

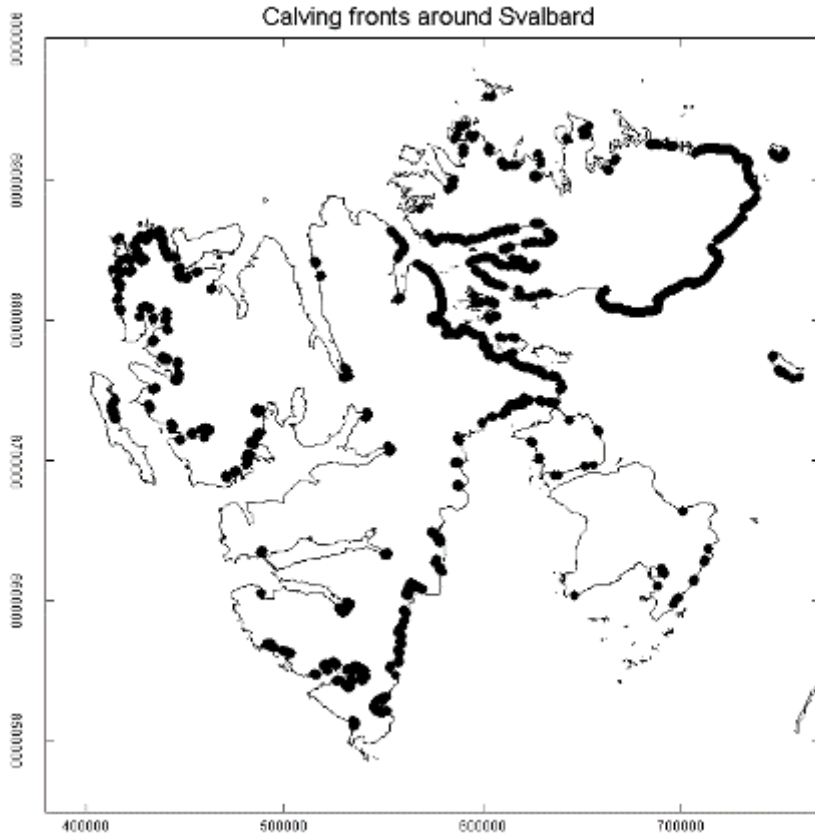


glacier

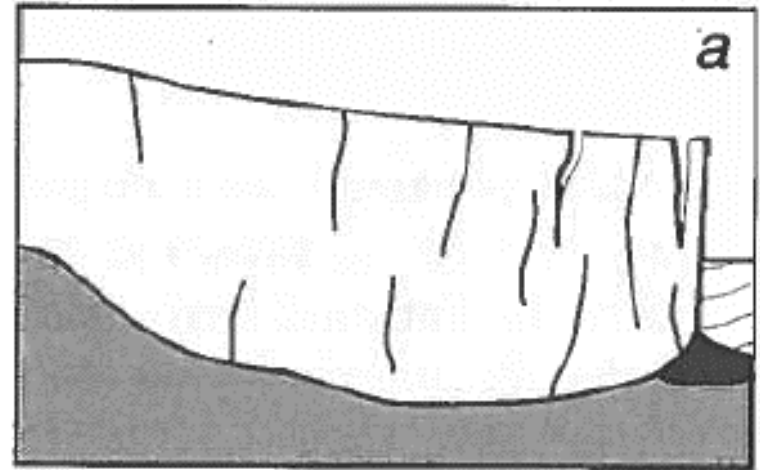
tidewater
(e.g. sea)

Tidewater glaciers

Svalbard tidewater glaciers



163 tidewater glaciers
in Svalbard



More than 60% of
Svalbard ice drains via
tidewater glacier

Total length of calving
ice-cliffs is 860 km



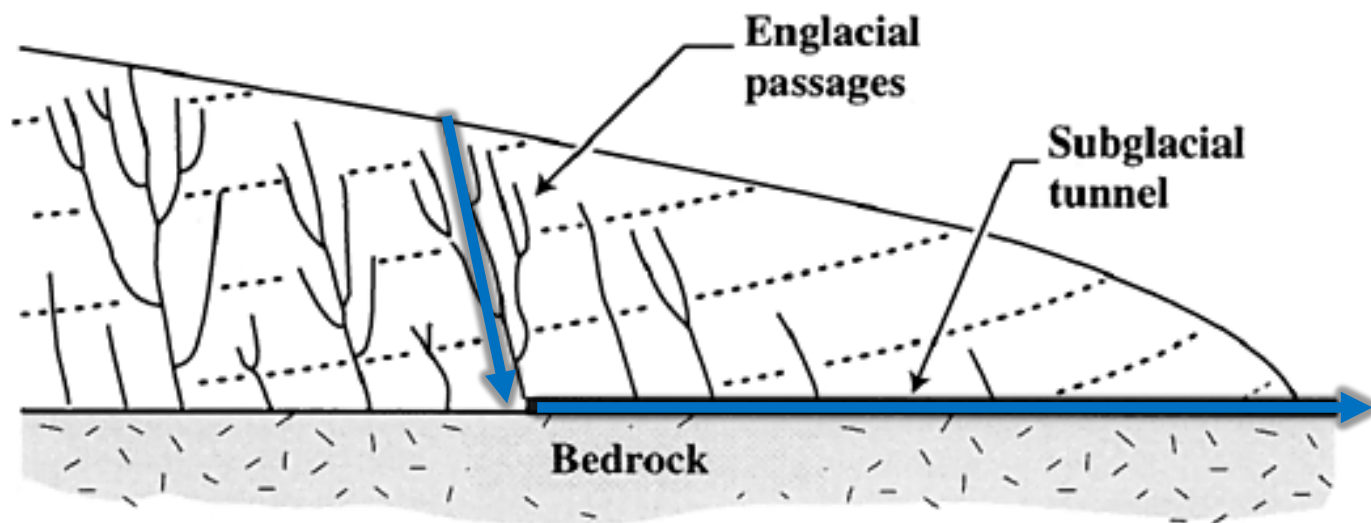
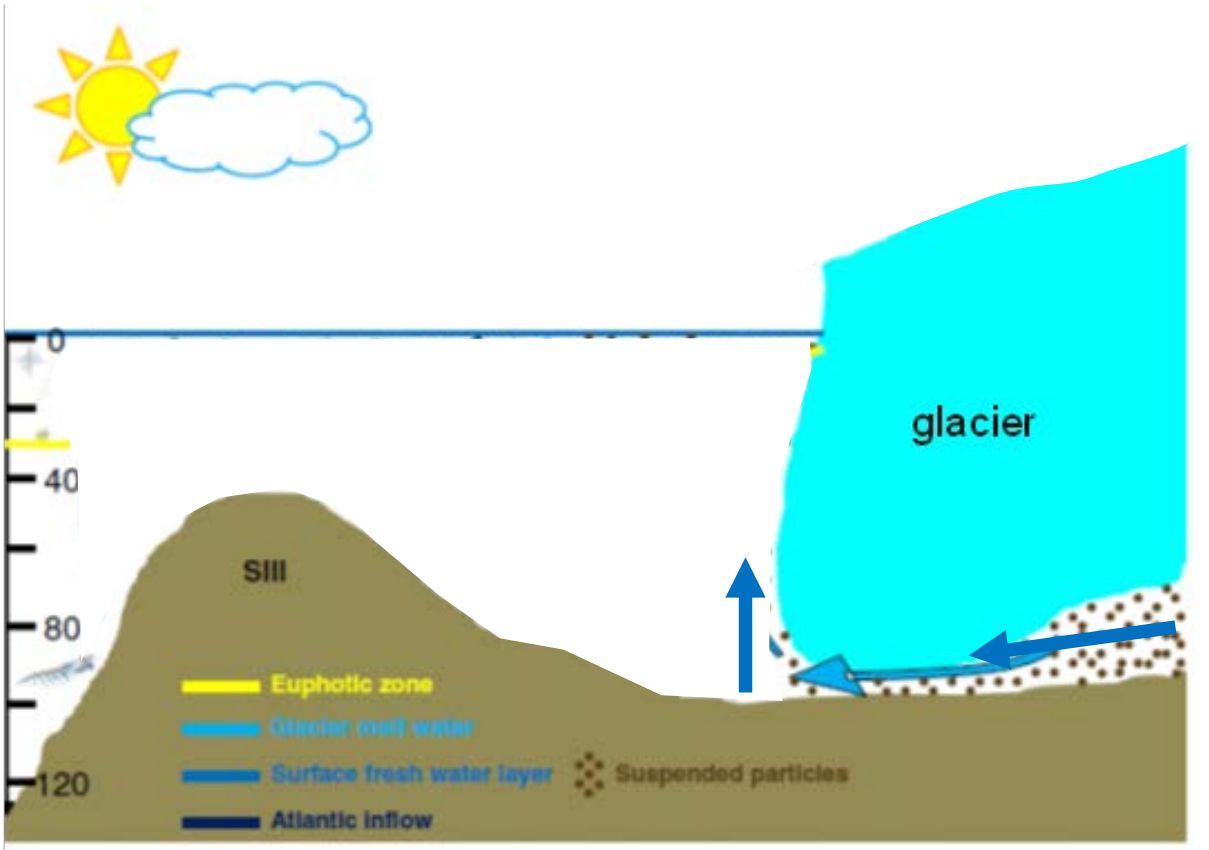


Figure 4. Fluid equipotentials (dotted curves) and a hypothetical network of arborescent englacial channels [after *Shreve*, 1985]. Reproduced with permission of the publisher, the Geological Society of America, Boulder, Colorado USA. Copyright @ 1985 Geological Society of America.



Tidewater glacier



Journal of Marine Systems 128 (2015) 152–175

Contents lists available at ScienceDirect

Journal of Marine Systems

journal homepage: www.elsevier.com/locate/jmarsys

ELSEVIER

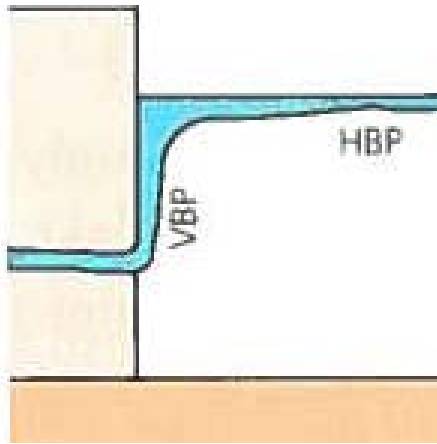
The importance of tidewater glaciers for marine mammals and seabirds in Svalbard, Norway

Christian Lydersen ^{a,*}, Philipp Assmy ^a, Stig Falk-Petersen ^{a,b}, Jack Kohler ^c, Kit M. Kovacs ^d, Marit Beigestad ^d, Harald Stoen ^e, Hallvard Strøm ^e, Arild Sundfjord ^e, Øystein Varpe ^{a,f}, Waldemar Walczowski ^g, Jan Marcin Weskrowski ^g, Marek Zagajkowski ^g

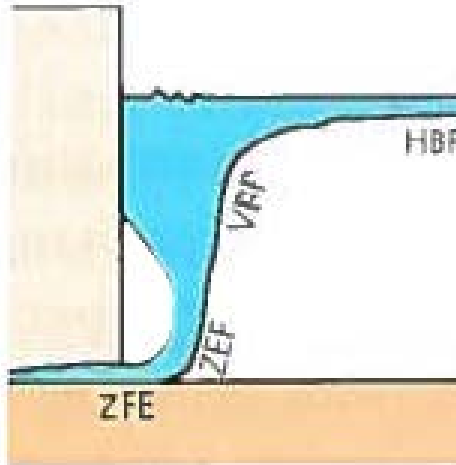
^a Norwegian Polar Research Centre, Postboks 4070, Tromsø, Norway
^b Department of Arctic and Marine Biology, University of Tromsø, N-9007 Tromsø, Norway
^c Institute of Oceanography, University of Wrocław, Poland



(a)



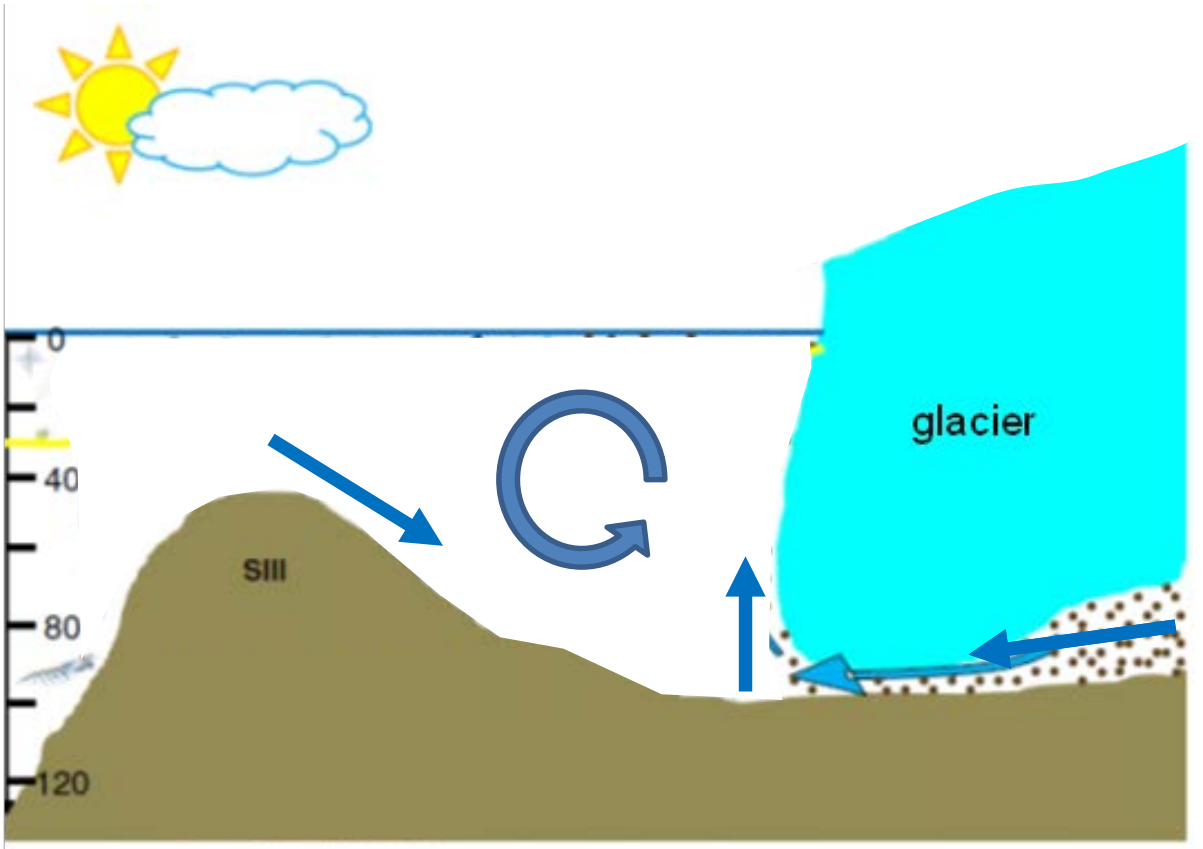
(c)



Plumes

Figure 10.61 Patterns of meltwater discharges from tidewater glaciers. (a) Forced plume dominated by buoyant forces. (b) Axisymmetric jets developing into axisymmetric plumes as momentum forces give way to buoyant forces. (c) Plane jets developing into axisymmetric jets and plumes. ZFE = zone of jet flow establishment; ZEF = zone of established jet flow; VBP = vertical buoyant plume; HBP = horizontal buoyant plume (Powell, 1990, reproduced with permission of the Geological Society of London)

Tidewater glacier





Blomstrandbreen

Conwaybreen

Kongsbreen N

Kongsbreen S

Kronebreen

Kongsvegen

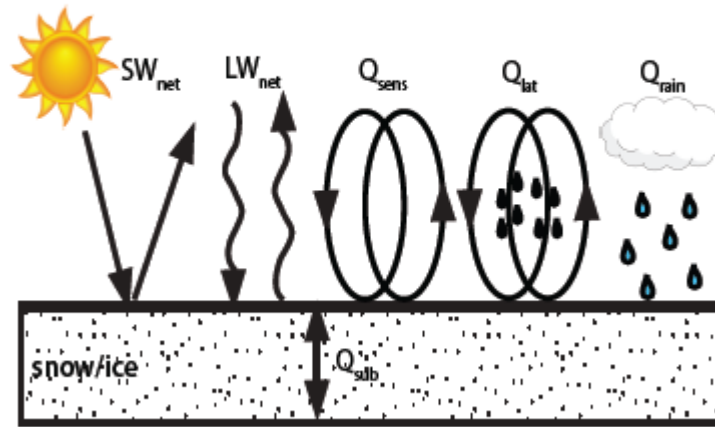
Kongsfjord

0

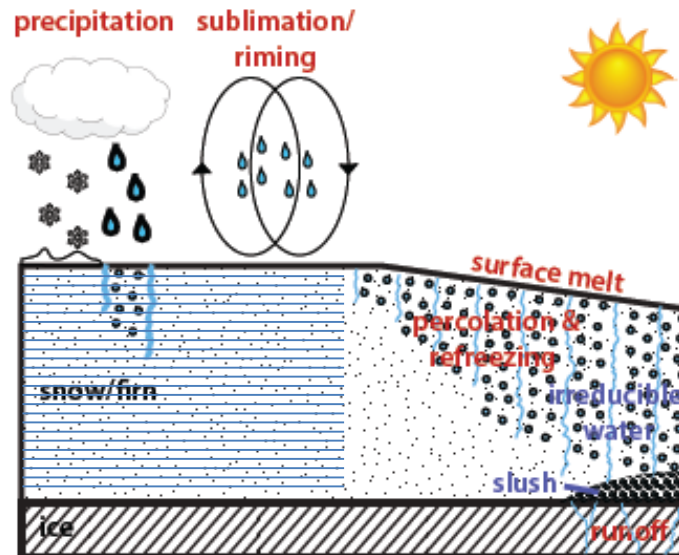
10 km

Runoff modelling

Surface energy balance model used to compute surface temperature and melt production.



+



Surface model coupled to multilayer snow model simulating vertical evolution of density, temperature and water content, accounting for percolation, refreezing, storage and water runoff.

Journal of Glaciology, Vol. 48, No. 166, 2008
 Modelling the long-term mass balance and firm evolution of glaciers around Kongsfjorden, Svalbard

Ward VAN PEEK^{1,2} and Jostein NERØYD²

¹Department of Oceanography, Norwegian University of Science and Technology, Trondheim, Norway
²Department of Earth Sciences, UiT Arctic University of Norway, Tromsø, Norway

ABSTRACT. We analyse the long-term (1950–2007) firm evolution, mass balance and ice evolution of the Kongsfjorden and Helheimfjorden glacier systems in northwestern Svalbard. We couple a surface energy balance model to a firm model, which derives profiles from top and climate model output. In situ observational data are used to calibrate model parameters and validate the output. The simulated area-averaged surface mass balance for 1950–2002 is slightly positive (1.08 m w.e. yr⁻¹), which only marginally compensates for mass loss by sublimation. Sublimation of precipitation water in spring/summer (0.11 m w.e. yr⁻¹) and snow melt in fall/winter (0.11 m w.e. yr⁻¹) provides a buffer to the runoff. Instead, accumulation, i.e. refreezing below the previous year's summer surface in the accumulation area, provides up to 0.22 m w.e. yr⁻¹ and is counteracted by melt observations. Reperforated firn formation in the firn accumulation area ranges in height as 0.56 m w.e. yr⁻¹ at a maximum at the periphery (0.61, 0.50 and 0.50 m w.e. yr⁻¹) to higher central melt rates near 0.00 and a 50% increase in runoff, which can only in part be sustained by recent snowmelt and firn conditions. In response to the firm return, both albedo lowering (from 0.18 to 0.16) and runoff reduction (from 0.16 to 0.14 m w.e. yr⁻¹) occur.

1. INTRODUCTION

Despite the relatively small ice volume of Svalbard glaciers, compared to the ice sheets of Greenland and Antarctica, they play an important role in studying changing Arctic climate and its impact on the global environment. The coupling between mass and energy transfer to the atmosphere, the surface albedo and its response to change, the surface meltwater runoff and its impact on the global ocean (Strombolini and Denton, 2004; Brown and Braaten, 2007; Thompson and Langenbruch, 2008) has been studied by a number of authors (e.g. Braaten and Braaten, 2005; Braaten and Braaten, 2007; Thompson and Langenbruch, 2008; Braaten and Braaten, 2009). These studies are related to estimates of the firm evolution, which is a key parameter in the firm evolution model (e.g. Braaten and Braaten, 2005; Thompson and Langenbruch, 2008; Braaten and Braaten, 2009).

The interaction between a glacier surface, the atmosphere above, and the underlying firn determines the surface mass balance, defined as the sum of snow gain and loss per unit area. While model observations in multilayer and double-layer models provide an insight into the evolution of the snow and firn layers, mass balance models are used to study the evolution of a glacier surface. The mass balance and the underlying energy balance are coupled and are large positive of firm. Detailed modelling of the mass balance requires solving the surface energy balance to obtain the surface temperature and melt production, and then coupling the surface model to a multilayer model to account for the impact of the mass storage and refreezing on the mass and energy budget.

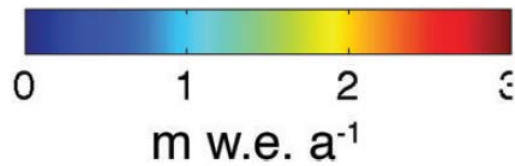
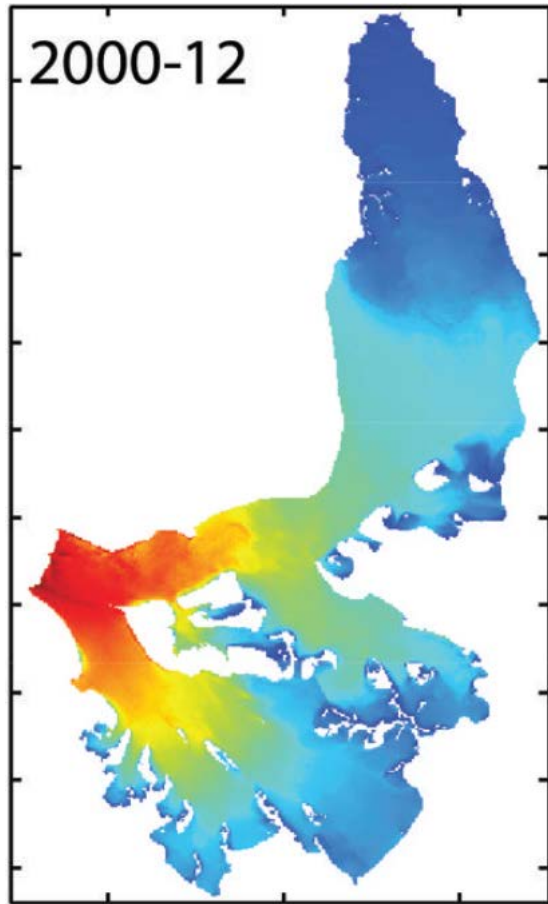
Energy transport to and from the surface may be related again to the snow pack state, temperature and ice refreezing, which affect refreezing of precipitation or snowmelt.

Refreezing not only acts as a buffer to the mass loss, it also acts as a buffer to the mass loss over part of the melt period as the surface is exposed in the next year, thereby increasing the mass density. By refreezing the mass budget of polythermal firn glaciers is known to be substantial (Langley, 1993; Braaten and Braaten, 2005; Braaten and Braaten, 2007). Refreezing has a seasonal cycle and is generally most pronounced in the end of the melt season, when both heat stress and melt rates peak (Madsen and Langenbruch, 2008). In the context of the melt season, refreezing occurs preferentially near the surface during sublimation (Braaten and Braaten, 2009) and may be limited by the absence of a snow pack in the accumulation area. When the melt season subsides, if abundant water continues to be accumulated over the winter with snow production the snow and firn (Braaten and Braaten, 2005; Braaten and Braaten, 2009).

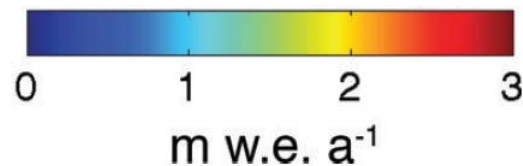
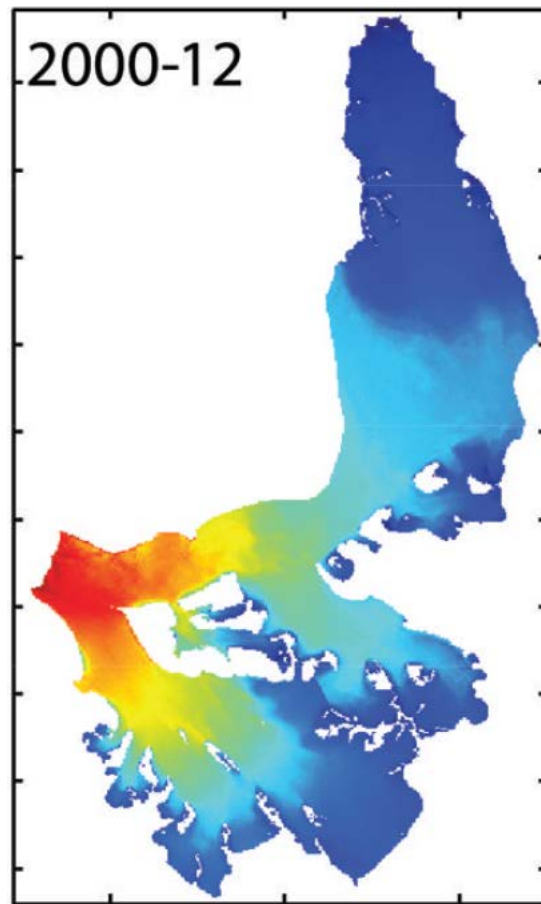
When refreezing in the accumulation area occurs before the previous year's summer surface, this is generally referred to as refreezing accumulation. It is also possible to refreeze accumulation with summer melt charges above the previous year's summer surface. Instead, accumulation may lead to a substantial accumulation of snow loss from melt observations in the accumulation area (Thompson and Braaten, 2008; Braaten and Braaten, 2009; Braaten and Braaten, 2009). As the meltwater subsides from the ice to ice, meltwater is refreezing and it may refreeze when moving from above to below surface to form an ice layer. When this refreezing occurs in response to the surface it is generally referred to as refreezing in the snow and it is the most common refreezing type in a firm (not just above the surface but also in the firn accumulation area and may complicate the evolution of the equilibrium line altitude (ELA). An experimental firn model (van den Broeke and Braaten, 2008) has investigated the impact of refreezing on a multilayer model of the mass budget (e.g. Braaten and Braaten, 2005; Braaten and Braaten, 2009).

Runoff modelling

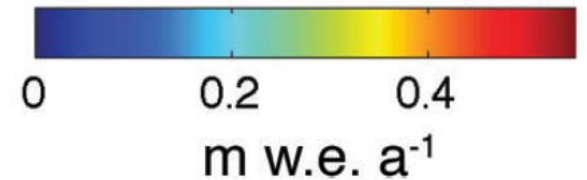
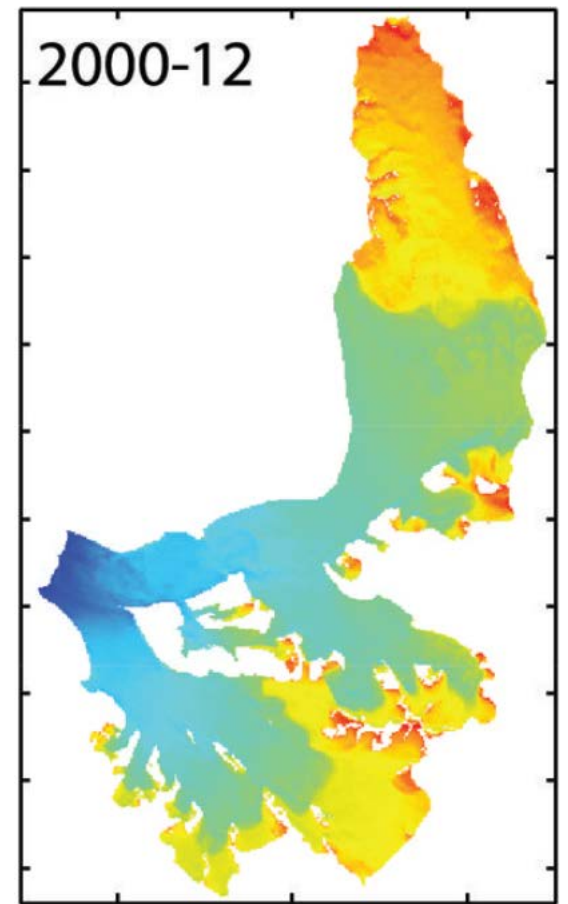
Surface melt



Runoff

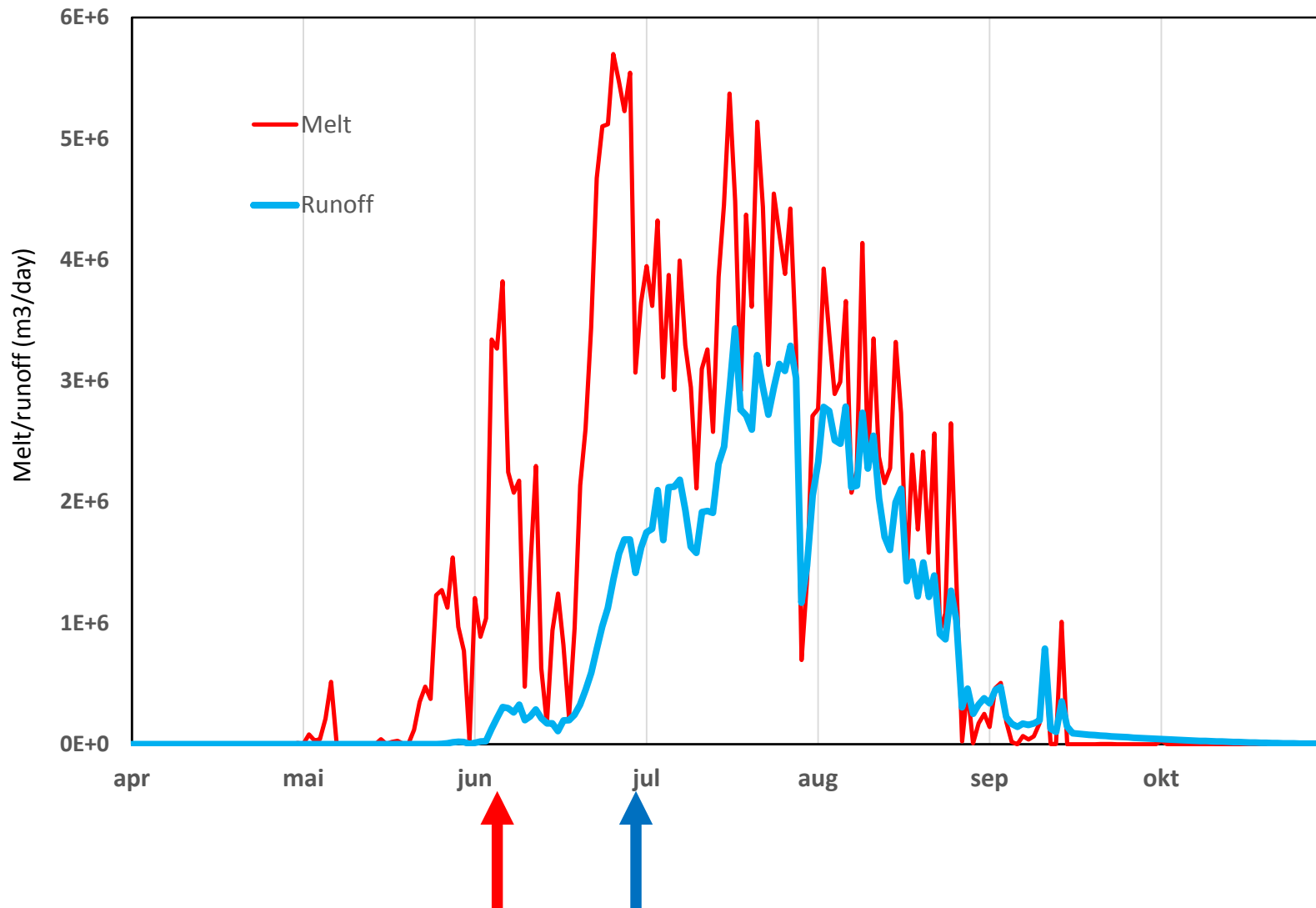


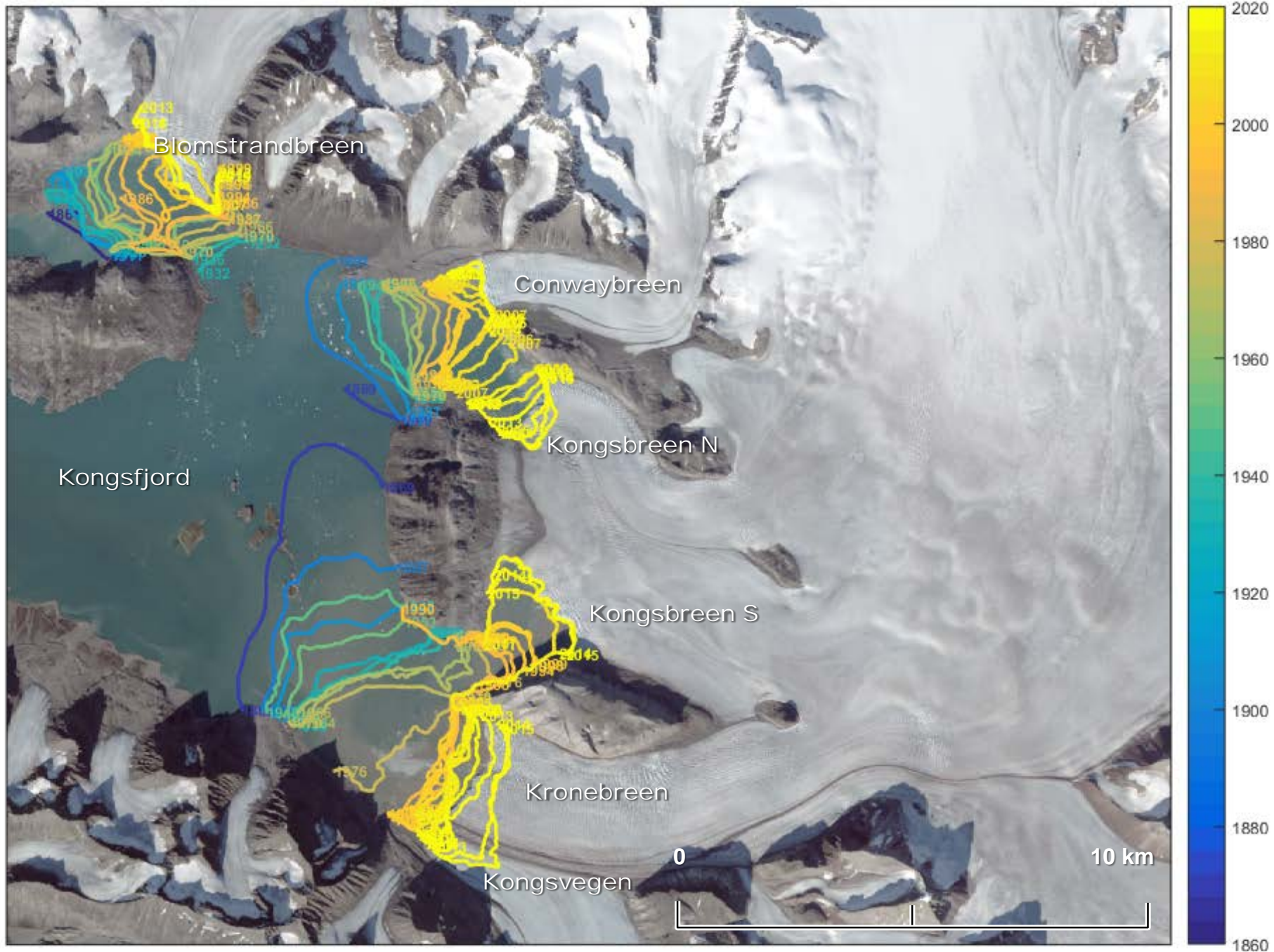
Refreezing



Runoff modelling

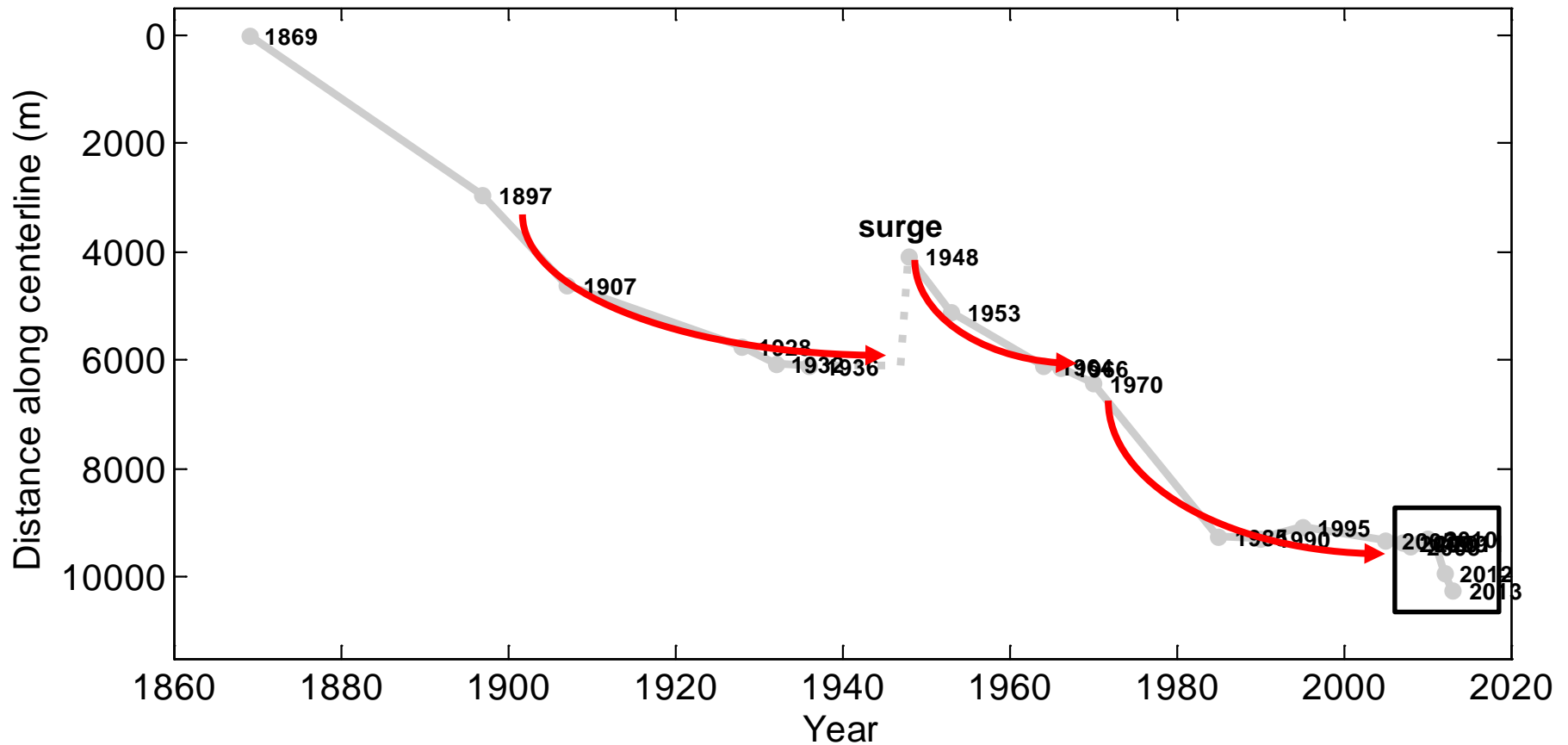
Model melt and runoff 2014





Kronebreen front position

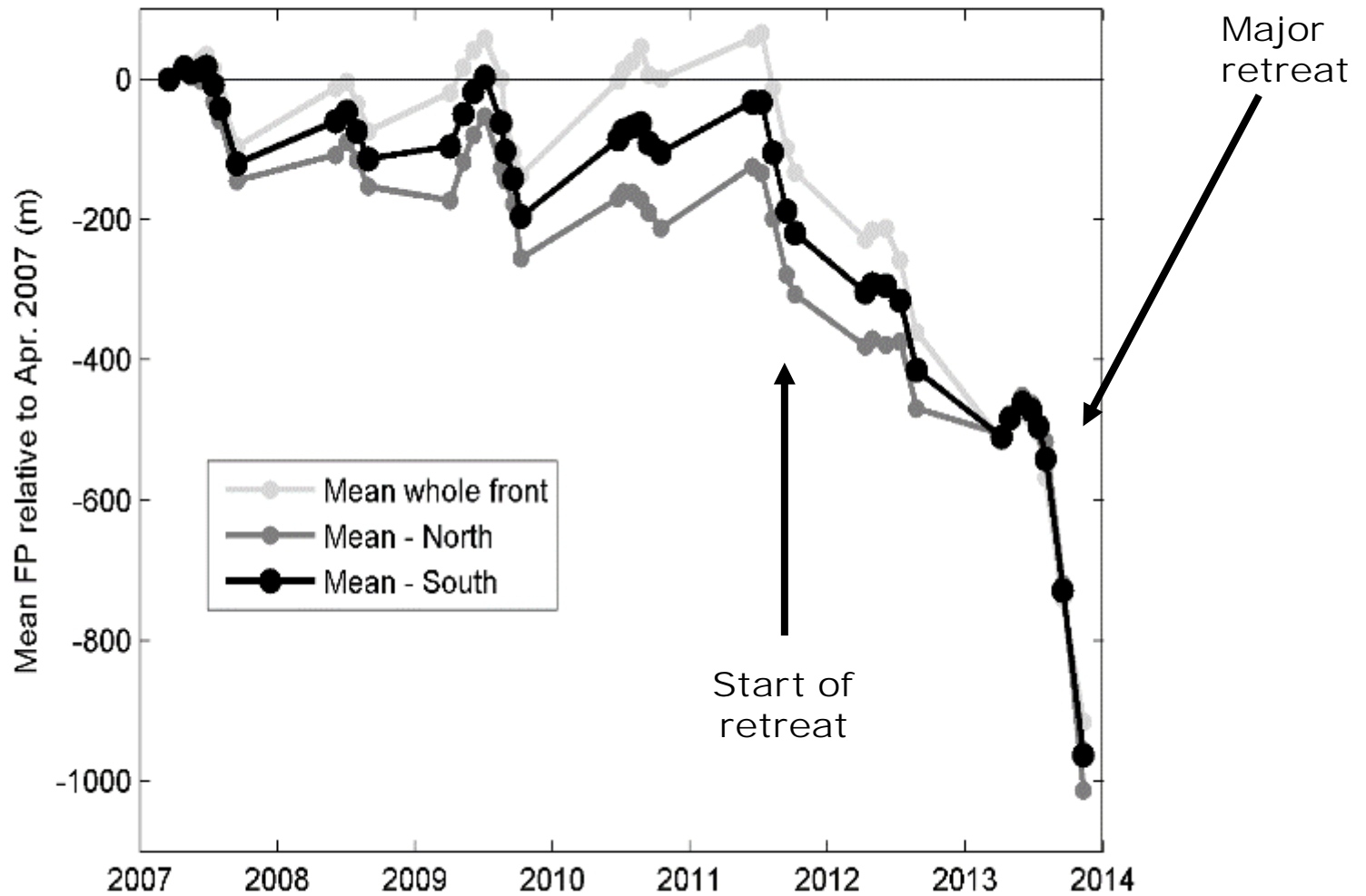
Episodic retreat history



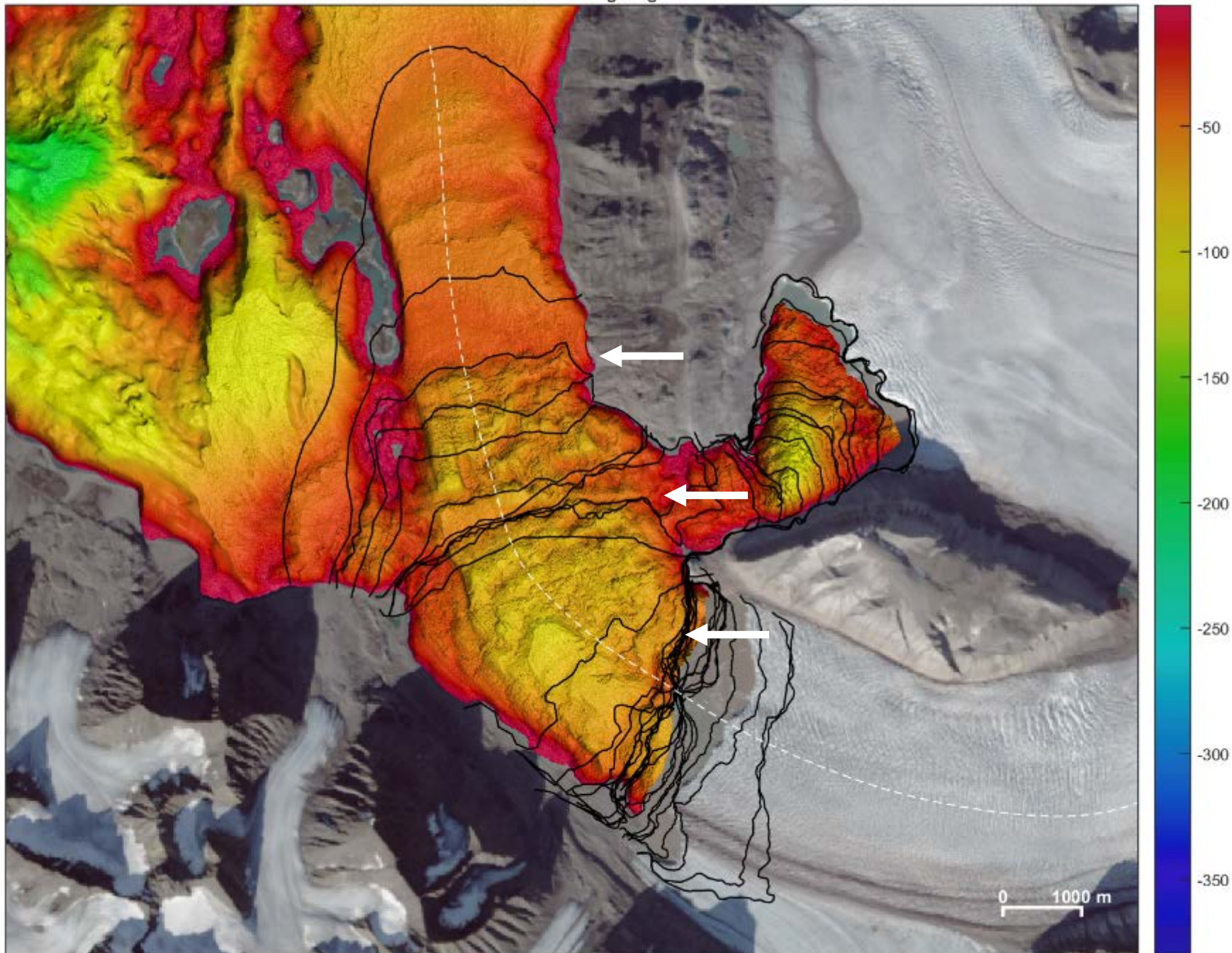
Kronebreen front position

Latest retreat starts 2011

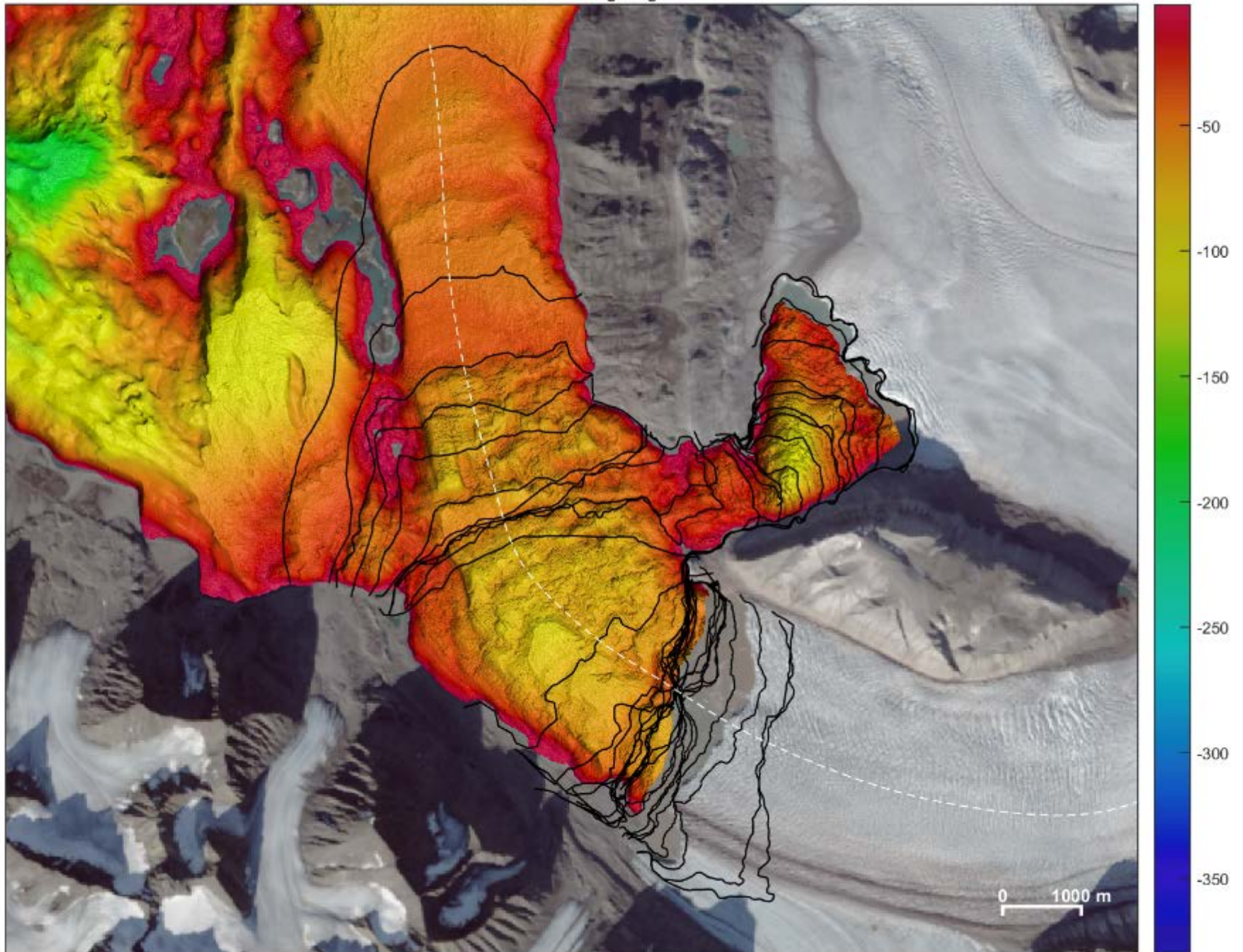
Major retreat (> 500 m) in late summer 2013

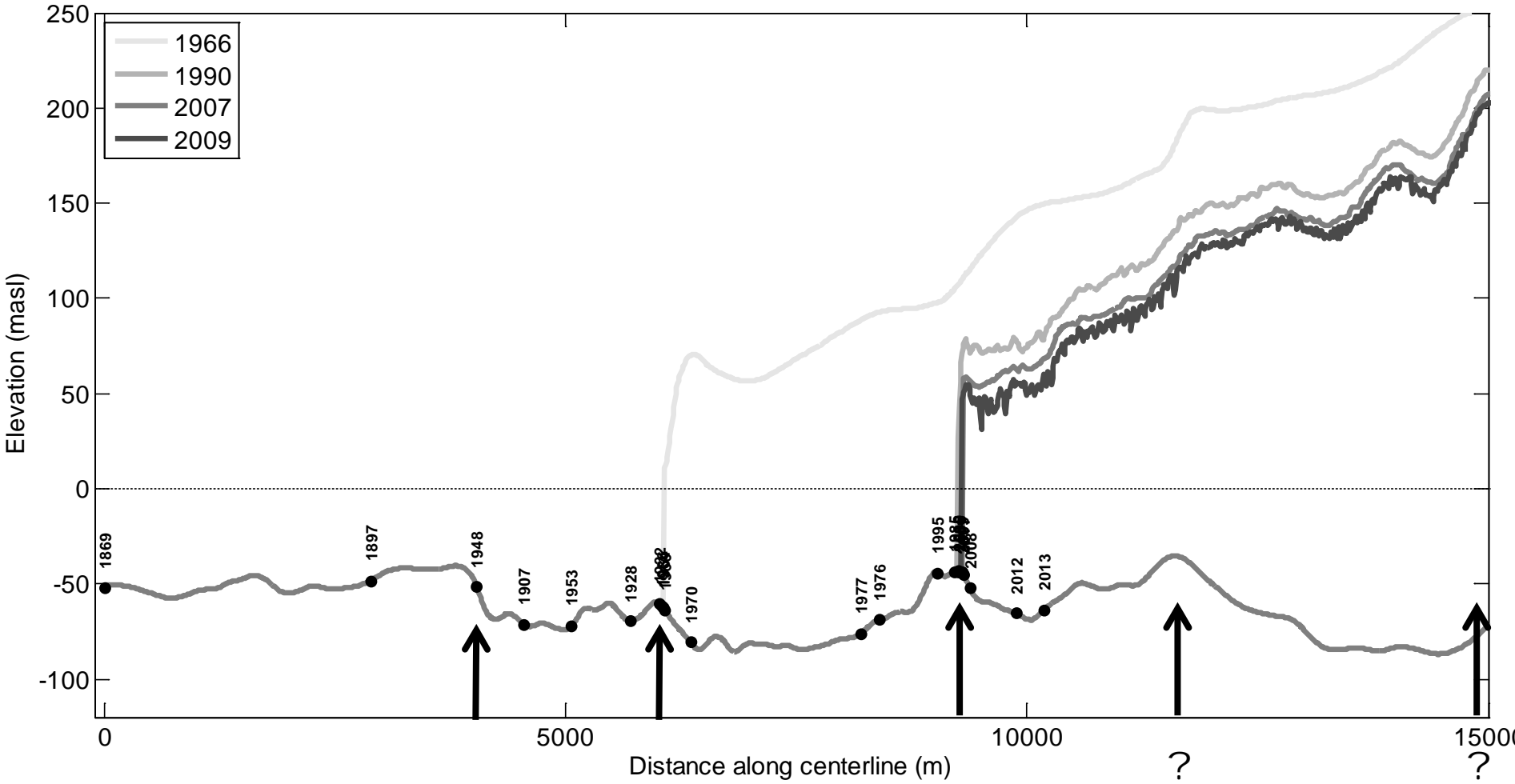


Kronebreen-Kongsvegen



Kronebreen-Kongsvegen





Given that Svalbard tidewater glaciers are retreating...

- What will be the impact on fjord circulation when they retreat so much that they terminate on dry land?
- What are the implications of circulation changes for fjord ecosystems?

TIGRIF: Tidewater Glacier Retreat Impact on Fjord circulation and ecosystems

NFR-funded project, 2015-2018

Norwegian Polar Institute:

J. Kohler, P. Duarte, A. Sundfjord, K. Kovacs, C. Lydersen

Institute of Marine Research:

J. Albretsen, P. Budgell, L. Asplin

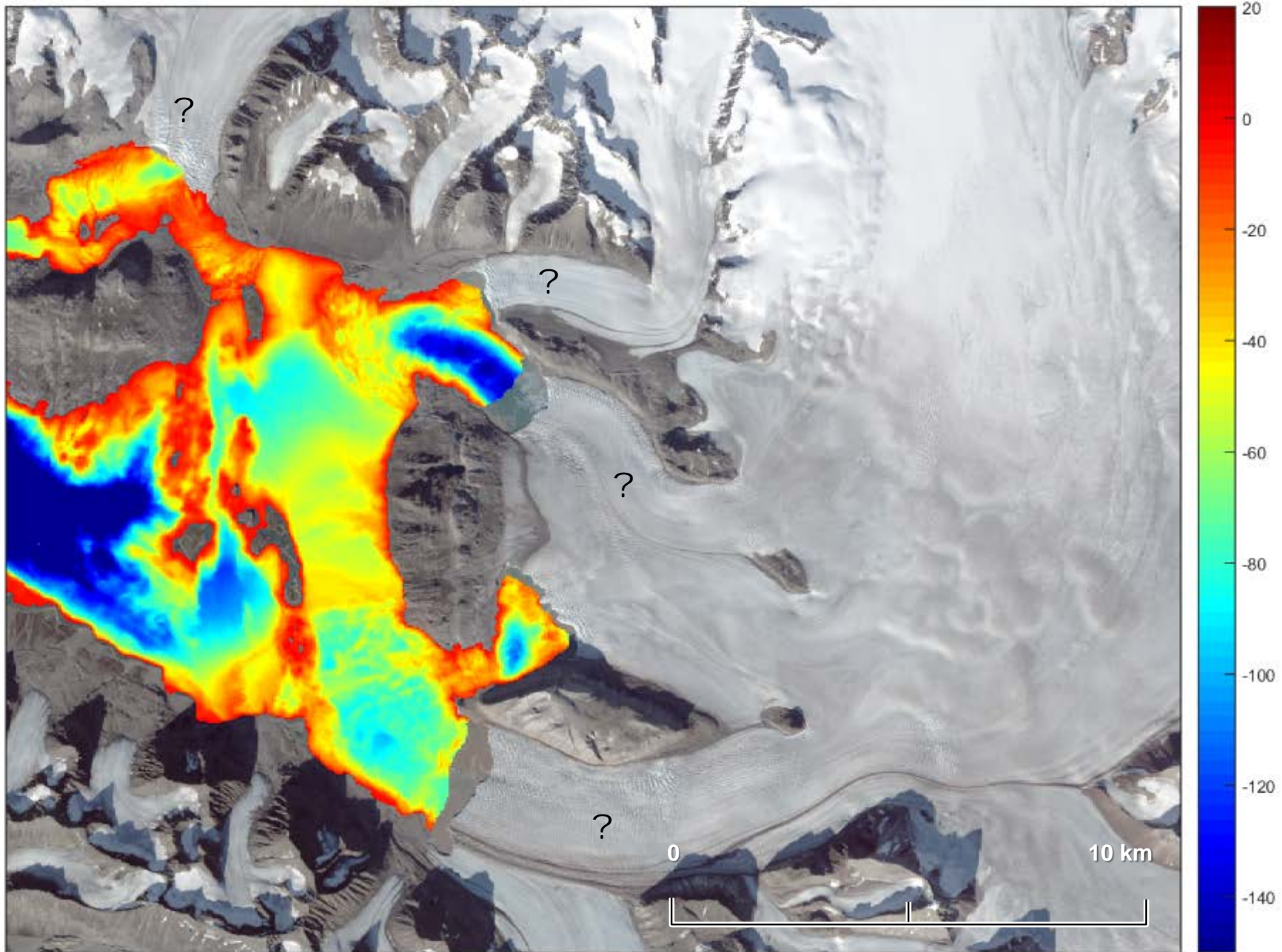
U. Oslo Dept. of Geoscience:

T.V. Schuler, J.O. Hagen



TIGRIF: Tidewater Glacier Retreat Impact on Fjord circulation and ecosystems

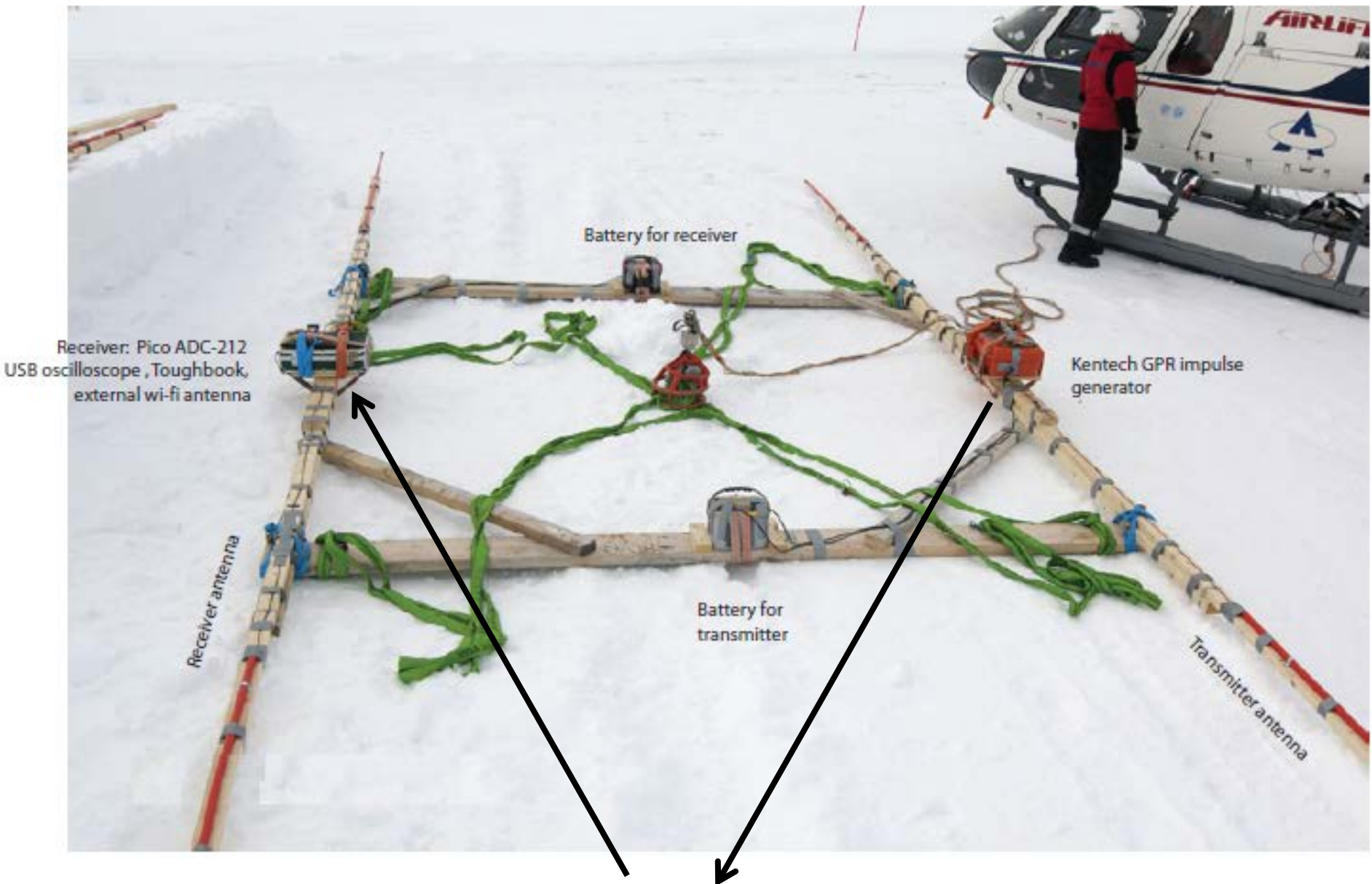
- A) Model fjord circulation under present conditions
- B) Model fjord circulation for glacier retreat onto land.
- C) Use ocean model output to drive a physical-biogeochemical ecosystem model
- D) Assess the impact of the resultant changes in biomass production to the higher trophic levels of the ecosystem



Helicopter radar







Battery for receiver

Receiver: Pico ADC-212
USB oscilloscope, Toughbook,
external wi-fi antenna

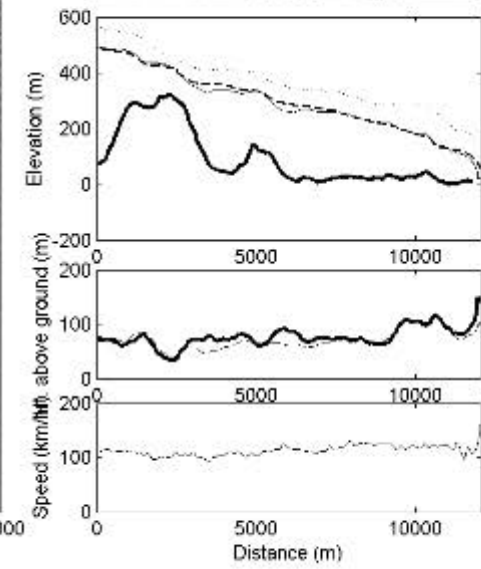
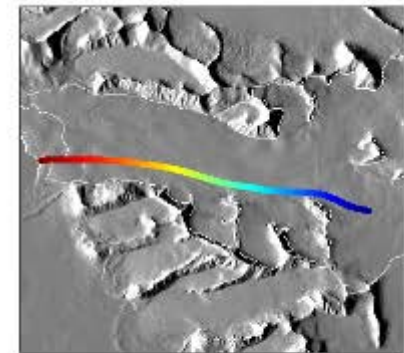
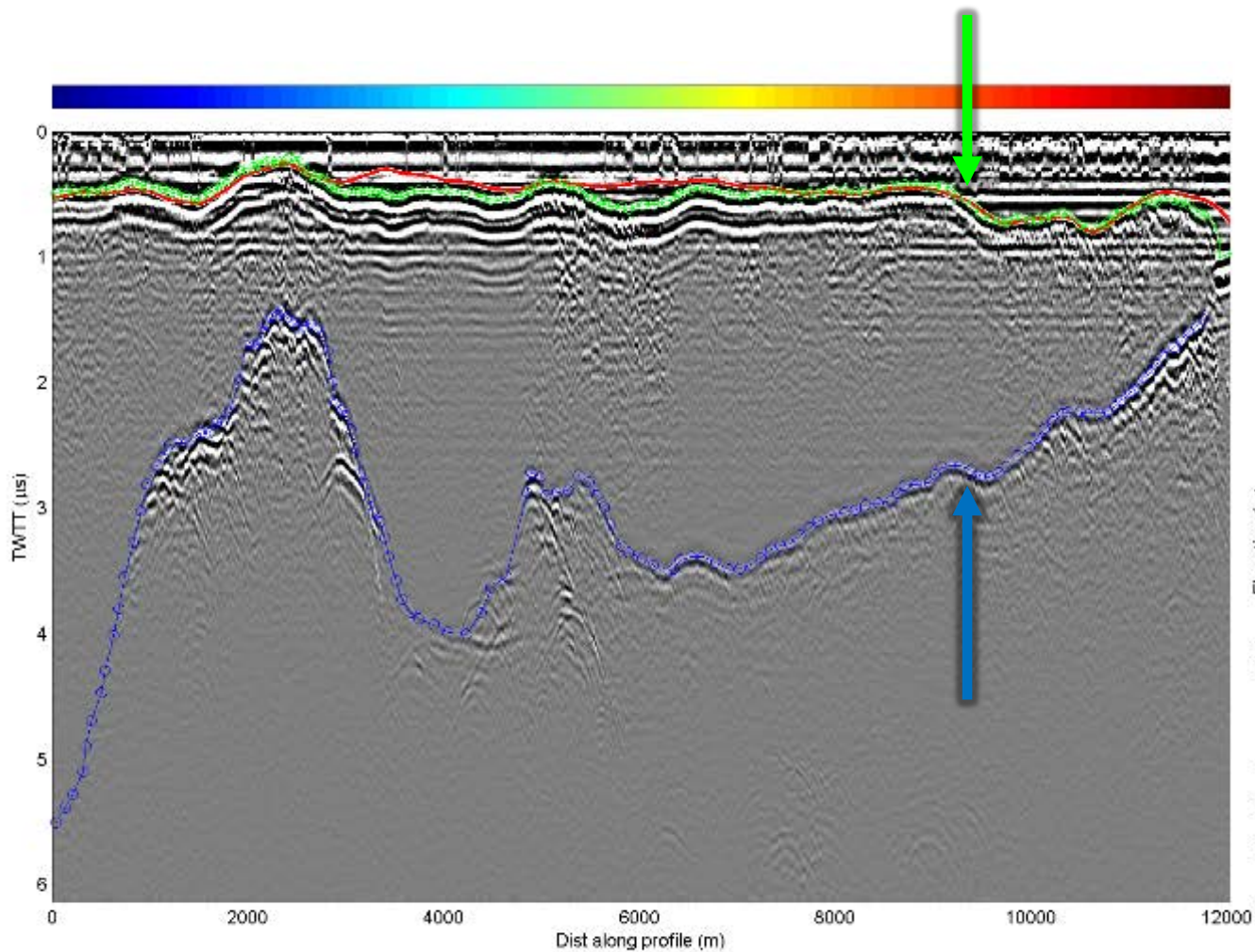
Kentech GPR impulse
generator

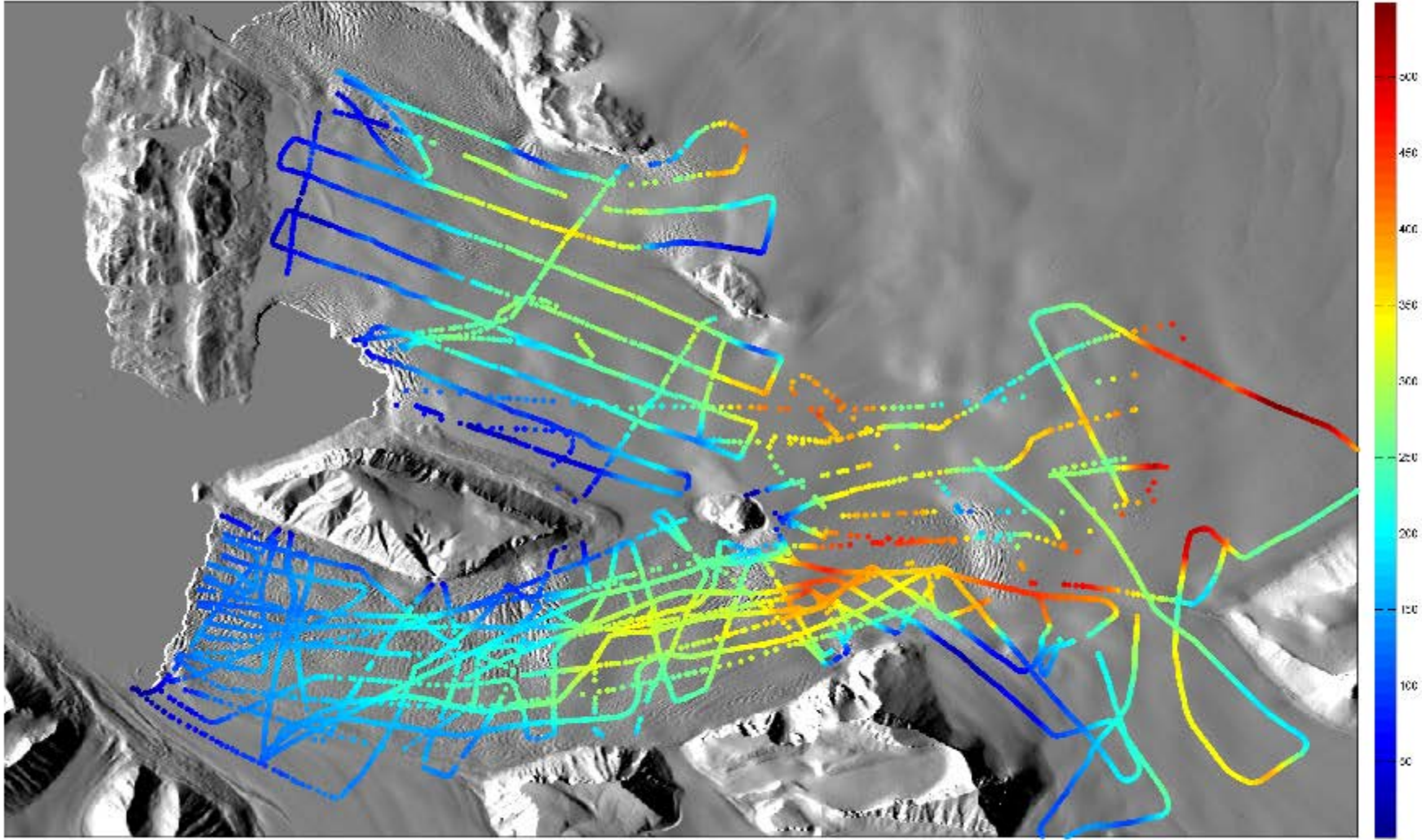
Battery for
transmitter

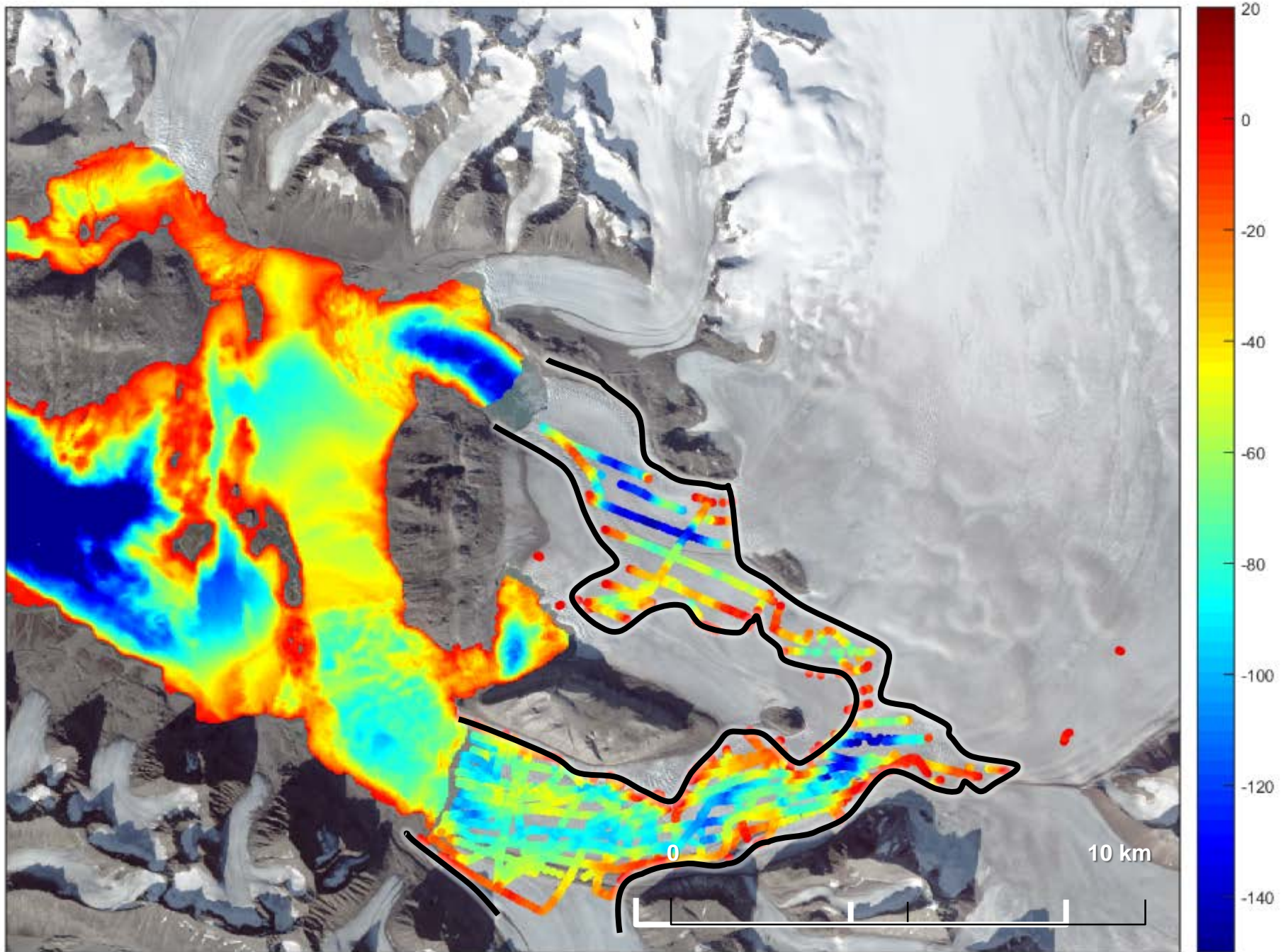
Receiver antenna

Transmitter antenna











No tidewater front →

no plume, reduced circulation

Narrow constricted inner fjord
geometry →

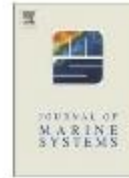
fjord ice throughout winter season



Contents lists available at ScienceDirect

Journal of Marine Systems

journal homepage: www.elsevier.com/locate/jmarsys



The importance of tidewater glaciers for marine mammals and seabirds in Svalbard, Norway

Christian Lydersen ^{a,*}, Philipp Assmy ^a, Stig Falk-Petersen ^{a,1}, Jack Kohler ^a, Kit M. Kovacs ^a, Marit Reigstad ^b, Harald Steen ^a, Hallvard Strøm ^a, Arild Sundfjord ^a, Øystein Varpe ^{a,1}, Waldek Walczowski ^c, Jan Marcin Weslawski ^c, Marek Zajaczkowski ^c

^a Norwegian Polar Institute, Fram Centre

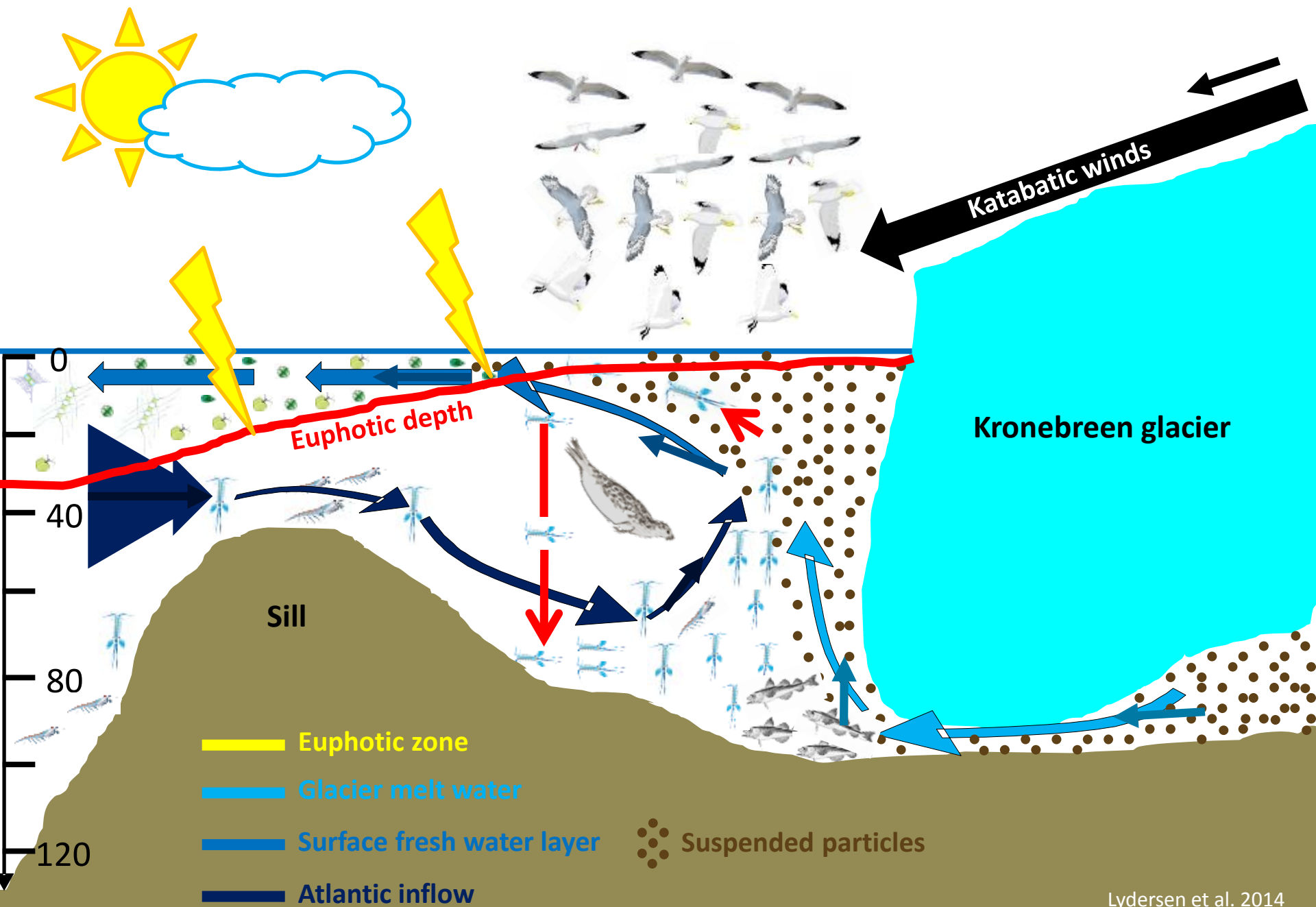
^b Department of Arctic and Marine Biology

^c Institute of Oceanology, D&M, Powsze

TW-ICE

Effect on ecosystem

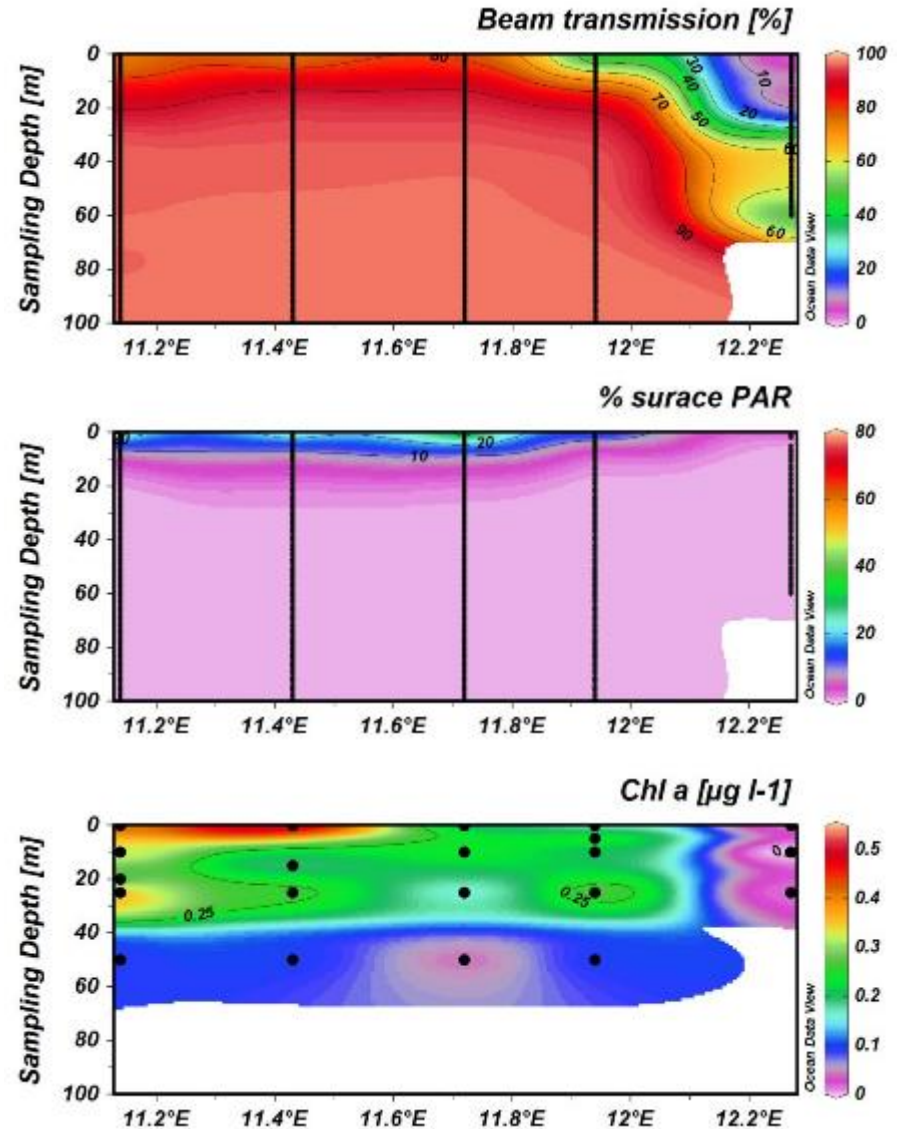




High sediment load limits PP close to the glacier during summer

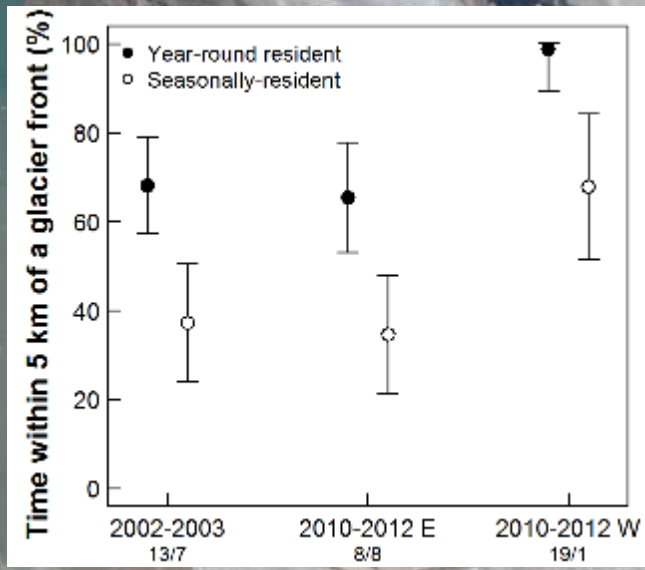
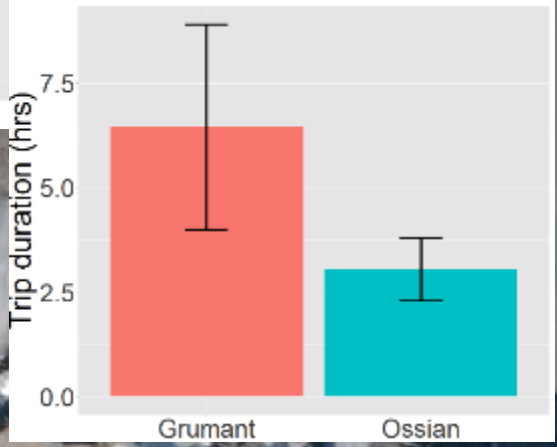
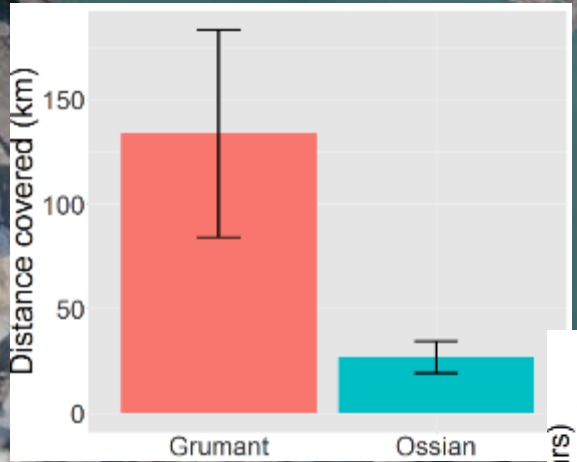
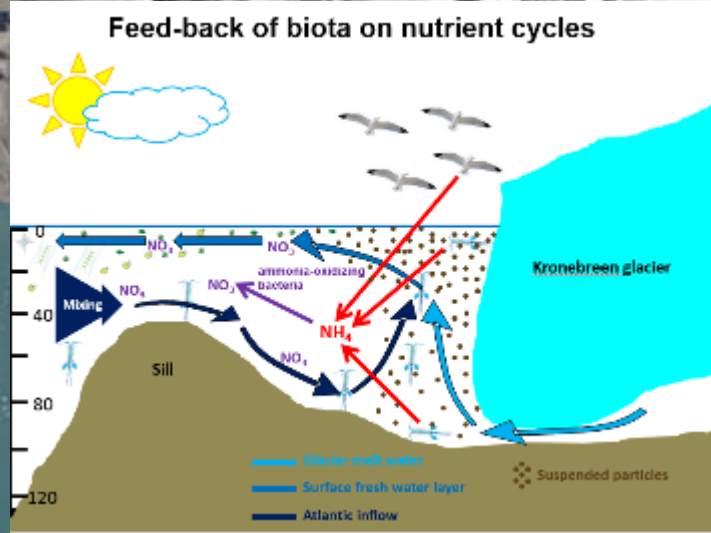


KongHau transect 2011



TW-ICE

Birds and animals



What happens in Kongsfjorden 2016

