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Narodowe Centrum Badań i Rozwoju

Uniwersytet Śląski w Katowicach

Instytut Geofizyki Polskiej Akademii Nauk

WP 5
Freshwater from the land
(introduction)

AWAKE2 Progress Meeting

Sopot, 29th September, 2014

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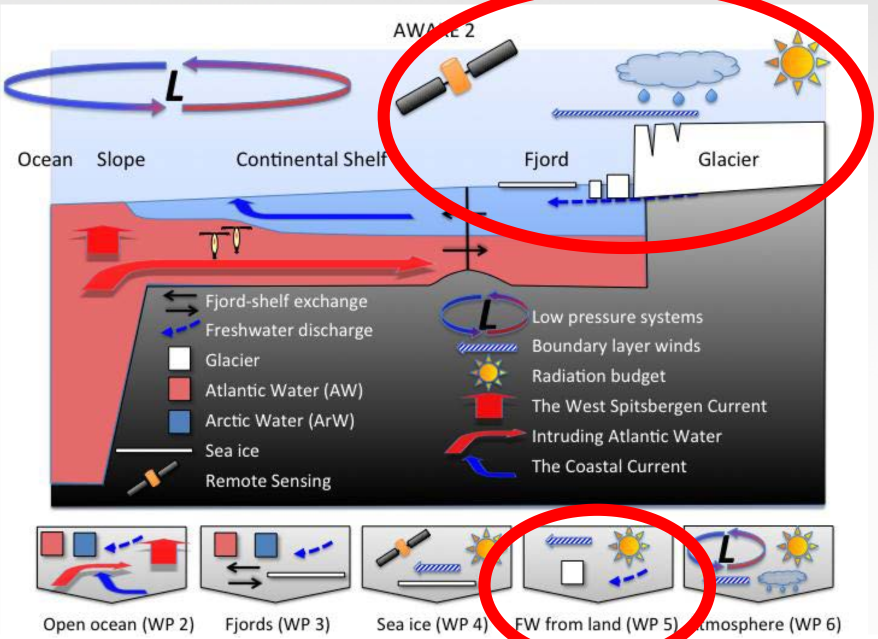
WP 5 Objectives

- To identify main features of the Hornsund hydro-glaciological basin and functioning of its drainage systems.
- To define the key factors of tidewater glaciers dynamics and calving intensity
- To estimate the total freshwater supply to the Hornsund from glaciers and unglaciated catchments as a model example for other Arctic fiords.



Task 5.1. Detailed mapping and evaluation of features of the current state and main features of glaciated and unglaciated catchments within the Hornsund hydro-glaciological basin

Task 5.2. Studies of factors and regimes of outflow from specific terrestrial sources i.e. partly glaciated and unglaciated catchments

Task 5.3. Building of conceptual and semi-quantitative model of water drainage system and discharge from tidewater glaciers emptying into Hornsund fiord

Task 5.4. Identification of key factors of the tidewater glacier's dynamics and calving intensity to the fiord

Task 5.5. Elaboration of the total water budget of the Hornsund hydro-glaciological basin including surface mass balance and icebergs production by tidewater glaciers

Project plans
presented on KoM May 2013:

Task 5.3.

- Collection of radar profiles along centerline of glaciers in Hornsund area for studies on hydrothermal conditions (done, RES on Hansbreen, Storbreen, Flatbreen, Hornbreen, Hambergbreen, Recherchebreen, c. 250 km of profiles in total).
- Processing archive radio echo-sounding data with respect to hydrothermal composition and bed properties (done, see next part of presentation).
- Recognition/interpretation of basal and englacial drainage conditions of glaciers and possibility of drainage within soft sediments underneath glaciers basing on radar profiles (subglacial drainage modeled, recognition of soft sediments questionable).
- Study of subglacial and englacial water storage (in progress).
- Development of model of hydrothermal evolution and functioning of hydroglaciological system (done).

Project plans
presented on KoM May 2013:

Task 5.4.

- Collection of new data on glacier front position changes (interannual, seasonal and short-term) from remote sensing, time lapse cameras, panoramic radar and laser distance meter (partly done, and progress in analysis).

- Collection of ice cliffs geometry and glacier velocity data from features tracking method and DGPS measurements (continuosly performer, new Hornsund glaciers included – Storbreen, Hornbreen).

- Continuous monitoring of frontal velocity and combining with periodical changes of hydro-glaciological conditions and subglacial water pressure (ongoing record and progress in analysis).

- Records of unsynchronized movement of particular parts of the glacier front (partly done).

- Definition the time of appearance of maximum and minimum seasonal cliff extend basing on permanent monitoring of the cliff position (partly done).

Project plans presented on KoM May 2013:

Task 5.5.

- Data collection and processing on superficial mass balance of Hornsund glaciers and estimation of glacier mass balance over entire basin (partly done, in progress).

- Mass balance recalculation in respect to internal accumulation by subsurface refreezing (temperature string implemented, waiting for data).

- New estimation of icebergs volume charging Hornsund due to glacier calving processes (estimation will be completed for time period 2010-2015).

- Quantification of total freshwater outflow from tidewater glacier including icebergs flux and expected trends for future (calculation possible after collection of detailed mass balance/calving data).

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Task 5.3. Building of conceptual and semi-quantitative model of water drainage system and discharge from tidewater glaciers emptying into Hornsund fiord

Hydrothermal state and evolution on Svalbard glaciers

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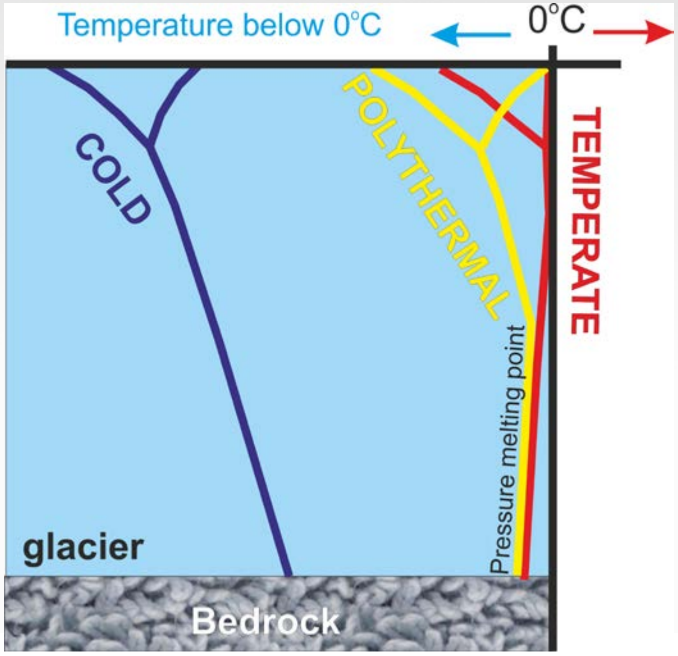
Introduction

The hydrothermal structure is result of the heat balance of glacier determined by internal and external factors influencing heat exchange process by conduction, convection and latent heat of fusion (Paterson 1994).

Thermal types of glaciers



Thermal types in Svalbard glaciers

Cold (or almost cold) glaciers:

Scott Turnerbreen (Hodgkins 1997),
Austre Broggerbreen (Björnsson et al., 1996, Stuart et al., 2003),
Tellbreen (Bælum and Benn, 2011),
Longyearbreen, Larsbreen (Etzelmüller et al. 2000)

Quasi-temperate glacier:

Erikbreen (Hodgkins 1997)

Polythermal glaciers – widespread in Svalbard

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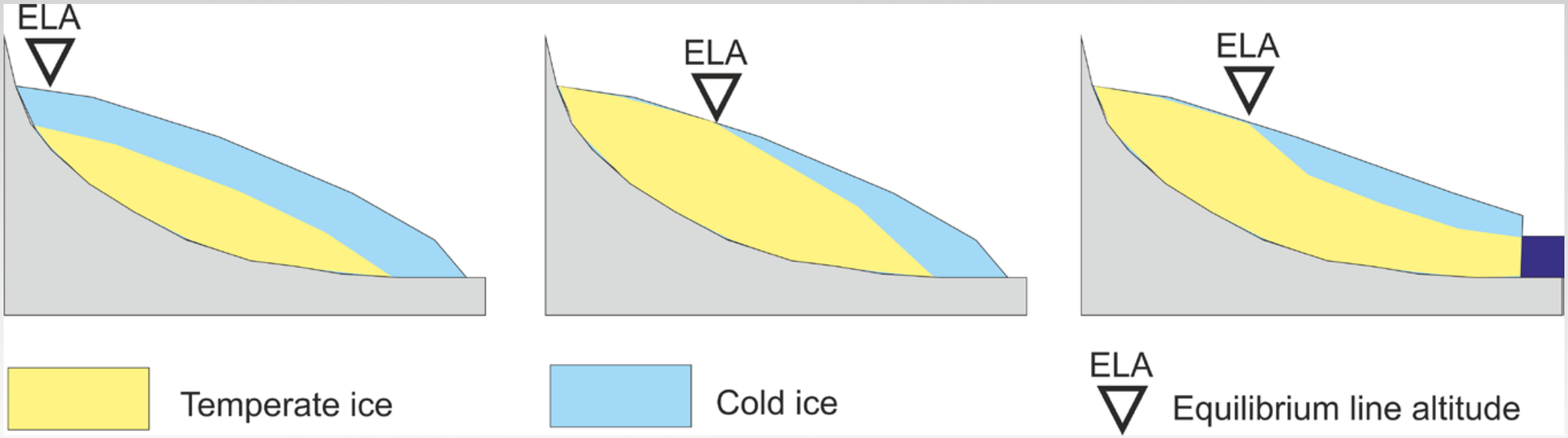

Temperate ice:

- Pressure melting point temperature
- Water content up to 9% (Macheret and Glazovsky 2000)
- Water permeable

Cold ice:

- Temperature far below 0°C
- Dry (almost no water)
- Water impermeable – prevailing supraglacial runoff

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Motivation

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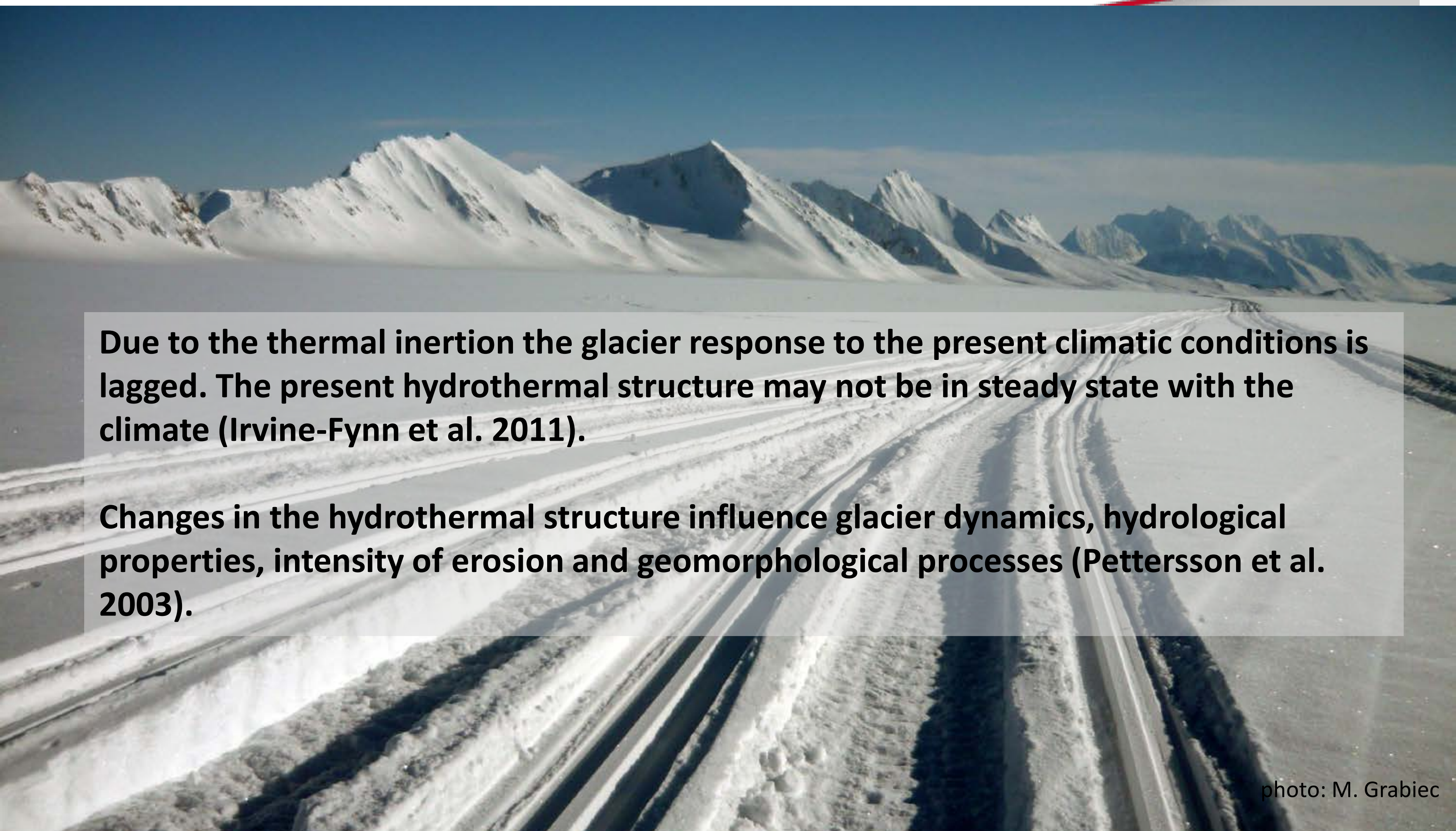

Due to the thermal inertion the glacier response to the present climatic conditions is lagged. The present hydrothermal structure may not be in steady state with the climate (Irvine-Fynn et al. 2011).

Changes in the hydrothermal structure influence glacier dynamics, hydrological properties, intensity of erosion and geomorphological processes (Pettersson et al. 2003).

photo: M. Grabiec

Objectives

- Identification of present hydrothermal state of glaciers on Wedel Jarlsberg Land and Torell Land
- Determination of key factors influencing thermal evolution of glaciers, and features of glaciers conditioning their thermal sensitivity
- Determine whether the Svalbard glaciers are in thermal equilibrium with the present climate and adaptation time

Deep radio echo-soundings 2008-2014

by University of Silesia and Institute of Geophysics PAS

Reported in:

Navarro F.J., Martin-Espanol A., Lapazaran J.J., Grabiec M., Otero J., Vasilenko E.V., Puczko D. (2014): Ice volume estimates from ground penetrating radar surveys, Wedel Jarlsberg Land glaciers, Svalbard. *Arctic Antarctic and Alpine Research*.

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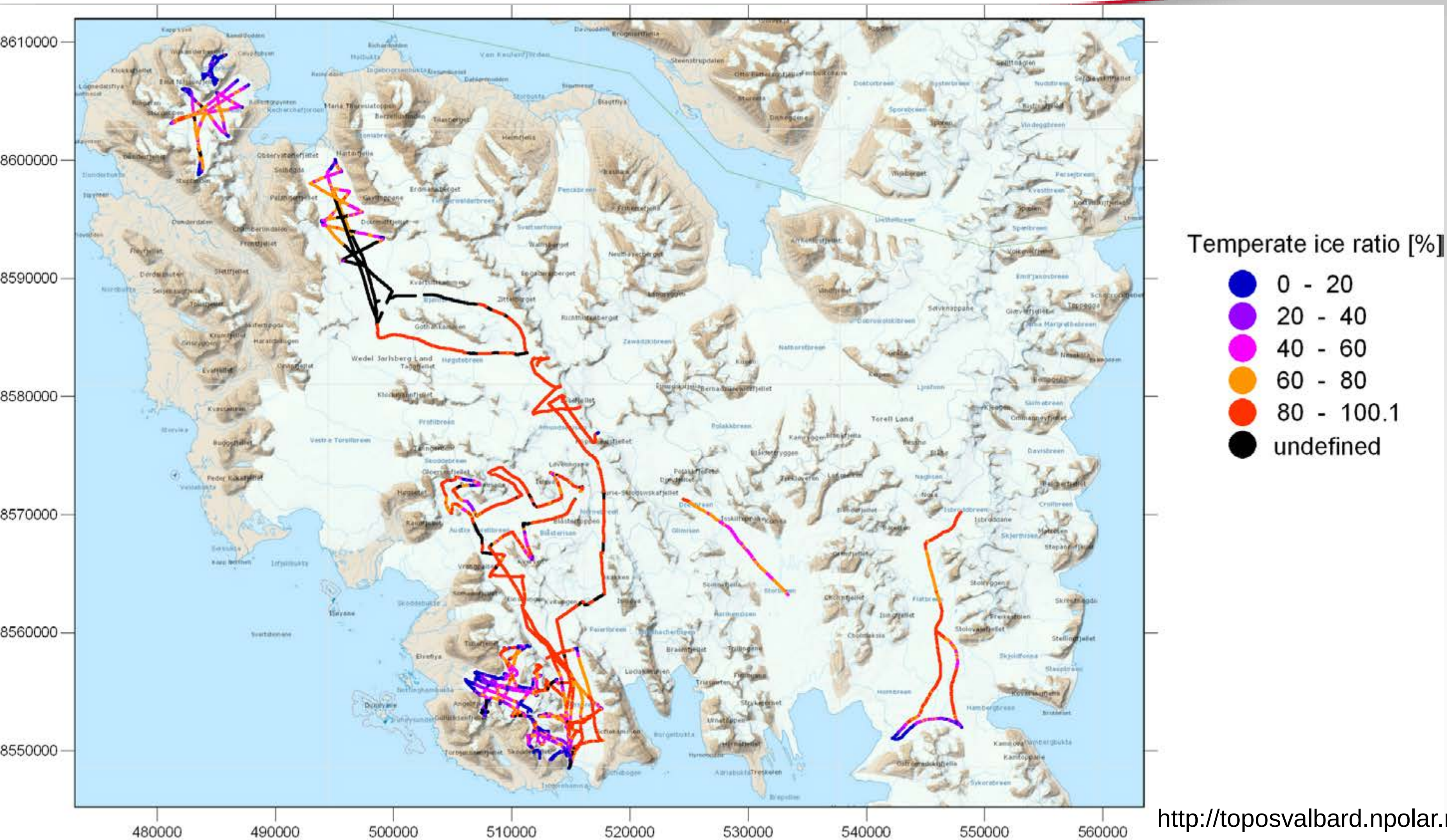

http://toposvalbard.npolar.no/

Are Svalbard glaciers in steady state with climate?

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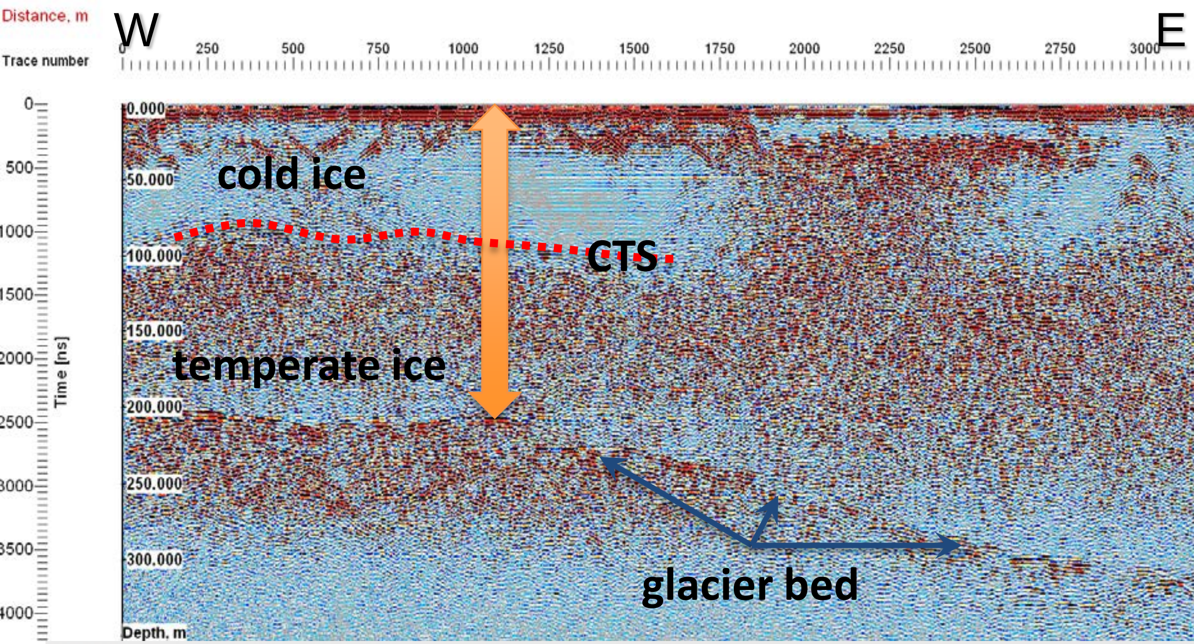
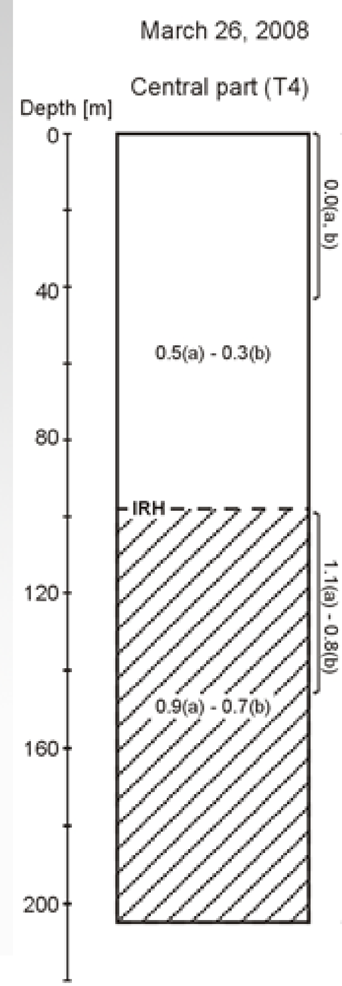


Average water content



Assumptions of present conditions:

- Initial ice thickness: 210m
- Initial cold ice layer thickness: 87m
- Mean surface lowering (1989-2007): -0.95 ma^{-1}
  including:
  - Negative mass balance (1988-2011): -0.66 ma^{-1}
  - Submergence velocity: -0.29 ma^{-1}
- Mean ice temperature at -20m: -2.1°C (Jania et al. 1996)
- Water content in temperate ice layer: 1%

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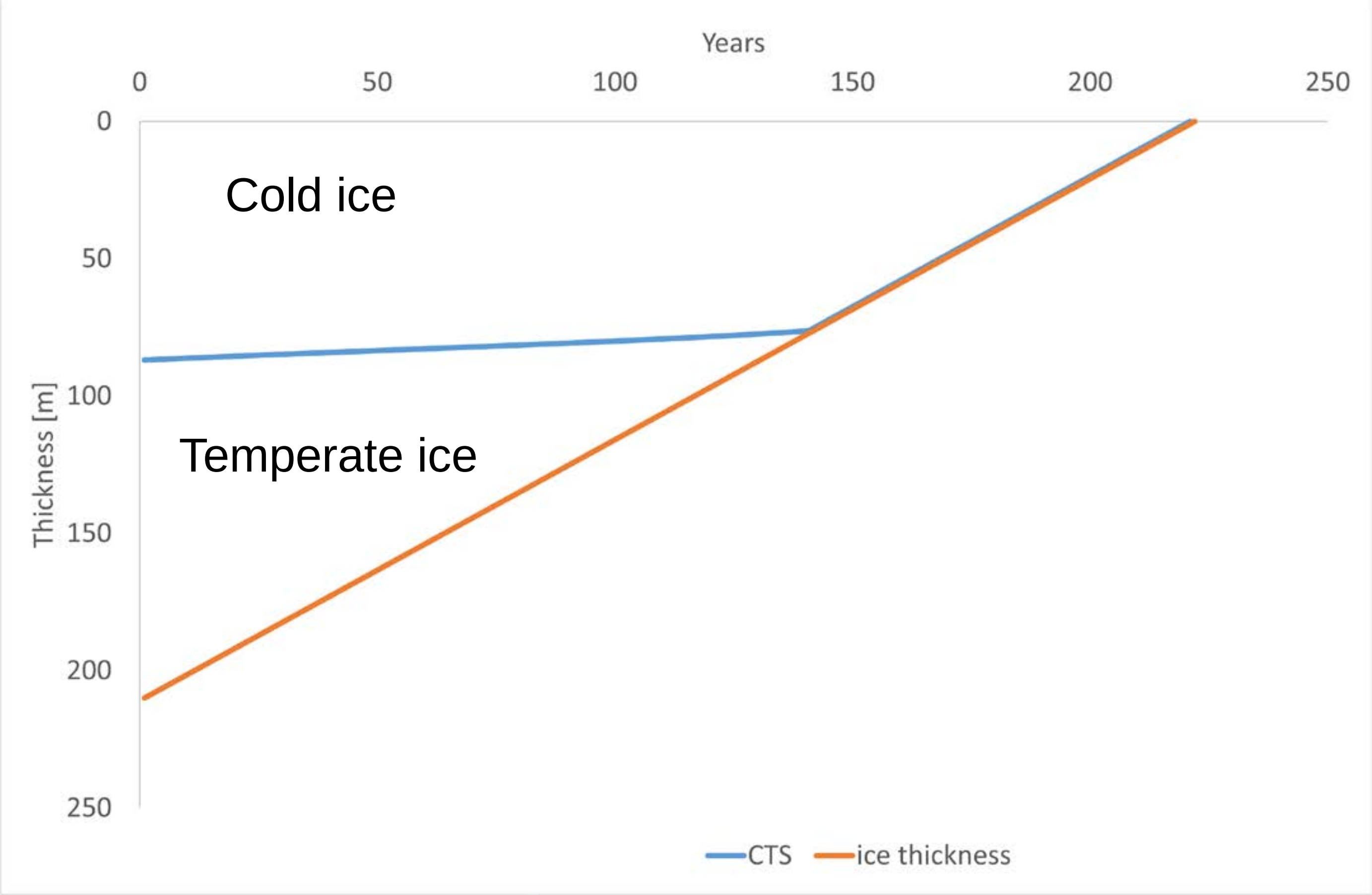
Simulation of ice thickness and hydrothermal evolution
Hansbreen



Are Svalbard glaciers in steady state with climate?

Assumptions of warming conditions:

- Ice thickness: 210m
- Initial cold ice layer thickness: 87m
- Mean surface lowering: -1.08 ma^{-1} including:
  - Negative mass balance (**-20%**): -0.78 ma^{-1}
  - Submergence velocity: -0.29 ma^{-1} (**no change**)
- Mean ice temperature at -20m (**+1°C**): -1°C
- Water content in temperate ice layer (**+1%**): 2%

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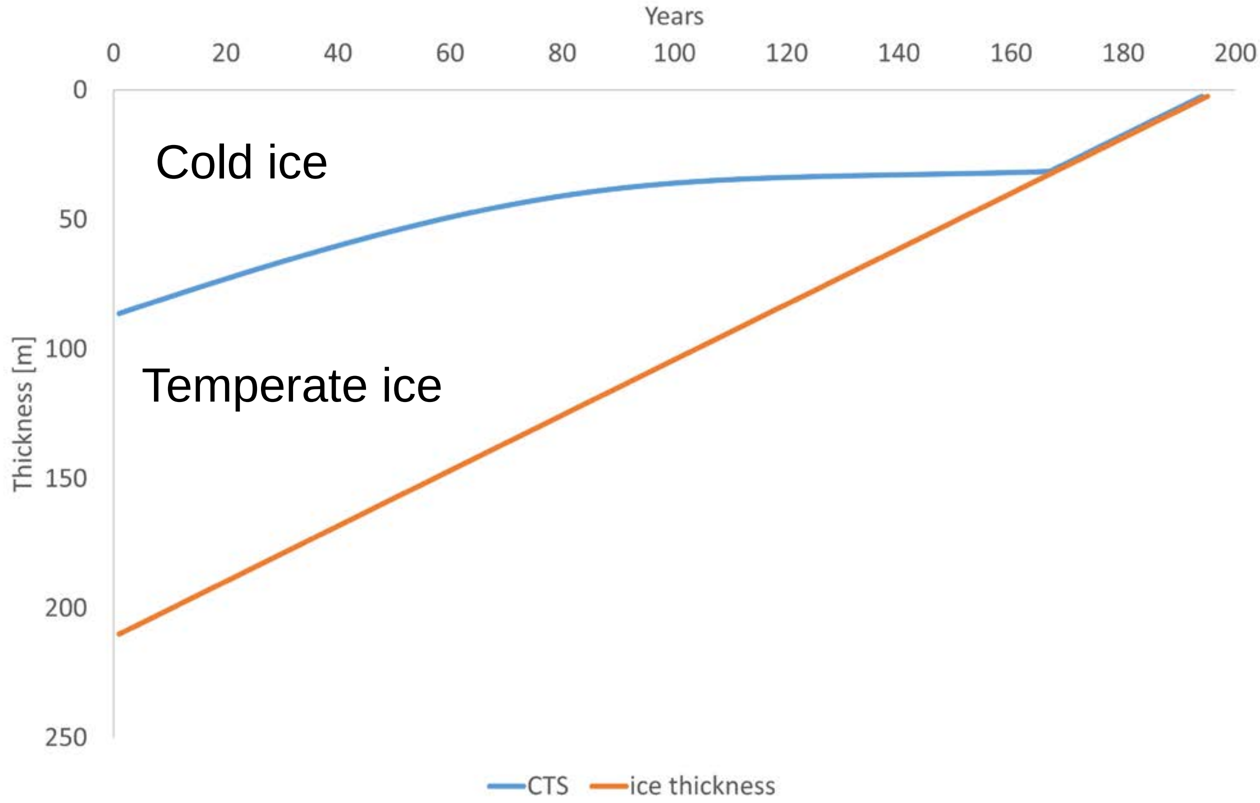
Simulation of ice thickness and hydrothermal evolution

Hansbreen under warming



Thermal structure evolution in polythermal glaciers on Svalbard under warming conditions

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Summer warming (mean annual temperature negative)

↓

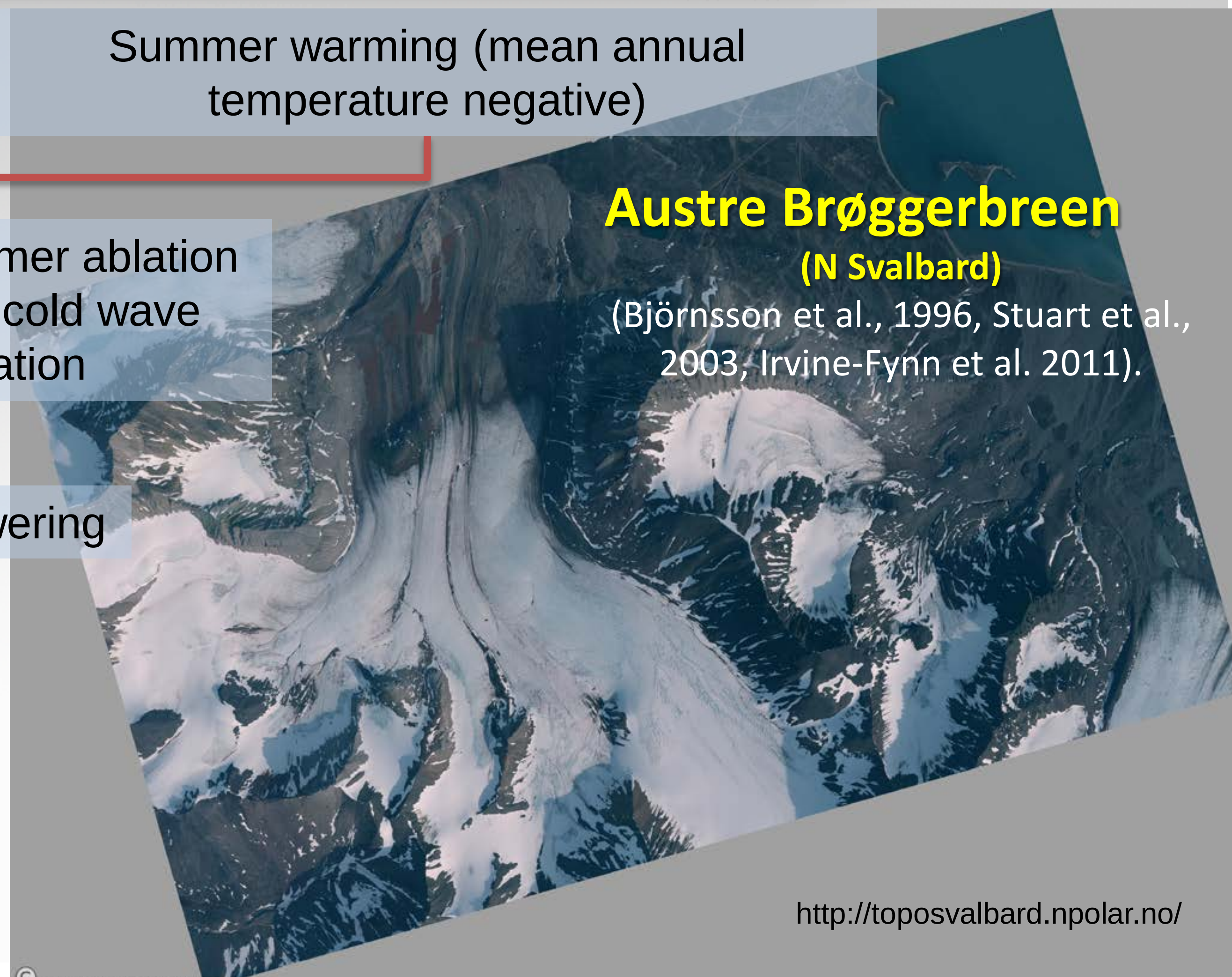
Increased summer ablation and effective cold wave propagation

↓

Intensive surface lowering

↓

cold glacier



Conclusions

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- Polithermal glaciers are the most frequent on Wedel Jarlsberg Land and Torell Land. Polythermal zones occur on 57.8% length of RES profiles, whereas temperate zone is present on 22.7% and cold zone on 6.6% of profiles length. Studied glaciers represent all spectrum of polithermal structure of cold/temperate ratio from 99-1% (Ariebreen), to 1-99% (Amundsenisen).
- Changes of hydrothermal regime on Svalbard glaciers tends to increase of cold ice part in glacier composition.
- Adaptation of glacier thermal structure to warming climate results in gradual moving CTS towards glacier surface, however the CTS shift is slower than surface lowering effect.
- According to simulation of thermal conditions on Hansbreen the thermal state is close to steady state with recent climate, mass balance and dynamics. (CTS shift c. 7 m $100a^{-1}$).

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Thank you!

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