidisciplinary concepts that view glacial systems as being shaped by the [interaction of both biological and abiological drivers](#). To stimulate the discussions the participants were encouraged to building on their established methodological and system specific knowledge to envision an innovative, multidisciplinary exploration of glacial systems and to thinking in pathways and networks rather than in isolated processes.

The agenda of the workshop was to [bring together experts in complementary fields](#) that have hitherto not collaborated as a group, to exchange research interests and building common grounds for future joint research projects, to [identify and discuss future research directions](#), to identifying additional required research competences that were not covered within the group of participants, and to plan future joint research projects and developing an application strategy.

On Tuesday 7 August, the participants arrived to Sogndal either by express ferry from Bergen or by flight to Sogndal Airport. Accommodation was in rented cabins located 20 km north of Sogndal towards Fjærland at a site called Selseng. A nearby café building was used for meals and meetings. The participants arrived throughout the day and for some there was time for a bit of sight-seeing. A small ice-breaker event was arranged in the evening by some of the participants.

On Wednesday 8 August, we had an early breakfast before departure to the excursion site at Austerdalsbreen, an outlet glacier from Jostedalbreen Ice Cap. At 10:00 we meet with Kåre Øst, head of the local guide company Norgeguidene, at the parking lot at Tungestølen in Austerdalen before hiking towards Austerdalsbreen. During the hike we stopped at several sites to discuss proglacial geomorphology in relation to geomicrobiology along the 260-yr chronosequence. Lunch was enjoyed at the top of a bedrock outcrop overlooking the glacier tongue of Austerdalsbreen. After lunch we went onto the glacier surface to examine deposition and spatial distribution of supraglacial debris. Then we went along the southern margin of the glacier terminus to discuss the recent (<1 year) fluvial deposition of sediments. At 16:30 we were back at the parking lot where the bus to Sogndal was expecting us. In the evening we had an informal workshop dinner at Kafe Krydder in central Sogndal and were back in Selseng late in the evening.



Workshop participants enjoying the beauty of glacier research on Austerdalsbreen, Norway (Photo: Josef Zeyer).

On Thursday 9 August, the day started with a series of short presentations on on-going research by the participants. The purpose of these was to let the participants become more familiar with each others activities and get ideas for potential research collaboration in the future. The presentation session lasted longer than expected, so the planned working group discussions were postponed by two hours. The content and objectives of the working groups were shortly discussed before the participants joined one of two working groups. Group I comprised development and implementation of new analytical methods to quantify geomicrobiological processes and to identify the biological and abiological drivers; and Group II concerned how to integrate the entire glacial system (supraglacial, subglacial and proglacial sub-systems) in a unified pathway model with measurable control on all major inputs and outputs of biogeochemical and microbiological components. A tasteful dinner was prepared by some of the participants in the café kitchen, while other participants had a chance to walk to the nearby Selseng moraine complex formed about 9200 year ago during a local readvance of glacier margins during the collapse of the Fennoscandian Ice Sheet. After dinner informal discussions continued on working group findings, planning of future collaboration, and potential sources of funding for joint research projects. At the end, a [steering group](#) consisting of five members from different countries and with different research expertises was [established](#) in order to realize the outcome of the workshop. The general atmosphere was very relaxed throughout the day and social gathering continued late in the night.

On Friday 10 August, many participants had to leave Selseng very early in the morning to catch the express ferry at Sogndal Harbour or a flight from Sogndal Airport. The remaining participants had time for breakfast before their flight departed. At about 14:00 all participants had left the workshop.

2. Scientific content of the event

The workshop participants provided expertises and interests covering both the different habitat types of the glacial environment as well as methods required to address complex glacial systems and the interplay between biological and abiological drivers.

We will give short summaries of the presentations given by the participants and conclude with a synopsis of the outcome of the discussion workgroup sessions. The individual presentations allowed us to become more familiar with each others research interests and fields of expertise. The short summaries of the presentations are given in alphabetical order and focus on the presenters field of interest and expertise:

1. Arwyn Edwards (University of Aberystwyth, United Kingdom). AE's prime research interest is the glacial surface and in particular the biology of cryoconite holes. Arwyn presented the ongoing work at his home university, his involvement in different projects and the methods he applies to investigate dynamic ecosystems.
2. Kai Finster, co-convenor (University of Aarhus, Denmark) (co-convenor). KF's prime research interest is the forefield of glaciers with special focus on methane cycling. He has also been studying the activity and diversity of microbial communities in basal ice.
3. Nina Gunde-Cimerman (University of Ljubljana, Slovenia). NG-C research addresses fungi in all kinds of glacial habitats with overall focus on adaptation to stresses imposed by restriction of water availability and radiation climate in glacial systems.
4. Christian Knoblauch (University of Hamburg, Germany). CK is involved in permafrost research in Siberia with special focus on methane dynamics and cycling. CK has not been working in glacial systems before but is interested applying his methods to measure methane turnover and fluxes on glacial systems.
5. Harry Langford (University of Sheffield, United Kingdom). HL studies cryoconite holes with special focus on cyanobacteria and their interaction with mineral surfaces. As primary producers and excretors of polysugars cyanobacteria shape the physical and biological properties of these highly diverse and dynamic habitats.
6. Natalie Leys (Belgian Nuclear Research Centre, Belgium). NL is a molecular microbiologist working on extreme environments but has not been working in glacial systems. Her interest in the workshop was because of an overlap in methodological challenges with respect to DNA extraction protocols that are used in environments that are either low in cell numbers or that contain compounds that restrict DNA extraction such as clays.
7. Rosa Margesin (University of Innsbruck, Austria). RM's work is focused on cold adapted microbes and yeasts in alpine glacial habitats. Applying molecular and cultivation-based methods she investigates the biogeography of microbes along alpine altitude gradients as well as the degradation of pollutants in cold environments.
8. Klara Rehakova (Biology Centre of AS CR, Czech Republic). KR's research interest is in the structure and function of algae and cyanobacterial communities in polar and high mountain regions. She is interested in adaptations to extreme environments and on the role these organisms play in shaping extreme environments including glaciers.
9. Andreas Schramm (Aarhus University, Denmark). AS has not been working in glacial systems before. His major interest lies in nitrogen cycling in aquatic and symbiotic systems, questions that he addresses primarily with molecular tools. Andreas was exploring the possibility of extending his field of research to include glacial systems.
10. Martin Schroth (ETH Zürich, Switzerland). MS major interest is on methane cycling and developing and improving methods to quantify methane turnover. He is involved

in studying methanotrophs in alpine glacial forefields and is particularly interested in studying the coupling between methane oxidation and nitrogen fixation.

11. Margit Schwikowski (Paul Scherrer Institute, Switzerland) MSch is an analytical chemist. Her research is focused on studying the effect of impurities on glacier albedo and the consequences on glacier melting. Once quantified MSch works on simulating the albedo changes with physical models.
12. Marek Stibal (Geological Survey of Denmark and Greenland, Denmark) MSt's research is currently focusing on carbon cycling on the Greenland Ice Sheet. He investigates the dynamics of heterotrophic processes using radiotracers and links it with studies on the spatial and temporal microbial diversity as well as the flux of microbes between the different compartments.
13. Benedetta Turchetti (University of Perugia, Italy) BT is a yeast taxonomist with special interest in isolated yeasts from pristine environments including glacial habitats. BT explores the biotechnological potential of the isolated yeasts.
14. Jacob Yde (Sogn og Fjordane University College, Norway) [convenor] JY is a glaciologist and biogeochemist who is working on microbial-mediated subglacial geochemical weathering processes in Greenland, Norway and Svalbard.
15. Josef Zeyer (ETH Zürich, Switzerland) JZ's research focus is on studying the microbial structures and functions in glacier forefields. He works on the nitrogen cycle, biodiversity and the influence of bedrock type on communities and function. In addition, he develops and implements new methods to address these questions.

Two discussions groups were constituted to address the following topics. Discussion group 1 was asked to deal with the development and implementation of new analytical methods to quantify geomicrobiological processes and to identify the biotic and abiotic drivers. First, the group members discussed topics that they consider important to be studied in more detail in the future. One of the important topics is [element cycling in glacial systems](#) because the rates at which elements are entering and leaving the system are indicators of the dynamics and evolution of a particular system. Carbon input and release in the inorganic form as CO₂ or as organic matter affect the heat budget of glaciers, due to its influence on albedo but also on microbial-mediated weathering processes as microbes may produce acids during anaerobic heterotrophic carbon turnover. In addition, the rates of carbon turnover influence the green house gas balance since CO₂, N₂O and CH₄ balances are affiliated with biotic and abiotic processes. The group suggested that [carbon turnover](#) could be the starting point in common future research projects, because of its central role in general and since all participants are already working related to that field. The group also discussed the advantage of [studying one glacier in detail](#) as a model for comparative studies on several glaciers. A central argument in favour of focusing on a single glacier is difficulties in organising simultaneous fieldwork at different sites. Here it is pointed upon the costs of the research but also the seasonal limitations, since most glaciers can only be accessed for a limited number of months in the summer period. This limitation was also recognized as a problem when it comes to modelling the element cycling on an annual basis. We have exclusive access to data that were collected during a limited period. Automated robot technics need to be developed that reliably [collect data throughout the year](#). Detailed studies of the different parts of the glacier [including the englacial and subglacial habitats](#) require the implementation of remote measuring methods that would allow accessing these parts of the glacier. The group also discussed whether the workshop participants have all the required expertises for a full circle approach. In its current set-up the group is dominated by [biologists](#) and thus the [inclusion of modellers, geophysicists, atmosphere chemists](#) would strengthen the group. Also available and desired methodologies were discussed. The participants have either directly access to the required methods and technics or work in an environment where

the methods are implemented. It was emphasised that efforts need to be made to develop [in situ methods and logged data in periods outside of field campaigns](#).

Group 2 discussed the value of generic models to [develop a holistic view of glacial systems](#). The participants identified [3 major compartments](#) that need to be [included in the model](#). These are [the atmosphere, the glacier and the underlying bedrock](#). The different compartments are connected and influence each other but may operate and evolve on different time scale. The group identified the [boundaries](#) of the different compartments as [particularly interesting sites for investigations](#), since organic and inorganic chemicals but also organisms may get either fixed or liberated during transition between the different compartments. These have significant effect on the albedo and thus heat regime of the glacial system, e.g. cells get fixed and frozen when deposited on the glacier but transferred by the ice and liberated into glacial streams when the ice melts. The group identified [carbon cycling and greenhouse gas turnover](#) as a major unifying research focus of upcoming research projects. They also suggest studying the development of landscapes when glaciers recede. The participants also stressed the importance of including detailed investigations of the abiotic processes in glacial systems including the [energy balance](#) in order to quantify the biological contribution. The group underlined the importance of having study sites that enable balancing the input and output parameters.

Finally the results of the group discussions were presented in plenum. The overall conclusion is that there exists an interest within the research community for establishing [one or more type glacier sites](#) where catchment-scale geomicrobiological processes can be studied, links between subsystem environments and microbial species examined, new instrumental methods tested, and where the results can be compared to process-scale studies worldwide. It will be challenging to find a perfect site where all research aspects of glacial system geomicrobiology studies can be met. However, one or a few sites with a confined topographic boundary, simple glacier ice dynamics, a well-documented proglacial foreland chronosequence, and all-year easy-access conditions would constitute an excellent starting ground(s) for developing this multidisciplinary research direction. The details on specific research aims and collaborative studies should be planned in a follow-up meeting when potential sites have been located.

3. Assessment of the results, contribution to the future direction of the field, outcome

As mentioned above the workshop contributed to assess the collaboration potential in the diverse research discipline of geomicrobiology in glacial systems. There is an interest within the research community exploring a new direction towards catchment-scale studies, where some of overall research questions on elemental cycling, biodiversity and microbial adaptation to extreme environmental conditions can be addressed. A [steering group of five members was established](#) to ensure that the results of the workshop will be followed up in the future. The steering group is responsible for locating one or a few glacier sites for future studies and look for relevant funding opportunities. At present, the ESF Research Networking Programme is under evaluation, which makes any concrete actions for ESF funding inconclusive at the moment. A very relevant and an interesting grant opportunity is the ERC Synergy Grant programme, which is currently discussed in the steering group.

4. Final programme

Tuesday, 7 August 2012

Afternoon

Arrival at Selseng

21:00-23:00

Welcome and Ice-breaker

Wednesday, 8 August 2012

06.30-07.30

Breakfast and official welcome by the convenors
Jacob C. Yde and Kai W. Finster

08.00-10.00

Transport to Austerdalsbreen
Information about the excursion site

10.00-16.00

Austerdalsbreen
Lunch in the field

16.00-18.00

Transport to Sogndal

19.00-23:00

Dinner

23:00

Transport to Selseng

Thursday, 9 August 2012

07.00-08.30

Breakfast

09.00-09.15

Introduction by Convenors

09.15-11.45

Short presentations

12.00-12.30

Lunch

12:30-15:00

Short presentations

15.00-17.00

Working groups

17.30-18.30

Dinner

19.00-19.30

Presentations and discussions of working group findings.

19.30-22.00

Future collaboration / formation of a steering group

Friday, 10 August 2012

07.00-09.00

Breakfast

09.00

End of Workshop and departure

5. Final list of participants

1. Jacob Yde (Sogn og Fjordane University College, Norway) [convenor]
2. Kai Finster (Aarhus University, Denmark) [co-convenor]
3. Arwyn Edwards (University of Aberystwyth, United Kingdom)
4. Nina Gunde-Cimerman (University of Ljubljana, Slovenia)
5. Christian Knoblauch (University of Hamburg, Germany)
6. Harry Langford (University of Sheffield, United Kingdom)
7. Natalie Leys (Belgian Nuclear Research Centre, Belgium)
8. Rosa Margesin (University of Innsbruck, Austria)
9. Klara Rehakova (Biology Centre of AS CR, Czech Republic)
10. Andreas Schramm (Aarhus University, Denmark)
11. Martin Schroth (ETH Zürich, Switzerland)
12. Margit Schwikowski (Paul Scherrer Institute, Switzerland)
13. Marek Stibal (Geological Survey of Denmark and Greenland, Denmark)
14. Benedetta Turchetti (University of Perugia, Italy)
15. Josef Zeyer (ETH Zürich, Switzerland)

6. Statistical information on participants

Age:

<40 years = 6

40-50 years = 5

>50 years = 4

Countries of origin:

Denmark = 3

Switzerland = 3

United Kingdom = 2

Austria = 1

Belgium = 1

Czech Republic = 1

Germany = 1

Italy = 1

Norway = 1

Slovenia = 1

Sex:

Female = 6

Male = 9