Challenges in observation and modelling of Arctic climate change

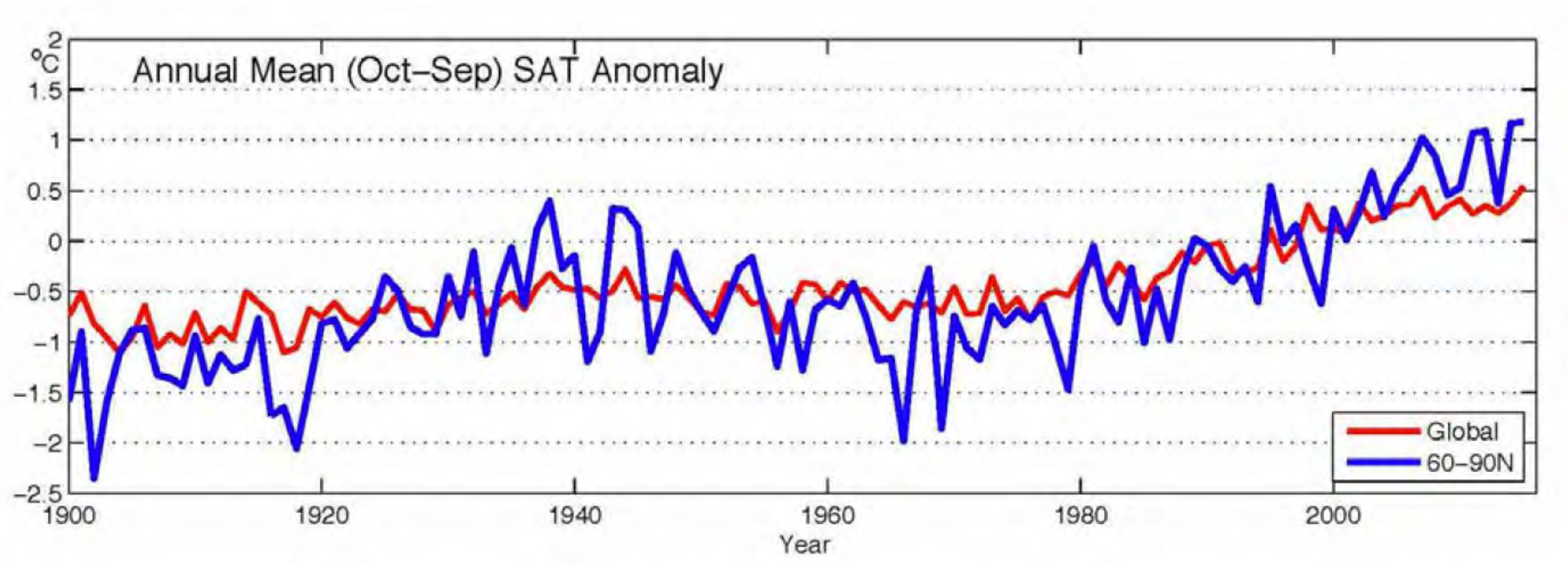
Third International Workshop
Non-linear processes in oceanic and atmospheric flows
ICEMAT, Madrid, 6-8 July 2016

Prof. Stein Sandven
Nansen Environmental and Remote Sensing Center, Norway

Why is Arctic climate change important ?

- The stongest climate change signals are found in the Arctic, but it is difficult to observe and predict many of the climate variables
- Large impact on a region with many unexploited resources, economic interests and geopolitical issues
- Many countries are enhancing their engagement in Arctic - > Arctic Council members, EU, China ++

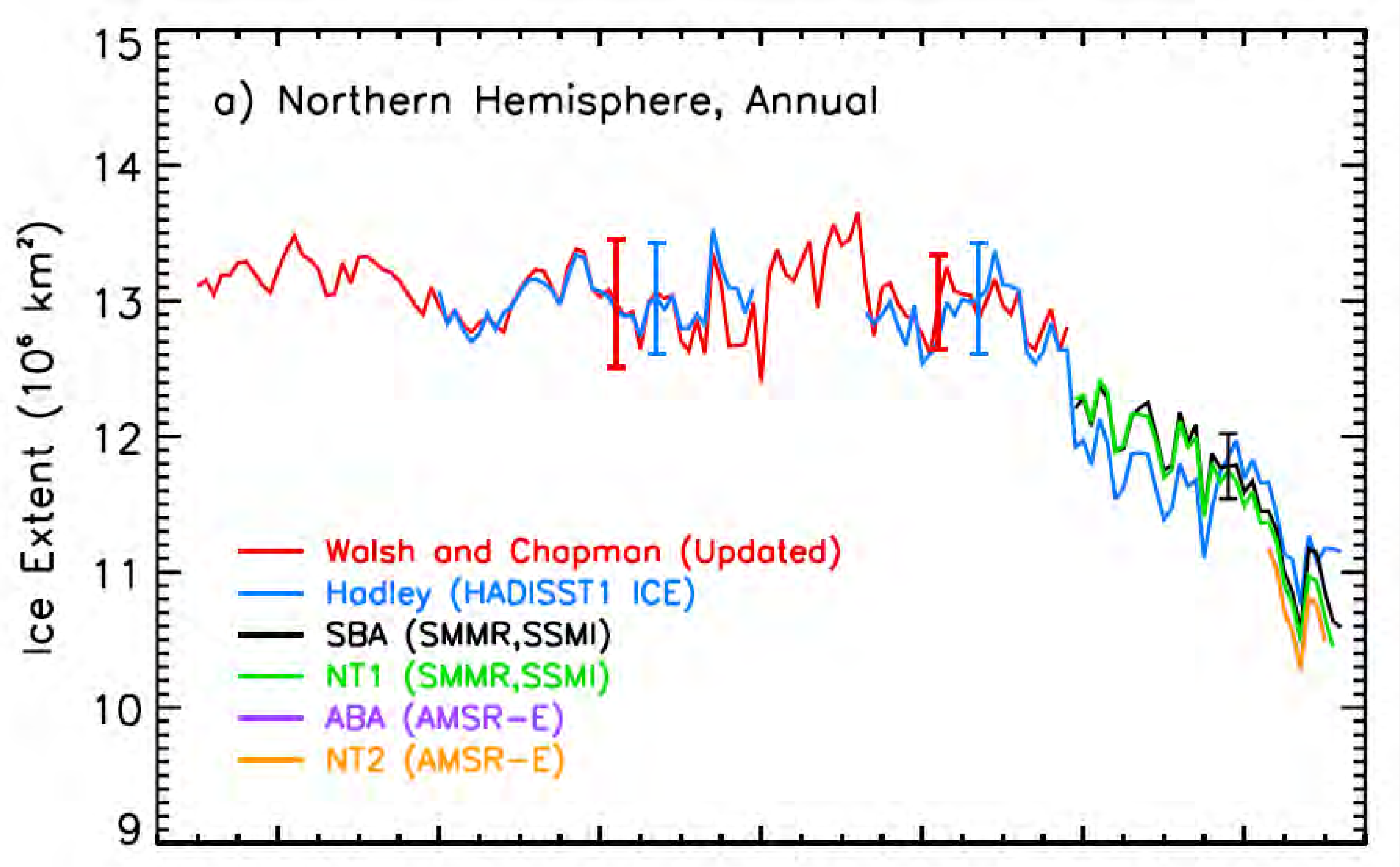
Air temperature 1900-2015



Arctic land stations north of 60N and global mean land surface air temperature (in deg C) anomalies relative to the 1981-2010 mean value. Data are from CRUTEM4 data set (www.cru.uea.ac.uk/cru/data/temperature/)

www.arctic.noaa.gov/reportcard/

Annual Arctic sea ice extent 1870-2011

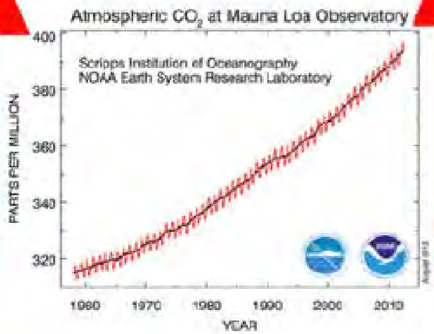


Unprecedented over the past 143 years decline of sea ice cover observed during the last few decades IPCC2013)

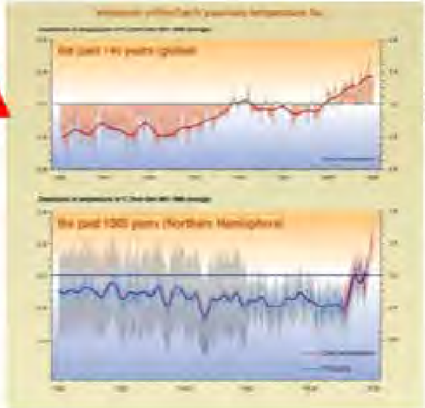
Copernicus Climate Change service

Climate Change fingerprints

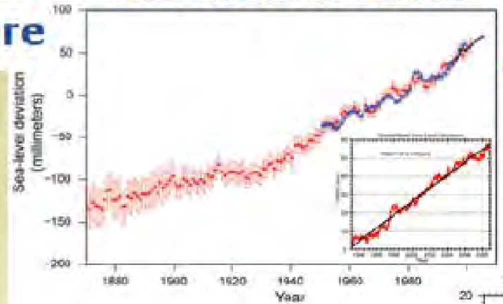
Atmospheric CO2



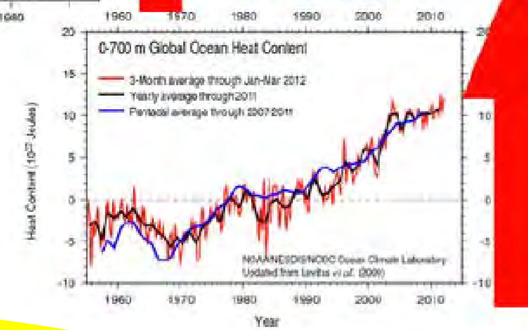
Surface Air Temperature



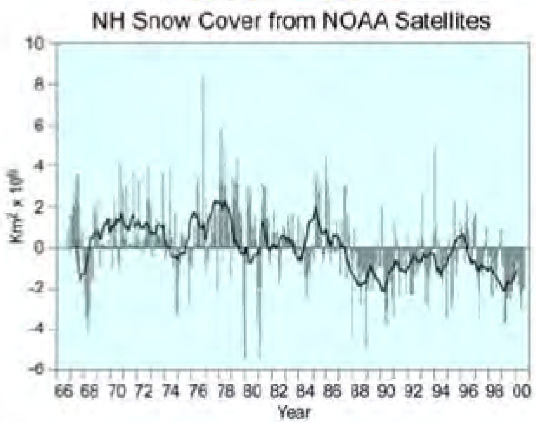
Global Sea Level



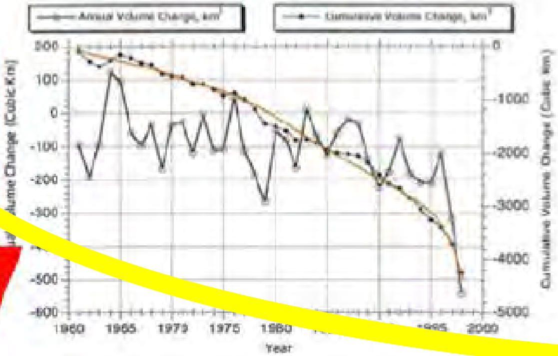
Global Ocean Heat Content



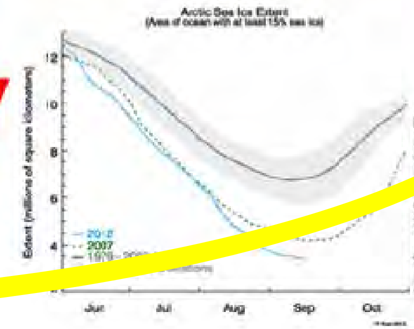
Snow cover



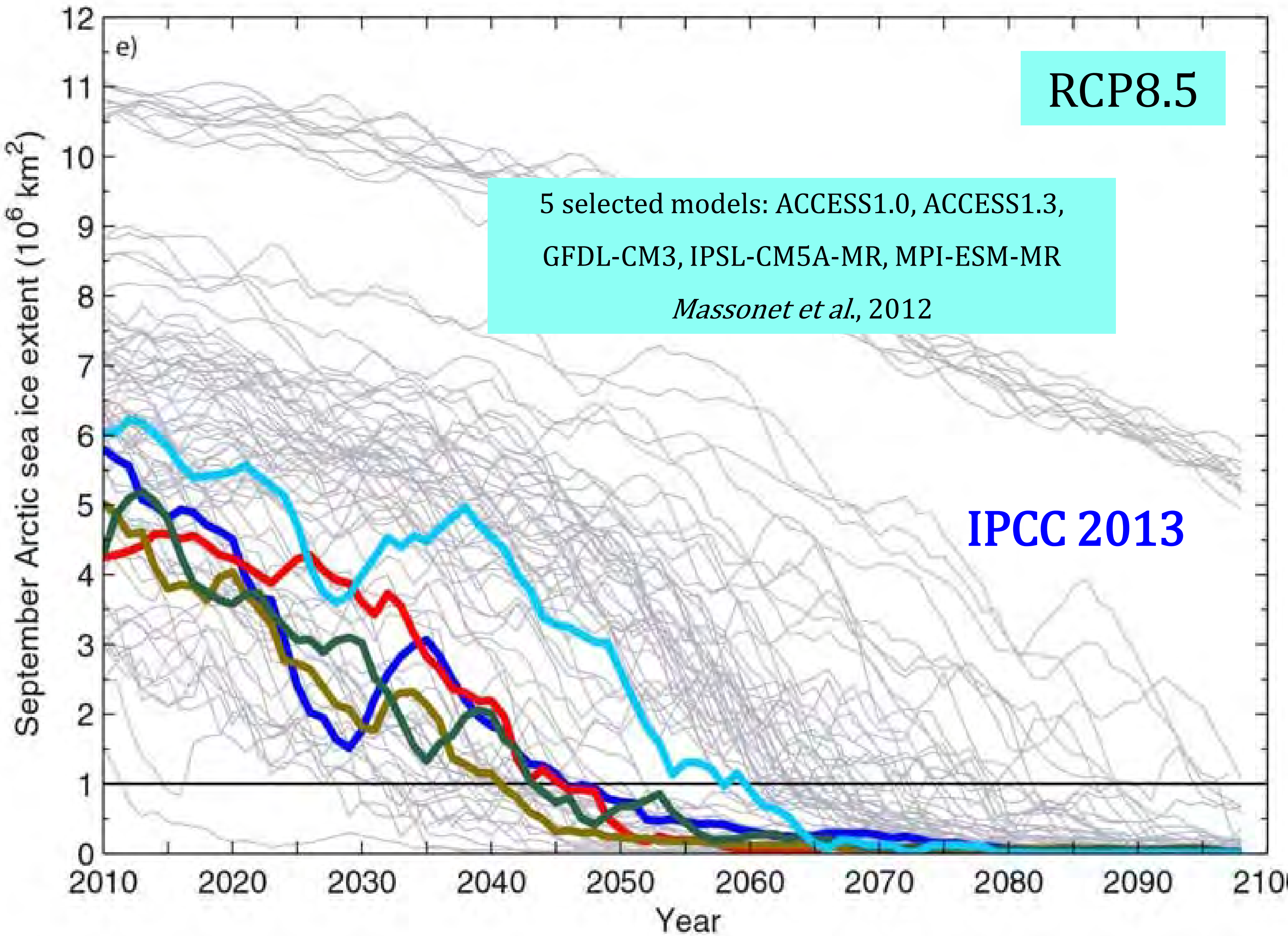
Glacier Volume



Arctic sea ice extent



When can a nearly sea ice-free summer be expected in the Arctic ?



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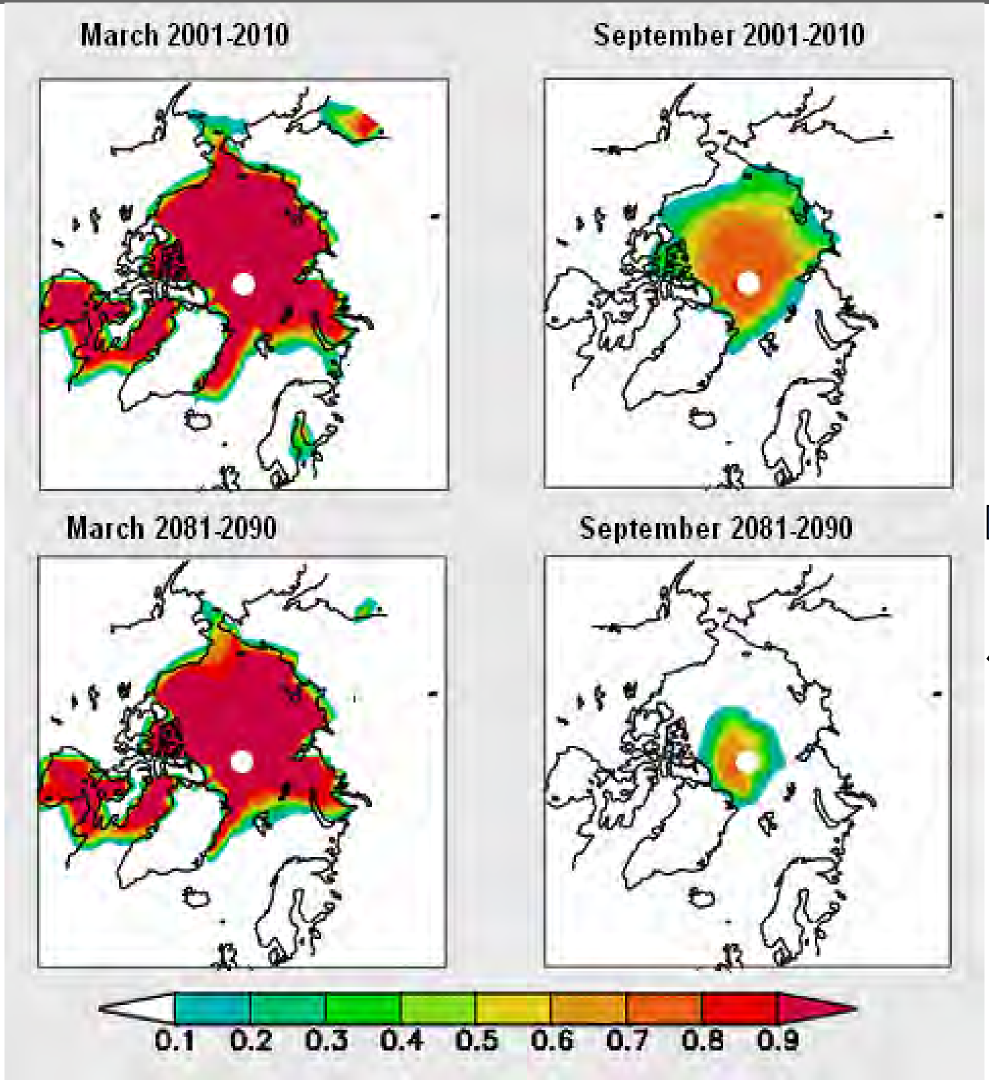
Example of projected Arctic sea ice extent

Present

2081-2090

Winter:
20% decrease

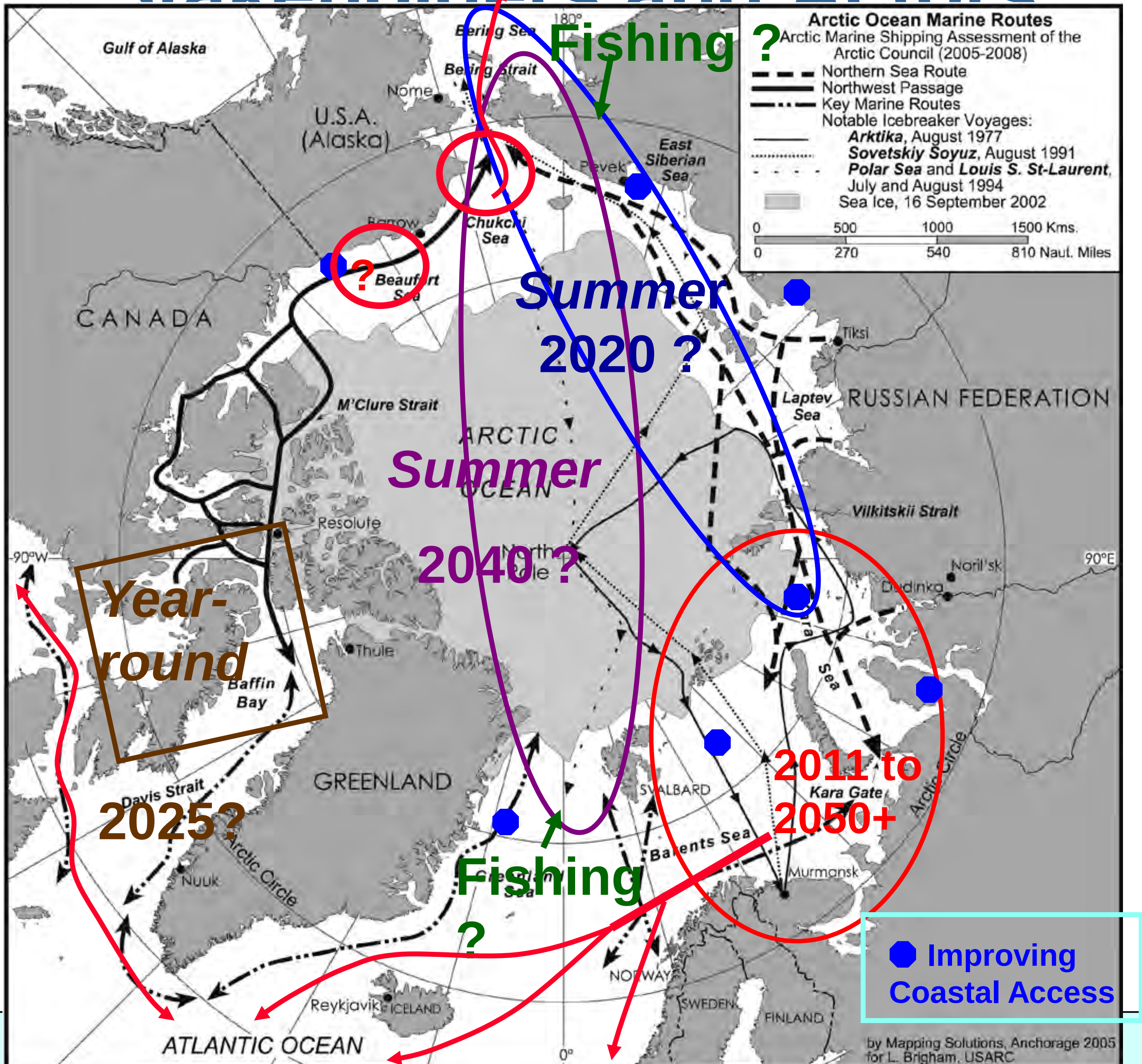


Ice concentration

Summer: 80%
decrease

Results from ECHAM4 simulations
Johannessen et al, 2004

Future Maritime Arctic ~ Many Stakeholders and Actors



Ref. Lawson Brigham

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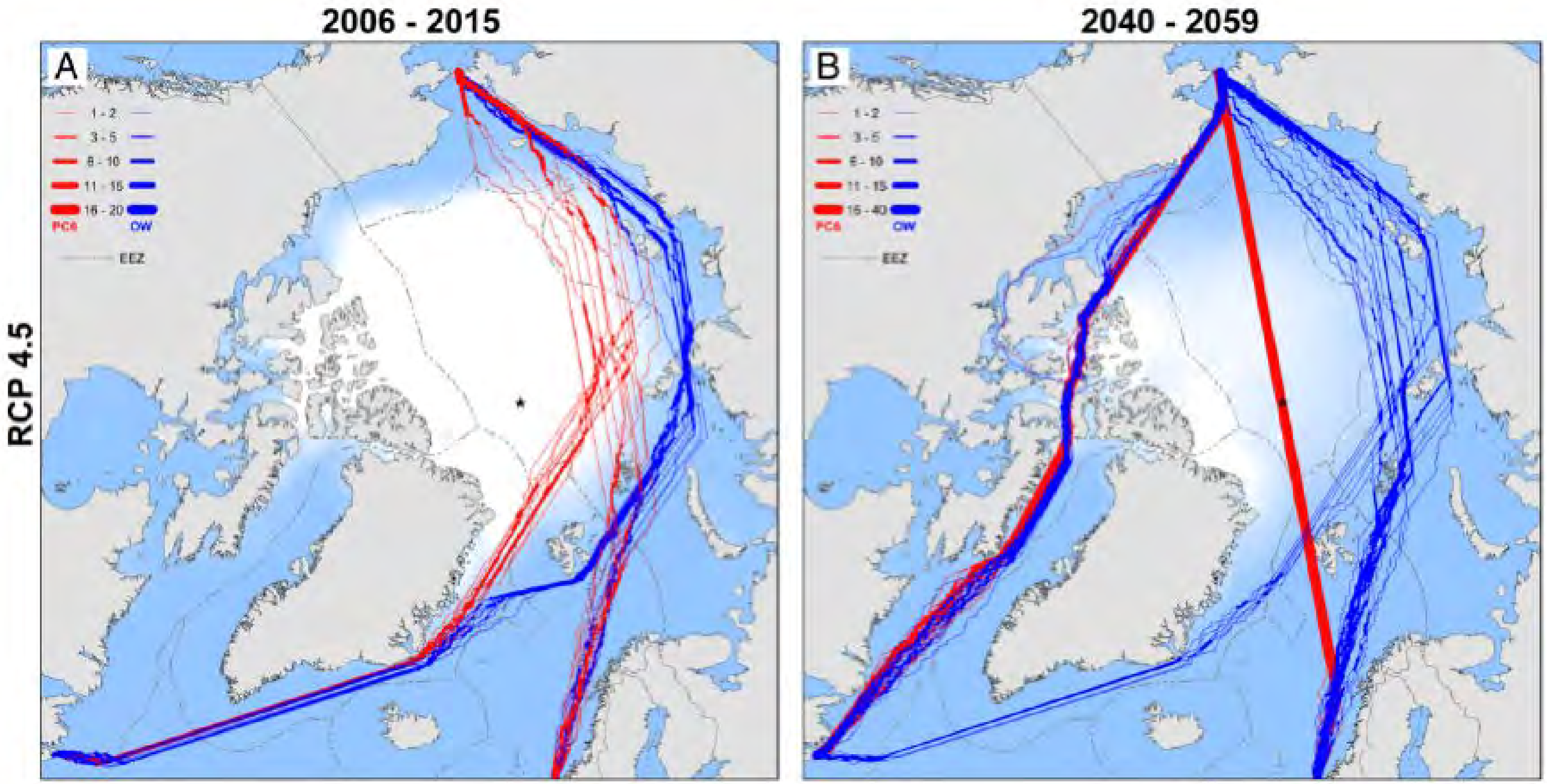
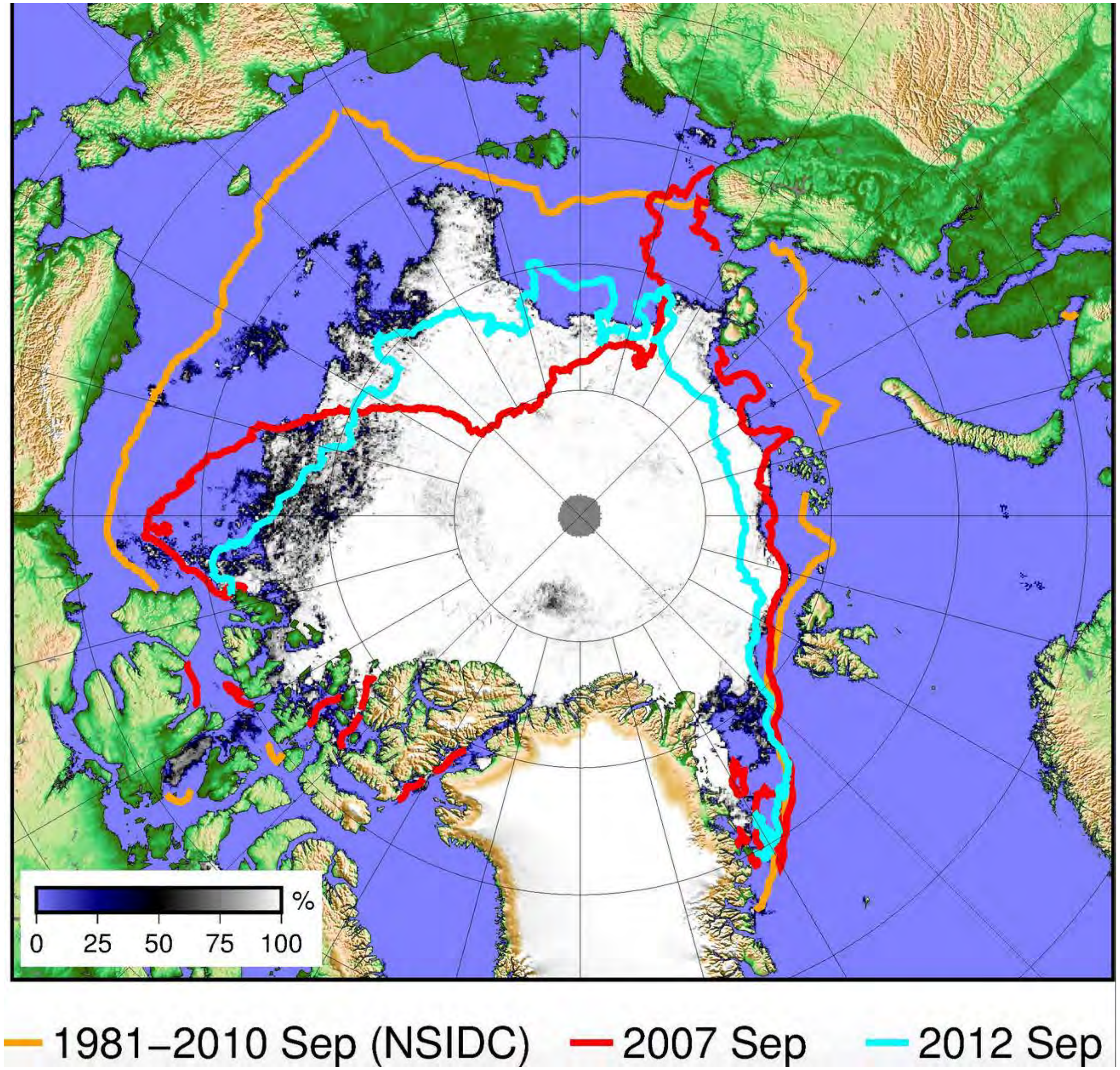
Scenarios of trans-Arctic sailing routes



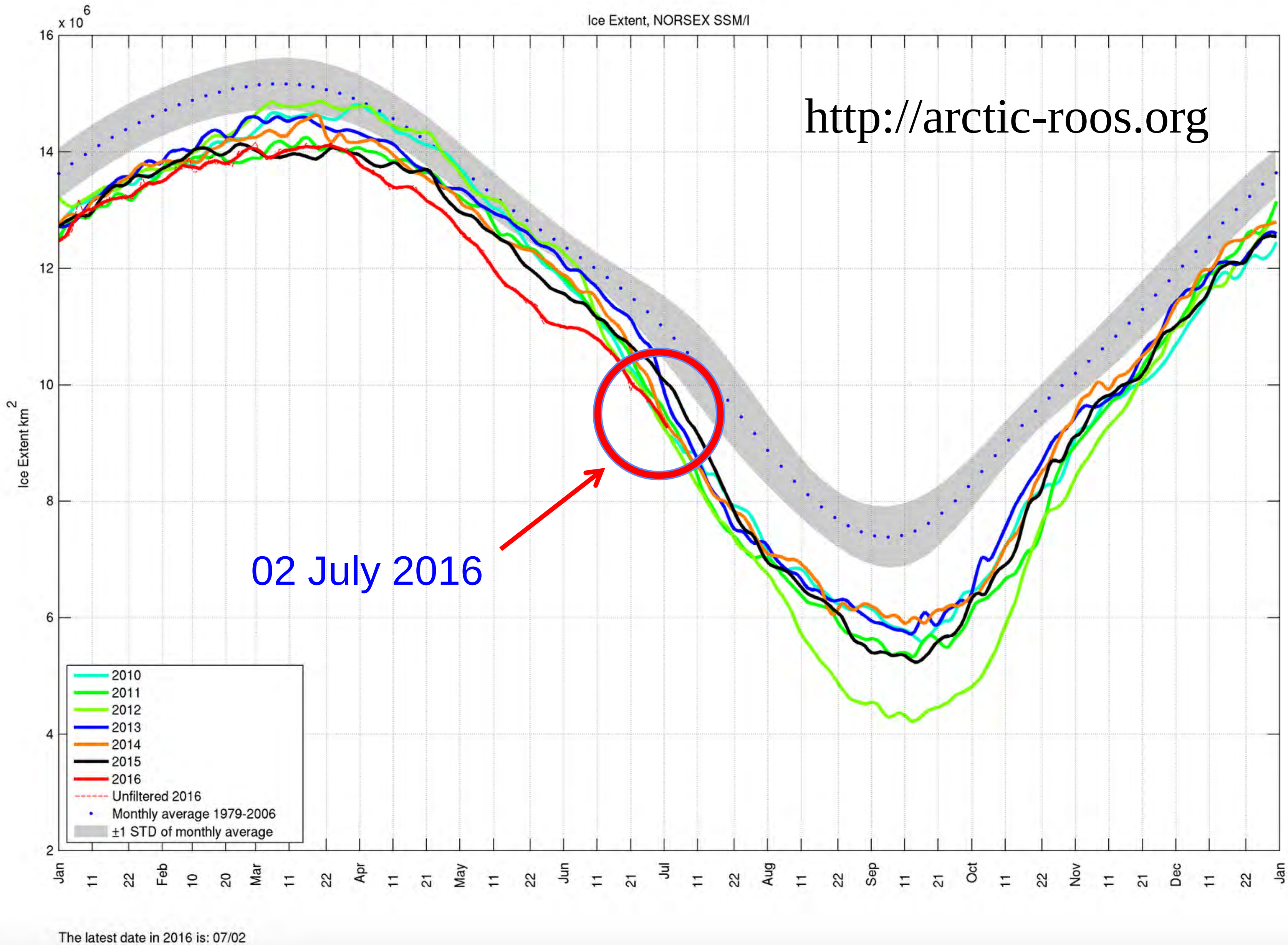
Optimal September navigation routes across the Arctic based on projected ice concentration and thickness from climate models using RCP 4.5 scenarios and an ice navigation model (ATAM). Red lines are for Polar Class 6 ships, while blue lines are for open water ships. Thickness of the lines indicate number of successful transits along the same route (Stephenson, 2013)

Polar orbiting satellites: key to observe the Arctic

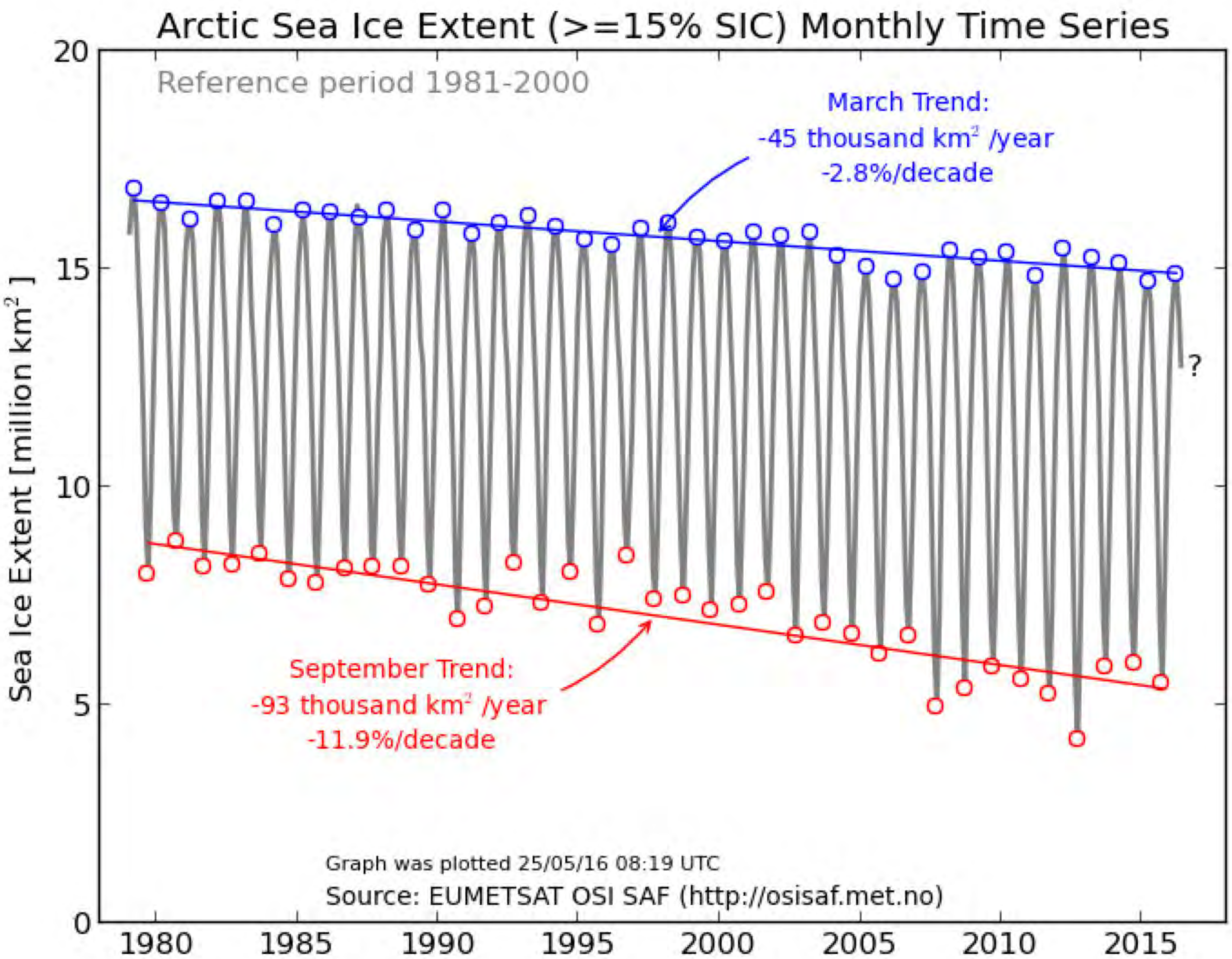
Sept 2015



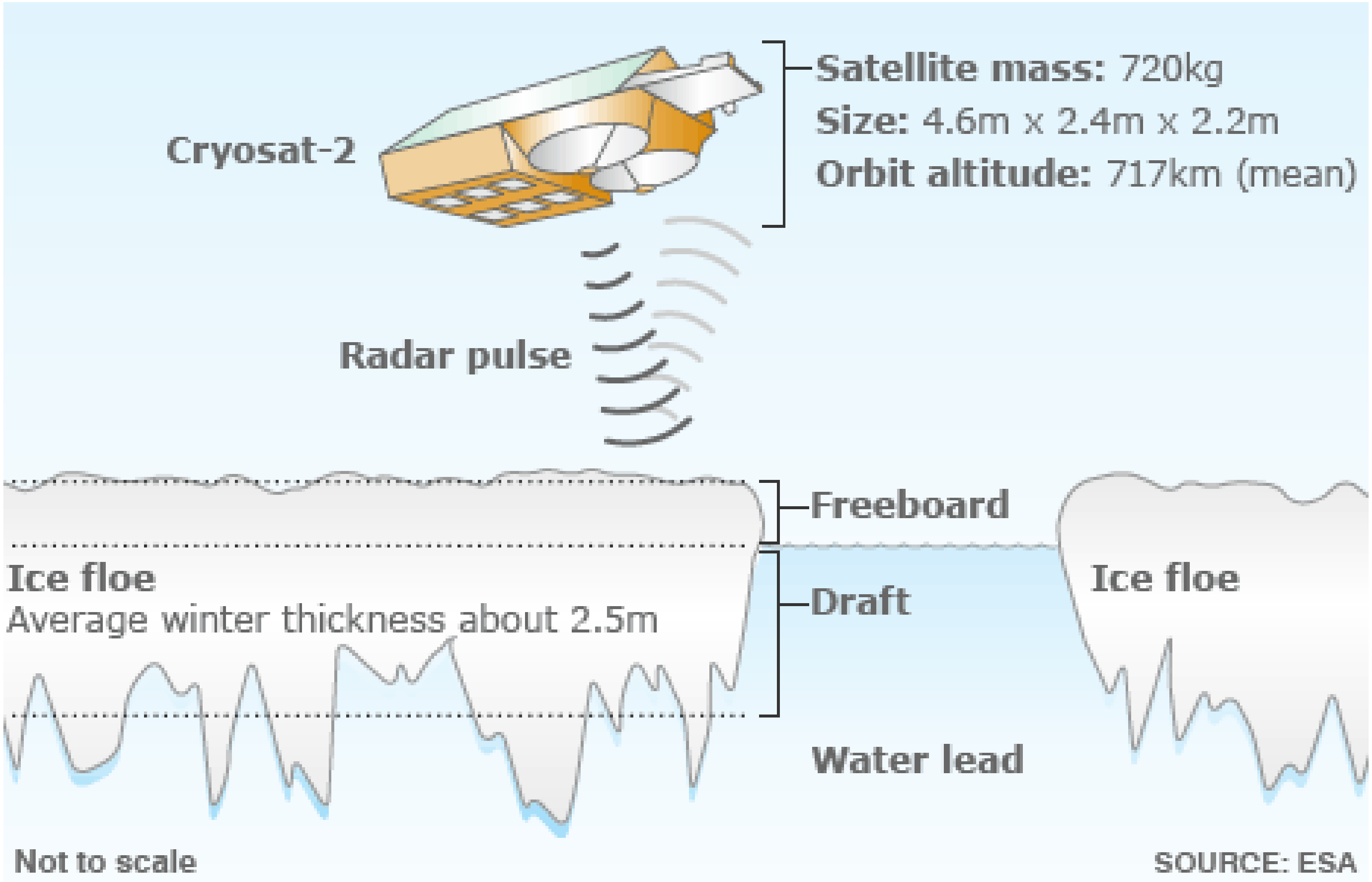
Arctic sea ice minimum 2016 ?



Arctic sea ice extent 1978 - 2016



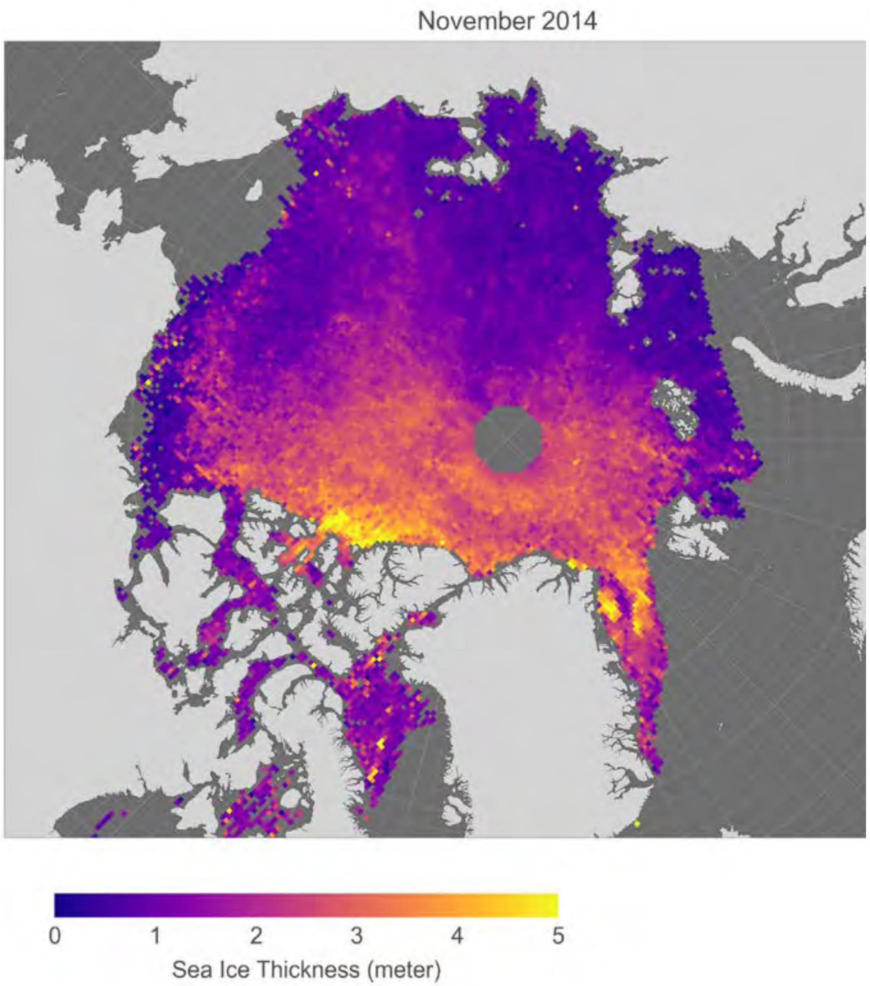
Sea ice freeboard from radar altimeters

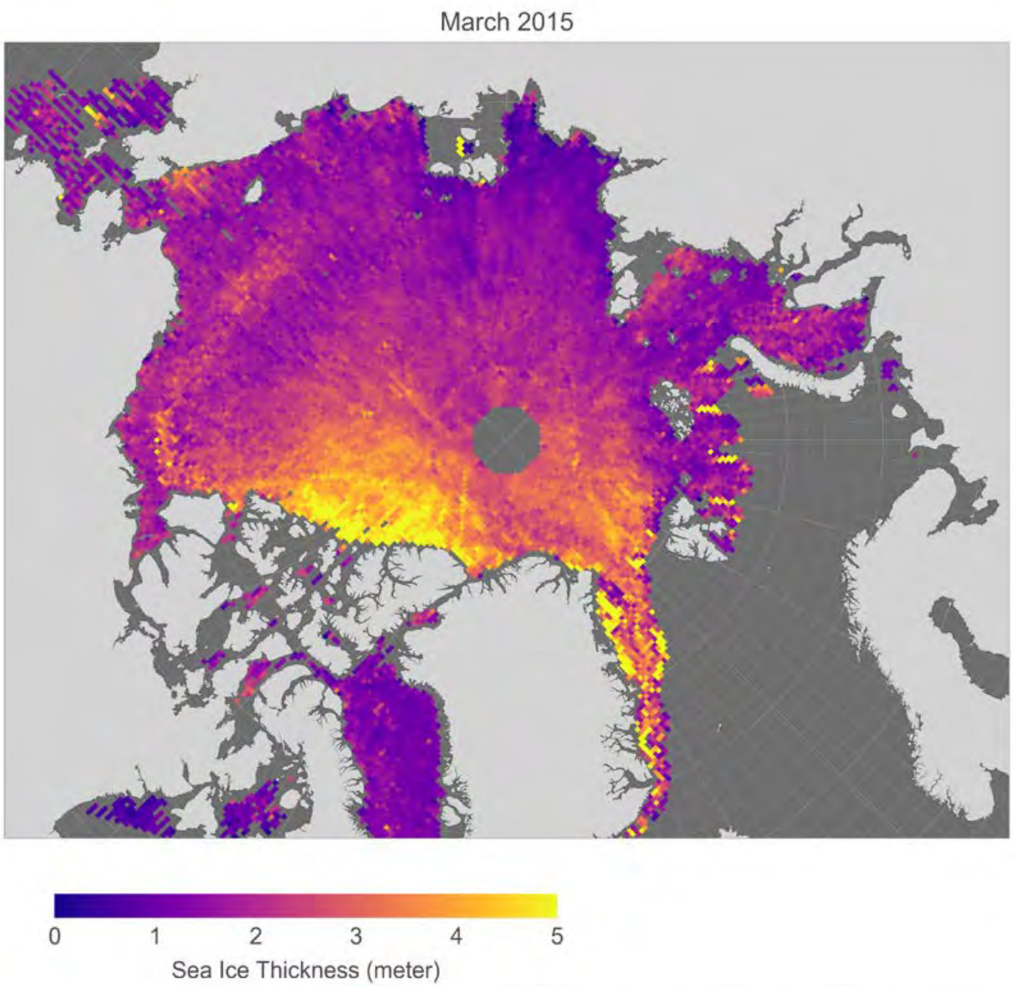


Sea ice thickness in the Arctic from CryoSat

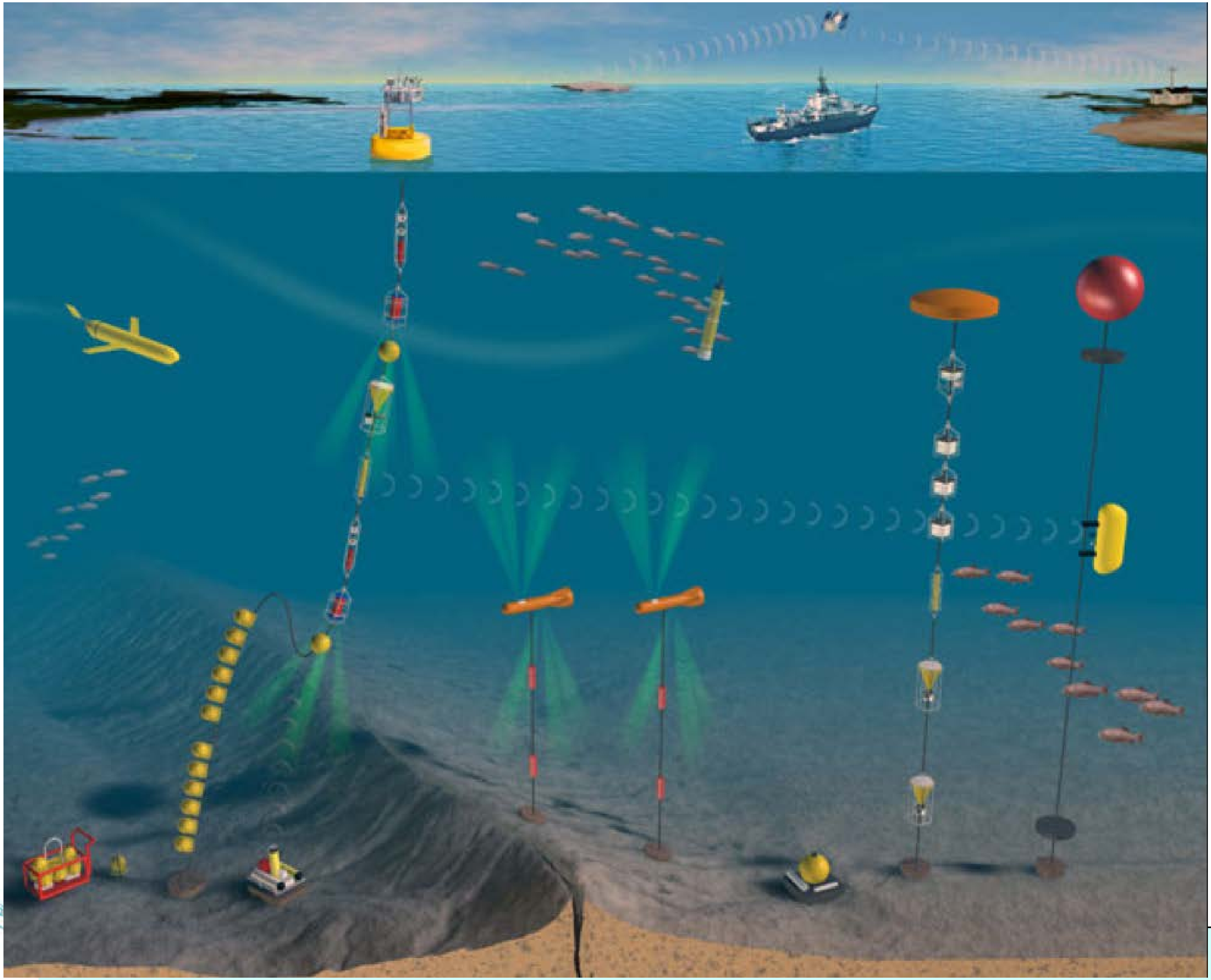
Early freezing season: November

Late freezing season: March





Instruments and platforms for ocean observations



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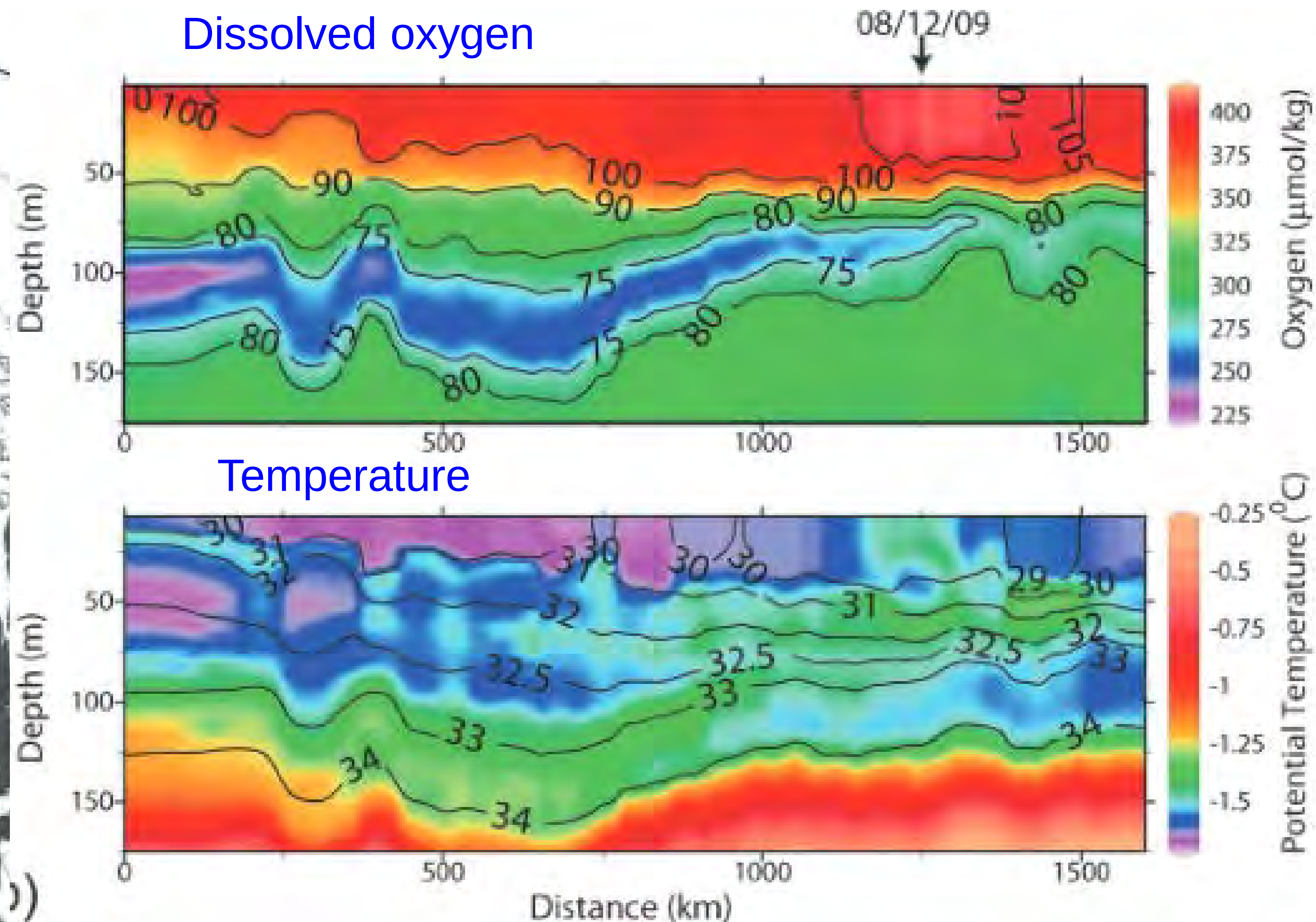
Ice-tethered profilers: an operational

Example of Ice-tethered profiler data



Data available at http://nsidc.org, www.whoi.edu/itp/, ++

(Ref. Timmermann et al., 2010)

Arctic ROOS data portal for in situ data

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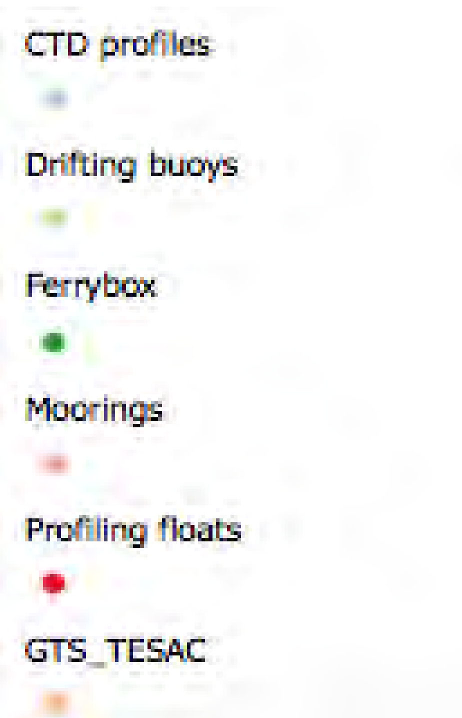
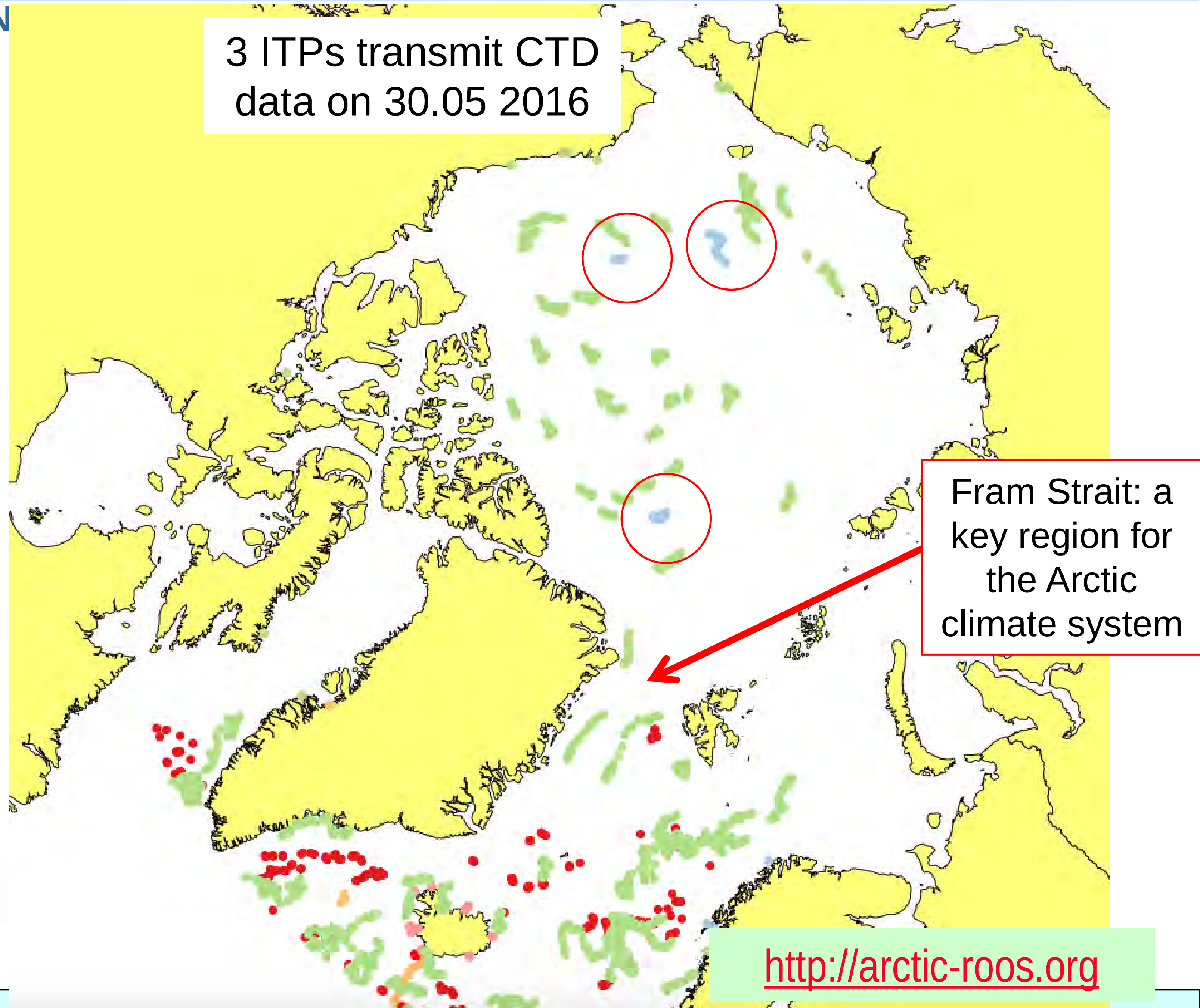
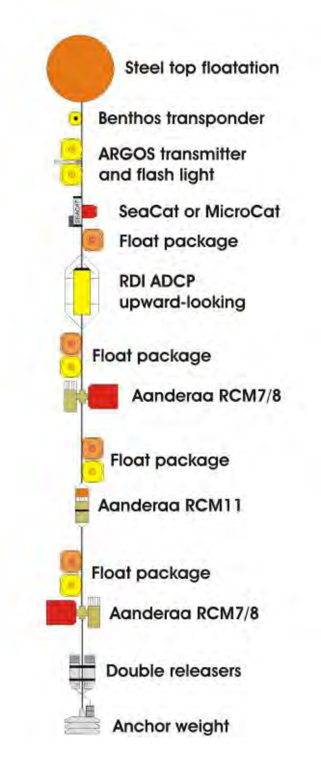
Data from last 30 days,

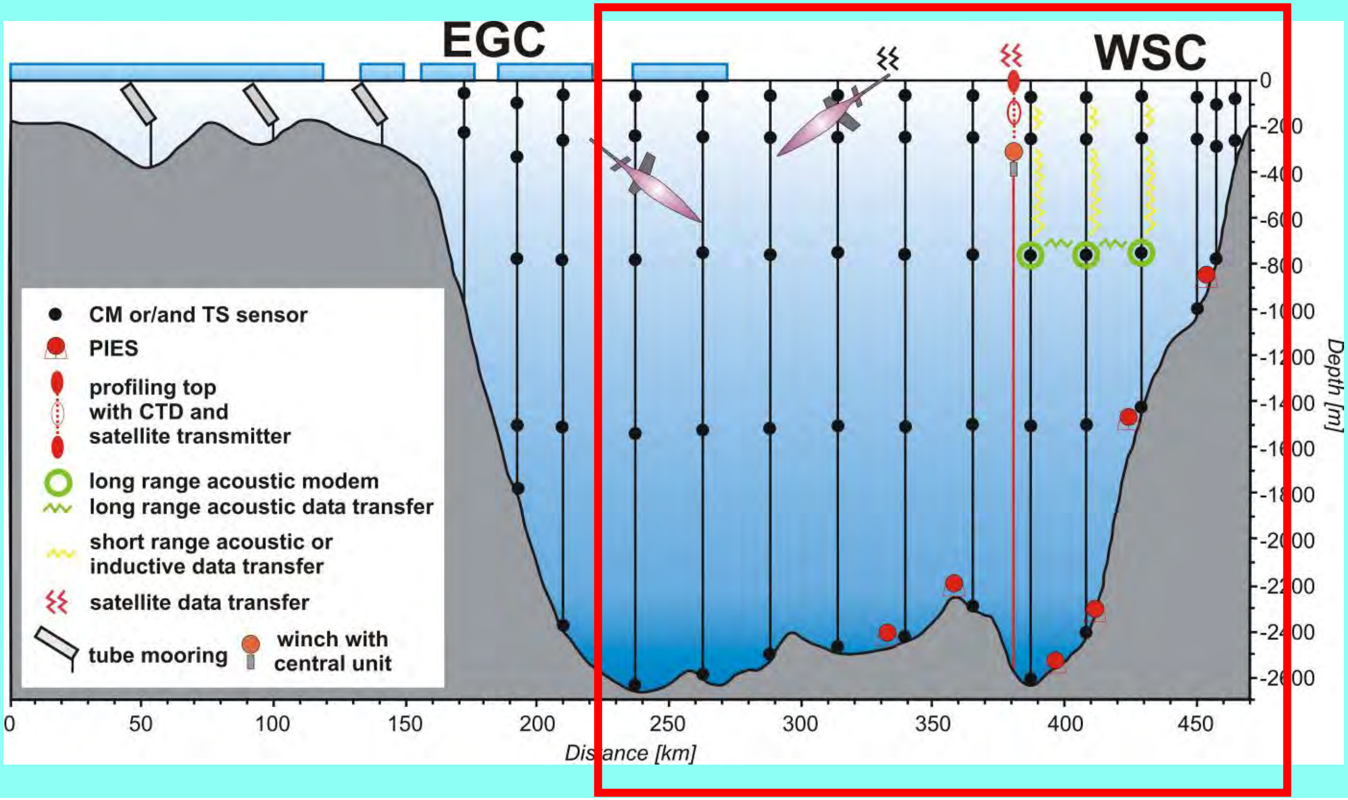
Updated 30 May 2016





Fram Strait moored array from 1997





• since 1997 – the array of 16-18 moorings along 78° 50'N measuring temperature, salinity, pressure and currents at selected depths (50m, 250m, 750m, 1500m, above bottom)

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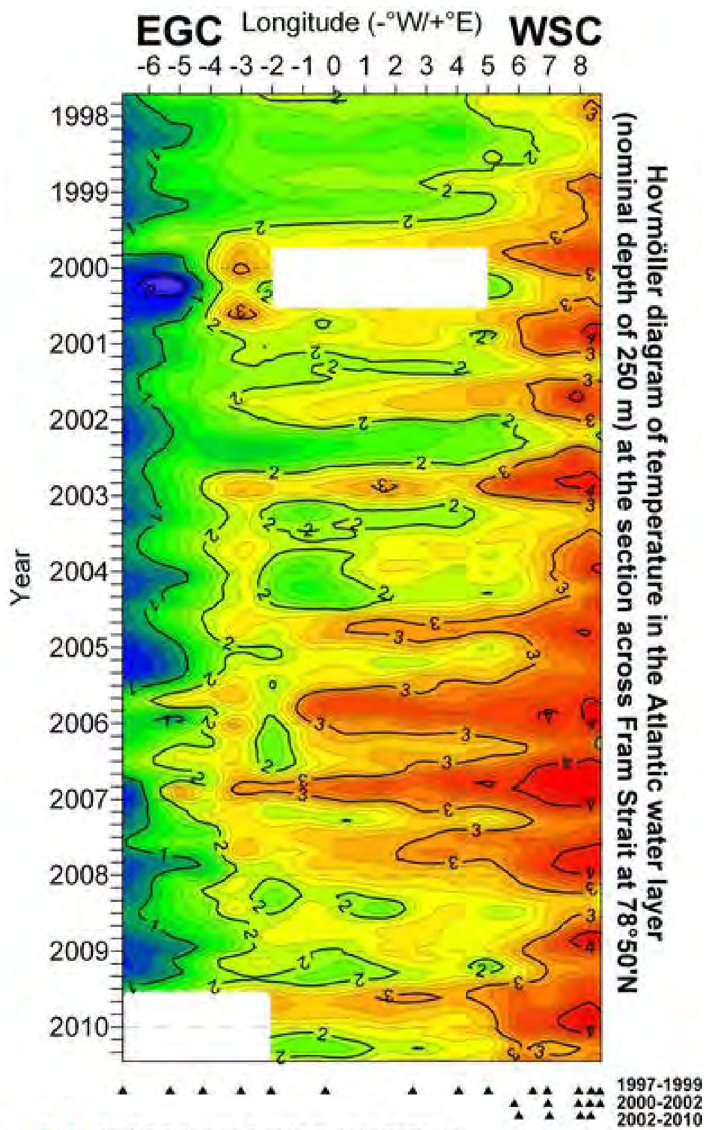
Temperature and current in Fram Strait (250 m) from moorings

Temperature (° C)

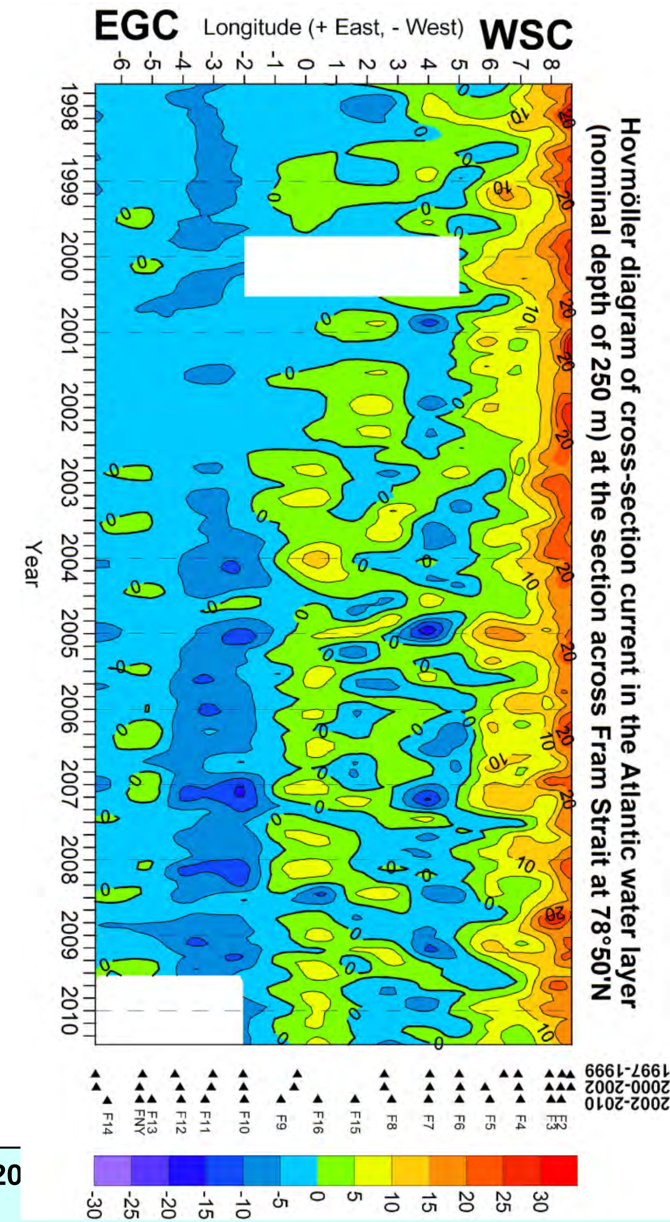


1997

Time (years)

2010

Meridional current (cm/s)



Repeated CTD summer section through Fram Strait

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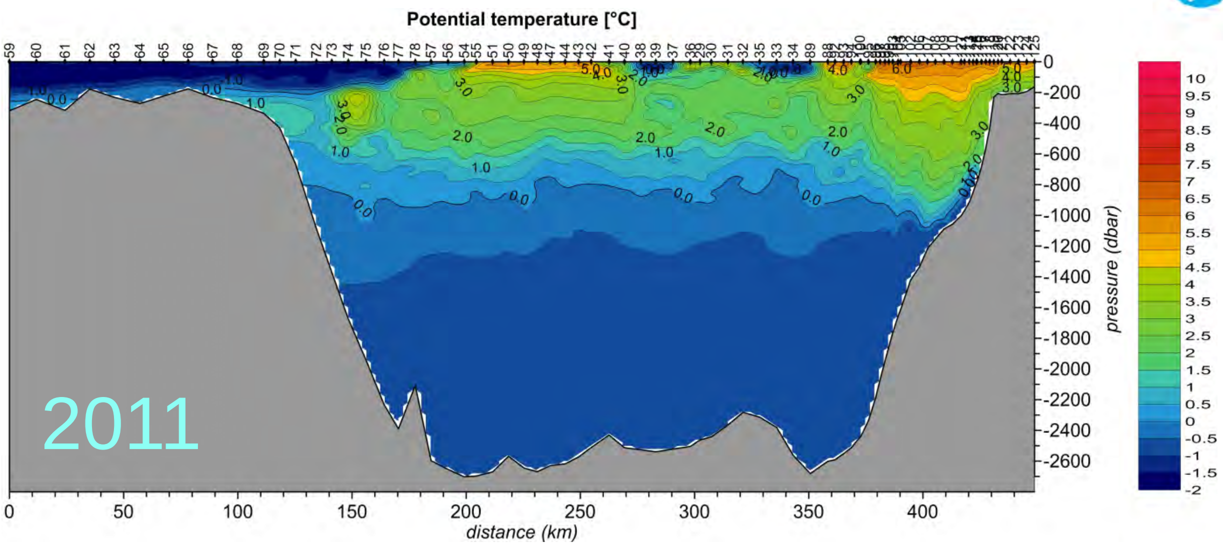
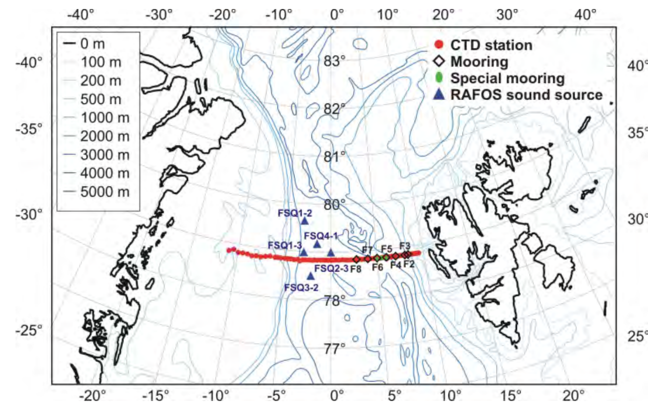
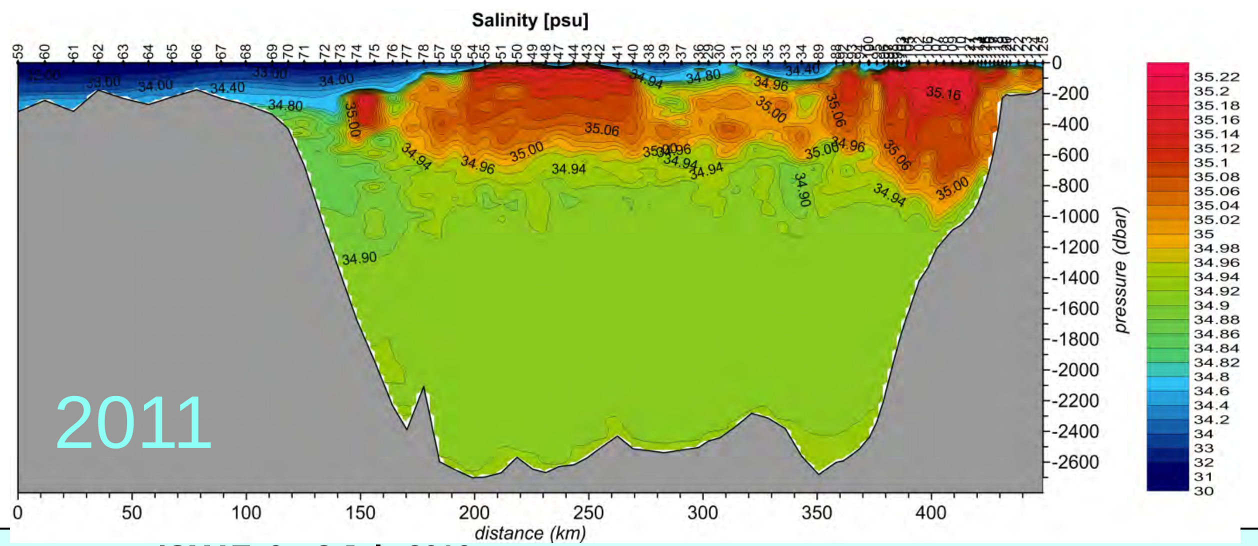




- 110 CTD stations along the moored array
- samples for salinity calibration



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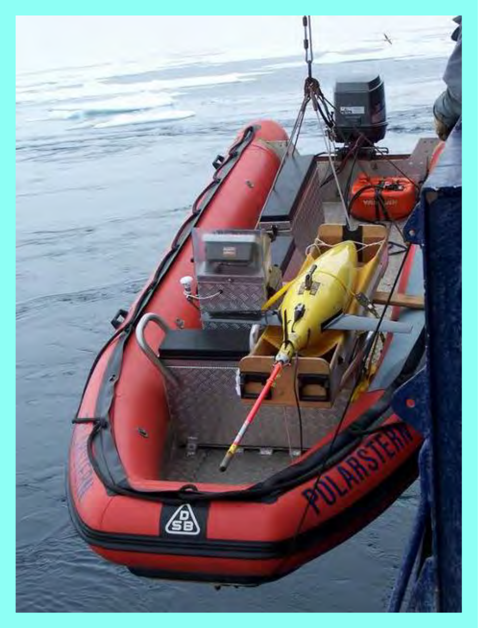
Glider experiments in Fram Strait in 2008-2012



In Fram Strait AWI employs Seagliders, developed in a collaboration between the Applied Physics Laboratory and the School of Oceanography of UW in Seattle.

Fram Strait gliders are operated from the base station at the Glider Operation Center, established by OPTIMARE, Bremerhaven. RUDICS service is successfully used for communication, the Iridium modem serves as a backup..

Example of a glider mission in summer 2012

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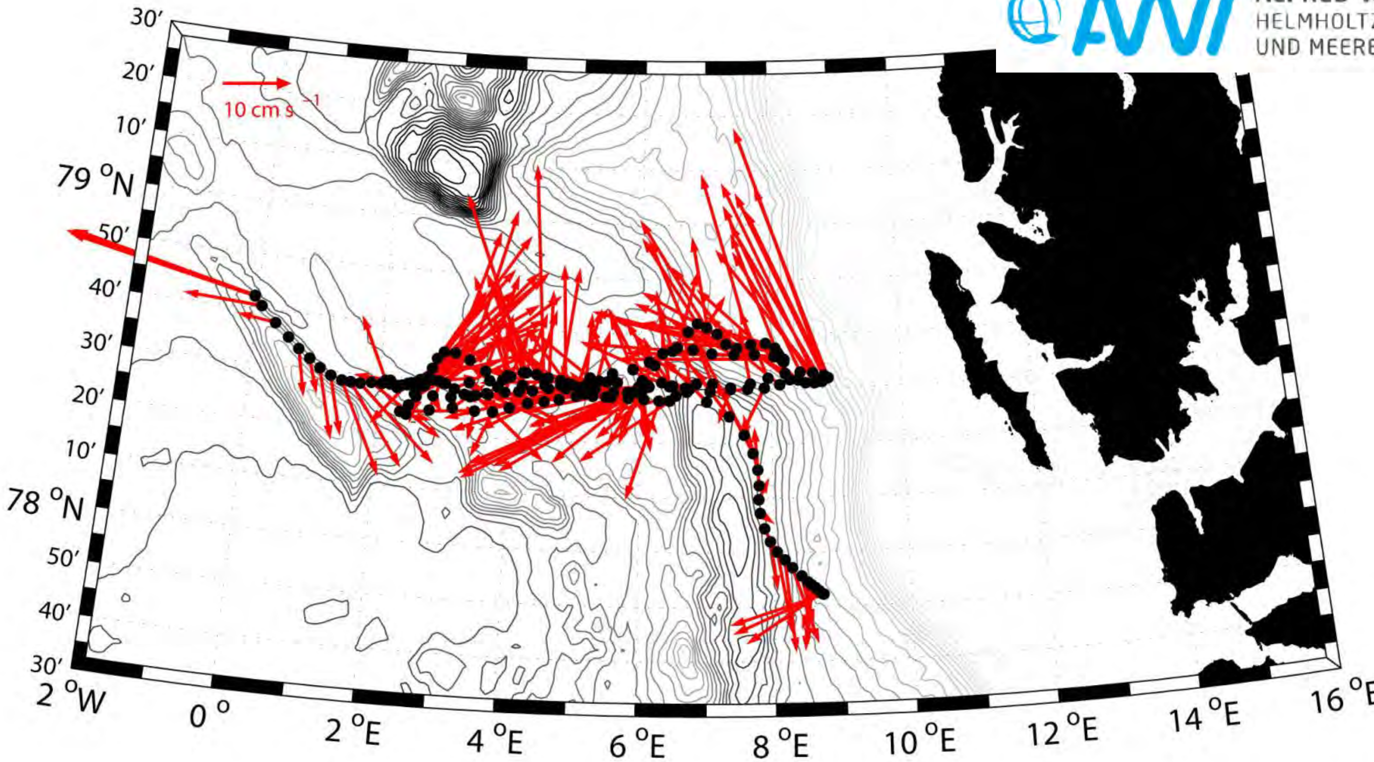
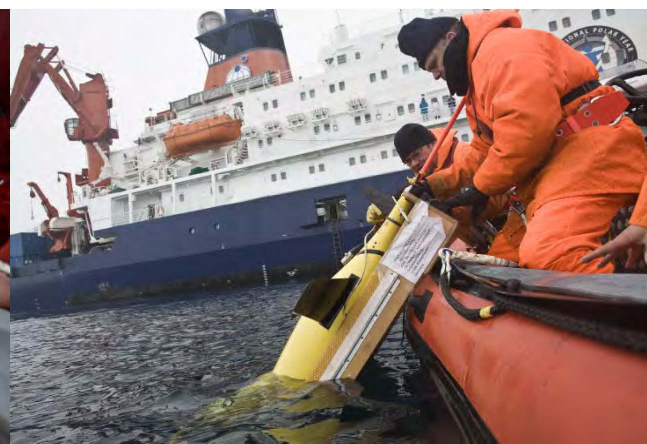
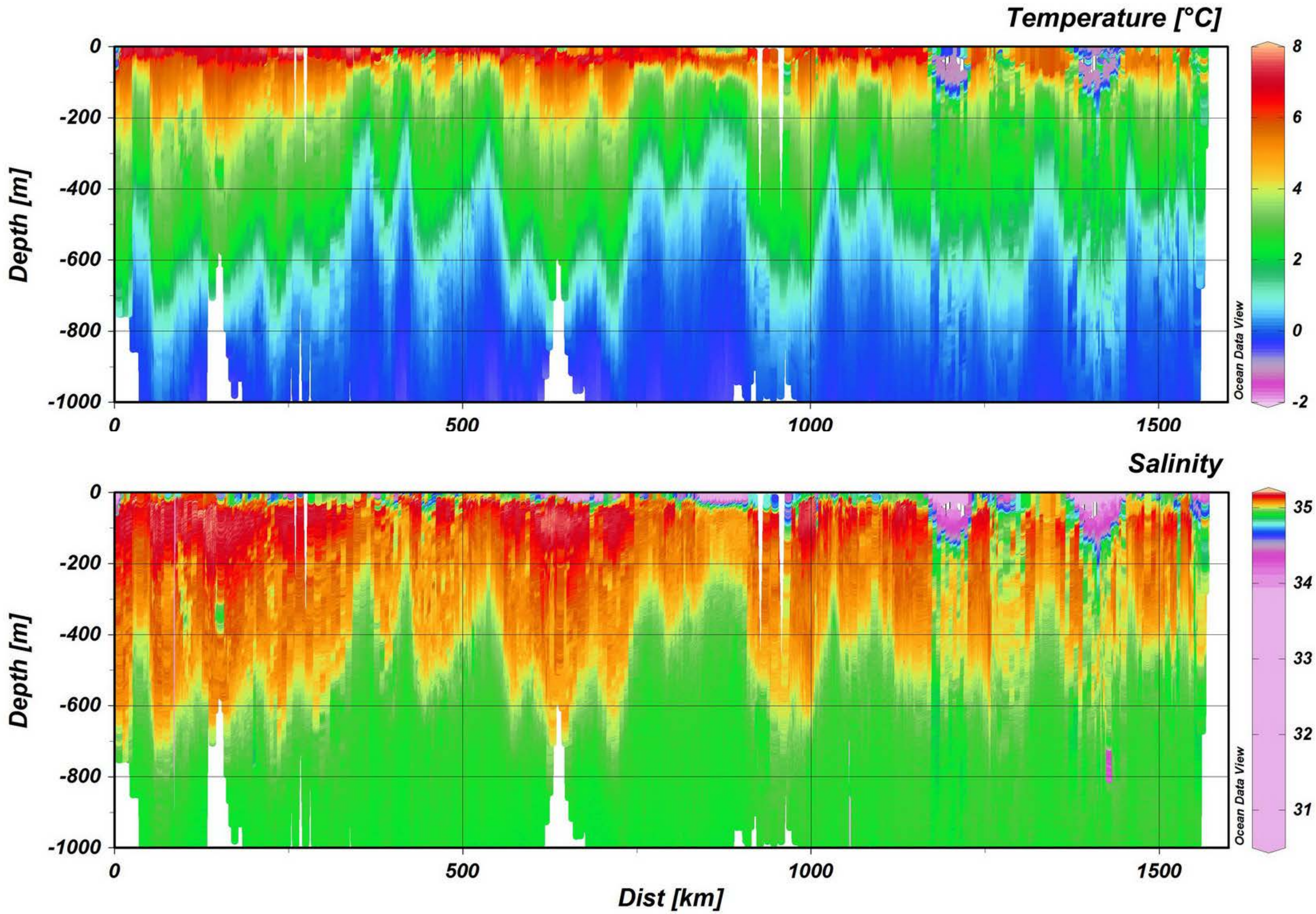




Profiles of temperature and salinity from a glider mission



Data from the SG127 mission in summer 2011

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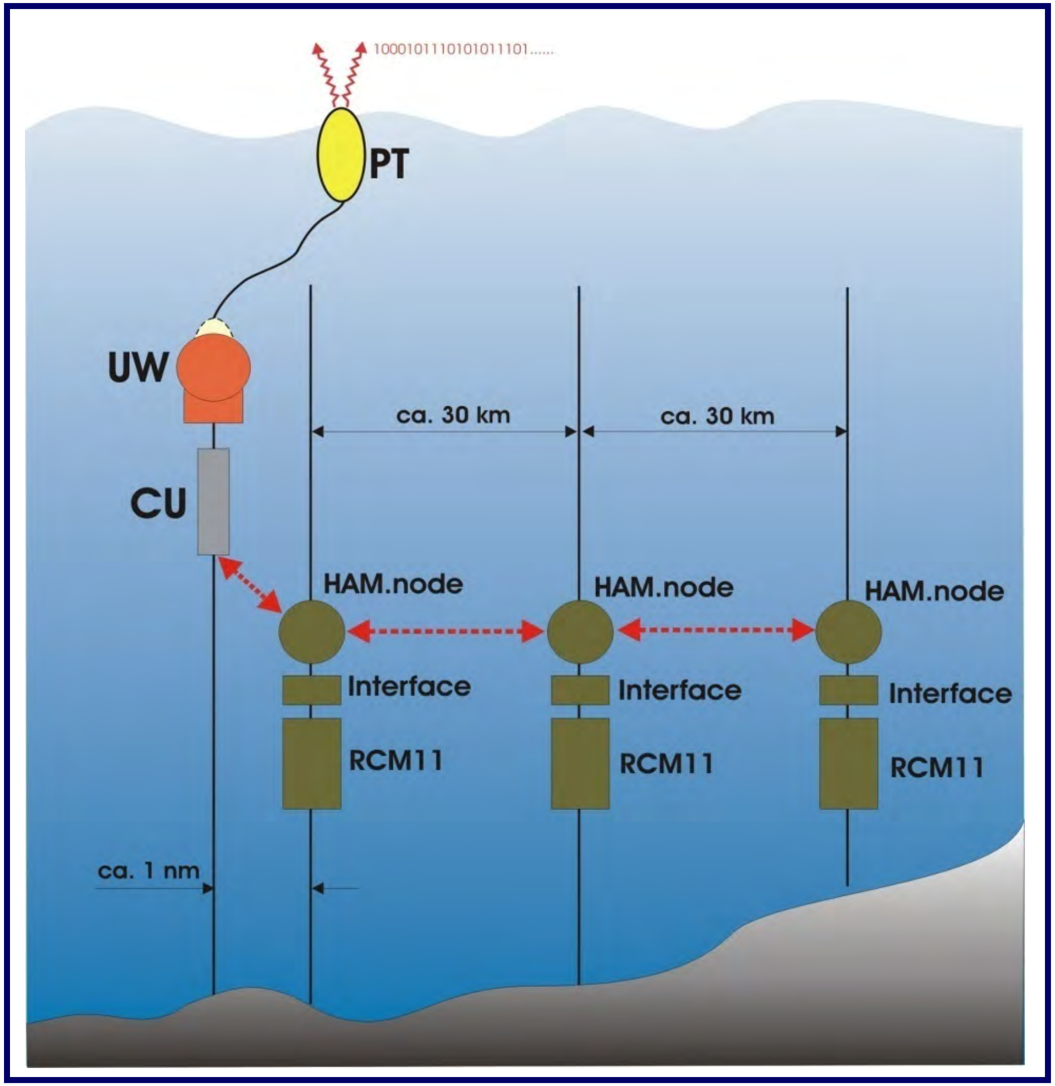
A concept to transfer data in near realtime from moorings

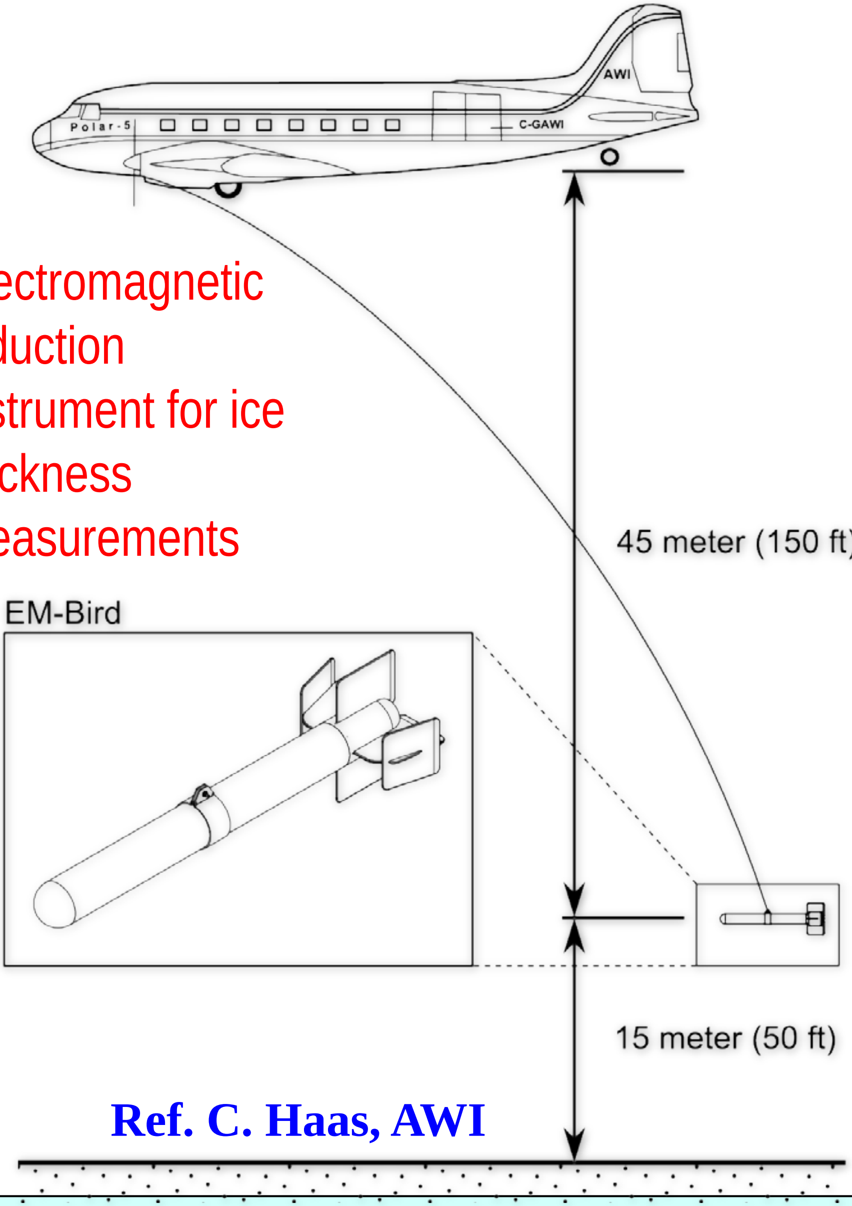


The idea is to employ acoustic data
to transfer between moorings:

• 3 moorings in the eastern part of Fram
Strait in the West Spitsbergen Current
were equipped with the long-range
(up to 30 km) acoustic modems

• the hydro-acoustic modem HAM.Node
will assure long range data transfer,
equipped with the transducer ITC2002a,
a broadband cylindrical transducer with

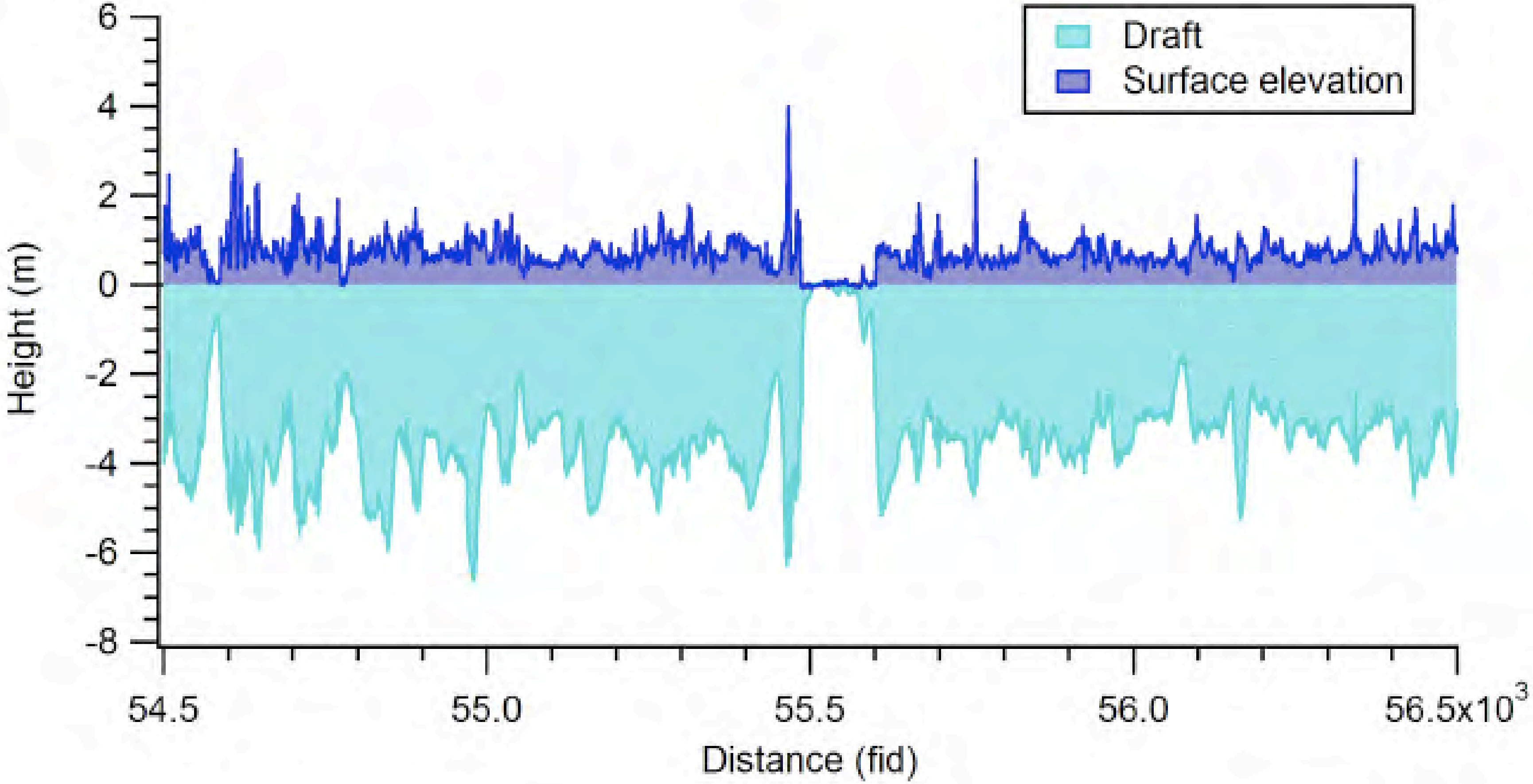
Airborne observing systems



Electromagnetic induction instrument for ice thickness measurements

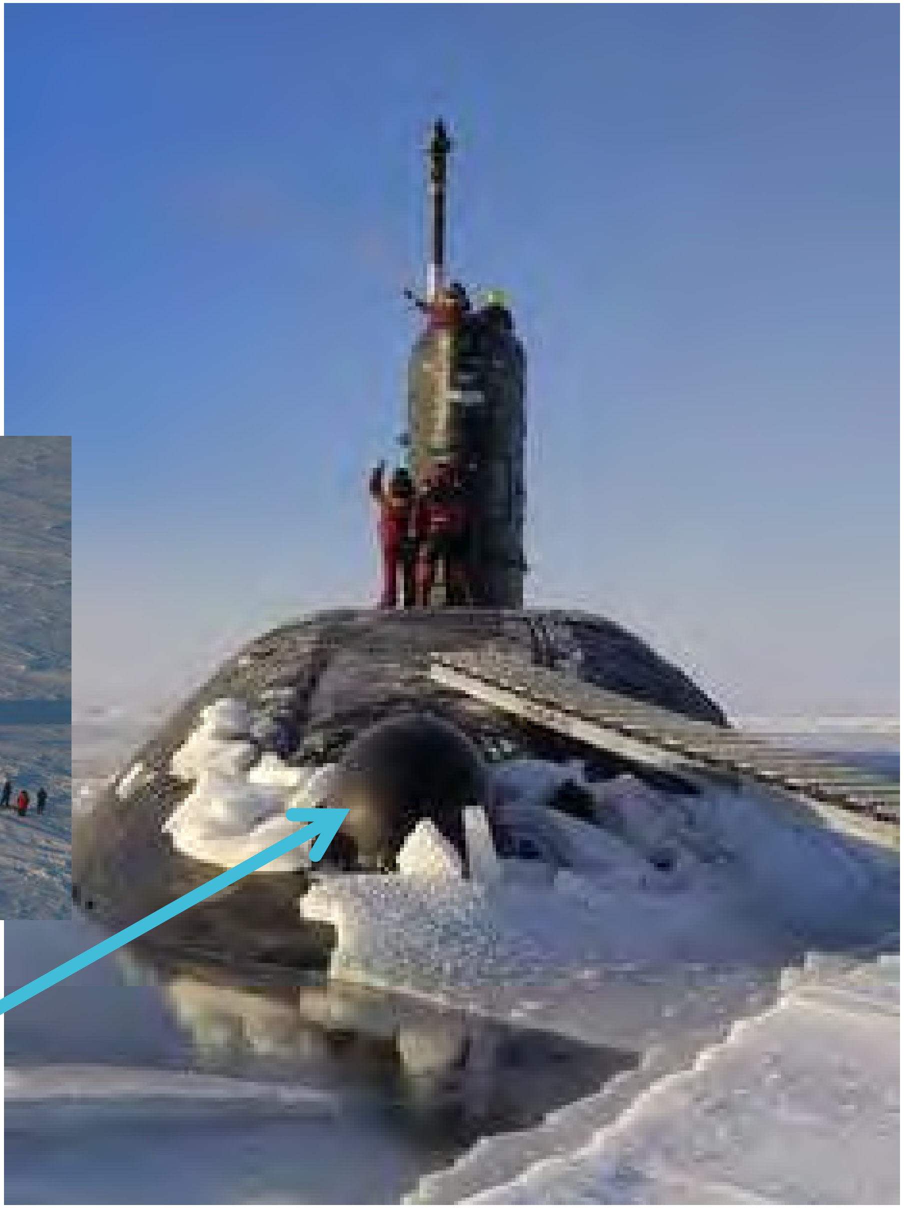
Ref. C. Haas, AWI

Sea ice freeboard and thickness data from airborne EM surveys



Ref. C. Haas, AWI

submarine upward looking multibeam sonar to measure sea ice draft



EM3002 multibeam sonar
in forward sonar dome

Courtesy: P. Wadhams

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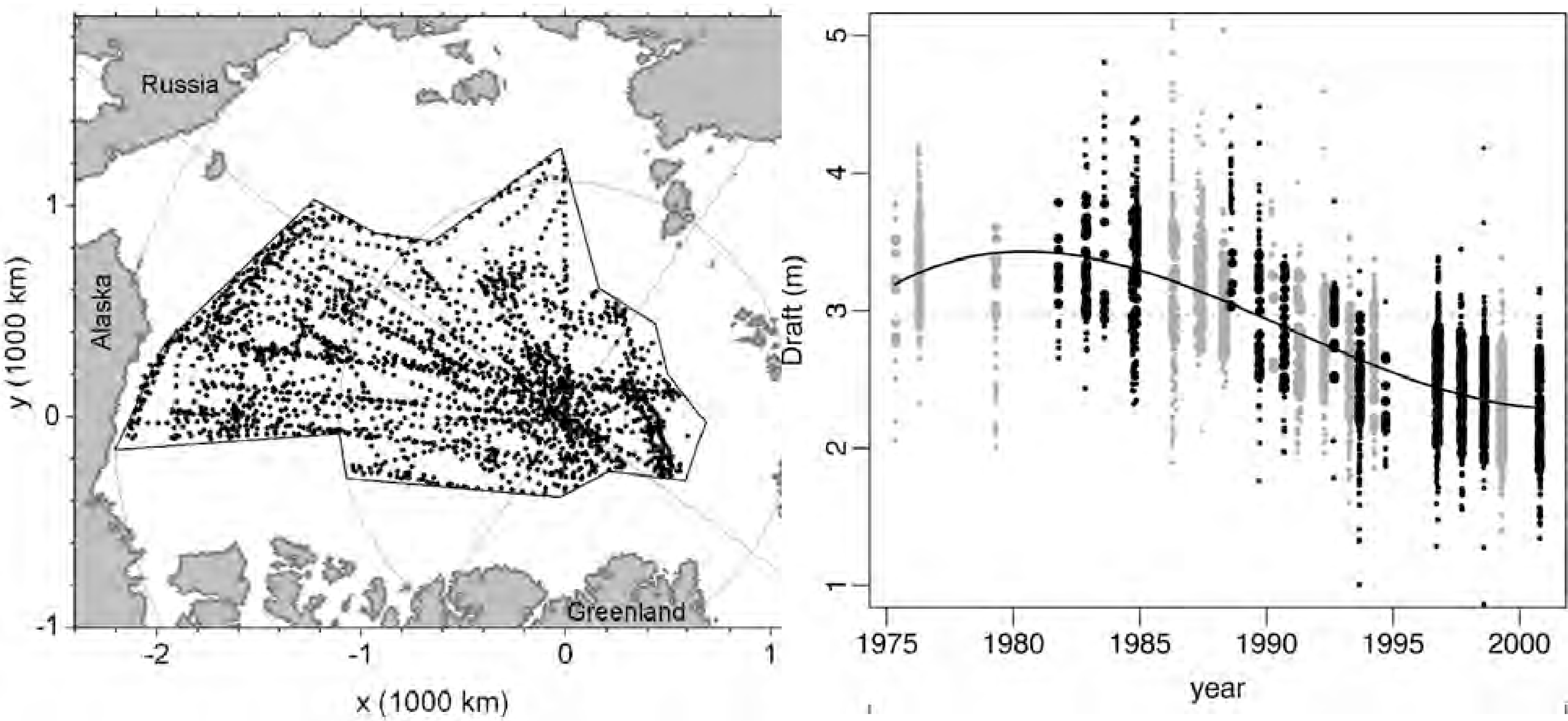
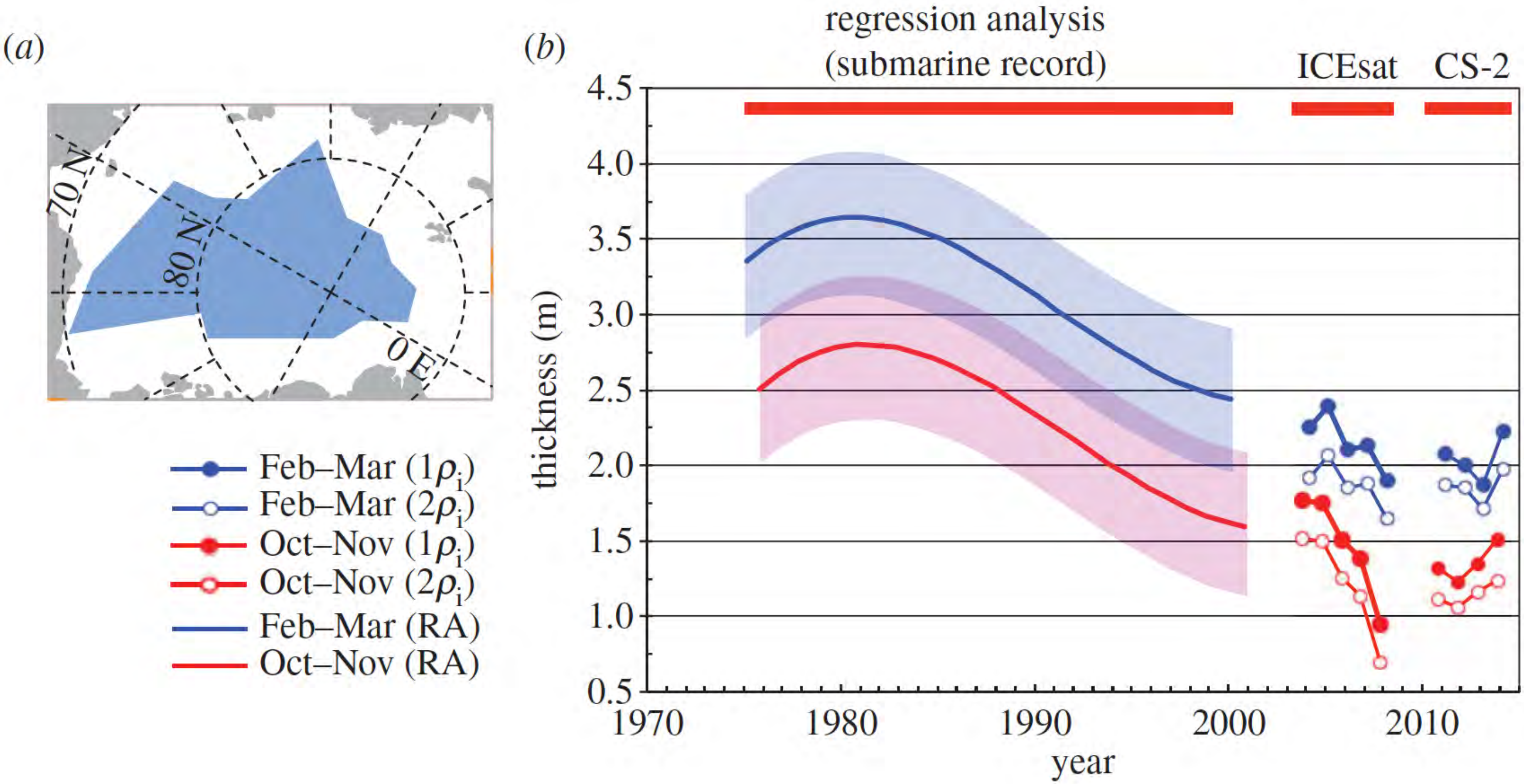
Observed thickness reduction from submarine data 1975 -2000



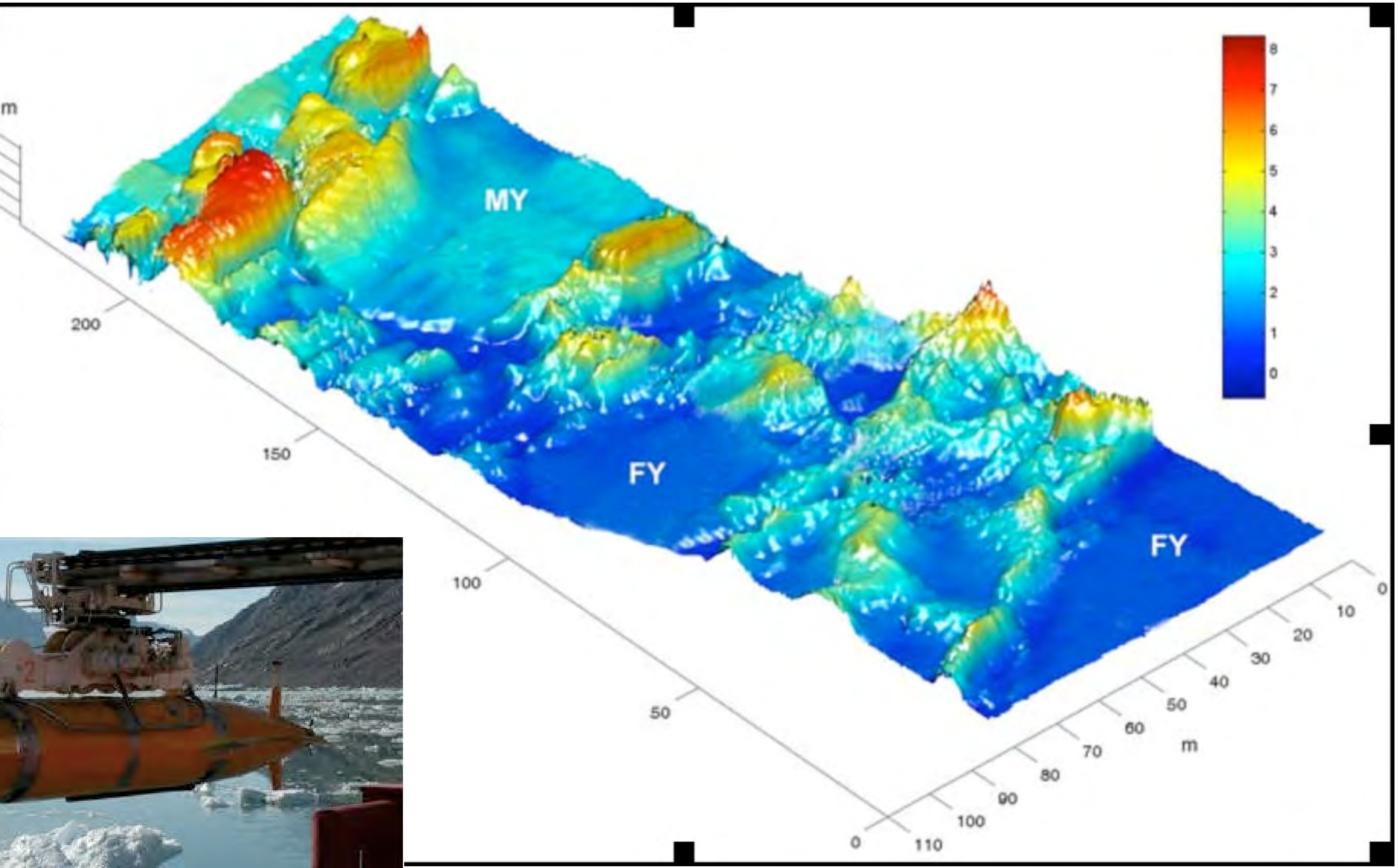
1980: 3.42 m, 2000: 2.29 m (mean value) Rothrock et al., 2008

Reduction in ice thickness from 1980 - 2014



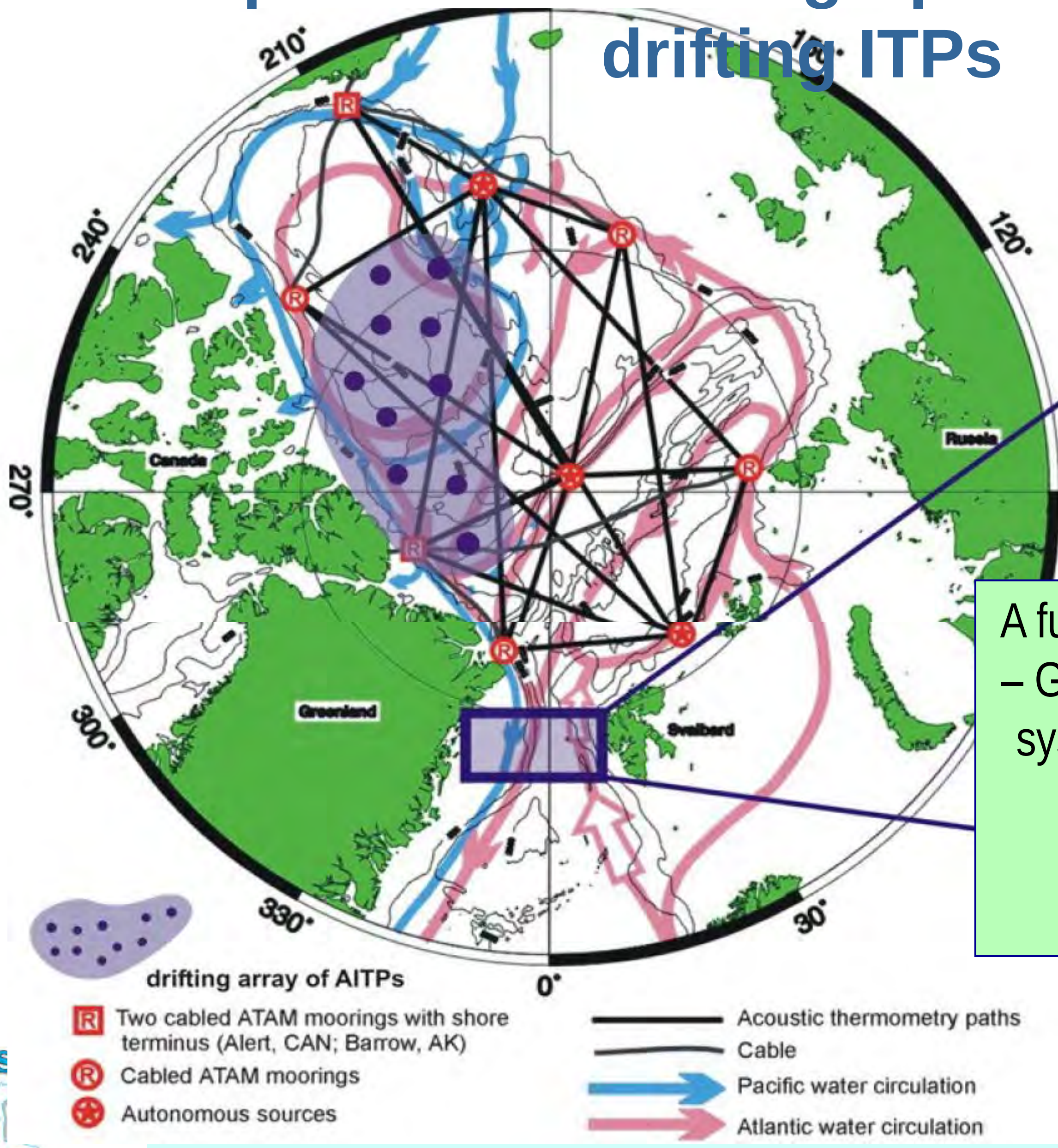
From Kwok and Cunningham, 2015

Detailed mapping of sea ice underside with 2D sonar



The GAIVA autosub equipped with Geoacoustics Geoswath Plus 500 MHz multibeam echosounder has been used to map the underside of the ice (ref. Peter Wadhams et al.)

the Arctic
- coupled with oceanographic moorings and drifting ITPs



The Fram Strait acoustic system: developed since 2008

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

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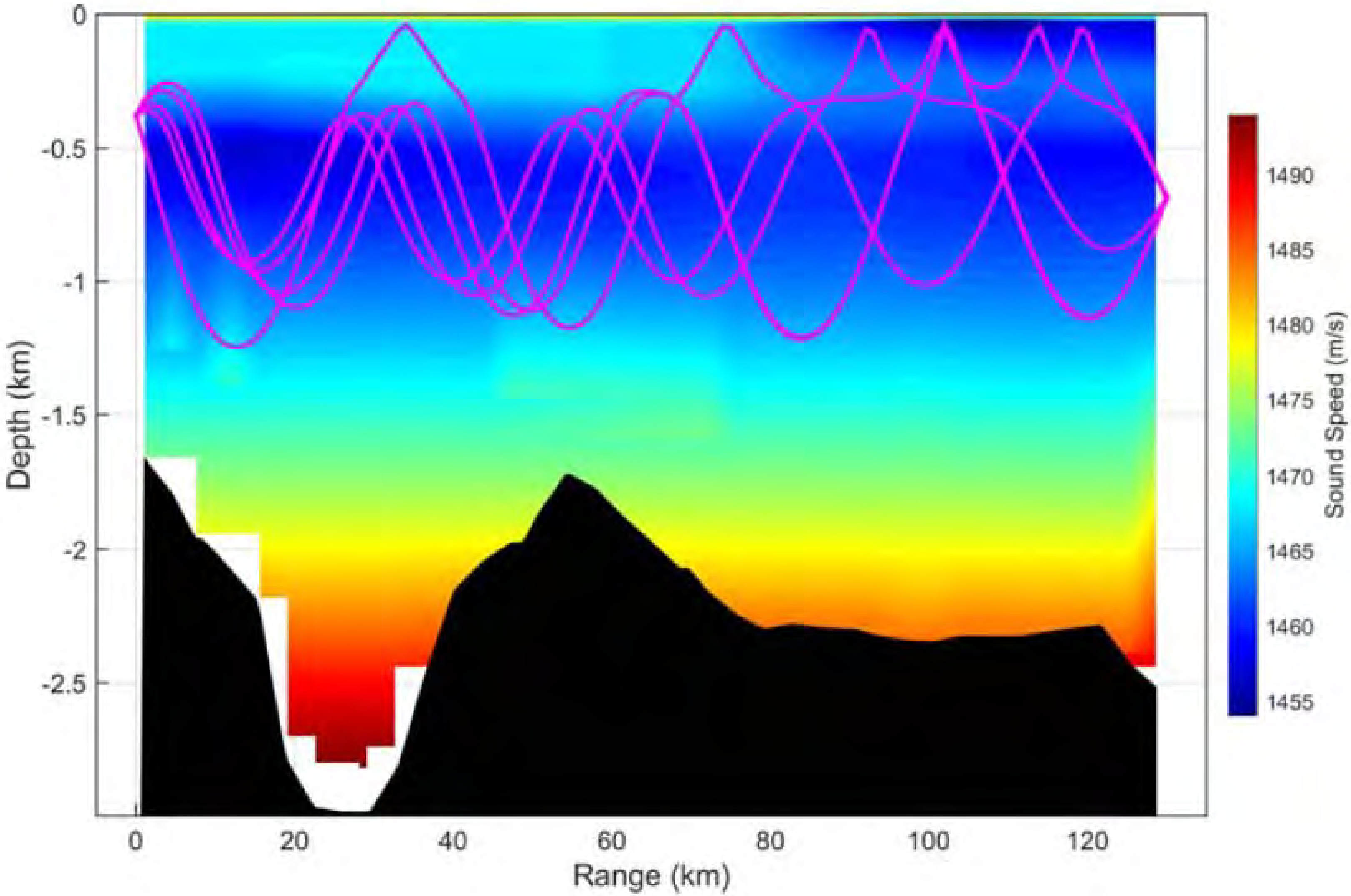
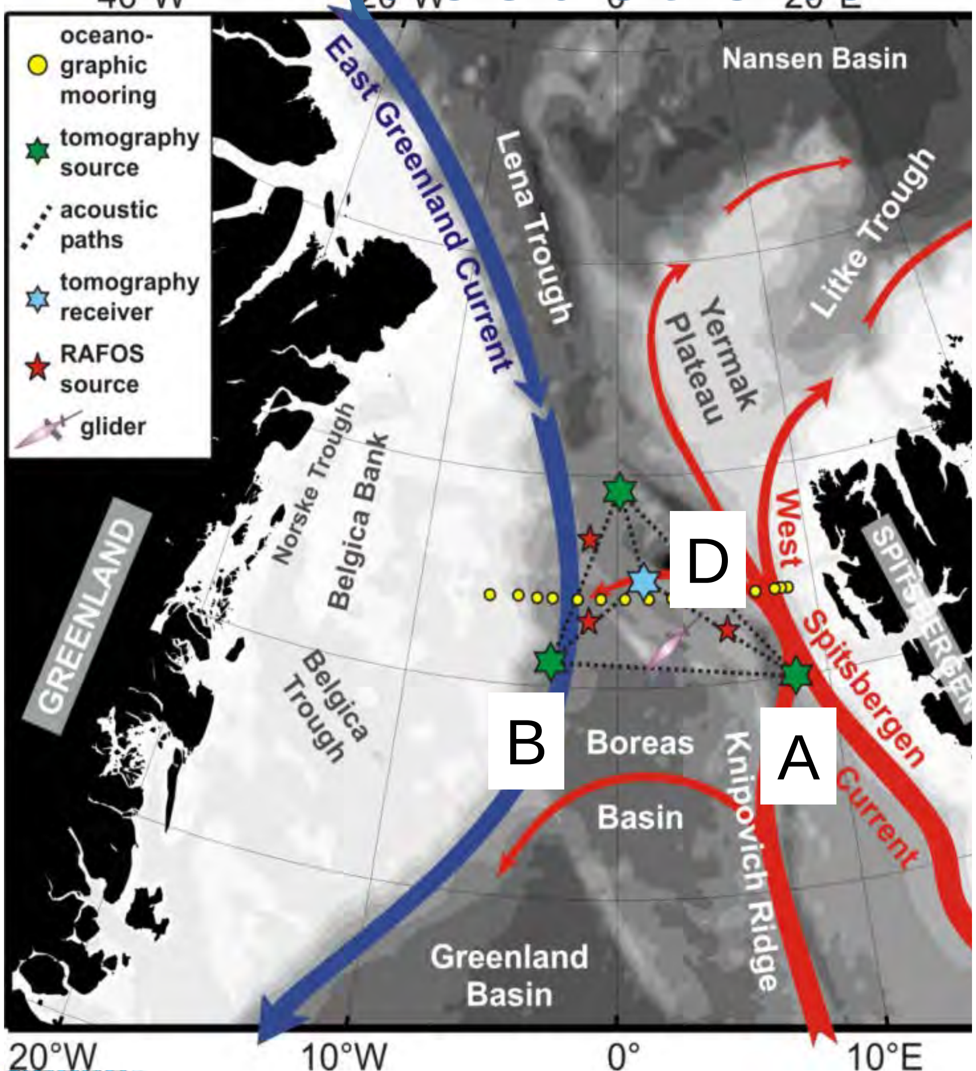
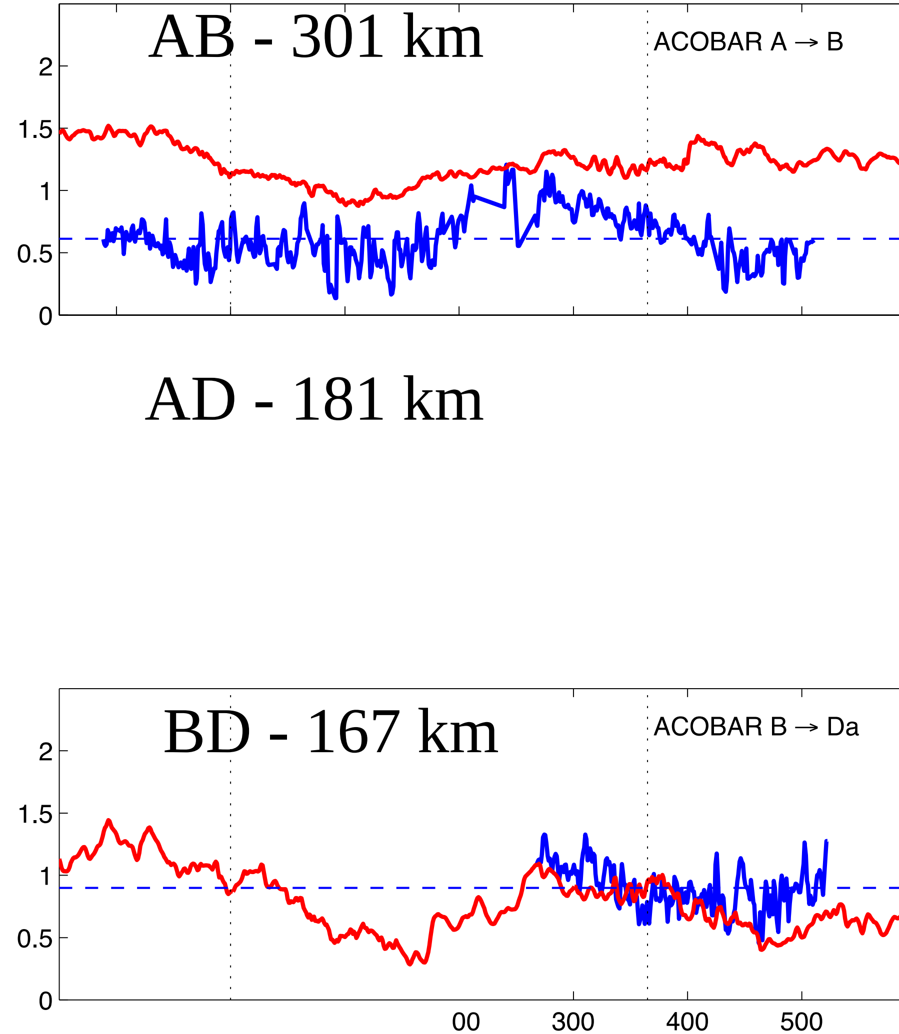
Acoustic signals from sources to receivers



A set of eigenrays obtained from a snapshot of the Fram Strait Model sound speed. The five eigenrays obtained represent similar measurements of the ocean (Sagen et al., 2016)

Ocean temperature in Fram Strait from acoustic travel time data (acoustic tomography)

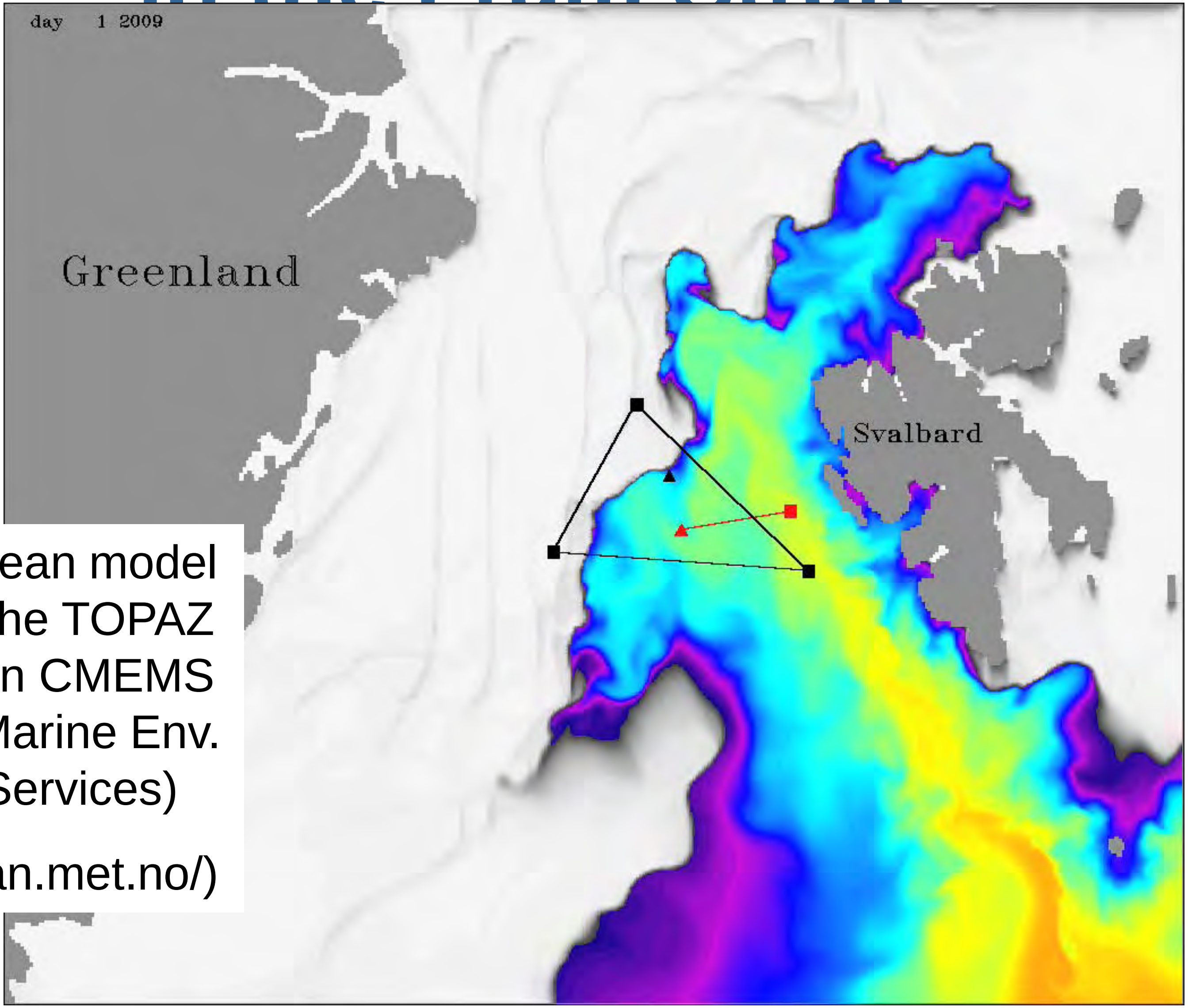




Blue: Temperature from acoustics

Red: Temperature from ocean model

Modelling the ice-ocean circulation in the Fram Strait



Simulation from 01 Jan to 31 Dec. 2009

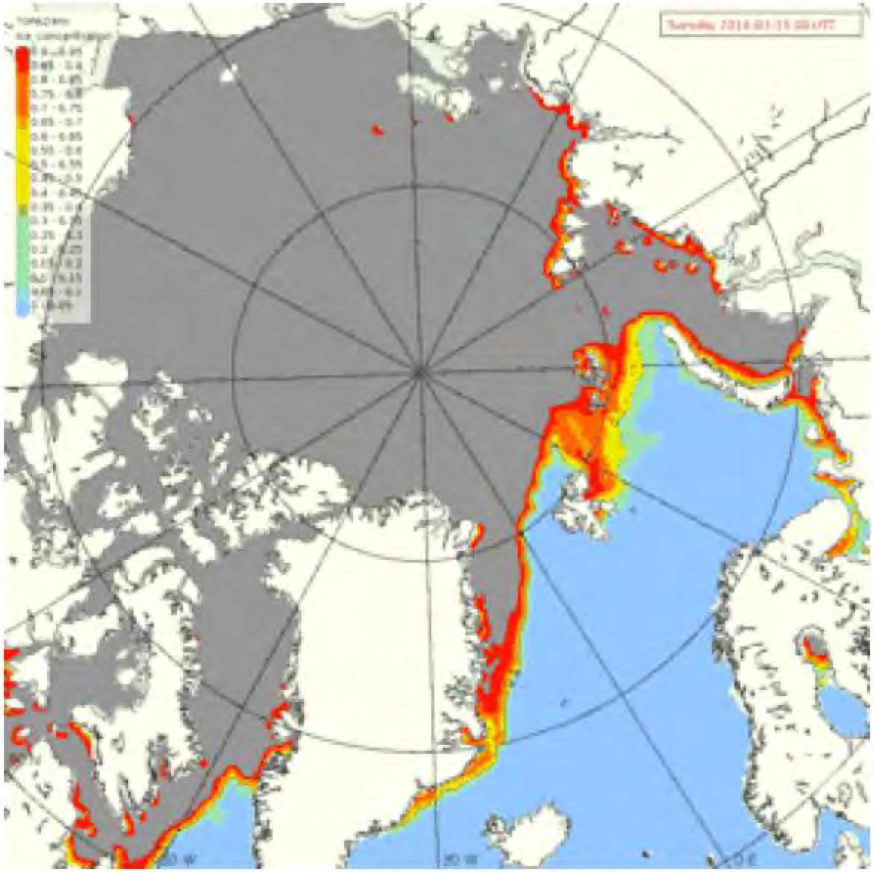
Nested ice-ocean model (HYCOM) to the TOPAZ system used in CMEMS (Copernicus Marine Env. Monitoring Services)

(http://myocean.met.no/)

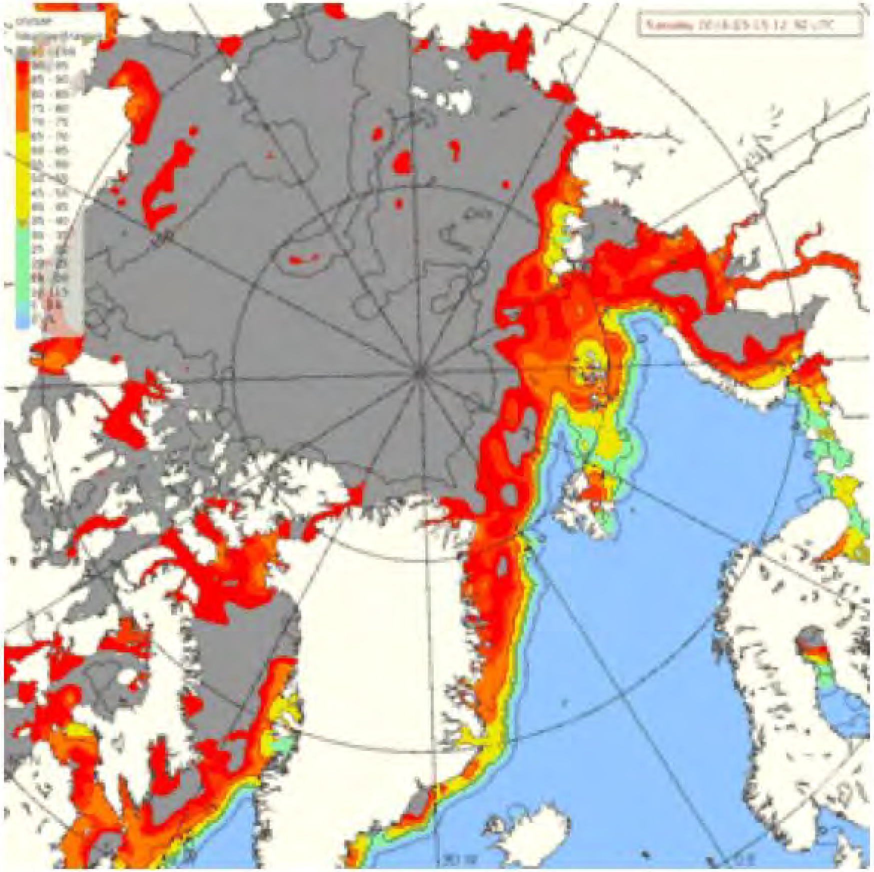
Copernicus Marine Environmental Monitoring Services (CMEMS)

15 March 2016

Sea ice yesterday
Model prediction



Sea ice yesterday
Satellite observation



http://www.copernicus.eu/main/marine-monitoring

http://myocean.met.no/

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Main challenges in building Arctic observing systems

- Define the scope of different systems (thematic area, scientific discipline, sensors, platforms, operational usage, etc.)
- Connect existing systems, which are usually discipline-oriented (or regionally defined or user defined)
- How to best identify and fill major gaps in the observing systems – depends on user requirements
- Establish Pan-Arctic agreements and collaboration between countries and transnational organisations
- Engage industry and stakeholders
- Resolve legal issues, ownership and rights of usage
- Cost and funding plan