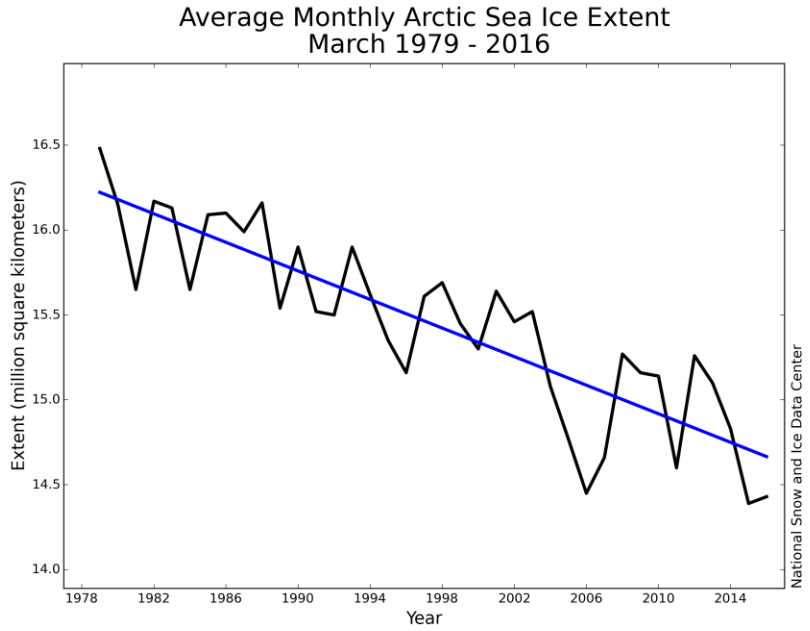
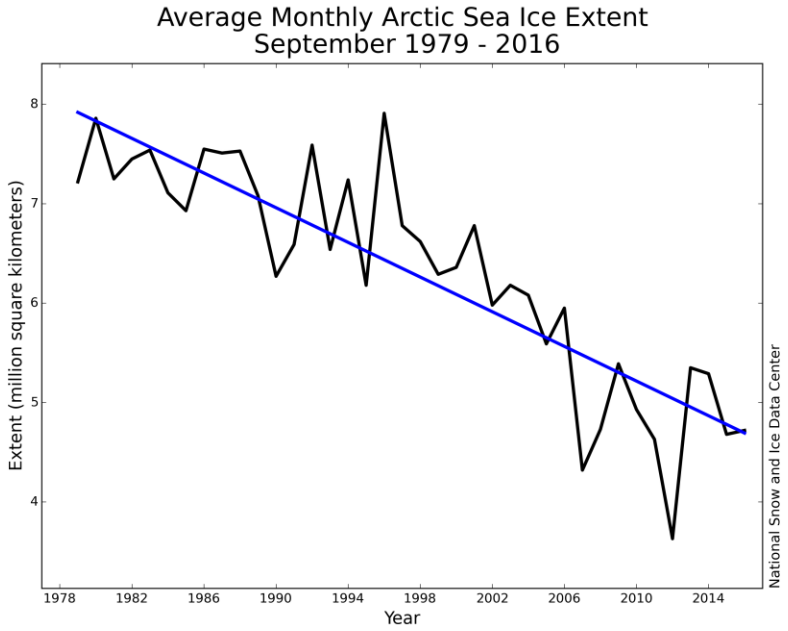
Observations in Baffin Bay with Autonomous Platforms

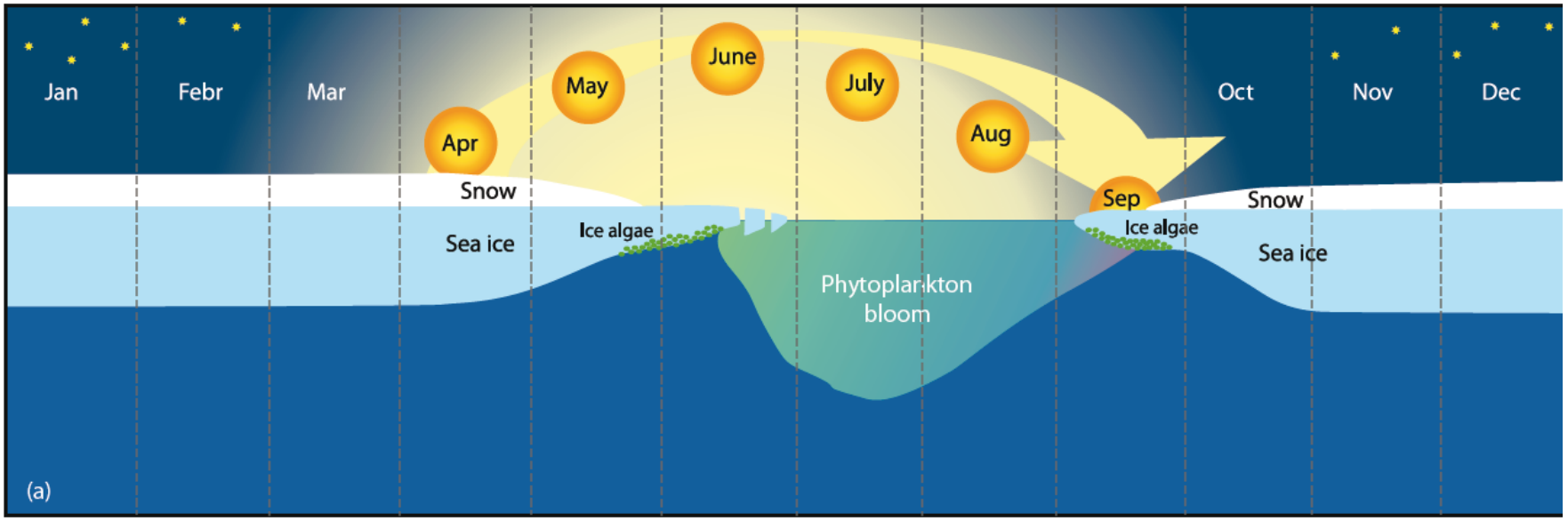
Eric Rehm, Marcel Babin

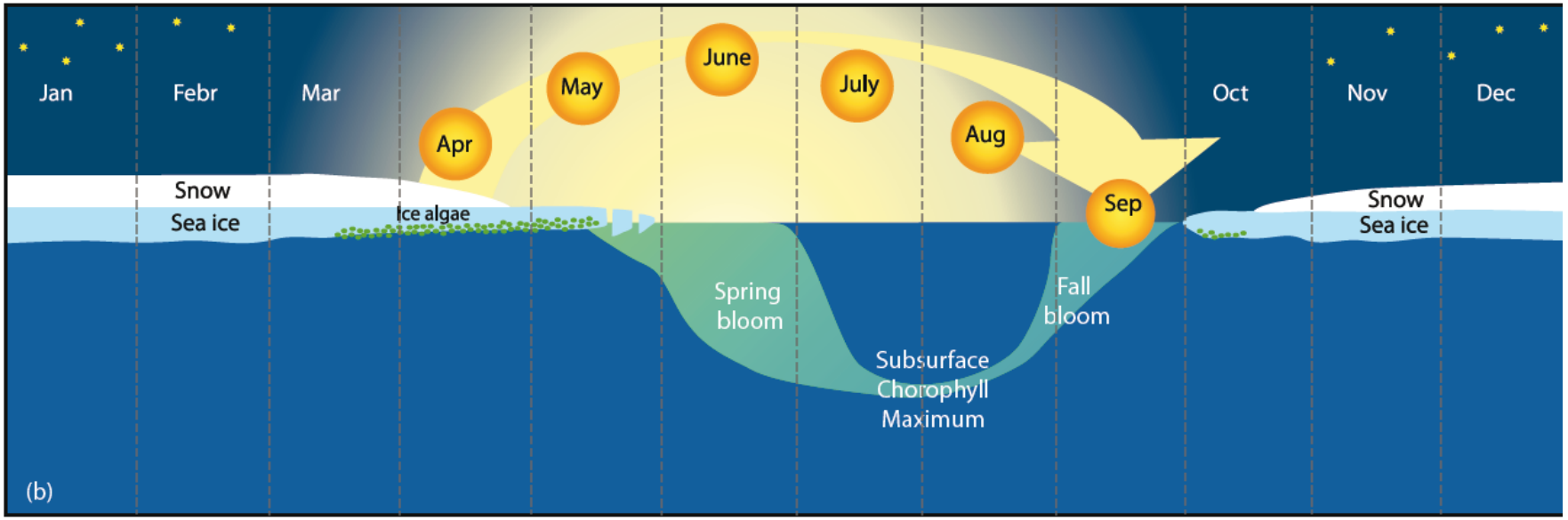
OASIIS, 2017

Takuvik Joint Laboratory / Université Laval

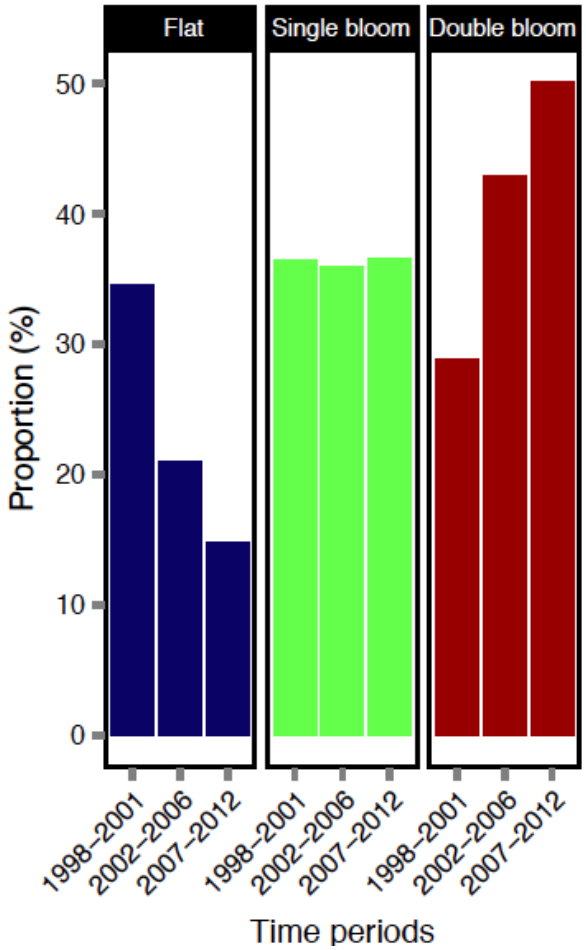

Average Monthly Arctic Sea Ice Extent
March 1979 - 2016
Extent (million square kilometers)
16.5
16.0
15.5
15.0
14.5
14.0
1978
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year
National Snow and Ice Data Center

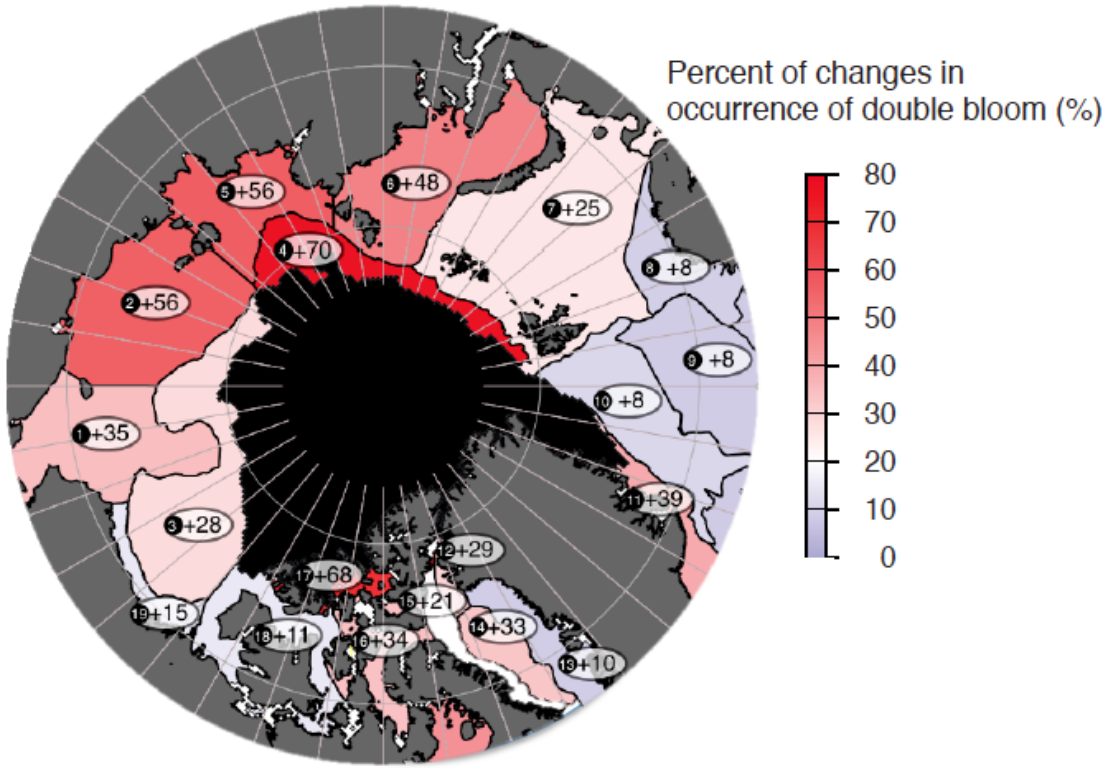

Average Monthly Arctic Sea Ice Extent
September 1979 - 2016
Extent (million square kilometers)
8
7
6
5
4
1978
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year
National Snow and Ice Data Center


Jan
Febr
Mar
Apr
May
June
July
Aug
Sep
Oct
Nov
Dec
Snow
Sea ice
Ice algae
Phytoplankton bloom
(a)


Jan
Febr
Mar
Apr
May
June
July
Aug
Sep
Oct
Nov
Dec
Snow
Sea ice
Ice algae
Spring bloom
Fall bloom
Subsurface Chorophyll Maximum
(b)

Increased occurrence of fall blooms





Ardyna et al. 2014

GREEN EDGE

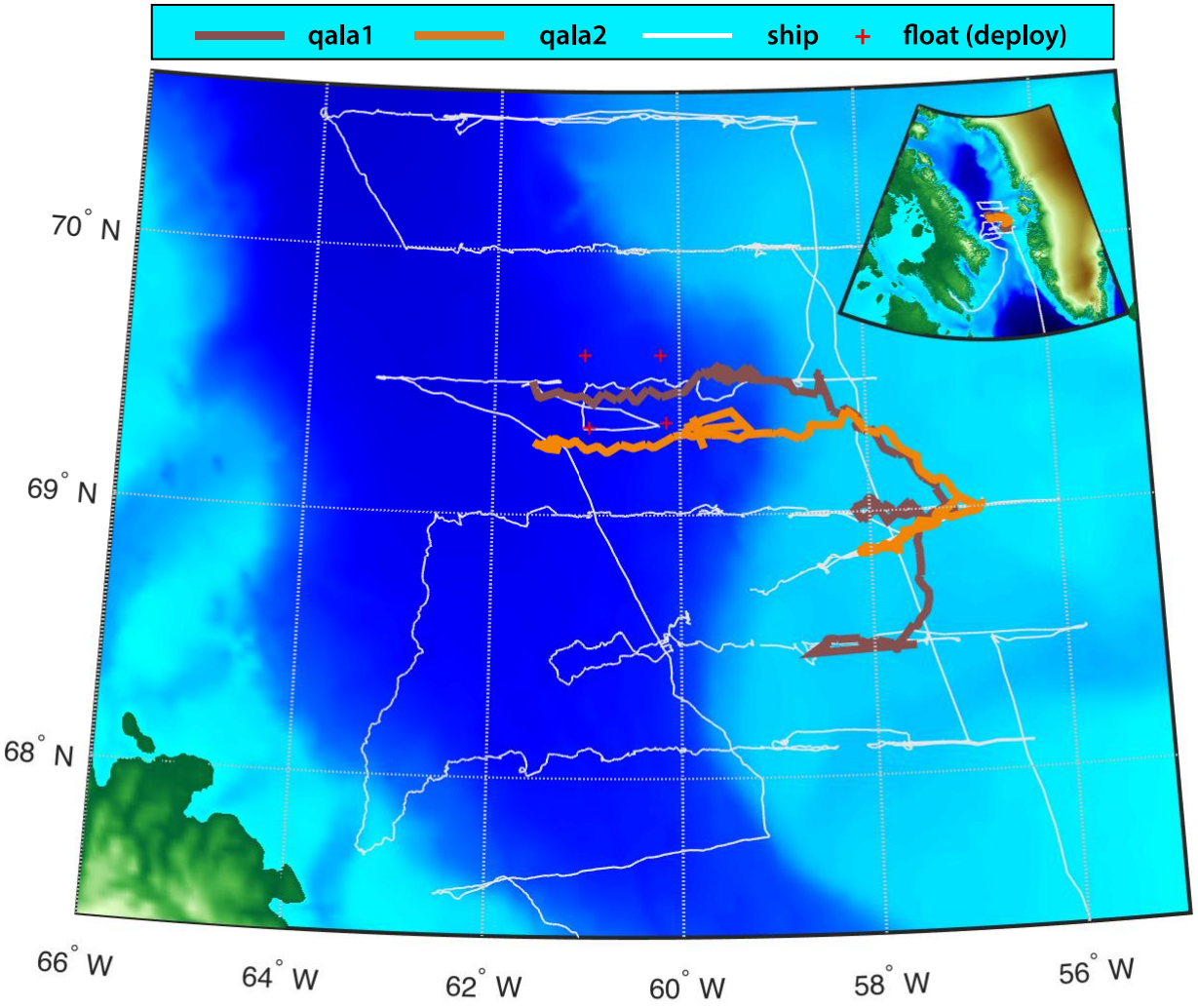
Understand the dynamics of the phytoplankton spring bloom (PSB) and determine its role in the Arctic Ocean of tomorrow, including for human populations.

1) Understand the key physical, chemical and biological processes governing/which governed the PSB
2) Identify the key phytoplankton species involved in the PSB and model their growth under various environmental conditions
3) Predict the fate of the PSB and related carbon transfer through the food web and toward the bottom sediments over the next decades.

Autonomous Platforms

- Increased presence
  - Bio-Argo Floats
  - Gliders: repeat sections
- Increased spatial and temporal sampling
- Some !! cross- and intercalibration required
  - Ships still needed, but different role
- More capable AUVs

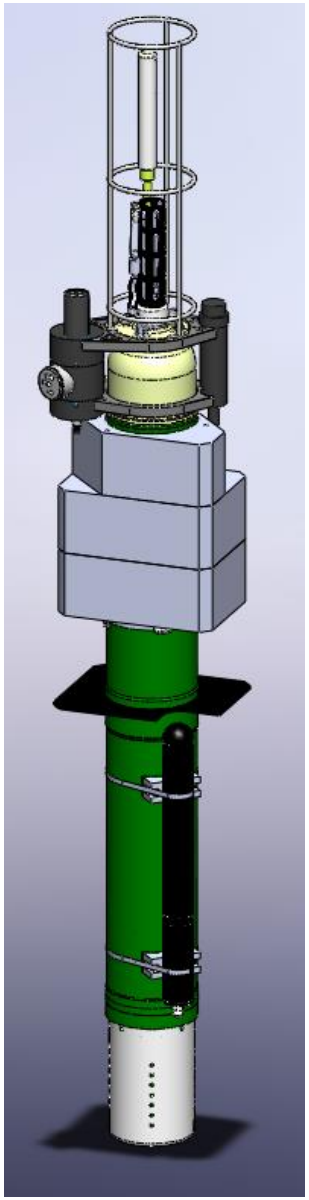
Green Edge 2016: Process Study



Observations

- Temperature, SalinityCTD

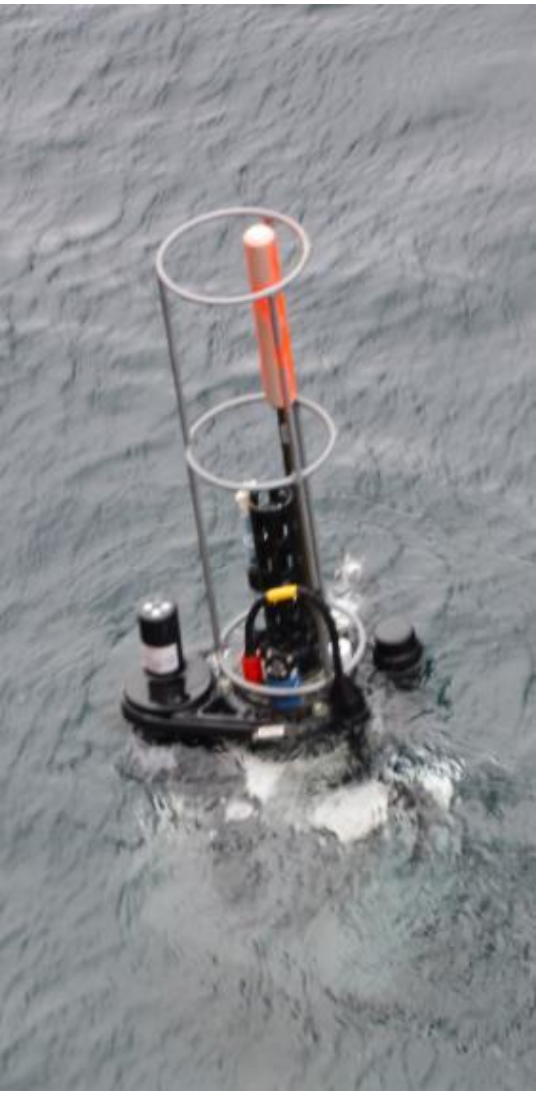
• Light	PAR sensor, multi-spectral light
• Nutrients (NO_3^-)	UV spectrophotometer (e.g., SUNA)
• Chlorophyll	Chlorophyll fluorometer
• DOM	CDOM fluorometer
• Particles	Optical vol. backscattering (multi-λ)
• Photosynthesis / O_2	Oxygen sensor (fluorescence)
• Ice	LiDAR, acoustic altimeter
• Marine mammals	Passive acoustics (future)
• Under-ice nav	Passive + active acoustics (future)

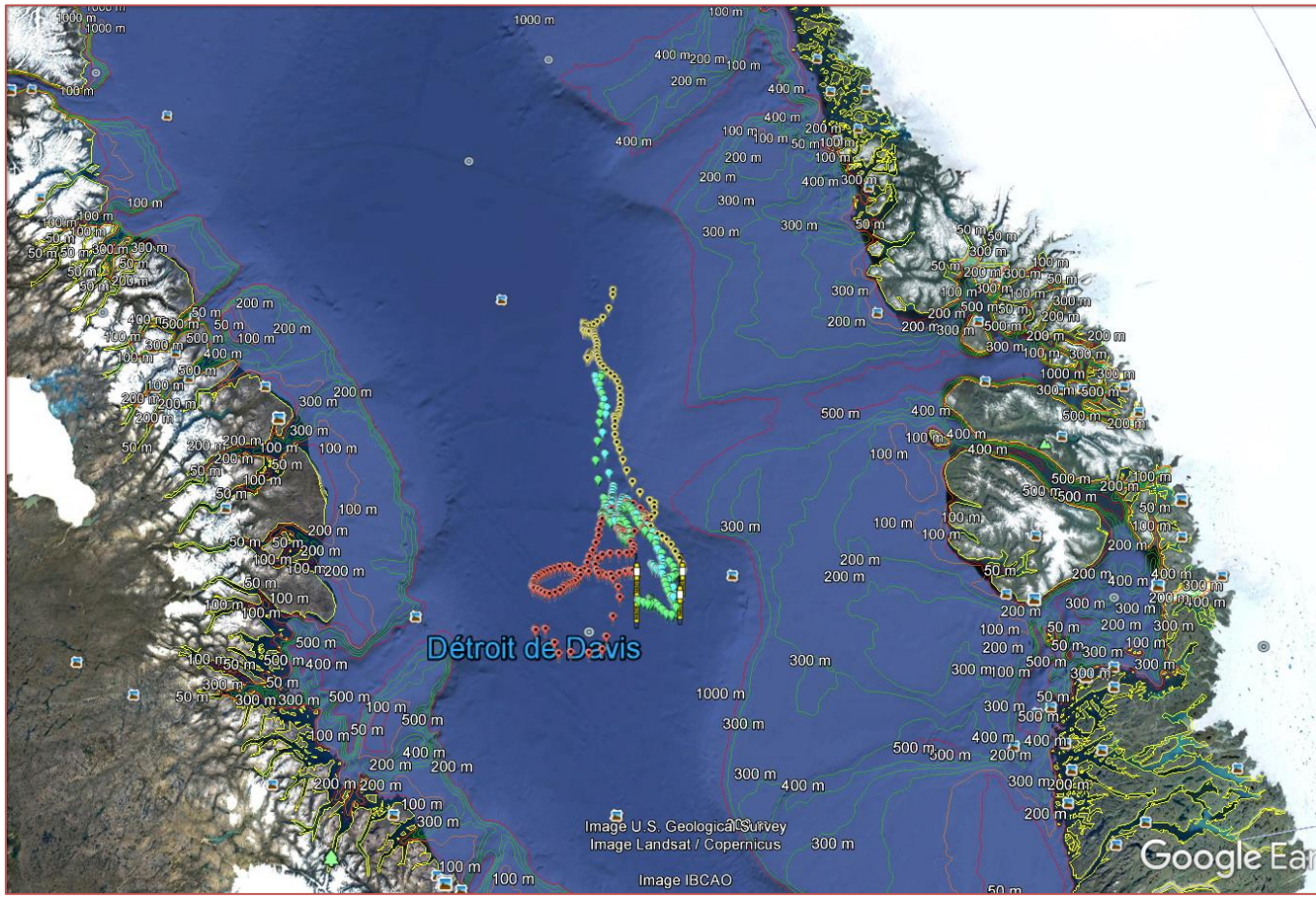


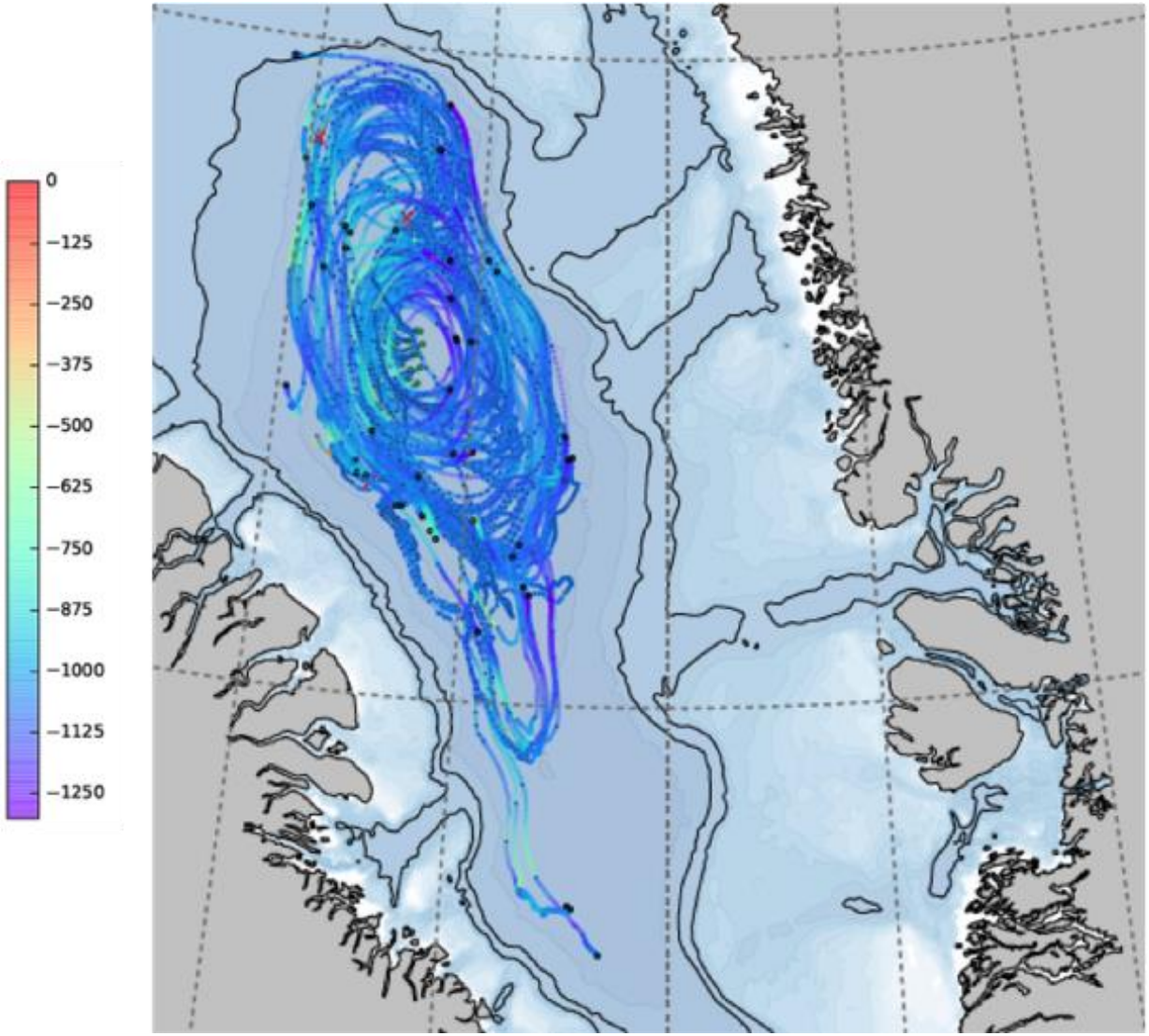

HUGIN 1000
HISAS 1030
Image of © Kongsberg Maritime

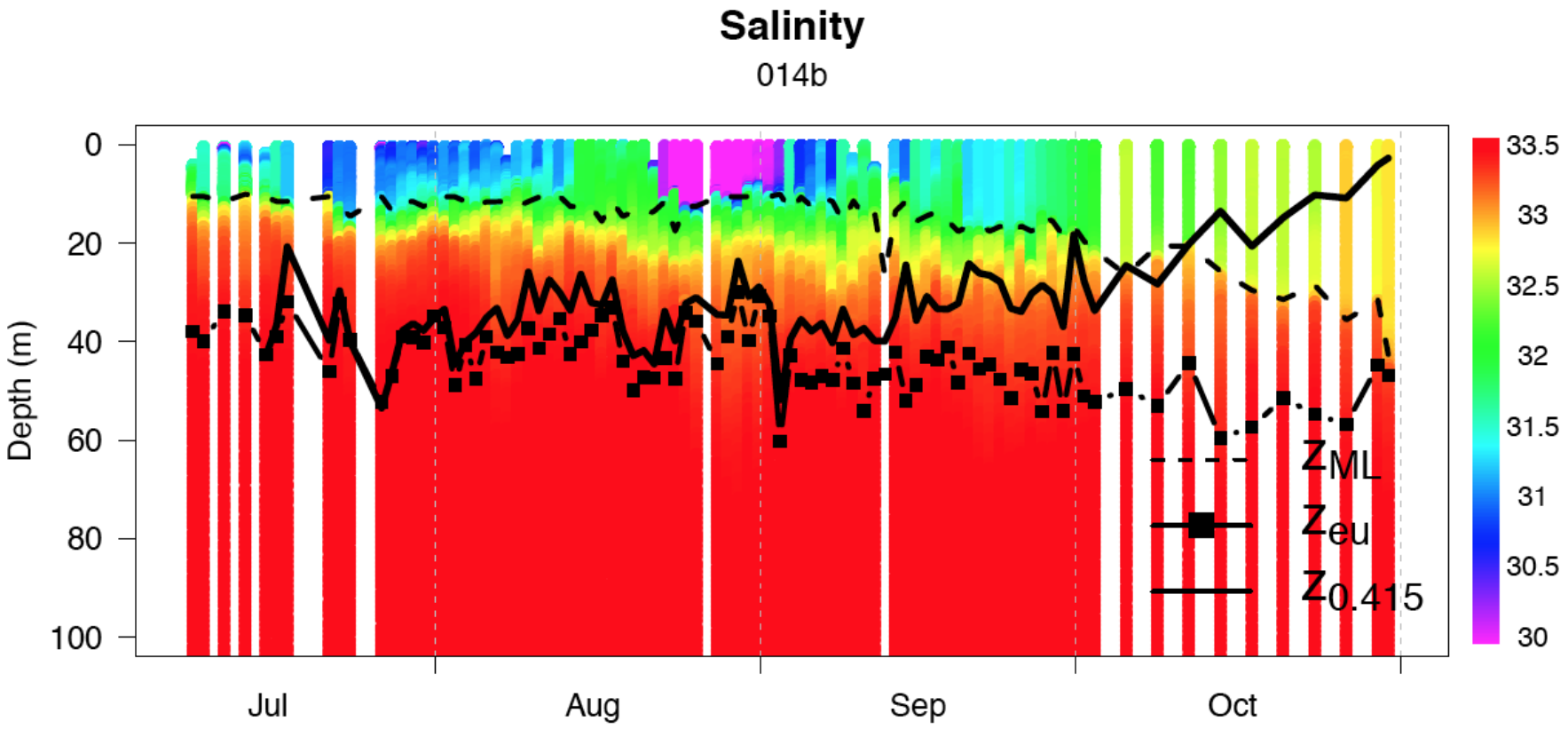
NAOS
Novel Argo Ocean observing System

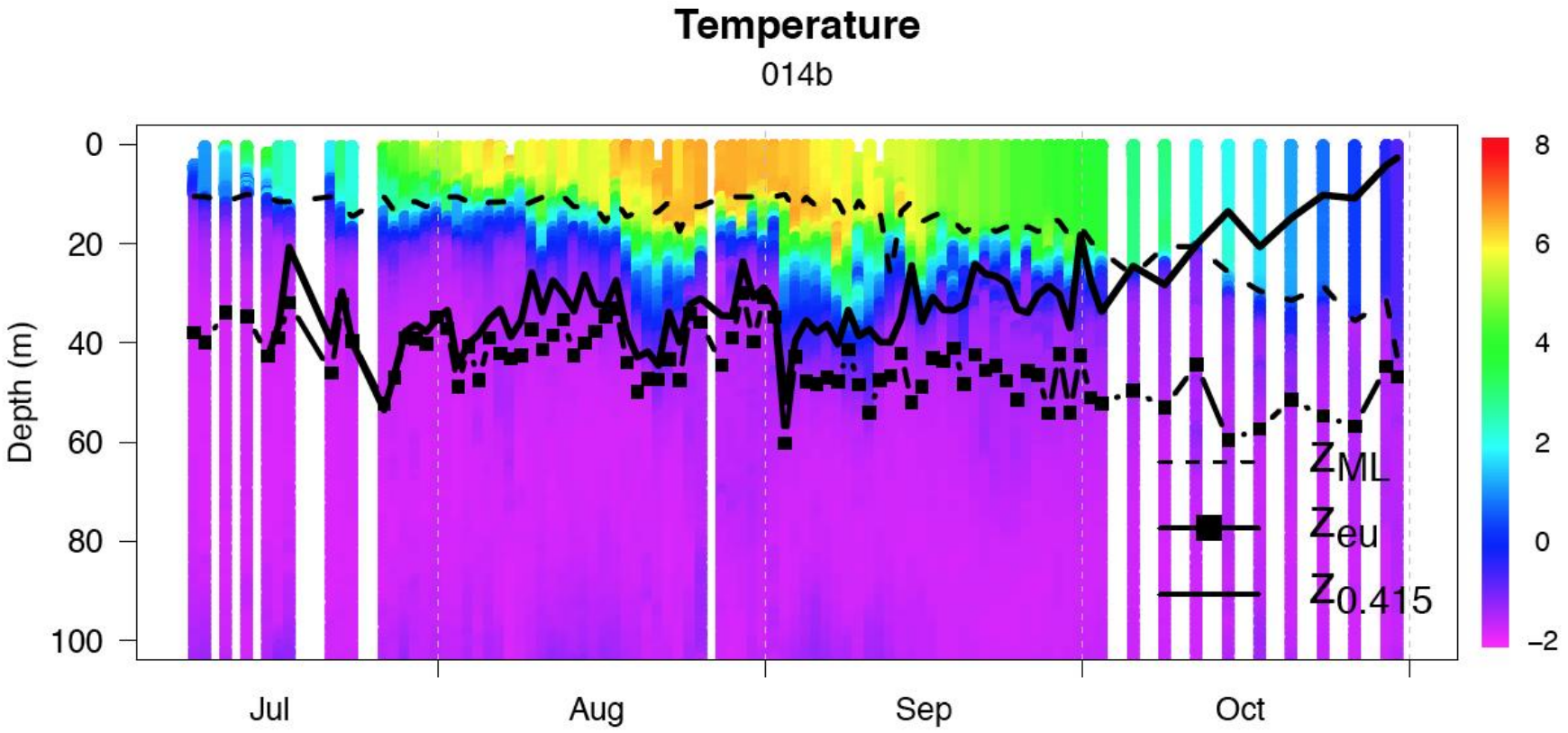
INNOVATION.CA
CANADA FOUNDATION FOR INNOVATION | FONDATION CANADIENNE POUR L'INNOVATION



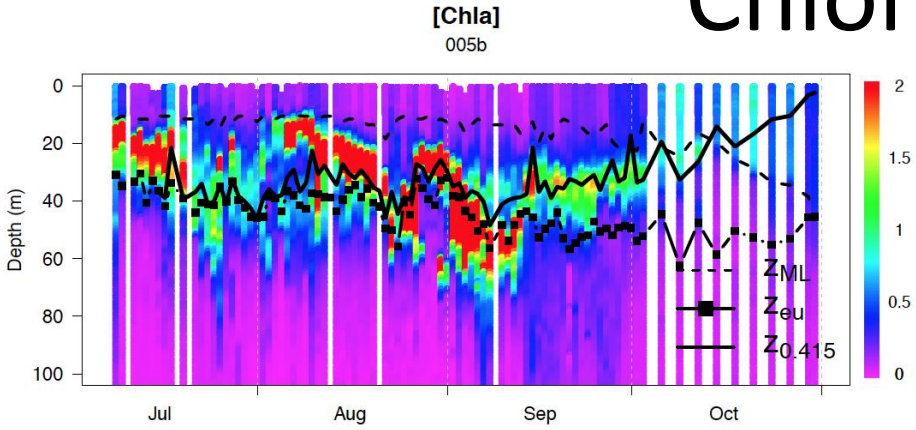


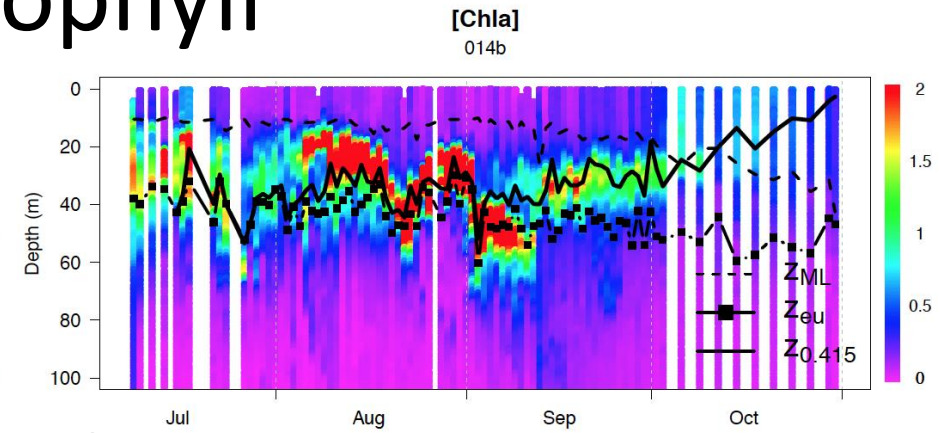

0
−125
−250
−375
−500
−625
−750
−875
−1000
−1125
−1250


Salinity
014b
Depth (m)
0
20
40
60
80
100
Jul
Aug
Sep
Oct
33.5
33
32.5
32
31.5
31
30.5
30
z_{ML}
z_{eu}
$z_{0.415}$

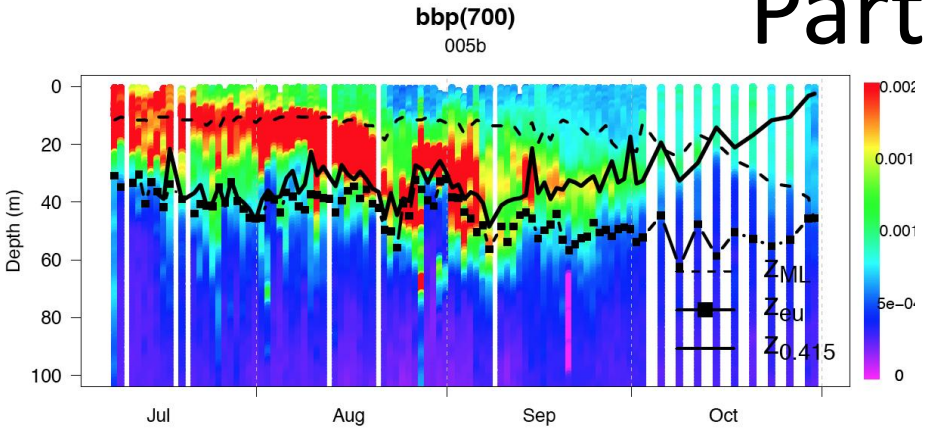

Temperature
014b
Depth (m)
0
20
40
60
80
100
Jul
Aug
Sep
Oct
8
6
4
2
0
−2
z_{ML}
z_{eu}
$z_{0.415}$

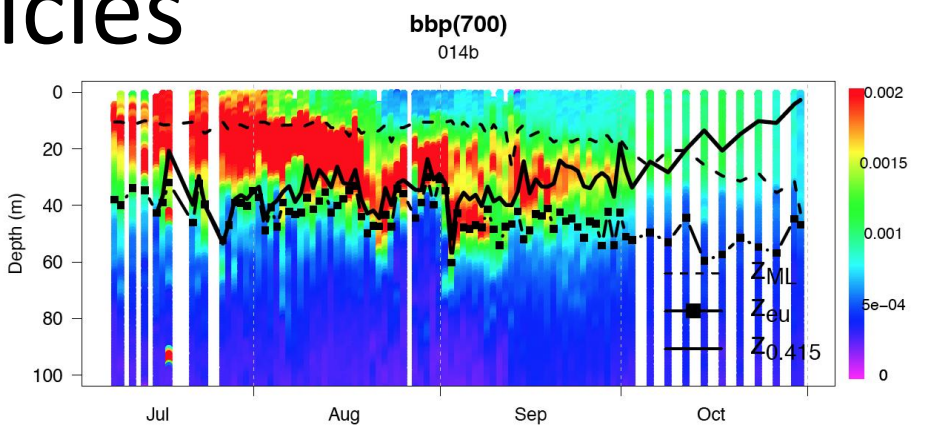
Chlorophyll



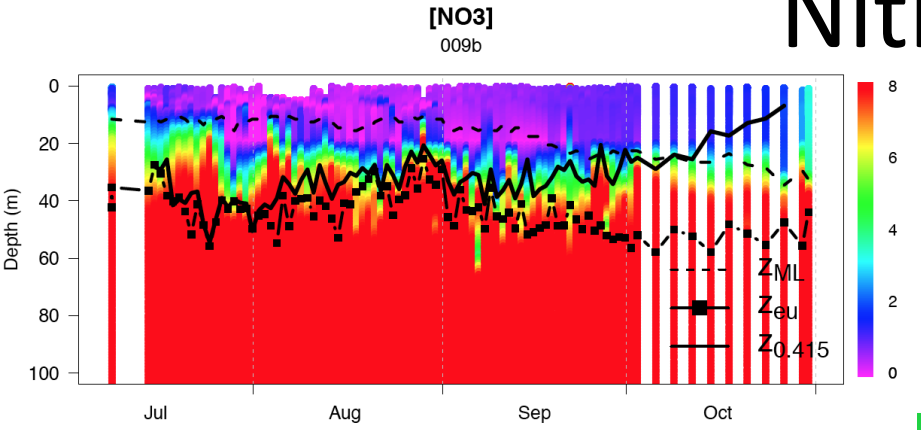


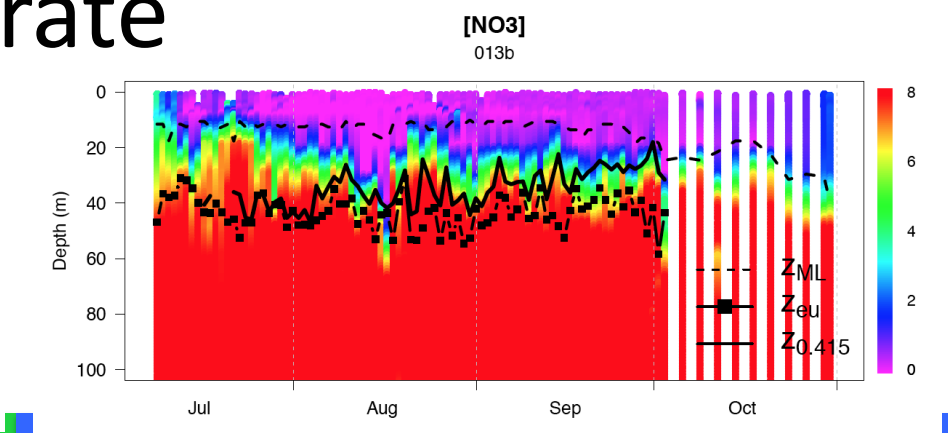
Particles





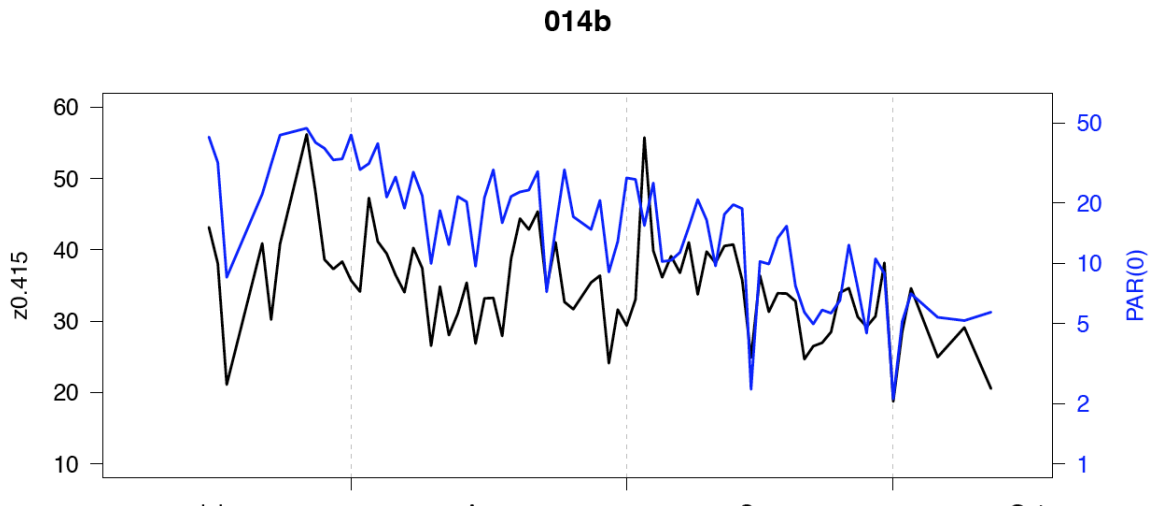
Nitrate



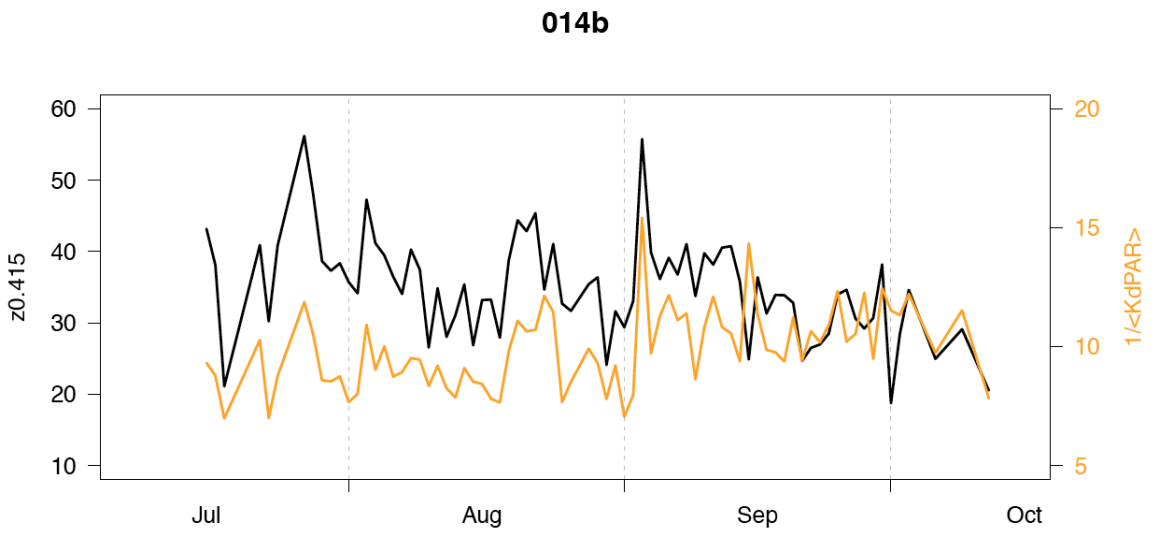


What's driving $Z_{0.415}$?

Incident irradiance (PAR) or attenuation (K_d) in the water column?



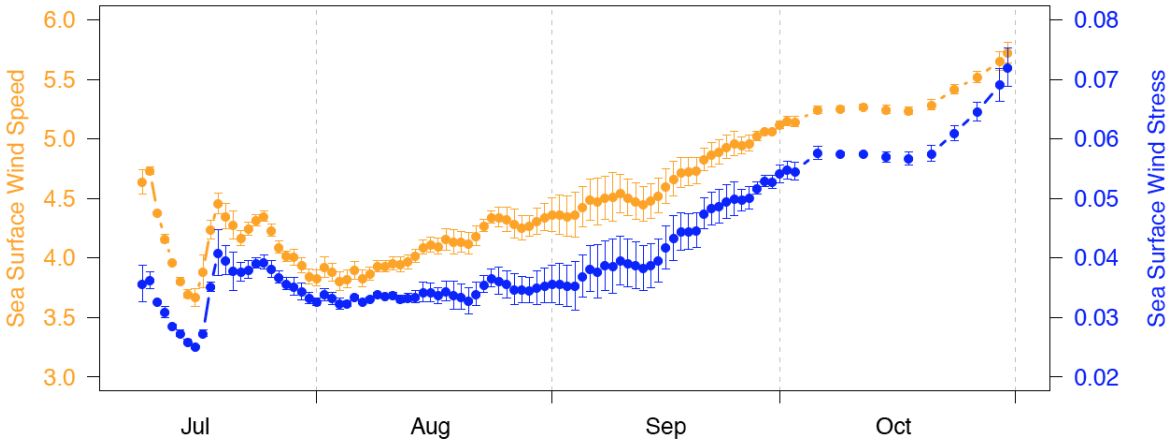
PAR

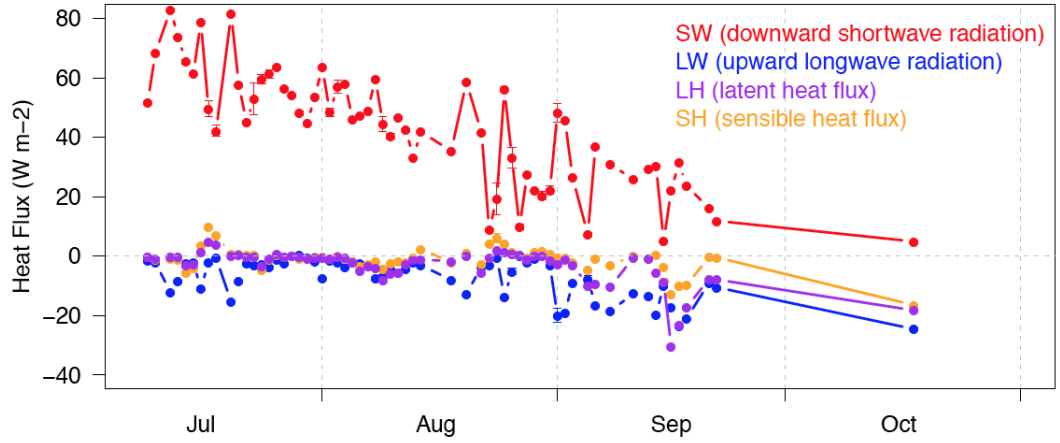


K_d

What's driving vertical mixing in Sep-Oct?

Wind and/or thermal convection?





Wind stress

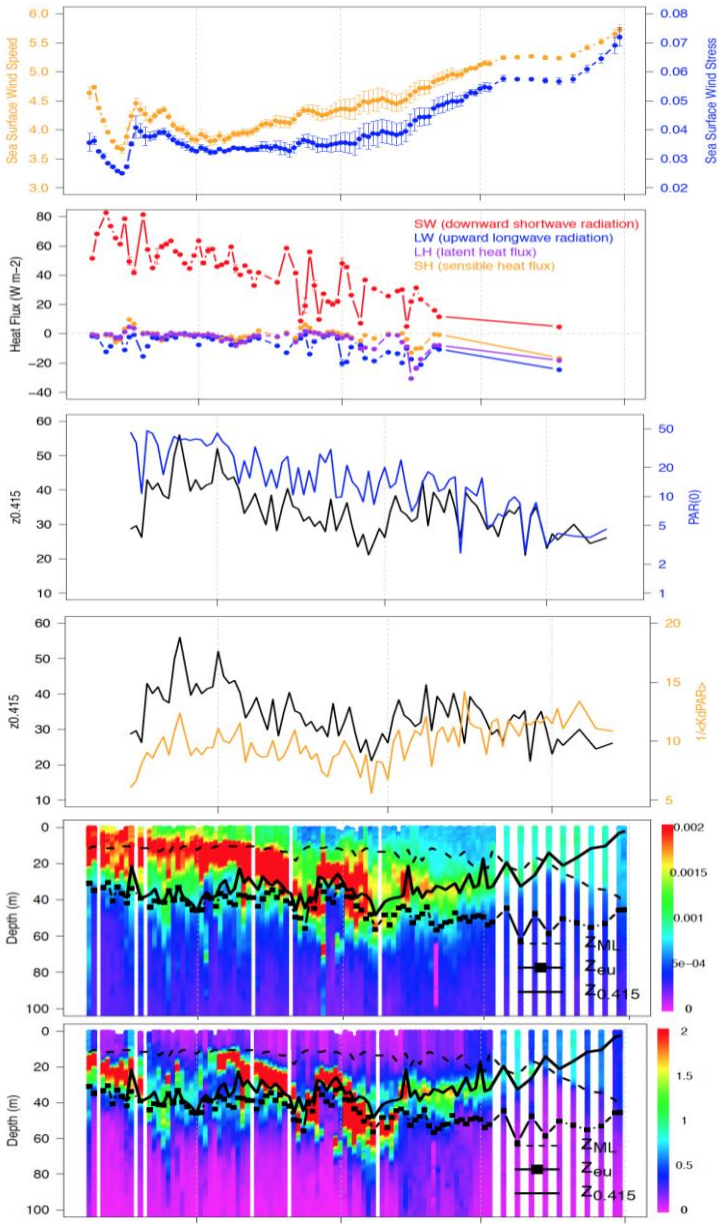
Heat flux

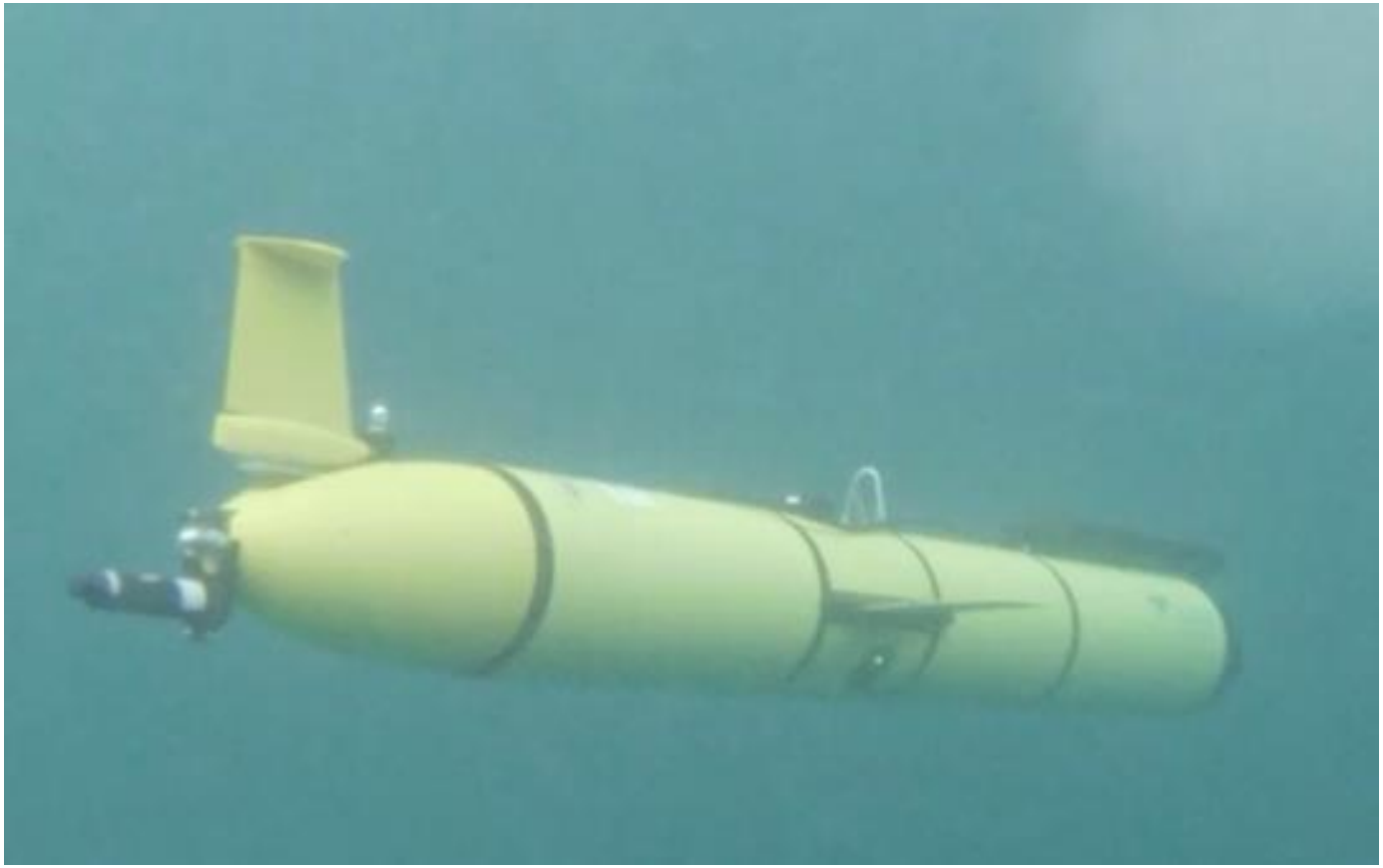
Incident irradiance

Vertical attenuation

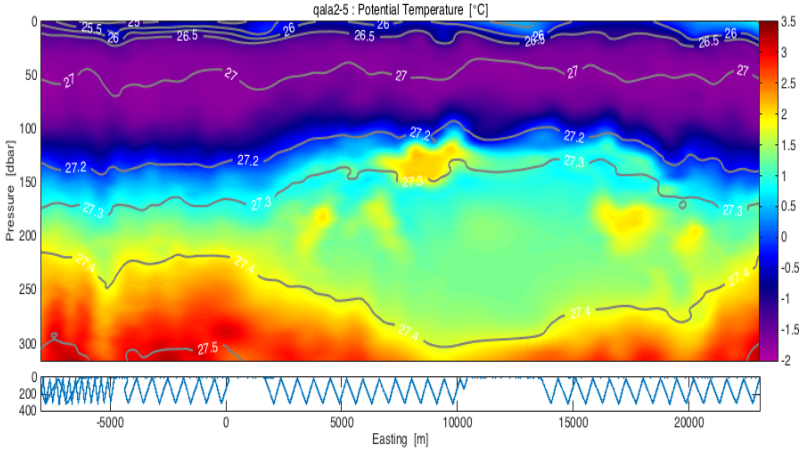
Particles

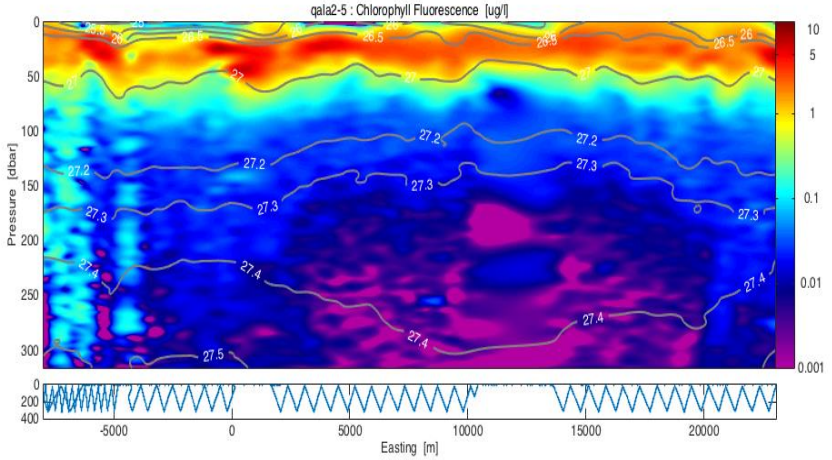
Chlorophyll

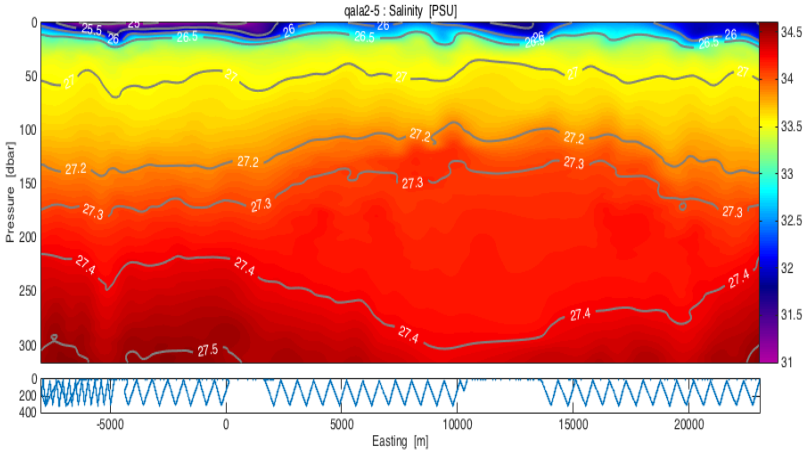


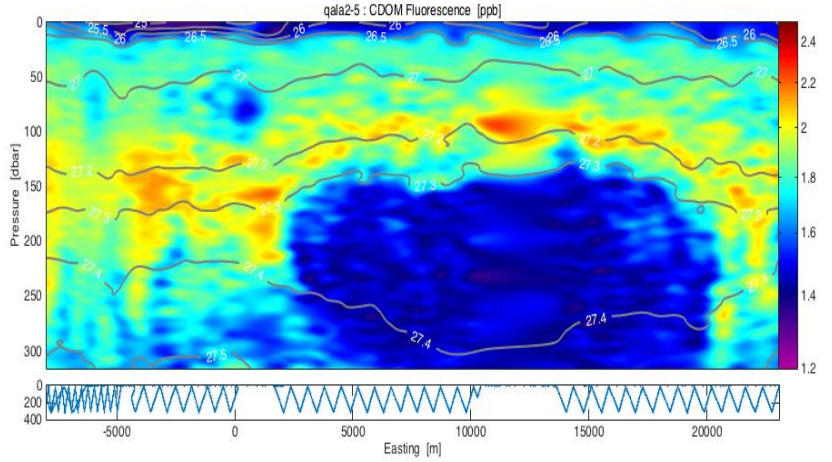


Properties of water masses

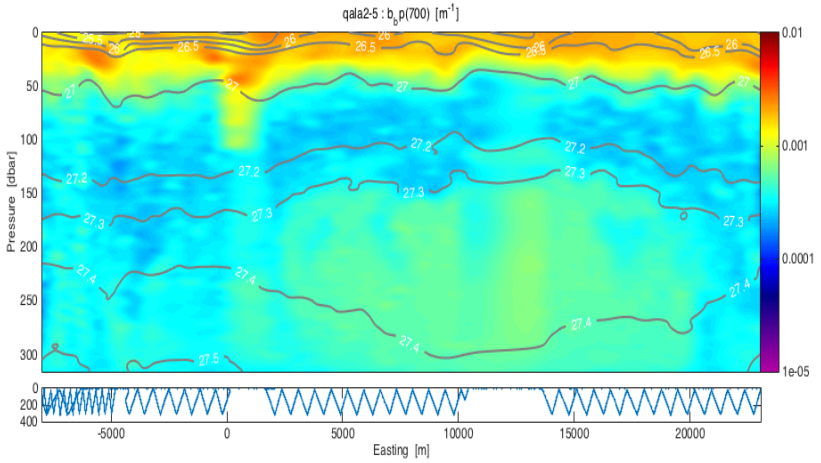


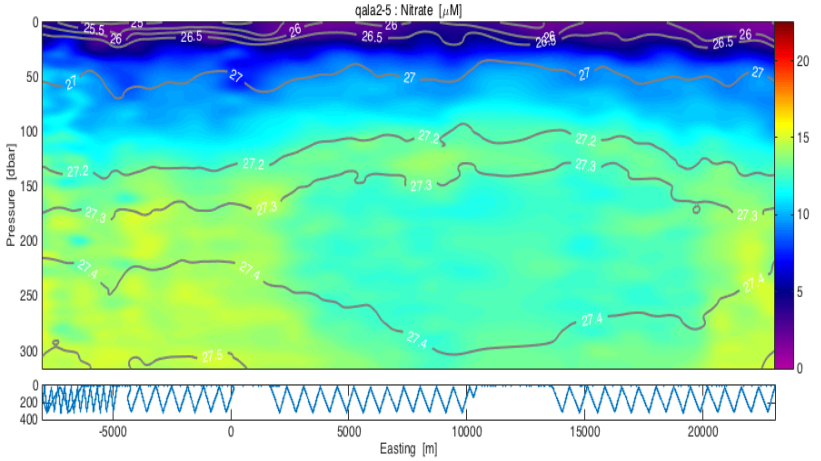


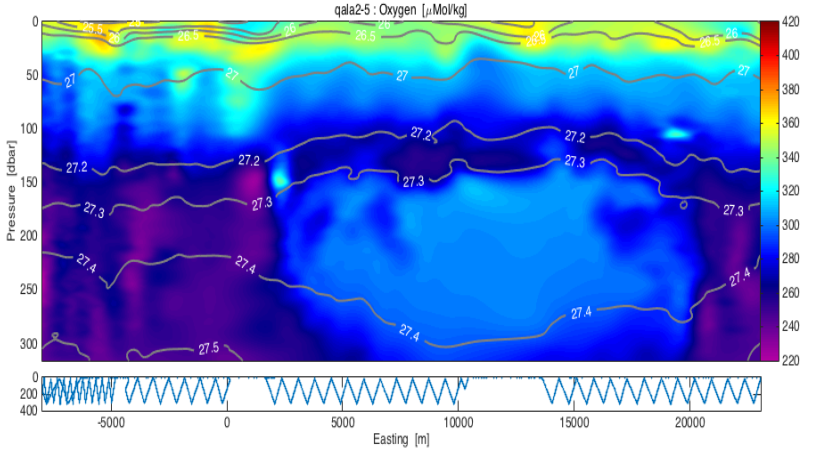


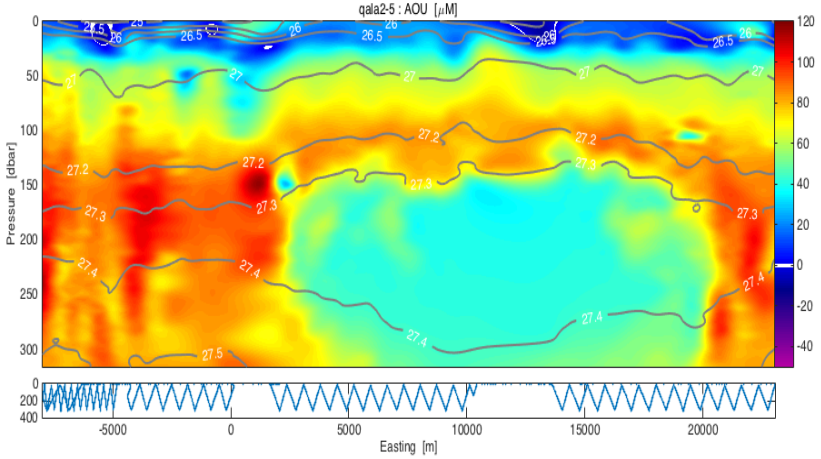


Properties of water masses

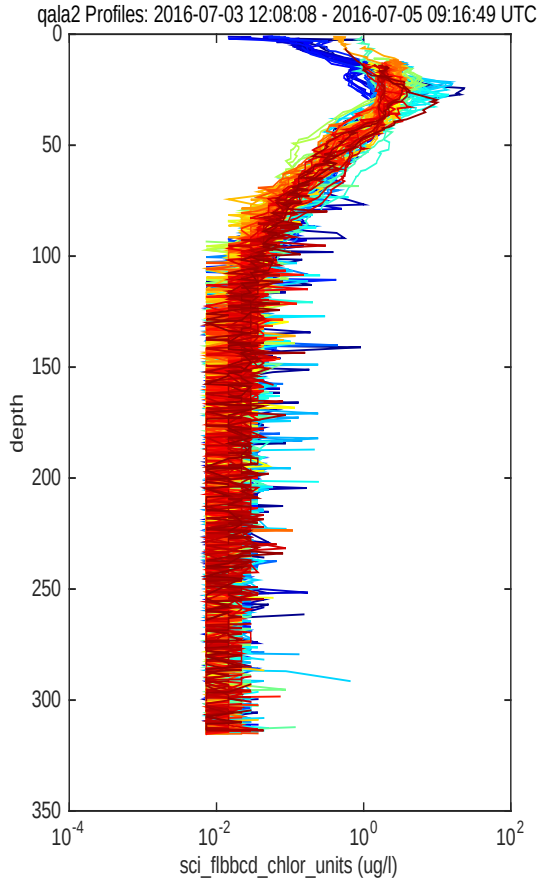


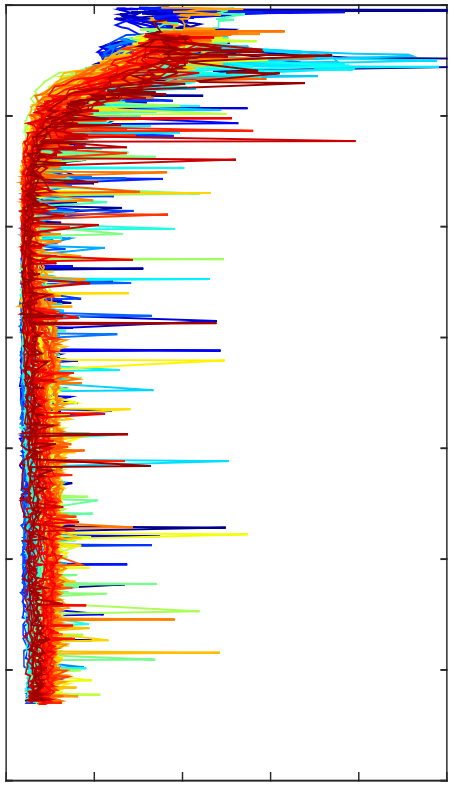


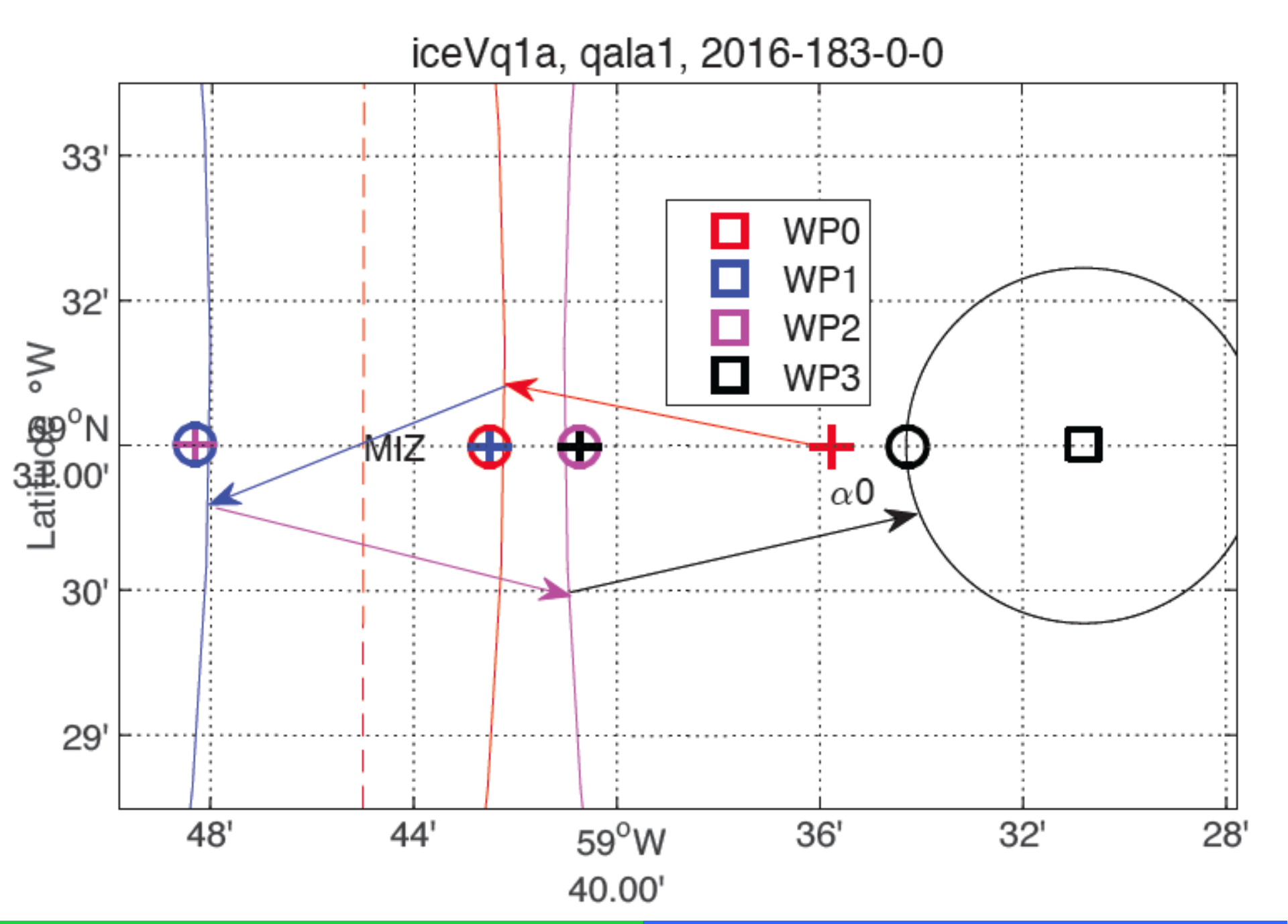




Observations of FChl and b_b spikes → carbon flux






iceVq1a, qala1, 2016-183-0-0
WP0
WP1
WP2
WP3
MIZ
α0
33'
32'
31'
30'
29'
48'
44'
36'
32'
28'
59°W
40.00'
Latitude °W
59°N
31.00'

Found…..

Smarter AUVs

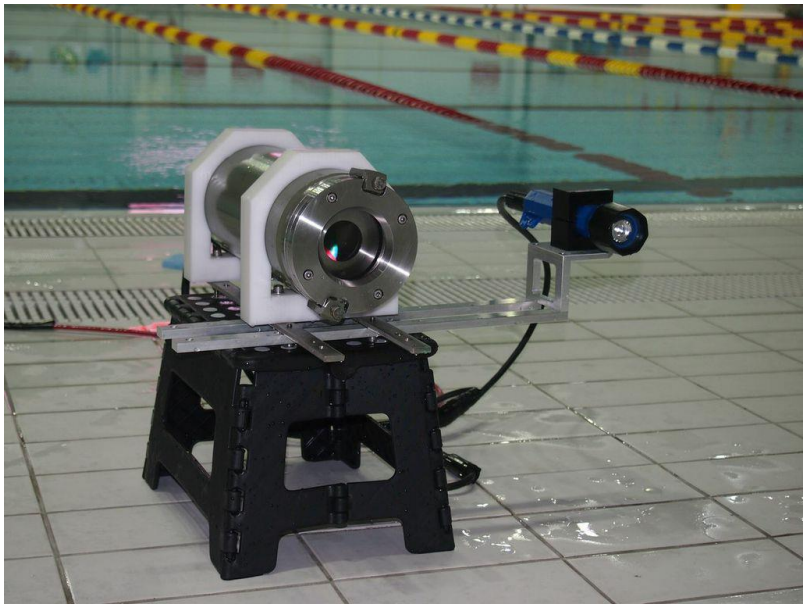
- Limited ability to make decisions based on what they have observed with scientific instrumentation
- Ideas
  - Navigation: ice / obstacle detection & avoidance.
  - Use of surface assets / vehicles / ASVs
  - Feature detection & adaptive ampling: subsurface chlorophyll maximum
  - Communications: under-ice, sensor networks
  - Feedback to predictive ocean models to plan future trajectories

Smarter AUV Development Objectives

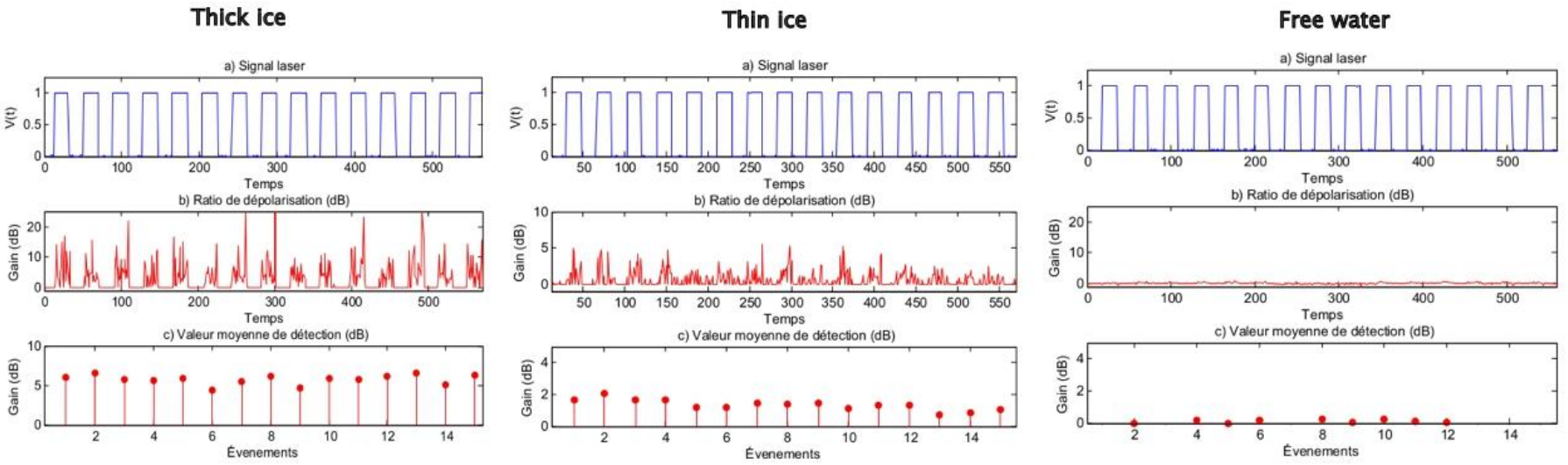
1. Novel AUVs specifically tailored to long autonomous missions under the arctic ice
2. Robust navigation, planning and positioning capabilities for swarms of AUVs
3. Novel in situ sampling and analysis capabilities onboard AUVs and
4. Novel robust acoustic communication techniques for highly reflective environments.

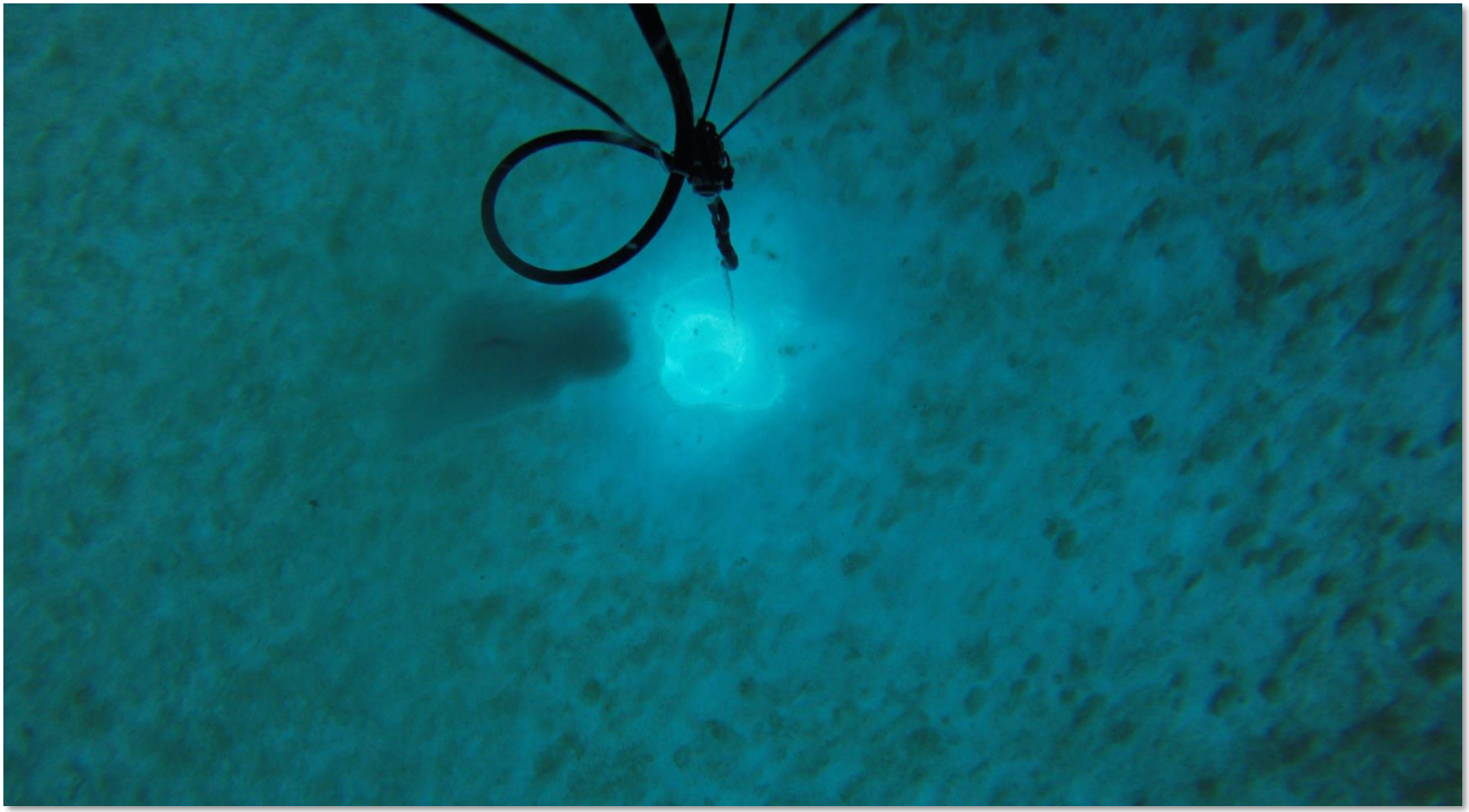
Ice Detection and Avoidance

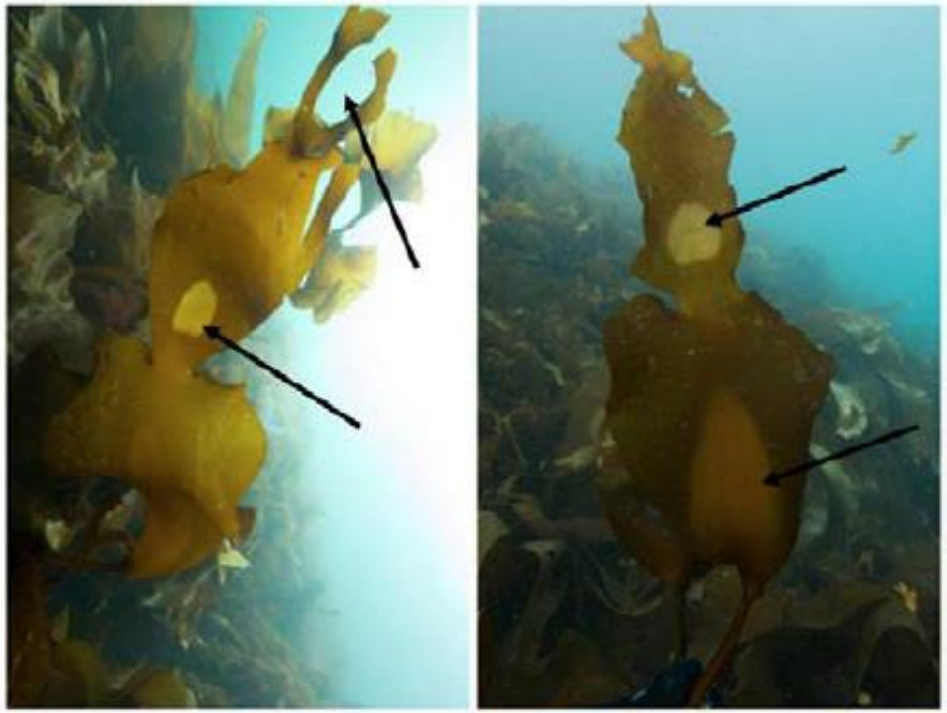
Capteur optique, mai 2014



Ice Detection and Avoidance







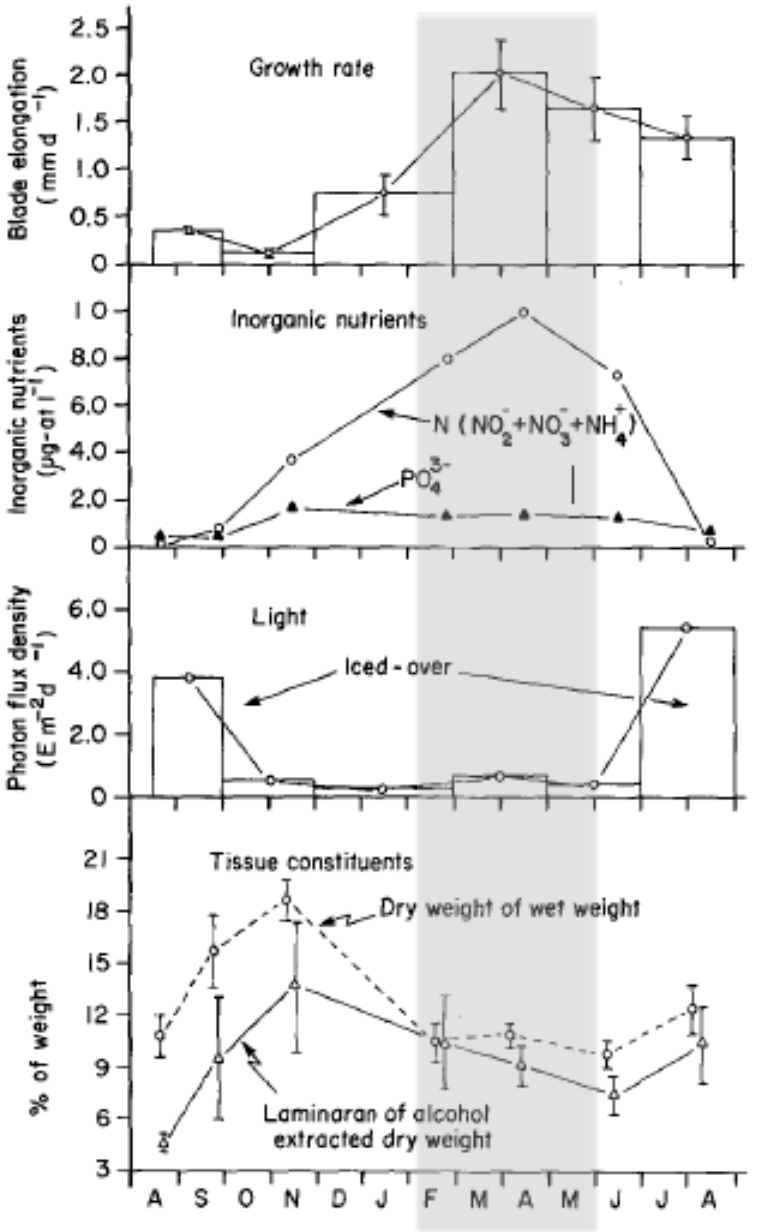
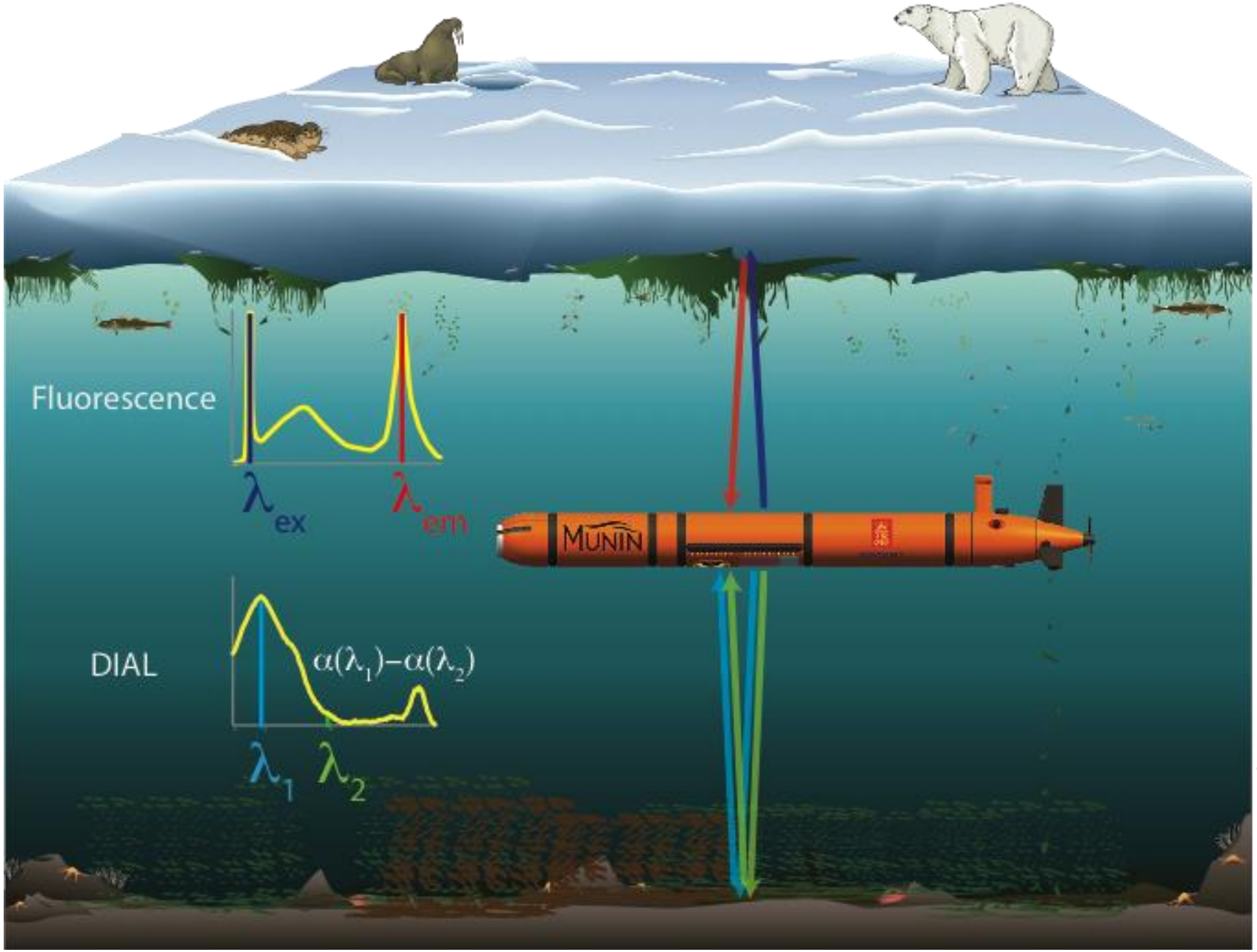


Fig. 1. *Laminaria solidungula*. Seasonal variation in blade growth (means ±95% confidence limits), inorganic nutrients, photon flux density and plant tissue constituents (means ±95% confidence limits) at 8 m depth

Chapman et al. 1980


Fluorescence
λ_{ex}
λ_{em}
DIAL
$\alpha(\lambda_1)-\alpha(\lambda_2)$
λ_1
λ_2
MUNIN
Jayne Doucette, WHOI Graphic Services

QUESTIONS?

BBANC

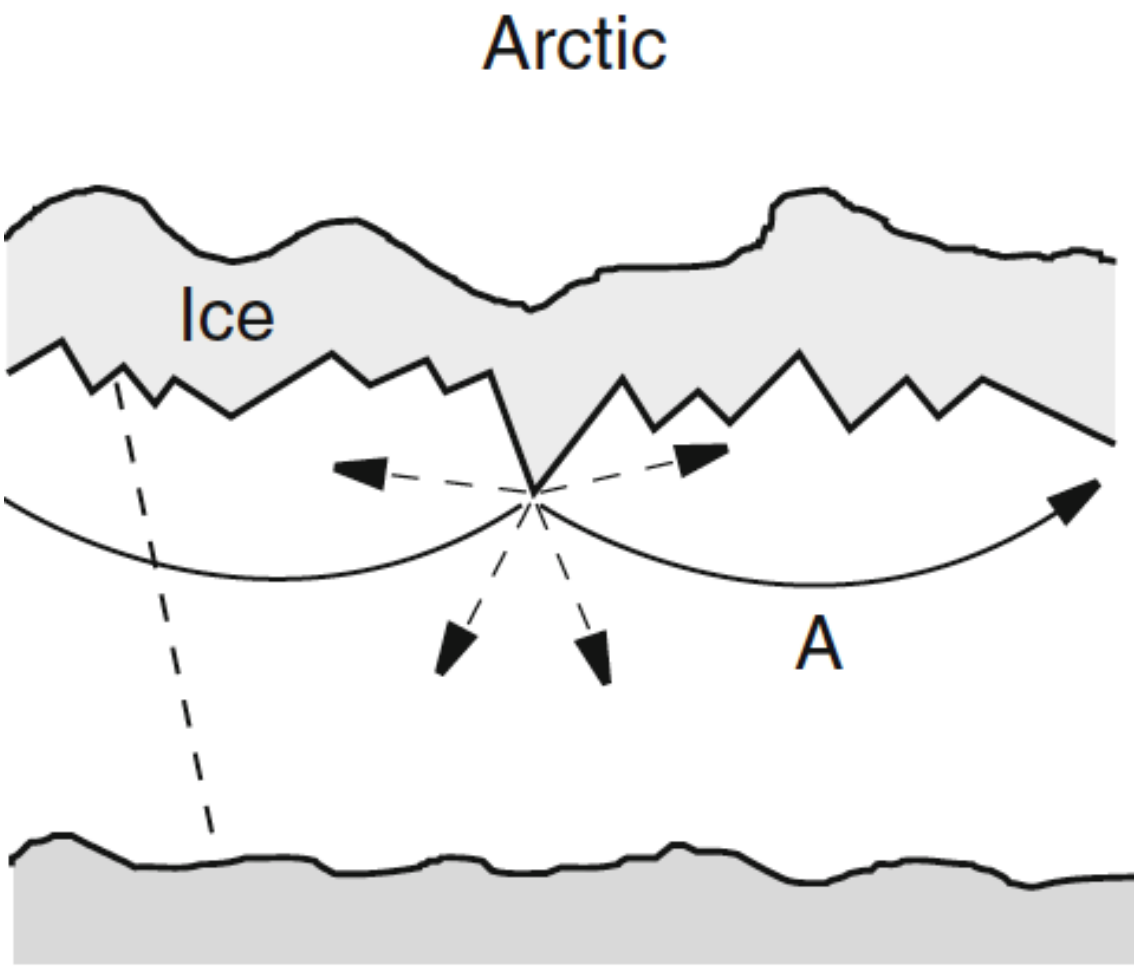
Baffin Bay Acoustic Navigation and Communication System

An evolving multipurpose acoustic network for Baffin Bay

BBANC
A multipurpose acoustic network

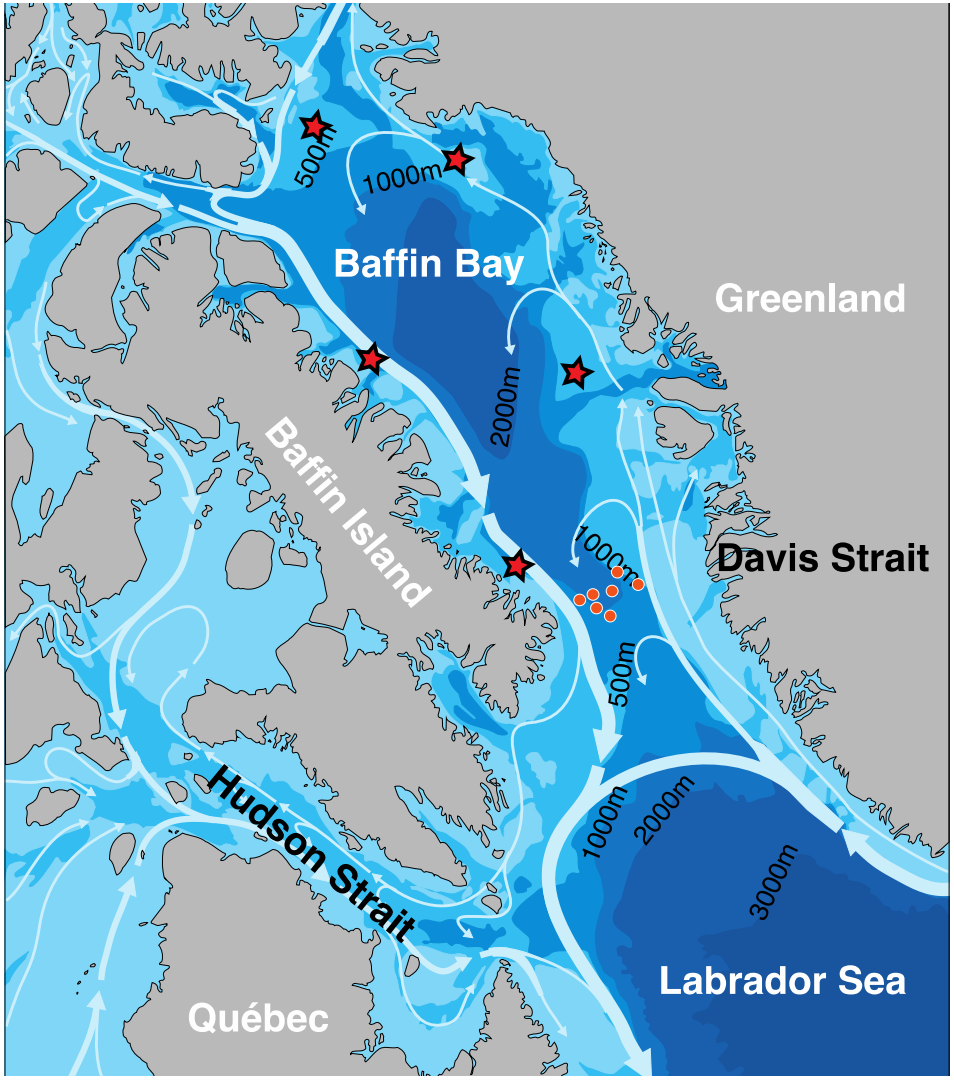
- **Underwater GPS** – Enable under-ice positioning of autonomous scientific platforms: floats, gliders
- **Thermometry** – Long-term monitoring of basin-scale temperature as climate change indicator
- **Underwater Communication** – Low bit-rate comms
- **Passive acoustic listening** – Characterize and monitor natural and anthropogenic soundscape

Sound in the Arctic



Baffin Bay Acoustic Modeling

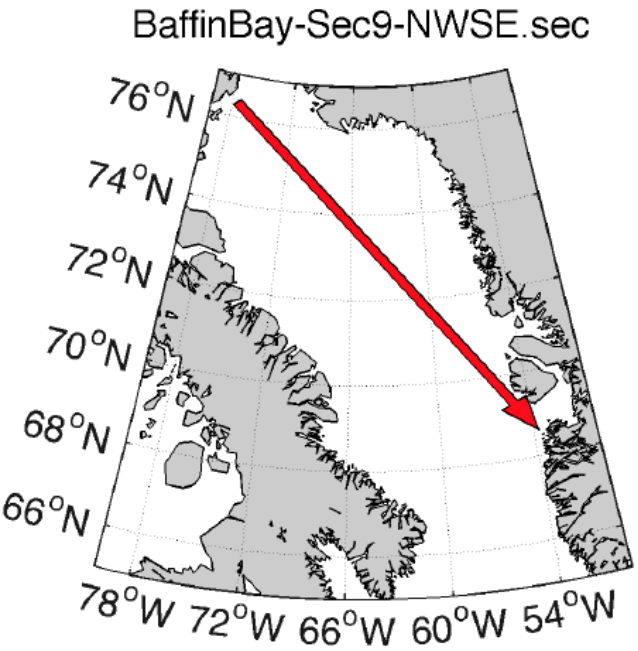
- Approximate Transmission Loss (TL) as a function of frequency, source depth
- Examine sensitivity to poorly understood environmental parameters
- Accurate treatment of the affect of rough sea-ice absorption and scattering.

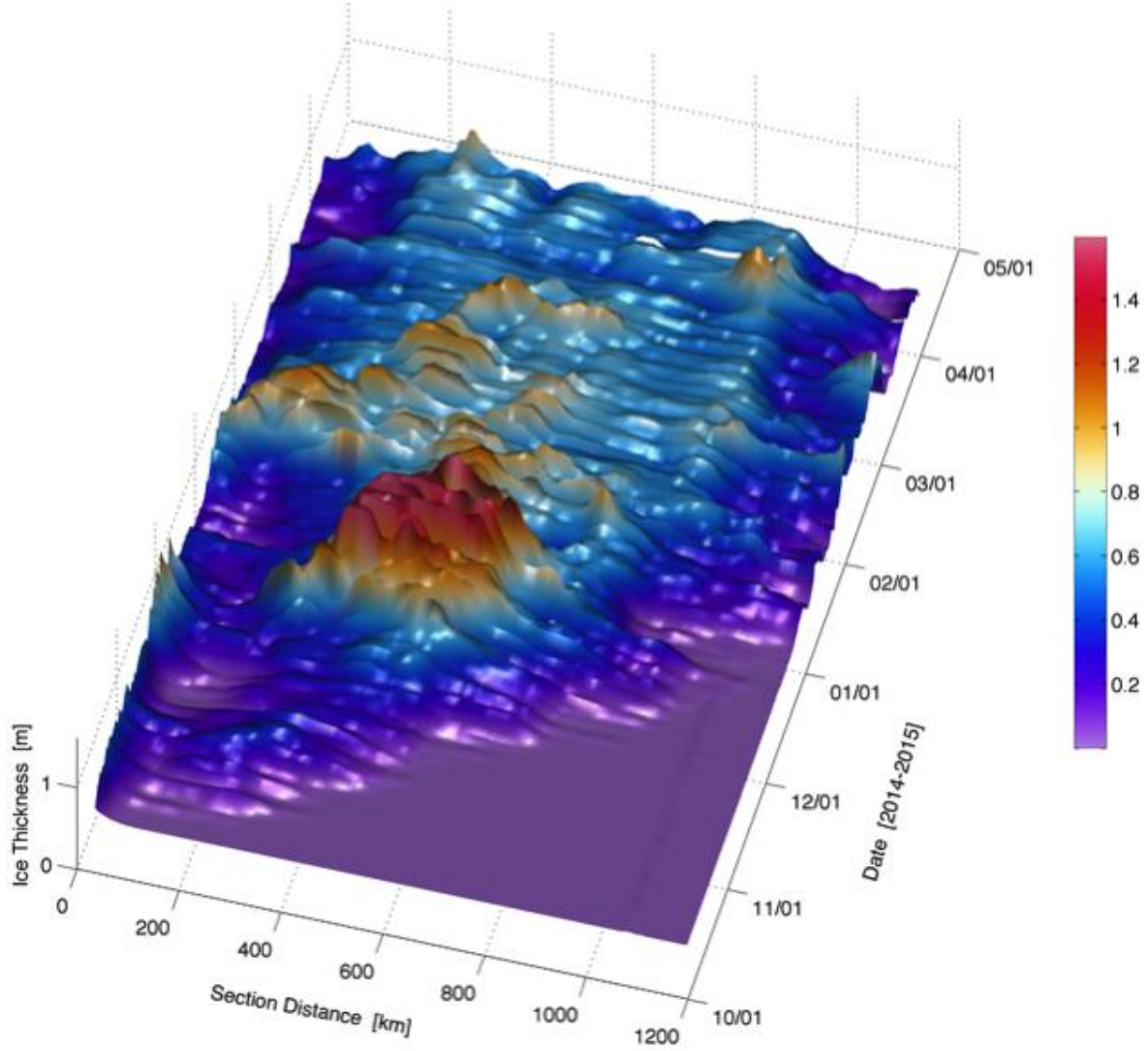


Modeling: Environmental Parameters

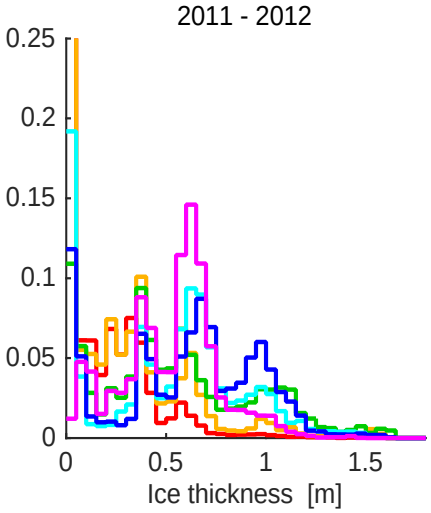
Acoustic Property	Environmental Parameters	Challenges / Solutions
Sound speed	Temperature and salinity under ice	**Few T-S profiles under ice**
Temperature of freezing point T_{freeze} mixed layer, 0-200 m.	Mixed layer temperature	**Residual near-freezing point mixed layer can be extend to surface**
Water Absorption	pH	Climate change: Increased CO_2 in ocean will reduce transmission loss: a noisier ocean
Ice Absorption	Ice thickness H, density Compressional wave speed c_p, Ice attenuation coefficient α	**Few direct measurements transmission loss and ice properties from** H, c_p,α can be estimated
Ice Scattering Keels scatters energy in a frequency-dependent manner.	Ice thickness probability distribution	**Few high-resolution measurements of ice thickness**

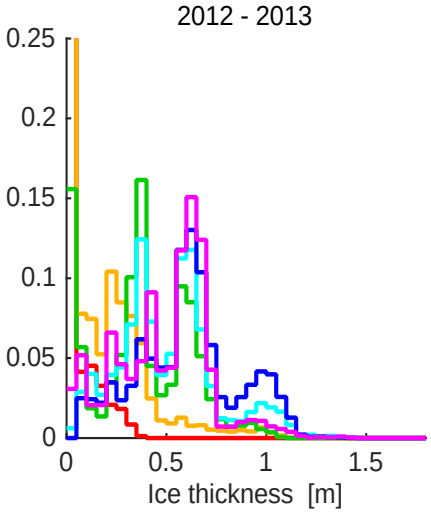
SMOS Sea Ice Thickness

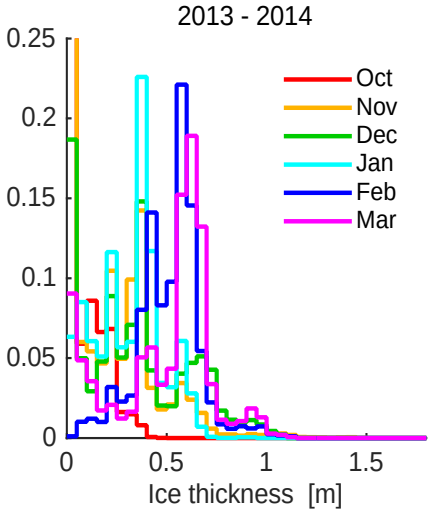


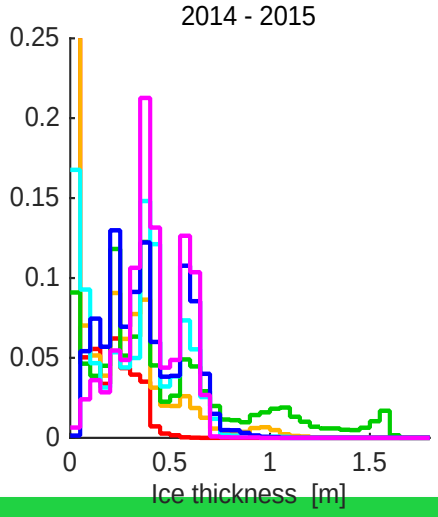


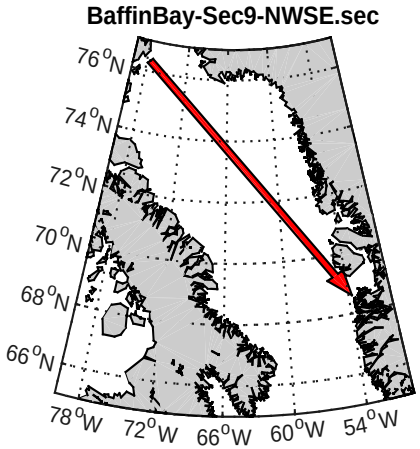
Ice Thickness PDFs



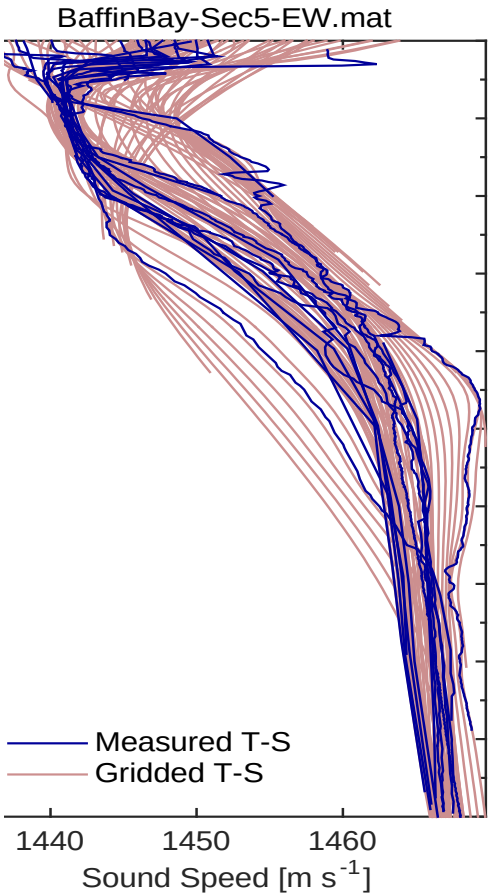


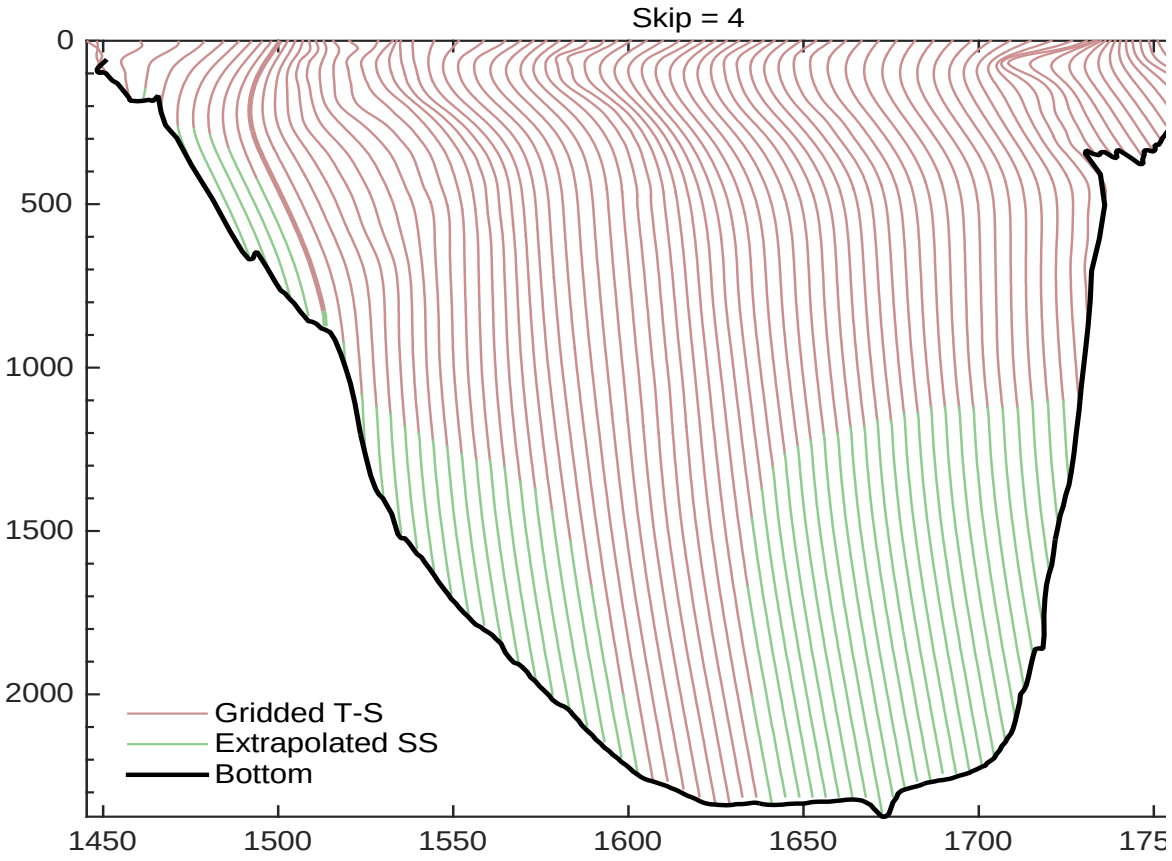




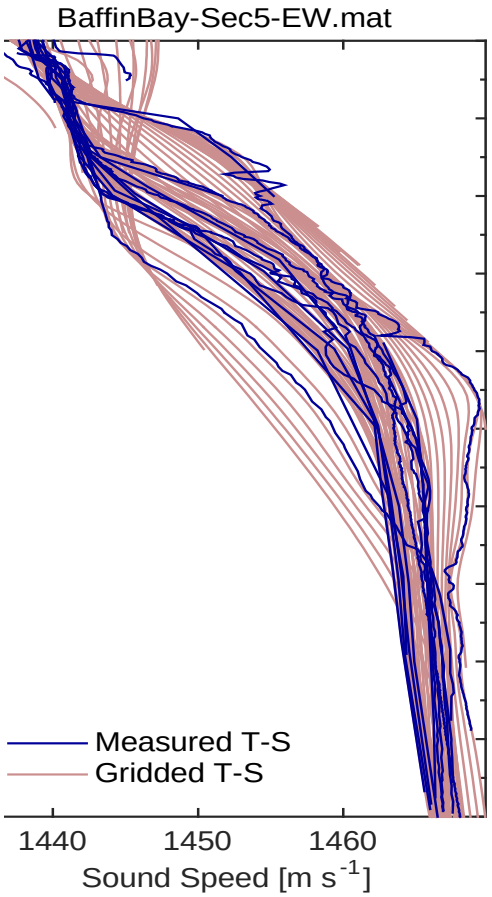


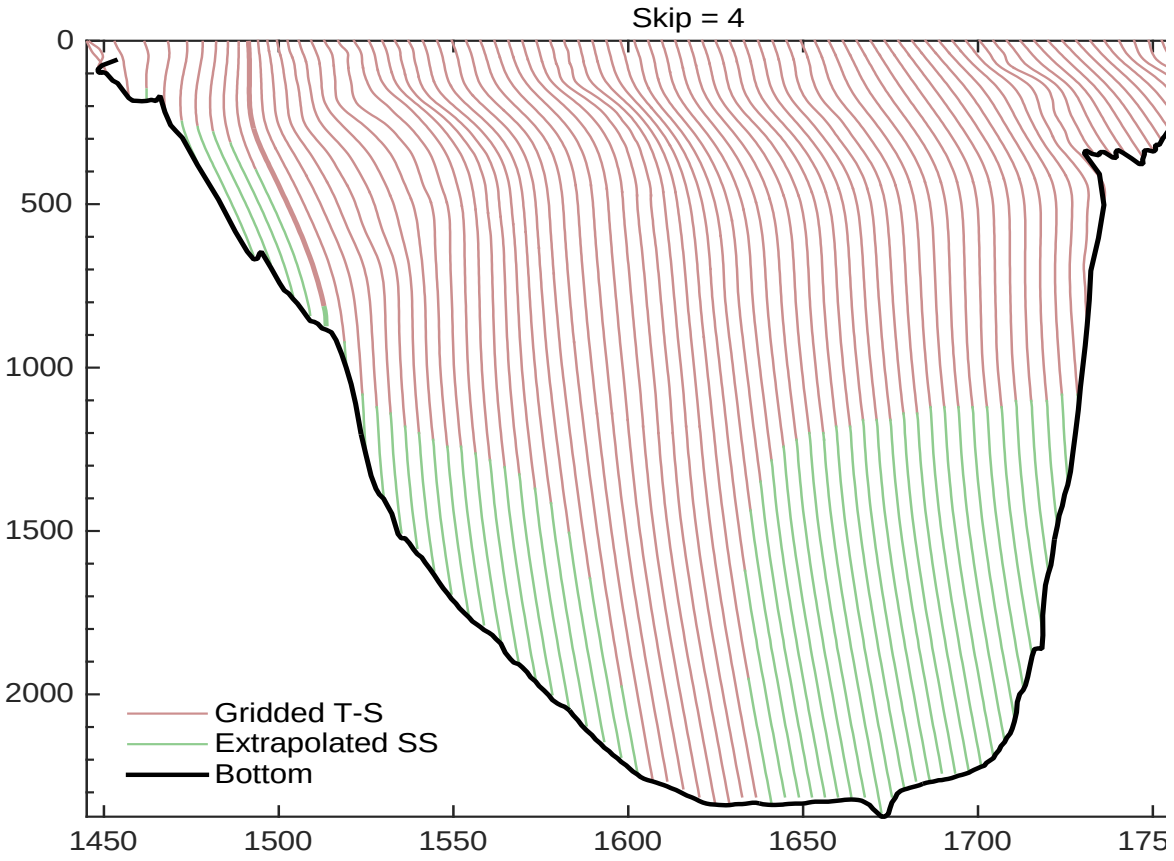
Sound Speed Profiles: Open Water



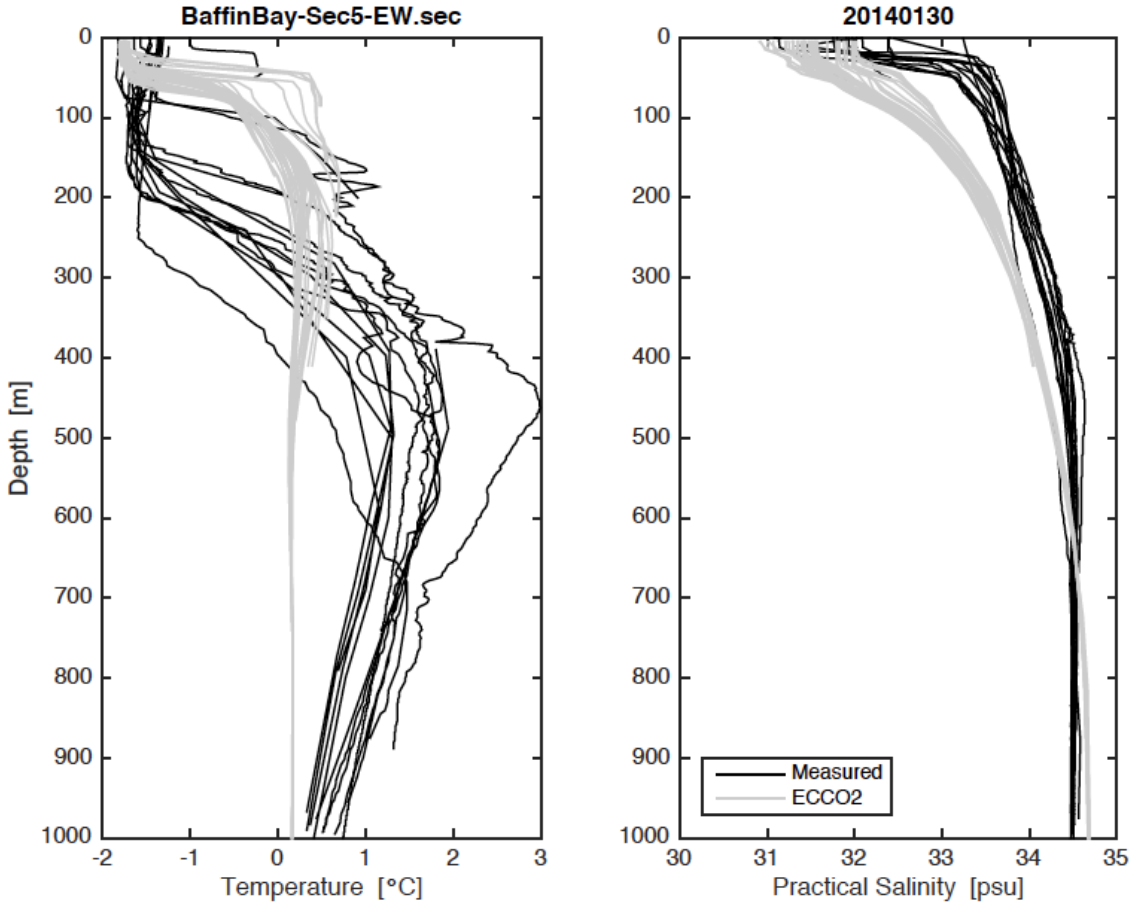


Sound Speed Profiles: Under Ice

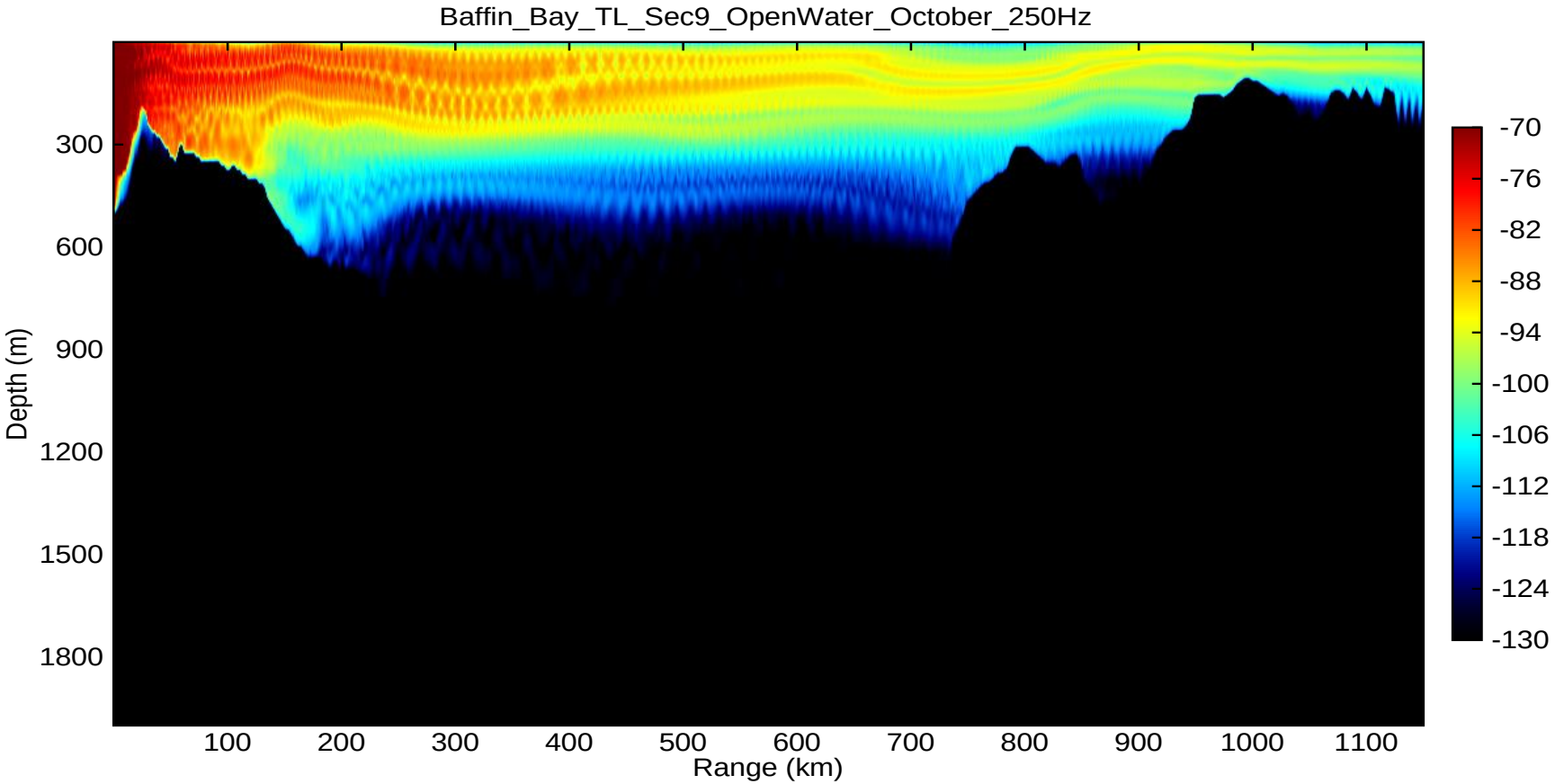




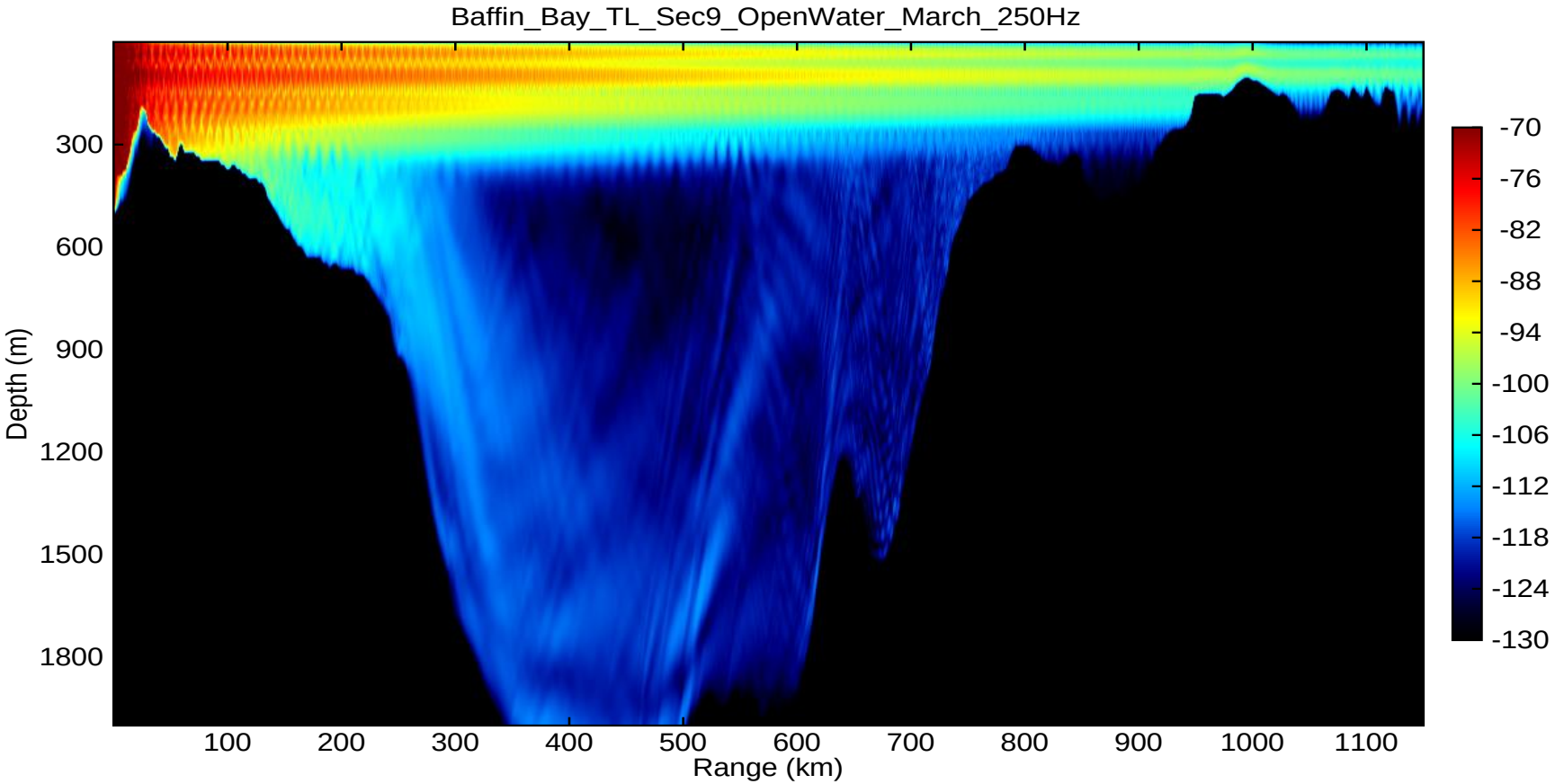
Observations vs. ECCO2 Climatology



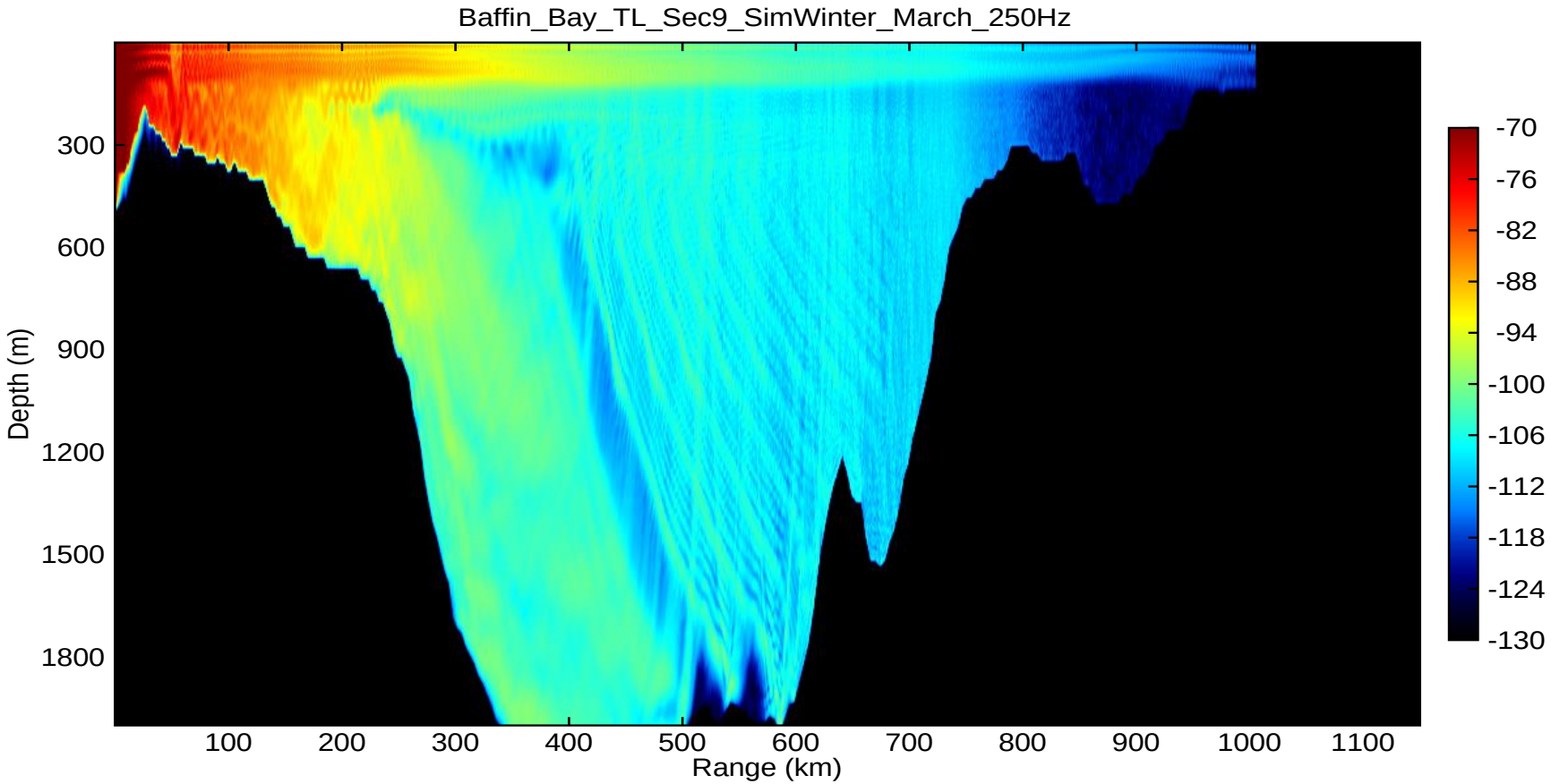
Open Water profiles, no ice (October)



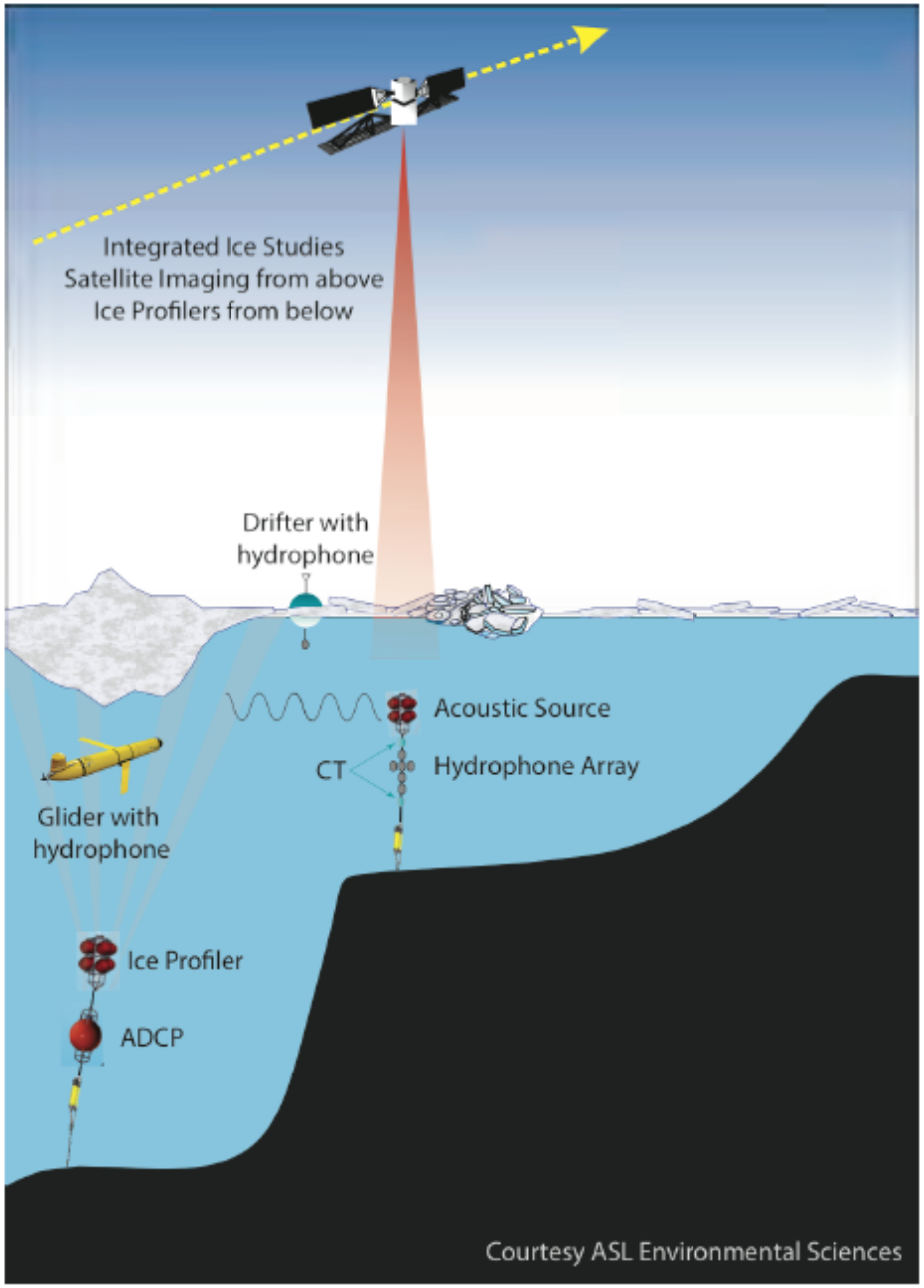
Open Water profiles, ice (March)



Open Water profiles, ice (March)



Proposed Acoustic Propagation Experiment


Integrated Ice Studies
Satellite Imaging from above
Ice Profilers from below
Drifter with
hydrophone
Acoustic Source
CT
Hydrophone Array
Glider with
hydrophone
Ice Profiler
ADCP
Courtesy ASL Environmental Sciences

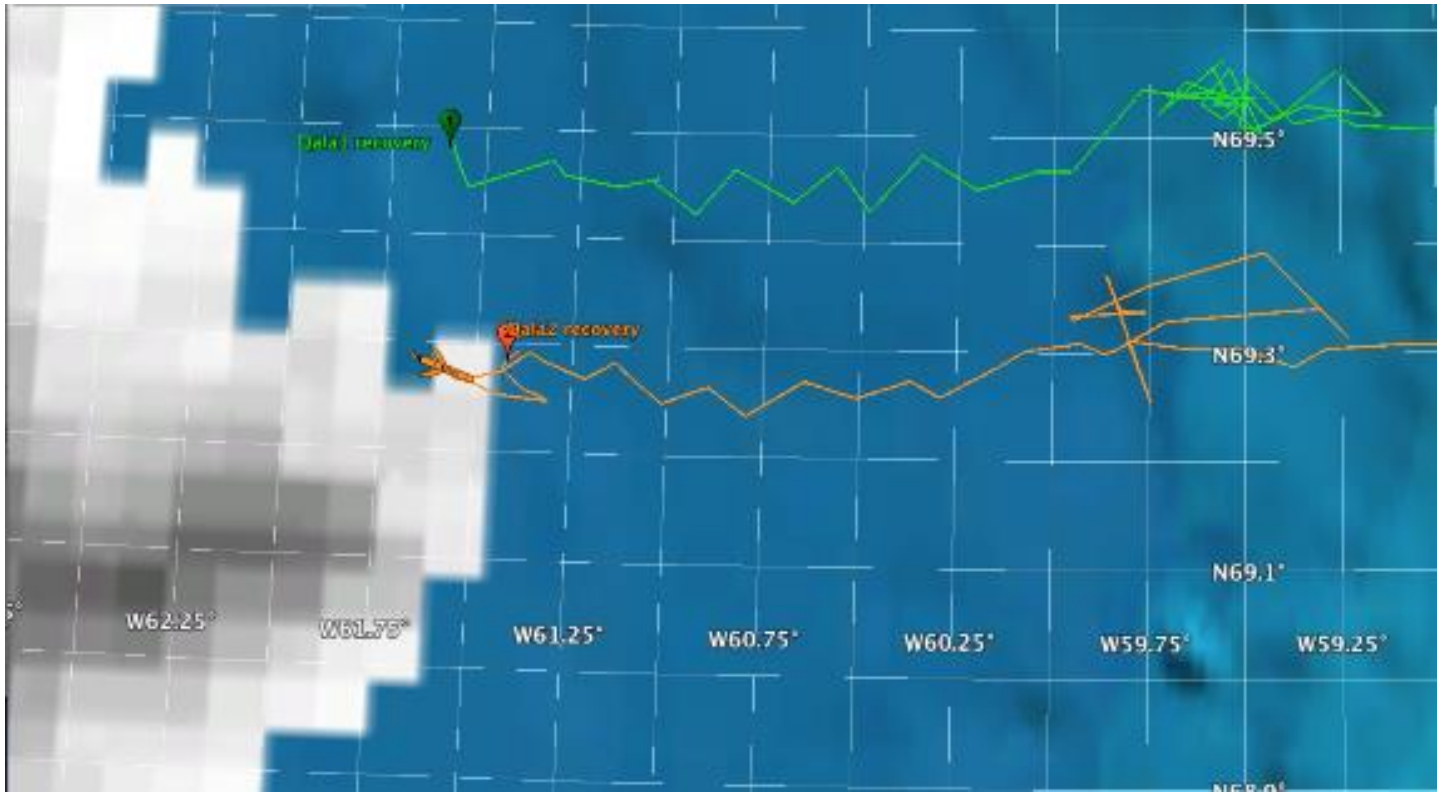
BBANC

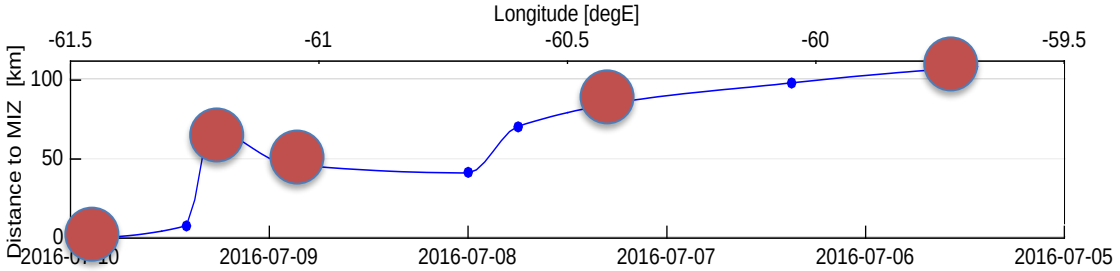
Baffin Bay Acoustic Navigation and Communication System

A W.G. Weston Foundation-funded feasibility study for a basin-scale multipurpose acoustic network in Baffin Bay. Key findings:

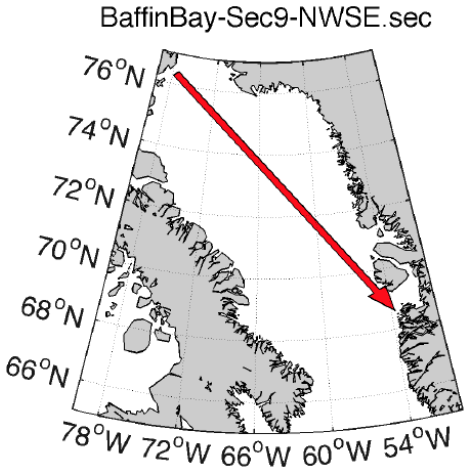
1. **Acoustic simulations demonstrate under-ice navigation, communication, and tomography signals are LIKELY feasible at basin scale at 150 – 250 Hz** with a small number (4-6) nodes. Further in-situ propagation tests are needed to narrow the ranges.
2. **A multipurpose acoustic network provides is the best use of acoustic resources.** Importantly, in addition to supporting tomographic studies of heat content, co-located acoustic sources and receivers provide the opportunity to control acoustic transmissions in presence of marine mammal populations.
3. **Acoustics in an ice-covered Baffin Bay are characterized by a near-surface duct** defined by scattering and absorption by ice at the top of the channel and temperature-pressure controlled refraction at depths < 200.
4. **Some physical parameters of ice cover that affect acoustic propagation (e.g., thickness, bottom roughness) are not well-known** at the required spatial scales. In-situ measurements with AUV/ROV platforms will improve modeling.
5. **Some acoustic parameters of ice cover can be estimated by inverse models** and controlled acoustic propagation experiments. (E.g., Compressional wave speed, acoustic attenuation coefficient).
6. **Baffin Bay ambient noise environment (soundscape) is not well characterized**. Existing passive acoustic observations should be gathered and new observations defined to fill spatio-temporal gaps as well as address mammal-mammal impacts.

The MIZ is highly dynamic

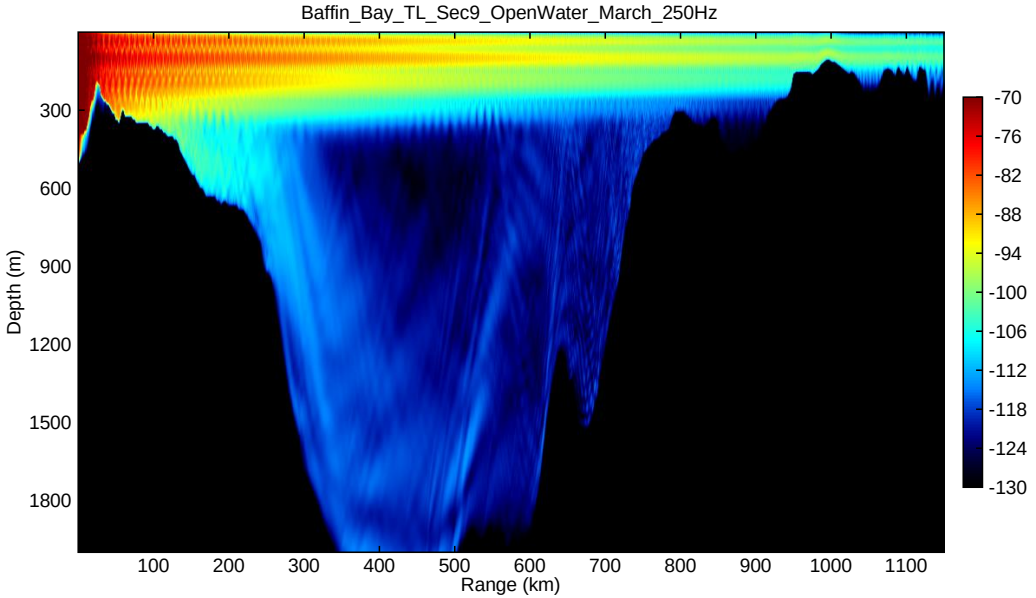


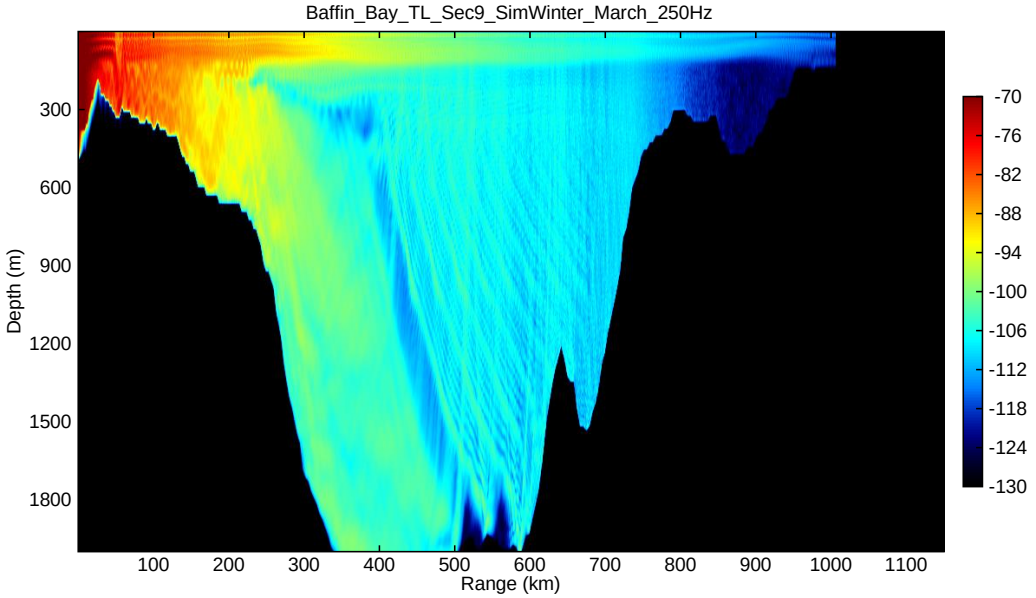


Open water propagation



Under-ice propagation

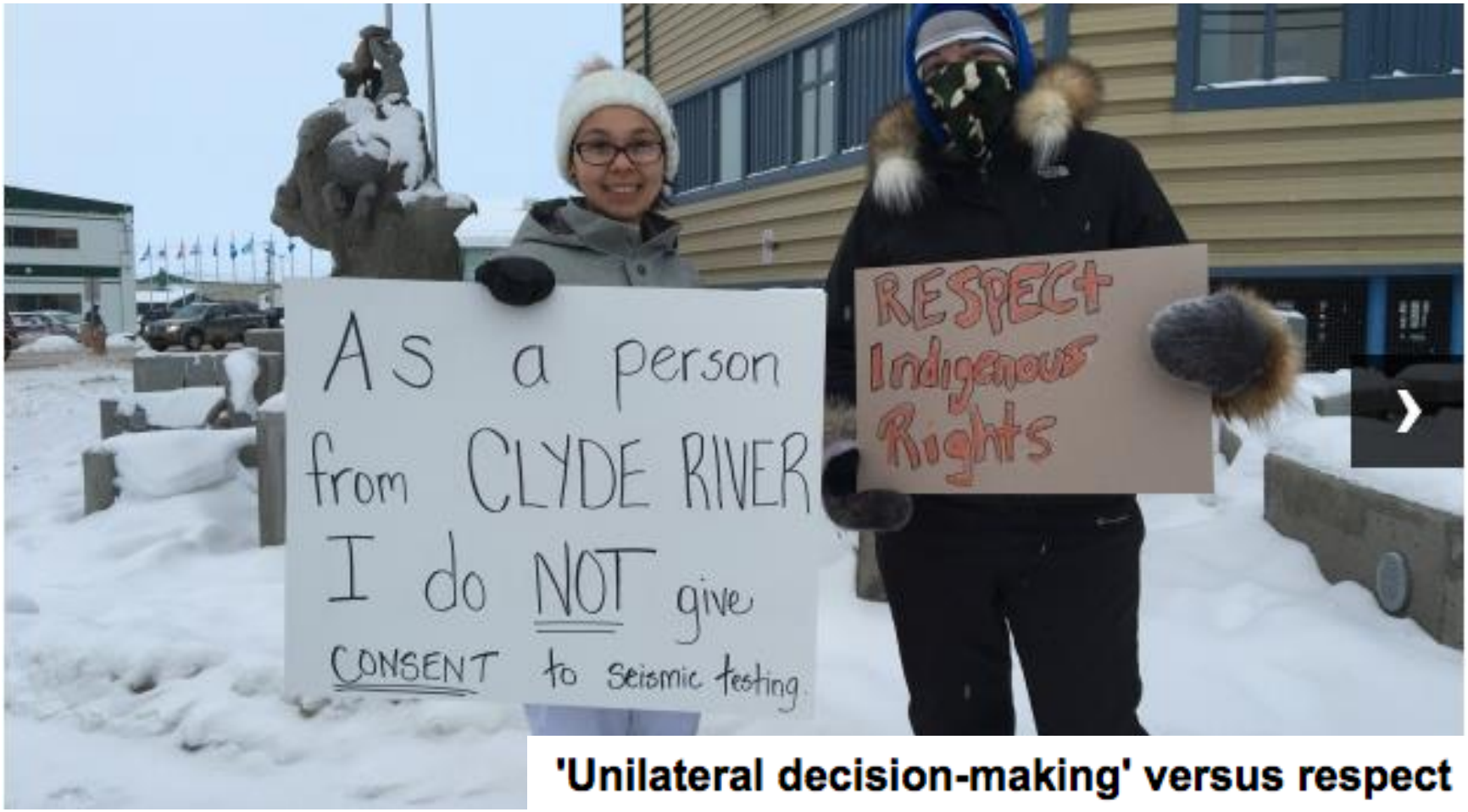




PHOTOS | 'We thought no one would care': Clyde River Inuit flooded with support

Hundreds show up for protest outside Supreme Court of Canada, as Nunavut hamlet argues case

By Elyse Skura, CBC News Posted: Nov 29, 2016 5:38 PM CT | Last Updated: Nov 30, 2016 7:14 PM CT



'Unilateral decision-making' versus respect

QUESTIONS?