IASC –CWG NAG workshop summary report

«Scientific seminar on the Importance of Calving for the Mass Balance of Arctic Glaciers»

15-17 October 2016, Institute of Oceanology, Polish Academy of Sciences, Sopot, Poland

Overview

The Centre for Polar Studies, together with the IASC Cryosphere Working Group and the IASC Network on Arctic Glaciology hosted a scientific seminar on the "Importance of Calving for the Mass Balance of Arctic Glaciers", 15-17 October 2016. Venue was the Institute of Oceanology, Polish Academy of Sciences, 55 Powstańców Warszawy Str., 81-712 Sopot, Poland. There were about 25 participants representing 9 IASC member countries and states adjoining the Arctic, including Russia, Norway, Canada and the US. The workshop agenda/program and participant list is attached to this report.

Main scientific objective

What is the current ice discharge of Northern Hemisphere Glaciers and ice caps to the ocean?

Secondary objectives

- What is the temporal variability of ice mass loss at marine glacier termini?
- What is the relative contribution of iceberg discharge/frontal ablation to total ice-mass loss?
- How does frontal ablation differ from region to region within the Arctic?
- Review terminology to describe mass loss at the glacier termini
- Review methods of determining frontal ablation
- Provide recommendations concerning terminology and methods

Scope of the workshop

Bring together international experts on methods to derive calving flux/frontal ablation, covering field methods, remote sensing and modelling. Bring together experts working on the various regions of the Arctic, namely the Russian Arctic, Svalbard, the Canadian Arctic, Alaska and peripheral Greenland. The first day of the workshop was used to present and discuss terminology and methods. On the second day, results and key data were presented on the various regions and regional challenges were discussed. The last day was reserved for continued discussions and making plans for how to follow up the objectives of the workshop.

Expected outcome of the workshop

1. a paper that will provide the first measure of northern hemisphere ice discharge to the ocean over the period ~2000-2015 for all glaciers and ice caps (including the periphery of Greenland, but excluding the Greenland ice sheet)
2. a report with recommendations on terminology and methods related to ice mass loss at the marine terminus of tidewater glaciers

Background:

From IPCC AR5: Over the last two decades, glaciers and ice caps in the Arctic, as well as the Greenland ice sheet continued to lose mass at accelerating rates. The annual mean Arctic sea ice extent decreased over the period 1979 to 2012, with especially large losses in summer extent. These changes coincide with atmospheric and oceanic warming at high latitudes (Arctic amplification of the observed global warming).

Neglect of calving flux estimates has led to underestimates of mass loss from Arctic glaciers and ice caps and thus, underestimation of the contribution to global sea-level rise (SLR). Total calving loss from Arctic glaciers and ice caps was previously estimated to ~35 Gt (Van Wychen, 2014). But the estimates for the various sub regions were derived for different time periods and using different methods, all of which have associated uncertainties. This estimate also excludes peripheral Greenland, i.e. glaciers and ice caps outside the ice sheet.

Data required for regional assessment of frontal ablation

The ice discharge to the ocean is usually expressed as the ice flux through a fluxgate near the marine terminus and the advance/retreat rate of the terminus.

We need to know:

1. Ice velocity at fluxgate
2. Ice thickness and width, i.e. cross-sectional area of the fluxgate
3. Rate of terminus retreat/advance

In addition, we need to have a complete inventory of tidewater glaciers for the entire Arctic

Scientific highlights with regards to terminology and methods

1. Different terms have been used to describe mass loss at the glacier termini – calving flux, dynamic discharge, ice discharge, frontal ablation, ice flux, iceberg production. However, in previous literature they have not always been clearly defined and at times used interchangeably. There is therefore a need to define what these terms really mean. We decided to follow the definition of the recently published "Glossary of glacier mass balance and related terms" by Cogley et al., 2011. "Frontal ablation" includes iceberg production as well as subaqueous and subaerial melting, where the calving front is in contact with water or air.
2. It was pointed out that currently available data and models allow assessment of total frontal ablation, however, we cannot distinguish between iceberg production and submarine melting on a pan-Arctic scale.
3. We agreed that during this workshop, we will not go into details with respect to mechanisms of iceberg calving / frontal ablation.
4. Frontal ablation is usually assessed as the balance between the ice flux towards the terminus and changes in the position of the terminus. We discussed whether or not terminus retreat and advance can be excluded from our pan-Arctic estimate. Presentations from various regions,

foremost Svalbard and the Russian Arctic, showed that marginal retreat can be as important as the ice flux term and should therefore be included.

5. How does frontal ablation translate to SLR contribution? If terminus advance and retreat is considered, this allows for separate estimates on ice-mass loss and sea-level rise contribution. A marine terminus that advances into the sea will lead to an instantaneous replacement of sea water and hence contribution to SLR, even when frontal ablation may be negligible.

   With respect to the above data needs:

6. Glacier inventories for the entire Arctic are provided by the Randolph Glacier Inventory and the GLIMS database. The marine terminus can be extracted from the provided glacier outlines.
7. Ice velocities should ideally present annual averages, but we often have winter snapshots. We discussed seasonal variations in glacier flow and frontal ablation. At Hornsund, Svalbard, for example, glacier flow during winter is at 90-95% of their annual average. This may not be the case in years with winter rainfall, when velocities can be above the annual average. We also need depth-averaged velocities, whereas observed velocities reflect ice-surface velocities, only.
8. Changes in terminus position change (retreat/advance rate) can be derived from topographic maps, satellite images or field measurements.
9. Ice thickness data is only available for some key glaciers. Ground-based ice thickness surveys often do not extend towards the calving front, whereas airborne surveys often only cover centerline profiles. In case of the latter, the centerline thickness can be scaled by a shape factor. Where available, bathymetric data in front of the tidewater glaciers can be used to assess the general shape and ice thickness of the terminus. Where no data is available, theoretical approaches can be used, which are based on principles of glacier dynamics or inversion from surface geometry, velocities and mass balance, calibrated against available data. The simplest approach in assessment of ice discharge is scaling of width and velocity.

10. Alternative approaches to estimate the mass loss through iceberg calving were discussed. These include calving estimates from seismic or acoustic records. For individual glaciers, models can be calibrated to relate seismic attributes to calving volume. Challenges are the separation of individual glacier-seismic sources, encompassing seismic noise originating in the hydrologic drainage system, slip-stick motion at the glacier bed, formation of surface crevasses, hydrofracturing and iceberg calving. Calibrated models may only work for the glaciers for which calibration data is available, i.e. independent estimates of calving event size or frontal ablation over certain time periods. Another approach presented was deriving DEM's of ice mélange, paired with residence times.
11. With respect to modelling: Calving processes are still not well understood. In addition, both the climatic forcing and the ice geometry not well constrained. Two schools of models exist. The first is based on empirical relations, such as water depth, the second on physical processes, such as crevasse penetration and damage.

Scientific highlights for the various regions

For each region, previous estimates of calving flux / frontal ablation were presented. We discussed the availability of ice thickness data, glacier velocity and changes in terminus position and the regional data constraints.

1. Where are floating and grounded marine termini? This affects calving processes, calving event size and rates.
2. What are the timescales of calving? These range from instantaneous (process studies), to seasonal (winter vs summer) and annual to decadal (incl. surging), centuries and longer (glacial cycles).
3. What drives seasonal variation in calving flux: ice dynamics, atmospheric and oceanic forcing, this means surface melt and its influence on enhanced basal motion and crevasse fracturing, as well as subaqueous melt and destabilization of the calving front by undercutting.
4. What is the importance of glacier surges?
5. The pan-Arctic study area was defined to include all Arctic glaciers and ice caps in Alaska, the Canadian Arctic, Svalbard, the Russian Arctic and peripheral Greenland (excluding the Greenland ice sheet)
6. The Russian Arctic contains small ice shelves. Until recently, glaciers and ice caps in the Russian Arctic are not known to be of surge-type. In recent years, however, several glaciers started surging, including the Vavilov ice cap on Severnaya Zemlya, which has advanced 10 km into the ocean with a surface velocity of >5 km/yr.
7. Tidewater glaciers on Svalbard are well-grounded on the sea floor. Many glaciers are of surge-type. Surging glaciers are major decadal contributors to calving-mass loss and need to be accounted for. The Basin-3 surge of the Austfonna ice cap has been ongoing for 5 years. The resulting annual ice mass loss matches previous estimates of calving from the entire archipelago and a current doubling of the Svalbard ice-mass loss. In the recent decade, Svalbard has experienced several large surges – besides Basin-3, Nathorsbreen and Stonebreen on Edgeøya.
8. Surging leads to shortly increased ice flux and short –term advance, followed by a long-term retreat of the marine terminus. This results in an instantaneous SLR contribution followed by a long-term frontal ablation/ice-mass loss. Considerable advances related to glacier surges result in instantaneous SLR contribution, even in case of negligible iceberg calving loss/frontal ablation.
9. Do terminus advances or retreats need to be accounted for? Yes, because for some regions, e.g. Svalbard and the Russian Arctic, ice mass loss due to terminus retreat may be larger as the ice flux towards the calving front. For Austfonna, 60% of the drainage basins were reported to be dominated by marginal retreat and only 40% by the ice-flux towards the calving front. For glaciers in Hornsund, southern Spitsbergen, 44% of the ice mass loss at the calving front was attributed to terminus retreat and 56% to the ice-flux component. What is the proportion of total mass loss from frontal ablation vs meltwater runoff?
10. The Canadian Arctic is a relatively small contributor to total Arctic glacier and ice cap dynamic discharge, accounting for less than 10% of the reported pan-Arctic discharge. 98% of the icebergs producing glaciers are located in the northern CAA. Two tidewater glaciers, Trinity and

Wykeham Glacier were responsible for ~62% of the total icebergs produced in 2015. In the Canadian Arctic, surface melt exceeds ice mass loss by calving. This may be different for colder regions and where a large fraction of the glacier area is drained through tidewater glaciers, such as Svalbard or the Russian Arctic.

11. Alaska: Many tidewater glaciers have retreated to the shorelines. Two glaciers, Hubbard and Columbia, dominate the total frontal ablation in Alaska. Columbia Glacier is one of the largest individual contributors to global SLR (about 1 mm since the start of its recent retreat phase).
12. Greenland Ice Sheet: Most of the ice discharge occurs from a few glaciers. The Greenland Ice Sheet contributes ~1 mm to global SLR per year, approximately evenly split between calving and surface meltwater runoff (van den Broeke, 2016). This estimate excludes peripheral glaciers and ice caps. Glacier outlines of peripheral glaciers are not well defined in the GLIMS glacier database, i.e. not very well distinguished from basins of the ice sheet.
13. Most regions have a small number of key glaciers that are responsible for a major part of the current ice discharge. Efforts should be made to monitor these key glaciers in more detail.

Guidelines & common methods to be used in the Pan-Arctic assessment of frontal ablation

- terminus retreat/advance should be investigated over the past decade (~2000-2015) and averaged over the terminus width, not just centerline
- assume recent velocities are representative of the past 10 years
- 0.9 depth averaged velocity compared to surface
- winter velocity 90% of annual mean
- ice density = 900 kg m^3
- where available, use cross-sectional ice thickness and velocity estimate to calculate flux
- use error estimate to deal with implementation of results from "non-standard" methods
- glaciers surges should be included, but clearly flagged as such

References

Cogley; J.G.; Hock; R.; Rasmussen; L.A.; Arendt; A.A.; Bauder; A.; Braithwaite; R.J.; Jansson; P.; Kaser; G.; Möller; M.; Nicholson; L. and Zemp M. Glossary of Glacier Mass Balance and Related Terms and IHP-VII Technical Documents in Hydrology No. 86 and IACS Contribution No. 2 UNESCO-IHP, 2011

Van Wychen; W.; Burgess; O., D.; Gray; L.; Copland; L.; Sharp; M.; Dowdeswell; A., J.; Benham & J., T. Glacier velocities and dynamic ice discharge from the Queen Elizabeth Islands and Nunavut and Canada Geophysical Research Letters, 2014

Scientific Seminar on

"Importance of calving for mass budget of Arctic glaciers"

with focus on ice mass loss at fronts of tidewater glaciers in Pan-Arctic scale

Sopot, Poland – 15-17 October 2016

The seminar will be hosted and financially supported by the Centre for Polar Studies - University of Silesia and Institute of Oceanology Polish Academy of Sciences, Poland under the umbrella and with support of the International Arctic Science Committee (IASC), through its Network on Arctic Glaciology, and the Committee of Polar Research Polish Academy of Sciences.

The purpose of the seminar is to:

a) assess the current knowledge on ice mass loss at fronts of Arctic tidewater glaciers;

b) provide a consistent description of methodologies and terminologies so that inter-comparison between Arctic regions will be more feasible;

c) consider estimation of discharge for regions where they currently do not exist;

d) assess the importance of frontal mass loss for the general mass budget of glaciers in different Arctic regions.

Participation:

The seminar will bring together invited experts on Arctic calving glaciers and mass balance (ca. 20 people) and is open to everyone interested in these issues. The total number of participants is limited to 40 persons.

Four - five working session are planned with 1-2 invited introductory talks and longer time slot for discussion during each. Uninvited presentations are not expected. Nevertheless, brief interventions on methods and regional data/results (up to 5 min.) could be possible.

Expected seminar outcome:
A report with recommendations for further coordinated activity and sketch of an overview paper(s) on already gained knowledge on frontal ablation and dynamic discharge of mass as a part of mass balance of Arctic glaciers.

Registration:

Everyone intending to attend the seminar is asked to submit short (maximum 300 words) motivation letter by email to Jacek Jania (jam.jania@gmail.com). Registration deadline is **September 15, 2016**. When number of applications exceeds the limit the Steering Committee reserves the right to decide on participation. The confirmation of the participation will be sent to applicants soon after registration deadline.

The registration fee of 430 PLN (c. 100 EUR) have to be paid on-site in cash. The registration fee includes coffee breaks and lunches during the meeting, the icebreaker and the seminar dinner.

Financial support:

The IASC Network on Arctic Glaciology (NAG) has some opportunity for financial support, provided by IASC, of early career scientists to allow them to attend the seminar. Those interesting are asked to send an application to Jacek Jania (jam.jania@gmail.com) containing motivation letter including name, affiliation, age, supervisors, basic description (maximum 300 words) of the pursued research project, information on amount of money requested and its justification (registration, travel and lodging expenses allowed). The decision on granting will be sent to applicants soon after registration deadline. Note that the support will be reimbursed after the seminar.

Venue, accommodation and travel information:

The venue and local organization will be provided by **the Centre for Polar Studies - Institute of Oceanology, Polish Academy of Sciences in Sopot** (http://www.iopan.gda.pl/index.html).

Sopot is a famous seaside resort having wide range of accommodation options. The full list of hotels can be found at: http://www.sts.sopot.pl/.

The nearest airport with the convenient flight connections is Gdańsk Lech Wałęsa Airport (http://www.airport.gdansk.pl/). The airport is located ca. 10 km from the seminar venue, with a variety of local transport options (http://www.airport.gdansk.pl/passenger/departure1/drive).

Steering Committee of the Seminar:
Thorben Dunse – Chair of the IASC NAG
Francisco Navarro – Chair CWG IASC
Luke Copland – Initiator of this direction of co-operative studies
Mariusz Grabiec – Polish Representative to the NAG - Local host - Centre for Polar Studies – Univ. of Silesia
Waldemar Walczowski – Centre for Polar Studies - Institute of Oceanology, PAS - Local host
Jacek A. Jania – Head, Centre for Polar Studies

"Importance of calving for mass budget of Arctic glaciers"

Sopot Scientific Seminar on Ice Calving in the Arctic (3SICA)

15-17 October, Sopot, Poland

Program

14 October 2016 – Friday: arrival of participants; Steering Committee Meeting (18.00)
19.00: Icebreaker & supper *("Browar LUBROW" TAP HOUSE, ul. Bohaterów Monte Casino 60, Sopot)*

15 October 2016 – Saturday
9.30: Welcome and opening
Introductory session (on aim and scope of the meeting – initiatory remarks - L. Copland, J. Jania; importance of outcomes for oceanographers – W. Walczowski; open questions related to calving processes in the Arctic and clarification of definitions – J.O. Hagen, A.F. Glazovsky) + discussion.
10.45: *Coffee break*
11.00: Methodology session 1 (studies of calving mass loss - state of the art; required data; field methods and techniques) – T. Dunse, M. Blaszczyk, F.T. Walter + discussion.
13.00-14.00: *Lunch*
14.00: Methodology session 2 (studies of calving mass loss – remote sensing methods) – J. Bassis, E. Enderlin, L. Copland + discussion
15.45: *Tea / coffee break*
16.00: Methodology session 3 (common methods, suggestions for unification and recommendations) – F. Navarro, J. Bassis* + discussion (*TBC)
19.00: *Supper (Restaurant "Smak Morza", Aleja Franciszka Mamuszki 2, Sopot)*

16 October 2016 – Sunday
9.00: Results from regions of the Arctic and key glaciers – J. Dowdeswell – a general introduction
Part 1 – Svalbard – J.O. Hagen/T. Dunse, G. Mohold, M. Blaszczyk;
Part 2 – Russian Arctic – I.V. Buzin, A.F. Glazovsky;
10.45: *Coffee break*
11.00: Part 3 – Canadian Arctic – L. Copland, A. Dalton; Part 4 – Alaska – B. McNabb + discussion.
12.45 -13.30: *Lunch*
13.30: Results from regions ctd. Part 5 – Greenland - E. Enderlin, F.T. Walter, and Part 6 – Gaps in a Pan-Arctic knowledge of calving glaciers (insights from different perspectives – L. Copland, J. Dowdeswell, J. Jania) + general discussion.
15.30: *Tea / coffee break*
15.45: Time for local sightseeing / rest or continuation of sessions
19.30: *3SICA* Dinner *(Restaurant "Hotel Haffner" ul. Jana Jerzego Haffnera 59, Sopot)*

17 October 2016 – Monday
9.00: Summary session with preparation of recommendations and a draft of the report from the meeting (possible work in subgroups: moderators TBD).
10.30: *Coffee break*
12.00: Concluding session and closing of the seminar (structure – TBD)
13.00: *Lunch*

Steering Committee of the Seminar:
Thorben Dunse - Chair of the IASC NAG, Norway
Francisco Navarro - Chair CWG IASC, Spain
Luke Copland - Initiator of this direction of co-operative studies, Canada
Mariusz Grabiec - Polish Representative to the NAG - Local host - Centre for Polar Studies – University of Silesia, Poland
Waldemar Walczowski – Local host - Centre for Polar Studies - Institute of Oceanology, PAS, Poland
Jacek A. Jania - Head, Centre for Polar Studies, Poland

Venue: Institute of Oceanology, Polish Academy of Sciences,
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