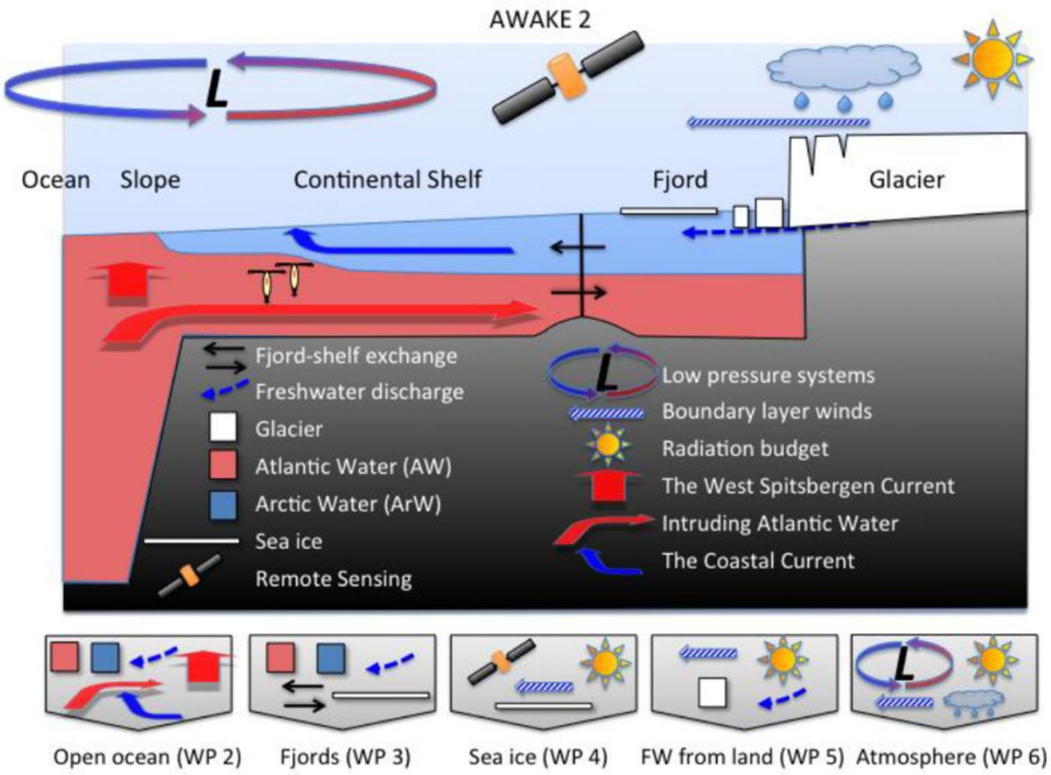
WP3 Fjord oceanography



Eva Falck (UNIS), Agnieszka Prominska (IOPAS),
and Arild Sundfjord (NPI)

WP3 Objectives

To understand the key parameters/processes that determine:

The interannual variability in

1. water mass distribution
   (Arctic Water versus Atlantic Water dominance)
2. freshwater content
3. and circulation patterns in Hornsund.

To do this we have used:

1.+2. available historical data and new data collected on two cruises each year (July and September)

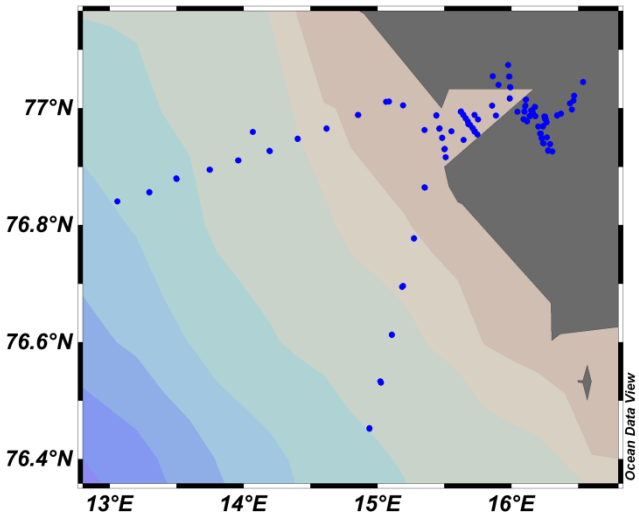
3. a high-resolution model (160 x 160 m horizontal resolution) with realistic water mass transports and heat fluxes, so that the oceanic contribution to glacier front melting can be properly assessed.

Available historical data

- IOPAS: July 2001 – 2012 (except 2004)
  - 2010-2012 (H, G, etc)

New data

- IOPAS: July 2013,2014, 2015
  - 2013-2014-2015 (H, G, etc)
- UNIS: September 2013
  April and September 2014
  September 2015



WP3 Tasks

- T3.1: Fjord hydrography from historical and new data (IOPAS)
  - *By Agnieszka Prominska*
- T3.2: Freshwater content and distribution from historical and new data (UNIS)
  - *By Eva Falck*
- T3.3: Arctic fjord circulation processes, observations, and modeling (IOPAS/NPI)
  - *By Arild Sundfjord*

WP3 Deliverables

- Hydrographic time series for 2000-2012 (16)
- Freshwater content time series for 2000-2012 (16)

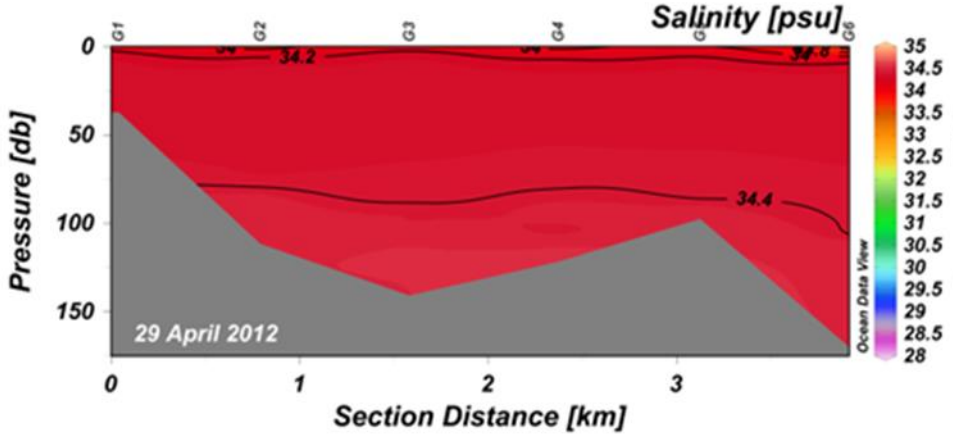
- Hydrographic time series for 2000-2015 (36)
- Freshwater content time series for 2000-2015 (36)

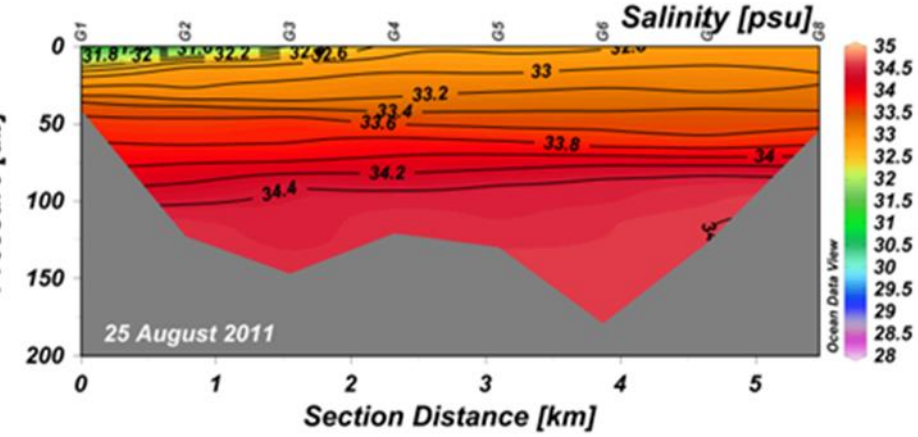
Calculation of freshwater content

$$FWC = \int \frac{Sref - Smeas}{Sref}$$

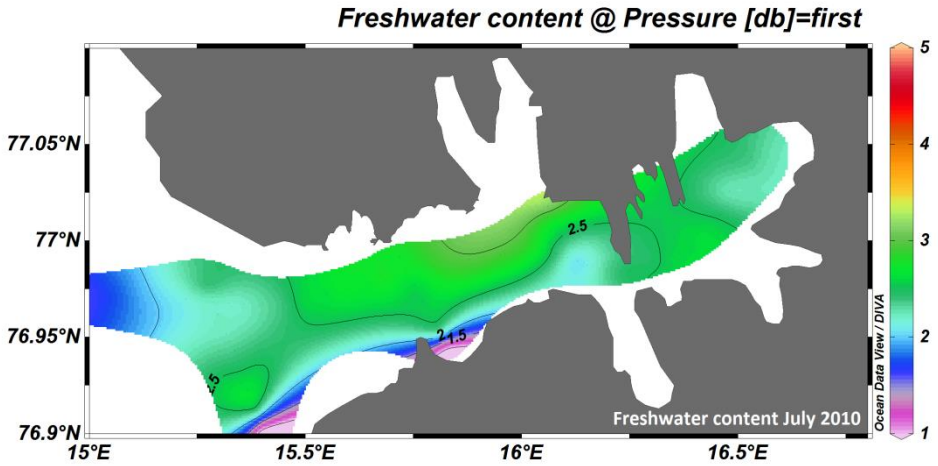
S_{meas} is the measured salinity

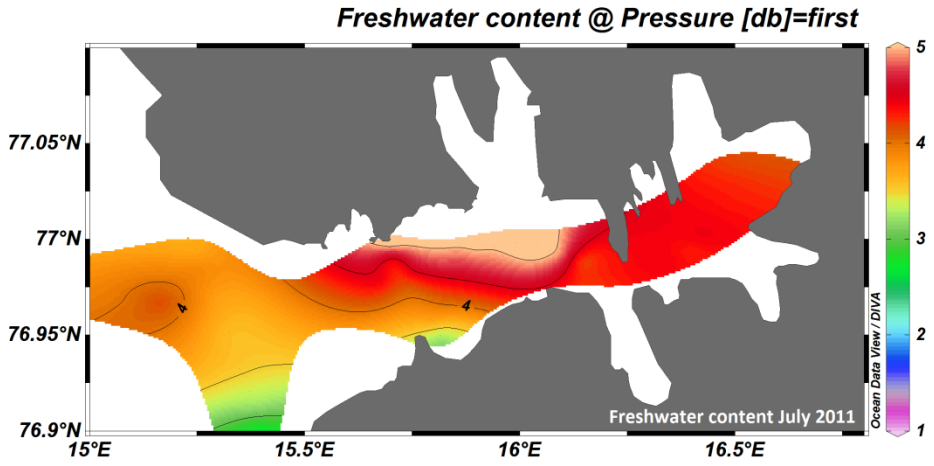
S_{ref} is a reference salinity

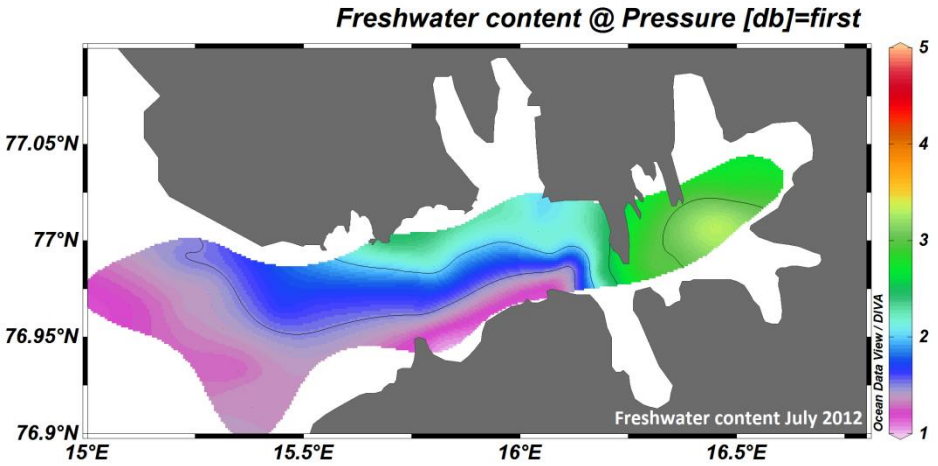


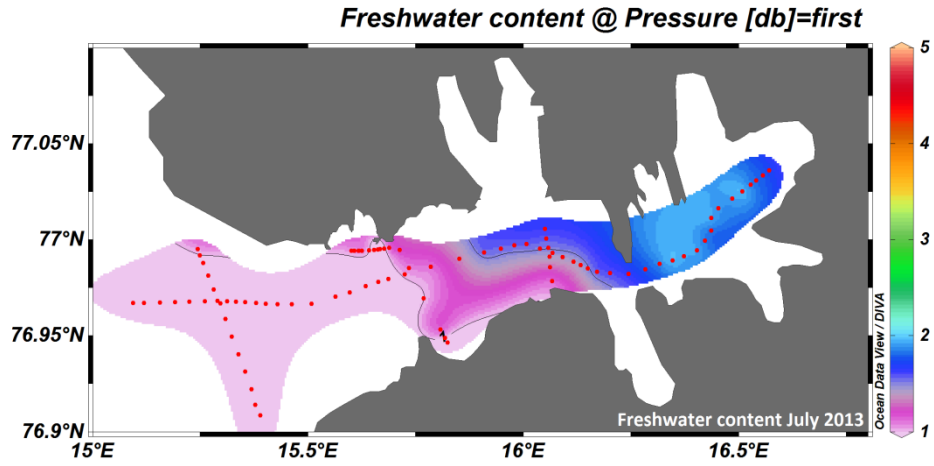


Freshwater content (meter)









Generally in July FWC is between 1 – 3 m

WP3 Deliverables

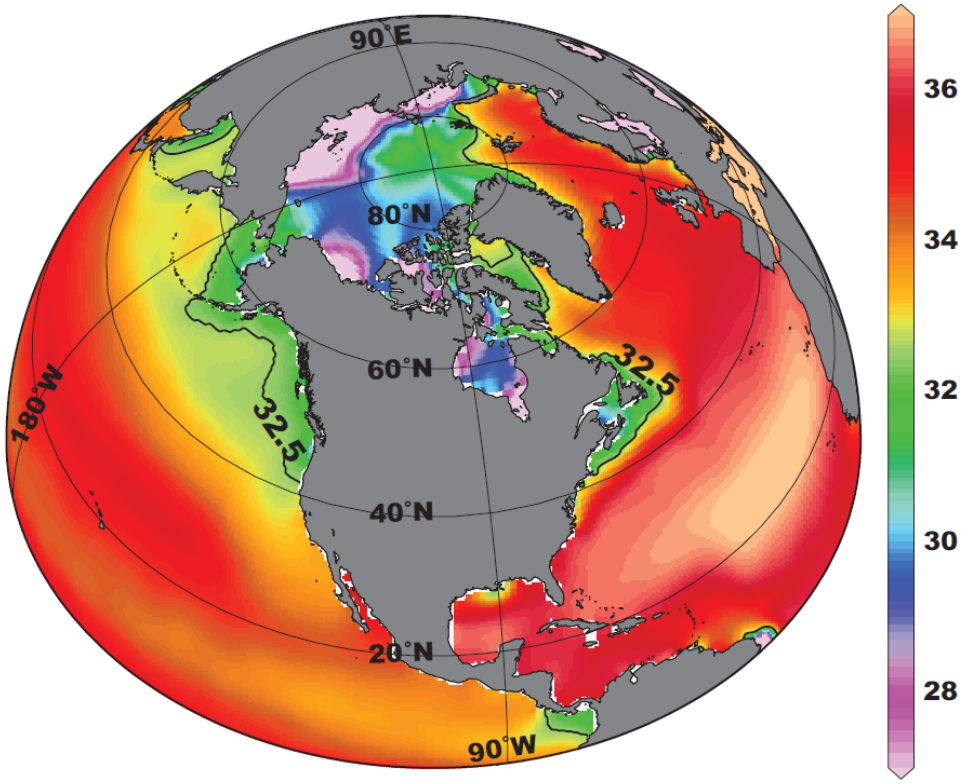
- Hydrographic time series for 2000-2012 (16)
- Freshwater content time series for 2000-2012 (16)

- Hydrographic time series for 2000-2015 (36)
- Freshwater content time series for 2000-2015 (36)

- Relative contribution of sea ice meltwater and glacier/river runoff for 2013-2015 (36)

Freshwater:
Sea ice melt or river runoff (glacial melt)?

What can we use to distinguish these freshwater sources?



Distribution of surface salinity created from World Ocean Atlas (2005).

Stable oxygen isotopes: delta ^{18}O

$$\delta^{18}O = \left[\frac{(H_2{}^{18}O/H_2{}^{16}O)_{sample}}{(H_2{}^{18}O/H_2{}^{16}O)_{VSMOW}} - 1 \right] \times 10^3$$

Two aspects of the oxygen isotope makes it a powerful tracer in Polar regions:

1) The progressive depletion of ^{18}O in water vapour as it moves to higher latitudes results in **polar precipitation** having extremely negative $\delta^{18}O$ values.
(-21‰ in the Arctic, -50 ‰ at the South Pole)

   The extreme depletion means that the isotopic composition is an effective tracer for the freshwater derived from these **meteoric sources**.

2) **Sea ice** has an isotopic composition close to that of the water from which it was formed. This is due to the small isotopic fractionation between sea ice and seawater. Sea ice meltwater will reduce the salinity but only have a very small effect on isotopic composition.
Brine exclusion from freezing results in large seawater salinity increase but with little change in isotopic composition.

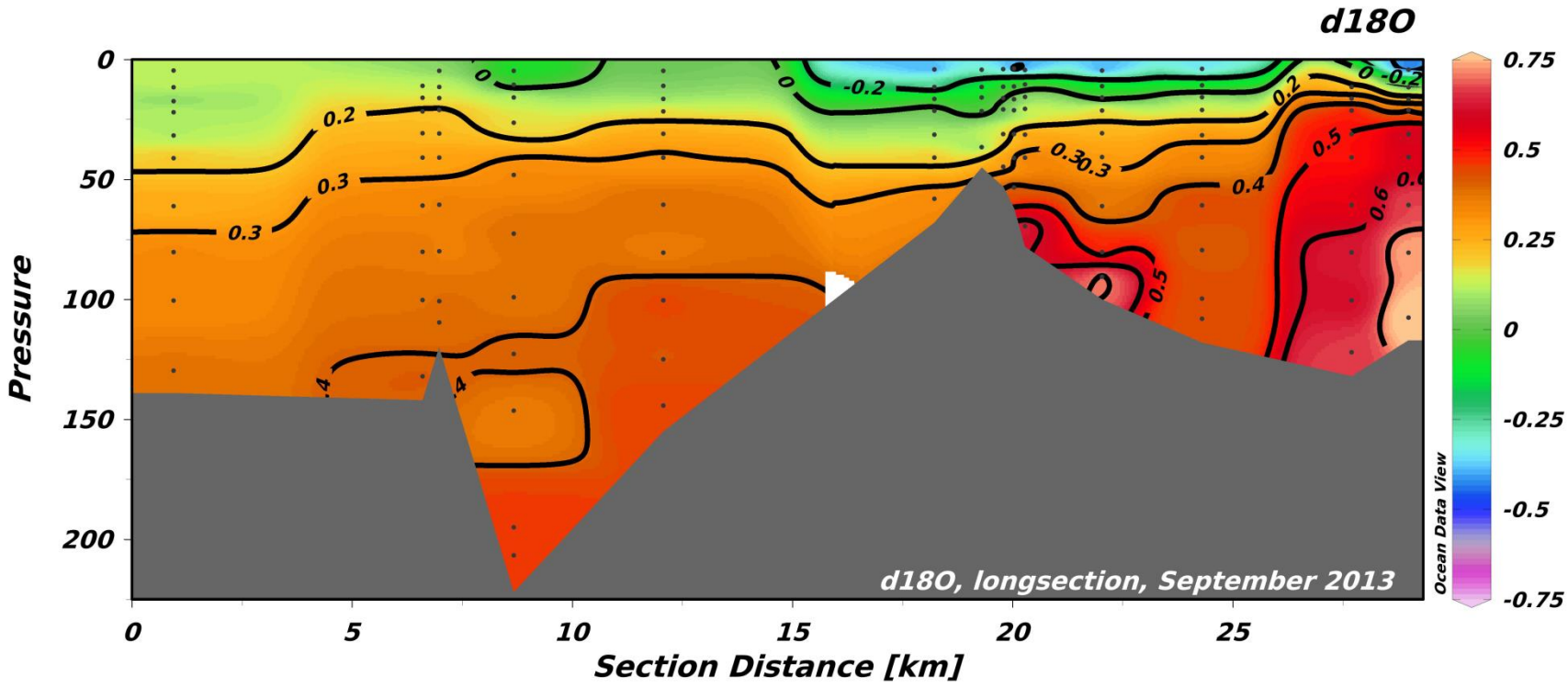
$\delta^{18}O$

- Relative contribution of sea ice meltwater and glacier/river runoff for 2013-2015.

Water samples:

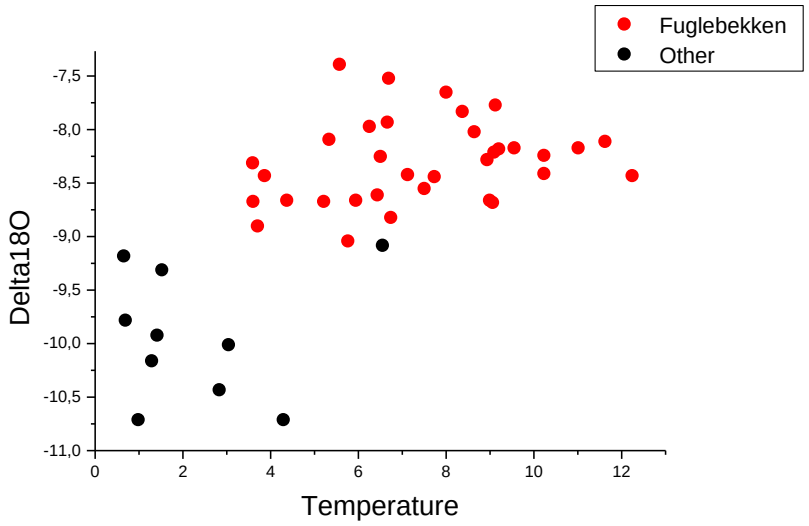
HM September 2013:	400
Lance April 2014:	96
HM September 2014:	365
IOPAS 2014:	250
HM September 2015:	120 (not analyzed yet)

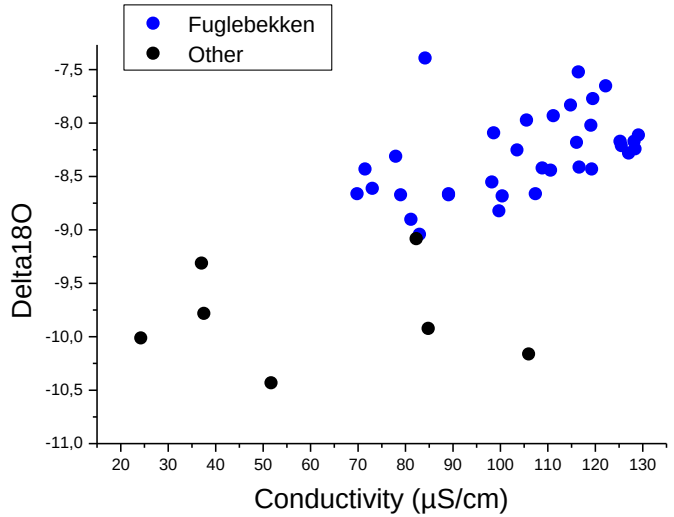
Hornsund Sep 2013

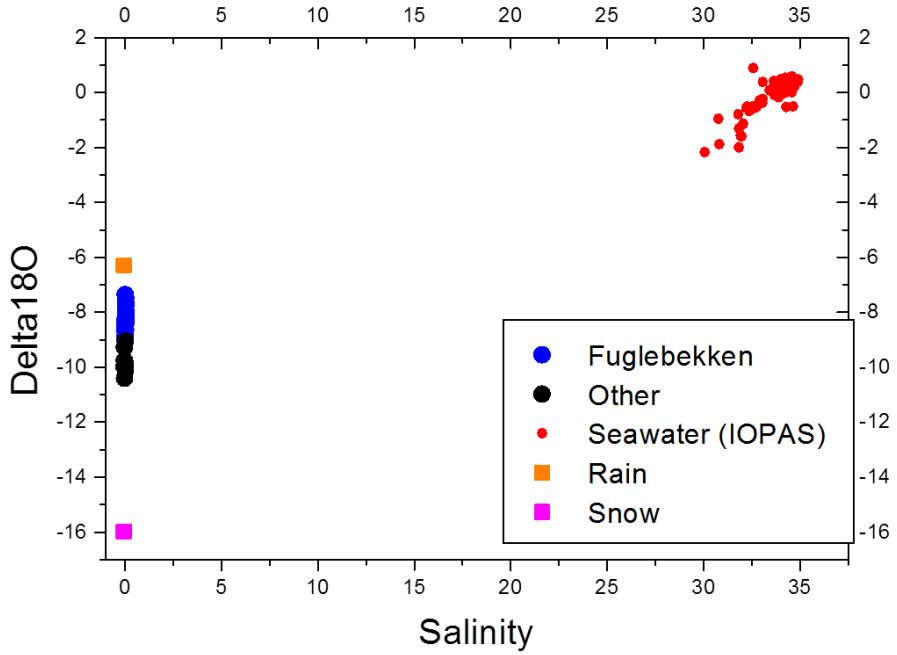


Station	Date	Delta18O
Ariedalen	01.07.2014	-9.32
Bautaelva	17.08.2014	-10.72
Lisbetelva	24.06.2014	-9.79
Lisbetdalen	17.08.2014	-9.09
Lorchbreen	30.08.2014	-9.93
Lorchbreen	18.08.2014	-10.44
Sofie-Bogstranda	15.08.2014	-10.17
Sofie-Bogstranda	31.08.2014	-9.19
Gåshamna river	24.06.2014	-10.72
Gåshamna	15.08.2014	-10.02
Gåshamna II	15.08.2014	-10.34
	Mean	**-9.98**
Fuglebekken	28.06 – 03.08.2014	-8.31
RAIN	27.07.2014	-6.34
SNOW	22.05.2014	-16.02

Water samples collected in Hornsund (IOPAS) in 2014

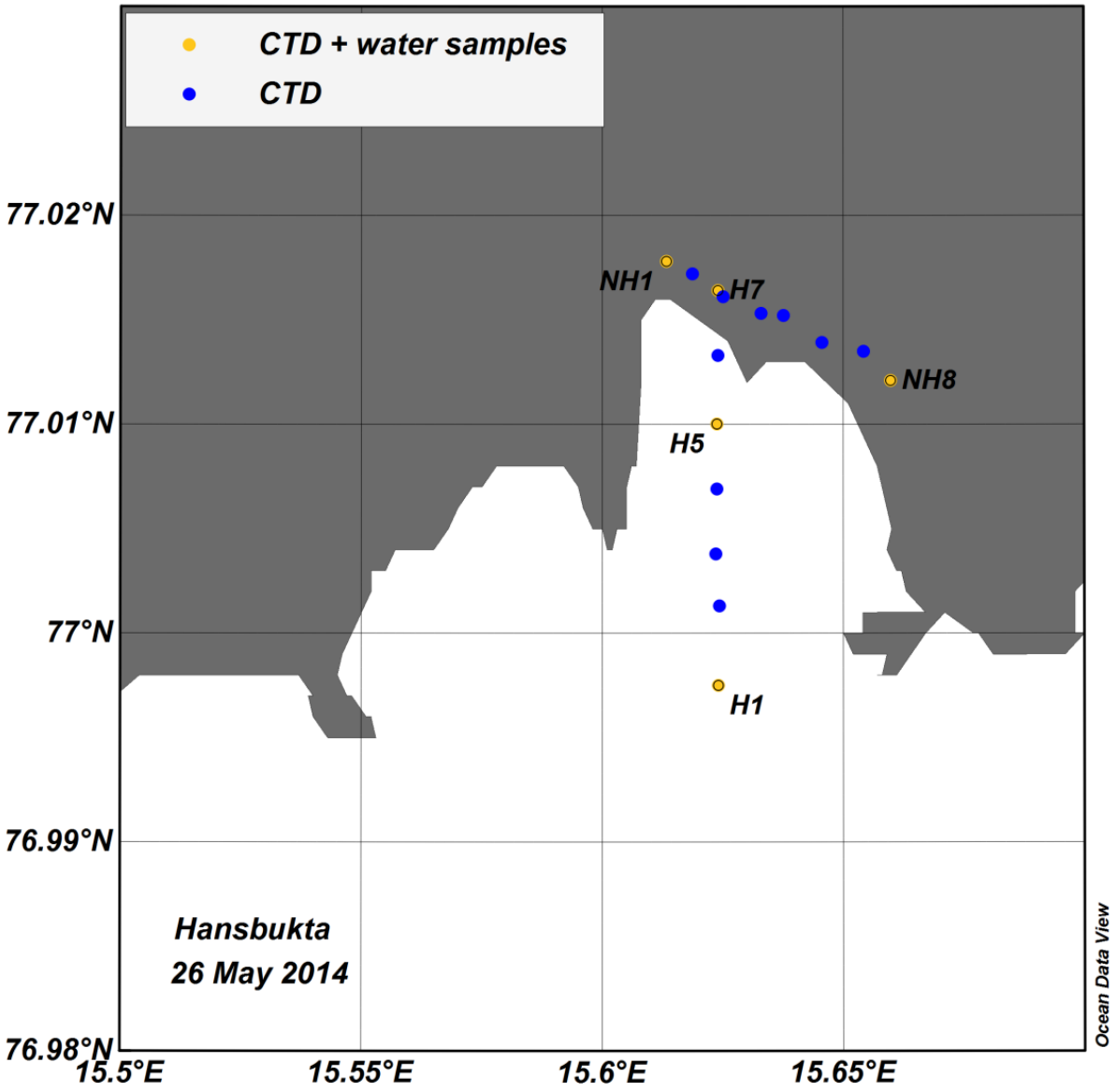




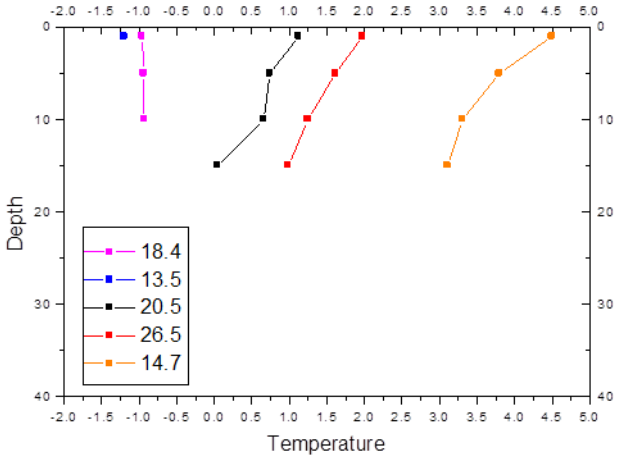


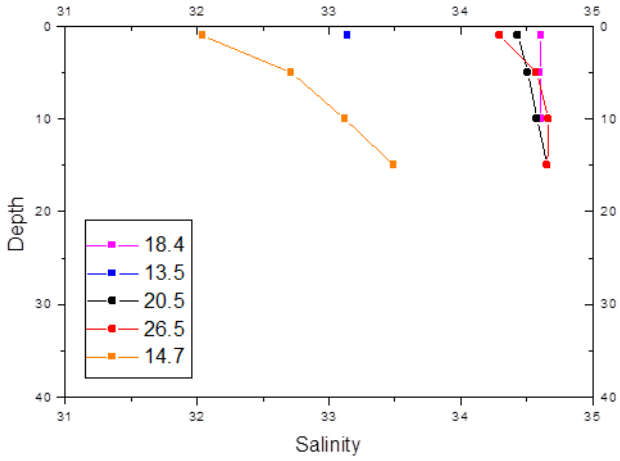
To get a better understanding of the fjord-glacier coupling the area close to Hansbreen will be investigated weekly during summer.

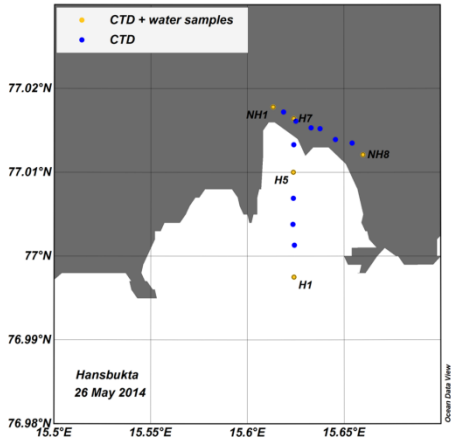
The planned field measurements will be carried out from early spring to autumn with an aim to obtain time series covering the glaciers melting season.

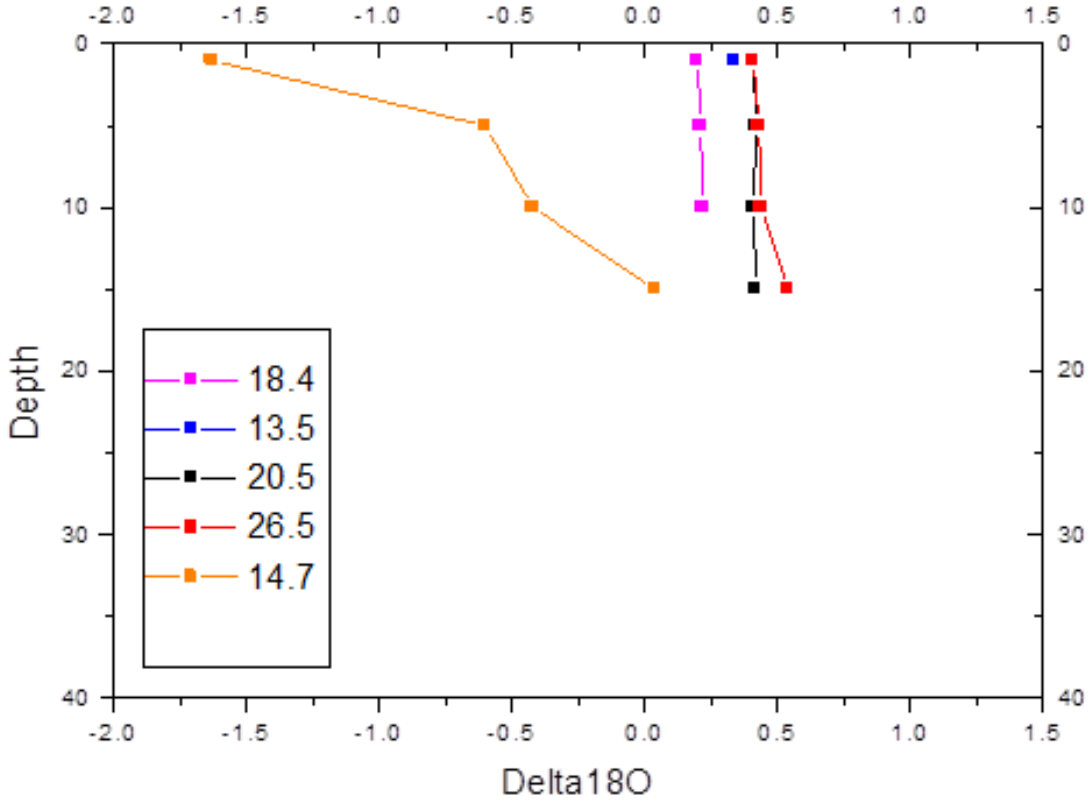

CTD + water samples
CTD
77.02°N
77.01°N
77°N
76.99°N
76.98°N
15.5°E
15.55°E
15.6°E
15.65°E
NH1
H7
NH8
H5
H1
Hansbukta
26 May 2014
Ocean Data View

H1 2014

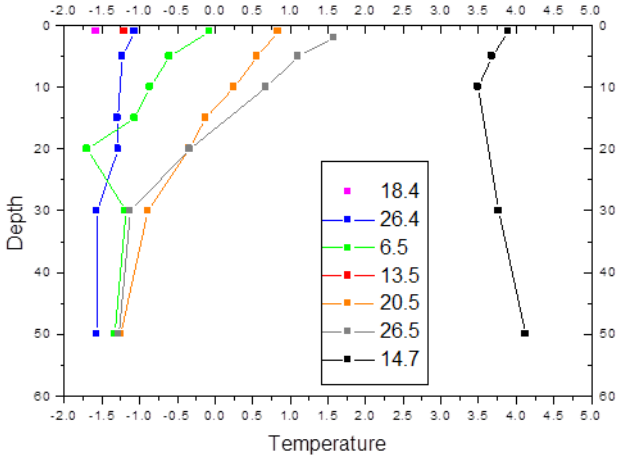

Depth
Temperature
18.4
13.5
20.5
26.5
14.7

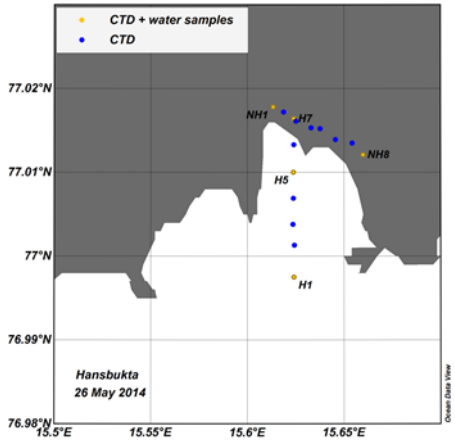

Depth
Salinity
18.4
13.5
20.5
26.5
14.7

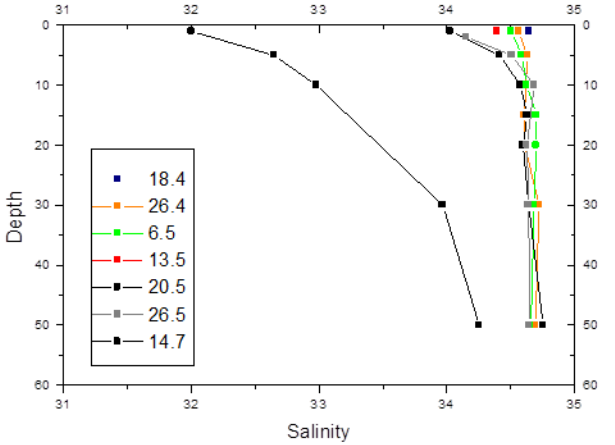

CTD + water samples
CTD
77.02°N
77.01°N
77°N
76.99°N
76.98°N
15.5°E
15.55°E
15.6°E
15.65°E
NH1
H7
NH8
H5
H1
Hansbukta
26 May 2014
Ocean Data View

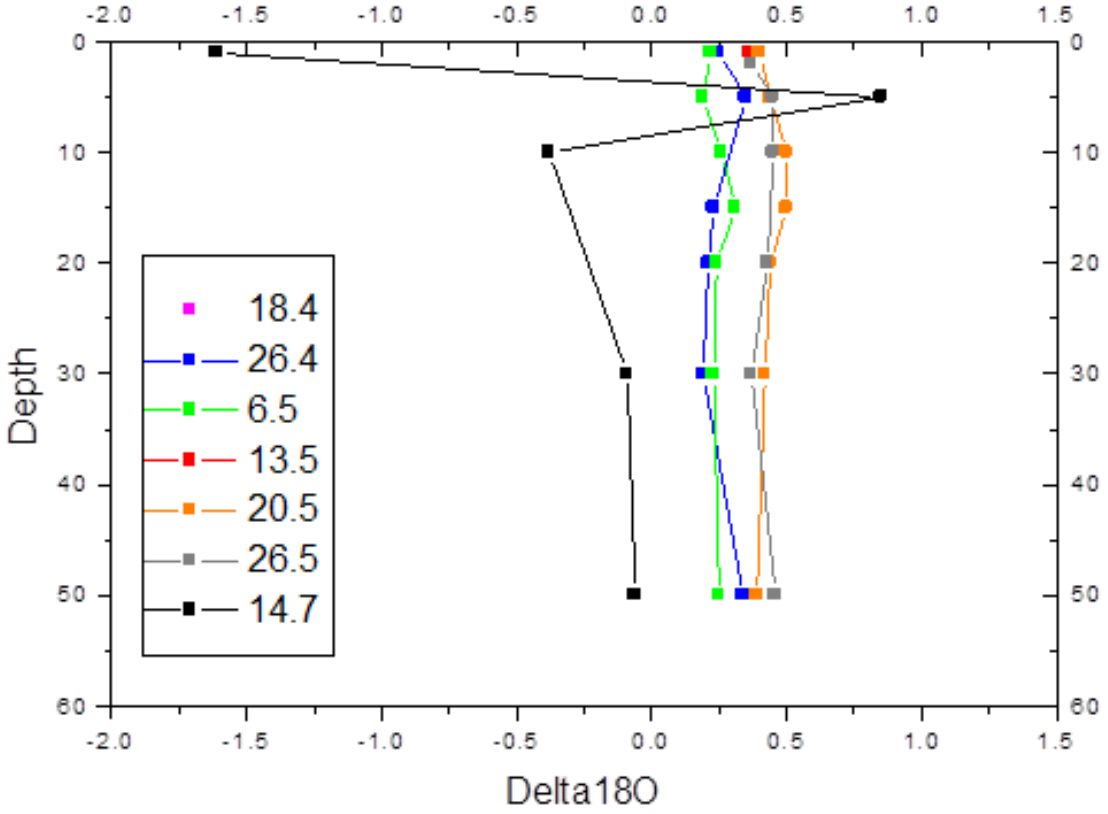

Depth
Delta18O
18.4
13.5
20.5
26.5
14.7

H5 2014

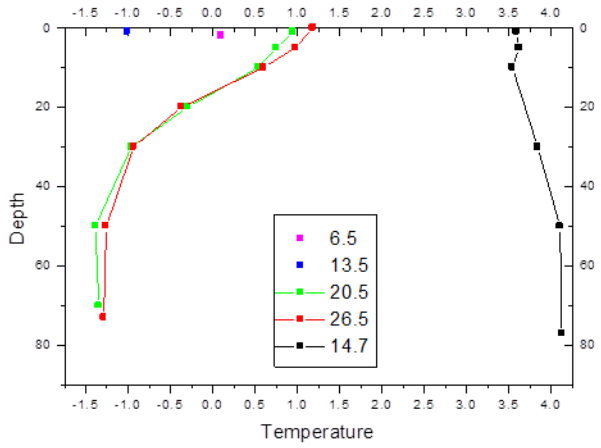

Depth
Temperature
18.4
26.4
6.5
13.5
20.5
26.5
14.7

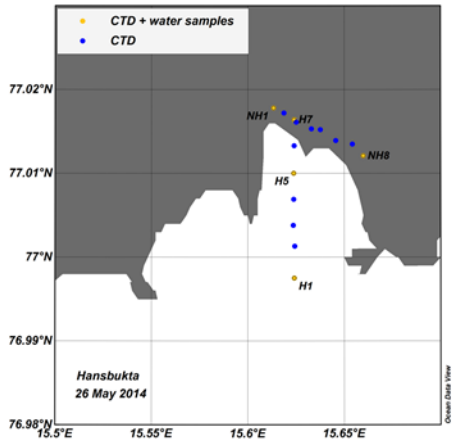

CTD + water samples
CTD
77.02°N
77.01°N
77°N
76.99°N
76.98°N
15.5°E
15.55°E
15.6°E
15.65°E
NH1
H7
NH8
H5
H1
Hansbukta
26 May 2014

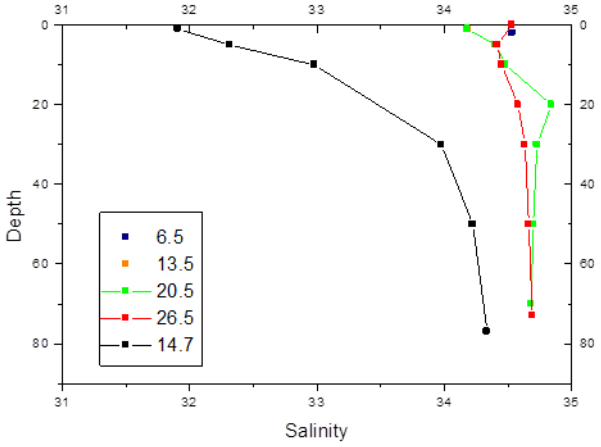

Depth
Salinity
18.4
26.4
6.5
13.5
20.5
26.5
14.7

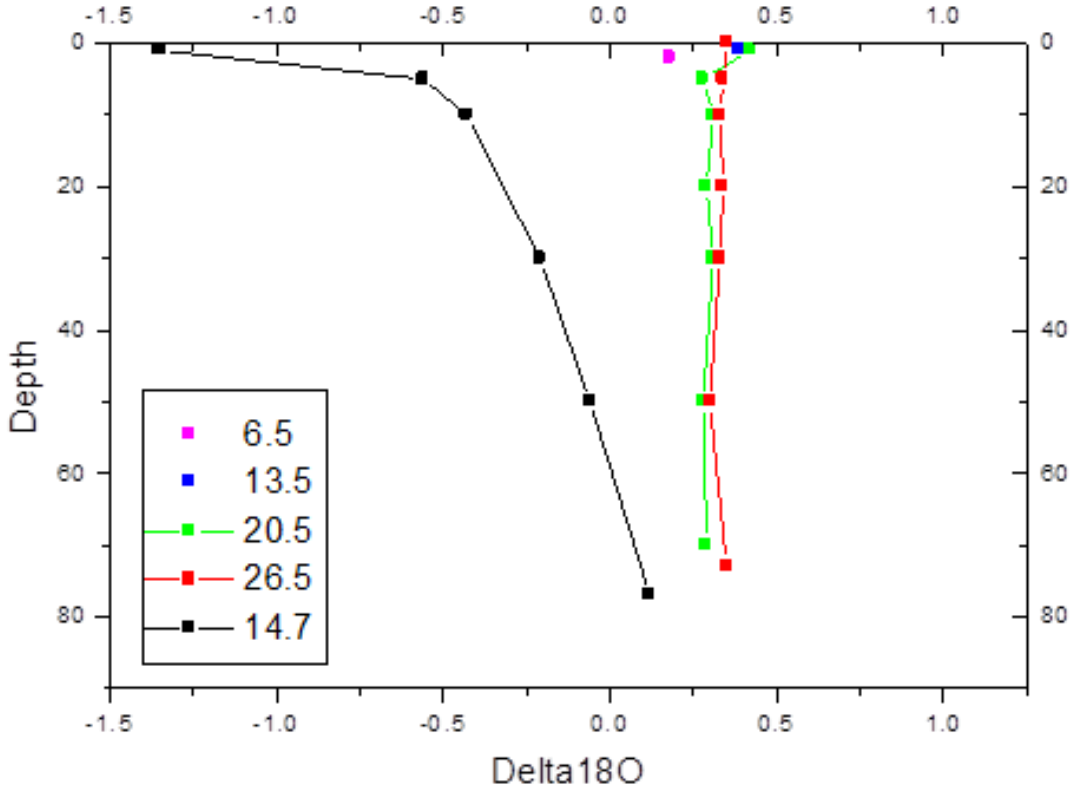

Depth
Delta18O
18.4
26.4
6.5
13.5
20.5
26.5
14.7

H7 2014


Depth
Temperature
6.5
13.5
20.5
26.5
14.7


CTD + water samples
CTD
77.02°N
77.01°N
77°N
76.99°N
76.98°N
15.5°E
15.55°E
15.6°E
15.65°E
NH1
H7
NH8
H5
H1
Hansbukta
26 May 2014


Depth
Salinity
6.5
13.5
20.5
26.5
14.7


Depth
Delta18O
6.5
13.5
20.5
26.5
14.7

We can calculate the amount of freshwater from land and sea ice melt:

$$f_{SW} + f_{MW} + f_{SIM} = 1$$

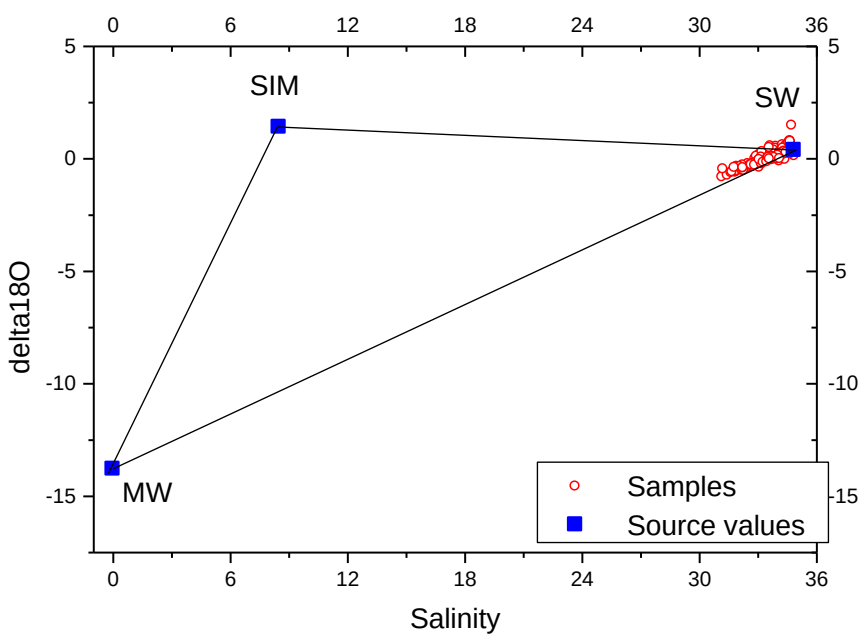
$$f_{SW}S_{SW} + f_{MW}S_{MW} + f_{SIM}S_{SIM} = S_{measured}$$

$$f_{SW}\delta_{SW} + f_{MW}\delta_{MW} + f_{SIM}\delta_{SIM} = \delta_{measured}$$

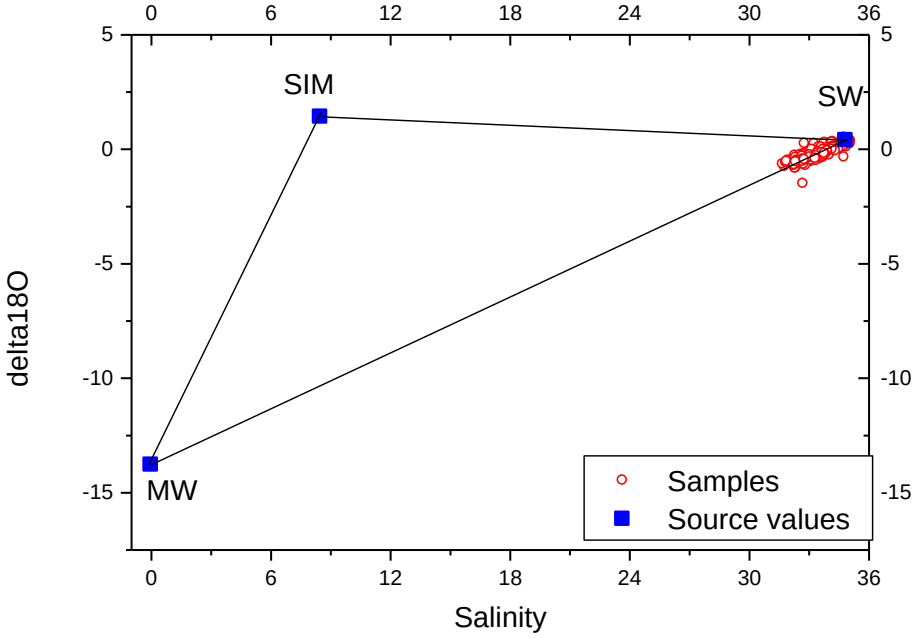
f = fraction
SW = seawater
MW = meteoric water
SIM = sea ice melt

S = salinity
$\delta = \delta^{18}O$

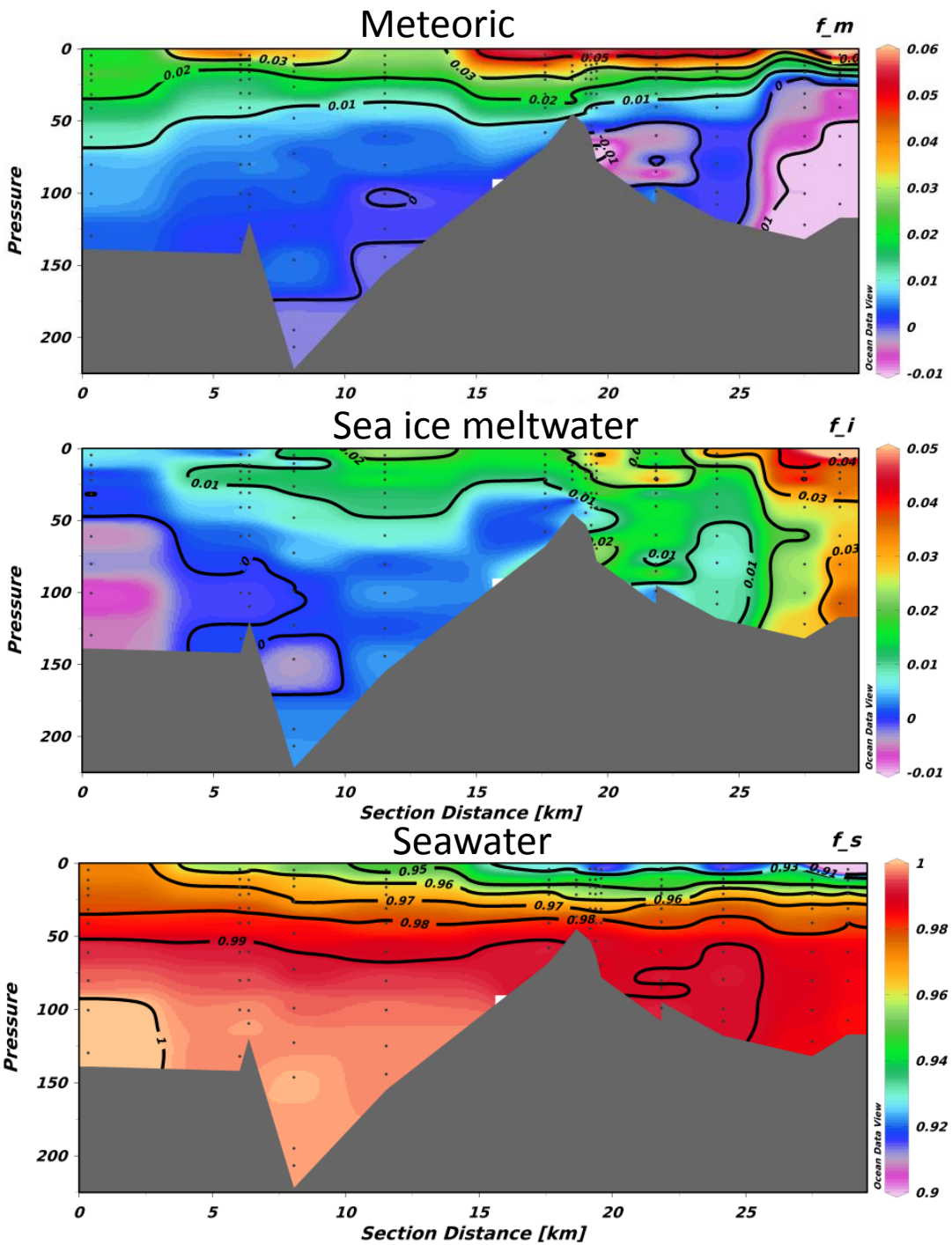
September 2013

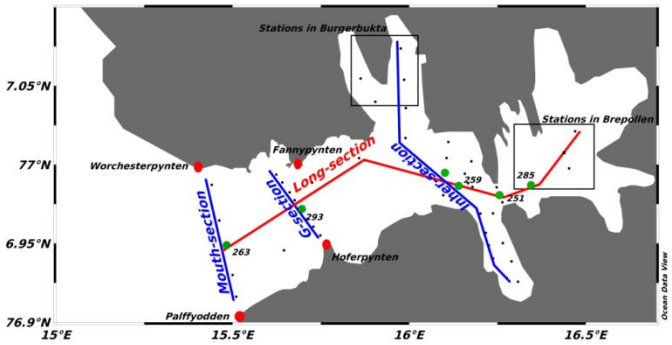


September 2014



Hornsund Sep 2013





(K. O. Dølven)

WP3 Deliverables

- Hydrographic time series for 2000-2012 (16)
- Freshwater content time series for 2000-2012 (16)

- Hydrographic time series for 2000-2015 (36)
- Freshwater content time series for 2000-2015 (36)

- Relative contribution of sea ice meltwater and glacier/river runoff for 2013-2015 (36)

- A qualitative description of key parameters/processes that determine water mass distribution, freshwater content, and circulation patterns (36)

Ocean-fjord-glacier interaction in Hornsund
NPIs contribution to WP3

Arild Sundfjord, Norwegian Polar Institute
Sopot, 3-4 December 2015

Polish-Norwegian Research Fund

Tools: data collection (mooring 2013-2015)
+ numerical circulation model (ROMS)

Data collection 2013-2015:

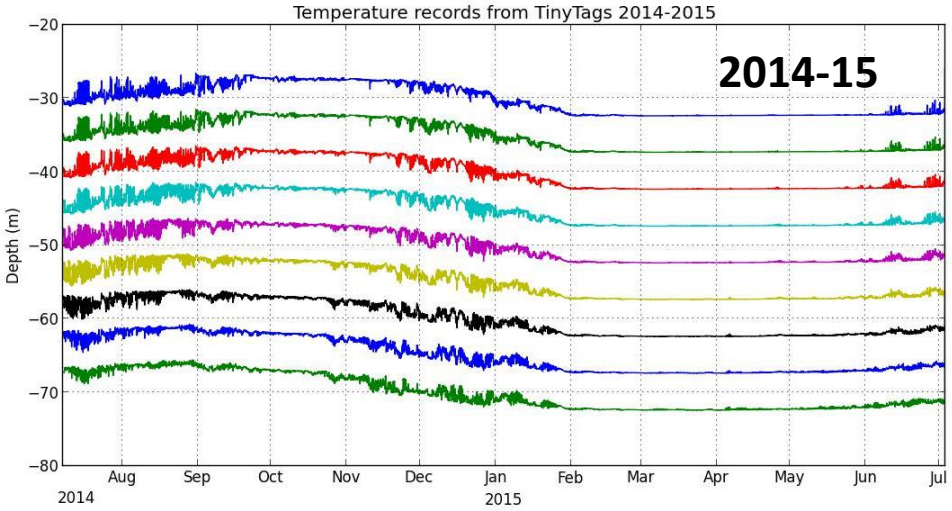
- Mooring deployed Sept 2013 - Jul 2014 + Jul 2014 - July 2015

- All sensors worked well

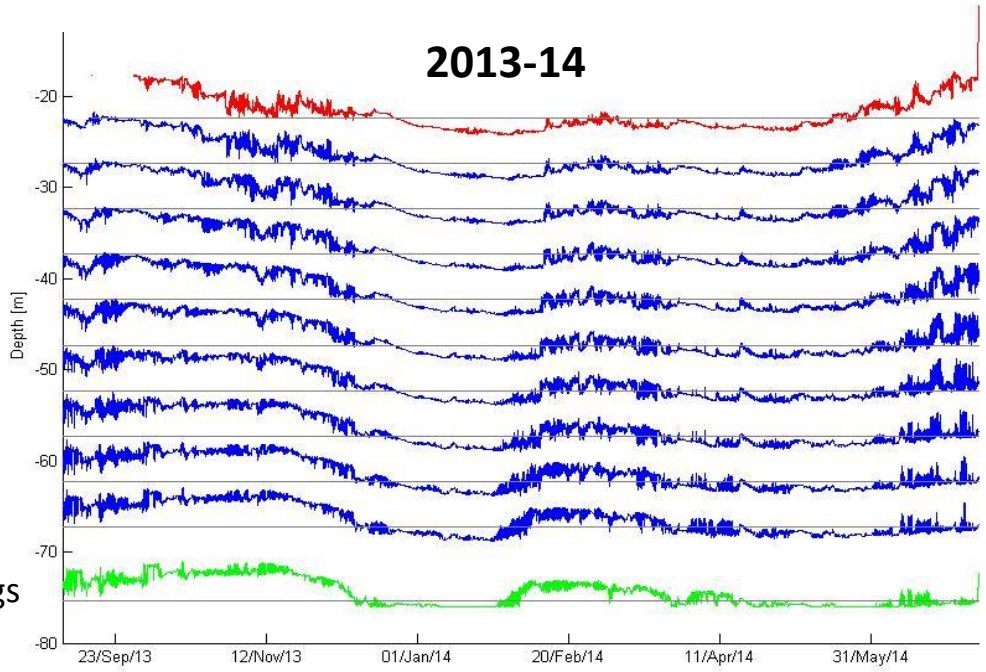
- Planned field work on fast ice in April 2014 was cancelled; no ice in the fjord!

- Additional CTD transects were made in early April (with UNIS, RV Lance) and late May (University of Tromsø, RV Helmer Hanssen) 2014.

Temperatures from mooring at Brepollen entrance



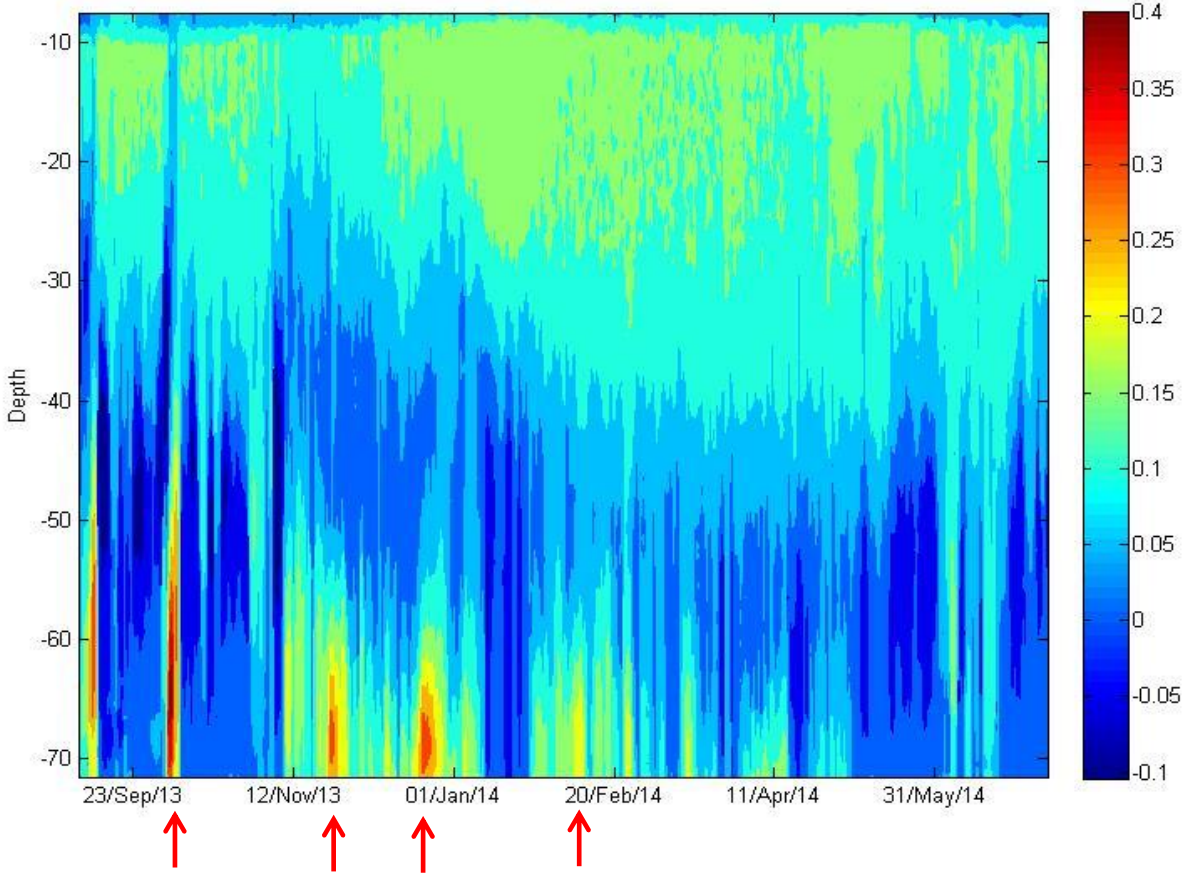
2014-15 was a "normal" cold year compared to the exceptionally warm 2013-14 winter.

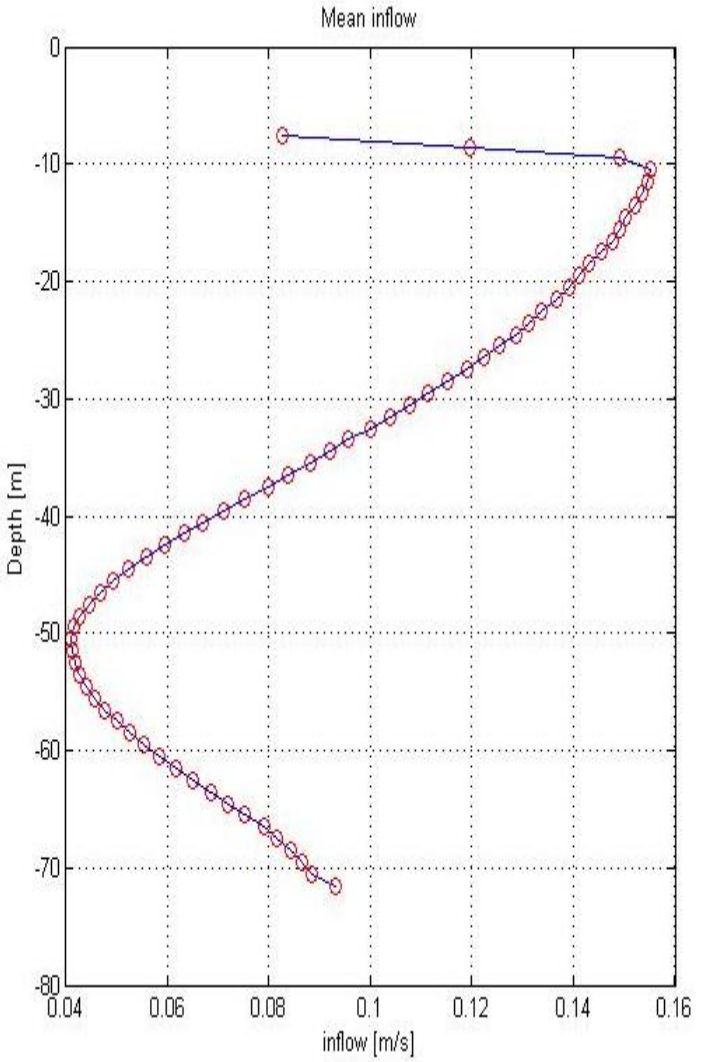


Blue: Tiny Tags
Red: HOBO
Green: RDCP
(Lines indicates zero °C)

Currents into and out of Brepollen, ADCP data from 2013-14

Currents and temperature together give heat flux.





Note episodic events of strong near-bottom inflow to Brepollen, allowing efficient heat transport.

Summary of field data

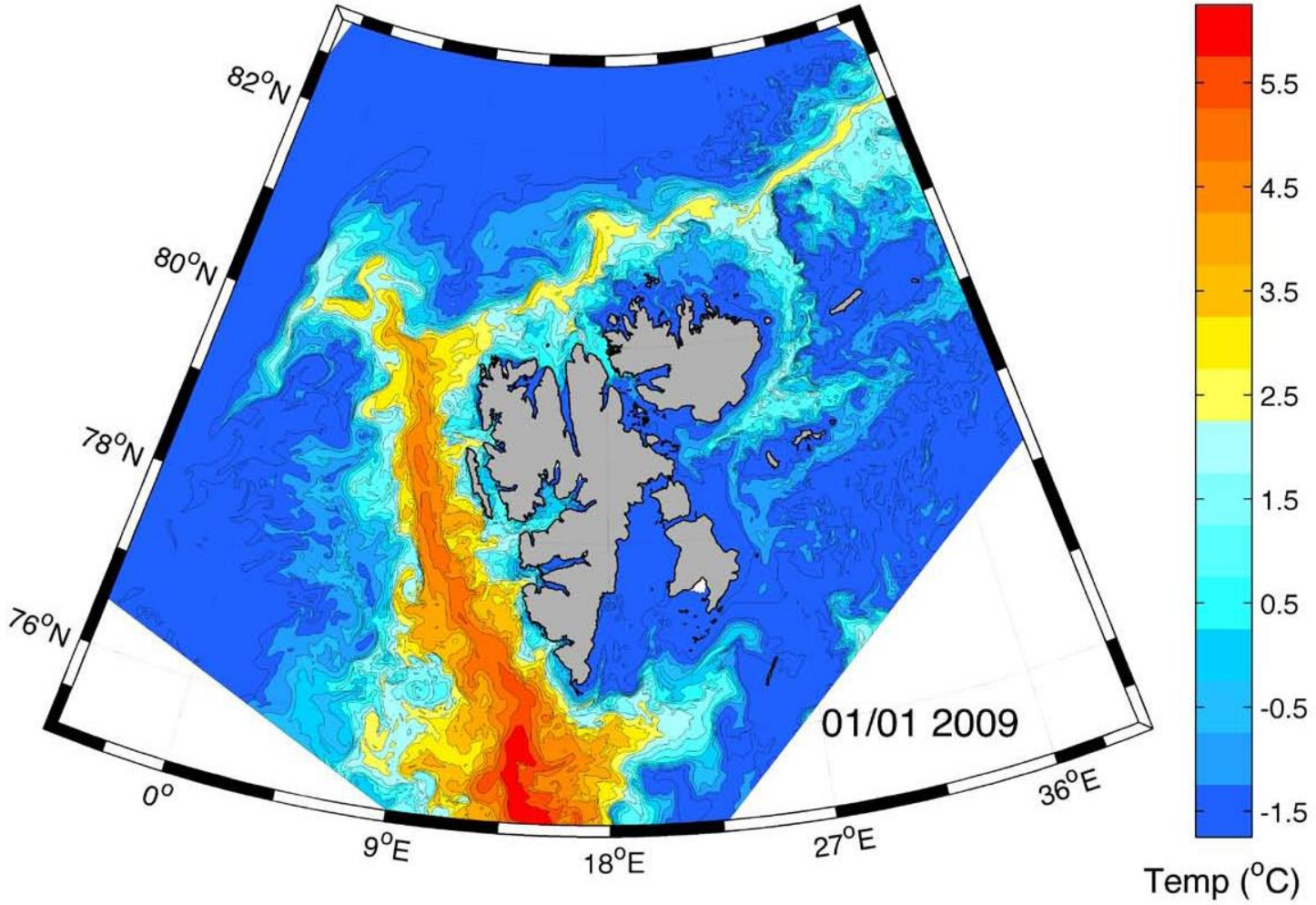
We have a unique time series of temperature and currents at the entrance to Brepollen. The data cover all seasons and some very different years in terms of fjord temperatures and sea ice cover.

By combining our data with data from project partners we can learn more about the mechanisms controlling the variability of the fjord environment including sea ice cover and potential for oceanic melting of glacier fronts.

The data will be used to evalute model performance and model results will be used to extrapolate measurement data in time and space.

Hornsund modelling

Mesoscale modeling of Ice, Ocean and Ecology of the Arctic Ocean (Fram Centre project): model of Fram Strait and Svalbard area, 800 m horizontal resolution

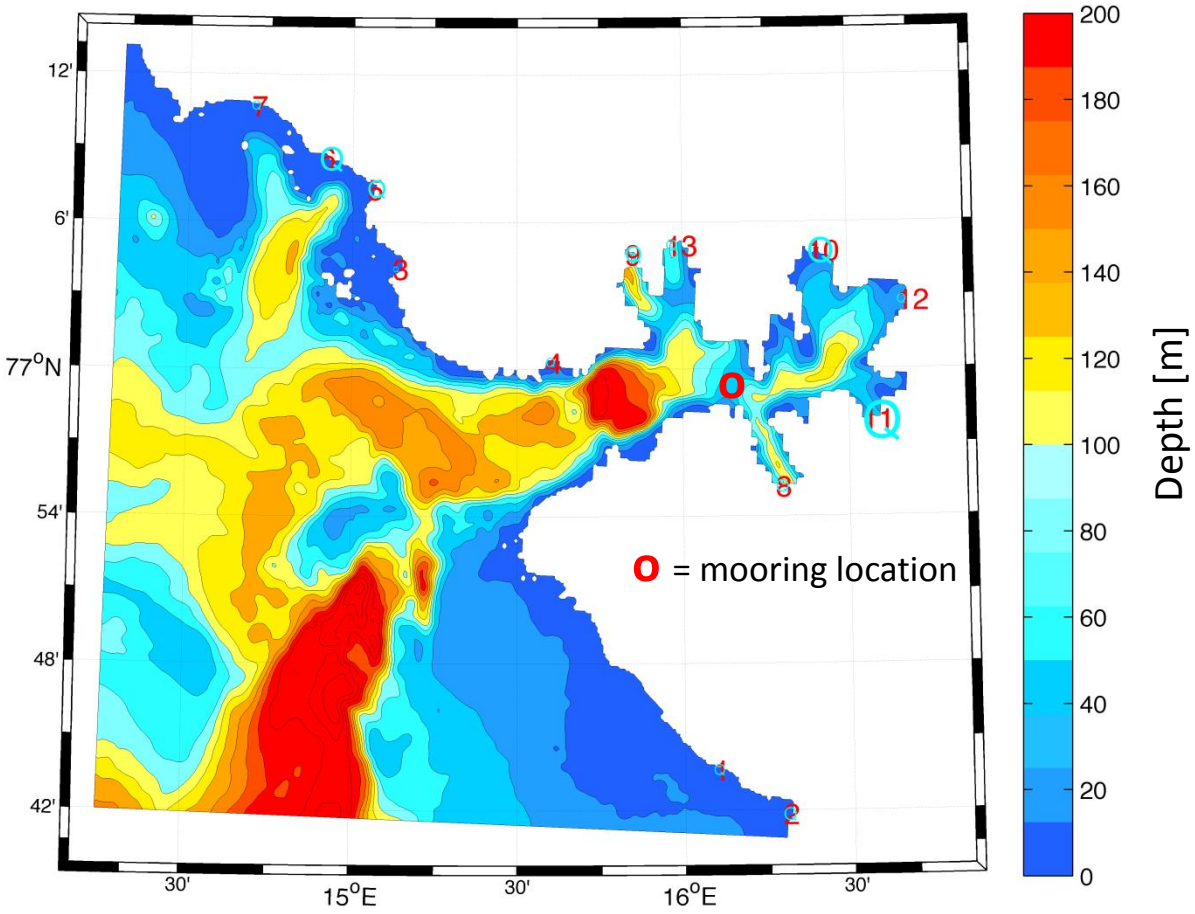


Partners: Norsk Polarinstitutt, Akvaplan-niva, Havforskningsinstituttet, Met.no, SINTEF.

Fram Centre

Hornsund modelling

ROMS – Regional Ocean Modeling System embedded in 800 m Svalbard domain.
Model depth grid with 160 x 160 m horizontal resolution and 35 vertical layers.
Red numbers denote size and location of glacier runoff points.

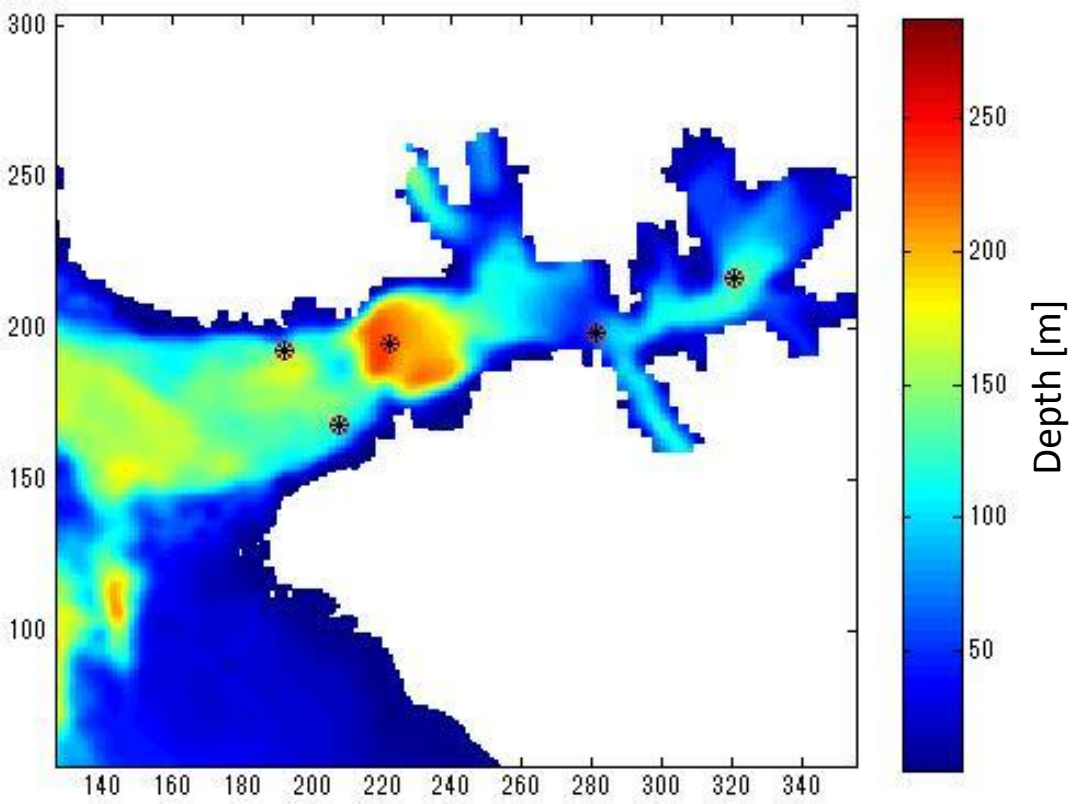


Hornsund modelling

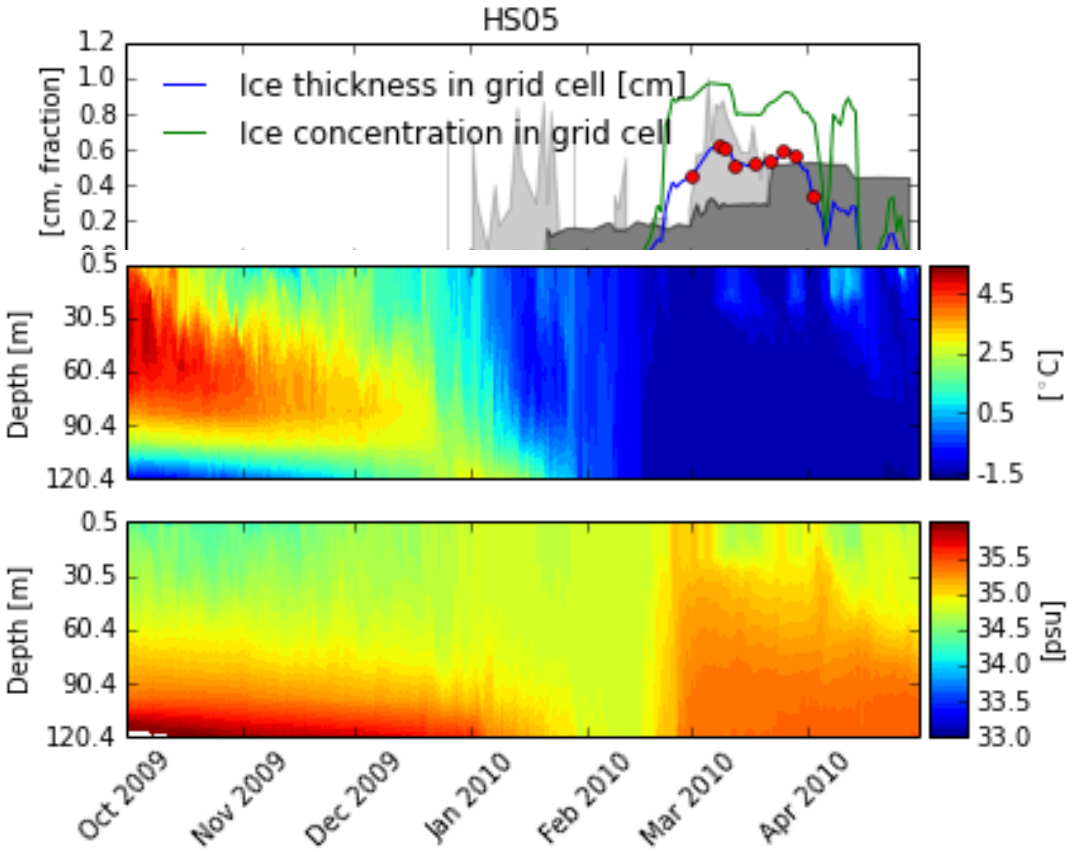
Simulations made for period Jan 2005 – Jul 2010.

Analysis is ongoing, focusing on forcing mechanisms and exchanges.

Figure shows locations of "stations" selected for in depth analysis of model output.



Hornsund modelling



ROMS simulated sea ice concentration and thickness (upper panel), temperature (middle) and salinity (lower) from deep basin in Brepollen over the winter season 2010. Shadings are observed ice cover from Muckenhuber et al. (In press?).

Figure from M. Arntsen's Master thesis.

Summary of activities and further plans

Data collection performed as planned (with greater success then one could realistically hope for!)

Model simulations are done as planned

Analysis of field measurements and model results is ongoing

Manuscript based on field data is progressing – plan to submit in Q2 2016

Manuscript using model results is setched – hope to submit in Q4 2016

Field data and model results are used in one manuscript by J. Jakacki, IOPAS (2015)

Model results are used in a Master thesis at UNIS (M. Arntsen)

We strongly support extension of project until end of 2016!

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