Observing the ocean under the melting sea ice.

Hanne Sagen & Stein Sandven

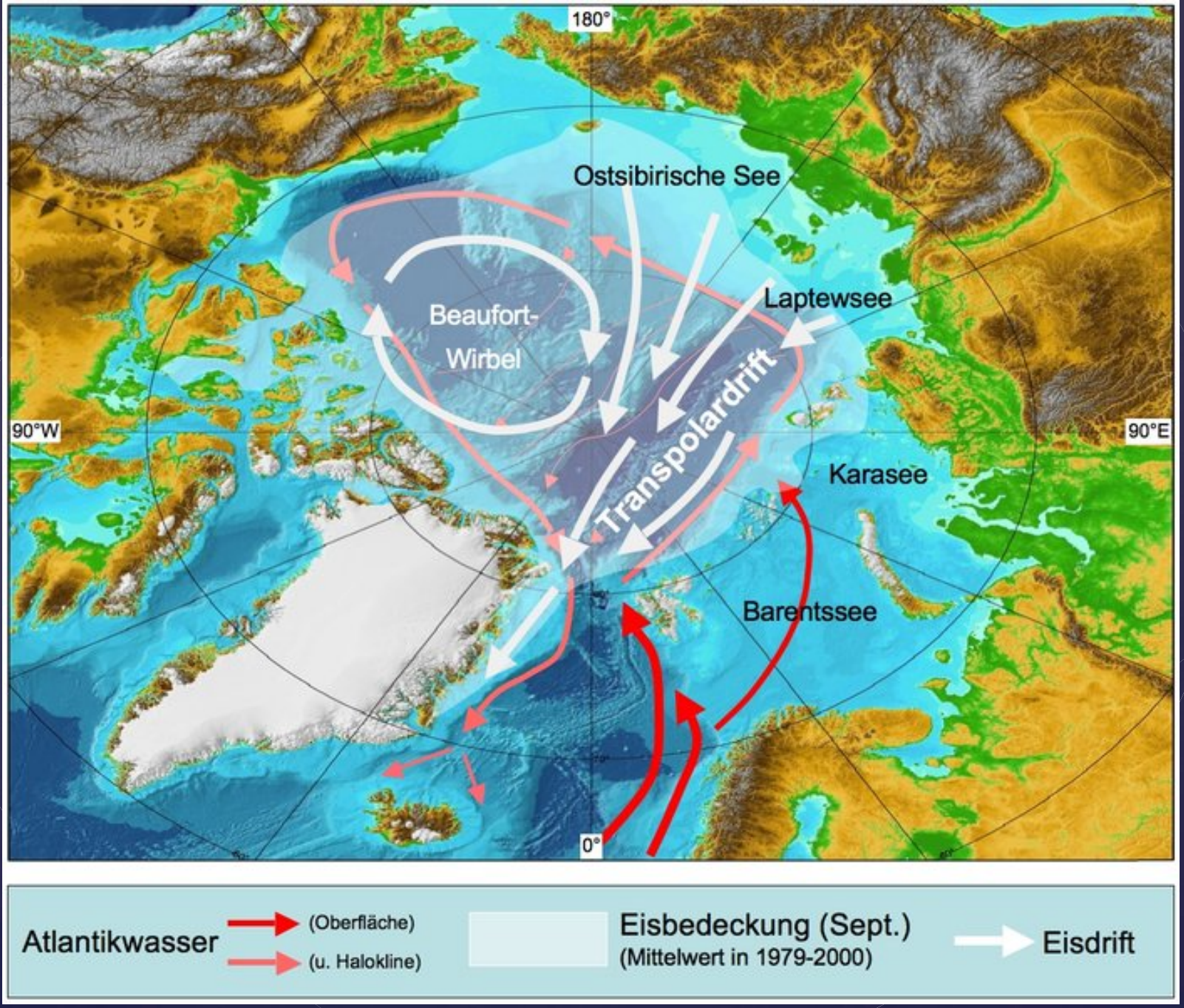
The Research Council of Norway

With funding from
The Research Council of Norway

GDF SUEZ

UNDER ICE

NERSC



From http://www.geomar.de

Key questions about the Arctic Ocean

Fresh water – high stratification

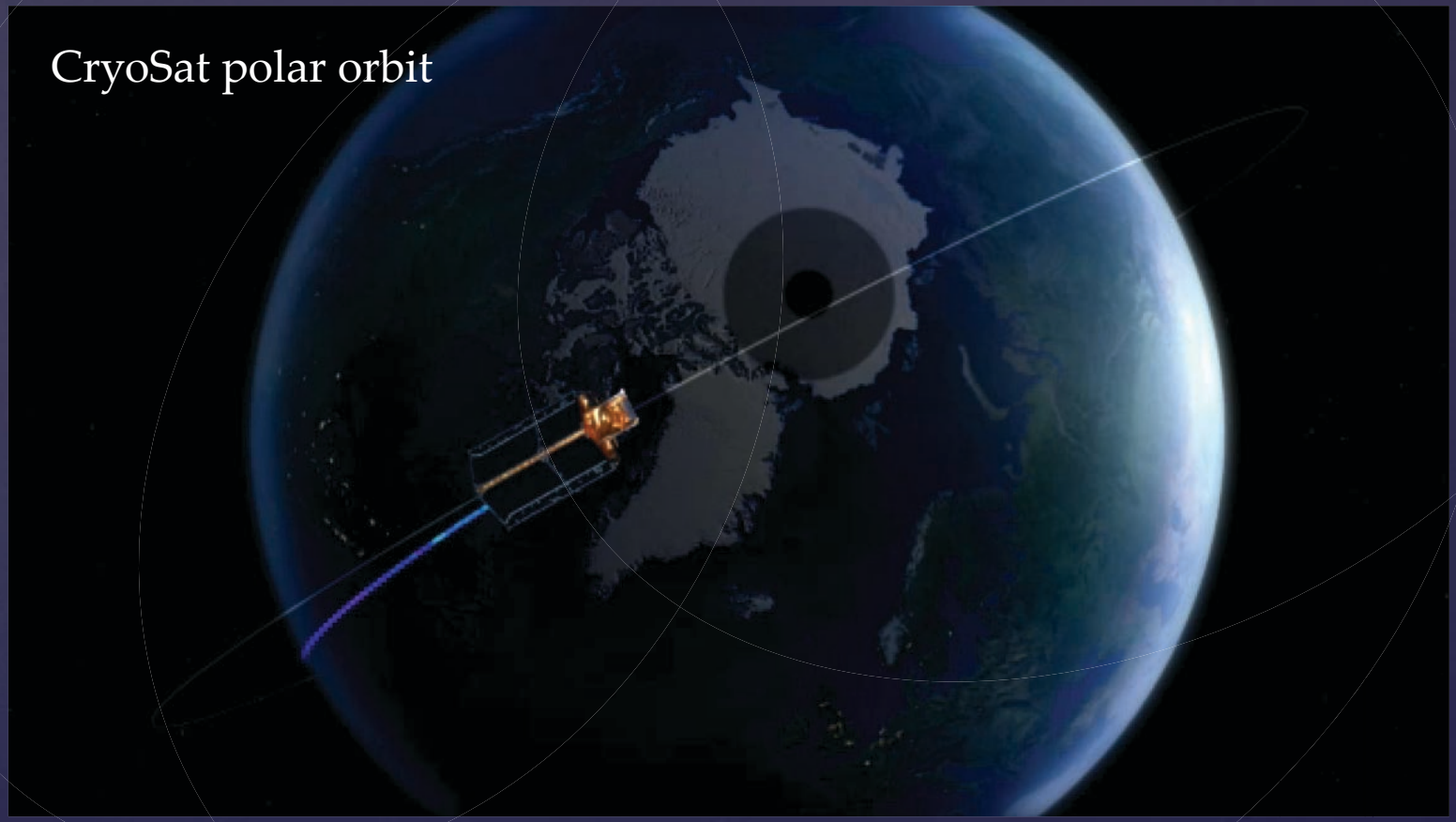
- How much heat is stored in the Arctic Basin?
- How will the freshwater content / upper ocean stratification evolve in the coming years?
- What are / will be the implications of upper ocean changes?
- What is the feedback of all these changes with the changing sea ice cover?
- What is the time and space variability of the warm Atlantic Water circulation?
- What are the implications of changes in the intermediate and deep circulation of water masses in the Arctic?

How can we observe the Arctic Basin to help to answer these questions?

Outline

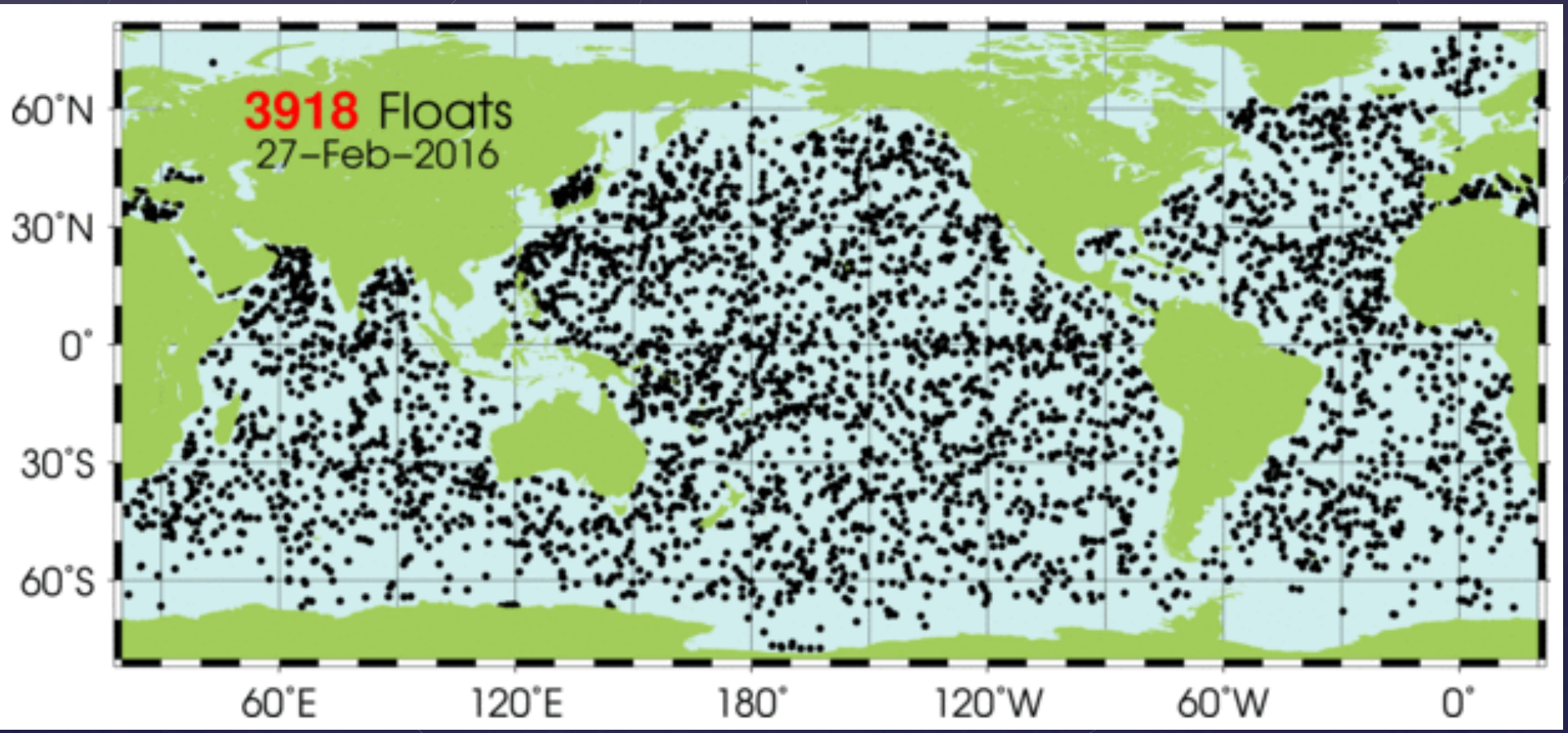
- **Challenges in observing the Arctic**
- **The ARGO program**
- **The International Arctic Buoy Program**
- **Multidisciplinary Moorings**
- **Acoustics in an Arctic Ocean Observing system**
- **The Fram Strait observatory (Film)**

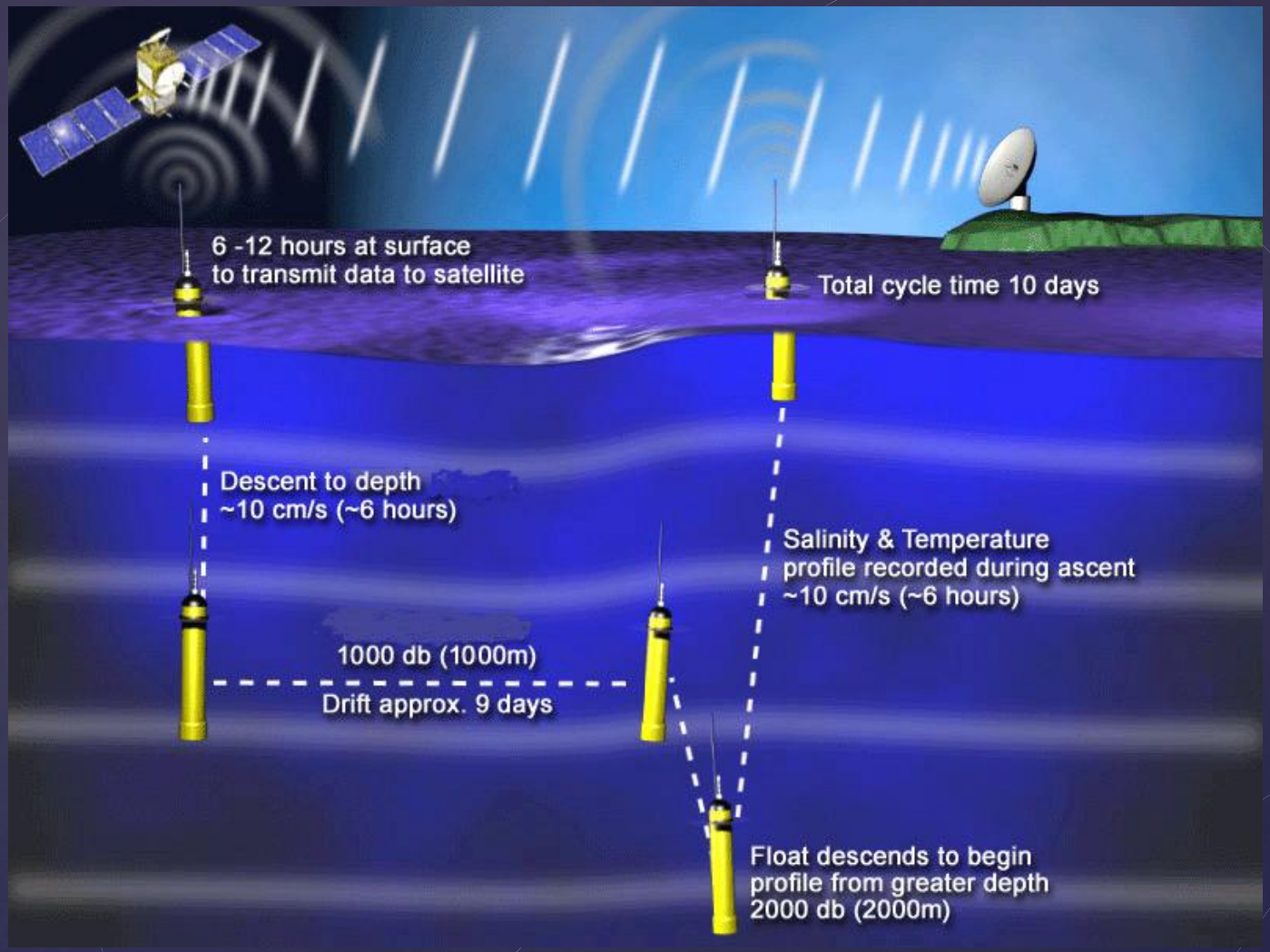
Sea ice observations from satellite remote sensning



© ESA

ARGO is the largest ocean observing system. It is a trans-national system. See Riser et al. 2016 “Fifteen years of ocean observations with the global Argo array”, Nature – Climate Change.



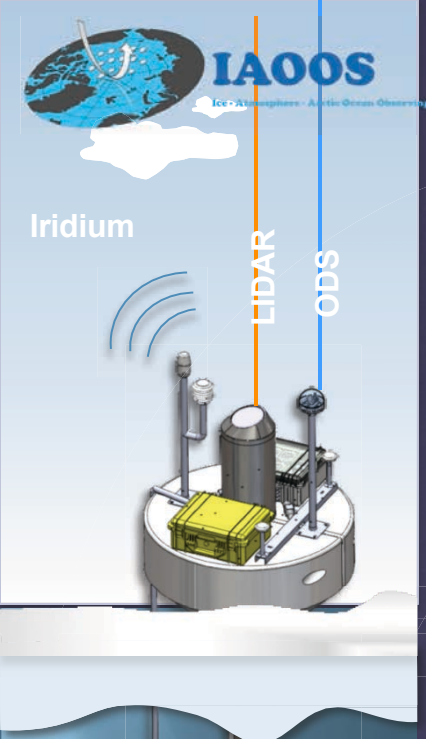


ARGO floats can not yet be used in the Arctic because the ice cover hampers satellite communication.

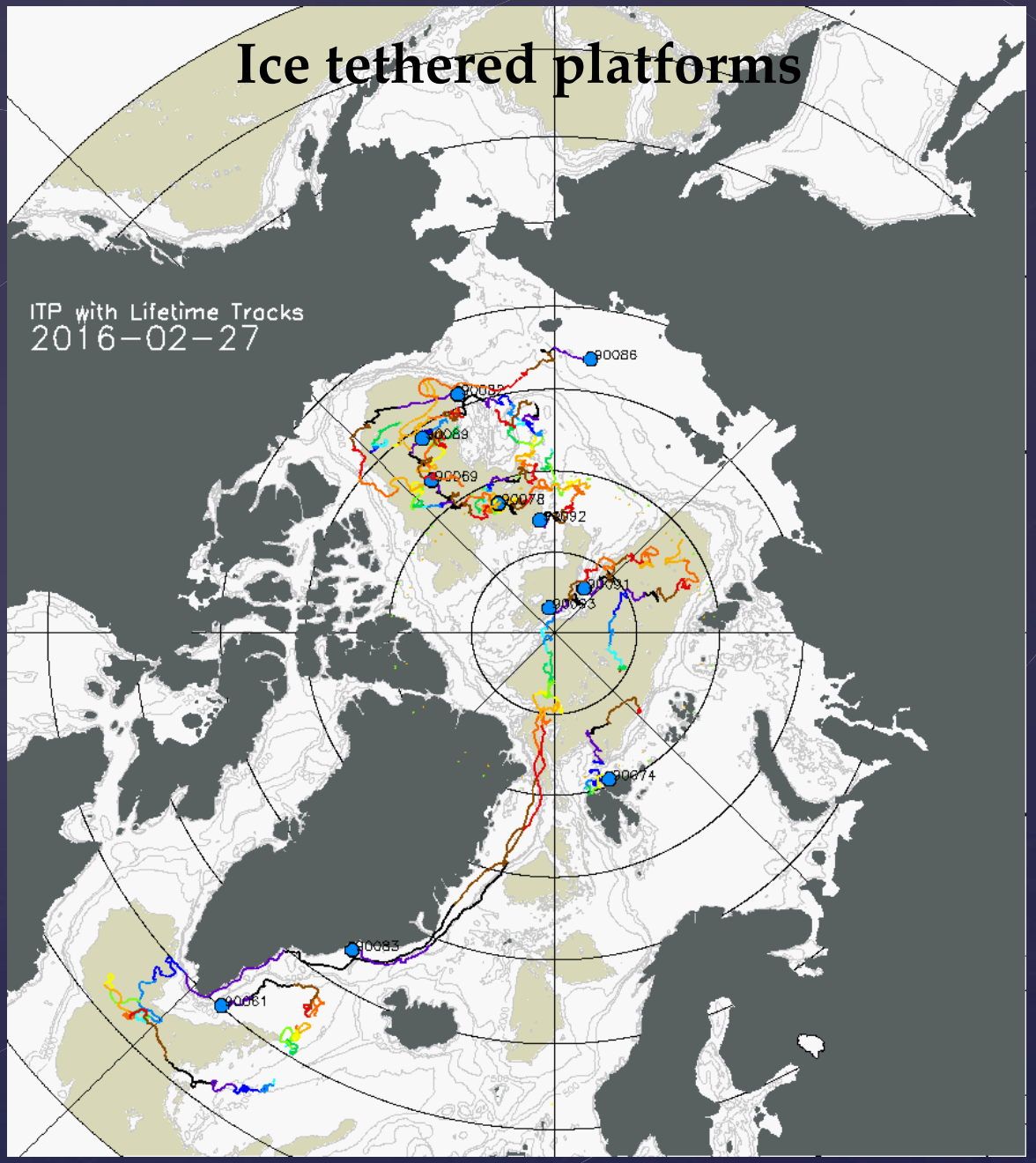
Drifting/Mobile platforms in the Arctic

IAOOS
Ice - Atmosphere - Arctic Ocean Observing System

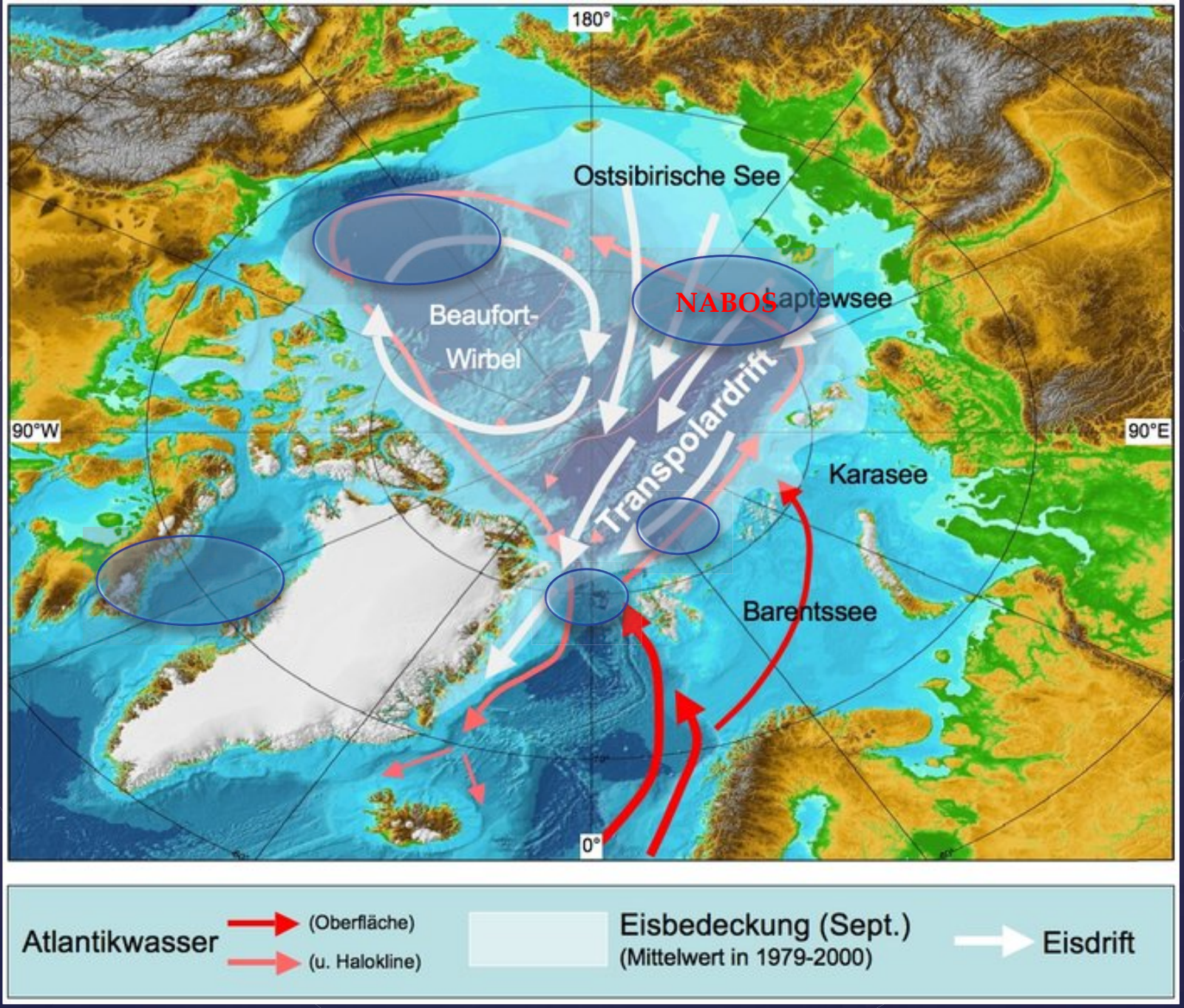
Ice tethered platforms



Courtesy: Christine Provost



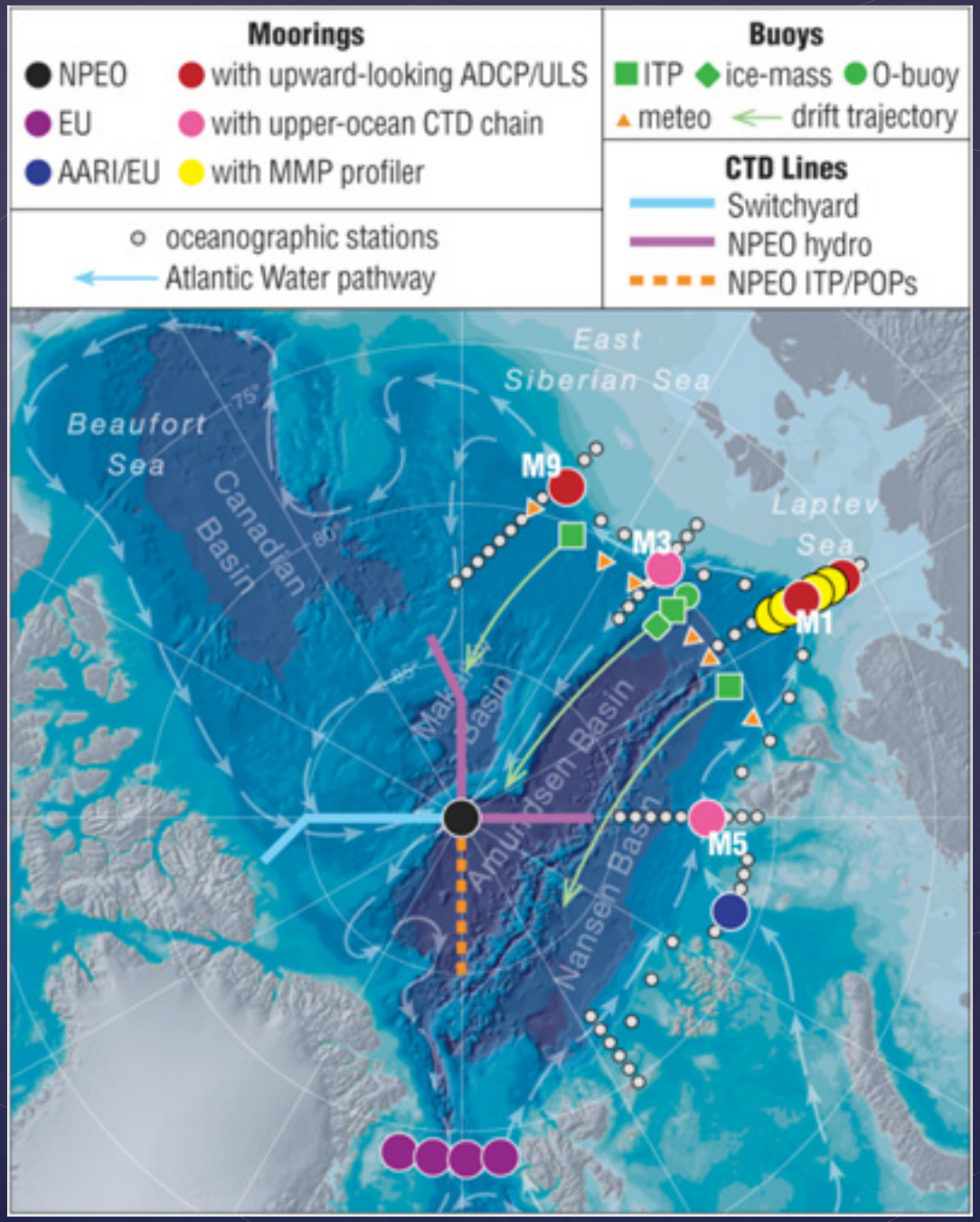
http://iabp.apl.washington.edu/maps_daily_oceanbuoys.html

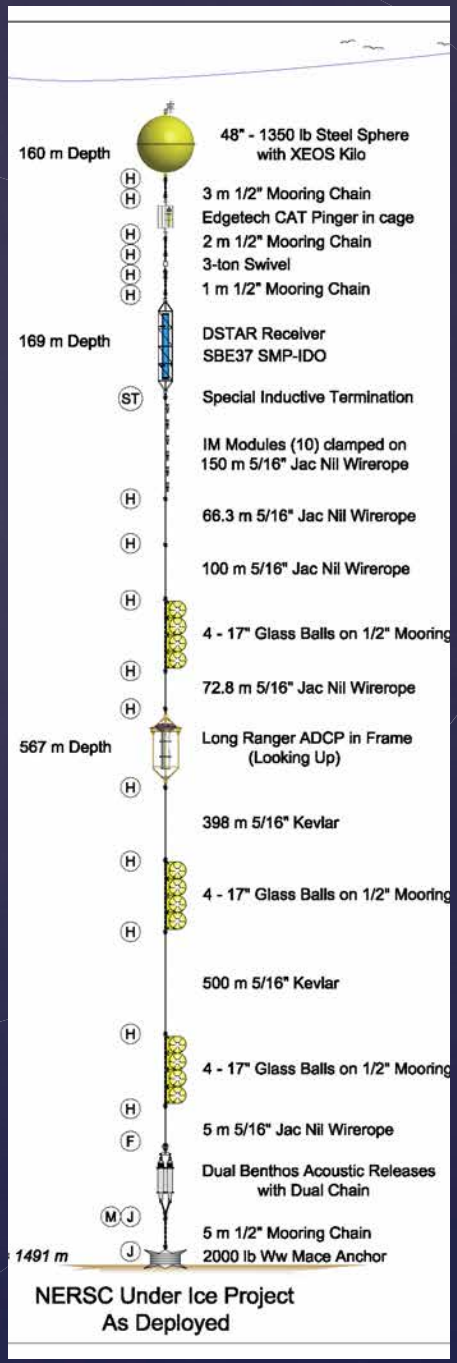


http://www.geomar.de

NANSEN AND AMUNDSEN BASINS
OBSERVATIONAL SYSTEM

NABOS - II





Regional and Basin wide multipurpose acoustic networks for tomography, underwater GPS and passive acoustics.

The Research Council of Norway

With funding from
The Research Council of Norway

GDF SUEZ

UNDER ICE

NERSC

Principe of acoustic measurements

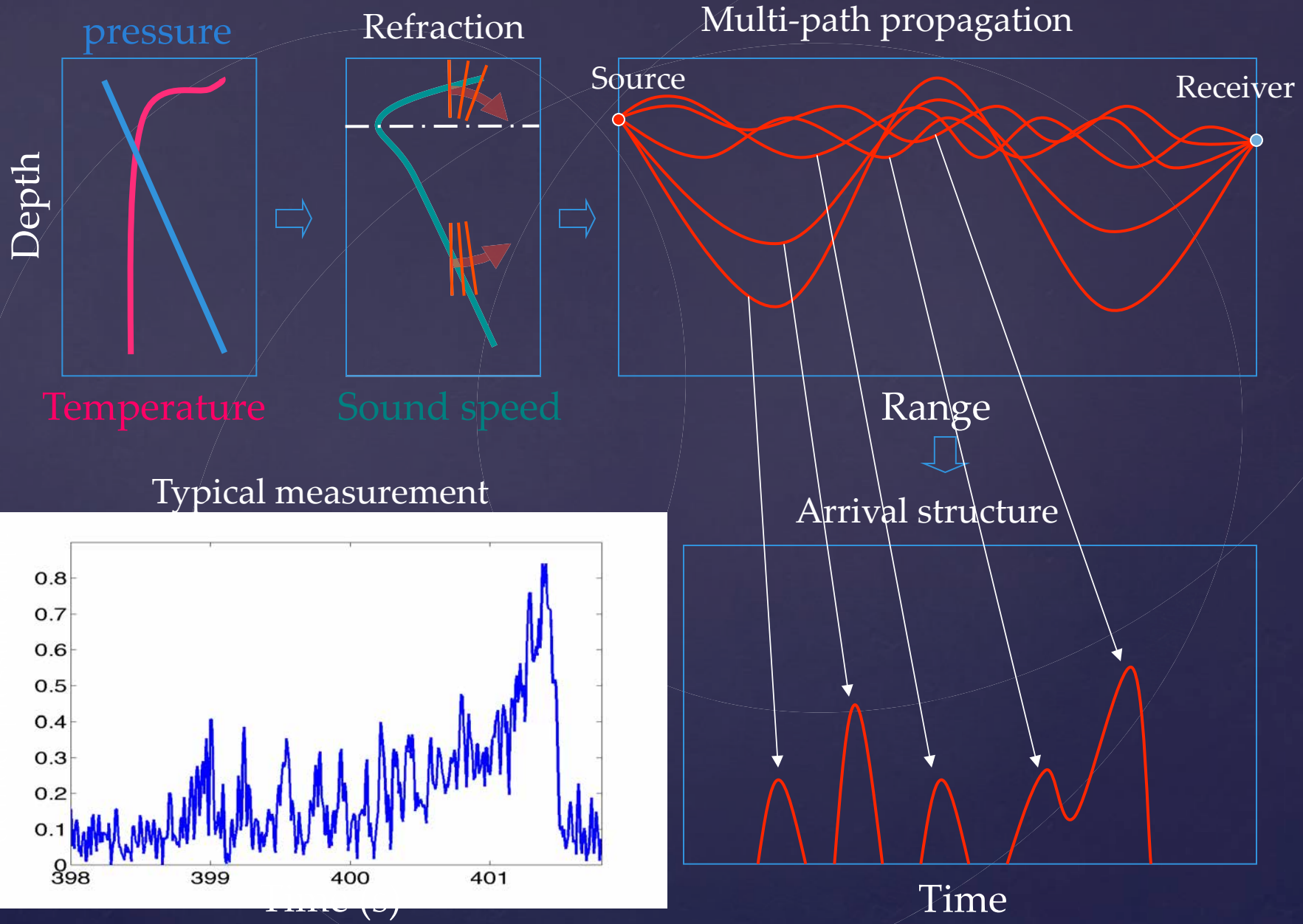
- 1826, Colladon and Sturm
- Lake Geneva
- Measure distance (navigation) and time

Acoustic thermometry
Travel time between source receiver – gives sound speed → temperature

Acoustic positioning/ localization
Measure travel time – known sound speed →gives Distance

Passive listening
Detect, localize, track sounds from different human and natural sources.

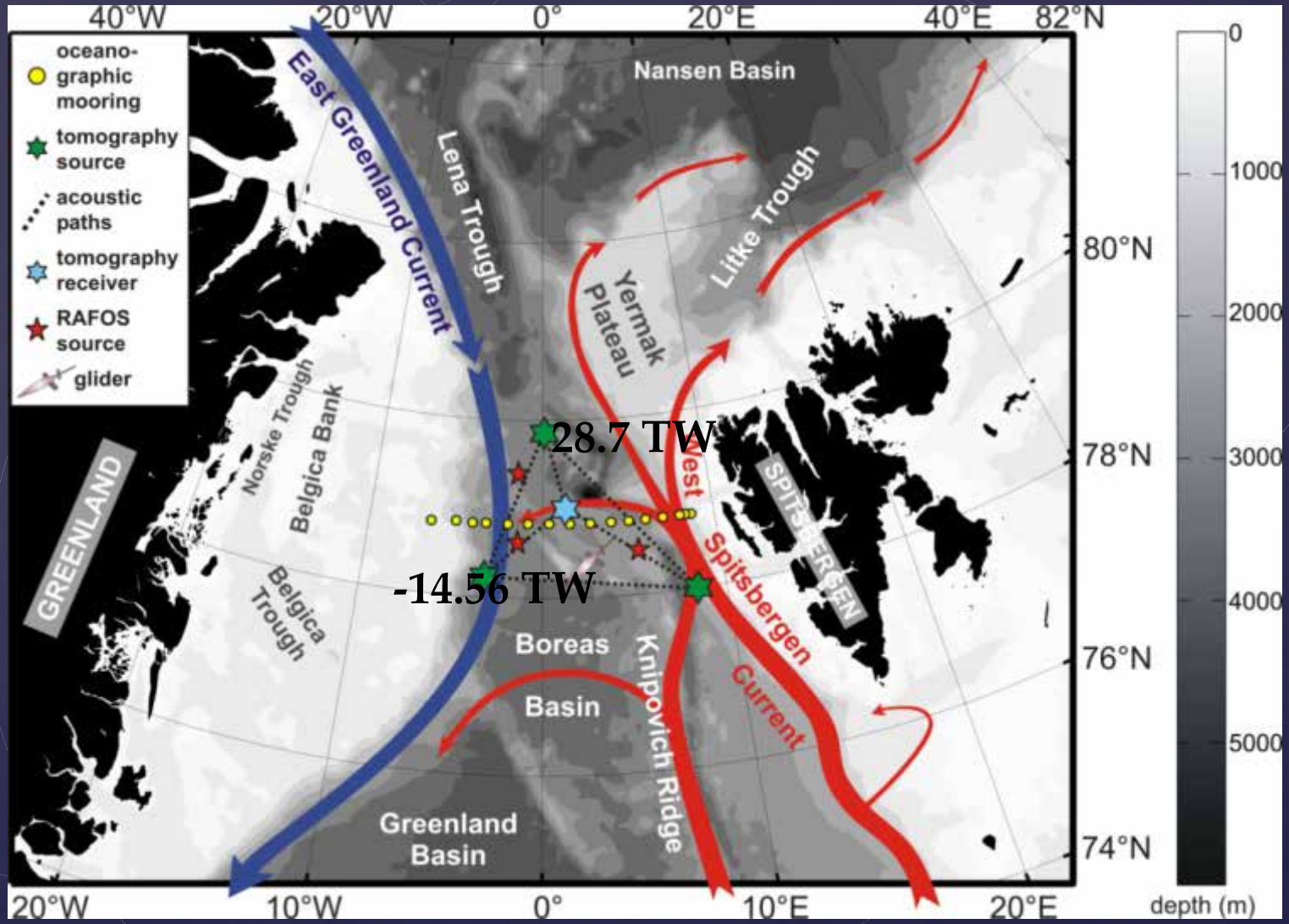
Concept of acoustic thermometer for the ocean

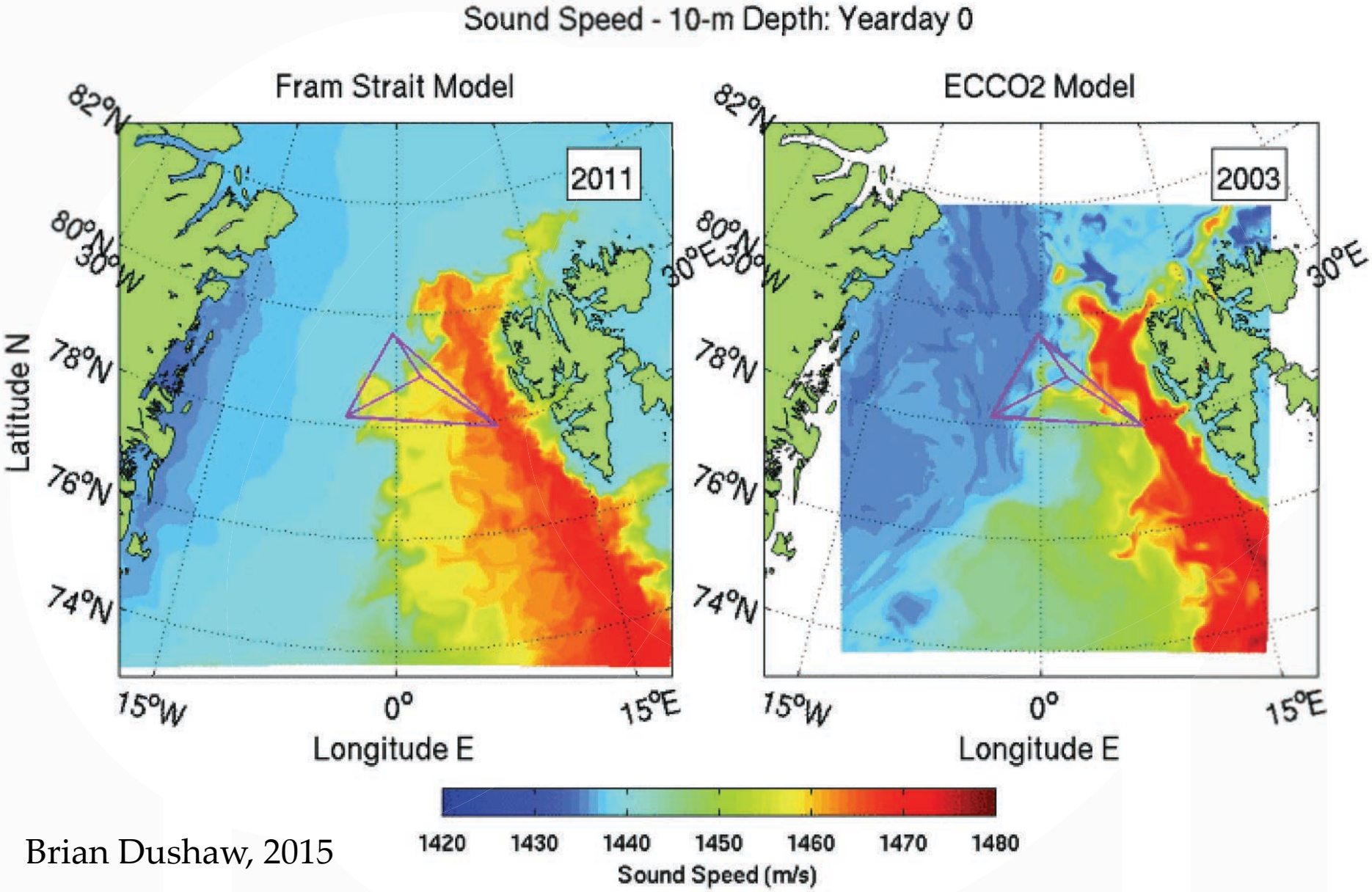


Courtesy: Emmanuel Skarsoullis

Fram Strait Ocean Observatory moored array and gliders

- Monitoring volume, heat and salt (freshwater) exchanges between the North Atlantic and the Arctic Ocean



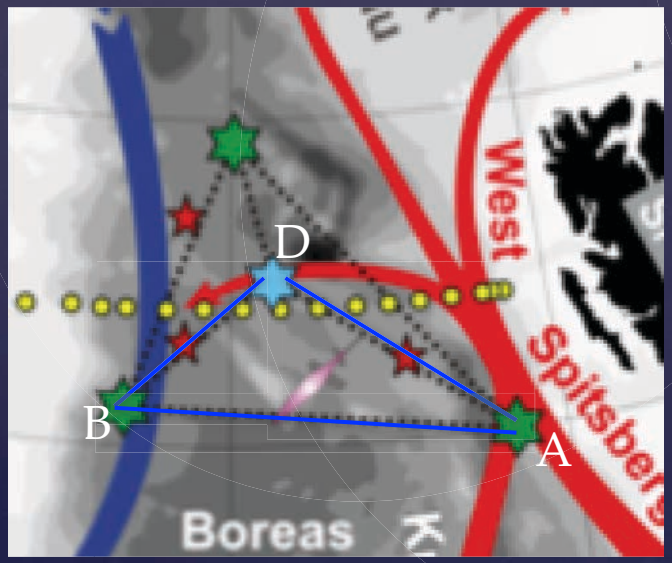


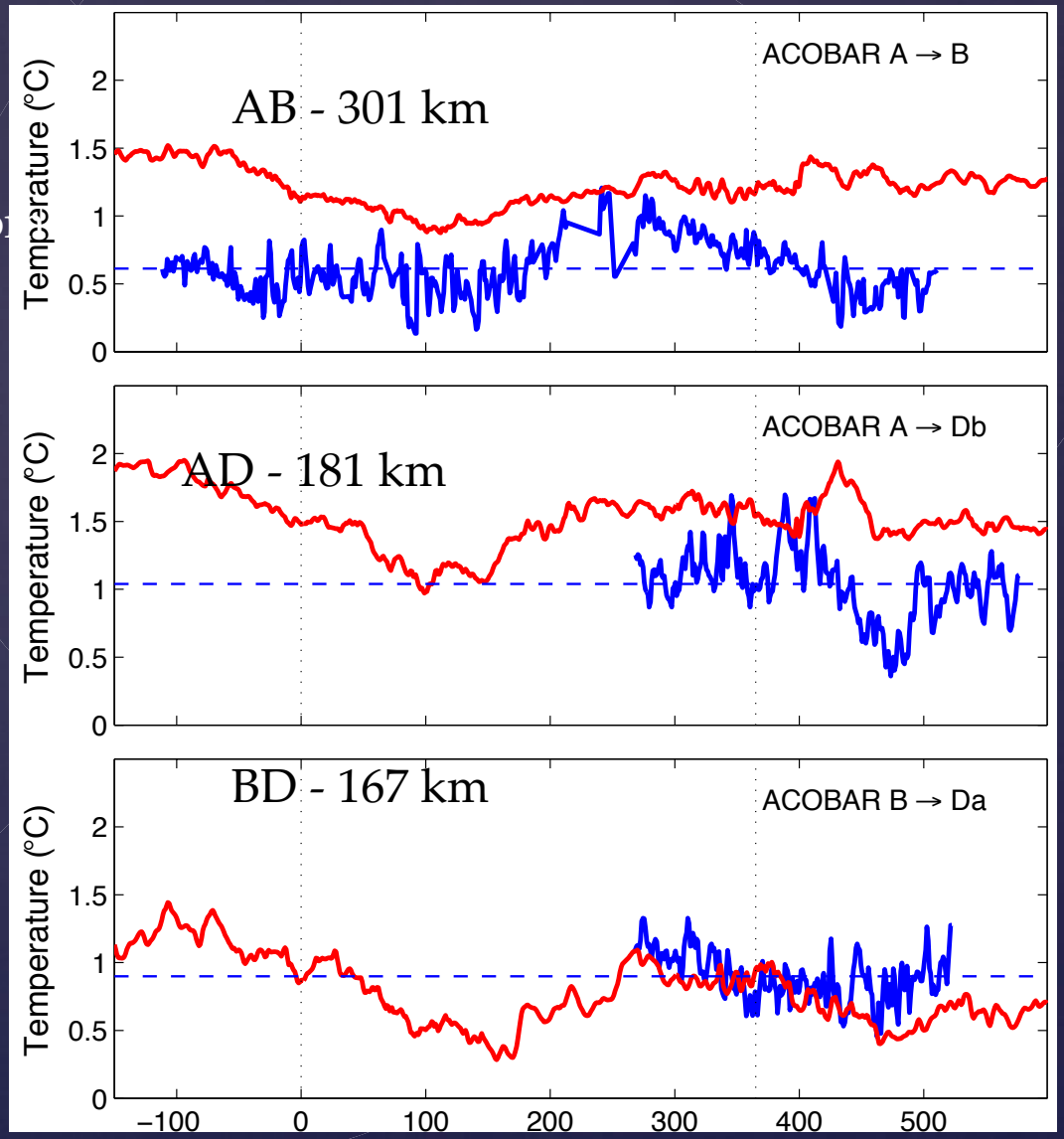
Brian Dushaw, 2015

Model validation results with depth averaged ocean temperatures from acoustic thermometry

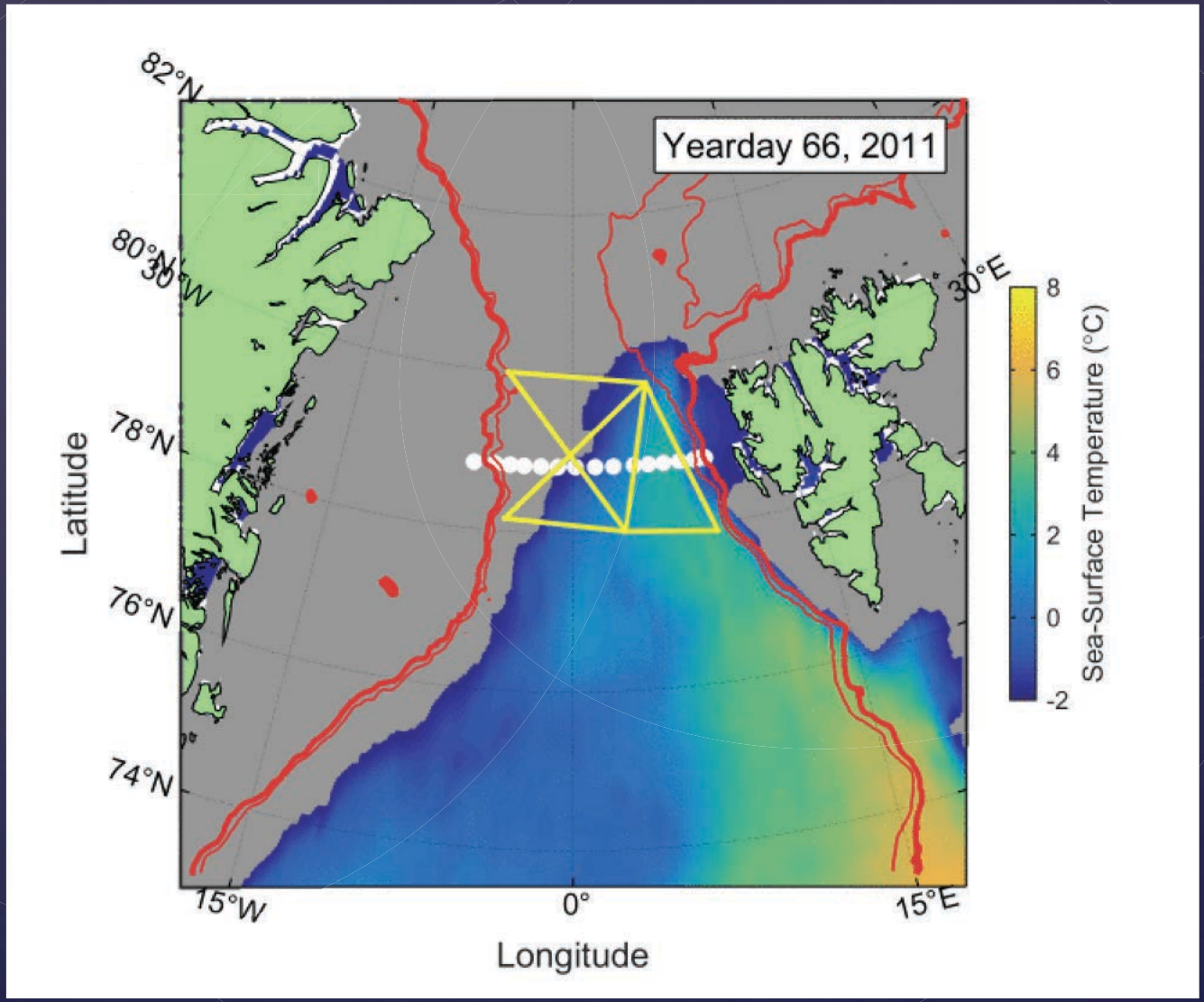
Blue line is the acoustically observed
Depth-range averaged temperature
Red line modelled measurements fro
High resolution ice-ocean model
(Hycom, 3 km, 28 layers)

Dushaw, Sagen et al. in prep.

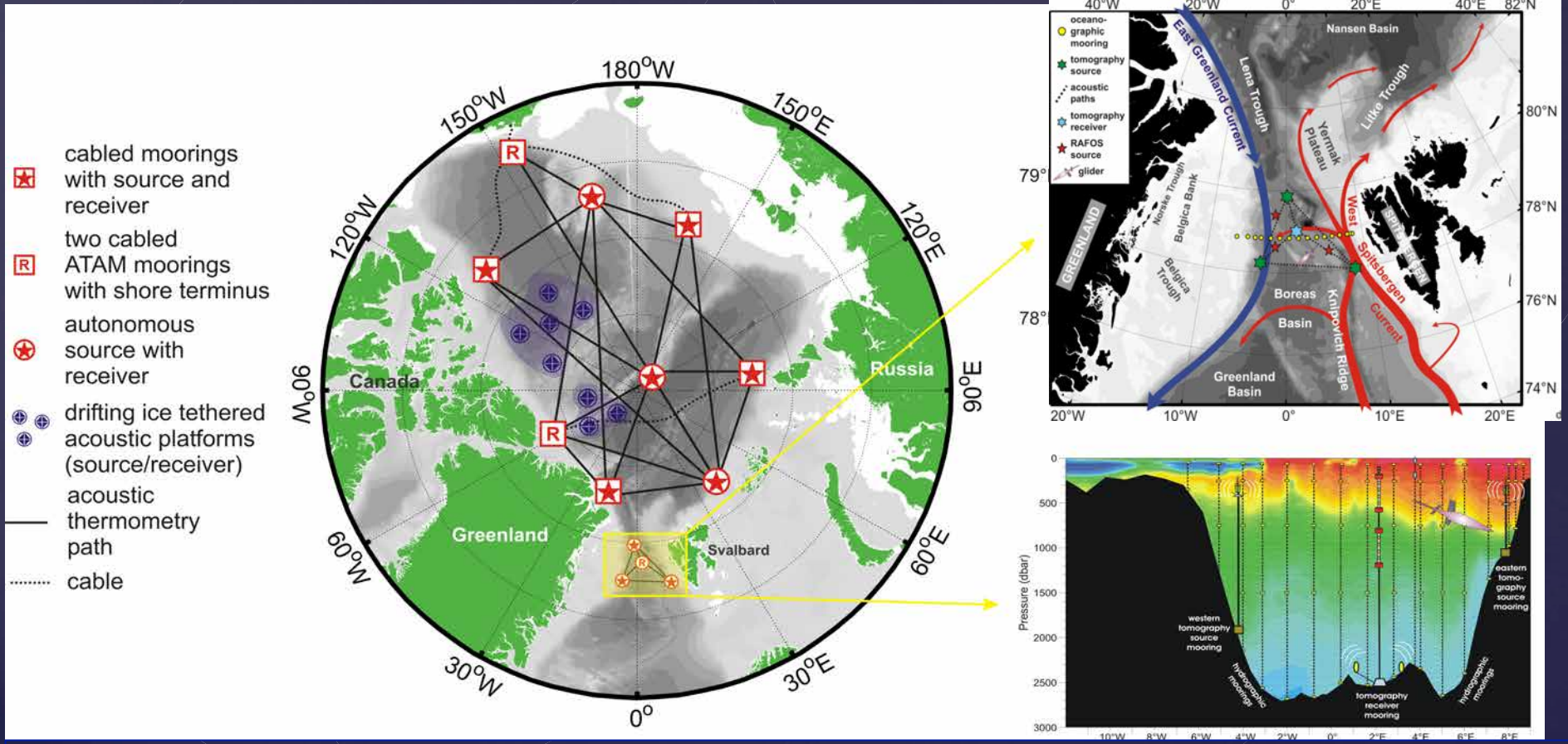




Operational regional multipurpose acoustic monitoring system
FRAM STRAIT – UNDER-ICE 2014-2016

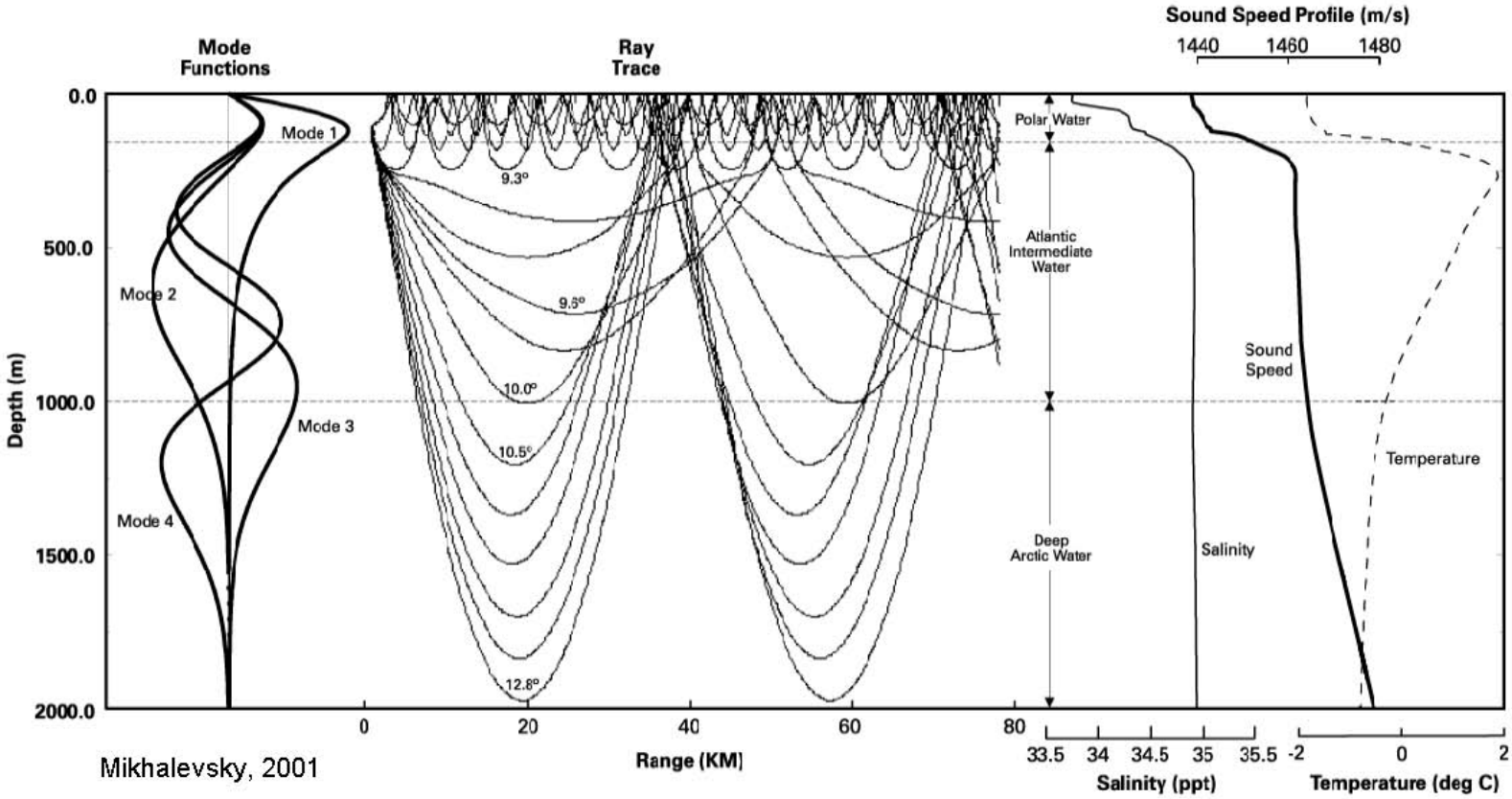


Multipurpose Acoustic Networks in the Integrated Arctic Ocean Observing System



A future underwater acoustic network – GPS for floats and gliders, listening system, and to measure averaged temperature and current. See Mikhalevsky, Sagen, Worcester et al. 2015

ACOUSTIC THERMOMETRY in the ARCTIC OCEAN

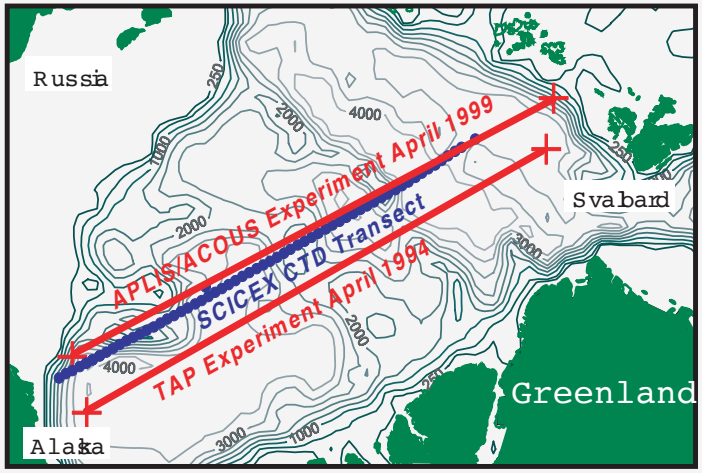


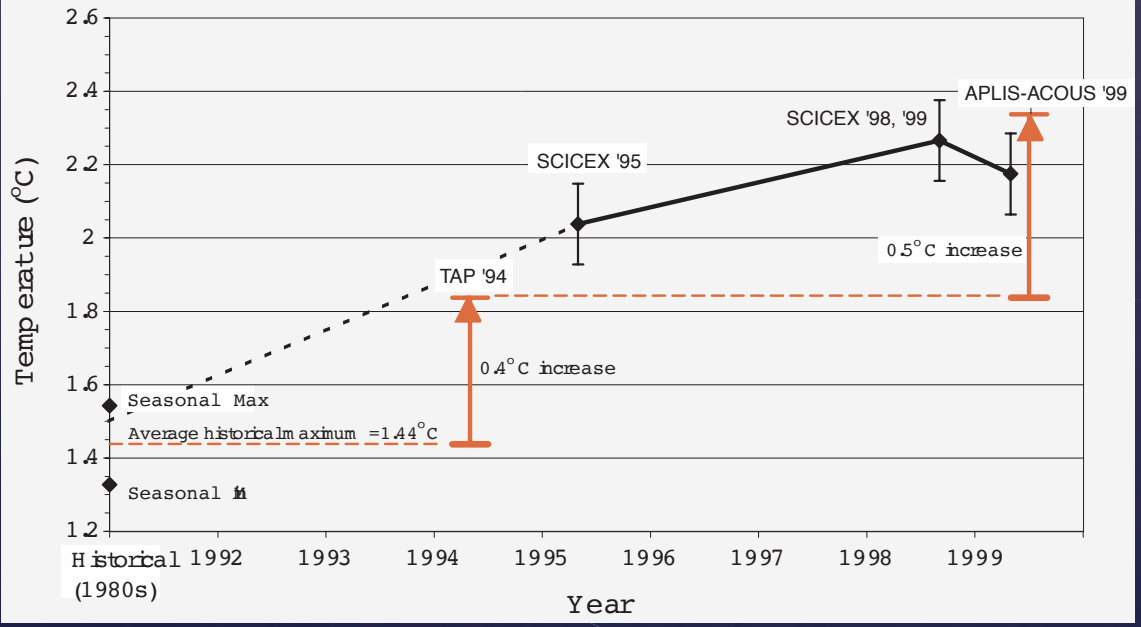
Mikhalevsky, 2001

MAJOR ARCTIC OCEAN WATER MASSES ARE WELL SAMPLED BY ACOUSTIC MODES/RAYS (Modes shown for 20 Hz)

Mikhalevsky, 2001

Trans Arctic experiment 1994-1999





Acoustic thermometry documented increased averaged ocean temperature in the Arctic.

This was confirmed by oceanographic section obtained during SCIEX

Mikhalevsky. Ocean Obs 99

A regional multipurpose acoustic system has been and is operational in the Fram Strait. Acoustic thermemetry have shown its strength in validation of ice ocean models

A new trans Arctic experiment will provide data to compare with measurements from 1994 and 1999. This will address the key question about temperature and heat content change in the Arctic Ocean interior over the last two decades.

Establish baseline measurements for validation and calibration of climate and ocean models to assess their capabilities to predict future climate both in the Arctic and on global scale.