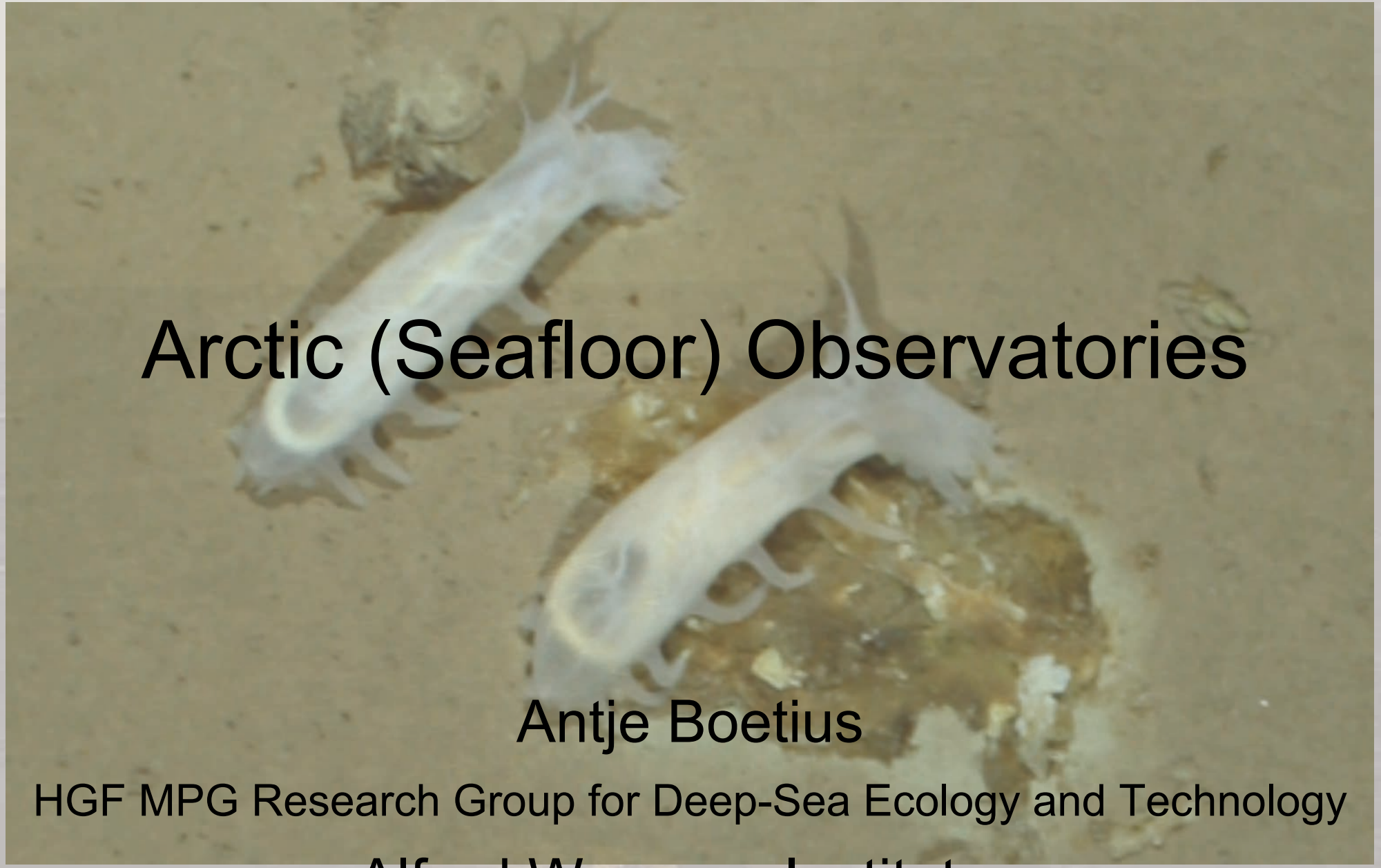


Arctic (Seafloor) Observatories

Antje Boetius

HGF MPG Research Group for Deep-Sea Ecology and Technology

Alfred Wegener Institute,
Helmholtz Centre for Polar and Marine Research

Observation

Scientific observation is the systematic **recording of data** by instruments and our **own senses**

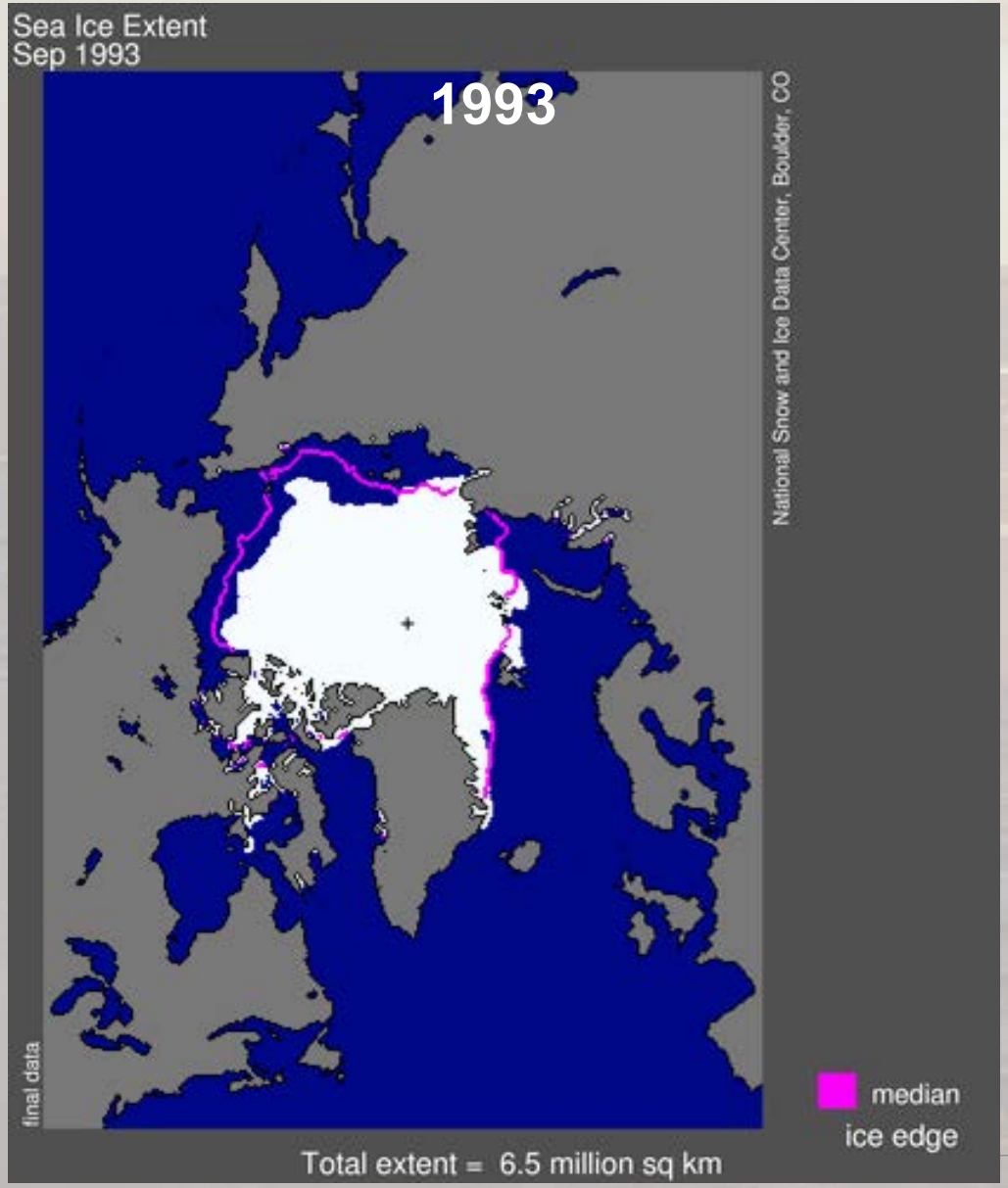
Observations provide a depiction of **reality** in time and space (status quo, reference, **baseline**)

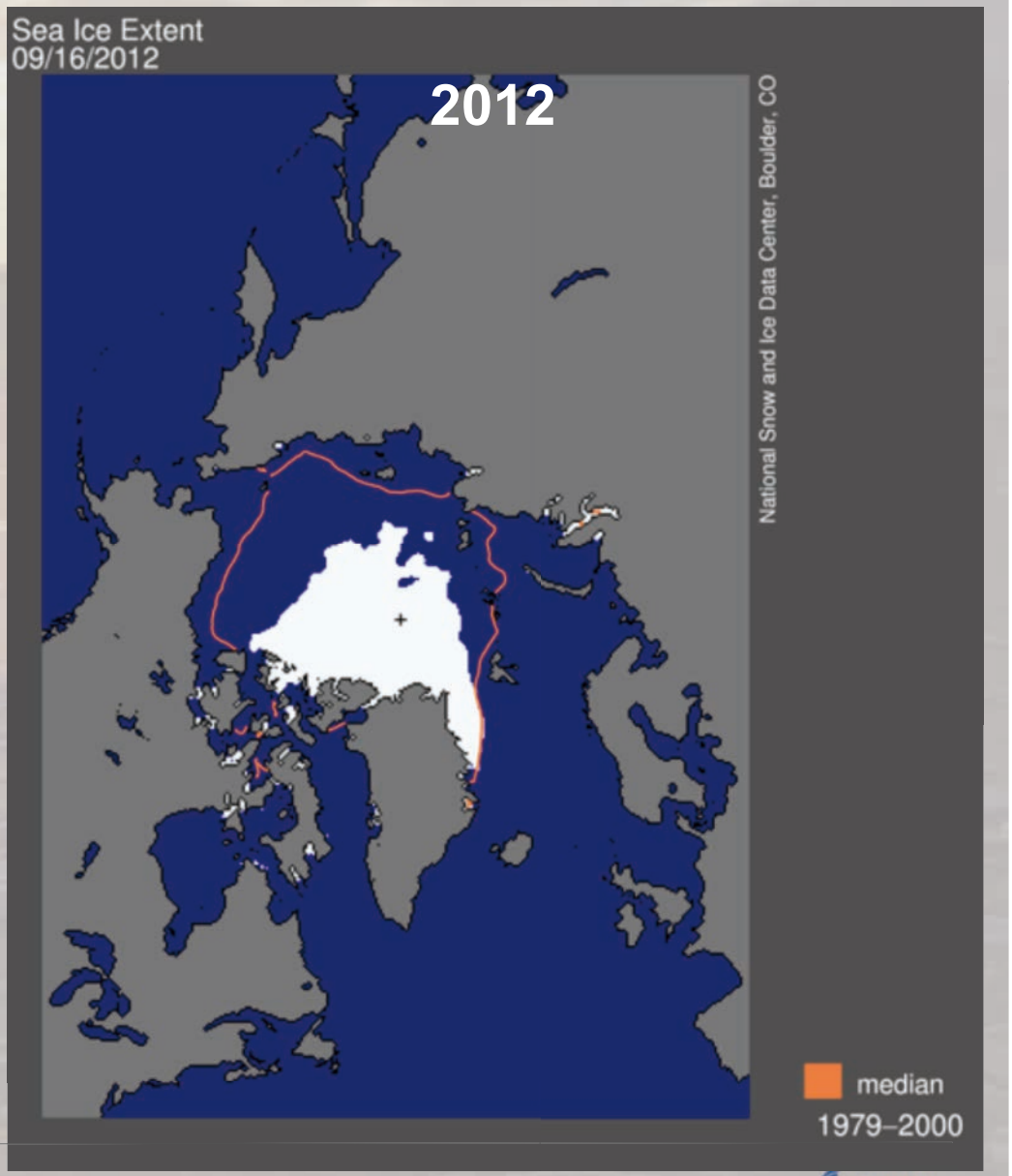
Observatories collect data in the form of **time series**, either by maintaining a fixed position (Eularian) or by moving/drifting (Lagranian)

Satellite observation: Sea ice extent

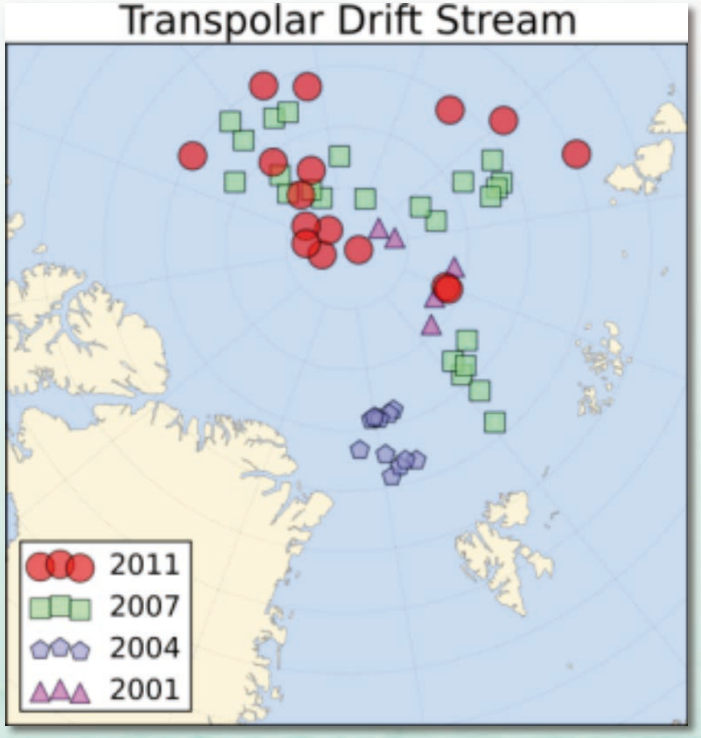
in September 1993 and 2012

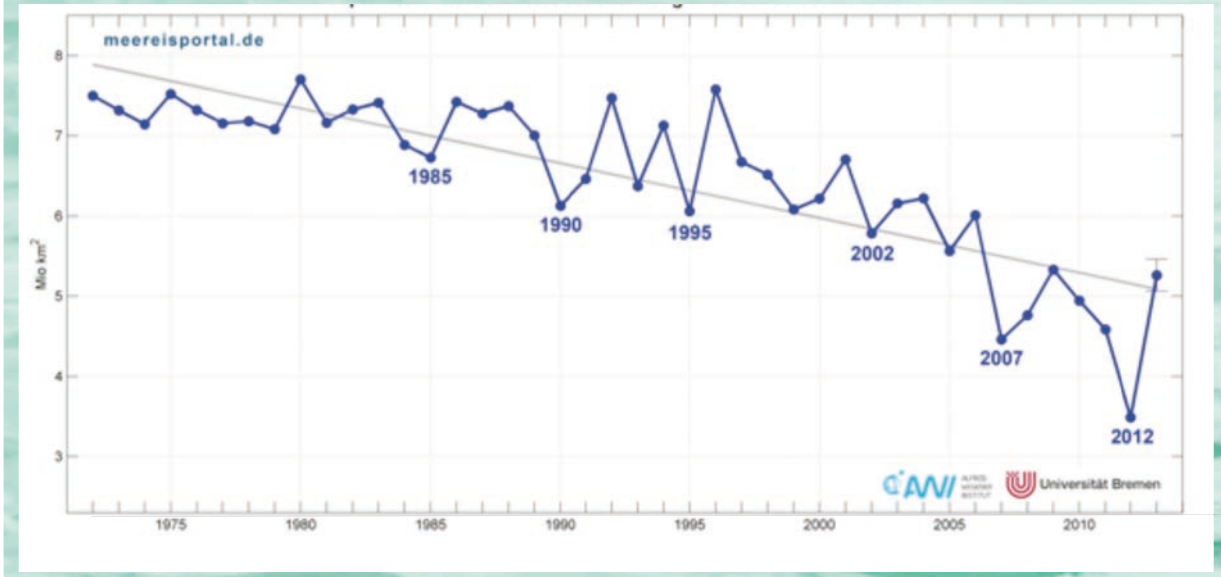
(National Snow and Ice Data Center)

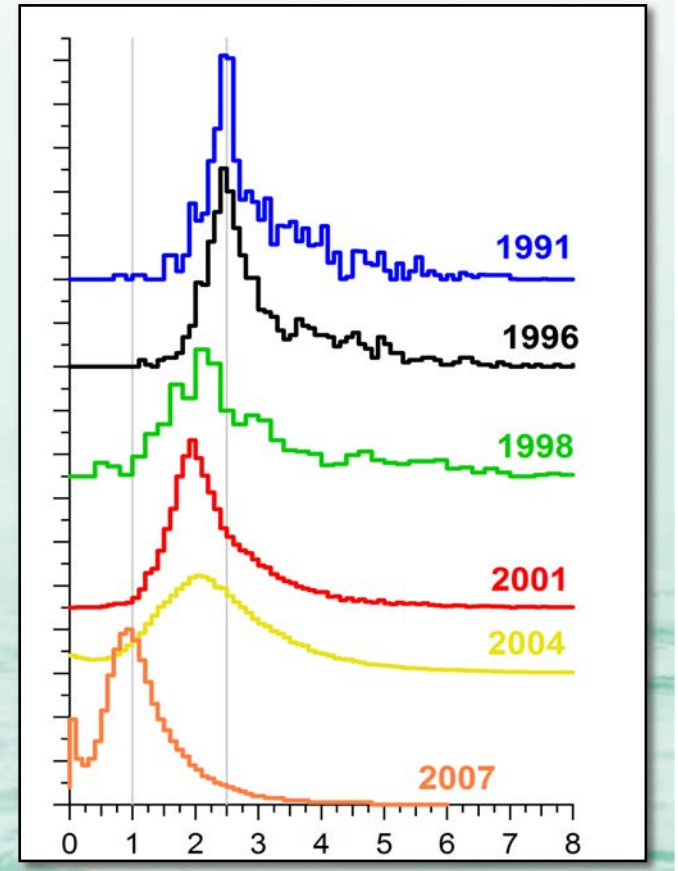




Sea ice (thickness) validation







M. Nicolaus, S. Hendricks, T. Krumpen et al. AWI

e.g. Renner et al. 2013

http://www.meereisportal.de/

Sea ice state 2012

Polarstern Expedition ARK27-3; IceArc; August-October 2012
Chief Scientist Antje Boetius

Movie by Stefan Hendricks, AWI

Typical questions to Arctic Change

What affect has the sea ice decline on our lives ?

Will it change weather where we live ?

What happens to the polar bear ?

Will there be more fish and resources ?

What is the risk to Arctic environment ?

What can we do to stop ice melt
and environmental degradation ?

Polarstern Bridge ARK27-3 2012

Is there really a long-term change into another state ?

How can we best document this large „experiment“ with nature?

Ecological consequences of climate change in the Arctic

Long term ecological observations

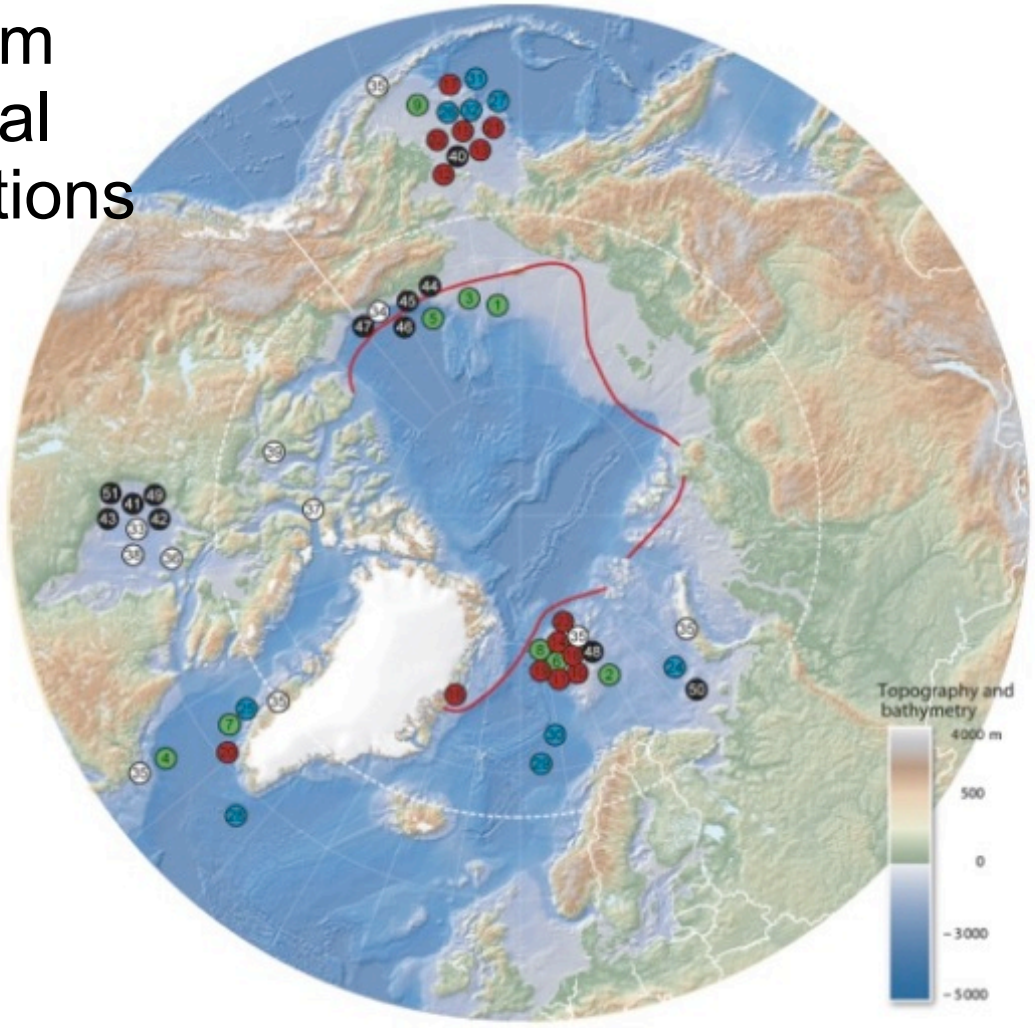


Fig. 3 Map of the Arctic showing the locations where footprints of climate change impacts on marine biota have been reported. The Arctic shelves and the mean minimum extent of ice (1979–2000) are indicated. The number of the symbols identifies the entry in Tables 1–5, and the colours identify the reported organisms: Green: plankton; Red: benthos; Blue: fish; White: birds; Black: mammals.

Wassmann et al. 2011

Observation is required by international environmental policies

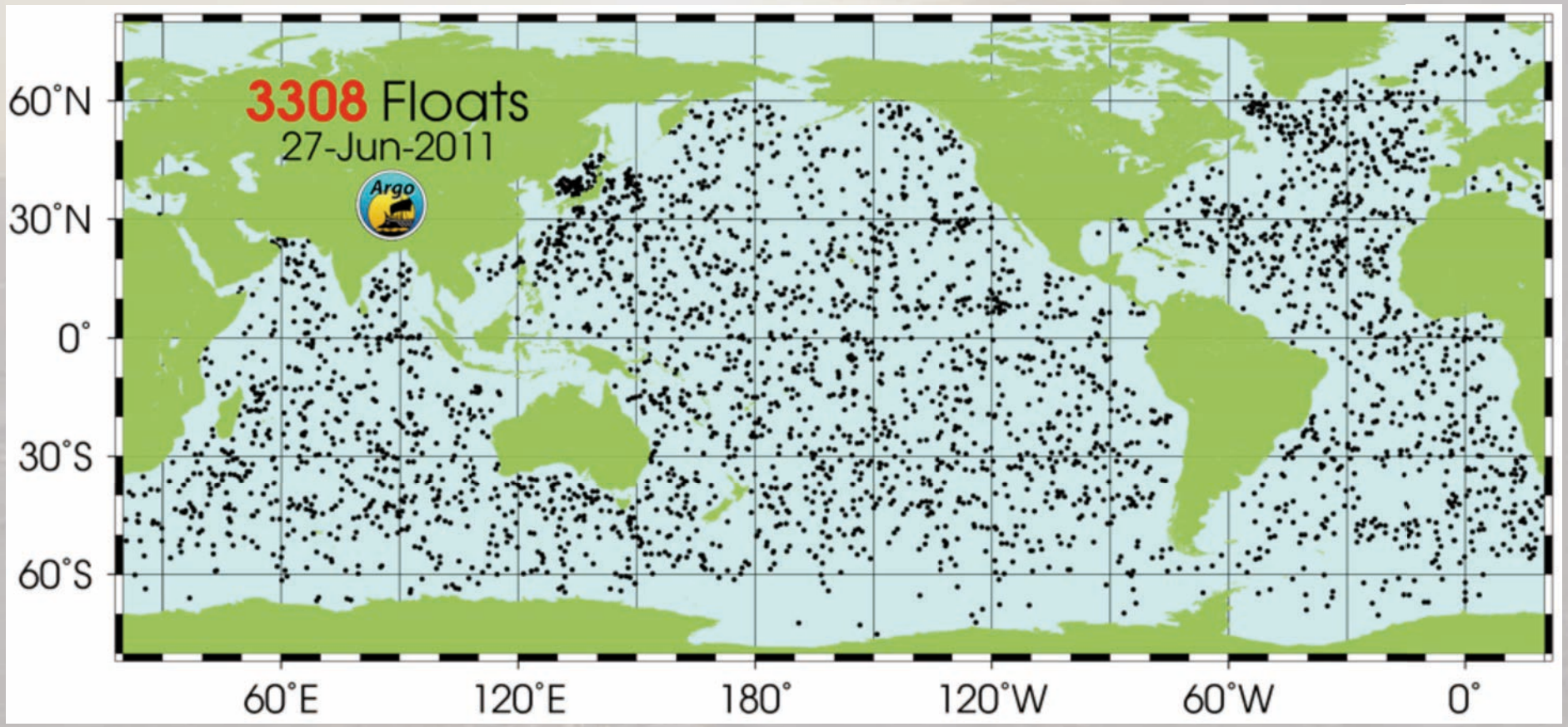
- analysis of the **characteristics** of, and **pressures** and impacts on, marine waters
- analysis of their use and the economic and social **cost of degradation**
- determination of a set of characteristics for **good environmental status**
- establishment of **environmental targets** and **monitoring programmes**
- evaluation on a **regular basis**

„The serious environmental concerns, in particular those due to climate change, relating to the Arctic waters, a neighbouring marine environment of particular importance for the Community, need to be assessed by the Community institutions and may require action to ensure the environmental protection of the Arctic.“

European Marine Strategy Framework Directive

Lack of infrastructure – lack of observation

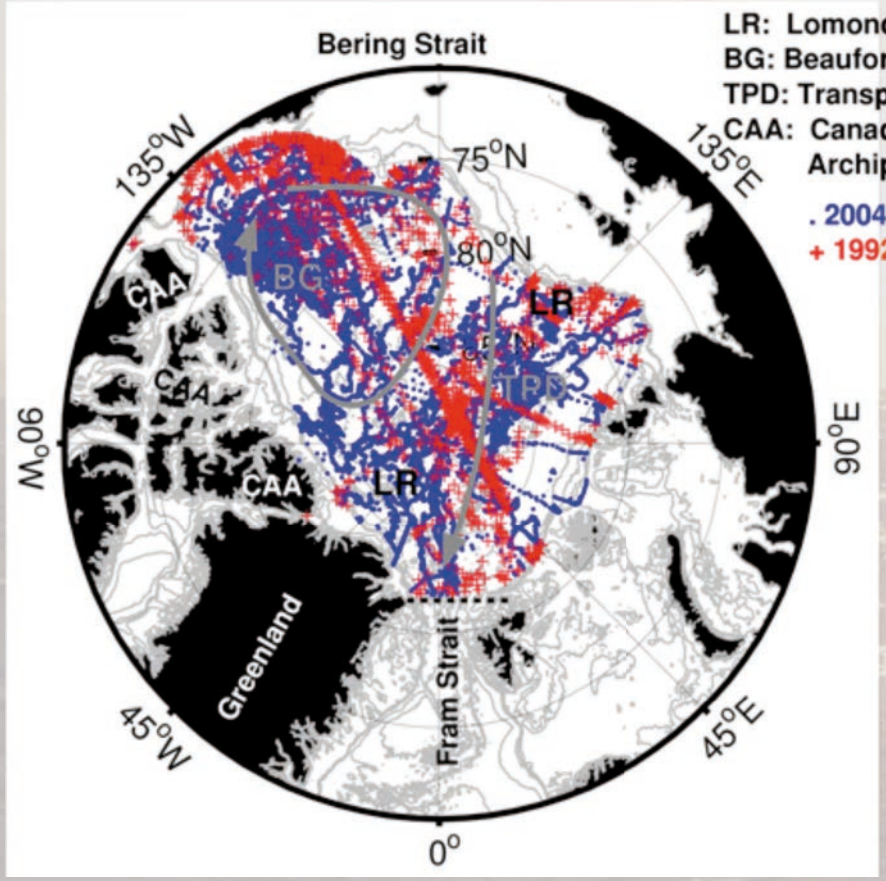
Global array of temperature/salinity profiling floats

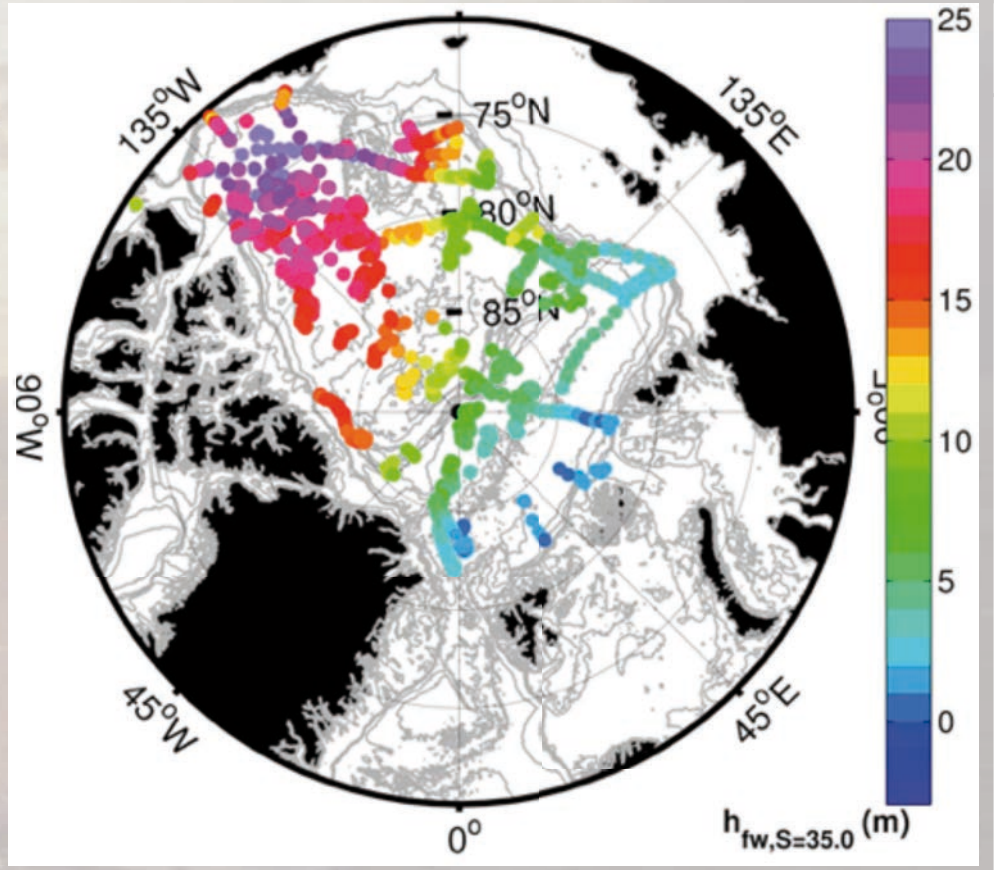


Not quite applicable to ice-covered seas

http://www.argo.ucsd.edu/

Progress by observation: ArcticROOS





Increasing freshwater content by 600±300 $km^3\ yr^{-1}$

International Cooperation: Multiship – Multiyear – PanArctic
Observation and synthesis of essential variables

Rabe et al. 2014

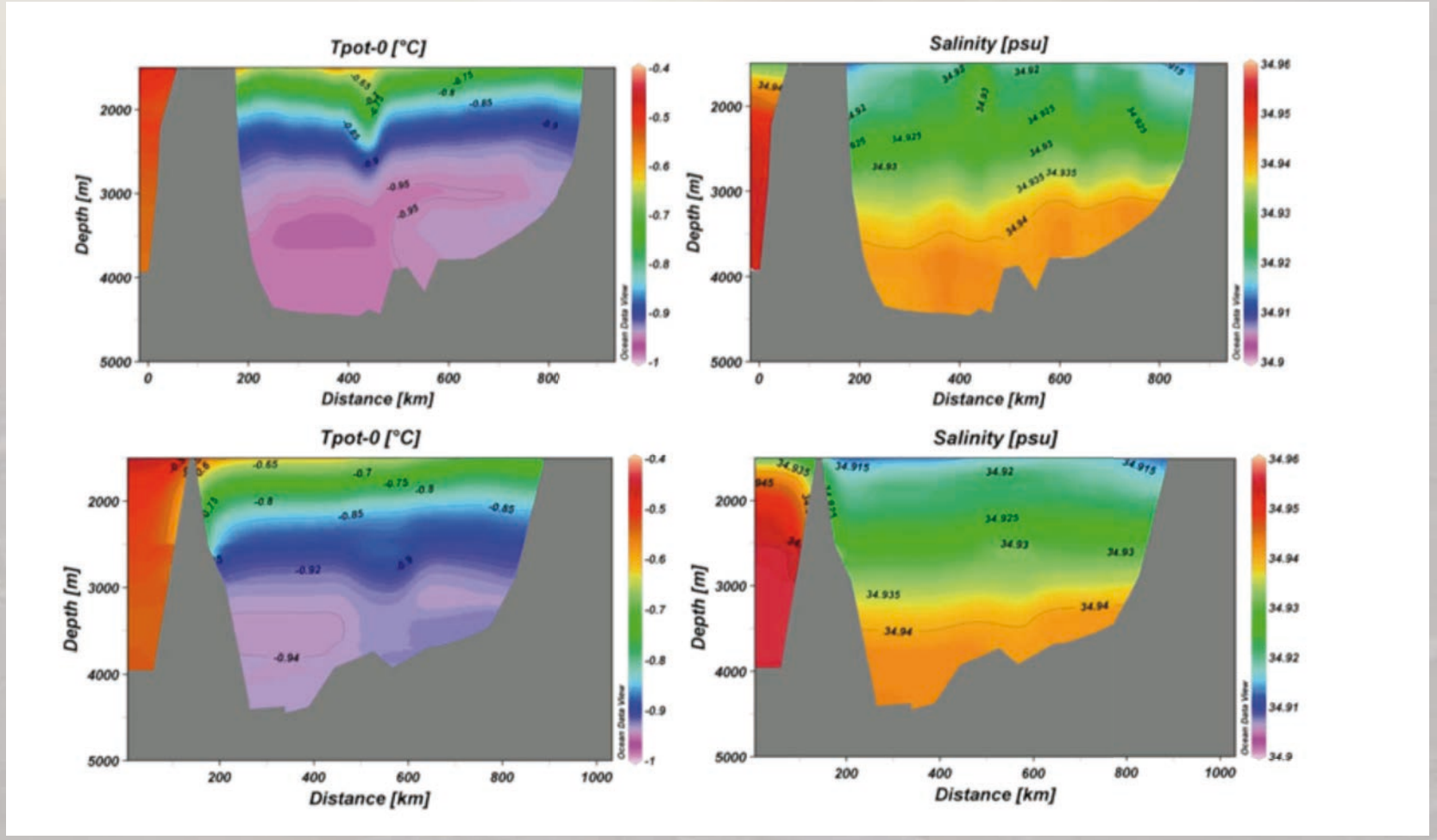
Documenting Change: Damocles & ArcticROOS

http://www.damocles-eu.org/

http://arctic-roos.org/

1996

2007

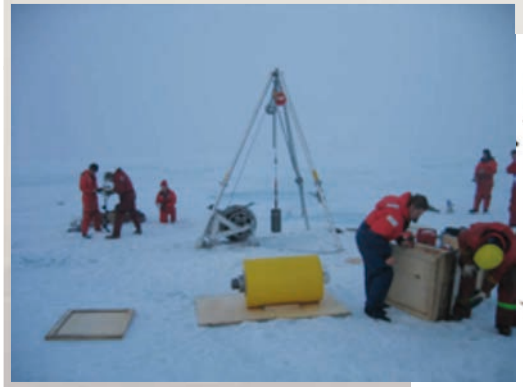


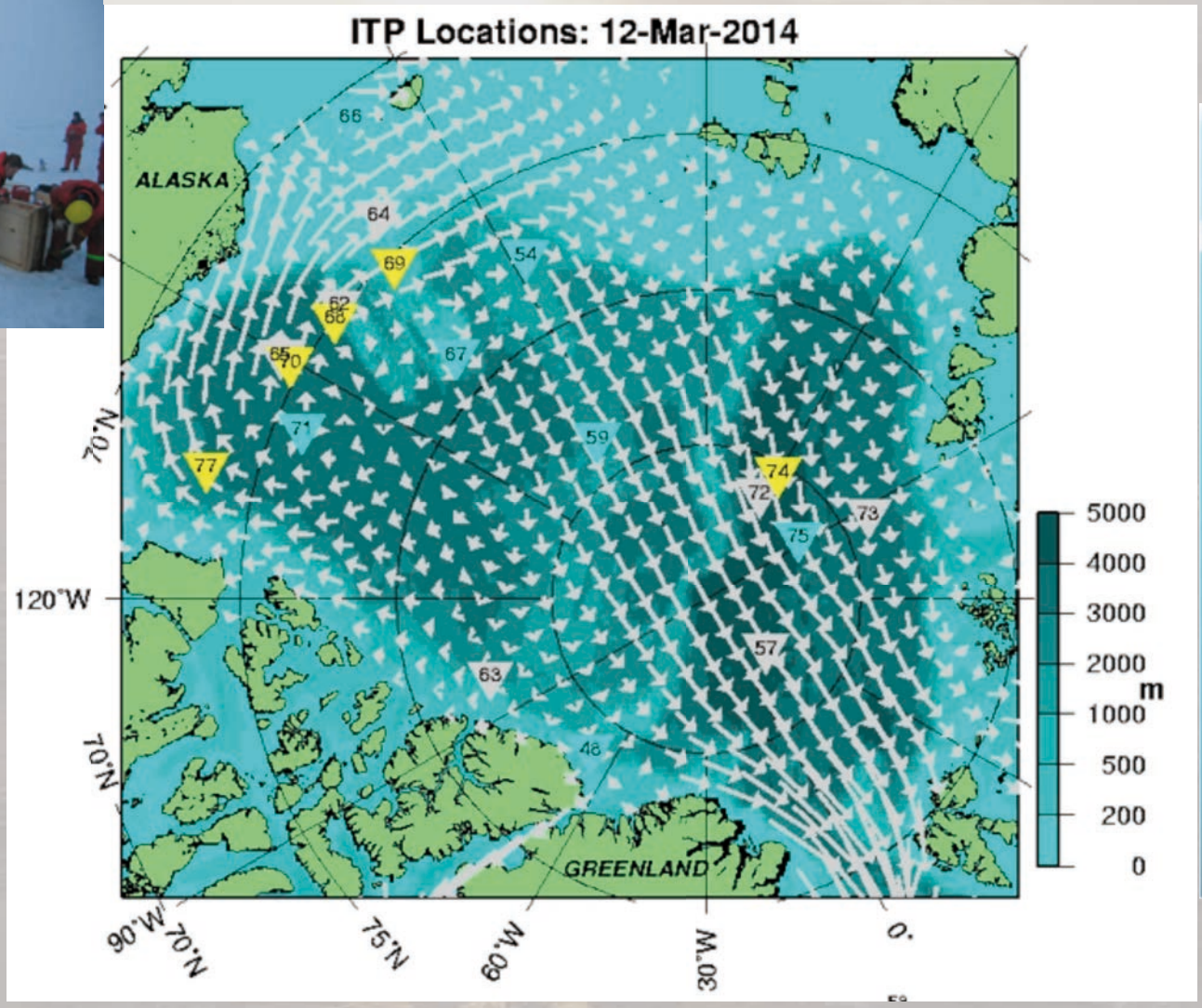
Potential temperature and salinity sections in 1996 and 2007;
the Arctic is warming and freshening

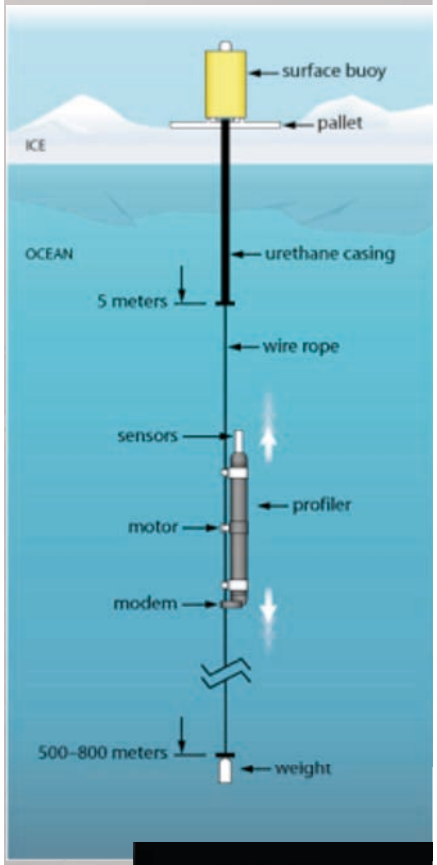
Rudels et al. 2013

Lack of infrastructure – lack of observation

Global array of temperature/salinity ice-tethered profilers (ITPs)



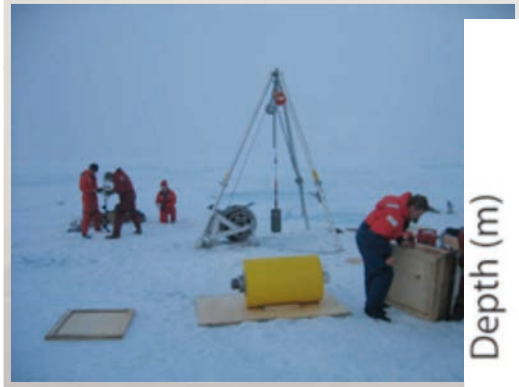


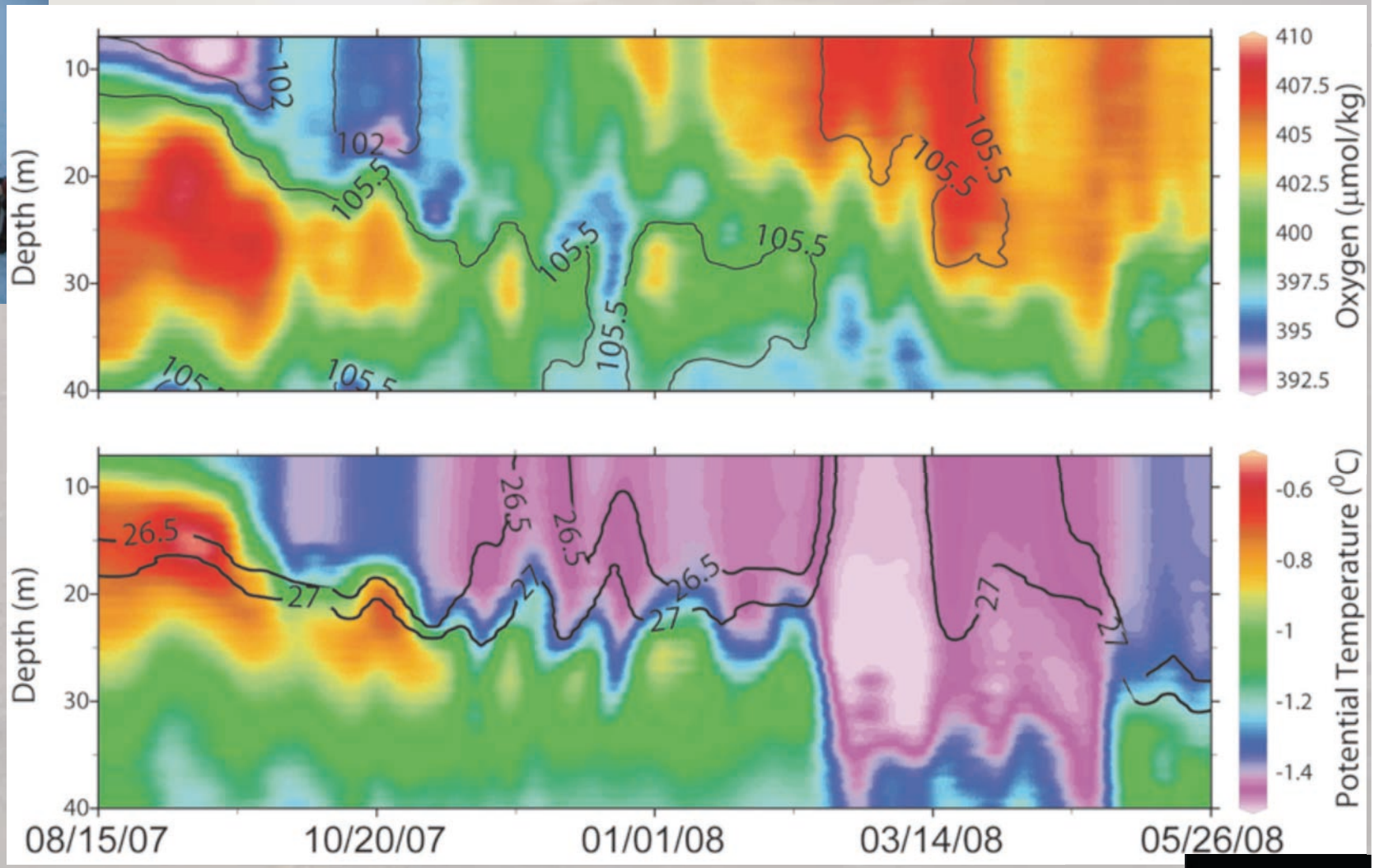


http://www.whoi.edu/website/itp/overview

Lack of infrastructure – lack of observation

Addition of biogeochemical sensors on ice-tethered profilers (ITPs): oxygen





http://www.whoi.edu/website/itp/overview

Essential ocean variables for biogeochemistry

✔ = autonomous

Oxygen	✔	
Nutrients	-	(maybe nitrate)
Carbonate System	-	(pCO2, maybe pH)
Transient Tracers	-	
Suspended Particulates	-	
Particulate Matter Export	✔	
Nitrous Oxide	-	
Carbon Isotope, 13C	-	
Dissolved Organic Matter	-	(fluorescence)

The Global Ocean Observing System

GOOS

International Ocean Carbon Coordination Project

Towards a sustained global observation network for marine biogeochemistry

IOCCP

UNESCO

SCOR

HELMHOLTZ GEMEINSCHAFT

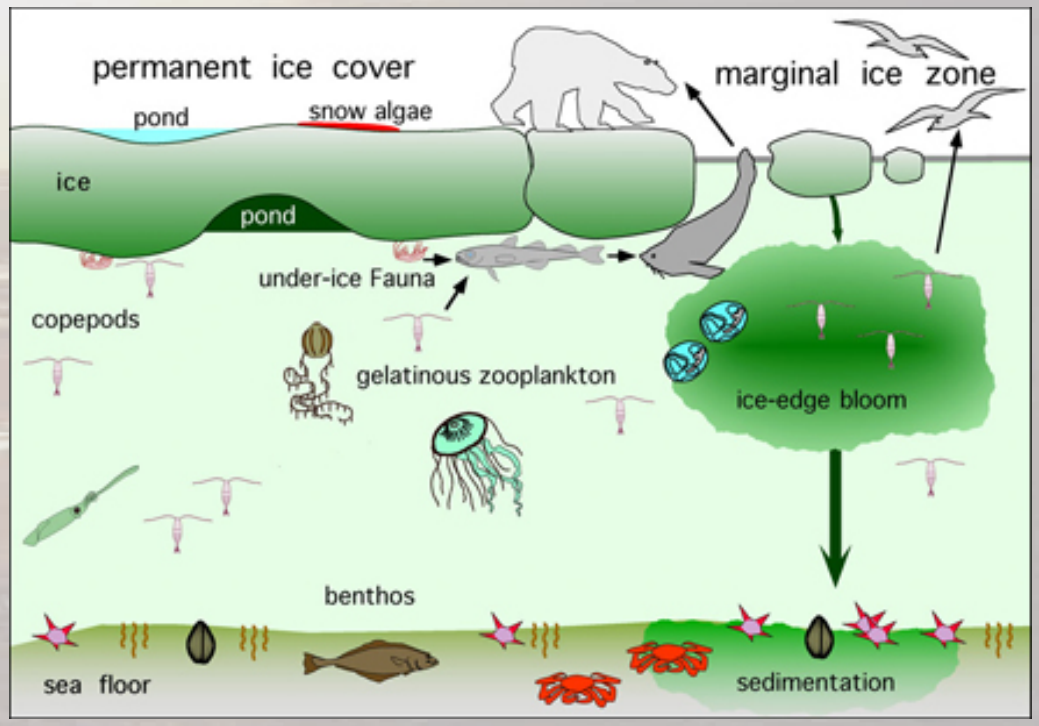
Essential ocean variables for biology

Fluorescence (chlorophyll) ✔

Zooplankton - (remnants from traps)

? ?n

? ? ? ? ? ? ? .....?n



The Global Ocean Observing System

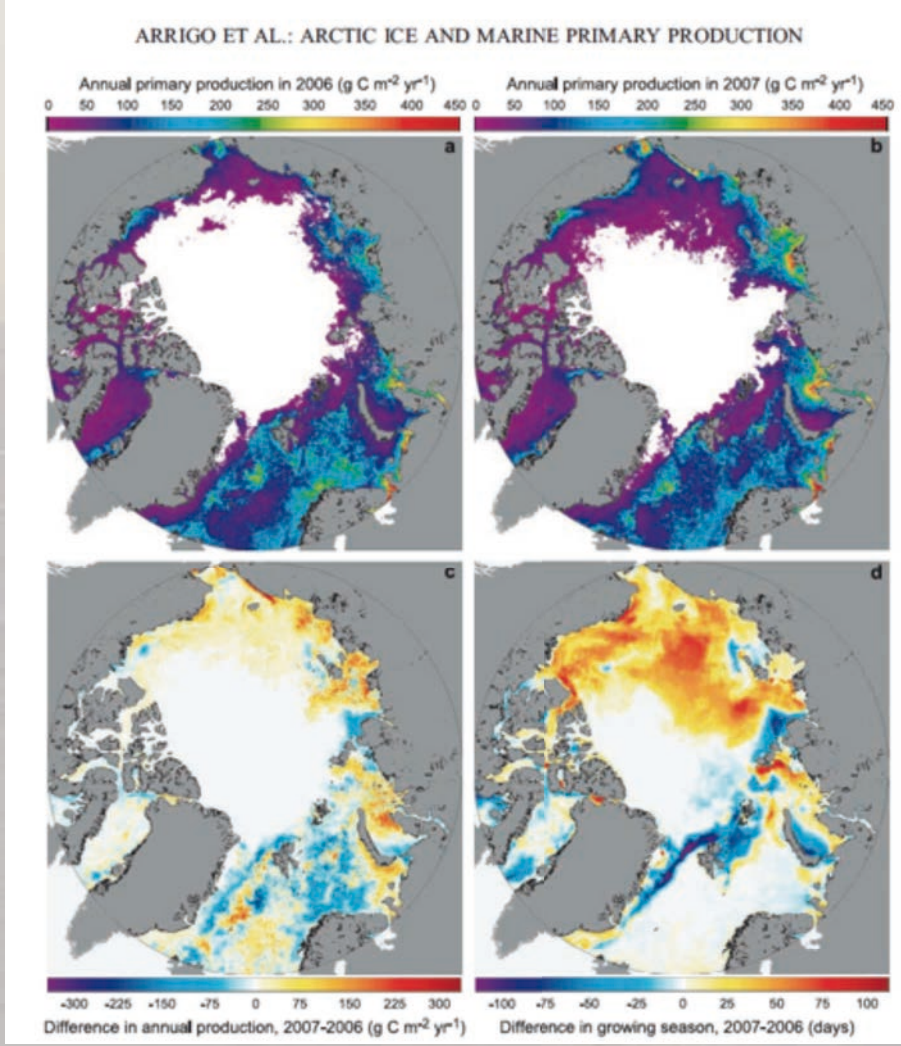
GOOS

UNESCO

SCOR

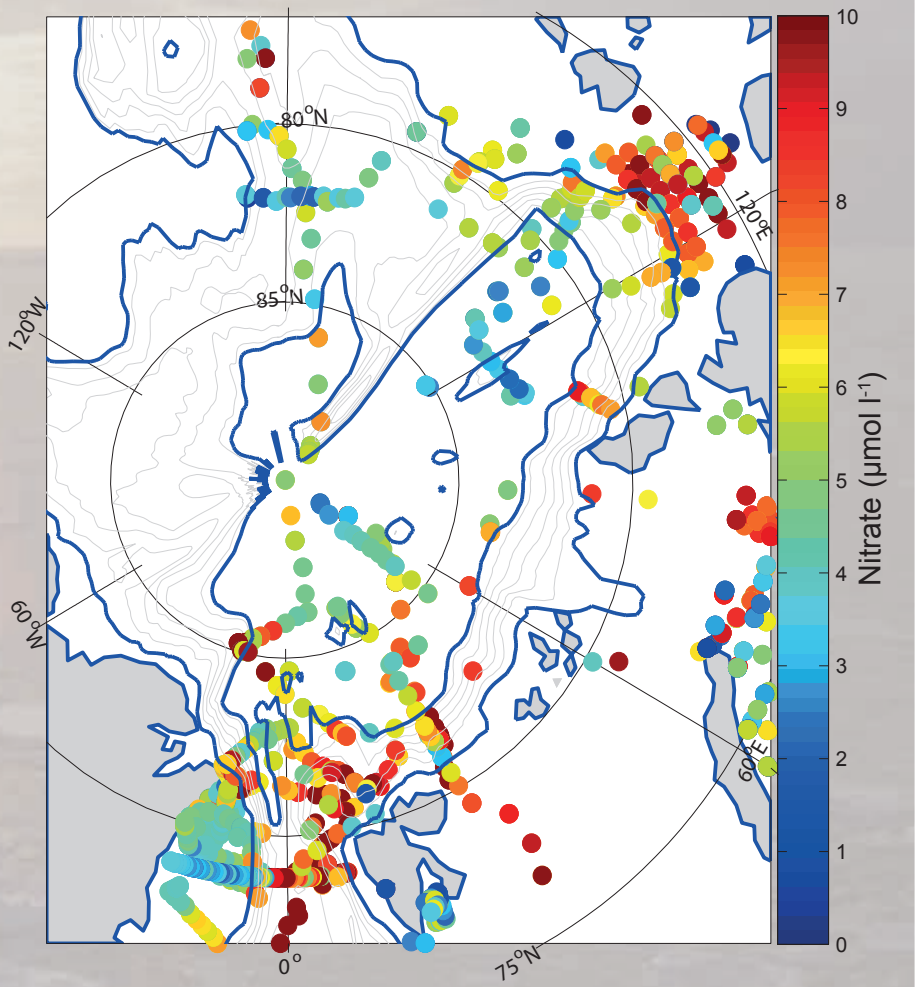
HELMHOLTZ GEMEINSCHAFT

Arctic productivity - and its past, present and future?



More light, more algae ?
-but satellites cannot sea through ice

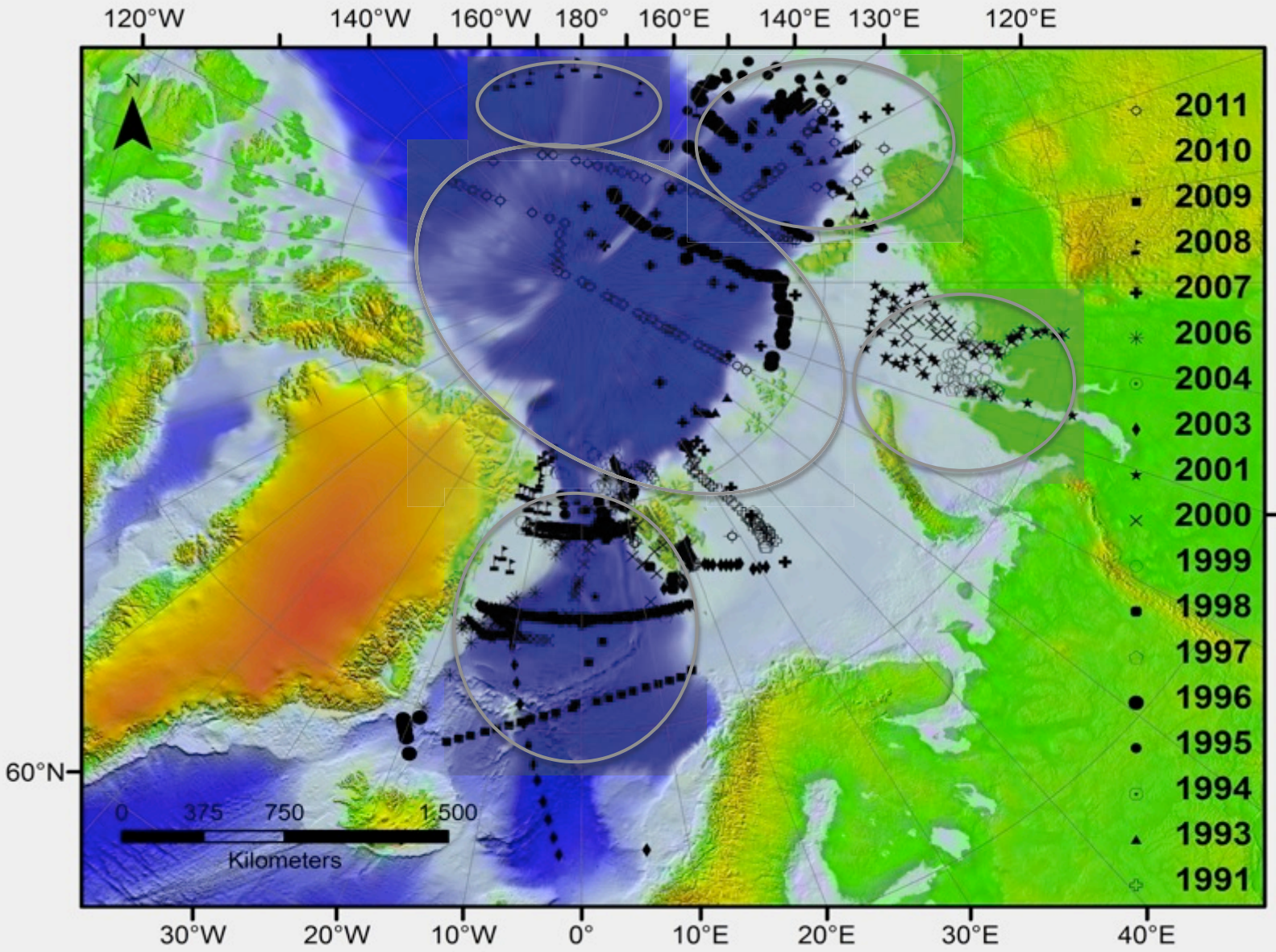
Arrigo et al. 2008, 2012



Change in nitrate concentration ?
Distributed data from the wrong season

Lalande et al., in review

Assessing the variability of chlorophyll *a* distribution: the need for coordinated ship surveys



1 Fram Strait/ Greenland Sea

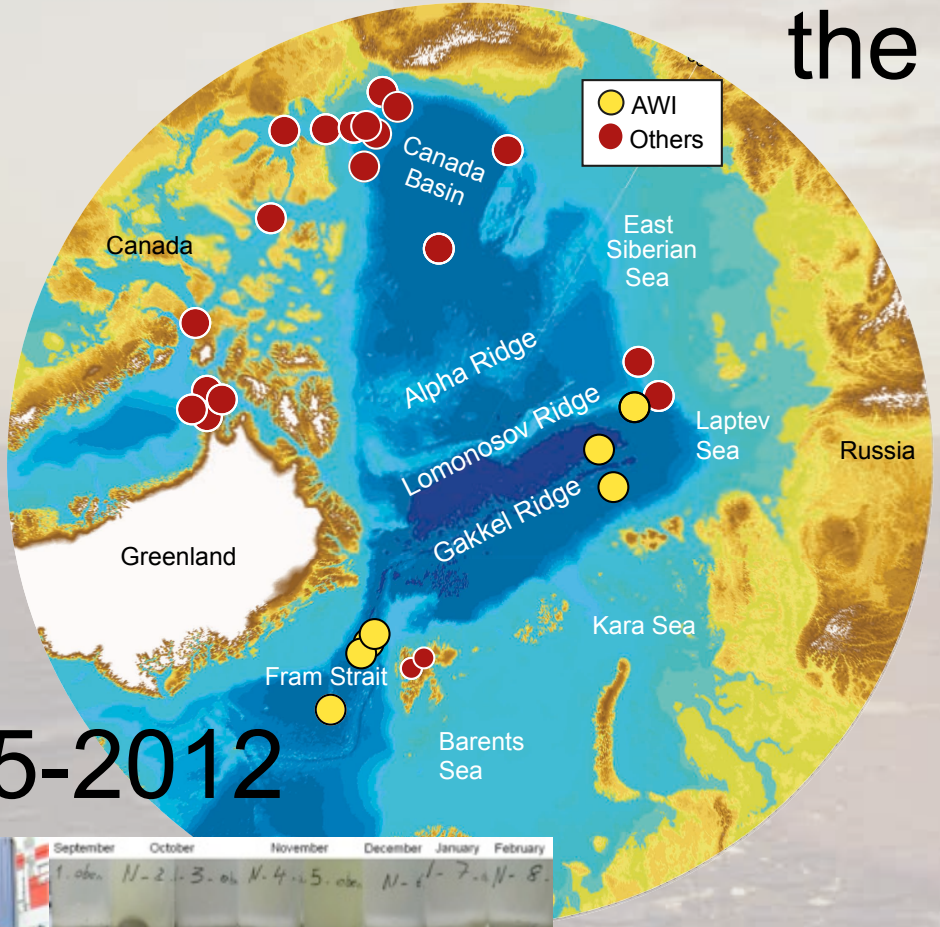
2 Central Arctic Ocean (AO)

3 Laptev Sea

4 Kara Sea

Nöthig, Haas, et al, in progress

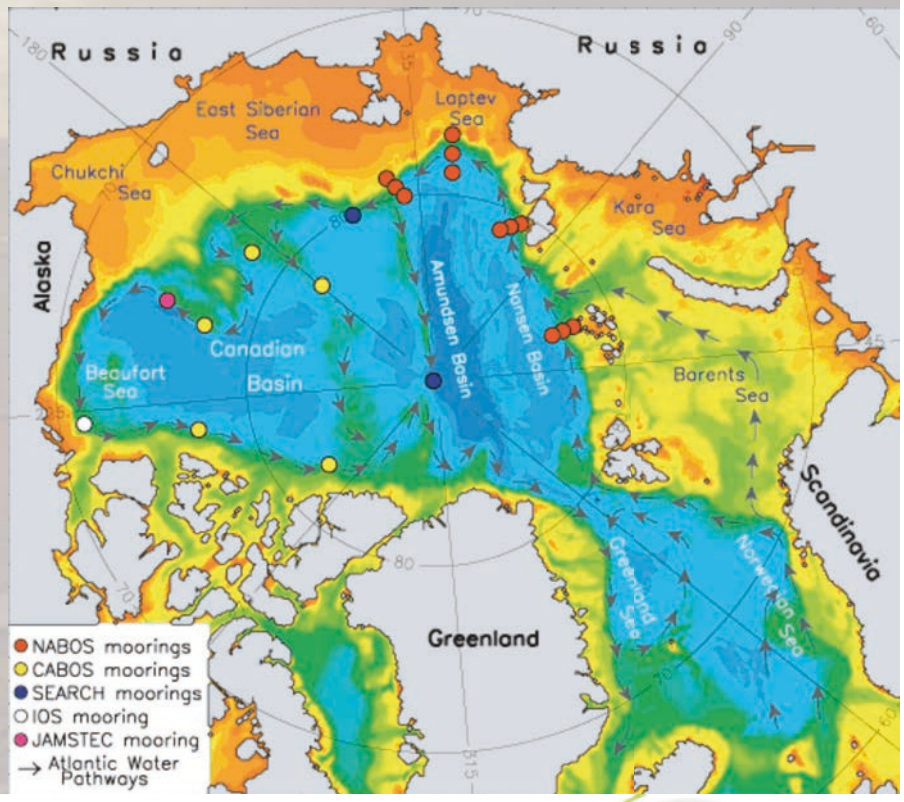
Moorings in the Arctic: carbon export and the role of sea ice life



1995-2012

Moorings with sediment traps

Proposed new programs with oceanography moorings



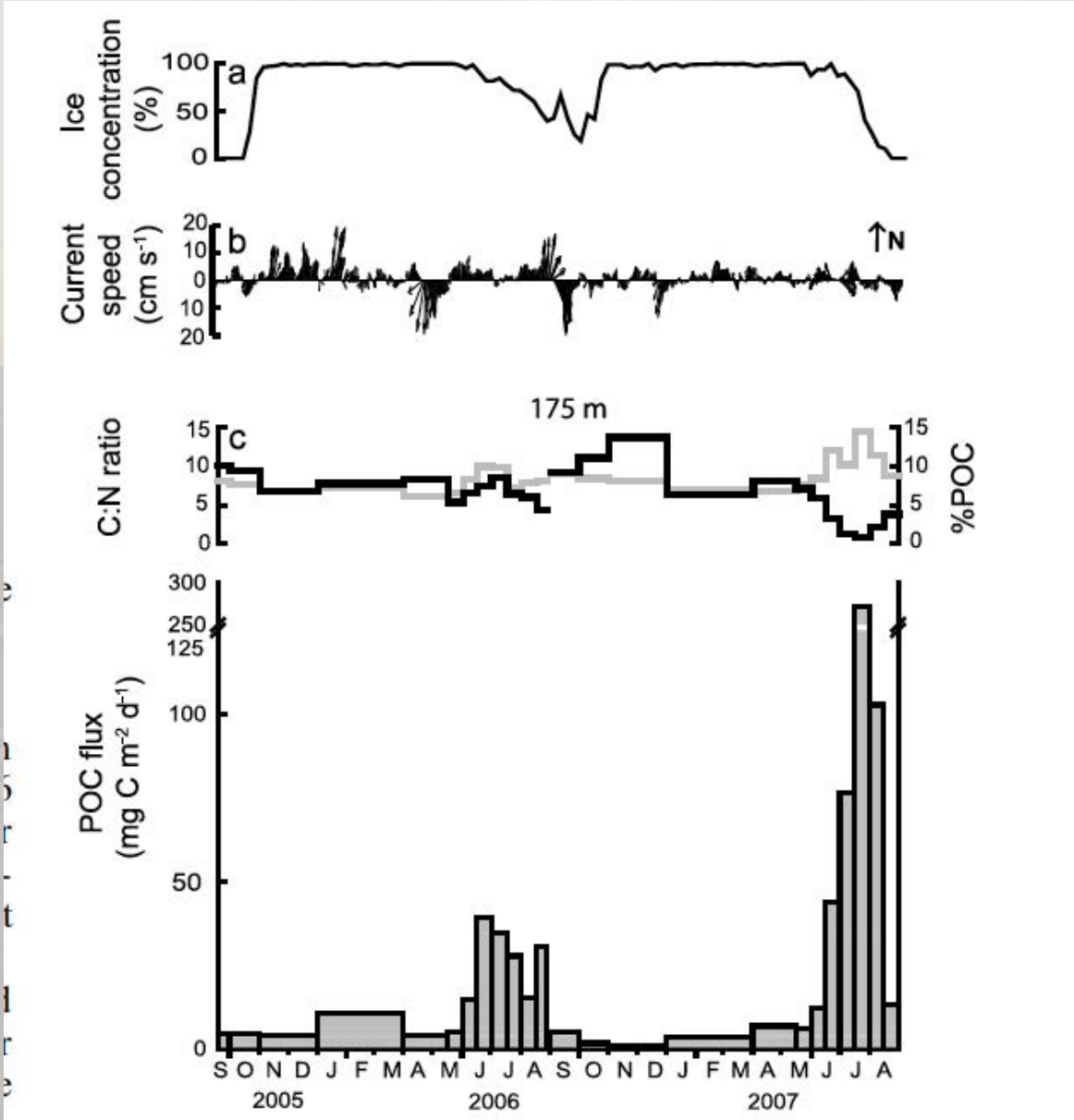
NANSEN AND AMUNDSEN BASINS OBSERVATIONAL SYSTEM

CANADIAN BASIN OBSERVATIONAL SYSTEM

http://nabos.iarc.uaf.edu/

Lalande et al. 2009; in review

Change in export flux to the seafloor?

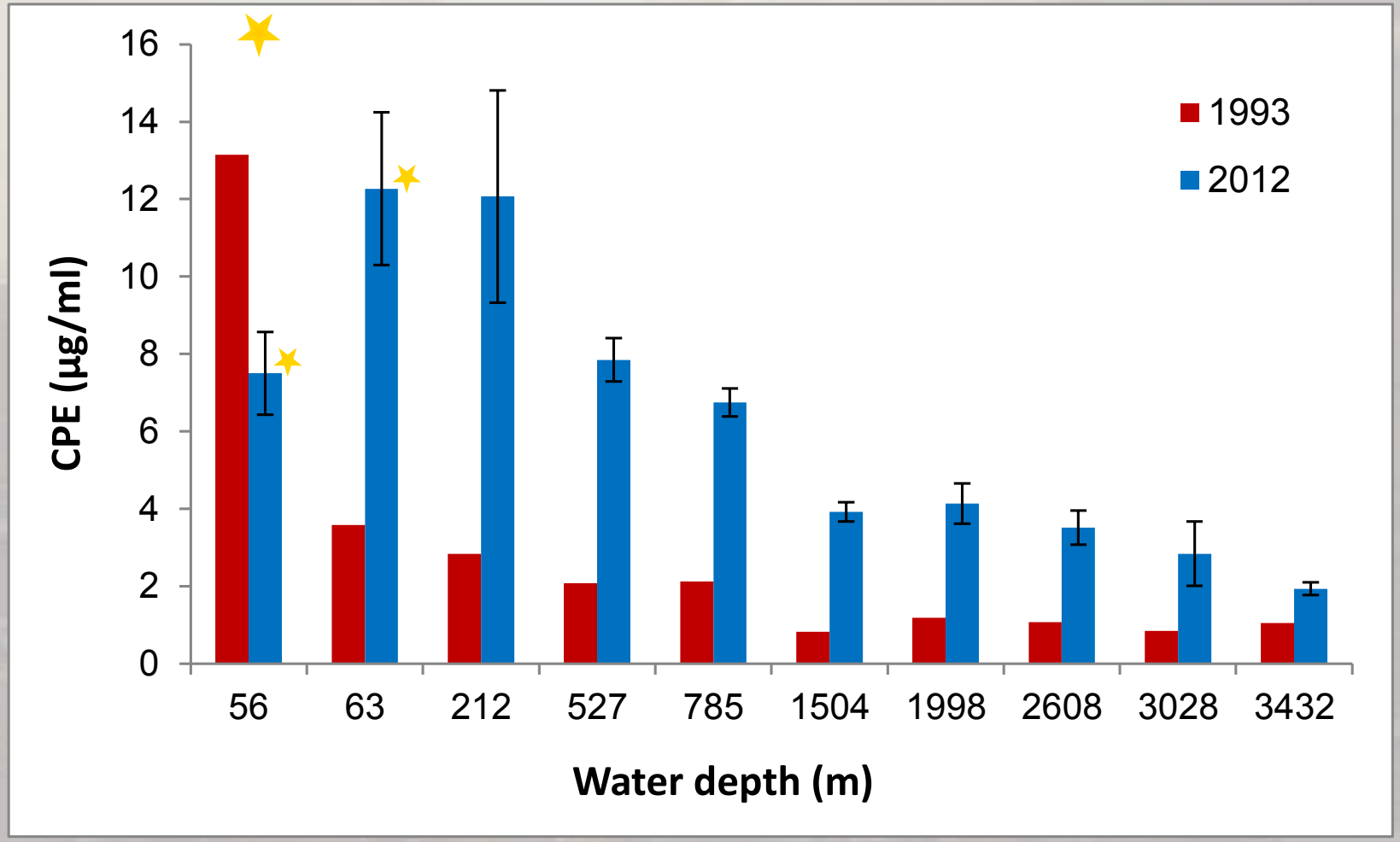


2007 and 2012 should peak export fluxes of 9 g C m-2 yr-1, related to ice melt

(Boetius et al. 2013)

Peak fluxes July-August; large proportion of sea-ice algae; Lalande et al. 2009

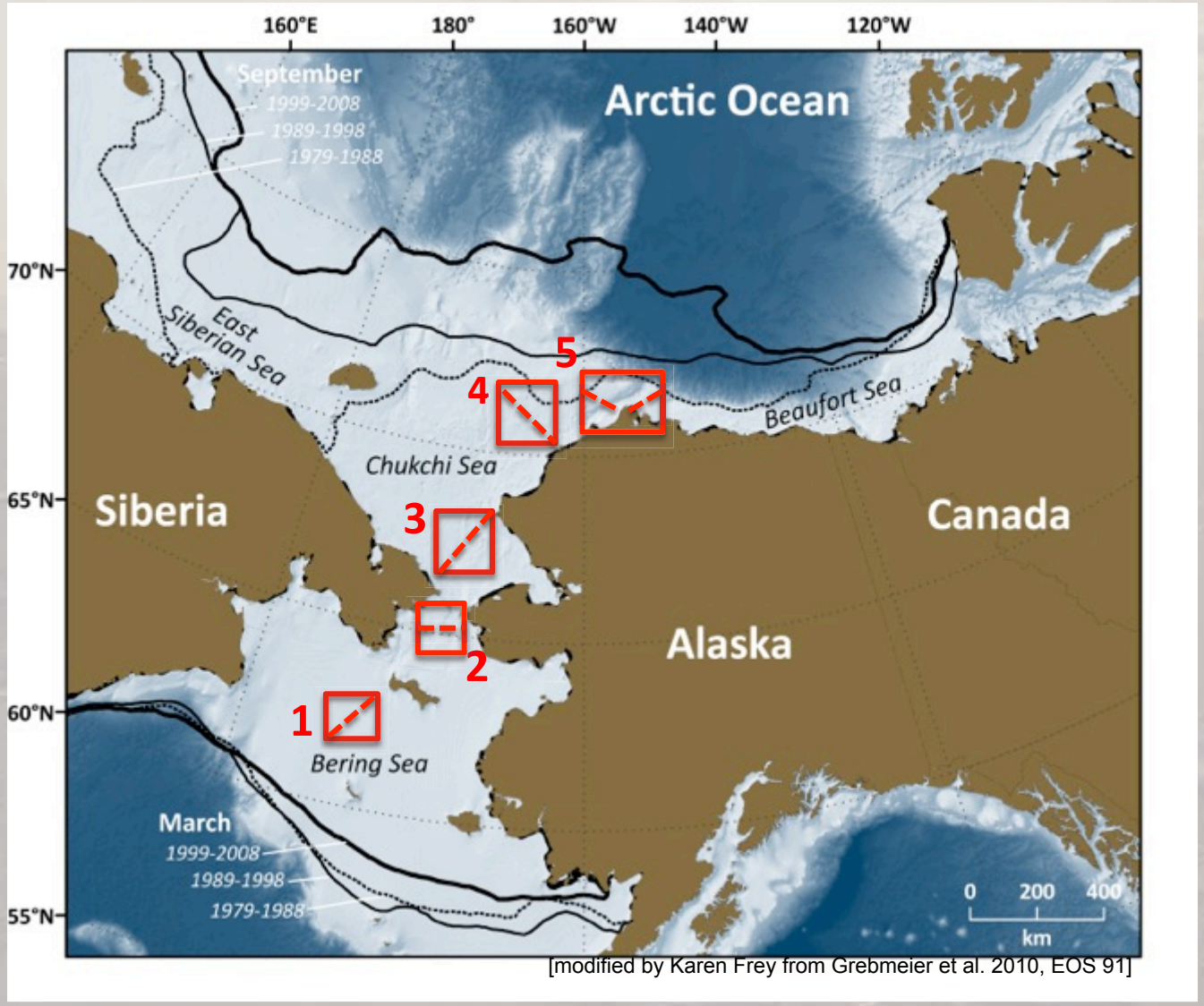
Seafloor as ultimate sediment trap



Chlorophyll pigment concentrations in surface sediments have increased in comparison to 1993 by a factor of at least 2

C Bienhold, A Boetius; in prep.; Boetius et al. 2013

Progress with Arctic seafloor observatories: US



[modified by Karen Frey from Grebmeier et al. 2010, EOS 91]

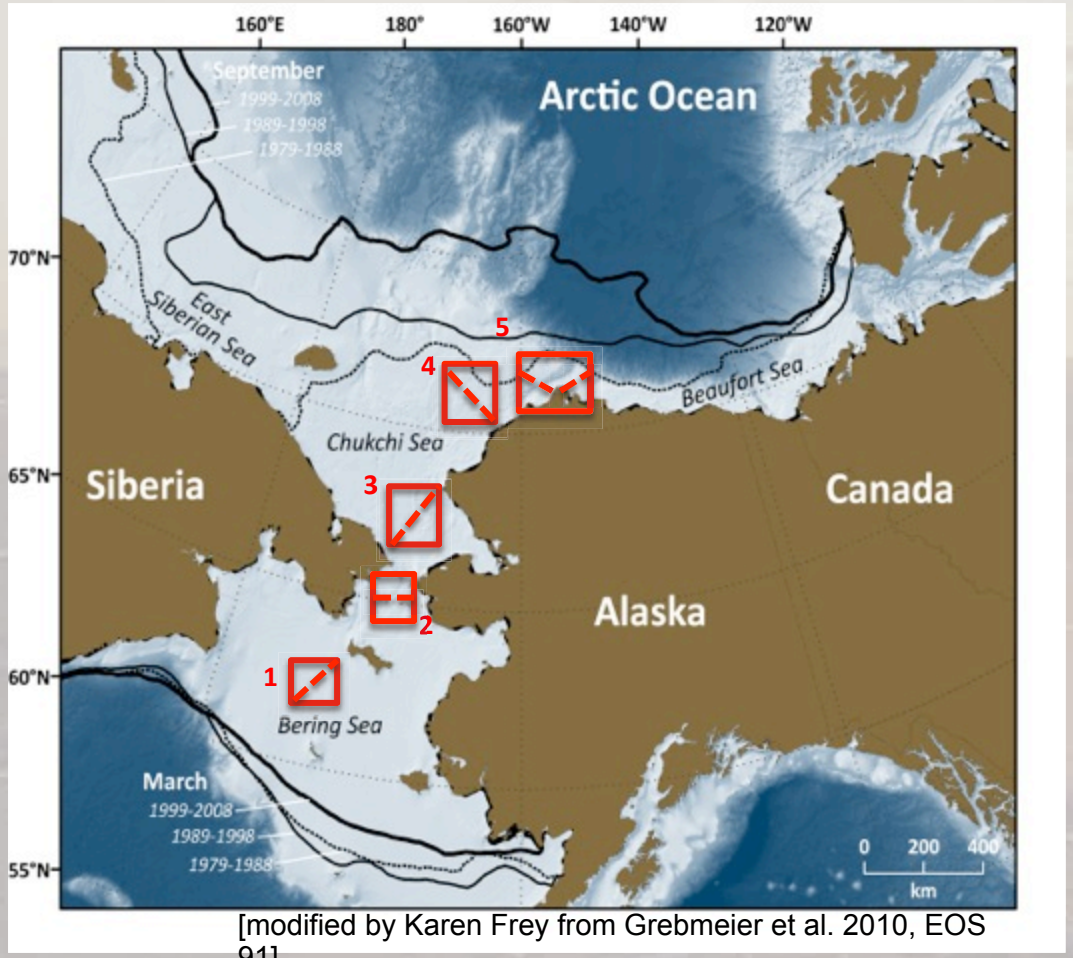
Linking Physics to Biology: the Distributed Biological Observatory (DBO)

DBO sites (red boxes) serve as a change detection array for the identification and consistent monitoring of biophysical responses

-migration
-benthic biomass change
-mammals and birds

http://www.arctic.noaa.gov/dbo/; Grebmeier et al. 2006

Progress with Arctic seafloor observatories: US



[modified by Karen Frey from Grebmeier et al. 2010, EOS 91]

Core standardized ship-based sampling:

- CTD
- Chlorophyll
- Nutrients
- Ice algae/Phytoplankton (size, biomass and composition)
- Zooplankton (size, biomass and composition)
- Benthos (size, biomass and composition)
- Seabird (standard transects, no additional shiptime)
- Marine mammal observations (no additional ship time)

http://www.arctic.noaa.gov/dbo/; Grebmeier et al. 2006

Progress with Arctic seafloor observatories: CA

First Arctic cabled observatory, cameras, acoustic sensors, CTD; ice thickness

Cambridge Bay, 6m water depth

http://www.oceannetworks.ca/

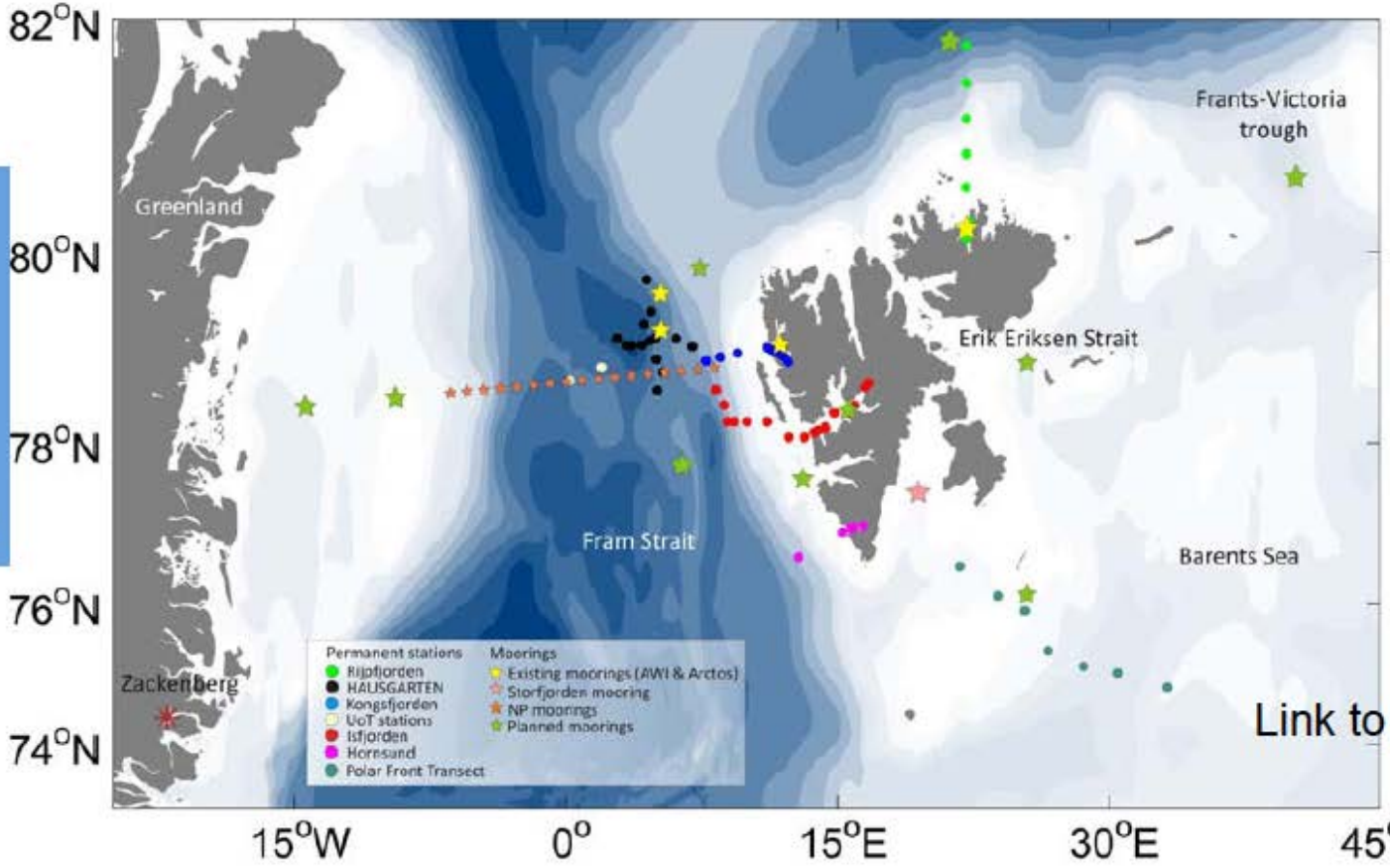
Fram strait seafloor observatories

Observation around Svalbard

- Community Time Series (Polar Front, KongHau, Rijpfjord)

CTD
PhPl
ZooPl
Nutr
Soft b.

Hard b.



Link to SIOS

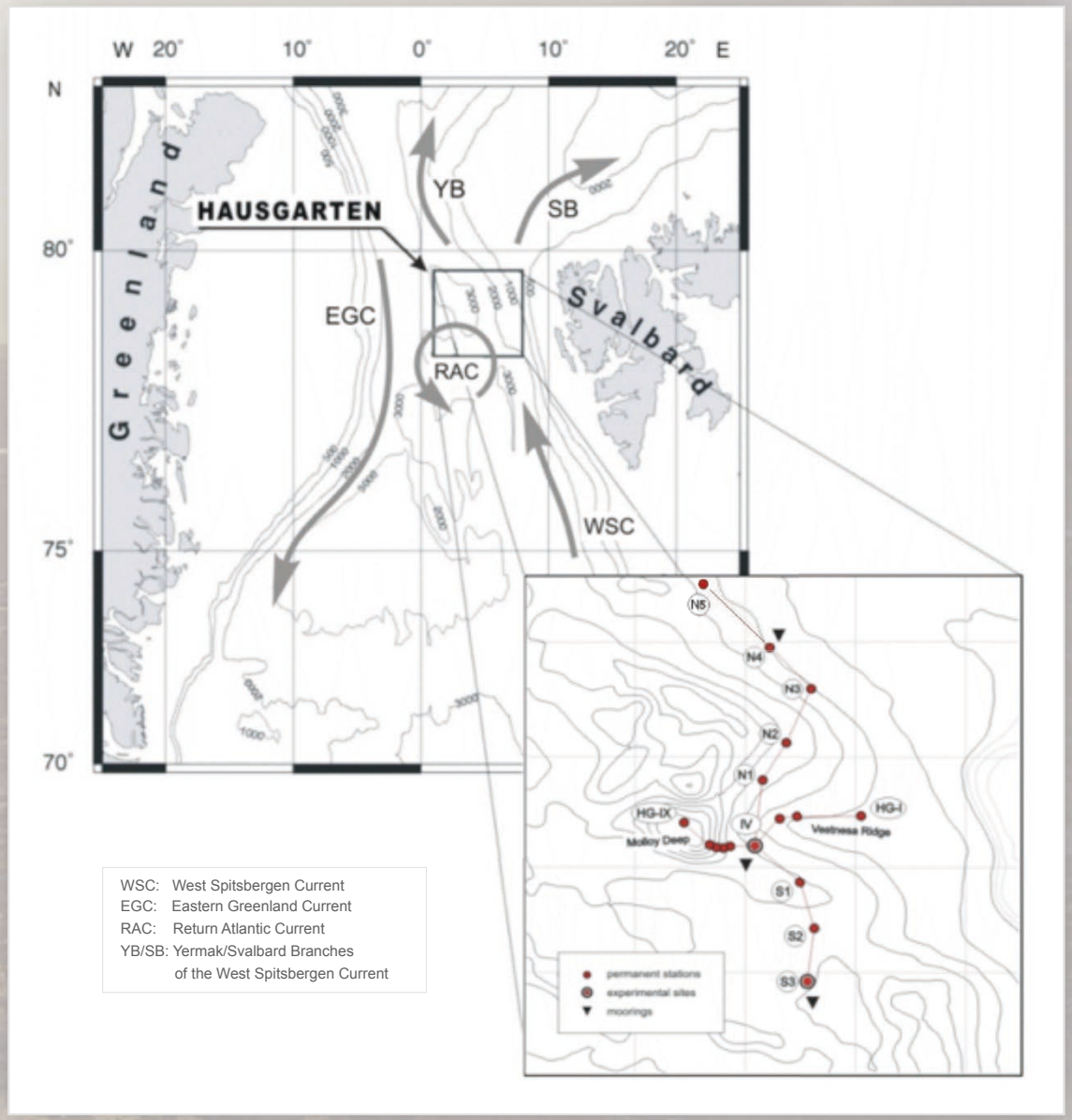
Courtesy by M Carroll

New program: CarboBridge (NO); M Reigstad et al.

FRAM strait LTER seafloor observatory

HAUSGARTEN
THE ARCTIC DEEP-SEA OBSERVATORY

- since 1999
- 17 stations
- 1000 - 5500 m
- bathymetric and latitudinal transect
- repeated sampling
- continuous sampling and measurements
- visual observations
- experimental work



Soltwedel et al. 2009

Core biological measurements at HAUSGARTEN

- **Pelagic Zone**

  temperature, currents [1](speed, direction), oxygen conce
  phyto-/zooplankton [2], particle flux rates (sediment tra

- **Sediment-Water-Interface**

  currents and oxygen concentrations, carb
  (oxygen microelectrodes, sediment co *nsumption)*

- **Sediments**

  granulometry, porosity, orga
  organic matter input (pig *ytodetrital matter),*
  biomarker [3](marine, t *s parameter (proteins, lipids)*

- **Benthos**

  bacteria *brauna [5], mega/epifauna, demersal fish*
  (micr *es, biomass, dispersion, biodiversity)*

Increase of litter at the Arctic deep-sea observatory HAUSGARTEN

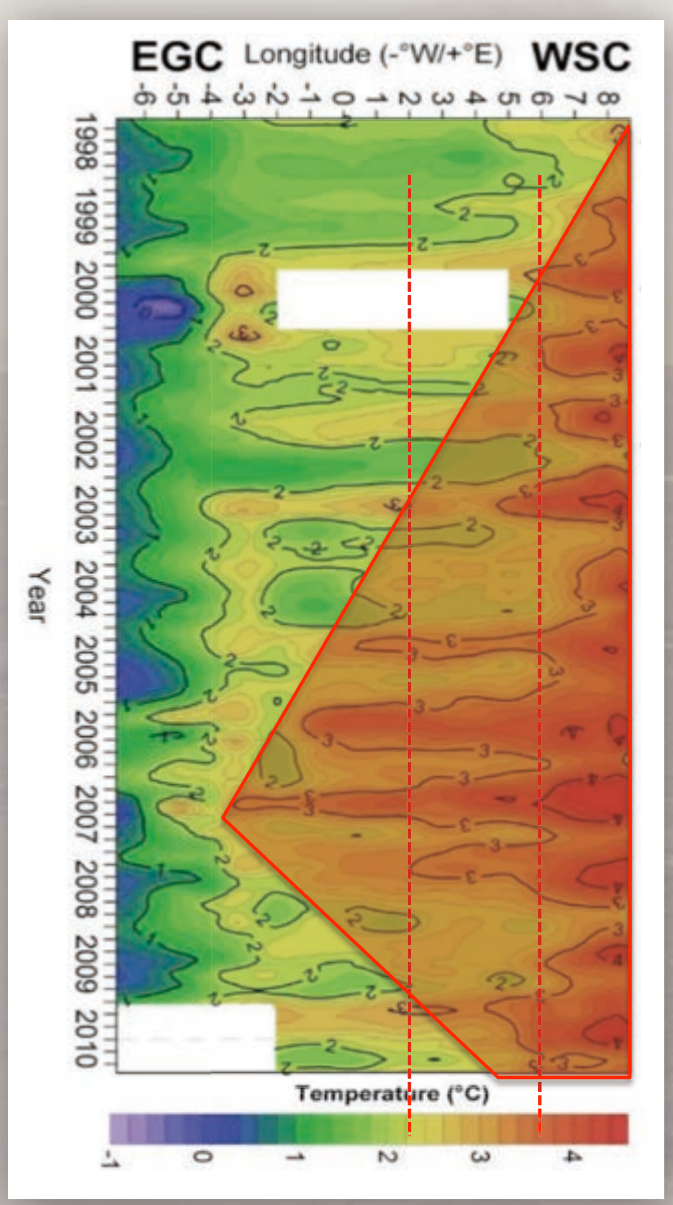
Melanie Bergmann *, Michael Klages

Marine Pollution Bulletin 64 (2012) 2734–2741

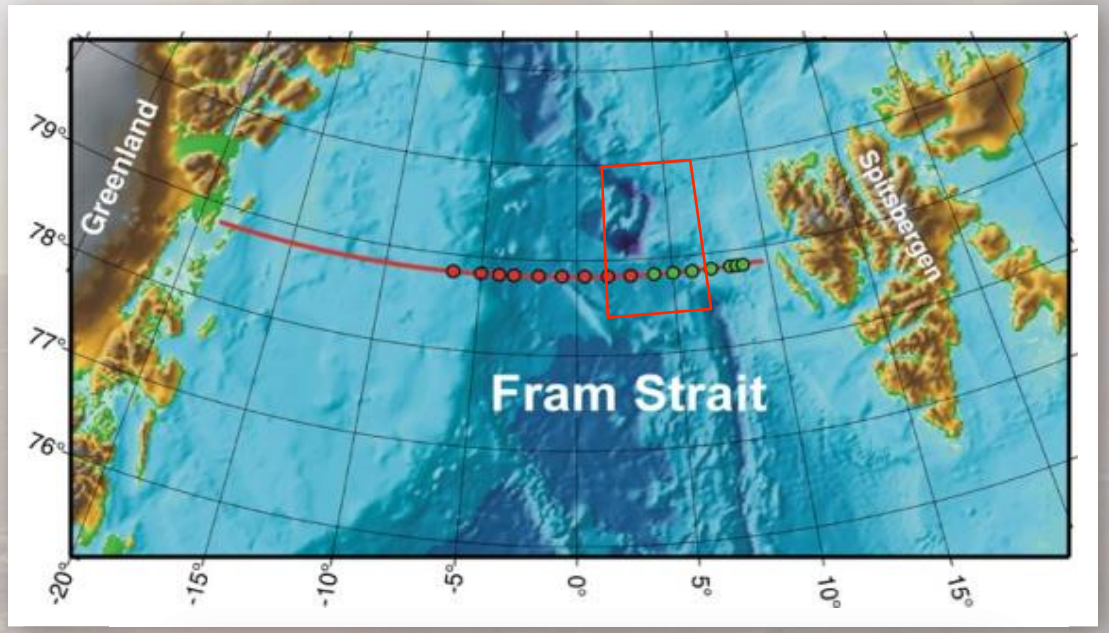
[1] AW *bservational Oceanography*
[2] *ar Biological Oceanography (PEBCAO)*
Marine Geology and Paleontology
nstitute for Oceanology / Polish Academy of Sciences
eanology / Polish Academy of Sciences, Shirshov Institute, Russian Academy of Sciences

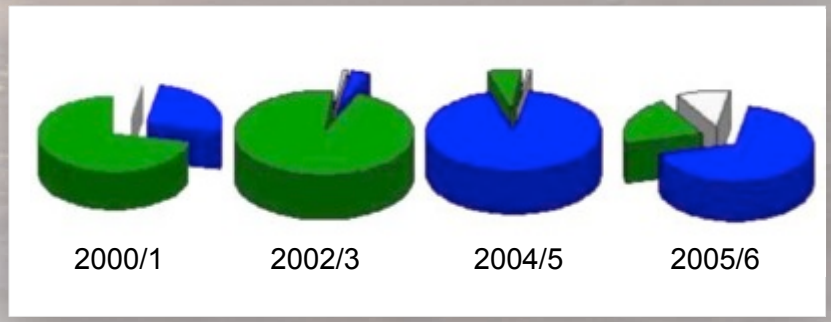
Soltwedel et al. 2005

Warming at HAUSGARTEN



Monthly means of temperature at 250 m
(Beszczynska-Möller et al., 2012)





Coccolithophorids Diatoms Tintinnids

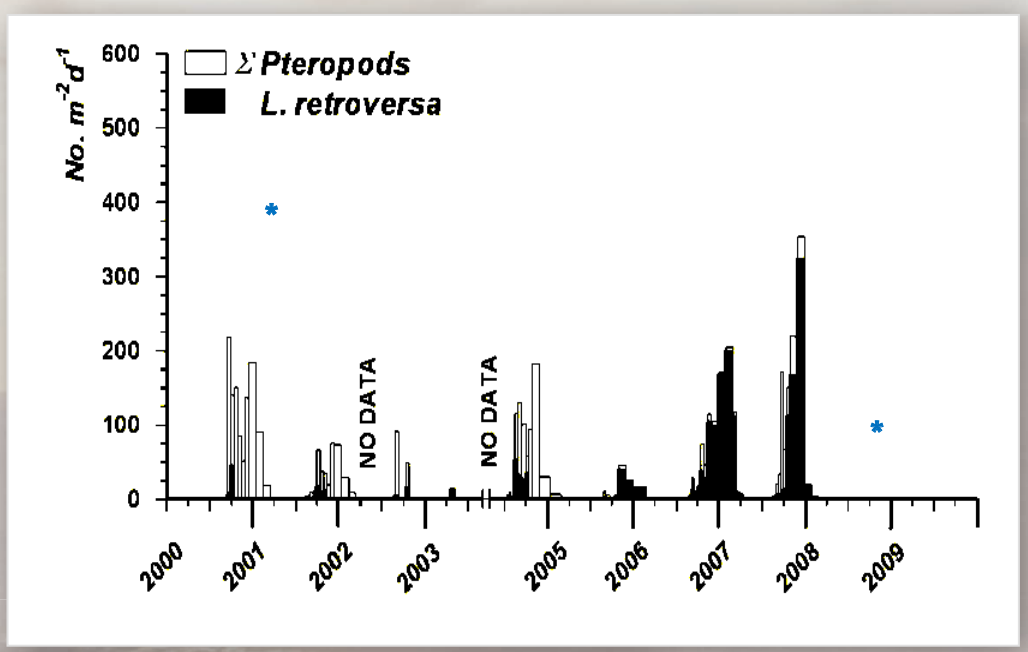
Temporal variability of plankton species
in sediment traps between 2000 and 2009

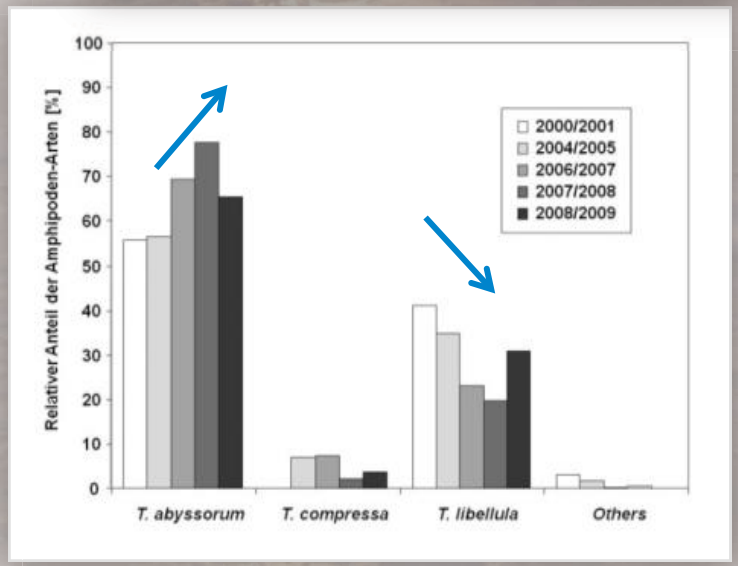
(Bauerfeind et al., 2009)

Shift of zooplankton at HAUSGARTEN

Strong increase of *Limacina retroversa* shells in sediment traps between 2006 and 2008.

(Bauerfeind et al., 2014)



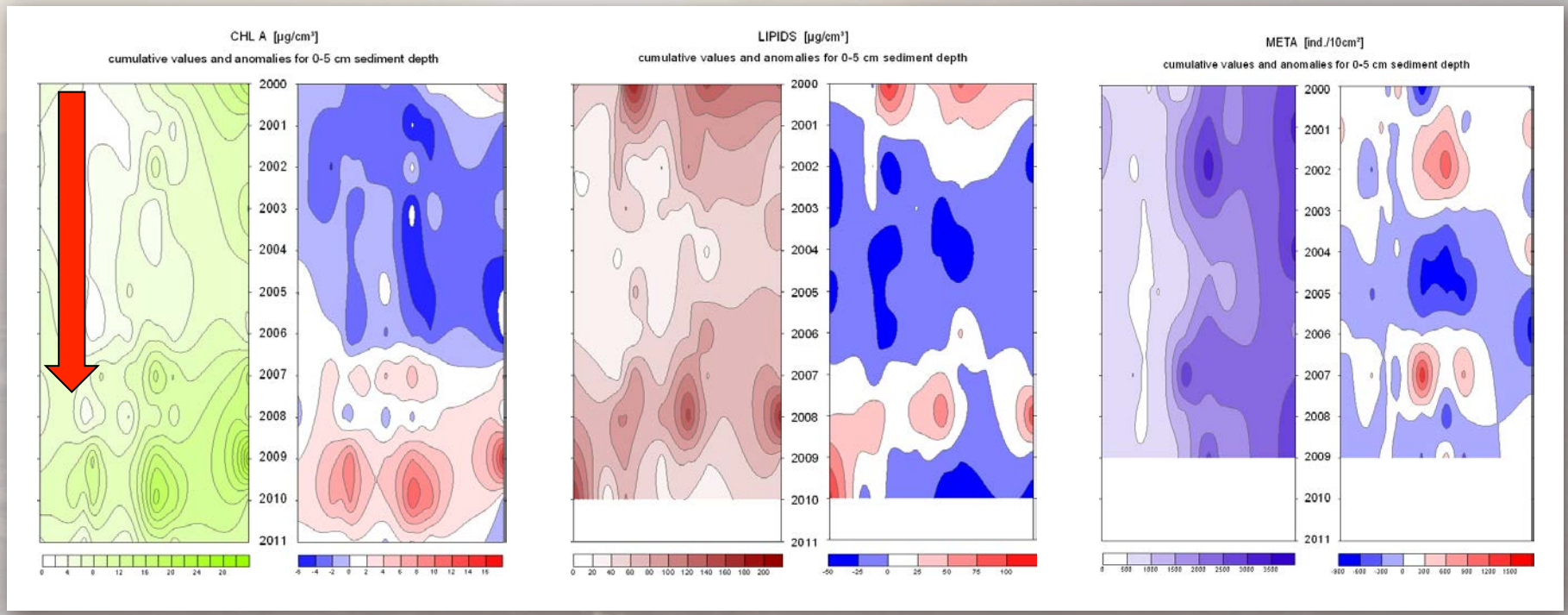


Relative proportions of *Themisto libellula* * (polar) and *Themisto abyssorum* (boreal-subpolar) in sediment traps between 2000 and 2009

(Kraft et al., 2010)

Temporal variations in biogenic compounds along the bathymetric transect

Starvation phase 2000-2008



Sediment-bound chlorophyll *a* indicating food availability between 2000 and 2011

(Schewe, unpubl. data)

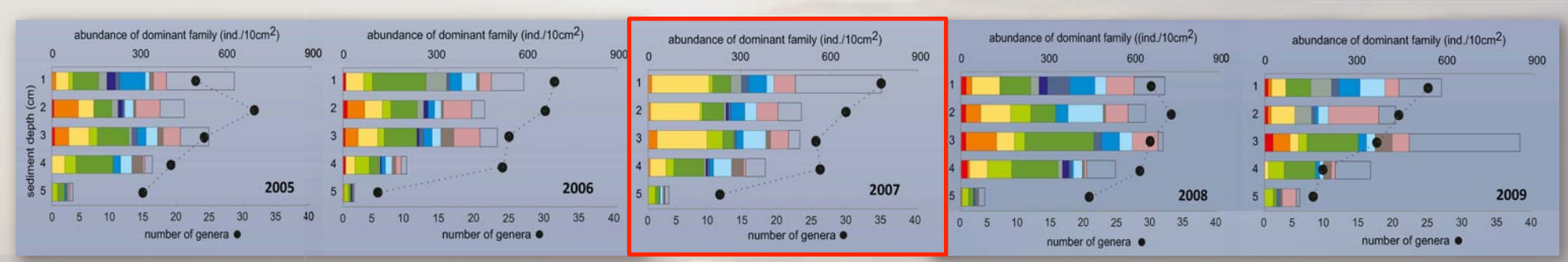
Phospholipid concentrations indicating total microbial biomass between 2000 and 2010

(Soltwedel, unpubl. data)

Metazoan meiofauna densities along the bathymetric transect between 2000 and 2009

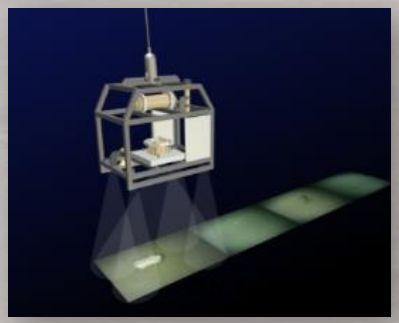
(2000-2004: Hoste et al., 2007; 2005-2009: Grzelak, unpubl. data)

Response of all benthic size classes



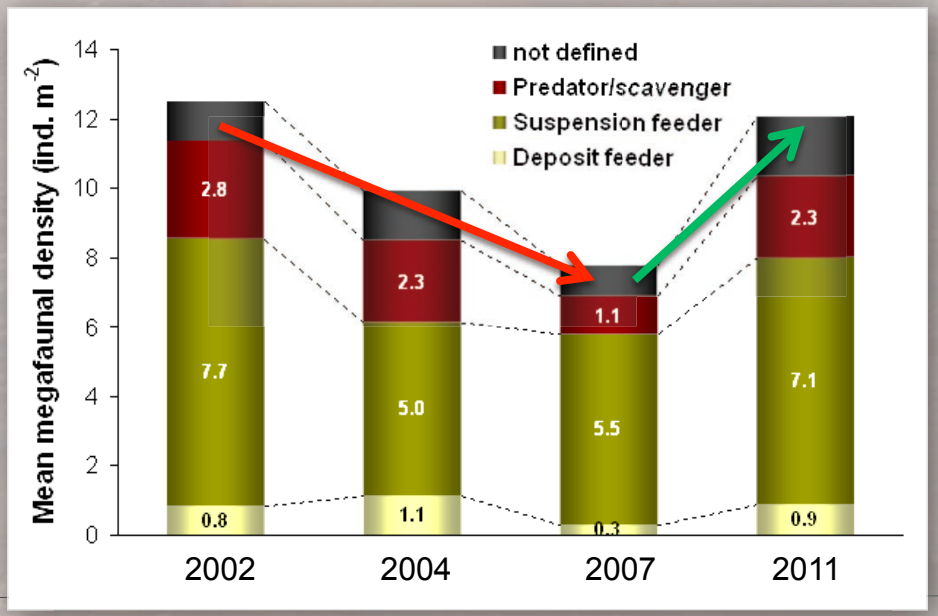
Nematode composition at the shallowest HAUSGARTEN site (1280 m) between 2005 and 2009

(Grzelak, PhD Thesis; Arctic Science Summit Week 2013)

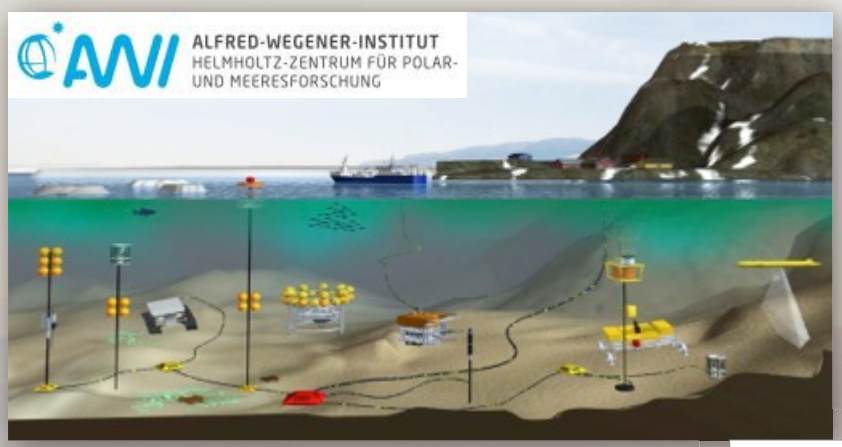


Variability in the mega/epibenthos at the central HAUSGARTEN site between 2002 and 2011

(Bergmann et al., 2011 and unpubl. data)



HAUSGARTEN & oceanography array convert to FRAM (June 2014)



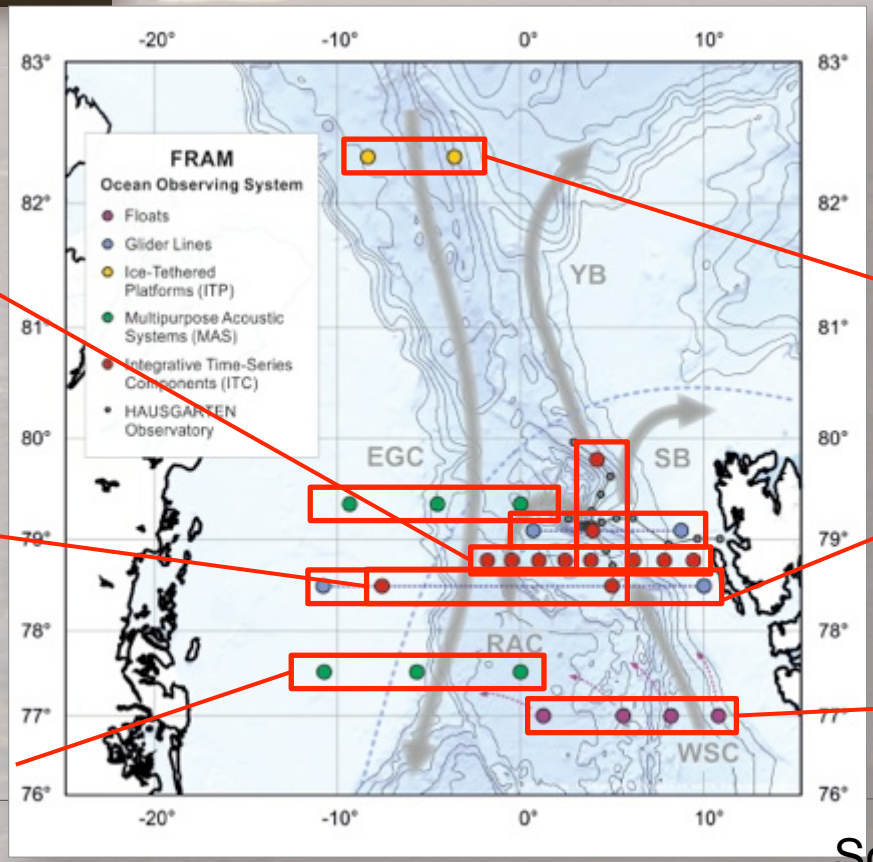
FRAM : Frontiers in Arctic Marine Monitoring; sustained time series for 20 yrs as Helmholtz (HGF) infrastructure

Fixed Units:

8+ ITC: Oceanographical and acoustical moorings with currentmeters, physical, bio-geochemical and biooptical sensor packages, and profiling systems on winches

4+ ITC: Moorings with visual and acoustic units and event recording/sampling capacities for plankton and benthos

Multipurpose Acoustic Systems for navigation, sound recording etc.



Mobile Units:

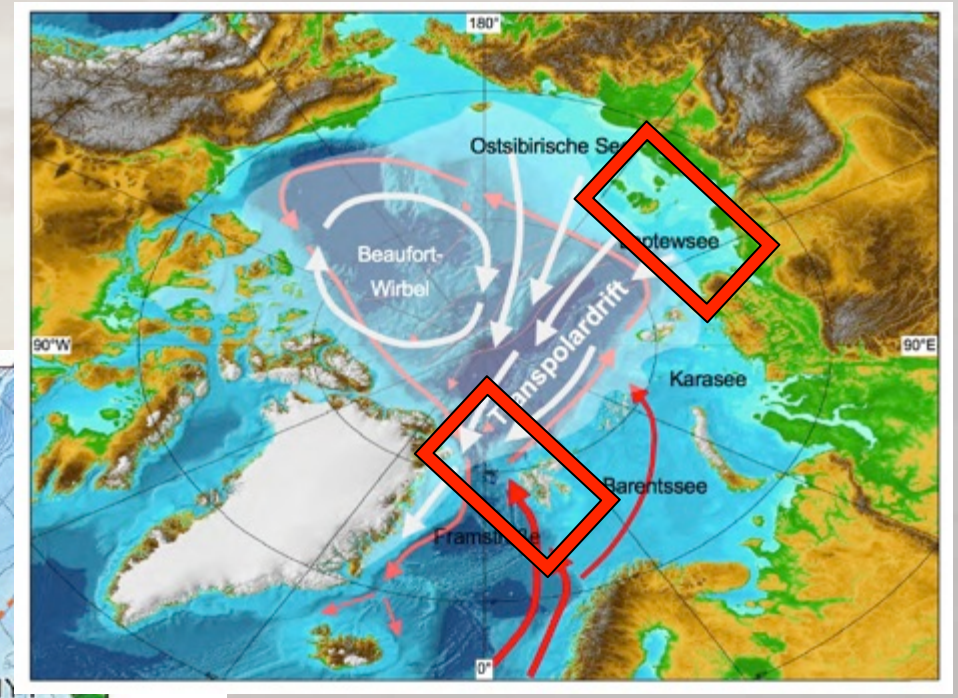
Ice-tethered platforms

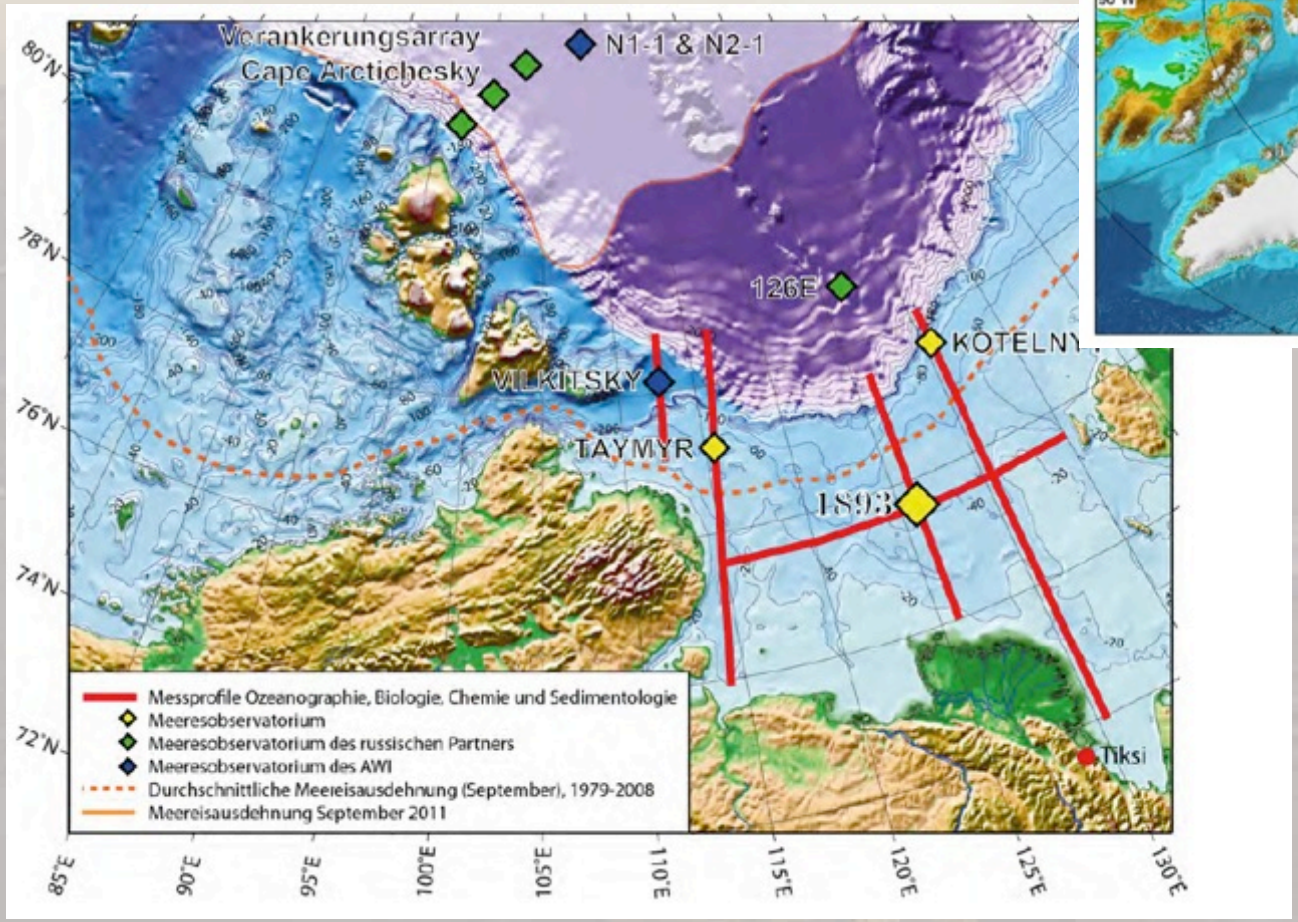
Sea gliders

Drifting floats

Soltwedel et al. 2013

Laptev Sea system and Transpolar Drift





Kassens et al. GEOMAR, AWI, AARI and partners

Svalbard Integrated Earth Observing System

The central node in the global monitoring of the High Arctic

SIOS Vision: Establish a cooperating and transparent research infrastructure which will give better estimates of the future environmental and climate changes in the Arctic.

Ny-Ålesund
- French-German Arctic Research Base (AWIPEV)
- Sverdrup Station (Norwegian Polar Institute)
- Dirigibile Italia Station (CNR)
- Zeppelin Observatory (Norway, Sweden, USA, Greece)
- Harland House, UK
- Kings Bay Marine Laboratory
- Japanese Station Ny-Ålesund
- Arctic Dasan Station, S-Korea
- Arctic Yellow River Station, PR China

Longyearbyen
- University Centre in Svalbard
- EISCAT Svalbard Radar
- Kjell-Henriksen Observatory

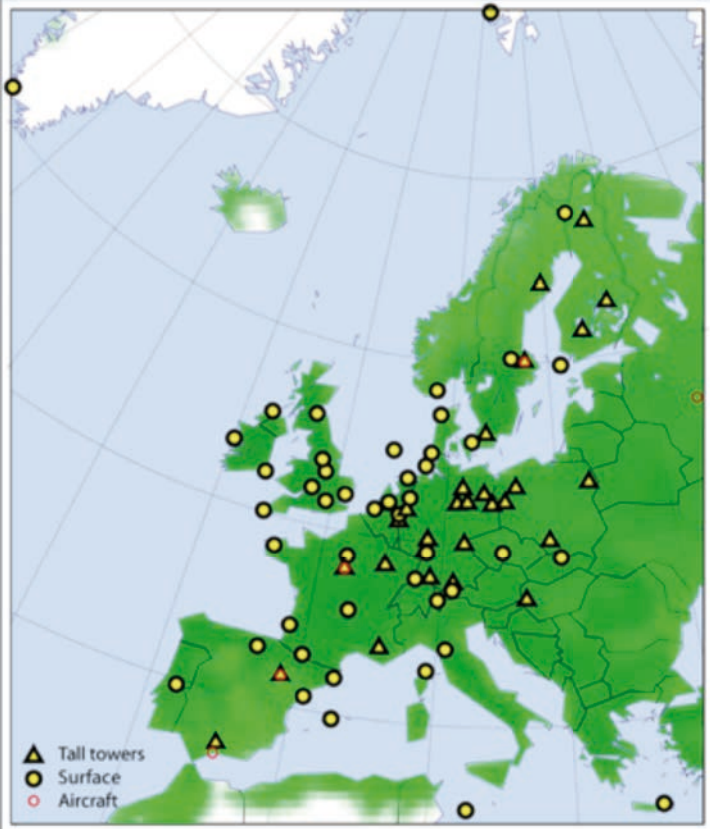
Hornsund
- Polish Polar Station

Barentsburg
- PGI Research Station

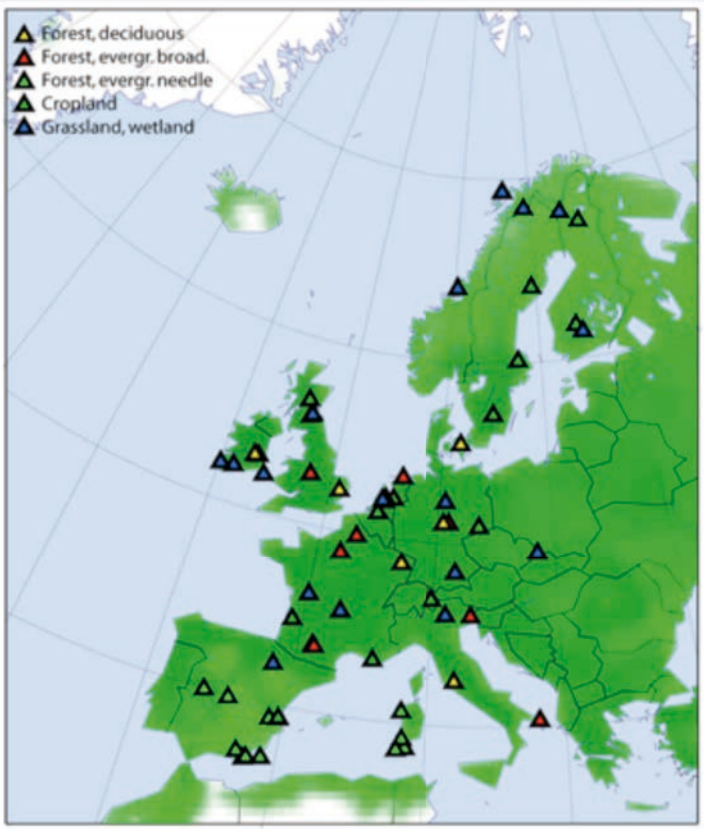
Marine observation platforms
- AOEM
- HAUSGARTEN Seafloor Observatory
- ARCOONE

www.sios-svalbard.org/

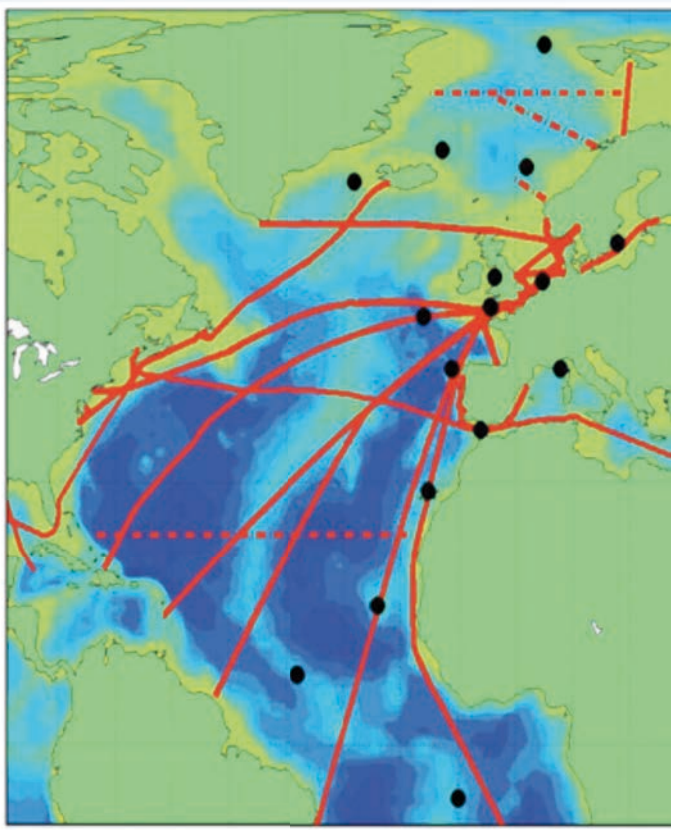
Integrated Carbon Observing System



Atmospheric network



Ecosystem network



Marine network

www.icos-infrastructure.eu/

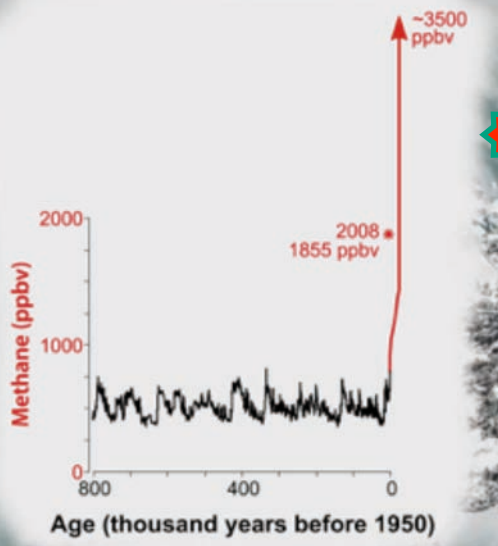

ARCTIC
NORWEGIAN MARGIN
NORDIC SEA
EMSO
www.emso-eu.org/
European Multidisciplinary Seafloor and Water-Column Observatory
CELTIC/ PORCUPINE
BLACK SEA
LIGURIAN
MARMARA
IBERIAN MARGIN
WESTERN IONIAN SEA
HELLENIC
AZORES
PLOCAN
http://www.emso-eu.org/

Centre for Arctic Gas Hydrate, Environment and Climate

Senter for fremragende forskning

Are we at the entrance to a methane age, that is abrupt and irreversible?

Methane expulsions warmed the prehistoric Earth, is it happening again?



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Forskningsrådet

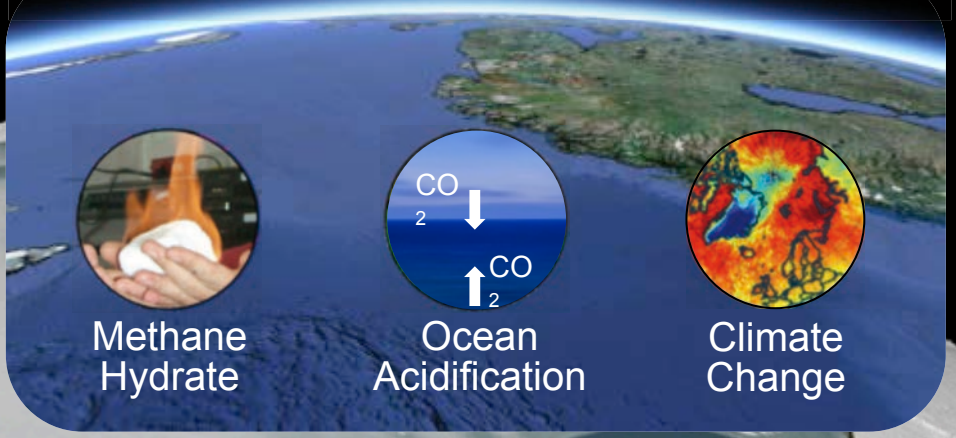
NGU

UNIVERSITY OF TROMSØ

CAGE

Senter for fremragende forskning

Environment and Climate



Added Values

Global Implications

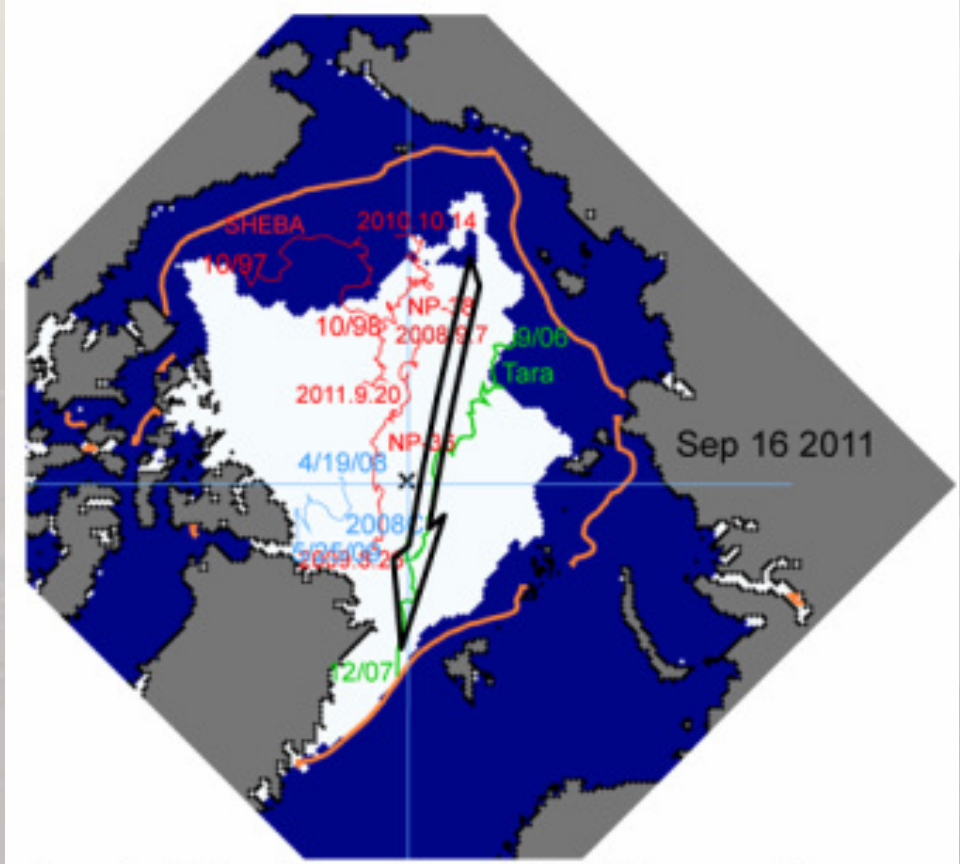
Underwater and Atmosphere technology

Forskningsrådet

NGU Norges geologiske undersøkelse

UNIVERSITY OF TROMSØ

Observatories pushing frontiers: Winter experiments



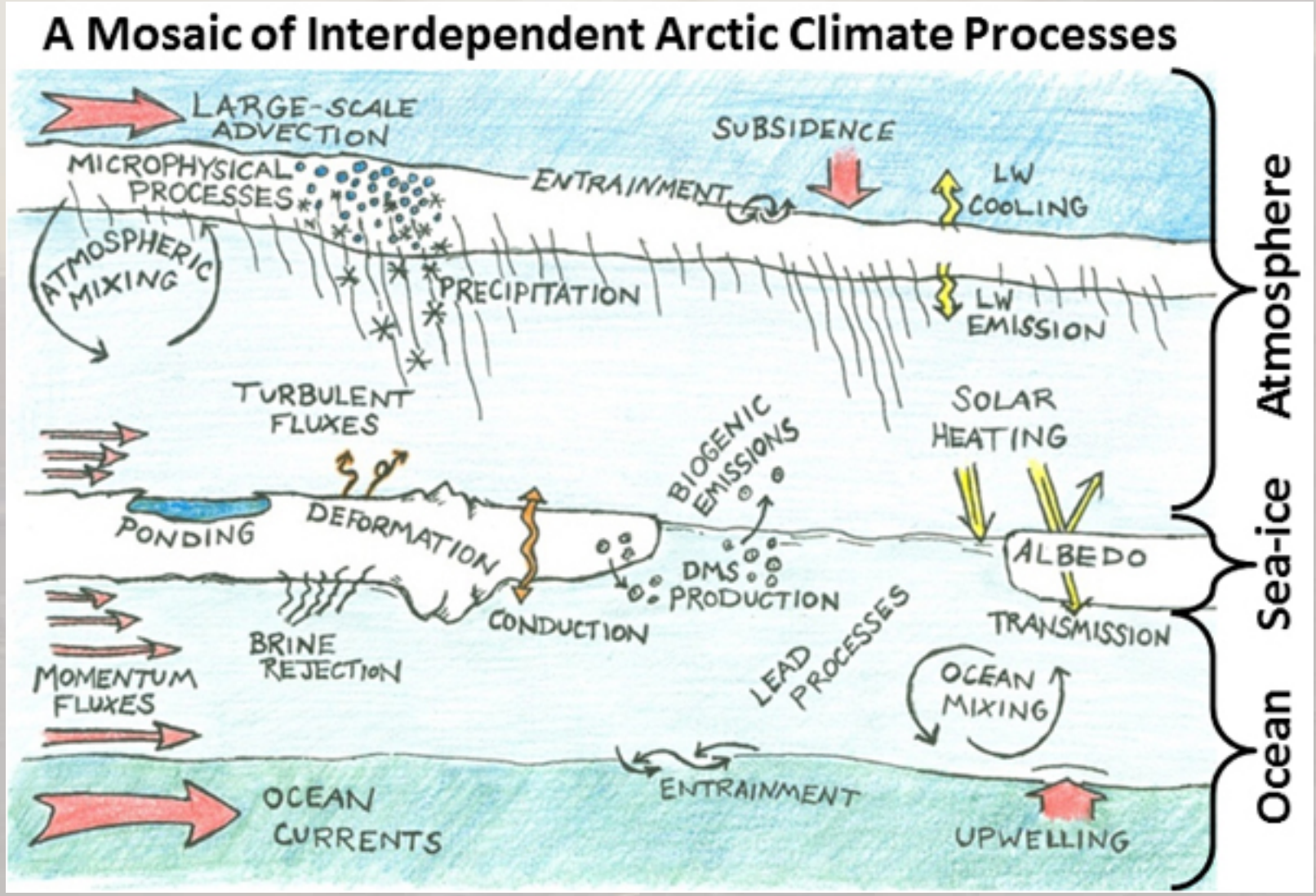
September 2011 sea ice extent (courtesy NSIDC). Numerous drift tracks of stations suggest possible observatory tracks

MOSAiC observations will be specifically designed to characterize the important processes within the atmosphere-ice-ocean system.

This observatory will be embedded within a constellation of distributed measurements made by buoys, ice-tethered profilers, remote stations, underwater drifters, unmanned aerial systems, aircraft, additional ships, and satellites.

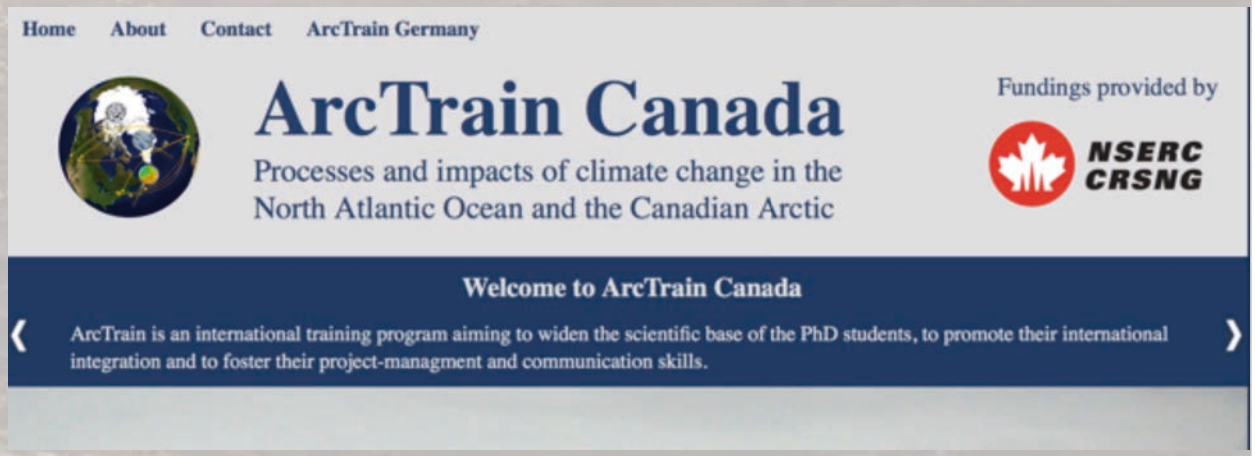
www.mosaicobservatory.org

Observatories pushing frontiers: Winter experiments



http://www.mosaicobservatory.org

Raising the next generation of Arctic observers : bi/multi-lateral graduate schools



Typical questions to Arctic Change

What affect has the sea ice decline on our lives ?

Will it change weather where we live ?

What happens to the polar bear ?

What is the risk to Arctic environment ?

Will there be more fish and resources ?

What can we do to stop ice melt
and environmental degradation ?

Polarstern Bridge ARK27-3 2012

Is there really a long-term change into another state ?

How can we document best this large „experiment“ with nature?