Updated Ny-Ålesund glaciology flagship strategy document 2015

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1 Glaciology in Ny-Ålesund

Ny-Ålesund is an ideal site for glaciological research; despite its remote location, it provides an excellent logistical base for fieldwork programs. Apart from large ice caps, the area around Ny-Ålesund most types of glaciers found in Svalbard and even the high Arctic: fast-flowing, surge type, polythermal, and calving glaciers. Two Ny-Ålesund glaciers, Midtre Lovénbreen and Austre Bøggerbreen, have among the longest arctic mass balance time-series, and in addition there are many other relevant long-term measurements available.

2 Gaps of knowledge

In terms of the overall science, many processes crucial for future glacier behavior are still relatively poorly understood. In particular, such important processes as calving, surging, sliding, and glacial drainage are still important open research topics. Ny-Ålesund glaciers provide a useful laboratory for studying these processes.

In terms of our local knowledge, a handful of glaciers have been studied extensively in the Ny-Ålesund area, mostly with respect to mass balance and hydrology. However, there are still gaps in our knowledge. We know little about spatial and temporal distribution of snow at the landscape and regional scale. While there are a number of mass balance programs established in and around Ny-Ålesund, little is still known about ice and meltwater fluxes from glaciers outside of this immediate area. And basic information, such as bed topography, is still missing for most glaciers in Svalbard, including most around Ny-Ålesund.

3 General topics to be addressed

The first workshop identified a number of important topics to be focused on, based on knowledge gaps, existing long-term series and advantages of the location Ny-Ålesund:

3.1 **Mass balance**

Glacier mass balance is the amount of snow and ice lost or gained on a particular glacier during a certain time period. It is usually reported as a single number which reflects the loss or gain for the glacier as a whole. Mass balance is a lumped climate signal influenced primarily by winter precipitation and summer temperature.

Roughly 60% of Svalbard is covered by glaciers, and these glaciers have been retreating from their last maximal front positions since about 1920. An important motivation for measuring mass balance is to determine the contribution of Svalbard glacier loss to sea level rise. Roughly half of the current observed sea level increase is attributed to “small” glacier melting, that is, all glaciers besides Greenland and Antarctica, but there are still relatively large error bars on these estimates. It is therefore important to determine the contributions to sea level from the different glaciated areas around the world. Svalbard is not an insignificant contributor, since it constitutes about 10% of the total Arctic glacier area (again, excluding Greenland). Furthermore, ice melt rates on Svalbard are relatively high due to its location in a relatively warm part of the Arctic.

Two of the longest artic mass balance time-series are from Ny-Ålesund; together with the available ancillary meteorological data, these data provide a useful foundation for conducting retrospective studies of mass balance. Furthermore, with its easy logistical access, the glaciers around Ny-Ålesund provide an ideal ground-truthing platform for mass balance models, from simple degree-day type models to full energy balance models, as well as downscaling and upscaling experiments using large scale climate model output.

3.2 **Dynamics**

One of the most significant current problems in glaciology with regards to understanding better future cryosphere behavior concerns the dynamical component, chiefly through the process of glacier calving. Physical calving laws are needed to improve our ability to model future ice volume changes and the resultant effect on sea-level rise.

Glacier calving model are currently being developed and tested on the fast-flowing tidewater glacier Kronebreen, at the mouth of Kongsfjord. Kronebreen is an ideal platform for calving studies, again because of the logistical ease of conducting research there, but also because of the wealth of available data such as basal topography, velocity distribution and surface mass balance. Kronebreen has been thinning in recent years, and it is predicted that the glacier will undergo acceleration and rapid retreat through a basal overdeepening once the ice margin thins to a critical threshold thickness

A related issue in glacier dynamics concerns surging. Surge-type glaciers alternate long periods of relative dynamic quiescence and short duration surges lasting 1-3 years, in which the glacier speeds increase dramatically and the glacier front advances, often by hundreds of meters, and up to several kilometers.

Estimates for the number of surging glaciers in Svalbard vary, ranging from 13 to 90%, however, only a limited number of glaciers in the Ny-Ålesund area have been observed to have surged. These include: Kongsvegen (ca. 1948), Blomstrandbreen (ca. 1966, ca. 2009), and Comfortlessbreen (ca. 2008). Surge frequency on Svalbard is observed for a few glaciers to vary from decades to 1 century or more.

The exact cause of surging remains an unsolved problem in glaciology, but is thought to be related to developments in the subglacial drainage system (see below).

3.3 **Hydrology**

Glacier hydrology exerts the dominant control on glacier sliding in temperate glaciers, primarily through flow of surface meltwater down to the bed and through the subglacial drainage system. Svalbard glaciers are polythermal, that is they consist of both cold and temperate ice. Glaciers that are entirely cold (on Svalbard, glaciers that are relatively thin, less than ca. 70 m thick on average) do not have subglacial drainage, and so their dynamics are relatively static throughout the year. Larger, and therefore thicker, Svalbard glaciers have temperate bases and are thus affected by summer melt. Glacier hydrology is also thought to be a key factor in glacier surging (see above).

Beyond its effect on dynamics, glacier hydrology is important for fluxes of sediment, chemistry, and nutrients. Glaciers which flow all the way down into fjords typically drain relatively large accumulation areas; combined summer melt and rain can lead to high concentrated discharge amounts at the glacier front. This has a significant impact on the freshwater budget for fjord circulation, on sedimentation processes, and as a result on the ecosystem.

Accordingly studies of glacier hydrology are of importance both for glaciologists as well as other disciplines. This includes melt studies, through energy balance modeling and deployment of automatic weather stations, through studies of the development of the summer drainage system, e.g. tracing studies, and through monitoring of sediment, chemistry and water fluxes at proglacial site. At present there is one permanent hydrology station in Ny-Ålesund, on Bayelva near the aiport. A temporary station is located at Austre Lovenbreen, closer to the glacier front.

3.4 Snow

Snow is the dominant component in the winter land water cycle; it provides insulation for plants and soils, it is a source of soil moisture in the growing season, and it gives shelter for animals and protection from predators. Snow changes the albedo of land surface, and alters the energy balance of the land surface significantly. Arctic climate is changing, but what the effect will be on snow cover, and what the cascading effects of changes to patterns of snowfall in the hydrological cycle and in arctic ecology remains an important research topic.

Despite the importance of snow, regular measurements of one of the most basic snow parameters, snow depth, or the related quantity snow water equivalent (SWE), are largely lacking in Ny-Ålesund. Regular measurements of snow depth have only started recently as part of the routine synoptic observations conducted by the Norwegian Meteorological Institute. There are no longer-term records at daily, weekly, or even monthly time-scales. Annual data have been available on the mass balance glaciers, with records of average spring SWE made on the four NPI mass balance glaciers. SWE amounts are available digitally since 1999, with map coordinates and elevations, collected on a roughly regular grid. However, a broader set of measurements are desirable.

Over the past decade, an ad hoc set of springtime snow measurements was initiated by NPI around the Brøgger peninsula, with data for most years since 2000. Snow depths were measured at ca. 200-500 m intervals along a series of more or less coincident profiles, useful long-term data, although they only represent a single picture of the snowpack in each year.

Besides the issue of spatial and temporal aspects of snow cover evolution, chemistry, impact on ecology, physical characteristics as density, crystal evolution and albedo.

A key goal will be to conduct systematic snow transects on Brøggerhalvøya, and to make these measurements available to the larger research community.

3.5 Ice cores

Our knowledge of climate variability over time scales of 100 years or greater is still incomplete. The relative shortness and sparsity of historical and contemporary instrumental records necessitates the use of various proxy-based sources of climate information. Studies of ice cores from glaciers and ice caps have developed into a powerful and successful paleoclimatic tool.

Since the 1970s a number of ice cores have been drilled on glaciers and ice caps in Svalbard. While most of these ice core records either cover short time periods or have time gaps created by negative balances at the drill sites during past warm periods, Svalbard ice core research has improved knowledge about climate variation in this part of the Arctic during the last 800 years. New ice cores will not only be important for furthering our knowledge of past climate, but it will also be valuable in increasing the spatial distribution of high resolution ice-cores around Svalbard for climate reconstruction.

Ice cores provide archives of not only climate proxies but also of wide range of chemical species, including black carbon, organic contaminants and heavy metals. Furthermore, new techniques make it possible to improve some of the previous work, making it of interest to obtain new cores from previous drill sites.

Using data from deep ice cores, shallow cores and snow pits it is possible to investigate links between atmospheric circulation, transport and deposition in snow/ice investigate the aerosol- temperature link through the ice cores proxies. For example, the atmospheric transport of black carbon to Svalbard was studied by connecting atmospheric soot measurements to back-trajectory calculations. Linking the observed atmospheric equivalent black carbon BC concentration at the Zeppelin Observqatory with air mass trajectories, shows that generally higher concentrations are observed when the air comes from the east than from west. Ice cores can then be linked to concurrent measurements at Zeppelin, and used to extend our understanding of long-term variability in atmospheric circulation and transport.

3.6 Biochemistry

Glacier ice and snow melt affects the timing, magnitude and release of nutrients to aquatic and terrestrial ecosystems. Important research topics center on improving our understanding of: the way glacial, snow, and permafrost melting influence the downstream transfer of nutrients and organic matter to aquatic ecosystems; how the carbon economy of glacier forefields and permafrost change as climate change continues to influence winter and summer thermal conditions.

4 Integrated glaciological activity

Currently research groups in Ny-Ålesund are not well integrated across national boundaries, and research activities at the different glaciers are often not coordinated.

Following the last flagship meeting, it was decided to coordinate better these activities to facilitate integration, reduce costs and minimize the environmental footprint of glaciological research. Ultimately with better integration and coordination, larger projects will be possible, increasing the scientific value of the work performed in Ny-Ålesund. Ideally more could be accomplished through teamwork than through the uncoordinated efforts of individual scientists or small research groups.

In the future we seek to facilitate sharing of data (including for example satellite data), to avoid research duplication, to develop new methodology. Integration could be achieved within glaciological systems (e.g. regional catchment studies) or with other systems, such as marine and terrestrial systems.

4.1 Improve integration

One means for better integration between groups and activities would be for groups to make more efficient use of data repositories (such as are planned in SIOS), as well as the RiS database. In addition links should be established between external data providers such as eKlima or NVE and localities outside of the immediate area of Ny-Ålesund (e.g. Kaffiøyra, Austfonna, Barentsburg, Hornsund, etc).

4.2 Communication between the groups

At the last Flagship Meeting, two measures were proposed to enhance collaboration and coordination: 1) conduct regular workshop meetings; and 2) establish an email group. While the latter has not had significant activity, this Flagship Meeting represents the second meeting of Ny-Ålesund glaciologists.

5 Results of latest Flagship Meeting

5.1.1 *Cooperation between groups*

In this latest Flagship Meeting, we reiterated in general terms the need to improve cooperation between glaciology groups, and to identify areas of future collaboration.

There is continued interest from other nations in establishing activities in Ny-Ålesund, with the potential for even more glaciological activity, underscoring the need again for more coordinated collaboration within Ny-Ålesund.

An interesting aspect of multiple national activities is that national funding agencies are not so bothered about duplication. Furthermore, duplication is not necessarily problematic; it can be used to advantage to test methods and uncertainties.

We discussed more specifically the need to reduce mass balance measurement duplication, in particular at Austre Lovenbreen (French/Chinese teams), and at Brøggerbreen (Norwegian/Indian teams). NPI proposes to collaborate with Indian colleagues to measure mass balance on the north side of Kongsfjorden. Boat transport is needed to go there, and lack of sea ice is a problem. NPI will take the initiative for this collaboration.

5.1.2 *Future funding*

We discussed the possibility for future funding sources. Only two nations have confirmed longer-term funding (10+ years) prospects: the Chinese and Norwegian programs. This may be the case for the Indian program as well, but no representative from India was in attendance. All other programs are contingent on short-term research projects.

Future sources for collaborative funding might include EU, although the “Horizon2020” program seems to have little interest in glaciology, as it focuses more on Arctic interdisciplinary work and on infrastructure. Nor is there any role in EU in Europe-Asian collaboration.

5.1.3 *Mass balance*

We discussed the need to compare available mass balance data. This is needed to understand the distribution of mass balance variables in space and time. In addition, the mass balance program can be starting point for more data collection of other variables. We discussed the possibility of arranging annual meetings in April in Ny-Ålesund, in connection with spring fieldwork. However, time is always limited, and the field parties do not always overlap. More formal meetings are required.

In Autumn 2016, we will hold an SSF-funded workshop meeting concerning glacier mass balance: “NÅGLAMB – Ny-Ålesund GLAcier Mass Balance workshop.” The primary aim of this workshop will be to bring together researchers from the five international groups studying glacier mass balance in the Ny-Ålesund area. Secondary aims are: 1) to promote better collaboration and cooperation between these groups, and 2) to integrate the field studies with modelling efforts, through inclusion of selected members of the Svalbard modelling community.

Finally, NPI will seek funding to organize a Svalbard Mass Balance Symposium in 2017. This year is the 100^{th} anniversary of the birth of Olav Liestøl’s birth, the NPI glaciologist who initiated mass balance measurements in Svalbard in the 1950s, and the two long-term programs at Austre Brøggerbreen and Midtre Lovénbreen in Ny-Ålesund in 1966 and 1967, respectively. In 2017, the record from Austre Brøggerbreen will be 50 years long, thus providing the occasion for this symposium.

5.1.4 *Hydrology station*

We proposed again setting up a hydrological station at Austre Lovenbreen. This would be a French initiative. Observations are needed only during the summer melt season. Cooperation will be required with engineers at AWIPEV, with one person needed one week per year for data checking. Data should be freely accessible.

5.1.5 *Airborne photographic campaigns*

Airborne photographic campaigns can be used for generating DEMs. NPI has developed a helicopter-borne system that allows rapid data acquisition for relatively modest costs compared to traditional fixed-wing photogrammetry. Helicopter costs still need to be covered, but with multiple nations sharing usage there could be saving.

5.1.6 *Other issues*

- Study linkage between glacier hydrology and calving (e.g. the CRIOS project). CRIOS has finished, but there will be legacy data, and new calving studies (UiO, NPI) are in the process of being started at Kronebreen.
- Integrate glaciological and marine studies. There are projects (NPI) currently in progress and underway looking at the linkage between the calving face, fjord circulation, and the fjord ecosystem.
- Integrate glaciological and terrestrial studies (e.g. snow)
- Cameras can be used to monitor snow distribution, e.g. from Zeppelin Observatory. Cameras might also be used to analyze calving, as well as ocean modeling.
- Snow research around Ny-Ålesund:
    - Setup more general operational system for snow modeling. Available models: Crocus (high-detail), Liston snow redistribution model (lack of ground ice)
    - Collaborate on snow monitoring (e.g. CC tower).
    - Implement camera at Zeppelin Observatory for snow distribution monitoring
- We should seek to improve integration with Hornsund research station

5.1.7 *Data and web*

- At the Glaciology Flagship webpage, links should be added to:
    - The World Glaciological Monitoring Service database
    - Mass balance data at the NP data site (data.npolar.no)
    - Austfonna page (still needs to be developed)
    - Hornsund page
    - MOSJ pages (monitoring mass balance Svalbard/Jan Mayen)
- We should add Austfonna/Nordenskiöldbreen mass balance data to WGMS
- Webpages should be developed at individual institutes with regards to mass balance or other glaciological observations
- Mass balance data from other nations could also be made available through the NPI data portal
- It was proposed that a list of Ny-Ålesund glaciology publications be put together. However, it was decided that it is better to use ISI or Google Scholar rather than making and maintaining our own list, a rather significant undertaking.