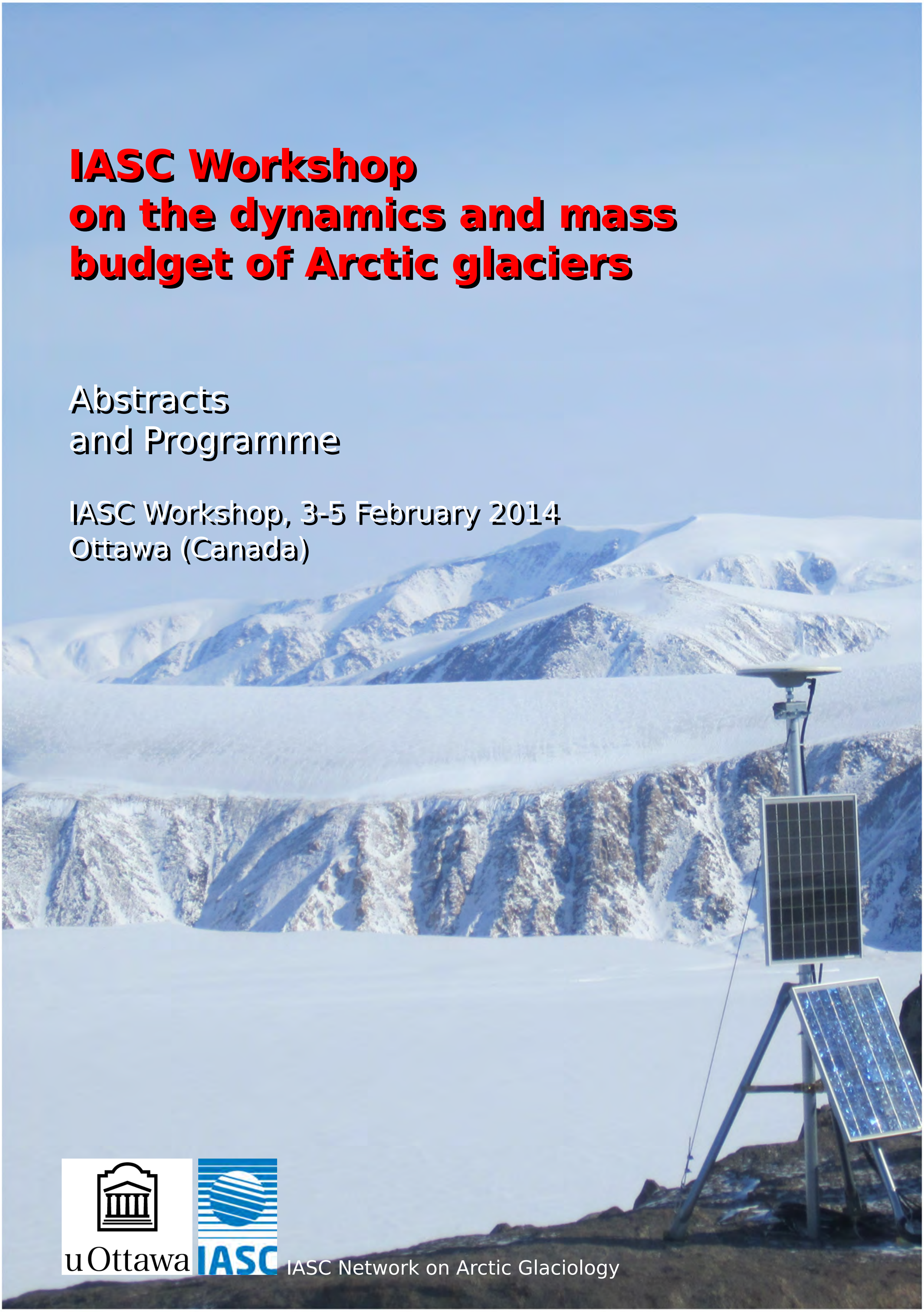
IASC Workshop on the dynamics and mass budget of Arctic glaciers

Abstracts and Programme

IASC Workshop, 3-5 February 2014
Ottawa (Canada)



uOttawa

IASC

IASC Network on Arctic Glaciology

IASC Workshop on the dynamics and mass budget of Arctic glaciers

Abstracts and program

**IASC Workshop &
Network on Arctic Glaciology annual meeting,
3-5 February 2014, Ottawa (Canada)**

Organised by L. Copland and C.H. Tijm-Reijmer

uOttawa IASC Network on Arctic Glaciology

Cover photo: Belcher Glacier, Devon Ice Cap, Nunavut. Photo by M. Sharp.

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Preface

For the 2014 meeting it was time again for us to go to North America. I was happy to accept the invitation of Dr. Luke Copland to organize the meeting at the University of Ottawa, Canada. There we were part of an Arctic week which included our annual workshop and open forum meeting, the Ottawa Carleton Student Northern Research Symposium, a GlacioEx project meeting, and celebrations on the 125th Anniversary of the Faculty of Arts at the University of Ottawa, the 500th meeting of the Arctic Circle and of course the 20th Anniversary of our own Network on Arctic Glaciology.

Somewhere in 1992-1993 the initiative was taken to start the 'Working group on Arctic Glaciology (WAG)' within IASC. This took shape in 1994 and the first meeting took place in Wisla, Poland in September 1994. The Network on Arctic Glaciology (NAG) was formed out of the working group in 2010 after a reorganisation of IASC. Already as a working group, and now also as a network, NAG is one of the more active networks within IASC with annual meetings and coordinated research activities.

The meeting in Ottawa again proved how active our community is with 37 participants representing about 10 different countries. IASC generously supported seven young scientists to attend the meeting. These 37 participants presented cutting edge science in 24 talks and 10 posters. We also had a demonstration of how a UAV can be used in glaciology. The open forum meeting again provided many ideas to initiate as a community.

Our meeting took place in the middle of the Winterlude, an annual winter festival in Ottawa. This provided the opportunity to skate on the largest ice rink in the world: the Rideau Canal Skateway. So the discussions related to, amongst others, science and fieldwork continued on the ice instead of on skiing slopes resulting once again in a succesful and informal event.

Finally, I want to thank Luke Copland for the excelent local organisation of the meeting. He also arranged financial support from the University of Ottawa and from the GlacioEx project, which helped keeping the registration fee for the participants reasonably low.

Next year the meeting will take place in the University Center Obergurgl from 23 - 25 March, 2015. I hope to meet you all there.

C.H. Tijm-Reijmer
April 2014

Program

The meeting took place in the Desmarais building of the University of Ottawa, Canada. (see map below the program)
Presentations were in Desmarais room 12102, posters, coffee and lunches in Desmarais room 12110.

Monday 3 February

08:30 - 09:00	**Registration**
Convener:	*Carleen Reijmer*
09:00 - 09:10	Welcome *L. Copland / C.H. Reijmer*
09:10 - 09:30	Validation of CryoSat-2 measured surface elevations over Austfonna ***Kirsty Langley****, T. Dunse, T. Eiken, J.O. Hagen, L. Langhammer, V. Helm and H. Skourup*
09:30 - 09:50	Cryosat reveals significant recent elevation change for some Arctic Ice Caps ***Laurence Gray*** *and D. Burgess*
09:50 - 10:10	Monitoring Baffin Island glaciers melt using RADARSAT-2 Stereo Radargrammetry ***Charles Papasodoro****, A. Royer and A. Langlois*
10:10 - 10:30	Tracking Summer Melt Conditions on Arctic Ice Caps using the MODIS Land Surface Temperature (LST) Product *M.-L. Geai and* ***Martin Sharp***
10:30 - 11:00	**Coffee break**
Convener:	*Kirsty Langley*
11:00 - 11:20	What do McCall Glacier, caribou, and monster truck tires have in common? ***Matt Nolan***
11:20 - 11:40	Repeat high-resolution 3D mapping of tidewater glaciers in Greenland ***Gordon Hamilton****, D. Finnegan, A. Lewinter, A. Fowler and L. Stearns*
11:40 - 12:00	Velocity and ice thickness changes at the Rusanov and Karpinsky ice caps in response to the destruction of the Matsuevich Ice Shelf, Severnaya Zemlya, Russian High Arctic. ***Michael J. Willis****, A.K. Melkonian, A.J. Stewart, E.M. Golos, M.E. Pritchard and J.M. Ramage*
12:00 - 12:20	Estimating Supraglacial Lake Depth with Landsat 8 ***Allen Pope****, T. Scambos and M. Moussavi*
12:20 - 14:00	**Lunch**
Convener:	*Carleen Reijmer*
14:00 - 14:30	Poster presentations by authors

14:30 - 16:00 **POSTER SESSION**

15:00 - 15:30 **Coffee break**

16:00 - 17:30 IASC Network on Arctic Glaciology Open Forum meeting *C.H. Reijmer / M. Sharp*

18:30 - **Dinner at Mother Tucker's restaurant** (Optional, own cost, http://www.tuckersmarketplace.ca/)

Tuesday 4 February

Convener: *Christian Zdanowicz*

09:00 - 09:20 Using various mass-balance observations to improve the resolution of a global-scale elevation dependent surface mass balance model ***A. Cody Beedlow****, A.K. Bliss, V. Radić, R. Hock, A.A. Arendt, J.G. Cogley and D. Hill*

09:20 - 09:40 Response of glacier mass balance and discharge to future climate change in the upper Susitna basin, Alaska ***Regine Hock****, A. Bliss, J. Braun, C. Aubry-Wake, J. Zhang, A. Liljedahl, J. Schulla and G. Wolken*

09:40 - 10:00 Coastal Arctic fog and its influence on glacier surface energy balance ***Hester Jiskoot****, S.Y. Gueye and J.H. van Boxel*

10:00 - 10:20 The surface mass and energy balance of Nordenskiöldbreen, Svalbard: 7 years of in situ observations ***Carleen H. Reijmer****, V. Pohjola, W.J.J. van Pelt and R. Petterson*

10:20 - 11:00 **Coffee break**

Convener: *Alan Pope*

11:00 - 11:20 Estimating Synoptic Scale Surface Mass Balance of Ice Caps in the Queen Elizabeth Islands, Canada: 1960-2050 ***David Burgess***

11:20 - 11:40 An Improved Mass Budget for the Greenland Ice Sheet ***Ellyn M. Enderlin****, I.M. Howat, S. Jeong, M.-J. Noh, J.H. van Angelen and M.R. van den Broeke*

11:40 - 12:00 High density monitoring to better understand dynamics of a small Arctic glacier basin: six years of measurements on the Austre Lovénbreen, Svalbard, 79°N ***Eric Bernard****, F. Tolle, J.M. Friedt, Ch. Marlin and M. Griselin*

12:00 - 12:20 Changes to the dynamics of Arctic mountain glaciers: Case study of White Glacier, Axel Heiberg Island, Nunavut ***Laura Thomson*** *and L. Copland*

12:20 - 16:00 **Lunch, visit winter festival, skating**

16:00 - 17:00 Demonstration: How to fly a UAV ***Matt Nolan***

17:00 - 18:00	Demo: How to construct a DEM from UAV collected images ***Matt Nolan***
18:00 - 20:00	**Celebration 20 years Network on Arctic Glaciology**
18:00 - 19:00	**Pizza Dinner**
19:00 - 20:00	Celebration lecture ***Hugh Dale-Haris*** New Land 2013: A journey through Otto Sverdrup's High Arctic

Wednesday 5 February

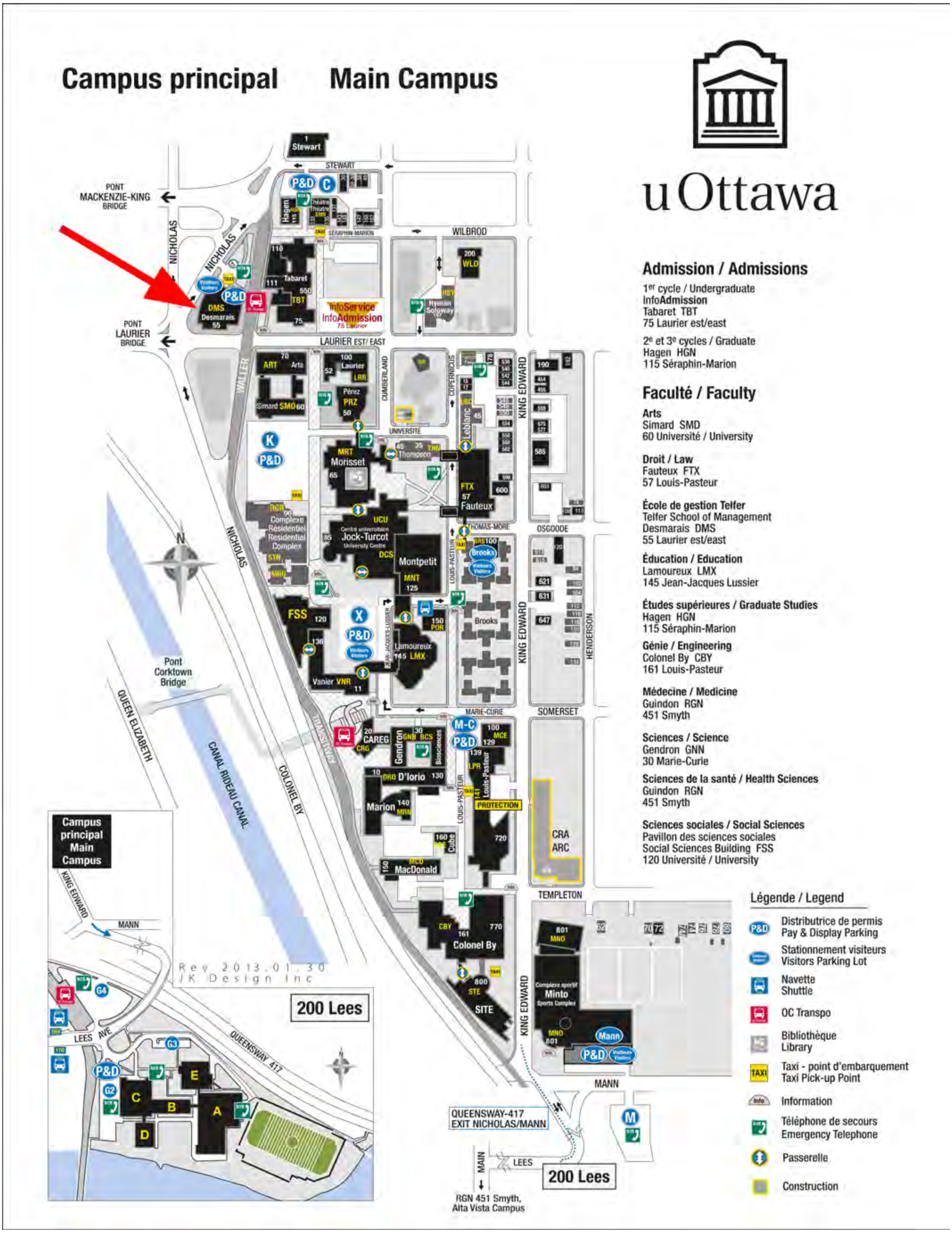
Convener:	*Hester Jiskoot*
09:00 - 09:20	How deep does a typical crevasse in Western Greenland carry meltwater? ***Kristin Poinar*** *and I. Joughin*
09:20 - 09:40	Seismic data reveal subglacial ponding under the Greenland Ice Sheet ***Coen Hofstede****, R. Petterson, D. Fritzsche, F. Wilhelms and A. Hubbard*
09:40 - 10:00	Subglacial lake volume changes due to replenishment by supraglacial melt, Northeast Greenland ***Michael J. Willis****, B. Herried and M. Bevis*
10:00 - 10:20	The 2009-10 surge of Lowell Glacier, Yukon, and its context within five surges since 1948 ***Luke Copland*** *and A. Bevington*
10:20 - 11:00	**Coffee break**
Convener:	*Michael J. Willis*
11:00 - 11:20	Interannual and multi-decadal velocity variations in the eastern St. Elias Icefields, Yukon Territory, Canada ***Alexandra Waechter****, L. Copland, E. Herdes, L. Gray and J. Poitevin*
11:20 - 11:40	Alaska tidewater glacier surface velocities and frontal ablation, 1985-2013 ***Robert McNabb***
11:40 - 12:00	Summer melt regulates winter glacier flow speeds throughout Alaska ***Evan W. Burgess****, C.F. Larsen and R.R. Forster*
12:00 - 12:20	A whale of a tale in 1710: East GreenlandÕs oldest weather and sea ice records ***Hester Jiskoot****, C. Bonifacio, M. Mueller and J. Palardy*
12:20 - 12:30	Final words *L. Copland / C.H. Reijmer*
12:30 -	**Lunch / Departure / Skating / Skiing**

Thursday 6 February

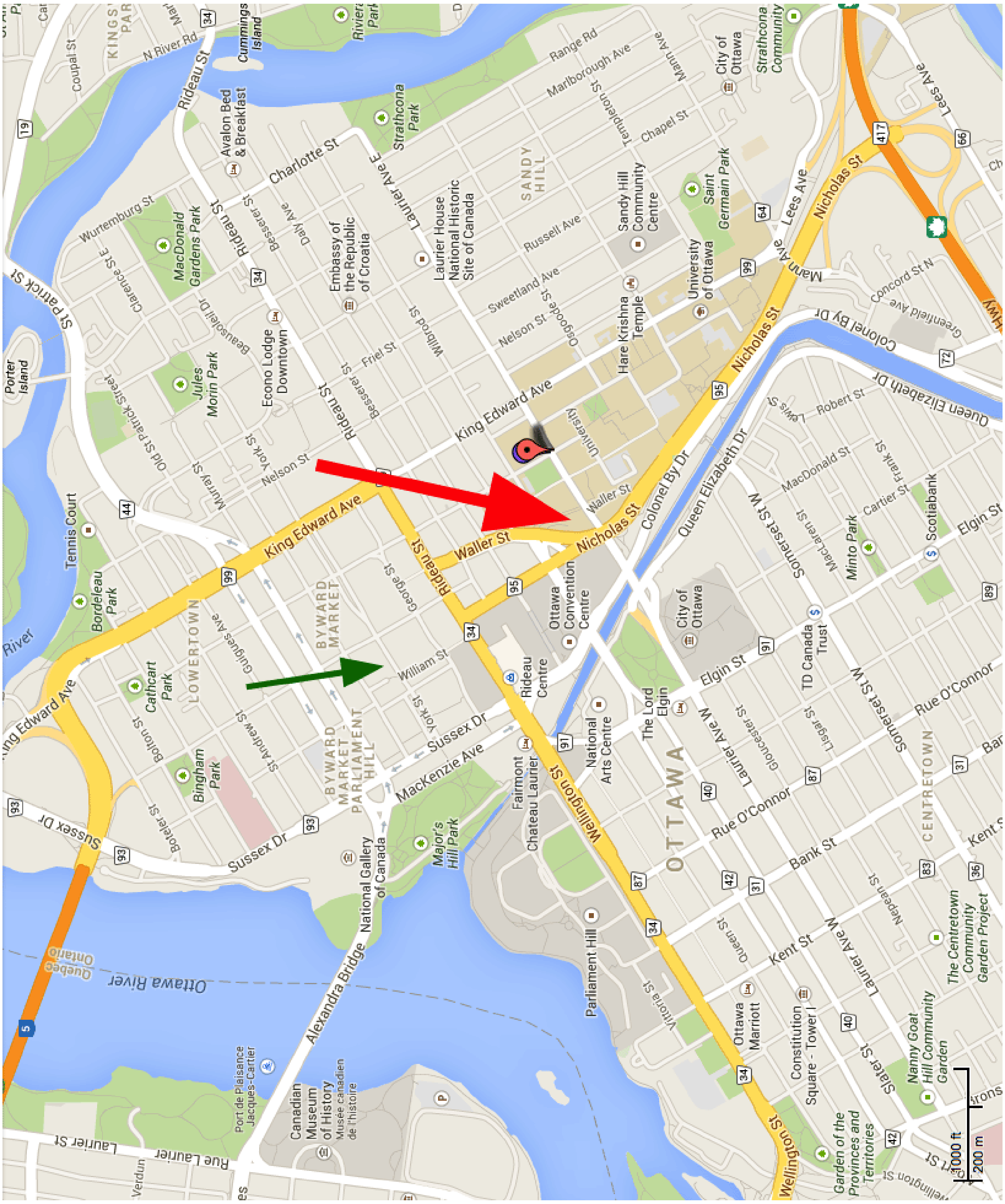
Ottawa Carleton Student Northern Research Symposium
(Desmarais building room 12102) Information will be available at:
http://www3.carleton.ca/northernresearch/OCSNRS.html

Posters

- Controls on intra-annual variations in motion of the Kaskawulsh Glacier, Yukon Territory ***Emilie Herdes*** *and L. Copland*
- Relationships between iceberg plumes and sea ice conditions on northeast Devon Ice Cap, Nunavut, Canada ***Emilie Herdes****, L. Copland, B. Danielson and M. Sharp*
- Derivation of a multitemporal set of transient snowlines for Alaska's glaciers ***Christian Kienholz****, A. Arendt, R. Hock*
- Catchment's hydrology of high-Arctic glacier (Werenskioldbreen, Spitsbergen): Changes in the ablation Season ***Elzbieta Majchrowska***
- Changes to the glaciers at Novaya Zemlya. *A.K. Melkonian,* ***Michael J. Willis****, M.E. Pritchard, A. Stewart and J. Ramage.*
- Recent ice shelf loss, Ellesmere Island, Nunavut, Canada. ***Derek R. Mueller****, L. Copland, A. White and T. Wohlleben*
- Assessment of sea ice conditions and shipping activity in Canadian Arctic waters between 1990 and 2012 ***Larissa Pizzolato****, S.E.L. Howell, C. Derksen, J. Dawson and L. Copland*
- Internal layering and stratigraphy from RES data on outlet glaciers in the Canadian Arctic ***Anja Rutishauser***
- Volume and mass changes over Penny Ice Cap, Baffin Island, from 2005-2013 determined from repeat airborne laser altimetry. ***Nicole Schaffer****, L. Copland, C. Zdanowicz, J. Nilsson and D. Burgess.*
- Documenting multidecadal recession of Grinnell and Terra Nivea ice caps, Baffin Island, Canada ***Robert G. Way***



Map: Arrow indicates the location of the Desmarais building.



Map: Red arrow indicates the location of the Desmarais building, green arrow Mother Tucker’s restaurant.

Participants

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(Young scientists receiving support are marked *).

Minutes of the Open Forum meeting

Chair: Carleen Tijm-Reijmer
Vice Chair: Martin Sharp
Minutes: Anja Rutishauser
Invited to attend: all participants of the workshop.

Agenda

1. Other items for the agenda
2. Background on IASC and NAG
3. Meeting minutes 2015
4. Location IASC-NAG workshop
5. Network activities
6. National contacts
7. Extended Abstracts
8. Anything else

Ad. 1

Coen Hofstede has an input with some information on what the AWI plans to survey in the Canadian Arctic. Carleen decided to discuss it under Ad. 5 (Network activities).

Ad. 2

Introduction to International Arctic Science Committee (IASC): There are five working groups within the IASC, where the Network on Arctic Glaciology is grouped within the Cryosphere group. The general idea of the network is to discuss where the scientific team should go as a group. The main activity is to organize this meeting which offers the possibility of talking to each other as a team.

Ad. 3

An overview was given about what was discussed last year. The main points were where the meeting 2014 takes place (Ottawa), updating the list of national contacts, the role of the website, and the abstract book. From now on, all abstract books are available online, where this year's book comes with an ISBN number.

Ad. 4

Carleen states that the idea was to have the meeting for two years in Europe, and then another two years out of Europe. It was previously suggested to have the 2015 meeting in the Pyrenees in Spain, and then in 2016 in Obergurgl in Austria. The group agrees and thinks that is a good idea.

Discussion about the dates for the meeting 2015: The general statement of the group is that the meeting should not be in January or March, but February would work well. Carleen mentions that the holidays in the Netherlands take place the last week of February, whereas a meeting in these holiday period would not work for Carleen. The group decides to check what is available at the meeting place in Spain in February, and then take it from there.

Extra information since the meeting:
Meeting in Pyrenees Spain has been postponed to 2016 due to overlap with Antarctic fieldwork of the organiser (Francisco Navarro) in winter 2015. Therefore, the meeting in 2015 will take place in Obergurgl, Austria. Unfortunately the only available dates with sufficient time and rooms available was 23-25 March 2015.

Ad. 5

Coen Hofstede presents an outlook of what the AWI (Alfred Wegner Institute) is planning to survey in the near future: The AWI plans to do airborne radar surveys on the '79 degree glacier' and four additional glaciers in Northern Greenland. The plan is to go there with a ship, collect seismic data, perform ice core drilling (and also sediment coring) and collect radar profiles to determine the ice dynamics of the glacier. There are already existing radar data available from the AWI and the Ice Bridge project. If anyone is interested in contributing or has any questions, they can contact the AWI.

Carleen talks about the meeting in Grenoble (glacier and ice-stream calving Ð Observations and Modelling, 2-3 June 2014, Grenoble, France), where around 30 people will participate and work on numerical modeling of tidewater glaciers. The aim of this meeting is to determine which dataset is best suited for testing the numerical models. The meeting is funded by the Cryosphere group, by IACS, and some Canadian funds.

Martin Sharp gives a brief overview of how funding works: Sometimes funding is directly allocated to IASC. There is also funding for meetings/schools etc, when people have an idea they can apply for funding, which is usually around 10'000-20'000 $. Young researchers are often supported by these funds.

For the tidewater glacier initiative, we are in stage three now. The question is why are there significant differences in ice sheet mass balance results from different measurements and models. Yet, there is no funding for that, but we could apply if someone is interested. Martin mentions that this group would like to get involved; Martin will talk to Jenny????? about this.

Firn processes: Responses of glacier ice caps and the Greenland ice sheet, how are firn processes involved. Martin mentions that if anyone is interested in that we can try to build up a group.

Update analysis of in situ mass balance records from Arctic Glaciers: It would be good to take a look at these data again, this would be something the IASC could support if someone is interested in that.

Albedo feedbacks: The ICAP3 final meeting will be in Tokyo 2015, they have just received funding for this. A meeting will probably take place in September 2014 to prepare for what has to be done for the upcoming meeting in Tokyo in 2015. If someone is interested in this get in touch with Martin.

Studying ice sheet-ocean interactions: The meeting in June 2013 was funded by agencies in the US on that. Development of observing systems for studying this would be relevant to our group.

Ad. 6

The list of national contacts shows that there is still no contact for China and Japan. The contact listed for Germany (Heinz Miller) is retired, thus the contact for Germany remains unsure. Someone mentions that Heinz Miller knows a lot of what is going on and could be contacted if needed. Nevertheless, a new contact for Germany should be announced.

Ad. 7

All books are available in pdf format on the website; they will be distributed in advance to the meeting. There is the opportunity to extend the abstracts, for the final book. The deadline for the extended abstract is March 30, 2014. The book will be published before August 1, 2014. The book will not be printed (due to no funding), but it will be available in pdf format.

Ad. 8

Question to Martin about the firn process studies: Martin explains that the aim is to determine long-term processes in the firn layer to understand the water storage processes in the firn in the Greenland ice sheet. We are interested in bringing 'field people' with field data and people who do modelling together. We also need multi-temporal data. Someone mentions that the University of Wallington is currently looking at this kind of modelling, a contact might be useful.

Closing of the meeting and thank you to Anna for writing the minutes.

Abstracts

Using various mass-balance observations to improve the resolution of a global-scale elevation dependent surface mass balance model

A.C. Beedlow, A.K. Bliss, V. Radić, R. Hock, A.A. Arendt, J.G. Cogley and D. Hill

Regional- and global-scale surface mass balance models have typically been used to estimate sea-level rise from glacier volume changes. These models, however, suffer from a lack of observations to adequately calibrate their parameters. Model parameters derived from a global array of observations are in general unlikely to represent those found at the regional- or individual-scale. Such models may be adequate for global surface mass-balance simulations, but their precision may degrade at finer spatial scales. Point mass-balance observations are typically measured in many glaciological field campaigns; however these data are often never published, and rarely used other than in the estimation of whole-glacier mass balance. Here we use an array of available surface mass balance observations for Alaska to calibrate and validate an elevation-dependent surface mass-balance model applied to all glaciers in Alaska. In particular, we use point mass-balance observations to help calibrate the various elevation-dependent model parameters using a general-purpose global optimization algorithm called the Shuffled Complex Evolution Metropolis Algorithm (SCEM-UA). We then compare the modeled volume projections calibrated with the various mass-balance observations.

High density monitoring to better understand dynamics of a small Arctic glacier basin: six years of measurements on the Austre Lovénbreen, Svalbard, 79°N

E. Bernard[1], F. Tolle[1], J.M. Friedt[2], Ch. Marlin[3] and M. Griselin[1]

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[3] CNRS UMR IDES, université Paris-Sud, Orsay, France

Arctic is a reliable indicator of global climate changes. Within this context, the observed evolutions are becoming faster and more unpredictable. Glacier dynamics are directly affected, and following processes becomes challenging: some fast but key events can be missed since they are short but significant. Beyond global climatic trends, glaciers dynamics are highly dependent on local climatic parameters such as temperatures and precipitation.

Thus, a monitoring protocol based on a network of stakes and complemented with regular snow drilling campaigns has been carried out for 6 years on the Austre Lovén glacier (Spistbergen, 79°N). Overall, 36 measurement points have been distributed at regular intervals over the 4.5 km^2 glacier surface. For each of these points the snowpack was measured at a period close to its yearly maximum and expressed in terms of snow height and water equivalent. Mass balance was also recorded yearly at the end of September. Furthermore, temperature is measured over a 20 sensors network on the glacier, which allows to calculate the hourly thermal state. At last, a network of 6 automated digital cameras (which provide a surface coverage of 96% of the glacier) is used to map snowcover dynamics.

From these data, we were able to highlight the significant impact of warm events. Indeed, results show that there is a strong link between these warm events, snowpack dynamics and glacier mass balance. In the middle of winter, short-violent warm events together with liquid precipitation could removed nearly all the snowpack in only a few hours, calling into question the seasonal accumulation.

This 6-year period belong to a hot decade which affects Svalbard: the observed trend is more due to lack of cold in winter than by excess of warm in summer. Observations at a local scale show the main impact of liquid precipitations on snowpack dynamics and then on glacier's behavior each season. The result is complex: a meanly warm and dry summer will have few incidence on the glacier mass balance, when a warm and very dry winter could be seen as detrimental at low altitude as it will contribute to an important snow refill of the glaciers over the 0°C isotherm.

Moreover, with respectively -1065 mm weq and -1063 mm weq, 2011 and 2013 mass balance seems to show very similar results. But actually, spatial trends are completely different for both years. Values are spatially much more smoothed for 2013, with minimum and maximum far less important. This will be another topic of this presentation.

Estimating Synoptic Scale Surface Mass Balance of Ice Caps in the Queen Elizabeth Islands, Canada: 1960-2050

D. Burgess

Geological Survey of Canada, Ottawa, Canada

Since 2005, ice caps in the Canadian high Arctic have become among the most important contributors to global sea level rise apart from the ice sheets of Antarctic and Greenland (Gardner et al, 2011). Providing longer term context to these changes is thus of interest for understanding the impacts of accelerated glacier shrinkage in this region on relative sea level rise and other effects associated with freshening of the ocean waters. In this study, annual estimates of climatic surface mass balance for the years 1960-2013 are derived across ice caps in the Queen Elizabeth Islands, Canada, from a simple model driven by NCEP 850mb air temperatures and in-situ mass balance records collected from the Devon and Agassiz ice caps since 1961 and 1977 respectively. Good overall agreement with independent satellite and model data gives confidence that this model provides a reasonable estimate of mass change for the region. As such, estimates of predicted mass change for the QEI ice caps to 2050 were computed based on global temperature warming scenarios (IPCC5) modified to account for arctic amplification. Methodology and preliminary model results will be presented.

References

Gardner, A.S., G. Moholdt, B. Wouters, G.J. Wolken, D.O. Burgess, M.J. Sharp, J.G. Cogley, C. Braun, and C. Labine, 2011. Sharply increased mass loss from glaciers and ice caps in the Canadian Arctic Archipelago. *Nature*, **473**, 357–360.

Summer melt regulates winter glacier flow speeds throughout Alaska

E.W. Burgess[1,3], C.F. Larsen[1] and R.R. Forster[2]

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[2] University of Utah, Department of Geography, Salt Lake City, USA
[3] U.S. Geological Survey, Anchorage, USA

Increases in surface melt rates are known to accelerate glacier flow in spring and summer, and decelerate flow in fall; whereas in winter, flow speeds have been found to be relatively invariant. Here we find that wintertime flow velocities on nearly all major glaciers throughout Alaska are not only variable but are inversely correlated with summertime positive degree days (PDDs). The response is slight, an 11% decrease in wintertime velocity per additional meter of summertime melt. The mechanism is likely due to inter-annual differences in summertime melt affecting the efficiency of sub-glacial drainage systems to evacuate water from the glacier bed in fall. Resultant inter-annual variation in bed separation come winter leads to the observed differences in flow speed. We find this mechanism to be ubiquitous in Alaska and thus is likely a global phenomenon. If the dynamic evolves over the long-term, it represents another hydrology-related flow mechanism affecting sea level rise contributions.

The 2009-10 surge of Lowell Glacier, Yukon, and its context within five surges since 1948

L. Copland and A. Bevington

Department of Geography, University of Ottawa, Canada

Field observations, aerial photographs and satellite images are used to reconstruct the past surges of Lowell Glacier since 1948 based on the timing of terminus advances. A total of 5 surges occurred over this time, each with a duration of ∼1-2 yrs. The time between successive surges ranged from 12-20 years, and appears to have been shortening over time. The relatively short advance and quiescent phases of Lowell Glacier, together with rapid increases in velocity during surges, suggest that the surging is controlled by a hydrological switch. The 2009-10 surge saw ablation area velocities increase by up to two orders of magnitude from quiescent velocities, and the terminus increase in area by 5.1 km^2 and in

length by up to 2.85 km. This change in area was the smallest since 1948, and follows the trend of decreasing surge extents over time. This decrease is likely driven a strongly negative surface mass balance of Lowell Glacier since at least the 1970s, and means that the current town site of Haines Junction is very unlikely to be flooded by damming caused by any future advances of the glacier under the current climate regime.

An Improved Mass Budget for the Greenland Ice Sheet

E.M. Enderlin[1,2,4], I.M. Howat[1,2], S. Jeong[1,2], M.-J. Noh[1,2], J.H. van Angelen[3] and M.R. van den Broeke[3]

[1] Byrd Polar Research Center, The Ohio State University, Columbus, USA
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Extensive ice thickness surveys by NASA's Operation IceBridge enable over a decade of ice discharge measurements at high precision for the majority of Greenland's marine-terminating outlet glaciers, prompting a reassessment of the temporal and spatial distribution of glacier change. Annual measurements for 178 outlet glaciers reveal that, despite widespread acceleration, only 15 glaciers accounted for 80% of the 730±26 Gt of ice lost due to acceleration since 2000, and four accounted for ∼50%. Among the top sources of loss are several glaciers that have received little scientific attention. The relative contribution of ice discharge to total loss decreased from 56% before 2005 to 34% between 2009-2012. As such, 85% of the increased in mass loss after 2009 was due to increased surface melting. These observations support recent model projections that surface mass balance, rather than ice dynamics, will dominate the ice sheet's contribution to 21^{st}-century sea level rise.

Tracking Summer Melt Conditions on Arctic Ice Caps using the MODIS Land Surface Temperature (LST) Product

M.-L. Geai and M. Sharp

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Much of the inter-annual and long-term variability in the climatic mass balance of Arctic glaciers arises from variability in the summer balance (from rates of surface melt). In the absence of direct mass balance measurements, measurements of summer ice surface temperatures and the duration of melting conditions may serve as a proxy for the summer balance. They may also shed light on the spatial pattern of summer balance within the larger regions for which mass balance is calculated using such methods as satellite gravimetry and laser altimetry. The Moderate Resolution Imaging Spectroradiometer (MODIS), launched on board the TERRA and AQUA satellites in 1999 and 2002, provides estimates of surface temperature with a target accuracy of 1 K at 1-km spatial resolution

from twice-daily overpasses. However, it can only measure LST under clear-sky conditions, generating a possible bias in measured surface temperatures relative to air temperatures in cloudy regions. To evaluate the effect of this bias on the utility of the LST data, we compared JJA mean LST derived from 8-day composites of daytime clear sky LST data for 10 km^2 pure snow/ice blocks from the interior regions of ice masses in major glaciated regions of the Arctic with mean summer 700 hPa air temperatures derived from the NCEP/NCAR R1 Reanalysis (NCEP) for the 2000-2011 period. Inter-annual variability in LST and NCEP air temperature records was well correlated ($r>0.65$) in regions with >45% LST data recovery. Such regions include the Canadian high Arctic, coastal Greenland, Svalbard and Severnaya Zemlya. Here we will present time series of mean summer LST from these regions for the period 2000-2012, and spatial mapping of annual summer mean LST and cloud cover (derived from variations in the LST retrieval rate) for ice caps in the Canadian high Arctic. Trends and variability in these patterns show good consistency with both field measurements of annual climatic balance and satellite-derived measurements of the total mass balance of glaciers and ice caps and glaciers in the region over the same time period.

Cryosat reveals significant recent elevation change for some Arctic Ice Caps.

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In the past satellite radar altimetry has provided information on ice elevation change over the central Greenland and Antarctic Ice Sheets, but has had very limited utility in monitoring change on smaller ice caps like those in the Canadian Arctic. Cryosat was developed by the European Space Agency with a special mode which, it was hoped, would allow the estimation of ice terrain elevation on the sloping edges of the larger ice sheets, and for the smaller ice caps and glaciers in many regions of the world. Indeed with the potential of climate change and uncertainty in future ice melt, the need for improved tools to monitor change in all the world's glaciated regions has become more pressing. As the smaller ice caps and glaciers will be a significant contributor to future sea level rise there is a clear need for appropriate satellite monitoring. We show that the Cryosat SARIn mode can provide relevant elevation change information for a number of Arctic Ice Caps.

The Cryosat SARIn mode has key capabilities that allow the extraction of suitable height information for smaller ice caps: The footprint size is relatively small; the cross-track interferometry allows mapping of the position of the 'point-of-closest-approach' (POCA) and the orbit pattern provides for relatively frequent coverage, particularly for the high latitude ice caps. Height change information has been derived for some key Arctic Ice Caps including Penny and Barnes on Baffin Island, the Ice Cap on Devon Island, and the Agassiz Ice Cap on Ellesmere Island. Our preliminary research shows that the summer of 2012 exhibited significant melt, particularly for the more southerly ice caps, Barnes and Penny on

Baffin Island. Where possible, the satellite height change data will be compared to appropriate airborne and in-situ surface measurements.

Repeat high-resolution 3D mapping of tidewater glaciers in Greenland

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The transfer of mass across the glacier-ocean boundary plays a significant role in ice sheet dynamics, mass balance and sea level rise, yet the processes controlling the rates of mass transfer are not fully understood. These processes operate on a range of spatial and temporal scales (cm to km, minutes to years), posing a challenge to traditional observational methods. Remote sensing from satellites and aircraft offers wide spatial coverage but at an inadequate temporal resolution for capturing transient behavior or critical episodic events. In situ observations, such as GPS networks, are capable of resolving short-period behavior and events, but logistic constraints and hazardous terrain limit the number of observations to a few isolated locations on a given glacier. Terrestrial LiDAR scanning is "near-situ" method which combines the strengths of the remote sensing and in situ approaches, i.e., wide spatial coverage and rapid temporal sampling. Most commercial LiDAR scanning instruments are not optimized for glaciology because of volumetric scattering in snow and ice at infrared wavelengths (1550 nm). Here we describe the development of a LiDAR scanner based on a green laser (1064 nm) which is capable of rapidly scanning the full width (> 10 km) of major outlet glaciers. We deployed the instrument at Helheim Glacier, southeast Greenland, and repeatedly scanned the near-terminus region every ∼0.5 h over a 5-day period. The results provide unique insights into short-term horizontal displacements of the glacier, tidally-induced uplift of the terminus, and motion of the fjord melange.

Relationships between iceberg plumes and sea ice conditions on northeast Devon Ice Cap, Nunavut, Canada

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This study investigates the impact of sea ice conditions on the production of iceberg plumes from two tidewater glaciers flowing from the northeast margin of Devon Ice Cap, Nunavut: Belcher Glacier and Fitzroy Glacier. These effects are quantified using a 12-year RADARSAT-1 satellite record from 1997-2008 that contains imagery from approximately every 1-2 weeks in the winter and every 1-4

days in the summer. Iceberg plumes identified in the satellite record are also compared with terrestrial time-lapse photography of Belcher Glacier from 2007-08. Together, these images enable determination of the date of annual sea ice retreat, the date of calving events, and the relative magnitude of iceberg plumes. The dates of calving events are further compared to climate and tidal data to ascertain the importance of external controls.

Results suggest that there is a strong relationship between iceberg plumes and the retreat of sea ice from the glacier termini, with the plumes caused by both the release of previously calved icebergs (ice mélange) and new glacier calving. Iceberg plumes are also observed at other times in the summer and in midwinter (occasionally on both glaciers simultaneously), with the events likely due to new glacier calving alone. Analysis of tides and air temperatures suggests that they provide a minor influence on the timing of iceberg plumes. Instead, it appears that changes in the presence of sea ice are dominant on seasonal timescales, although internal glacier dynamics likely play a significant role for winter plume events that occur when substantial thicknesses of landfast sea ice are present. The results of this study are important for determining the long-term evolution of tidewater glaciers in the Canadian Arctic.

Response of glacier mass balance and discharge to future climate change in the upper Susitna basin, Alaska

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Understanding and quantifying glacier melt is key to effectively project future changes in watershed-scale stream flow from glacierized basins. The Susitna River In South-Central Alaska is the site of a proposed large hydroelectric dam. The catchment of the reservoir in the upper Susitna watershed (13,289 km^2, 450-4000 m a.s.l.) is 4% glacierized and is characterized by sparse vegetation, discontinuous permafrost, and little human development. Changes in glacier extent in response to atmospheric warming and/or altered precipitation regimes have the potential to substantially alter the magnitude and timing of runoff, thus impacting water yields to the hydroelectric reservoir.

Here, we focus on the response of discharge in the upper Susitna River basin to projected climate change through the end-of-the century. We use DETIM, a runoff model focused on glacier processes, and WaSIM, a physically-based hydrological model. Both models are forced by daily temperature and precipitation data. The models are calibrated with runoff and glacier mass balance measurements from the 1980s and validated with measurements from ongoing field campaigns which started in spring 2012. With the past and present data, the models are able to match both the magnitude and timing of observed river discharge. However, the scarcity of meteorological observations from the upper Susitna basin presents a major challenge to simulating the catchment hydrology.

Seismic data reveal subglacial ponding under the Greenland Ice Sheet

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We present seismic survey results 70 km from the western margin of the GrIS. Previous ground-based HF radar indicate the existence of a subglacial body of water present under 1000 m of ice. Two 5 km lines were recorded, parallel and perpendicular to local ice flow direction which is east to west. A 200 m long snow streamer was towed by snow-mobile and explosives at 50 m intervals were used as a source for two experiments. A constant offset survey reveals a discrete lens shaped body at the ice-bed interface with an area of 1800m by 600m and a thickness of ~20 m, elongated in ice flow direction. Combining this data with amplitude verses offset analysis we further speculate regarding the size, character and nature of this lens shaped body and the substrate underneath it.

A whale of a tale in 1710: East Greenland's oldest weather and sea ice records

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In 1710, the Dutch whaling ship âĂŸDen Dam', embarked, together with on an adventurous whaling expedition to the coast of East Greenland. The ship became beset in the Arctic sea ice for several months, and slowly moved with the drifting ice southwards. A second whaler became shipwrecked and Den Dam took on its survivors. Den Dam eventually reached open sea and, after major repairs in Iceland, was able to return safely to Amsterdam. In 1711, the ship's helmsman published the captain's logbook and journal of their ordeal. HJ transcribed and translated this book. Daily weather, sea ice and other geographical data (e.g. whale, polar bear, iceberg and coast sightings) were extracted. Weather data include wind speed and direction, and nominal temperature, precipitation and visibility data. Sea ice data include extent, drift, type, density and pressure. These data were calibrated and verified, systematically classified, and compared to paleoclimatic data and historical sea ice maps. I will present highlights of this whaling expedition, its route, lessons in survivorship, and the oldest long-term record of weather and sea ice along the coast of East Greenland.

Coastal Arctic fog and its influence on glacier surface energy balance

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Breakup of sea ice causes advection and steam fog, which can be persistent over oceans and coasts but diminishes inland. Arctic warming has increased summer sea ice decline and open water exposure, affecting heat and moisture fluxes and therefore cloud formation. A slight increase in sea fog and slight decrease in land fog has been reported over the past decades, but regional and pan-Arctic patterns are equivocal. No studies have focussed on the coast-to-inland transition zone, where many ice sheet outlets and glaciers terminate, and where it is suggested that fog and related temperature inversions suppress glacier melt. In this study, we investigate whether melt season fog frequency and timing has changed in coastal East Greenland over the past 50 years. Fog occurrence and characteristics were analysed using DMI synoptic weather data, supplemented with Integrated Global Radiosonde Archive and NSIDC sea ice extent data. Occurrence of Arctic sea fog coincides with the glacier ablation season and peaks in July/August. Fog frequency, daily timing, duration, and temporal trends vary with latitude. Absence of a correlation with sea ice break-up timing suggests a stronger atmospheric than oceanic control on fog occurrence. This was further investigated by correlating monthly/seasonal fog frequency with NAO phase. Finally, using radiosonde data we calculated fog inland extent onto glaciers and its possible effects on the surface radiation budget.

Derivation of a multitemporal set of transient snowlines for Alaska's glaciers

C. Kienholz, A. Arendt and R. Hock

Variability in accumulation has remained a large unknown in glaciology, and has thus been a major error source, e.g., for mass balance modeling applications. We report on a project that aims at investigating spatial and temporal variability, as well as trends in snowline elevation on glaciers in Alaska and adjacent Canada. For this purpose, we derive transient snowlines from optical remote sensing imagery through spectral classification. Digital elevation model sampling along the snowlines, followed by a statistical analysis of the resulting snowline elevations, allows quantification of variability and trends from individual glaciers to entire regions. In our paper, we detail techniques used and present preliminary results.

Validation of CryoSat-2 measured surface elevations over Austfonna

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CryoSat-2 is the European Space Agency's newest Earth Observation satellite. It is a mission dedicated to monitoring variations of the earth's continental and marine ice cover. The key science instrument is a radar altimeter, SIRAL, capable of SAR and interferometric measurements. The ability to pinpoint the location of the measured surface in both the along and the across track directions means that, for the first time, the steeper marginal areas of the continental ice bodies can be monitored.

Validation of the data returned from the new mission is an important step toward allowing this satellite to become a useful monitoring tool. Converting measurements of changes in surface elevation to changes in volume and further to mass is not necessarily straightforward and requires assumptions about density as well as knowledge of what "surface" the satellite is measuring. Dedicated validation work has been carried out both prior and during the operation of CryoSat-2, at a number of sites. One such validation site is the ice cap Austfonna, Svalbard.

Here we show what we have learnt about CryoSat-2 and about Austfonna from 3 years of CryoSat-2 data acquisition and coincident field observations.

Catchment's hydrology of high-Arctic glacier (Werenskioldbreen, Spitsbergen): Changes in the ablation Season

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A hydrological monitoring program in the watershed of Werenskiold Glacier (Spitsbergen) is the part of an interdisciplinary effort led to the understanding of the functioning of the glacier system in the high-Arctic. In the study characteristics are described of annual hydrographs for basin draining area of 44 km^2 (including 27 km^2 coverage of the glacier). Measurements were conducted by author since 2007.

Typically flow season for southern Spitsbergen begins in June and freeze-up starts at beginning of October, but in the last years the observed river and proglacial streams are not completely frozen until the end of October and drainage system is started already in mid-May. The catchment hydrology was influenced the most by temperature and precipitation changes occurring in the spring and autumn time. The changes in river discharge were driven by higher temperatures at the beginning of the ablation season and by rainfall at the end. Heavy precipitation during September and at the beginning of October had the biggest influence on hydrology of glacier basin. In the results we note more intensive flood events from rainfall than from snowmelt. For example, in 2010 and 2011 in the autumn months flowed almost 30% of the total outflow and in 2008 this value of outflow exceeded 40% in September.

Furthermore, mean temperature and precipitation data for the hydrological year of the Werenskioldbreen catchment show distinct decadal and seasonal increases within the last 30 years (data from Polish Polar Station, Hornsund). The number of days with observed discharge (days with mean temperature above zero degrees Celsius) varied throughout the whole period of records from 82 to 149 days with small increasing trend each year.

Closer investigation showed that there are also significant winter rain episodes. The water percolate into the glacier and becomes a reserve to supply outflows and river in the next ablation season. Therefore, when calculating water-balance it should be considered rainfall events for early and late flows and precipitation gardient correction for rain and for snow, having regard to increasing share of these first.

Measuring and monitoring the discharge of glacially-fed rivers is a demanding task because of the temporal instability of their flow regimes, particularly if continuous, complete time series are required, as exemplified by the work presented here.

Alaska tidewater glacier surface velocities and frontal ablation, 1985-2013

R. McNabb

A significant portion of the world's glacier ice drains through tidewater outlets, though much remains unknown about the proportion of mass loss due to frontal ablation (the sum of ice loss through calving and submarine melt) from tidewater glaciers outside of the Greenland and Antarctic ice sheets. Frontal ablation contributes about half of the mass loss from the ice sheets, and the lack of both understanding of and data on these processes has been cited as an obstacle to accurate predictions of global sea level rise, ocean response to freshwater inputs, and impacts on estuarine ecosytems. We present a 28 year record of surface velocity for 26 Alaska tidewater glaciers (representing over 90% of the total tidewater glacier area in the region), derived using a feature tracking algorithm and all available cloud-free Landsat 5, 7, and 8 scenes. Ice thickness is estimated using an iterative approach, beginning with an initial estimate of ice thickness that is refined using surface velocities and estimated ice fluxes. We find the total mean rate of frontal ablation for these 26 glaciers over the period 1985-2013 is 20.4±8.1 Gt/yr. Six glaciers in particular, Hubbard, Columbia, Yahtse, LeConte, Harvard, and Guyot, account for over 70% of the frontal ablation signal of the region. Seasonal changes in surface velocity match well with seasonal changes in length, indicating that rates of frontal ablation do not remain constant throughout the year. Turner Glacier, the only surge-type tidewater glacier in Alaska, surged 5 times over the course of the study period, with an average period of ∼7 years. Despite coming from ∼15% of the glacierized area in the region, frontal ablation is a significant contributor to the regional mass budget. We estimate a specific mass loss through frontal ablation for all Alaska glaciers of 0.19 m w.e./yr, equivalent to estimates from Svalbard, and over three times the rate for Greenland.

Changes to the glaciers at Novaya Zemlya

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The Northern Ice Cap of Novaya Zemlya is the largest (22,000 km^2) and most rapidly changing ice cap in the Russian High Arctic, accounting for 80% of the region's estimated 0.025 mm/yr contribution to sea level rise between 2003-2009 (Moholdt *et al.*, 2012). We use several remote sensing instruments to extend this time series forward and create a detailed glacier-by-glacier inventory of elevation and velocity changes. We focus on three glaciers along the Barents Sea coast of the ice cap: Vil'kitskogo, Inostrantseva and Bunge, all of which experienced area reduction at an average rate of roughly 1 sq. km/yr from 1990 to 2000 (Kouraev *et al.*, 2006). Our estimates of the current surface elevation change rates (dh/dt) and velocities at these glaciers will allow us to determine the connections between thinning, dynamics and the documented climatic changes – 2004-2009 mean summer temperatures in Novaya Zemlya were anomalously high, +0.50±0.28°C greater than mean summer temperatures from 1980-2009 (Moholdt *et al.*, 2012), while Meng (2013) found that melt duration increased by 1.3 days/yr from 1996 to 2011.

We estimate dh/dt by applying a weighted linear regression to time series of ASTER DEMs acquired between 2003/07/29 to 2013/07/27 and Russian cartographic DEMs from 1952. Velocities are calculated using automated normalized cross correlation ("pixel-tracking") applied to ASTER image pairs from 2003 to 2013. We supplement our ASTER time series with velocities and DEMs from very high-resolution (0.5-2 m/pixel) imagery acquired by QuickBird, WorldView and GeoEye, from 2010 to the present. These provide far more detailed snapshots of glacier flow, improve our temporal sampling density, and allow us to better discern seasonal and inter-annual speed variability. We will compare this with ERS interferometry and pixel-tracking we produce from imagery acquired in the 1990s and pixel-tracking we apply to Landsat imagery acquired from the 1980s through the present to detect any longer-term speed changes.

The overall mass loss for Novaya Zemlya is -5.4±0.9 Gt/yr (with 95% coverage), which falls between the 2004-2009 and 2003-2010 mass loss rates estimated from GRACE data (-5.8±3.0 and -4.1±2.9 Gt/yr, respectively, Moholdt *et al.* (2012). Inostrantseva and Vil'kitskogo have more negative mass balances (-0.53±0.05 and -0.42±0.07 m/yr w.e., respectively) than the average for Novaya Zemlya (-0.26±0.04 m/yr w.e.). Bunge, farthest north and slowest of the three, has a positive mass balance (+0.17±0.10 m/yr w.e.).

We find a spring to summer velocity increase at all three glaciers ranging from 30% to 100%. Inostrantseva Glacier shows an inter-annual increase in velocity from 2002 to 2013 of roughly 2 m/day where results from the two different time periods overlap. Differencing of two Worldview DEMs over Inostrantseva from 2012/06 to 2013/03 reveal a higher thinning rate than the 1952-2013 average dh/dt, suggesting that the observed acceleration and has led to an increase in calving-induced thinning there.

References

Kouraev, A.V., B. Legrésy and F. Remy, 2006.

Meng, 2013.

Moholdt, M., B. Wouters and A. Gardner, 2012. Recent mass changes of glaciers in the Russian High Arctic. *Geophys. Res. Lett.*, **39**(L10502).

Recent ice shelf loss, Ellesmere Island, Nunavut, Canada

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Canadian Arctic ice shelves are thick (30-100 m), extensive (10s-100s km^2) and ancient (3-5.5 ky-old) features that fringe the northern coast of Ellesmere Island. They are primarily formed by landfast sea ice thickening over time through under-ice accretion and surface accumulation of snow, although glaciers do contribute mass in certain places. In 1906, a single ice shelf totaling an estimated 8,900 km^2 was present along 400 km of Canada's northernmost coastline. This 'Ellesmere Ice Shelf' broke up into six main ice shelves over the last century, which totaled 1043 km^2 in 2002. Since 2002, further major changes have occurred, including the complete loss of the Ayles Ice Shelf in 2005, the complete loss of the Markham Ice Shelf in 2008, the loss of 60% of the Serson Ice Shelf in 2008 and the loss of 25% of the Ward Hunt Ice Shelf (primarily in 2008 & 2010). Here we describe and quantify further losses of the ice shelves since 2008. We used a combination of optical (MODIS) and synthetic aperture radar (Envisat ASAR and Radarsat-2) imagery to determine the timing of calving events. Our results show that both remnant portions of the Serson Ice Shelf began to calve in early August 2011. The northern portion (a sea-ice ice shelf) was reduced to 7 km^2 whereas the southern portion (a floating glacier tongue) is currently 18 km^2. In August and September 2011 the fractured central area of the Ward Hunt Ice Shelf broke away, separating its eastern and western portions. The eastern Ward Hunt Ice Shelf is now 74 km^2 and the western Ward Hunt Ice Shelf is 221 km^2 with freely drifting ice islands between them. The Petersen and Milne ice sheves lost several square km of extent over the last two years at their southern margins. The total Ellesmere Island ice shelf area is now 526 km^2. Recent Ellesmere ice shelf attrition is thought to be partly due to air temperature increases (particularly during the winter) and a prevalence of open water shore leads during the summer melt season. A concomitant reduction in landfast sea ice along this coast suggests that the ice shelves will not reform in the current or projected climate.

What do McCall Glacier, caribou, and monster truck tires have in common?

M. Nolan

I have developed an airborne mapping system using unmodified digital SLR cameras that creates digital elevation models and orthorectified image mosaics that can be used to map anything from glaciers to caribou to truck tires with these specs:
- Spatial resolution: 5 cm to 50 cm ground sample distance (pixel size)
- Absolute x,y,z positioning with no ground control: <50 cm
- Absolute x,y,z positioning with ground control: ~2 cm (or as good as ground control)
- Random and systematic errors: <20 cm
- Orthoimage co-registration to DEM: Perfect (made with same data)
- Processing can take a few hours to a few days depending on project size

Other systems have been around for a while that can also do this, or something close to it. What's different about mine is that it is affordable enough to make time-series of these maps, opening up brand new lines of scientific inquiry.

Monitoring Baffin Island glaciers melt using RADARSAT-2 Stereo Radargrammetry

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Given the recent pronounced arctic warming and associated glacier melt (Sharp *et al.*, 2011; Gardner *et al.*, 2012), the development of new innovative monitoring tools has become essential to better understand their response to climate change. Pioneer work from Thierry Toutin on Stereo RadarGrammetry (SRG) using RADARSAT-2 images now allows overcoming the difficulties of optical technologies, especially given the weather and luminosity independences from radar and its possible use without any ground control points (Toutin and Omari, 2011; Toutin *et al.*, 2013). Aside Toutin *et al.* (2013) who determined an accuracy of 17.9 m (LE68) on a low slope glacier surfaces, SRG has never been used for glacier measurements applications (surface mass balance analysis).

Hence, the main goal of this research is to explore and characterize the potential of SRG for glacier mass balance measurements. Specifically, we focus on Barnes and Penny ice caps, as well as Grinnell glacier. RADARSAT-2 Wide UltraFine stereoscopic couples have been acquired in summer 2013 via the SOAR Education program for Barnes and Grinnell, while Penny images (winter 2012) have been shared by Luke Copland Team (U. Ottawa). Historical Canadian Digital Elevation Models (CDED) are used for historical elevation changes calculation, as well as 2011 Airborne Topographic Mapper (ATM) laser altimetry (exclusively for Barnes) and ICESat for SRG DEMs validation. Preliminary validation results show accuracy of 10 meters (LE68) on the Barnes ablation zone and about 6-7 meters (LE68) outside the glacier. This represents an improvement from Toutin's recent works, given the low relief that characterizes this area of Baffin Island. We hypothesize that the penetration depth of the RADARSAT-2 C band signal on the glacier surface is between 1 and 4 meters, such as suggested by Rignot *et al.* (2001). Finally, elevation changes calculated between CDED and SRG DEMs on Barnes have been proved to be similar to Gardner *et al.* (2012). In this presentation, we first describe the necessary steps for accurate SRG DEM extraction and then we discuss these results.

References

Gardner, A.S., G. Moholdt, A. Arendt and B. Wouters, 2012. Accelerated contributions of Canada's Baffin and Bylot Island glaciers to sea level rise over the past half century. *The Cryosphere*, **6**, 1103–1125.

Rignot, E., K. Echelmeyer and W. Krabill, 2001. Penetration depth of interferometric synthetic-aperture radar signals in snow and ice. *Geophys. Res. Lett.*, **28**(18), 3501–3504.

Sharp, M. et al., 2001. Mountain Glaciers and Ice Caps In Snow, Water, Ice and Permafrost in the Arctic (SWIPA): Climate change and the Cryosphere.. *Arctic Monitoring and Assessment Programme*, Oslo, 553 p.

Toutin, T. and K. Omari, 2011. A new hybrid modeling for geometric processing of Radarsat-2 data without user GCP. *Photogrammetric Engineering Remote Sensing*, **77**(6), 601–608.

Toutin, T., E. Blondel, D. Clavet and C. Schmitt, 2013. Stereo Radargrammetry with RADARSAT-2 in the Canadian Arctic. *IEEE Transactions on Geoscience and Remote Sensing*, **51**(5), 2601–2609.

Assessment of sea ice conditions and shipping activity in Canadian Arctic waters between 1990 and 2012

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Declining sea ice in the Canadian Arctic has attracted attention to the possibility of increased marine transportation activity. Observational analysis of Canadian Arctic maritime activity and sea ice area/age (e.g. total ice, MYI (multi-year ice), and FYI (first year ice)) was undertaken over the NORDREG zone within the Canadian Arctic on monthly, shipping season (June 25 to October 15), and annual time scales. Linkages between shipping, sea ice, surface air temperature and melt season length were also explored.

Non-parametric trend analysis was undertaken on all datasets using the Zhang method of Sen's slope of the trend. Due to a shift in mandatory vessel reporting to NORDREG in 2010, Rodionov's statistical regime shift detector was used to identify breaks in the time series to establish the influence of the reporting change on the NORDREG dataset (Fig. 1). Subsequently, correlation analysis was undertaken using Kendall's Tau rank based correlation for relationships between sea ice, shipping, melt season length, and surface air temperatures.

Total annual shipping activity in the NORDREG zone has exhibited a step increase since 2007 (Fig. 1). While shipping activities have risen significantly in the months of June, July, and November, sea ice over the same time period has experienced a significant decline. However, only weak correlations exist between the

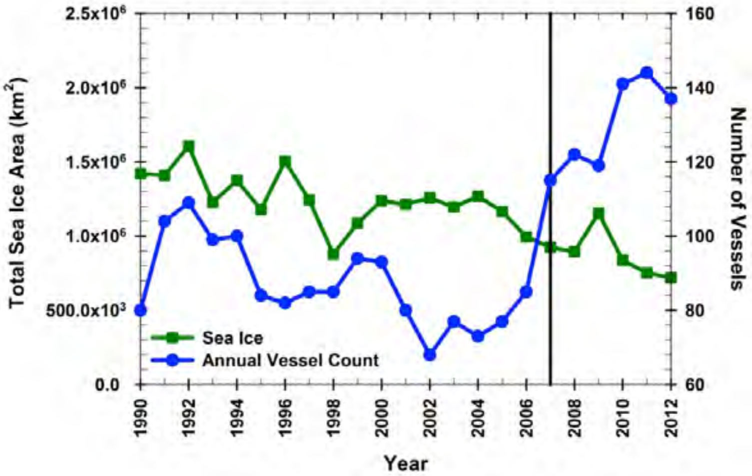

Figure 1. Total sea ice area (km^2) (Green) and total annual vessel counts (Blue) in the NORDREG zone over the shipping season. The solid black vertical line indicates the regime shifts detected in the annual vessel count time series in 2007.

two suggesting that other factors in addition to sea ice (e.g. Community re-supply, tourism demand) are contributing to the shipping increase.

Increasing surface air temperatures are seen across the entire NORDREG zone in January, February, and July through October between 0.7 and 1.8°C decade^{-1}. Freeze onset increasing at 8 days decade^{-1} and the melt season length increasing at 11 days decade^{-1} over the 1990 to 2010 time period.

Moving window correlation analysis indicates that the relationship between total/MYI area and shipping activity has strengthened in recent years. Although MYI area is declining, the remaining MYI will continue to pose a hazard to shipping routes within the Canadian Arctic's NORDREG zone.

How deep does a typical crevasse in Western Greenland carry meltwater?

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A flurry of recent work has shown that cryo-hydrologic warming, the transfer of latent heat from meltwater back to the ice sheet, may significantly increase the velocity of large regions of slow-moving ice-sheet ice, causing additional sea level rise. A key assumption of cryo-hydrologic warming is that crevasses penetrate deep into the ice sheet, preferably all the way to the bed. We test this assumption. Given a field of crevasses with typically observed spacing (∼20 to 100 meters) and the production rate of meltwater available to fill them, how deep can the meltwater drive these crevasses, and if they reach the bed, how many years does that take? We answer these questions by coupling a viscoelastic model for crevasse shape and depth, which accounts for elastic opening and creep closure rates, to a thermal model for the surrounding ice, which gives us refreezing rates. The elastic opening, creep closure, and healing by refreezing evolve in tandem with crevasse depth and ice temperature. We apply the model to the Pakitsoq area of Western Greenland and find that crevasses can only reach a few hundreds of meters depth over the course of their few-century journey westward to the ice sheet margin. Our work suggests that current cryo-hydrologic warming models overestimate the depth at which meltwater can be refrozen and thus also overestimate the flow enhancement from this process. In some cases, our model predicts sizable pods of water at depth that have pinched off from the surface and are too large to refreeze. These features may be detectable by radar.

Estimating Supraglacial Lake Depth with Landsat 8

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Supraglacial lakes play a significant role in glacial hydrological systems - for example transporting water to the glacier bed in Greenland or leading to ice shelf fracture and disintegration in Antarctica. To investigate these important processes, multispectral remote sensing provides multiple methods for estimating supraglacial lake depth - either through single-band or band-ratio methods, both empirical and physically-based. Landsat 8 is the newest satellite in the Landsat series. With new bands, higher dynamic range, and higher radiometric resolution, the Operational Land Imager (OLI) on board has a lot of potential. This study uses in situ spectra and depth measurements to investigate the ability of Landsat 8 to estimate lake depths using multiple methods, as well as quantify improvements over Landsat 7's ETM+. Preliminary results are applied to a case study in Northwest Greenland using four images from summer 2013. In addition, altimetry measurements from NASA's Operation IceBridge are used to validate the different techniques used to estimate lake depth.

The surface mass and energy balance of Nordenskiöldbreen, Svalbard: 7 years of in situ observations.

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In spring 2006 a climate monitoring program on Nordenskiöldbreen, Svalbard, was initiated, which is still on going. The program focuses on the dynamics and mass budget of the glacier, and includes mass balance (stake and sonic height ranger) and automatic weather station (AWS) observations.
The annual mass balance observations show large variability and no trend over the observational period (2006-2013). The equilibrium line altitude (ELA) during this period is located at about 610 m a.s.l. This is in line with the average ELA over the period 1989-2010 of 631 m a.s.l. based on output of a distributed energy

balance model (EBM), and slightly higher than presented in literature for this area. At the AWS site (±600 m a.s.l.) the average annual temperature is about -8.5°C. Annual mean wind speed is about 4.5 ms^{-1} and is predominantly directed down glacier with a directional constancy of about 0.65, a predominant katabatic wind. Throughout the year the sensible heat flux is positive due to a constant surface based temperature inversion. From May to September this temperature inversion is caused by cooling of the surface by long wave radiation while in the summer months the surface temperature is limited by 0°C, the temperature of a melting surface. At the AWS site the amount of melt energy available in the summer months corresponds to about 0.82 m w.e. snow and ice melt. This is less than derived from the observations (1.1 m w.e. of which 0.7 m w.e. is ice melt). This is due to problems with the temperature observations in the summer months resulting in an underestimation of the sensible heat flux towards the surface and consequently an underestimation of the melt flux.

Internal layering and stratigraphy from RES data on outlet glaciers in the Canadian Arctic

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Airborne radio-echo sounding (RES) is a powerful tool to investigate the subsurface properties of ice sheets and glaciers. The most common reflections observed in RES over ice sheets result from the ice surface, the subglacial bedrock and internal layers. Internal layers most likely represent past snow deposits of similar age and thus may be treated as isochrones, whereas the stratigraphy of these isochrones is a result of the surface accumulation rate (or the burial rate) and the internal ice flow. Continuous internal layers detected by RES can be used as an independent tool for stratigraphic control on ice-core data, as well as for synchronising ice core records and determining the accumulation rates between individual core locations. Additionally to calculations of the mass gain through accumulation, the rates of basal melting and the associated mass loss can be determined from internal layers. Disruptions in the internal layer stratigraphy in areas of relatively uniform accumulation and melting rates, must result from ice flow and thus might be associated to past and present variations in ice flow. Therefore, studies on internal layering can help us understanding changes in past flow processes and ice dynamics, which is relevant to understand flow and ice dynamic processes under current conditions.

In this study we present an upcoming research project (starting in spring 2014) involving RES measurements over ice caps and outlet glaciers in the Canadian Arctic. A particular interest of the campaign is the analysis of internal layers where we hope to derive ice flow processes and the internal ice structures especially at the transition zones between an ice sheet and the outlet glaciers. Additionally, we plan to correlate the internal layer stratigraphy from RES data to stratigraphy recorded in ice cores.

Volume and mass changes over Penny Ice Cap, Baffin Island, from 2005-2013 determined from repeat airborne laser altimetry.

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Recent observations of accelerated glacier wastage in Greenland and Alaska have prompted reassessments of mass balance trends and volume changes on Canadian Arctic glaciers and ice caps. While long surface mass balance measurements are available from glaciers and ice caps in the Queen Elizabeth Islands (e.g., White Glacier, Devon Ice Cap, Meighen Ice Cap), no such records exist for Baffin Island glaciers. In the absence of such data, air- and space-borne measurements can be used in combination with in situ data to evaluate historical and recent trends in ice cover changes. Here, we use repeat laser airborne altimetry surveys conducted in 2005 and 2013 by NASA to estimate recent volume and mass changes of Penny Ice Cap, the southernmost large ice cap on Baffin Island (66°N). These data are validated against in-situ surface mass balance measurements from 2013 and IceSat derived elevation change from 2003-2009. Once validated, surface elevation changes along altimetry lines are extrapolated to the entire ice cap using a digital elevation model (DEM). Changes in areal extent of the ice cap are constrained using satellite imagery (e.g. Landsat). From these data we estimate the total mass wastage of the ice cap and its recent contribution to sea level rise. This work builds on previous surveys for the period 1995-2005 (Abdalati *et al.*, 2004; Gardner *et al.*, 2012).

References

Abdalati, W., W.B. Krabill, E.B. Frederick, S. Manizade, C. Martin, J. Sonntag, R. Swift, R.H. Thomas, J. Yungel, and R. Koerner, 2004. Elevation changes of ice caps in the Canadian archipelago. *J. Geophys. Res.*, **109**(F00407).

Gardner, A.S., G. Moholdt, A. Arendt and B. Wouters, 2012. Accelerated contributions of Canada's Baffin and Bylot Island glaciers to sea level rise over the past half century. *The Cryosphere*, **6**, 1103–1125.

Changes to the dynamics of Arctic mountain glaciers: Case study of White Glacier, Axel Heiberg Island, Nunavut

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Under a changing climate, glacier geometry should be expected to adjust, by the mechanics of ice motion, to a hypsometry that is stable in the new climate regime. However, the stability of the physical response for glaciers in the Canadian Arctic is essentially unknown. This project examines the internal and environmental

controls on the dynamics of White Glacier. It will assess whether contemporary ice motion is creating glacier geometries that are stable under current climate conditions, or whether ice dynamics are forcing glaciers into lower elevations with increasingly negative mass balance conditions. In particular, the primary objectives of this project comprise: 1) Determination of long-term (decadal) changes to ice motion; 2) Detection of changes to the duration and magnitude of short-term (hourly to daily) velocity events in recent decades; and 3) Assessment of the changes to glacier geometry and the stability of this response when united with contemporary ice dynamics.

White Glacier provides an ideal location for this study given the 53 year mass balance record and previous measurements of ice velocities during the 1960s and 1970s. By comparison with these early studies, long-term changes to ice velocities are being measured using modern remote sensing techniques including offset tracking of optical satellite scenes, speckle tracking of Radarsat-2 imagery, and DInSAR. Changes to short-term velocity fluctuations will be determined using *in situ* differential GPS stations and theodolite surveys of prisms drilled into the glacier. Climate data is being gathered at four automated weather stations on the glacier, and hydrological monitoring is employing time-lapse photography of stream levels and water pressure sensors. A new model of glacier hypsometry will be created using LIDAR and oblique stereo photography, and validation will be derived from *in situ* differential GPS measurements.

Interannual and multi-decadal velocity variations in the eastern St. Elias Icefields, Yukon Territory, Canada

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Gulf of Alaska glaciers, including the St. Elias Icefields contained in the Yukon Territory and adjoining Alaska and British Columbia, have been the largest contributor to sea level rise outside of Greenland and Antarctica (Jacob *et al.*, 2012). Significant mass losses may be expected to engender changes in the rate and nature of flow of these glaciers, but long-term records of ice dynamics are particularly limited in the St. Elias Mountains.

This work will present the most comprehensive velocity mapping of the eastern portion of the St. Elias Icefields to date, derived from speckle tracking of Radarsat-2 imagery acquired in winter 2011 and 2012. The technique employs a cross-correlation approach to determine the displacement of the 'speckle' pattern of phase returns between two repeat-pass SAR images. Further reconstruction of past velocities is performed on several key glaciers using feature tracking of Landsat-5 imagery, allowing for the investigation of variability in glacier motion on interannual and decadal time scales. Differential GPS measurements from four stations on the Kaskawulsh Glacier permit both validation of the remote sensing analysis and an assessment of the range of seasonal and interannual variability in glacier velocity. An updated estimate of the Hubbard Glacier ice flux is presented. With the exception of the non-surge-type Kaskawulsh Glacier and the upper Hubbard Glacier trunk, all major glaciers in the region experienced significant interannual variability, typically related to surge activity (e.g. Logan, Lowell, Donjek Glaciers). At the Kaskawulsh Glacier, a long-term reduction in velocity relative to field measurements from the 1960s was noted, the pattern of which is broadly congruent to measurements of surface elevation change over a similar period. The magnitude of this decrease (~200 m a^{-1} near the ELA) cannot be explained by seasonal or interannual variability and most likely represents a dynamic response to mass loss.

References

Jacob, T., J. Wahr, W.T. Pfeffer and S. Swenson, 2012. Recent contributions of glaciers and ice caps to sea level rise. *Nature*, **482**, 514–518.

Documenting multidecadal recession of Grinnell and Terra Nivea ice caps, Baffin Island, Canada

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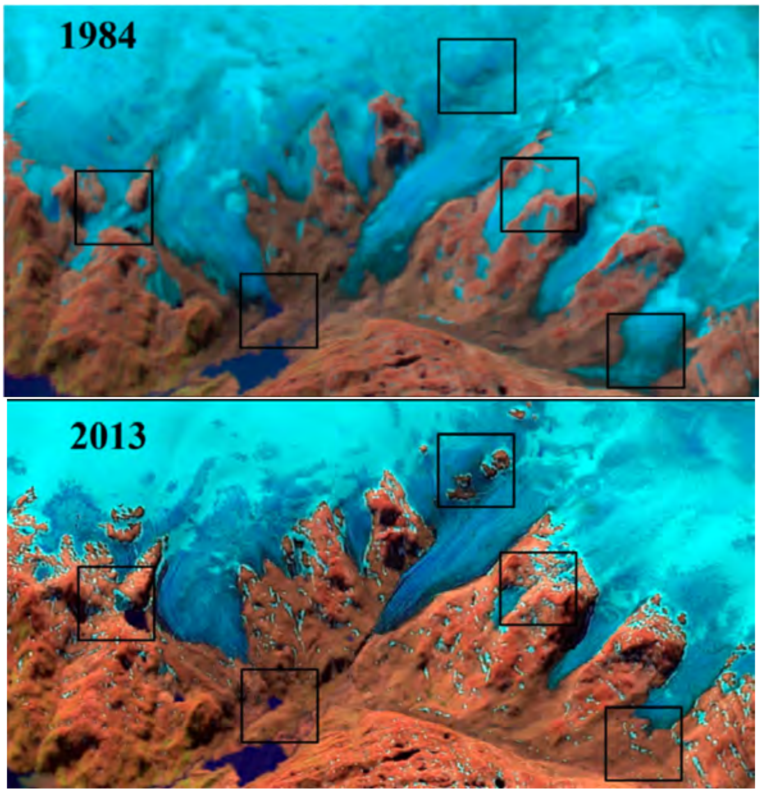

Figure 1. Three-dimensional oblique of Terra Nivea's northeastern ice margins for 1984 (*top panel*) and 2013 (*bottom panel*). Obliques were derived by draping 7-4-2 false colour composite satellite images over a digital elevation model. Areas of significant ice decline are delimited by black rectangles.

In the Canadian Arctic, ice losses and melt rates have begun to exceed those recorded over the past several millennia with some ice caps having receded beyond their extents during the Holocene thermal maximum. Although there are considerable efforts to document and monitor glacier and ice cap changes in the western, central and northern Canadian Arctic, the eastern low-Arctic has been comparatively under-studied. The region contains shrinking small mountain glaciers (Torngat Mountains) and two small ice caps at the southern tip of Baffin Island. These ice caps (Grinnell and Terra Nivea) are the southernmost in the Canadian Arctic and according to recent studies have thinned over the past decade. Analysis of multi-temporal satellite imagery (1973-2013) and historical aerial photography reveals that Grinnell Glacier and Terra Nivea have experienced considerable change over the past several decades (Fig.1). Overall these ice caps have reduced in area by ∼21% or 68 km^2 since the late 1950s with total ice loss accelerating over the past several decades to -1.69 km^2/yr. The larger of the two, Terra Nivea, has receded at nearly double the rate (-1.1 km^2/yr) of Grinnell Glacier (-0.57 km^2/yr) possibly due to factors such as coastal proximity and ice cap geometry. Satellite imagery clearly shows the exposure of Nunataks and ice free areas far from outer ice cap margins indicating considerable ice thinning. The observed rapid reduction in ice area is shown to be linked to increasing summer air temperatures and suggests that these ice caps are at disequilibrium with current climate conditions. A continuation of observed ice decline will lead to a ∼57% reduction in total ice area by 2100 AD and projected Arctic warming may lead to the disappearance of both ice caps during the next century.

Velocity and ice thickness changes at the Rusanov and Karpinsky ice caps in response to the destruction of the Matsuevich Ice Shelf, Severnaya Zemlya, Russian High Arctic.

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The ∼240 km^2 Matusevich Ice Shelf is/was the largest remaining ice shelf in the Russian High Arctic. The constricted, fjord-spanning ice shelf has a cyclical history of destruction with a period of about 30 years. A break-up occurred in 1985 and, as predicted by Williams and Dowdeswell (2001), the ice shelf disintegrated again in late 2012.

In contrast to previous break-ups, in 2012 the iceberg detritus of the ice shelf quickly evacuated the fjord, clearing the shallow region at the mouth of the fjord, suggesting the 1985-2012 ice shelf was thinner than the incarnations of the 1930s, 1950s and 1980s.

We compare pre-break up ICESat and optically derived elevations of the feeder glaciers of the 2,480 km^2 Karpinsky Ice Cap to the south and the 1,060 km^2 Rusanov Ice Cap to the north with recent, high-resolution elevations from half-meter stereo imagery from Worldview-1 and -2 in order to examine the evolution of the dynamic response of the glaciers to the removal of backstress caused by the destruction of the ice shelf.

We examine pre-and post-break up speeds at the glaciers from feature tracking on Landsat, ASTER, high-resolution and TerraSAR-X image pairs to search for accelerations analogous to those seen at the grounded glaciers after the destruction of the Larsen Ice Shelf on the Antarctic Peninsula. We further examine recent climate, sea surface temperature records and the regional ice surface melt history, and comment upon the causes of the ice shelf break up.

References

Williams, M. and J.A. Dowdeswell, 2001. Historical fluctuations of the Matusevich Ice Shelf, Severnaya Zemlya, Russian High Arctic. *Arctic, Antarctic and Alpine Research*, **33**, 211–222.

Subglacial lake volume changes due to replenishment by supraglacial melt, Northeast Greenland.

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We use a time series of high-resolution digital elevation models (DEM) and imagery to examine the evolution of an 8.7 km^2 basin formed by the drainage of a subglacial lake beneath the southern summit of the 8500 km^2 Flade Isblink Ice Cap (FIIC) a peripheral icecap in northeastern Greenland. The ∼70 meter deep basin appeared between August 16th and September 6th, 2011 at the site of a recurring moulin, visible in low resolution MODIS imagery.

DEMs are extracted using the NASA Ames Stereo Pipeline for the period between June 2012 and late 2013 from 0.5 m resolution along-track stereo image pairs available from Worldview satellites. A 3-m resolution DEM is compared to a contemporary airborne laser altimeter swath flown by NASA Icebridge in mid-April 2013 to derive the volume of the basin and the uncertainties on the high-resolution DEMs.

The "mitten" shaped basin is bounded by crevasses on three sides, with a shallow ramp to the south. It is ∼70 m deep, 3.7 km north-to-south and 3 km east-to-west and has a volume of ∼0.3 km^3. Ice penetrating radar from the Icebridge mission indicates the ice is approximately 550 m thick and that water is present at the bed.

It is not clear why the basin formed, but the timing, at the end of the 2011 melt-season, suggests overfilling of the subglacial lake. The imagery shows supraglacial meltwater streams draining into crevasses adjacent to the basin during the extraordinary melt season of 2012. The floor of the basin rises 35 meters between the start of the 2012 melt season and the spring of 2013, while its elevation stays constant during colder periods with no visible supraglacial melt activity. This is the first documented evidence of the direct connection of supraglacial melt to a subglacial lake in the polar regions that we are aware of.