How do we measure the Ocean under the ice?

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Introduction

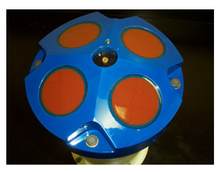
An ice-covered ocean is hard to measure. Most ships (except for icebreakers) cannot go into the ice and even modern icebreakers can struggle in thick ice. Additionally, the ice hides the ocean from the view of satellites which inhibits large-area surface measurements.
Since the polar oceans play an important role in the global ocean circulation, we need to find ways to observe them.

Ship-based measurements

- Flexible platform for all kinds of operations
- „Moon-pool“: Hole in the middle of the ship helps with deployment of instruments when the ship is surrounded by ice
- Limited by weather, ice and time

Icebreakers have a reinforced hull to withstand and break ice (e.g. RV Kronprins Haakon can break ice up to 2.5 m)

CTD-Rosette
- Measures **C**onductivity, **T**emperature, **D**epth and can be equipped with more sensors (e.g. for nutrients, chlorophyll, flow velocity)
- Rosette of bottles for water samples



ADCP - Acoustic Doppler Current Profiler
- Measures the velocity under the ship using the Doppler Effect
- Can be mounted on a lot of other measurement devices (e.g. CTD)

Microstructure Sonde
- Measures flow shear and temperature at an extremely high resolution
- Used to deduct energy dissipation and mixing

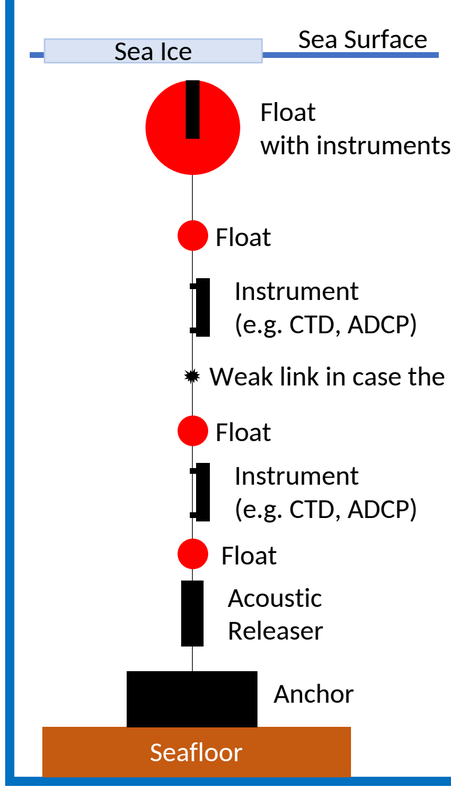
ROV - Remotely Operated Vehicle
- Remote-controlled Robot
- Equipped with lots of instruments, arms and storage for samples

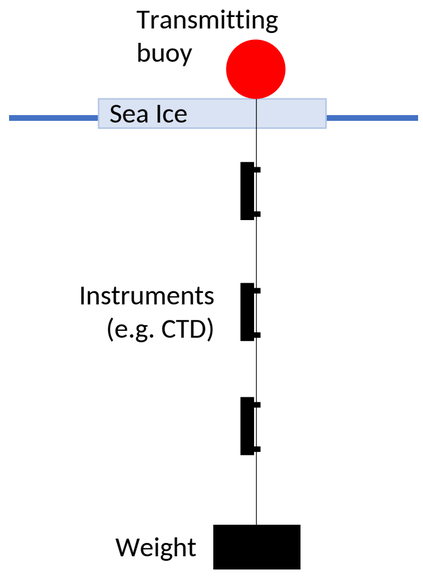
Ice-based measurements

- Instruments can be lowered into the ocean through holes in the ice
- Require thick enough ice and a way of keeping the hole open
- Possible to measure the direct boundary between ice and the ocean

Moored instruments

- Long measurement time-series, even during times where icebreakers can‘t reach the locations
- Instrument replacement every few years
- Some instruments can move up and down the wires -> profiles
- Multiple moorings can form mooring arrays -> large scale observations





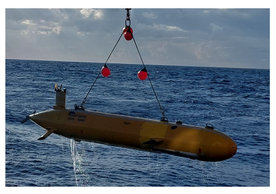
Ice-tethered moorings can even drift into areas that ice-breakers can‘t reach!

Autonomous measurements

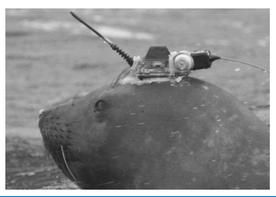
- Stay in the Ocean for months to years without needing a ship present
- Can reach areas where ships can‘t go, but need to surface every now and then to verify their position
- Can be controlled via satellites from anywhere in the world
- Positioning is a huge challenge

Glider
- Navigates by changing its density and using its wings to glide around
- Surfaces to verify its position
- Missions can last multiple weeks to months

ARGO Float
- Drifts with the Ocean
- Profile every 10 days
- Very easy to deploy
- Can last multiple years



AUV - Autonomous Underwater Vehicle
- Moves with a propellor
- Can be used for mapping the seafloor or the underside of sea ice



Tagged Seals
- Insights into animal behavior
- Can cover great areas and dive deep

Key points

- Ice makes it hard to get measurements, especially over larger areas and in winter
- Different measurement techniques for different goals
- Autonomous measurements are good to extend in-situ measurements

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Seal: Roquet et al. (2009; see left for full citation).