

Proposal
for a coordinated programme on the

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**THE DYNAMIC RESPONSE OF ARCTIC GLACIERS
TO GLOBAL WARMING**



Working Group on Arctic Glaciology

International Arctic Science Committee (IASC)

The Working Group on Arctic Glaciology (WGAG) was initiated about 12 years ago by IASC to study the mass budget of Arctic glaciers. The Working Group has representatives from Austria, Canada, China, Denmark, Finland, France, Germany, Iceland, Japan, Norway, Poland, Russia, Sweden, Switzerland, United Kingdom, U.S.A.

The WGAG has a 10-year tradition in the organization of annual workshops on the mass budget of Arctic glaciers. These workshops have also been used as informal planning meetings for combined field work in the Arctic. The WGAG has made a significant contribution to the Arctic Climate Impact Assessment (ACIA). The programme proposed here will deliver new knowledge and novel methods, making projections of future glacier response to global warming more precise.

1. Background and rationale

It is expected that global warming will have a large impact on natural systems in the Arctic region. In an earlier article produced by WGAG members (Dowdeswell et al., 1998) mass-balance measurements on Arctic glaciers were summarized and the relevance of such measurements for future monitoring and detection of climate change in the Arctic was discussed. An extensive account of how global warming may manifest itself in the Arctic and of what could be the consequences for nature and mankind has been given in the Arctic Climate Impact Assessment (ACIA, Approved Report due in November 2004). One aspect of this involves the response of glaciers and ice sheets, and the implications for sea-level change and fresh water supplies in embayments and fjords.

In the ACIA-Report, a simple approach was taken to estimate the runoff of all glaciers and ice sheets in the Arctic for a set of climate-change scenarios from coupled ocean-atmosphere models. In this so-called *static approach* dynamic effects were not considered, i.e. changes in the surface mass balance were calculated without dealing with the fact that glacier geometries will change. Moreover, it was also assumed that the rate at which icebergs are produced at calving fronts would not change (Oerlemans et al., in press). Those simplifications had to be made because knowledge about the dynamic response of Arctic glaciers is inadequate.

A particularly important albeit poorly understood process is *calving*. Many glaciers in the Arctic flow into the ocean to form calving fronts where icebergs are produced. There are also many glaciers (notably in the margin of the Greenland ice sheet) that flow into fresh water lakes.

The mass budget of any glacier has basically three components: accumulation (A), ablation and runoff (R), and calving (C). Any change in ice volume V is related to changes in these components according to

$$\frac{dV}{dt} = A - R - C$$

For a glacier in balance runoff and calving ($R+C$) should be equal to the accumulation (A). It is believed that for many Arctic glaciers C is 20% to 50% of the accumulation, i.e. somewhat smaller than the runoff but still quite significant. For the Greenland ice sheet C is estimated to be 40% to 60% of the total accumulation. These figures make clear that changes in the calving speed of glaciers are potentially important. Evidence is accumulating that ice velocities and calving rates tend to increase when more water is supplied to a glaciers' drainage system (e.g. Zwally et al., 2002). Therefore a powerful feedback mechanism operating on the lower parts of calving glaciers becomes apparent:

more surface melting
 → *increased sliding and calving*
 → *surface lowering*
 → *more surface melting*

This mechanism can lead to a dynamic response of calving glaciers to global warming that is faster and more pronounced than assumed so far.

Calving glaciers have been studied for a long time. The focus has been on the mechanics of the calving process and on the relation between calving and geomorphological processes (Van der Veen, 1997). In recent years more and more satellite data have been used to estimate calving rates from Arctic glaciers. However, research carried out so far has not led to models of calving glaciers that can be used to predict future changes. It appears necessary to make a coordinated effort to increase our

knowledge of the dynamics of Arctic glaciers. The key elements in such an effort should be (i) to *make better use of existing observational techniques* to assess the detailed dynamics of a key set of glaciers, and (ii) to *develop models* that can be used to aggregate data of different kinds and that are sufficiently robust and sophisticated to have predictive power.

The WGAG constitutes an ideal vehicle to coordinate a programme sketched above. All nations which are a member of IASC are represented in the WGAG, and there is a great expertise on Arctic glaciology. It can be expected that a programme on the dynamic response of glaciers to global warming will produce very relevant input for future assessments.

2. The work to be done

The programme will be built on existing expertise and logistic facilities. First a set of glaciers and ice caps will be identified to be the key targets of intensive observations (in situ and from space) for the period 2007-2010. These glaciers should cover a wide range of climatic and geographical settings (i.e. from continental to maritime; from steep mountain terrain to plateau-type orography). The programme will therefore be truly circum-Arctic, with studies in Alaska, Canada, Greenland, Iceland, Northern Scandinavia, Svalbard, Franz-Josef Land, Novaya Zemlya, Severnaya Zemlya. For each target glacier the following parameters will be measured:

- *surface mass balance*
- *surface velocities (3-dimensional), preferably including seasonal cycle*
- *bed topography*
- *surface topography (with high accuracy)*
- *surface albedo at the end of the ablation season*
- *calving rates*
- *water pressure in boreholes*
- *temperature profiles in the ice (for polythermal glaciers)*

In addition close to or on each target glacier an

- *automatic weather station*

will be installed and operated for at least two years.

Among the target glaciers should be glaciers for which information is available on length/area in historical times [reports, drawings, photographs, old maps, etc.]. This information will be combined with the newly derived maps to

- *reconstruct glacier evolution from the Little Ice Age into the present*

For each target glacier a research group will be asked to take the overall responsibility for coordination of the observations with other participating groups and for data collection and handling. Quality-checked data will then be made available to the scientific community through the WGAG website.

Model development will go in parallel with the observational programs and will be an important component of the programme. The modelling work will deal with processes acting on the smaller scale (understanding and parameterization of the calving process) as well as the larger scale (global dynamics of tidewater glaciers, response to climate change, interaction with sediment dynamics). A *hierarchy of models* will be developed, ranging from quasi-analytical approaches to 3-dimensional numerical models.

3. Products

- Extensive datasets for target glaciers around the Arctic.
- A better understanding of the factors that control the response of Arctic glaciers to climate change.
- Improved techniques to retrieve glacier parameters from satellite data
- Models that can be used to predict glacier behaviour for imposed climate change scenarios.

4. Organization

To avoid large overheads, the programme will be run with a simple organizational structure. The annual WGAG meeting and workshop will be the main occasion for discussion of results, planning of combined field work, and shaping of the output. A small Steering Committee (4 or 5 members) will be established to run and coordinate the daily matters (including the maintenance of a high-quality website). All participants have to seek funding from their national research councils or other organizations. It is hoped that IASC can provide some basic funding for the annual meeting, occasional planning meetings, and travel costs of the Steering Committee.

References

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