Listening to the Oceans - Enabling Effective Techniques for Acoustic Imaging of Oceanic Structure

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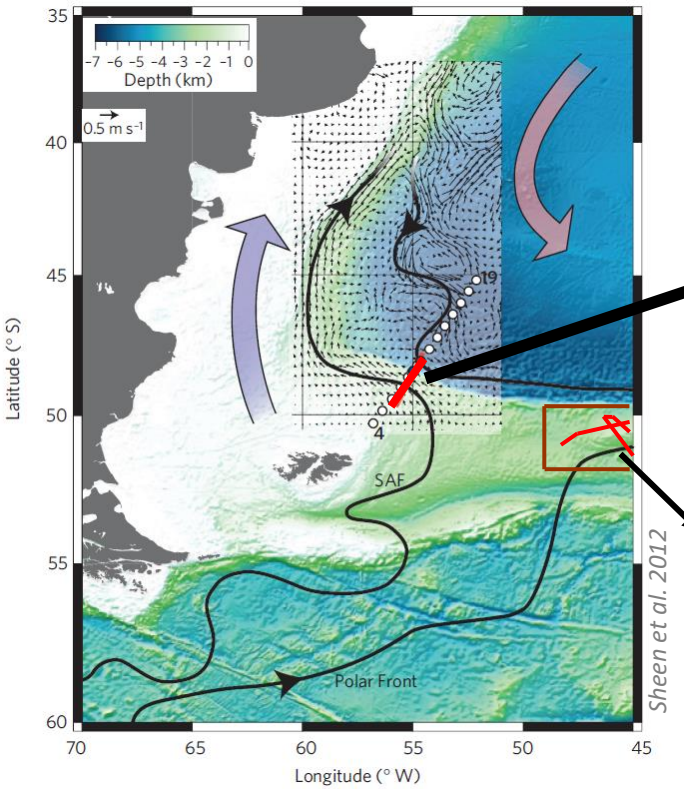
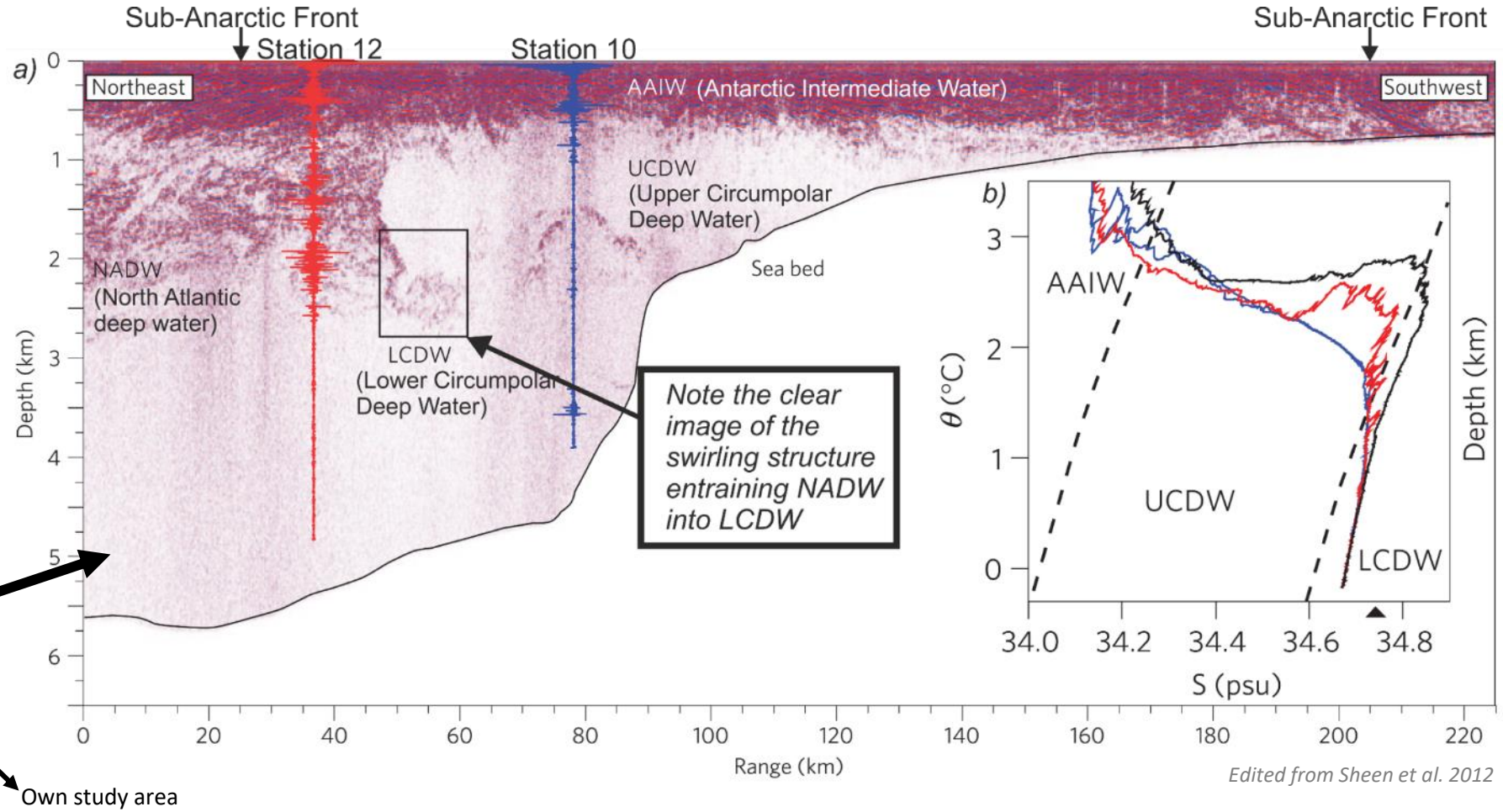
What is seismic oceanography?

- Acoustically images **temperature and salinity gradients**
- Provides **unprecedented horizontal and vertical resolutions O(10m)**



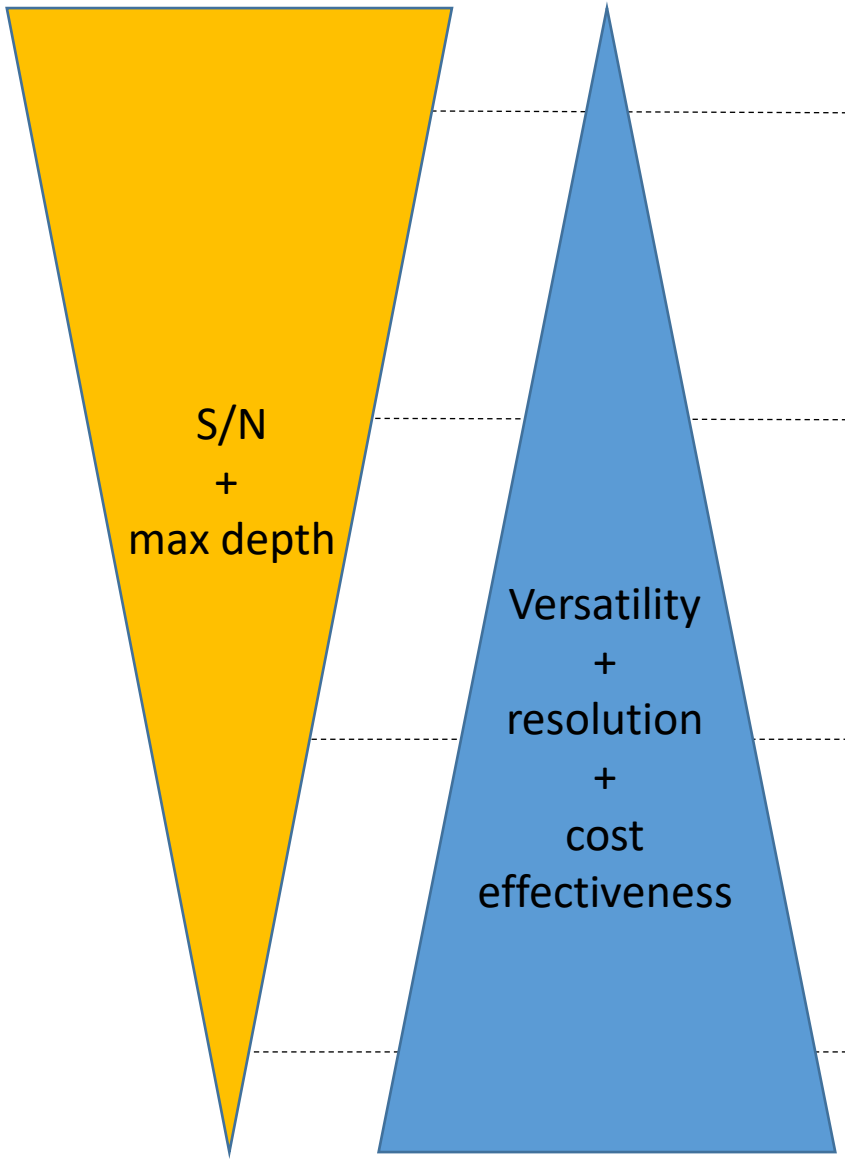


Multichannel seismic profile of the water column crossing the Brazil/Falkland Current in the SW Atlantic. Note the corresponding CTD stations (red and blue plots).

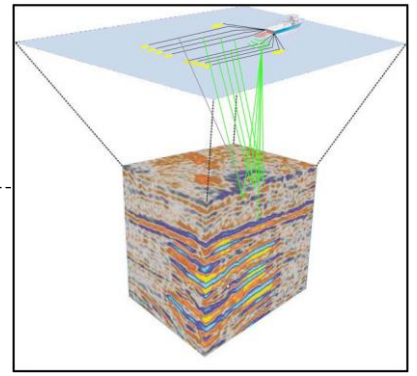
Finding a balance in the search for methods

Goal:

Working on three different datasets and analyse feasibility and effectiveness regarding their use in seismic oceanography

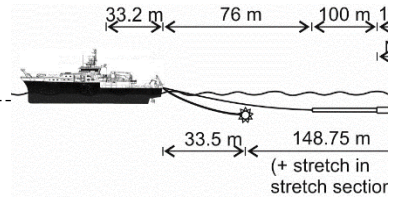


3D seismic survey
(source and streamer array)

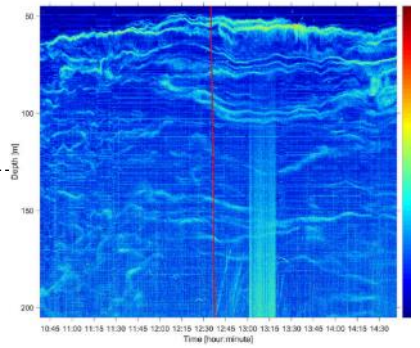


Camaselle 2010

2D seismic survey
(single source and streamer)



Hull mounted echo sounders



Stranne et al. 2017

Acoustic transceivers on autonomous vehicles

Own photograph

Dataset 3: Echo sounder data

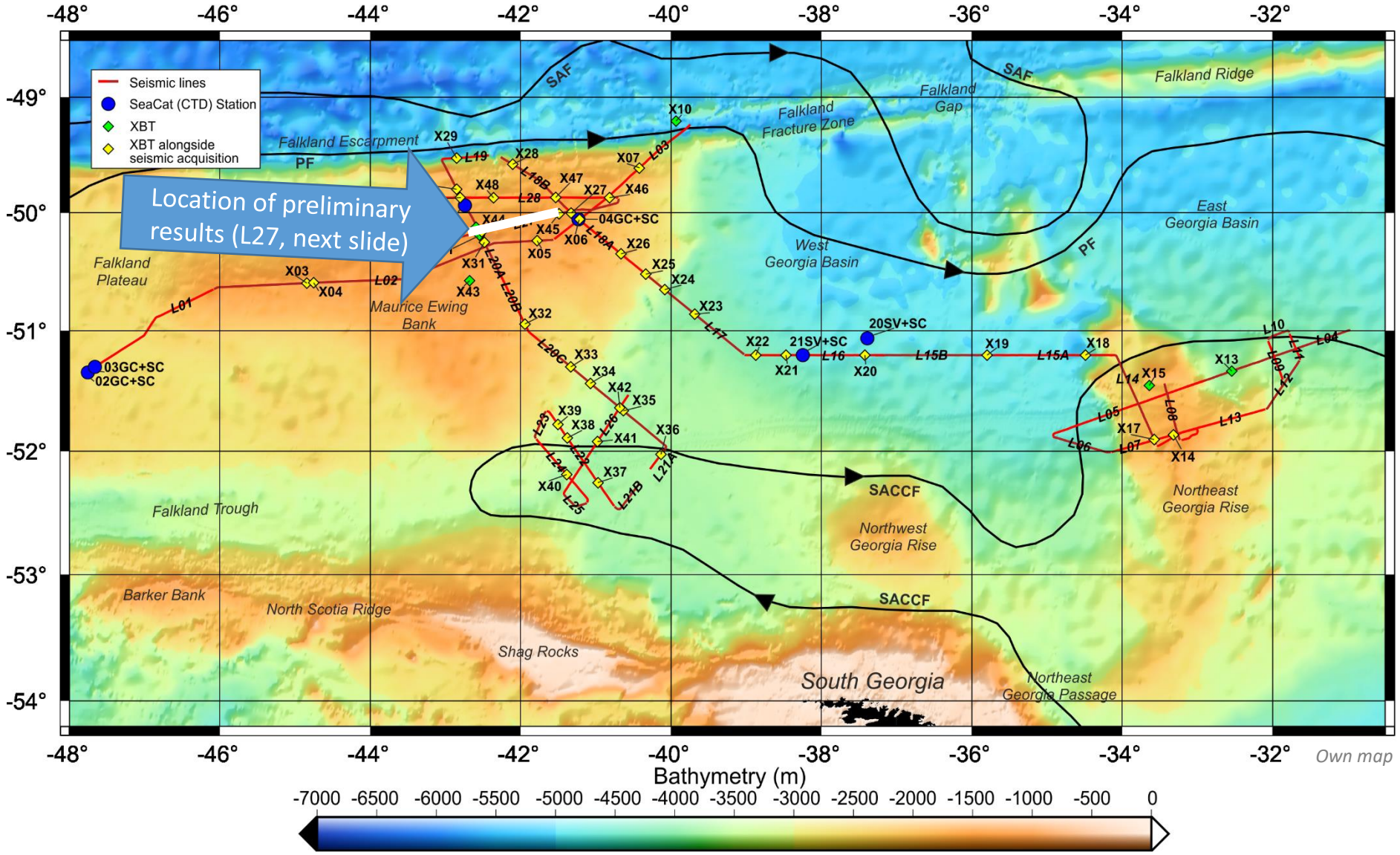
Dataset 2: 3D seismic data

Dataset 1: 2D seismic data

2D seismic data: results of DY087

Study area north of South Georgia, Southern Ocean

- 3286 km of seismic data
- 44 XBT deployments
- 7 CTD deployments



Dataset 3: Echo sounder data

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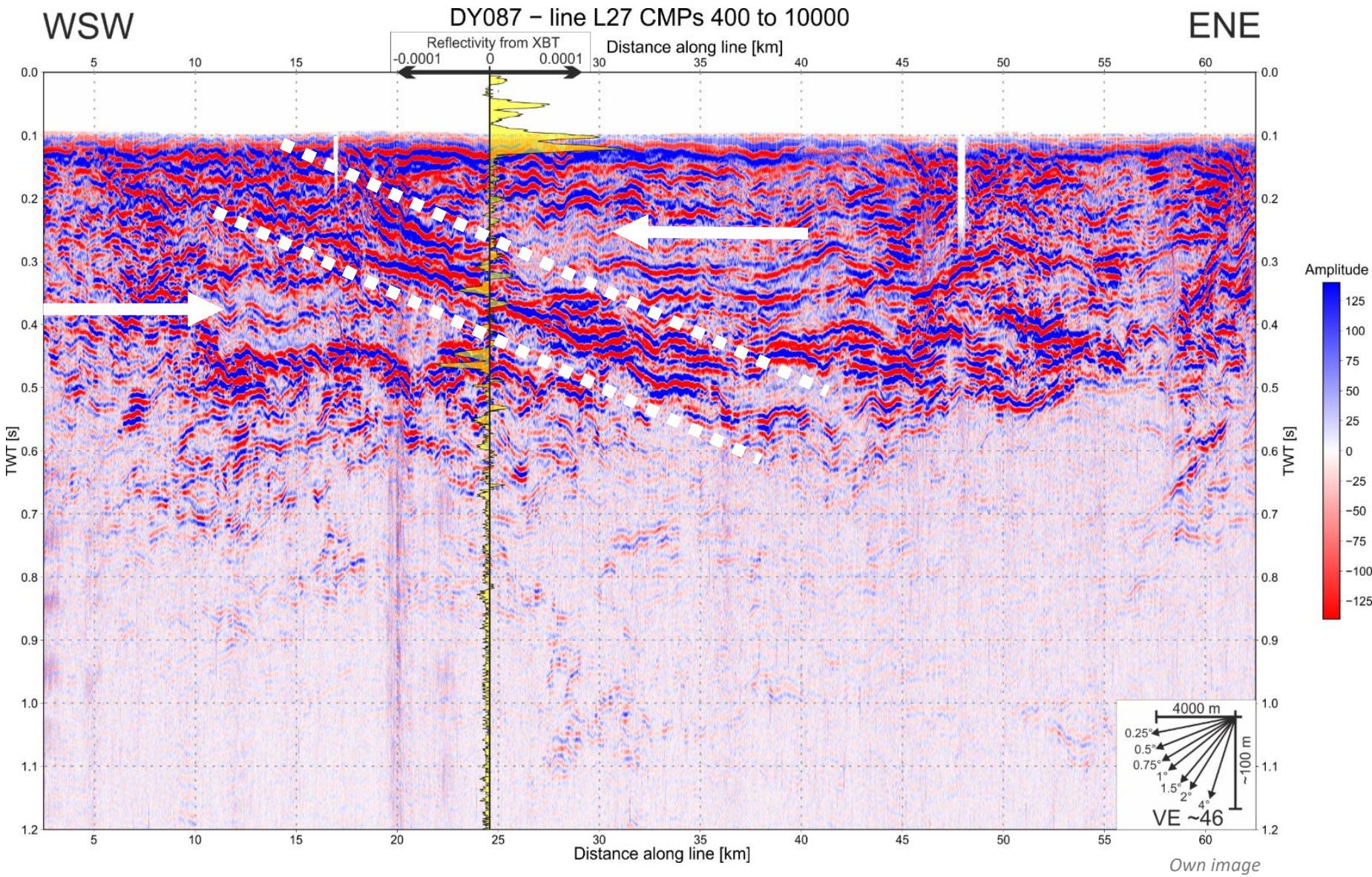
2D seismic data: preliminary results

- Data shows structure in up to ~800 m depth with a high horizontal resolution
- Prominent diagonal reflectors show where the oceanographic setting is changing horizontally



Own image

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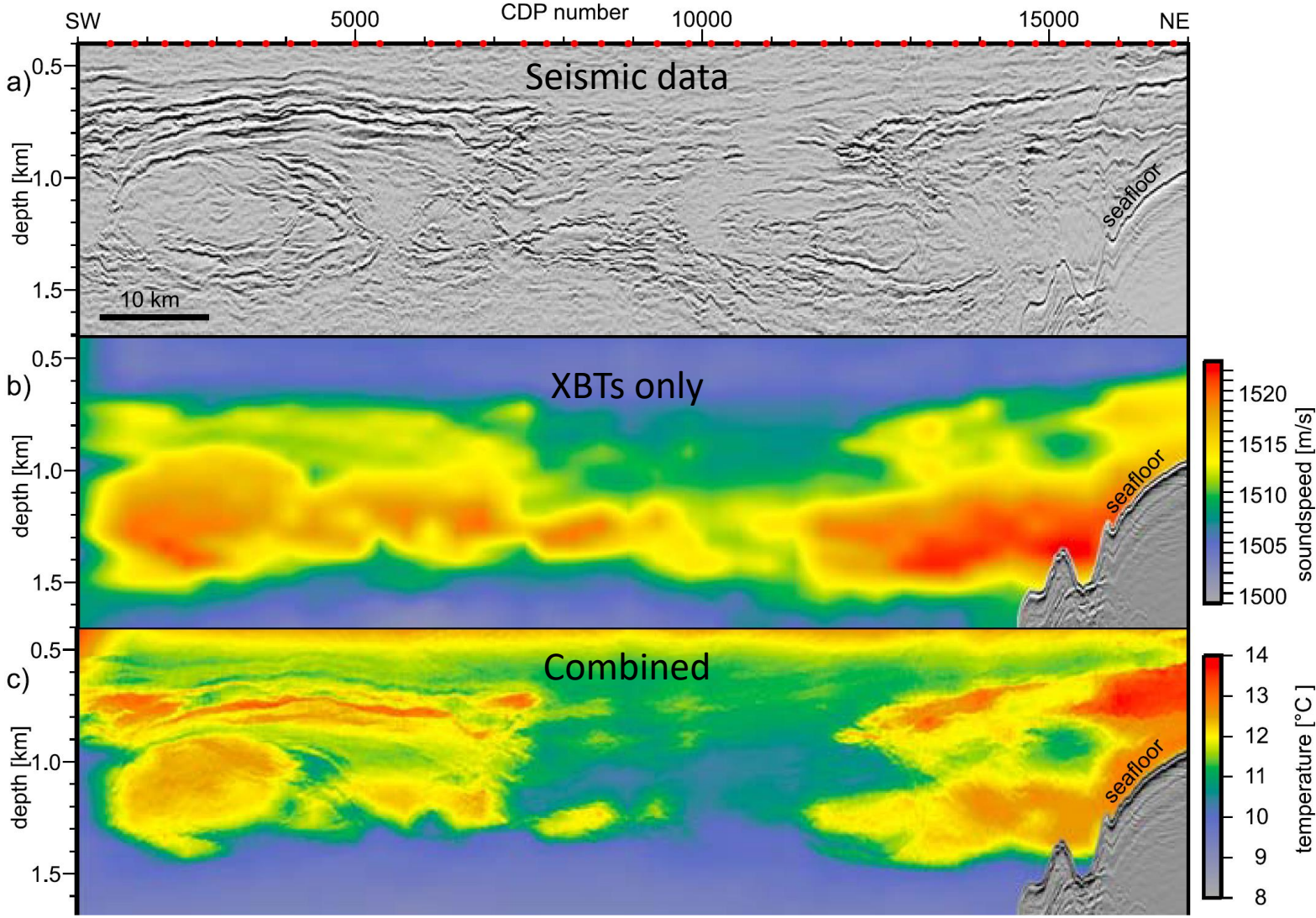
In progress: seismic data inversion

Combining seismic data with vertical temperature profiles (here from XBTs and CTDs) produces refined maps of physical properties

- Temperature
- Salinity where available
  - Velocity
  - Density



Papenberg et al. 2010

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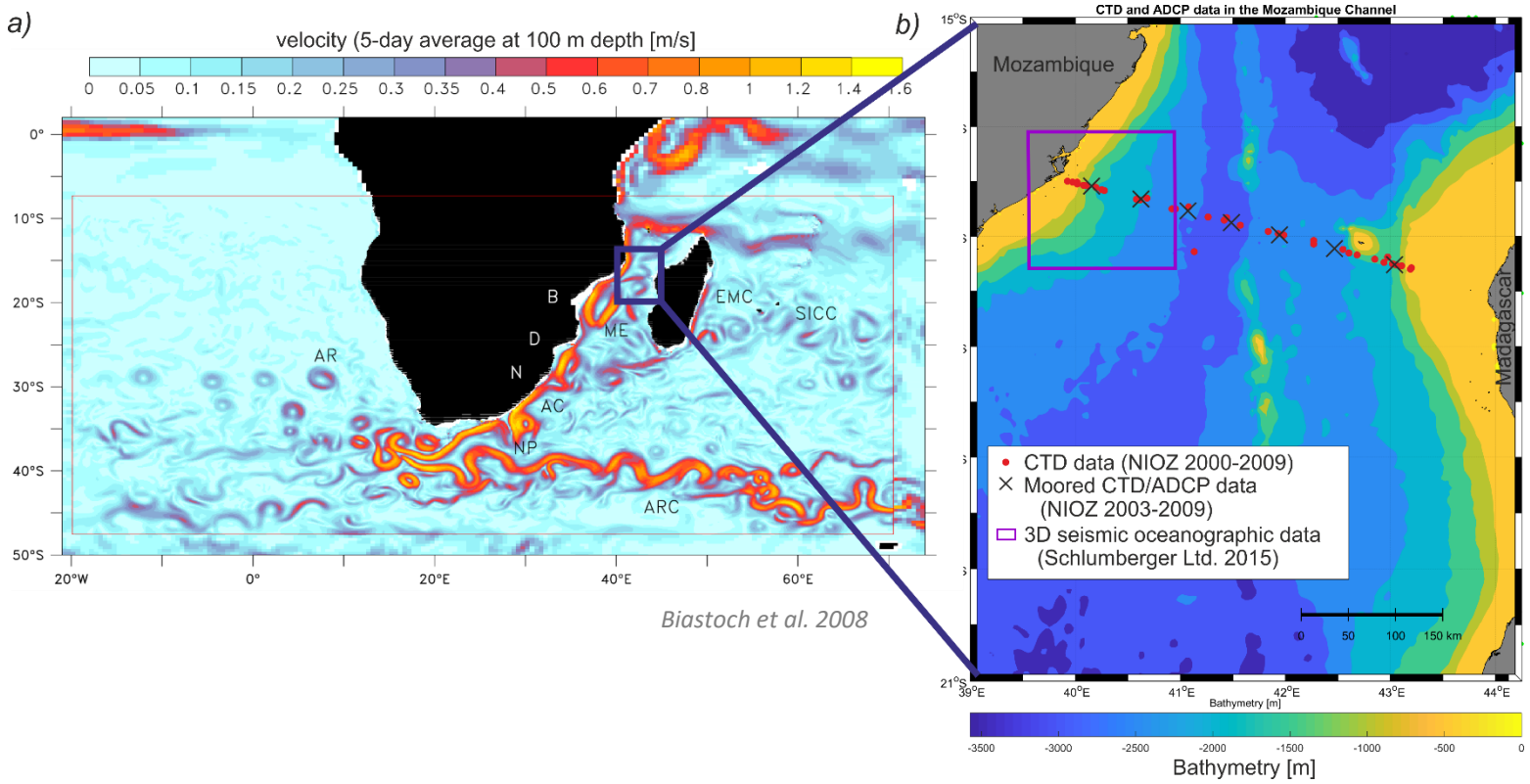
3D seismic data

Data provided by **Schlumberger**

- **Study area: Mozambique Channel**
  - affected by eddies and change in transport direction, channel volume and velocity
  - acts as a pacemaker for the Agulhas Current system
- High quality industry dataset



Biastoch et al. 2008

Own map. Position of 3D seismic survey not accurate

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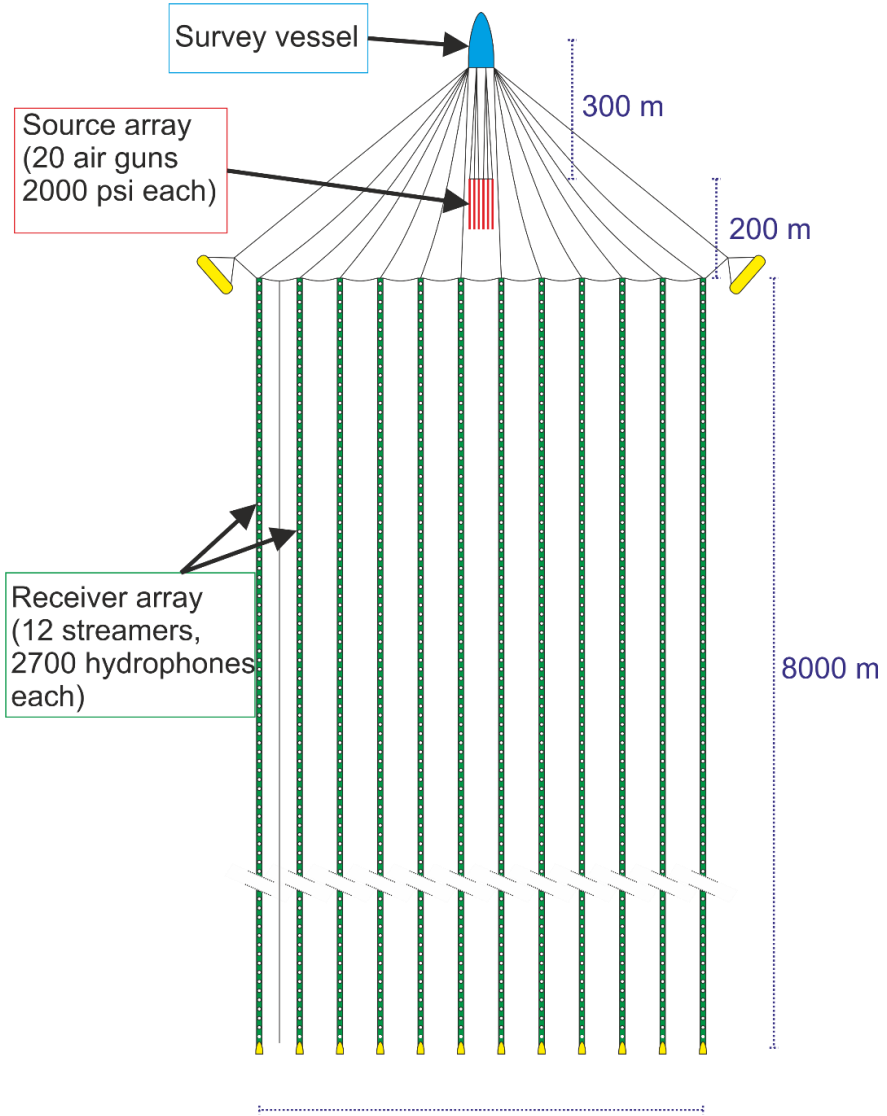
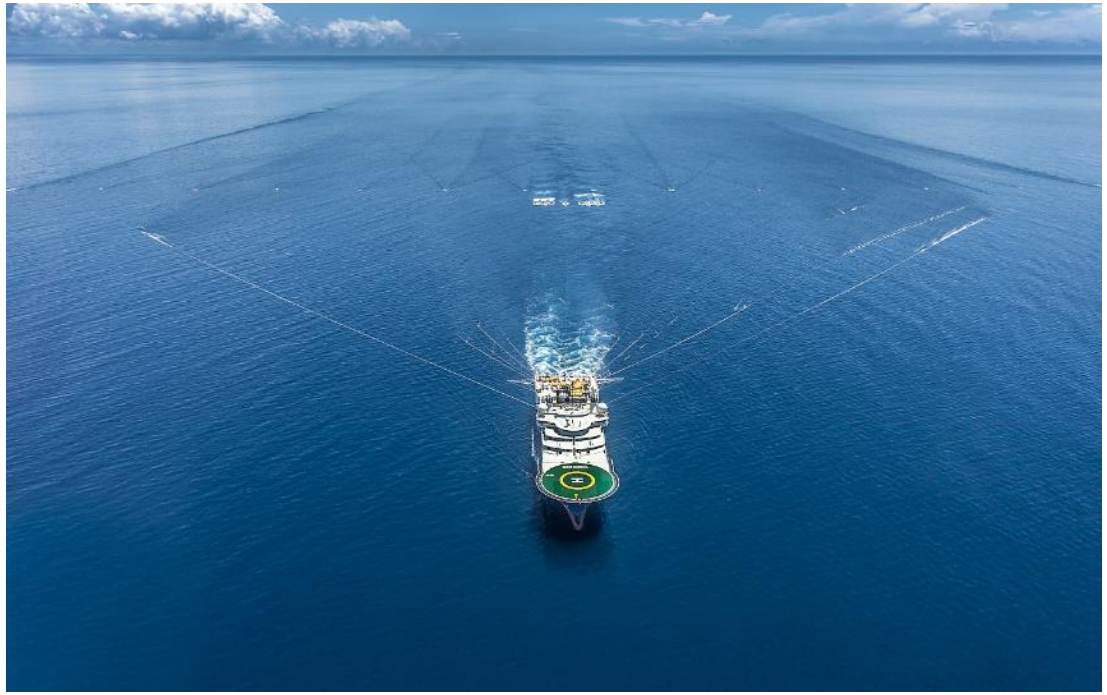
3D seismic surveys



Own sketch, exemplary numbers not accurate



www.maritimeherald.com, 9th June 2017

- 3D seismic surveys result in a extraordinarily high data density: locations are sampled repeatedly
- Require a high amount of logistical effort and money
- High pressure sources and towed hydrophone arrays with several kilometres in length and hundreds of metres in width

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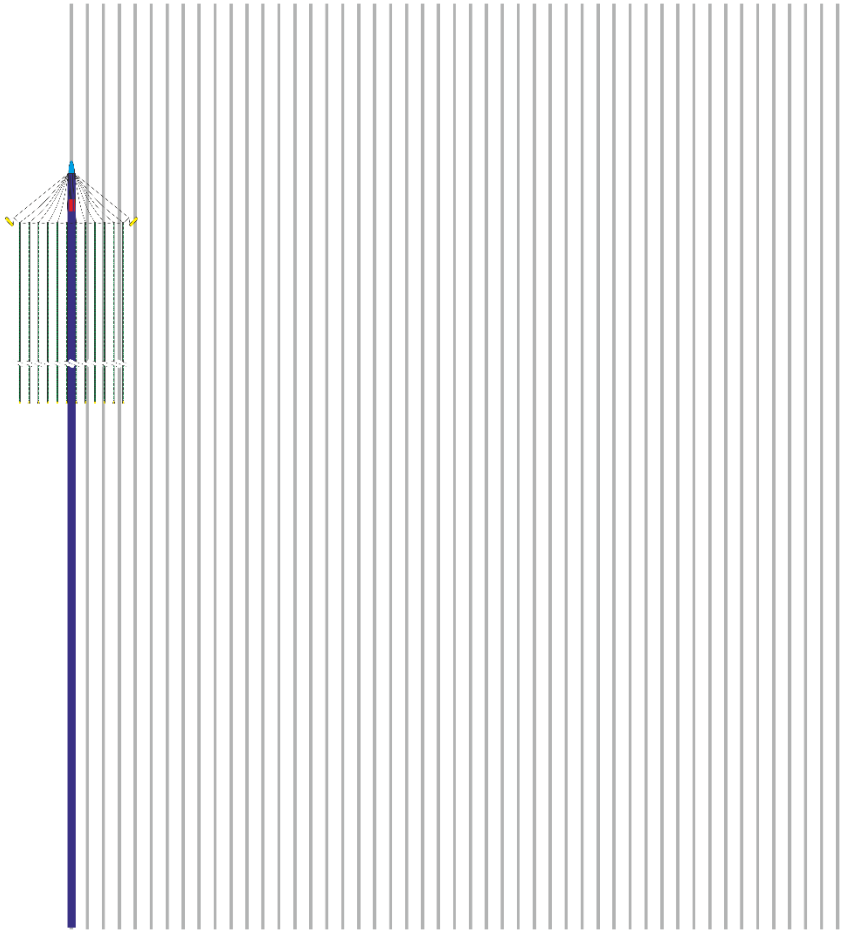
Why use 3D seismic surveys for seismic oceanography?

- 3D seismic surveys feature very dense grids, with **distances of O(10 m) between lines**

Continue to see how the survey progresses



Own sketch

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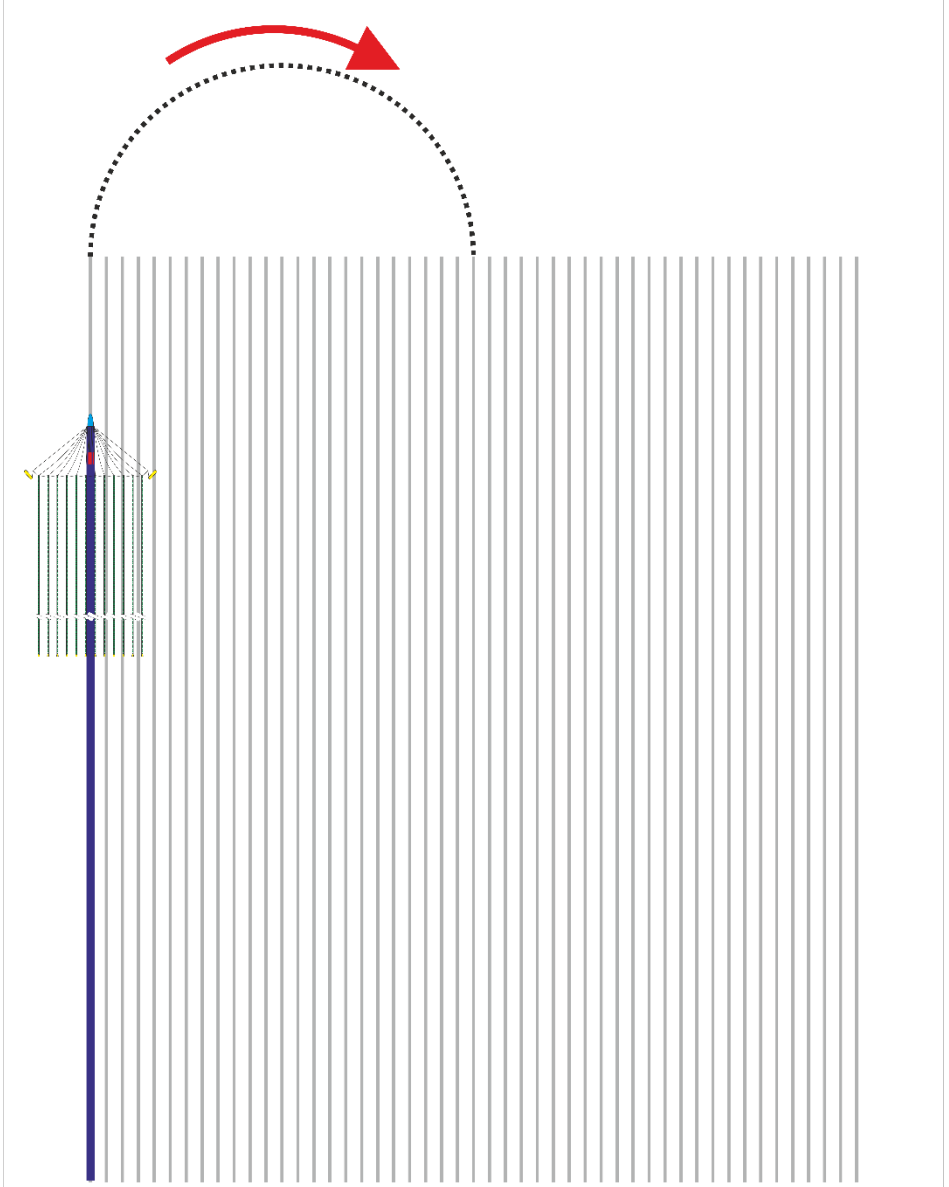

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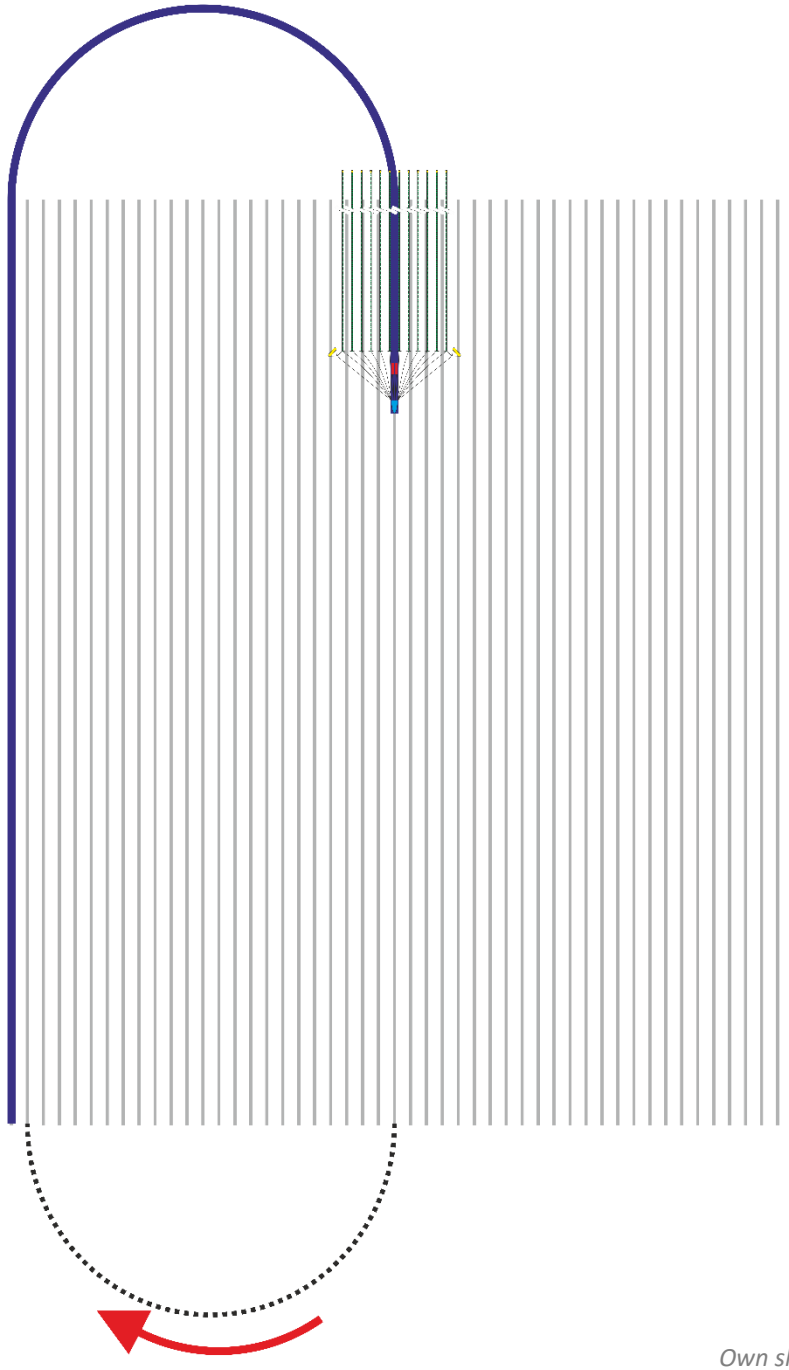

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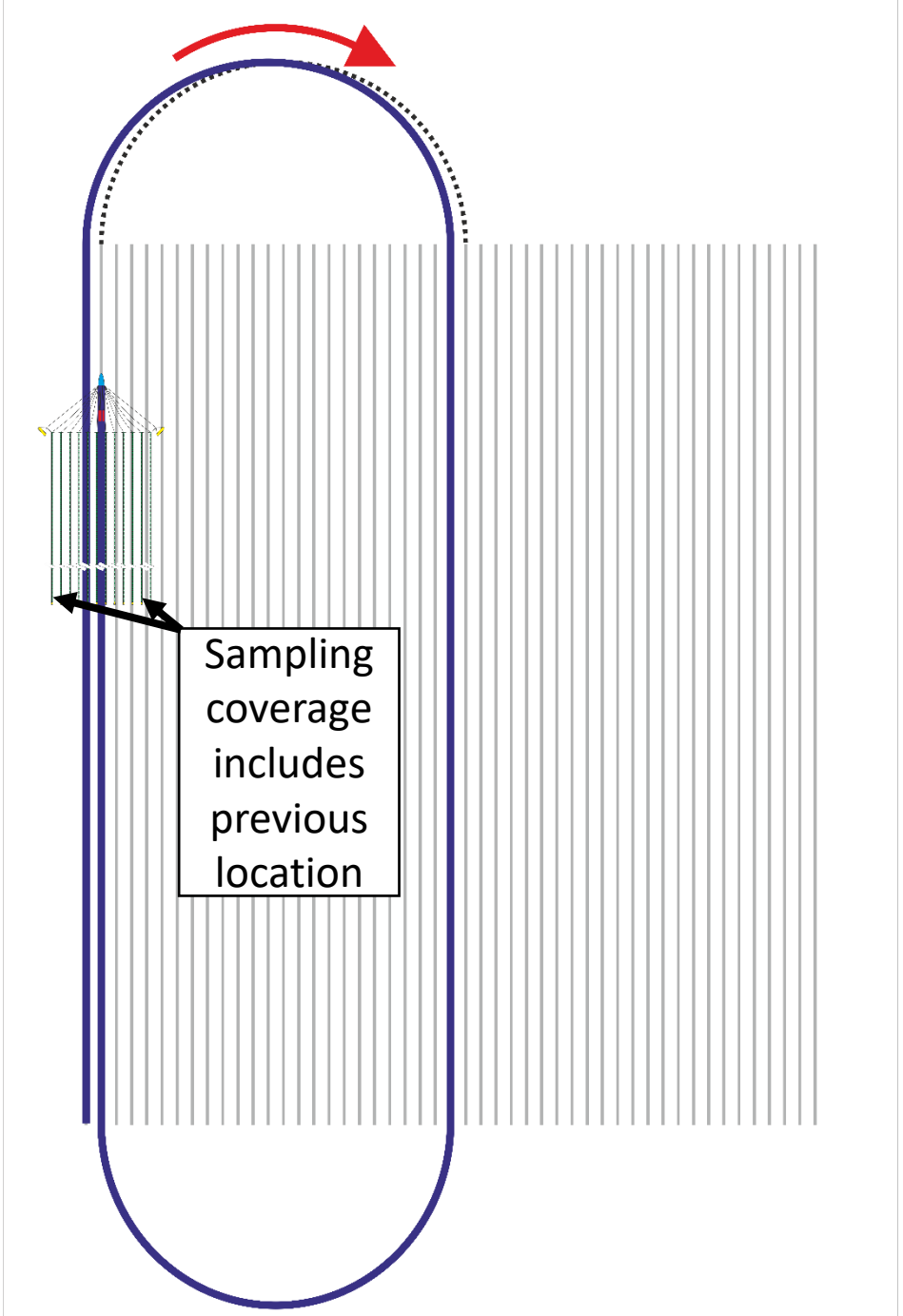

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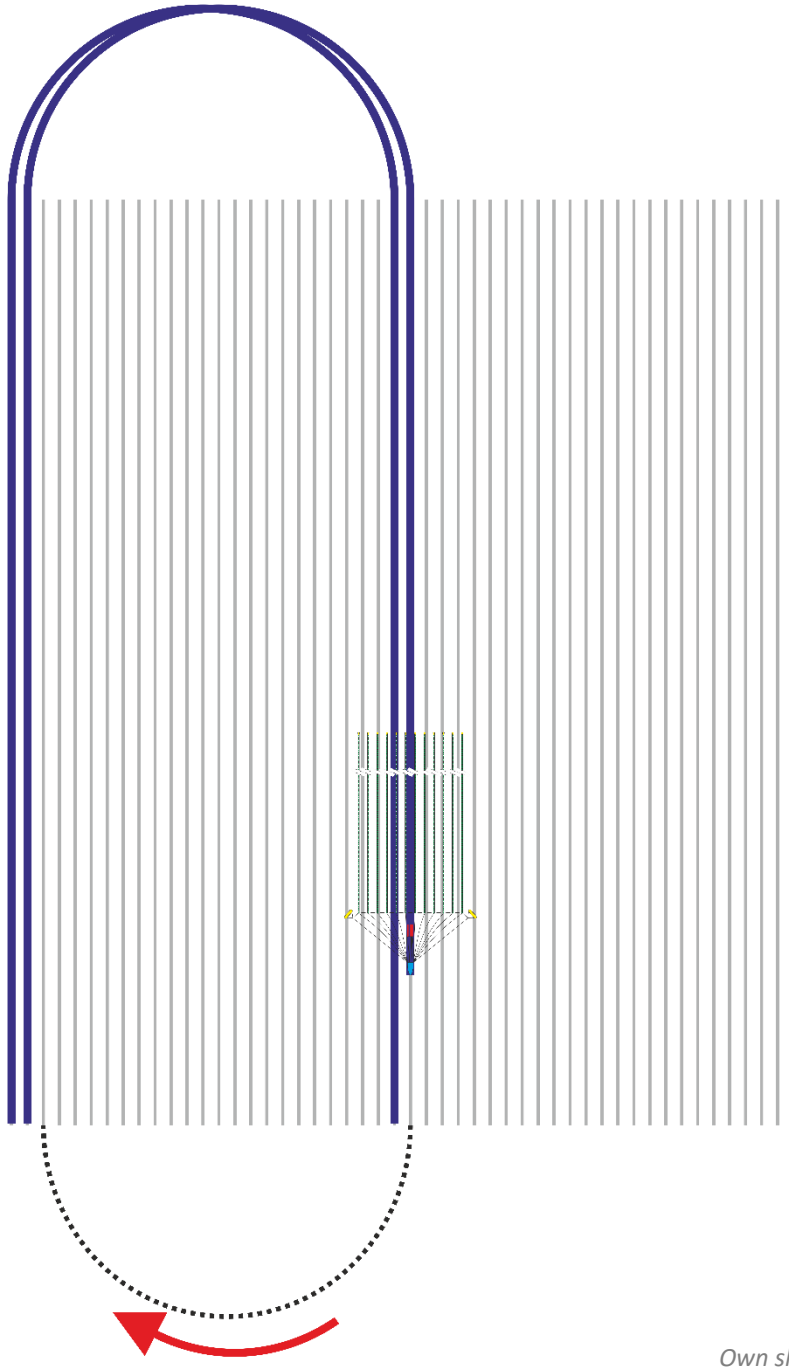
Limited sampling over time to observe ocean dynamics possible



Own sketch

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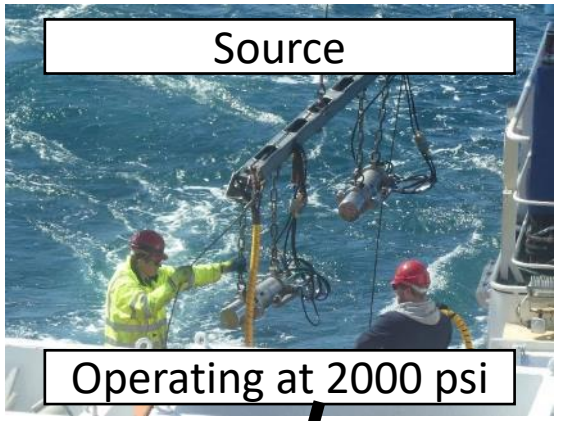
Limitations of using conventional seismic surveys

- Expensive
  - High logistical effort
  - Appropriate vessels and equipment are very expensive and need specialists

- Survey track most of the times not controlled by oceanographers
  - Spatially limited
  - Temporally limited

Not suited for <u>long term observations</u> to <u>extract temporal variability of the ocean</u>

Own photograph



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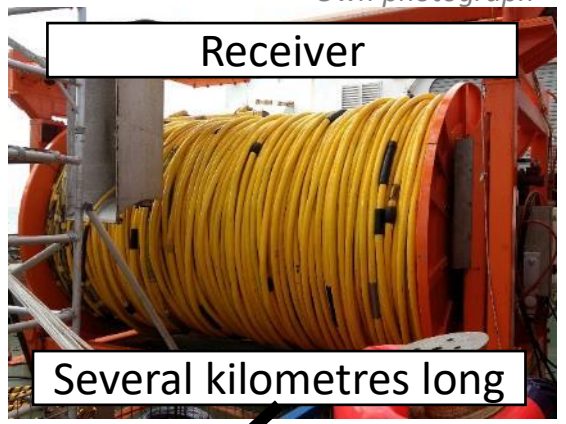

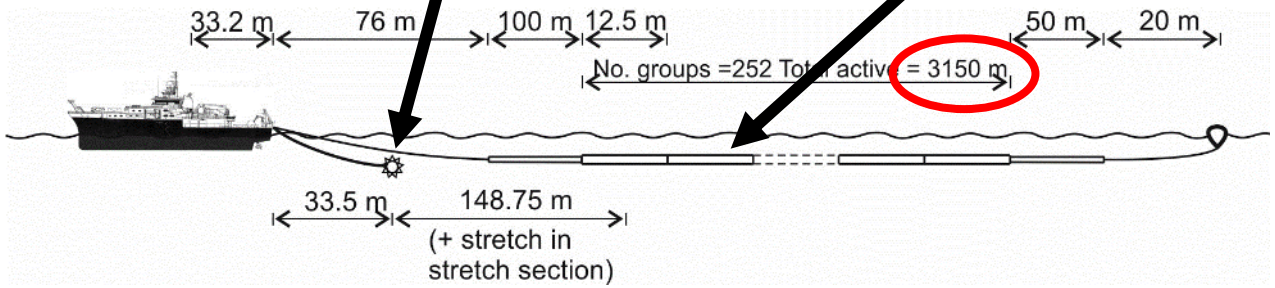

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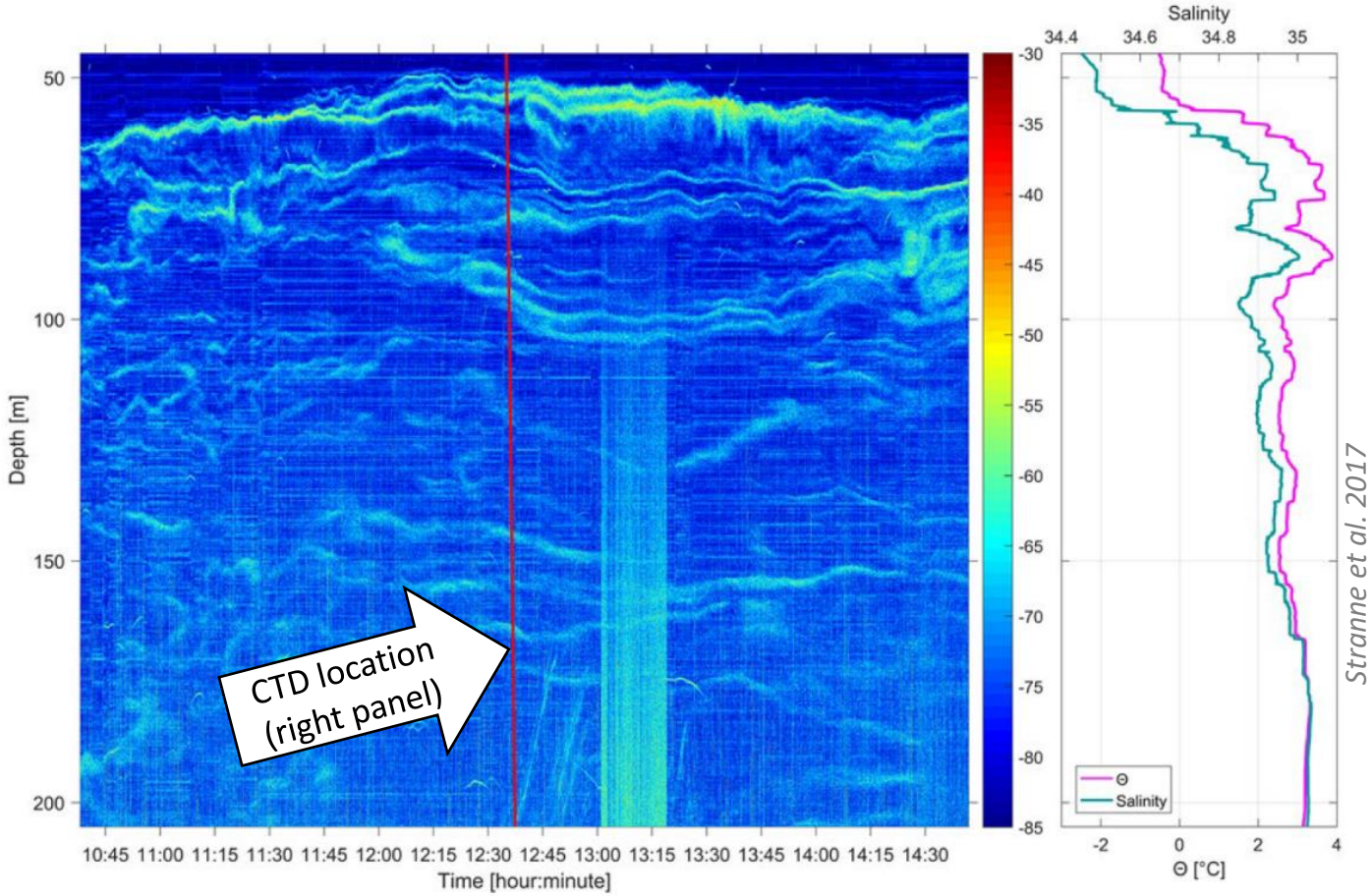
Alternatives: Hull mounted echo sounders

- More **readily available** (installed on most research and fisheries vessels)
- **Higher resolution**, but lower maximum depth and S/N
- **Own data: ICEBERGS project** on *RRS James Clark Ross*
  - Running calibrated EK80 (38, 70 and 120 kHz) with CTDs and VMADCP
  - In progress: can thermohaline gradients from a rapidly deglaciating region be observed using a higher frequency echo sounder?



Stranne et al. 2017:
Imaging of thermohaline staircases in the high Arctic Ocean Hull-mounted EK80 broadband echo sounder (15-25 kHz) on icebreaker Oden

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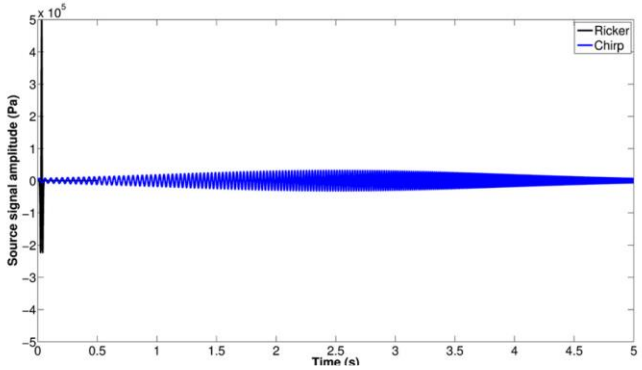
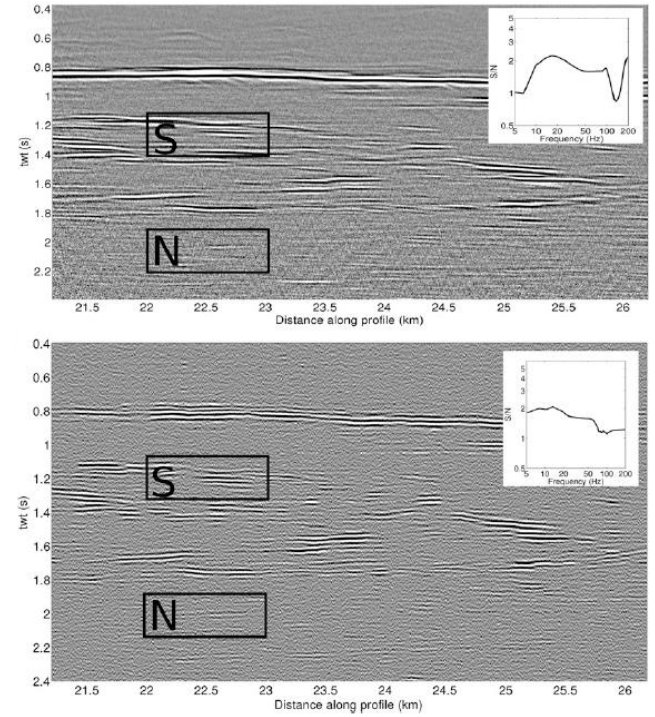
Wrapping up: Which acoustic source to use?

All datasets will be fed into acoustic forward modelling to provide answers:

- Higher frequencies improves **vertical resolution**, while the penetration depth of the signal decreases – **what frequencies work best for seismic oceanography**?
- Can the amplitude be reduced to levels that **minimize the impact on the marine environment**?
- How **small/inexpensive** can the source get? Can it be used with **autonomous technology**, e.g. on unmanned surface vehicles?





***Forward modelling by Biescas et al. 2015**: amplitude over time for two different wavelets (top) and 5 km synthetic seismic profiles based on multichannel seismic data showing the edges of an eddy in the Gulf of Cadiz using those two wavelets (right)*

Biescas et al. 2015

Own photograph

***Cefas' Waveglider "Lyra"** operates a fisheries echo sounder (70 and 200 kHz) to analyse plankton density.*