

The Balzan Ice Modelling Study

Dorthe Dahl-Jensen and Johannes (Hans) Oerlemans

2022 Balzan Prize for Glaciation and Ice Sheet Dynamics

Balzan GPC Advisers: Sierd A.P.L. Cloetingh

Affiliated Institution: Niels Bohr Institute, University of Copenhagen; Utrecht University (IMAU)

Deputy Director: Joergen Peder Steffensen

Period: 2023-

Dorthe Dahl-Jensen is Canada Excellence Research Chair, Centre for Earth Observation Science, University of Manitoba, Winnipeg, Canada, and Villum Investigator, Physics of Ice, Climate and Earth – Niels Bohr Institute, University of Copenhagen, Denmark, where she was also Associate Professor (1997-2002).

Johannes (Hans) Oerlemans is Professor Emeritus at the Institute for Marine and Atmospheric Research at Utrecht University (IMAU) and holds an honorary professorship at the University of Stockholm (Sweden).

Modelling the Mueller Ice Cap, Northern Canada

The Arctic Ocean is undergoing dramatic changes as sea ice thins and retreats further north during both summer and winter seasons. This sea ice retreat greatly affects the climatic conditions of the landmasses surrounding the Arctic Ocean. Ice fields situated on these landmasses are thus gradually being exposed to warmer climatic conditions, triggering an increase in surface melting and a loss of mass, and consequently contributing to sea-level rise.

By studying ice cores from ice caps near the Arctic Ocean, it is possible to retrieve proxy records of past Arctic Sea ice conditions and past Arctic climatic conditions. Furthermore, stratigraphic analysis and dating of the ice cores provide a window into the age and past ice flow dynamics of the small ice caps, thus yielding information on their response to climate change. Ice cores have been drilled on a few small ice caps surrounding the Arctic Ocean (Hans Tausen Ice Cap and Flade Isblink in northeast Greenland). These ice caps melted away during the Holocene Climatic Optimum. In contrast, an ice core from the Agassiz Ice Cap contains glacial ice and thus has survived the Holocene.



Location of ice caps mentioned in the text

The Mueller Ice Cap is an ice mass located further to the west on Axel Heiberg Island in the Canadian High Arctic (see

figure above). It has been selected as an interesting target to retrieve a new ice core. Some of the questions to be studied are:

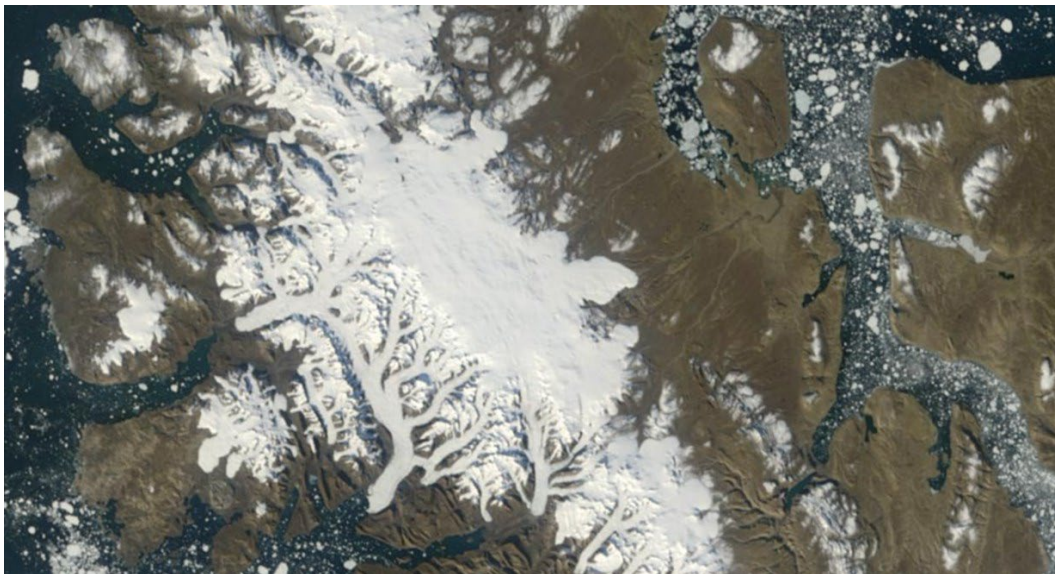
- (i) How did sea ice extent change during the past millennia?
- (ii) What climatic conditions did the Arctic ice caps experience over the past millennia?
- (iii) How old is the Mueller Ice Cap?

Another key objective is to retrieve the ice core while the stratigraphy still is preserved. With continuing climate warming in the Arctic, surface melt starts to penetrate and refreeze into deeper strata in the ice caps thus mixing the annual layers. It is thus imperative that ice cores are retrieved from the small ice caps before the warming in the Arctic degrades or completely annihilates their stratigraphy.

The drilling operation is currently in its planning phase, involving geophysical surveys and logistic planning. The Principal Investigator of this project is Dorthe-Dahl Jensen. “The Balzan Ice Modelling Study” (BIMS) wants to add a significant component to the Mueller Ice Cap Project. Computer modelling of the dynamics of the ice cap and its outlet glaciers is necessary to understand the relation between the history of the ice cap and the related regional climatic conditions through the Holocene. Climate proxies from the ice core can eventually be used to drive the glacier models. In turn, glacier models may deliver surface elevation changes of the ice cap which are needed for a proper interpretation of the ice core record.

Although the Mueller Ice Cap constitutes a continuous ice field, the dynamics of the outlet glaciers, notably the calving glaciers flowing to the (south)west, differ substantially from the dynamics of the main ice body which rests on a higher bedrock (see Figure below). Therefore, the project envisages two approaches: one focusing on the central part of the ice field with high resolution modelling in the region of the drill site; and one focusing on the outlet glaciers (both land-based and calving, and here a comparison with the outlet glaciers of the ice fields on Spitsbergen may be an interesting additional target).

Two two-year postdoc positions are foreseen to carry out this work. Use will be made of existing ice-dynamics models, output from high-resolution climate models, weather station data, satellite data, already existing ice-core proxies, etc. One postdoc will be based in Copenhagen, and the other in Utrecht, with ample possibilities for exchange and collaboration. Specific targets are: (i) to reconstruct the size of the ice cap through the Holocene and compare this with the geomorphological record; (ii) to investigate whether the ice cap size and ice core records from the Canadian Arctic are mutually consistent; (iii) to predict what will happen with the Mueller Ice Cap for a set of climate change scenarios. Three workshops focusing directly on the dynamics of the Mueller Ice Cap are planned, as described below.



The Mueller Ice Cap on Axel Heiberg Island. Two large tidewater glaciers drain the ice cap to the southwest. The eastern margin is land-based with lob-type structures. The highest point of the ice caps is about 188 m a.s.l. (Terra image made in August 2008).

Workshops on the Dynamics of the Mueller Ice Cap

BIMS will start with a workshop, planned to be held in Karthaus (Italy) in October 2023 (postdocs should have been recruited by that time). The goal of this first workshop is to make an inventory of existing data, try out glacier models, and define a good modelling strategy. Since one of the major aims is to involve young researchers in the project, smaller subprojects that are of interest for a bachelor's thesis or for a talented high school student will be defined. The first five-day workshop will take place in October 2023. The dates of the second and third workshops will be decided once progress on the project can be evaluated. More than just presenting preliminary manuscripts, the true aim of these workshops is to work together with sufficient computing facilities to try out ideas on the spot.

Student Excursions (in Collaboration with *GlaciersAlive*)

The study of glaciers and ice sheets is a fascinating branch of Climate Science. Changes in the cryosphere (degradation of permafrost, glacier retreat, shrinking of sea ice cover, shorter snow season) are the most obvious signs of global warming. This fascination should be exploited to educate young people and demonstrate that action is needed to reduce global warming and to deal with the consequences of the changes that are currently underway.

A series of excursions for international groups of ten to twelve talented high-school students is planned, perhaps in combination with undergraduate students, in Switzerland and possibly Norway. An excursion would essentially be a high school 'masterclass' with three days in the field and three days with lectures and computer exercises.

GlaciersAlive is a non-profit organization that has the objective of fostering small-scale projects for protecting glaciers and dealing with the consequences of glacier retreat (e.g., water supply for mountain huts). The foundation is sponsored by local communities and commercial parties, as well as supported by personal gifts. *GlaciersAlive* has experience with the organization of excursions for students, politicians, and journalists. Close cooperation with *GlaciersAlive* is foreseen for these workshops. Each one-week masterclass has four basic ingredients: lectures, field trip, computer exercise, and music. TangoGlaciar (<https://www.youtube.com/watch?v=onp7tRRyCAQ>) will be involved to offer the possibility for students to play in a small 'glacial orchestra'. The press will also be involved in working towards the production of a documentary about the workshop and the underlying theme of cryosphere and climate change.



Excursion to the glaciers of Switzerland

Dissemination of Results and Outreach

The scientific results of this project will be published as articles in peer-reviewed journals, with appropriate acknowledgement of the support from the Balzan Research Project of Dorthe Dahl-Jensen and Johannes Oerlemans. Results will also be presented at conferences, notably at the Assemblies of the European Geosciences Union in 2024, 2025, and 2026. Practice has shown that the press is always very interested in cryospheric research, and it will not be difficult to present results to the general public.

Linked to the abovementioned master classes, a documentary may be made in collaboration with a Dutch and/or Danish broadcasting company. The documentary should not only deal with the scientific background per se, but also with the attitude and possibilities of young people to foster creative and innovative ideas to deal with climate change.

The scientific results of this project will be published as articles in peer-reviewed journals, with appropriate acknowledgement of the support from the Balzan Research Project of Dorthe Dahl-Jensen and Johannes Oerlemans. Results will also be presented at conferences, notably at the Assemblies of the European Geosciences Union in 2024, 2025, and 2026. Practice has shown that the press is always very interested in cryospheric research, and it will not be difficult to present results to the general public.

Linked to the abovementioned master classes, a documentary may be made in collaboration with a Dutch and/or Danish broadcasting company. The documentary should not only deal with the scientific background per se, but also with the attitude and possibilities of young people to foster creative and innovative ideas to deal with climate change.