Arctic Ocean research at WHOI

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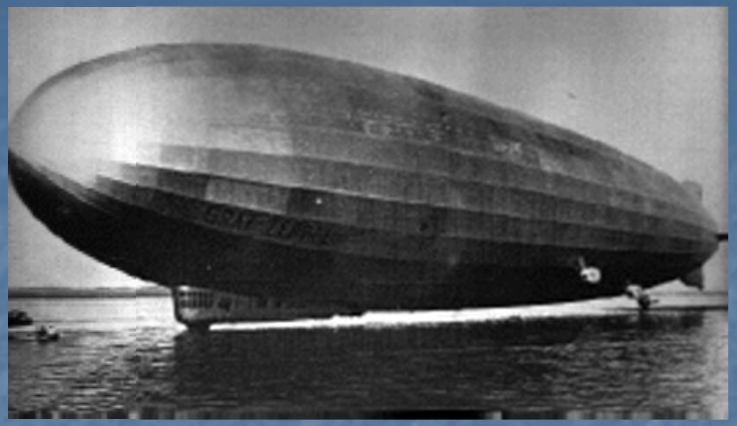
TWIN SCIENCE CITY – BERGEN & WOODS HOLE
workshop 12-13. February 2013, Woods Hole

Sir Hubert Wilkins (center, 1931).

In 1930, Sir Hubert Wilkins acquired the submarine O-12 from the US Navy. He outfitted her and renamed her *Nautilus*, and prepared an undersea expedition to the North Pole. The leader of the scientific staff was Harald U. Sverdrup, who was to make measurements from a specially rigged diving compartment.

The submarine headed north into the pack ice north of Spitsbergen in August 1931, but when the diving plane became damaged, the submarine could no longer cruise very far under the ice, and was relegated to making oceanographic observations outside of the ice pack. However, the *Nautilus* did make several short runs under ice, indicating that submarines could feasibility operate in and under the ice pack.

The scientific report about this cruise was published as WHOI contribution #1 by Harald Sverdrup and was the first WHOI input to Arctic studies.



The *Graf Zeppelin* practicing a water landing on the Bodensee (Lake Constance) in preparation for the 1931 polar flight.

Edward H. Smith (WHOI director: 1950-1956) was one of two Americans to fly over Arctic in Graf Zepplin in 1931.

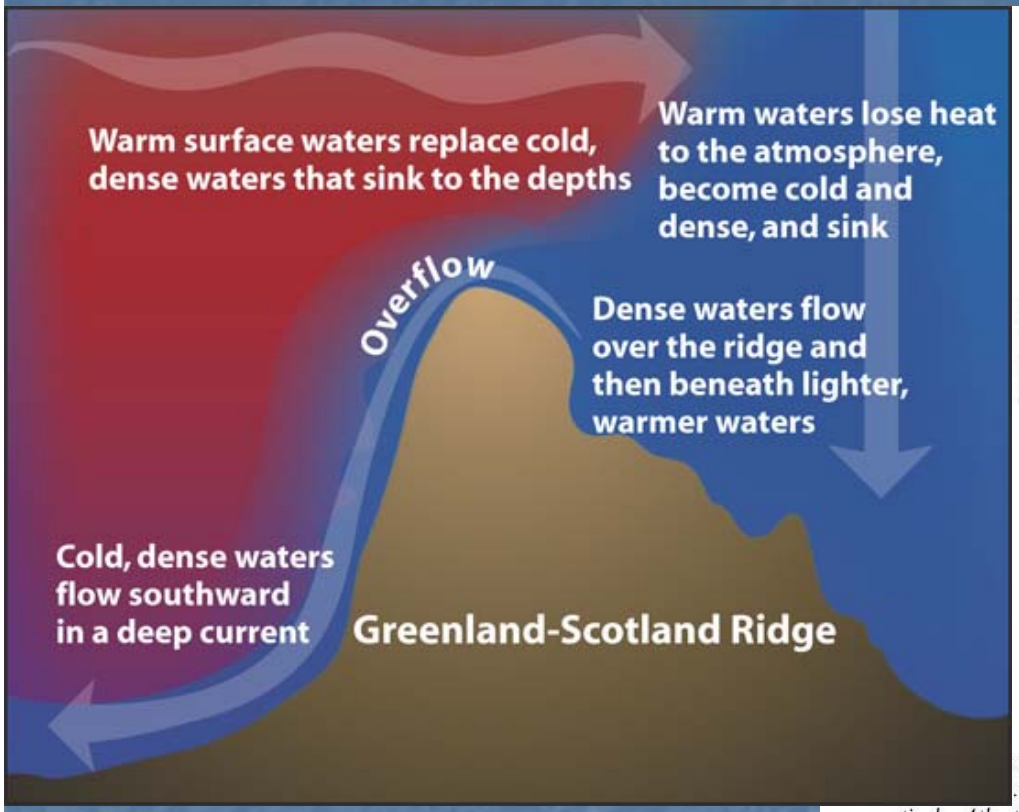
The 1931 polar flight of the *Graf Zeppelin* is possibly the least well-known of several spectacular flights the giant rigid airship made in the late 1920s and early 30s.

Originally, plans called for a meeting at the North Pole between a submarine and the airship. But mechanical problems with the submarine prevented the rendezvous from taking place and the *Graf Zeppelin* continued with the less well-publicized scientific pursuits of the flight. If for no other reason, the flight should be remembered as a tribute to Count Zeppelin who in 1910 envisioned the use of airships in polar exploration.

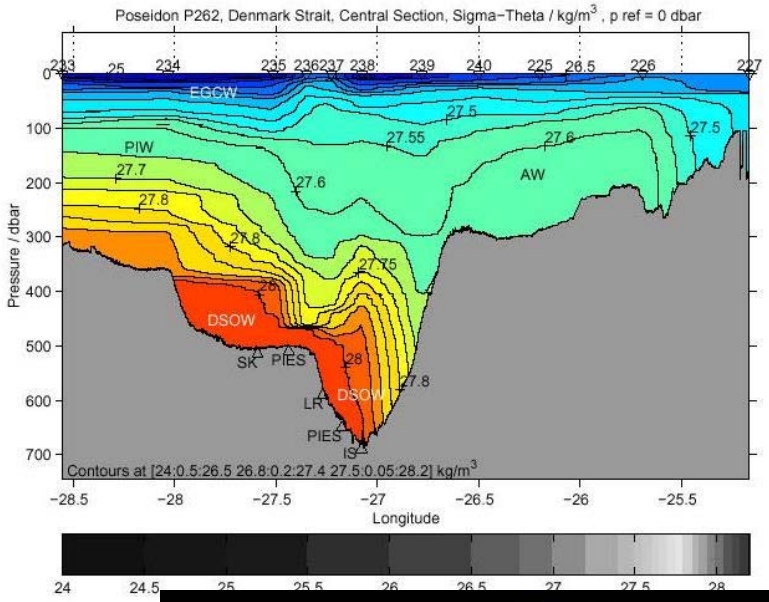
One more remarkable contribution to arctic studies from WHOI was the first oceanographic observations made from ice floes by US aircraft in 1951 and 1952 (Worthington, 1953). These observations indicated that the circulation of the Atlantic waters in the Arctic Ocean was more complicated than the cyclonic system suggested by Nansen (1902). The major feature postulated by Worthington was a large anticyclonic gyre in the northern parts of the Beaufort Sea.

Fig. 3--Atlantic water circulation in the North Polar Basin

March 1967, Worthington moored array across Denmark Strait only one useable record was recovered



Macrander, Käse, Send, Valdimarsson & Jóns



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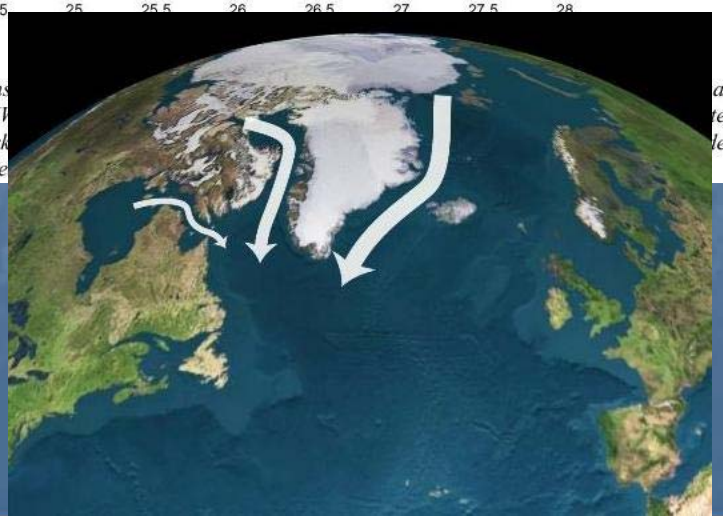
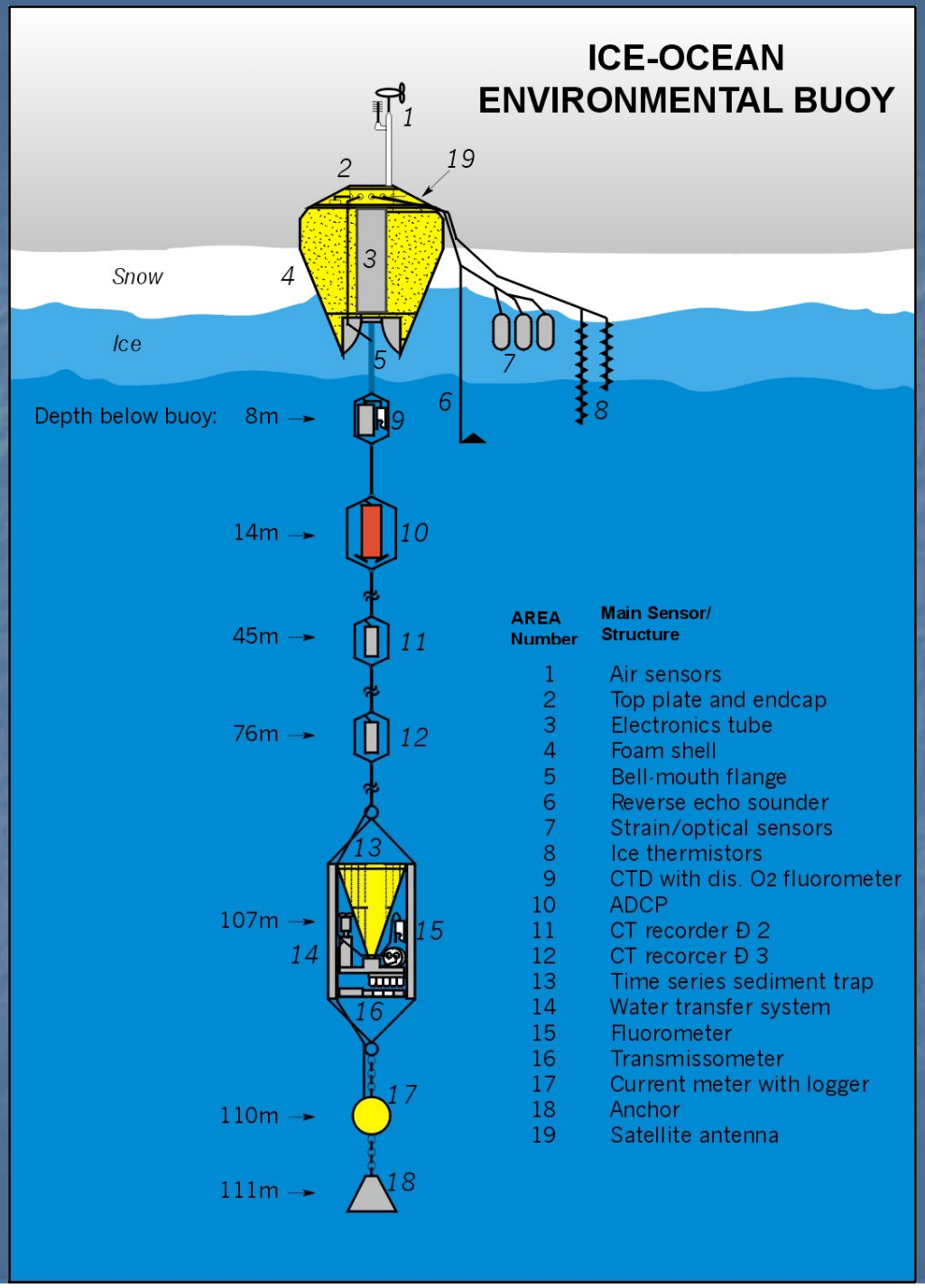


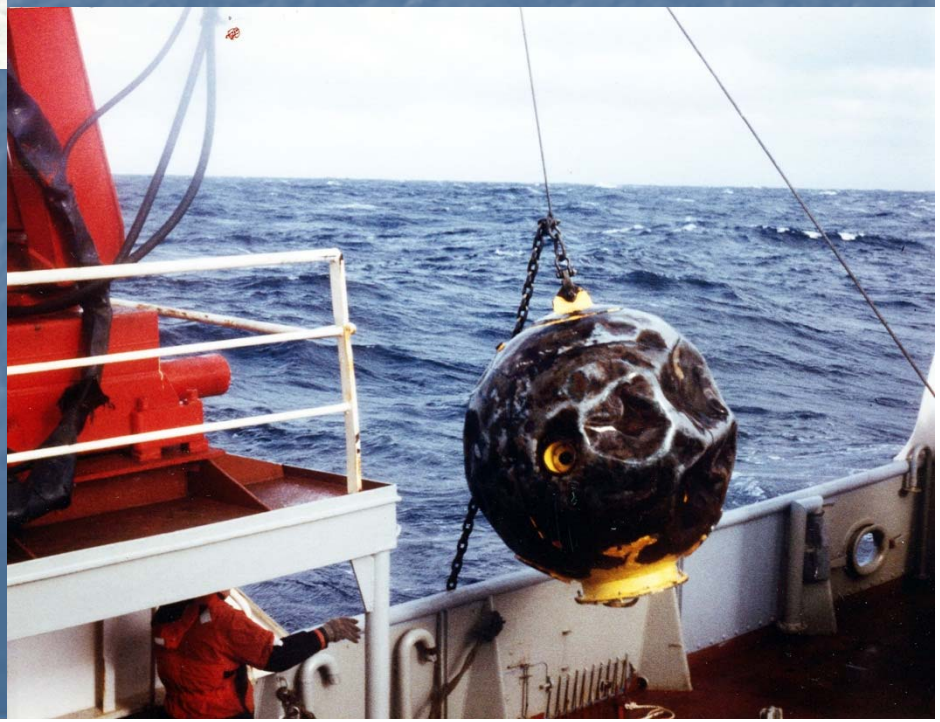


S. Honjo,
A. Plueddemann and
R. Krishfield

1987 – Arctic Environmental Drifting Buoy recovered by Icelandic ship after 225-day, 4000 km drift

1992-1997 – series of IOEB deployments

Deployment and recovery of AEDB float



IOEB deployments in
1996 and 1997

Major directions of research

- Fundamental studies of the Arctic's atmosphere, sea ice, biology, water properties and circulation and geology
- Development and implementation of new technologies and instruments for Arctic observing
- Design and implementation of field and numerical experiments for the studies listed above

Some scientific questions:

- What is the Arctic's role in the global climate system? How does the Arctic work?
- What is the general circulation of the Arctic, how does it vary in time? What are the important water mass transformations that occur in the Arctic, how do they vary on seasonal, inter-annual, and decadal time scales?
- What is the ocean's role in the changes in sea ice extent/mass? What are the impacts of (liquid) fresh-water inventory change?
- What are the relationships between the Arctic physical oceanography and the polar ecosystem? How will changes in the former effect the latter?

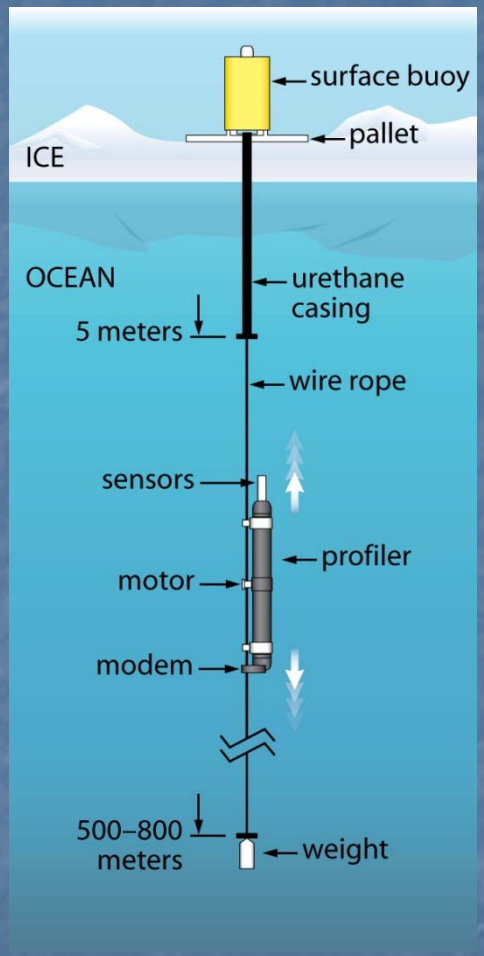
Some current Arctic research activities

- Beaufort Gyre Fresh water storage
  observations, models
- Shelf-Basin Exchange
  moorings, modeling, REMUS
- AOMIP – numerical model intercomparisons
- Mixing studies
- Boundary currents and eddies and overflows
- Atlantic water studies
- Deep convection
- Annual State of Arctic assessment
- Greenland ice-ocean interactions

- Ice-Tethered Profilers
- Polar Profiling Floats
- AUVs (REMUS)
- Bottom-anchored moorings
- Arctic winch
- Microstructure sensor

WHOI Ice-Tethered Profiler (ITP)

PIs: John Toole, Rick Krishfield, Andrey Proshutinsky



Jayne Doucette (WHOI)

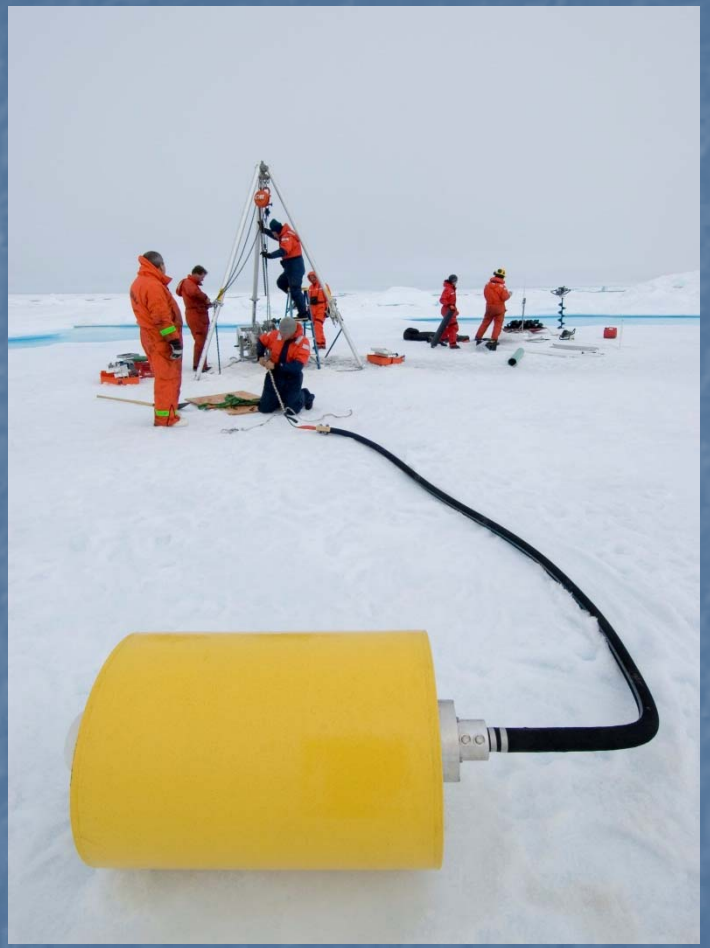


Photo by Chris Linder (WHOI)

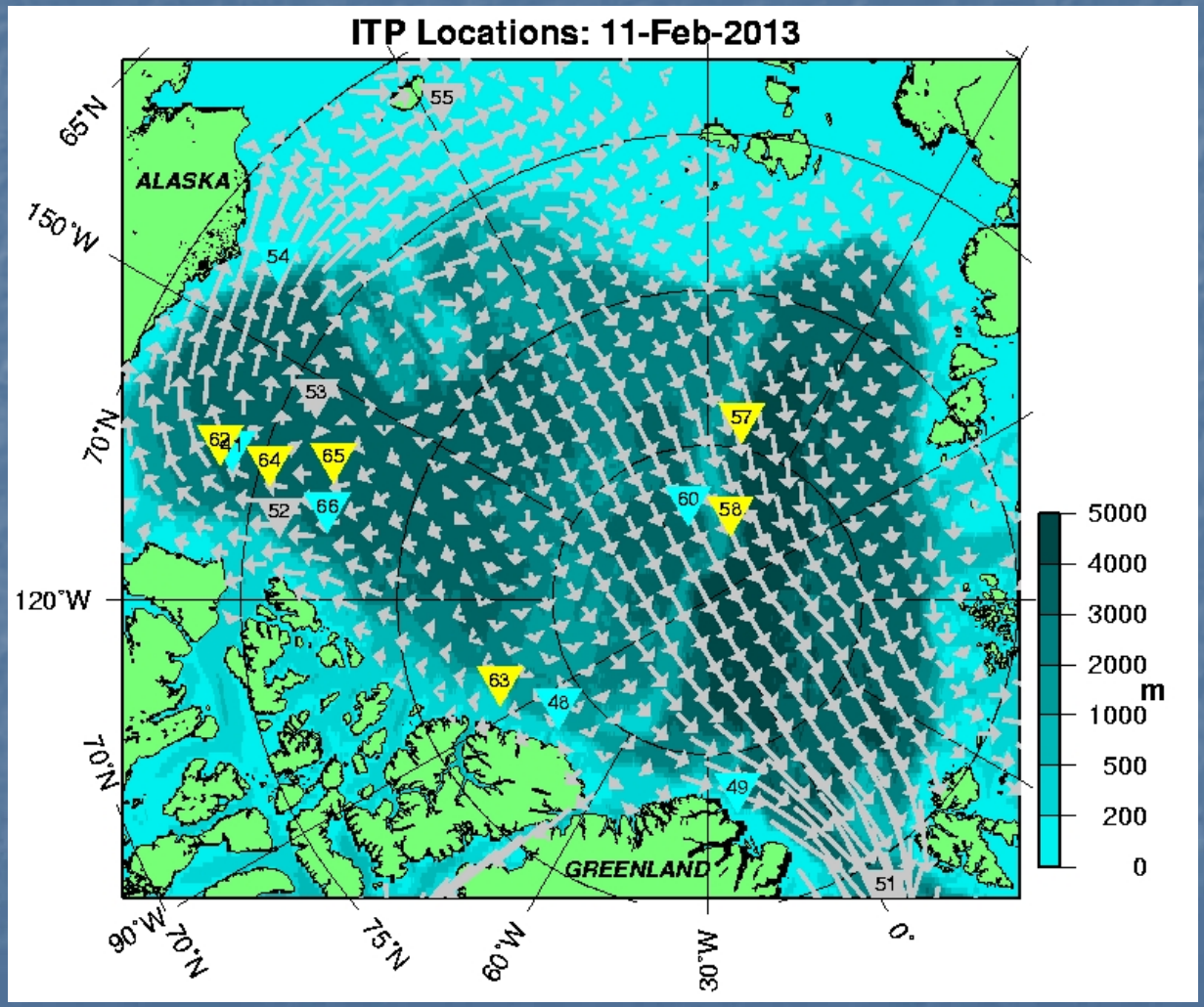
ITP development was initiated by a WHOI Green Technology Award and the ITP program is currently supported by NSF and European collaborator funds (www.whoi.edu/itp).

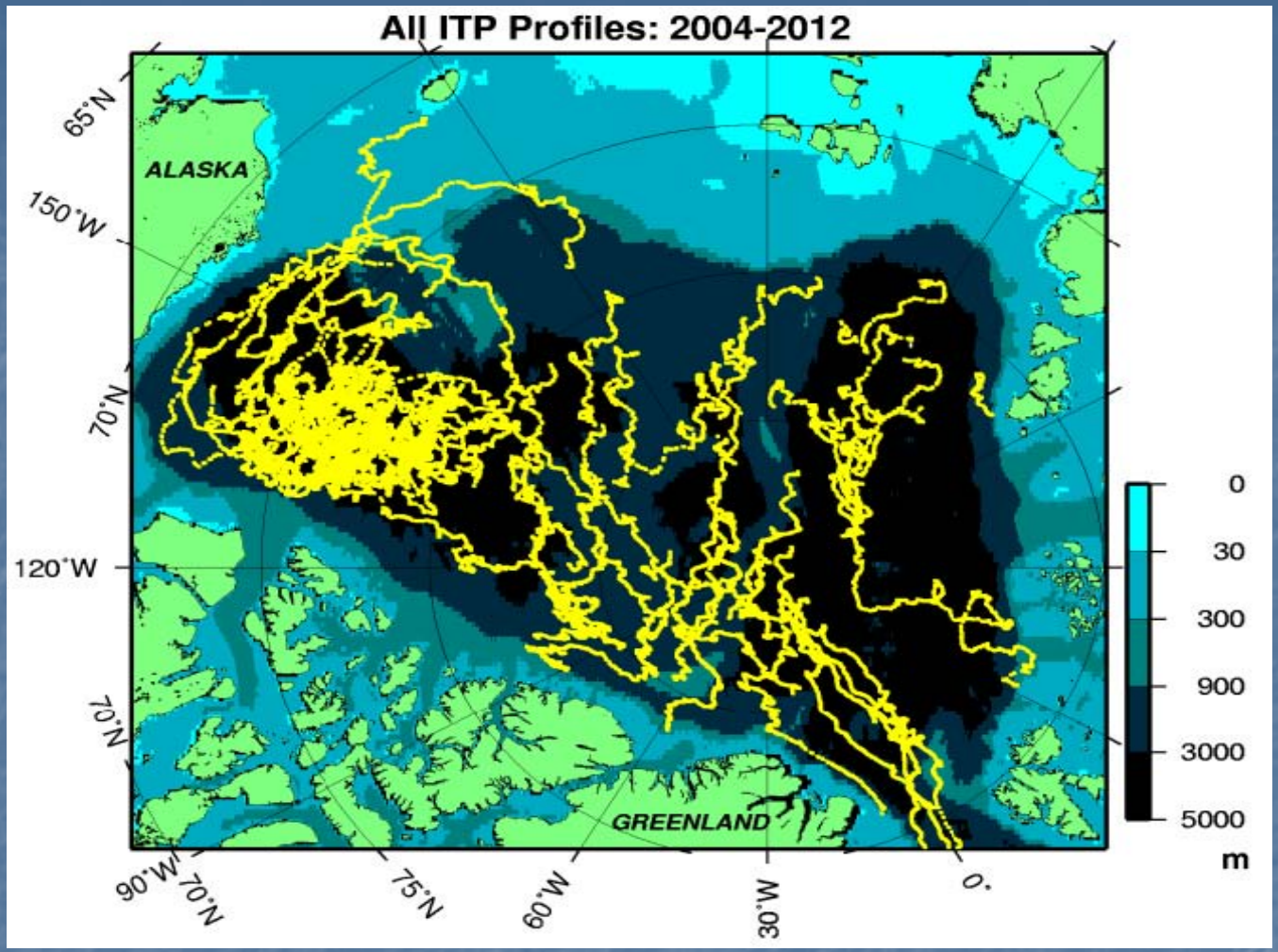
Ice-Tethered Profiler concept

CLICK HERE FOR ITP CONCEPT ANIMATION

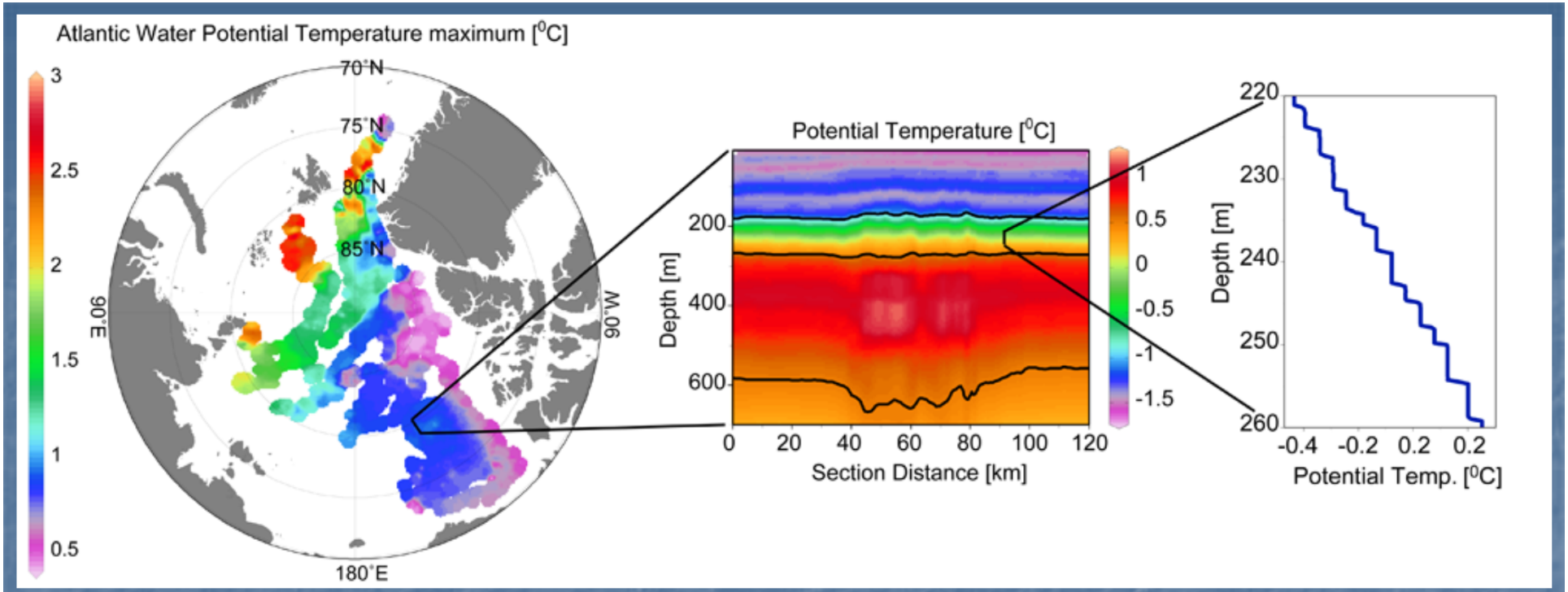
Current ITP locations (www.whoi.edu/itp)

Latest locations of active ITPs and annual ice-drift vectors.

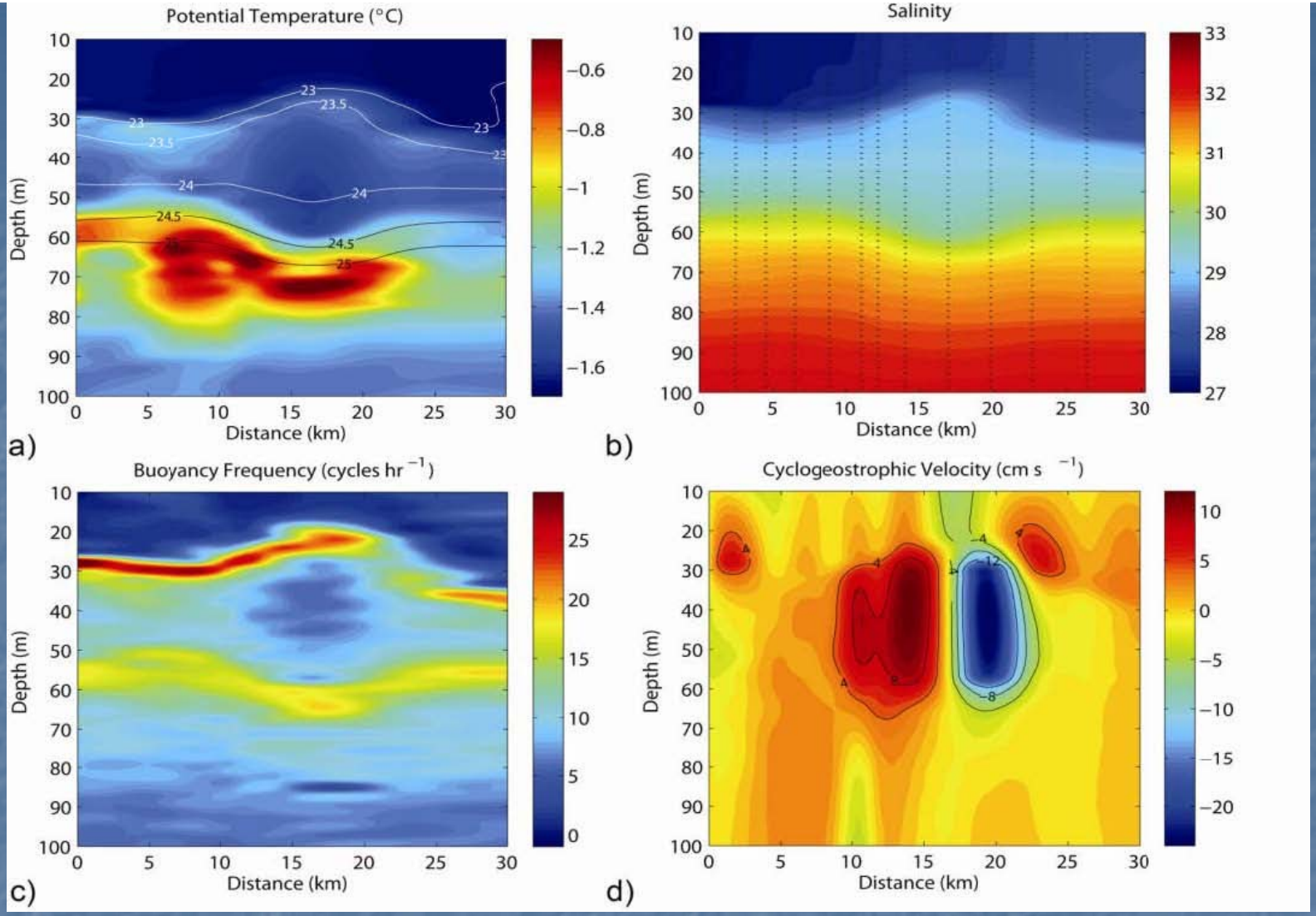




Location of all full-or partial-depth CTD profiles obtained by ITPs since the first system was deployed in late summer, 2004. Owing to the close spacing of the profiles, these profile position locations at this plotting resolution look like continuous drift tracks of the ITP systems.

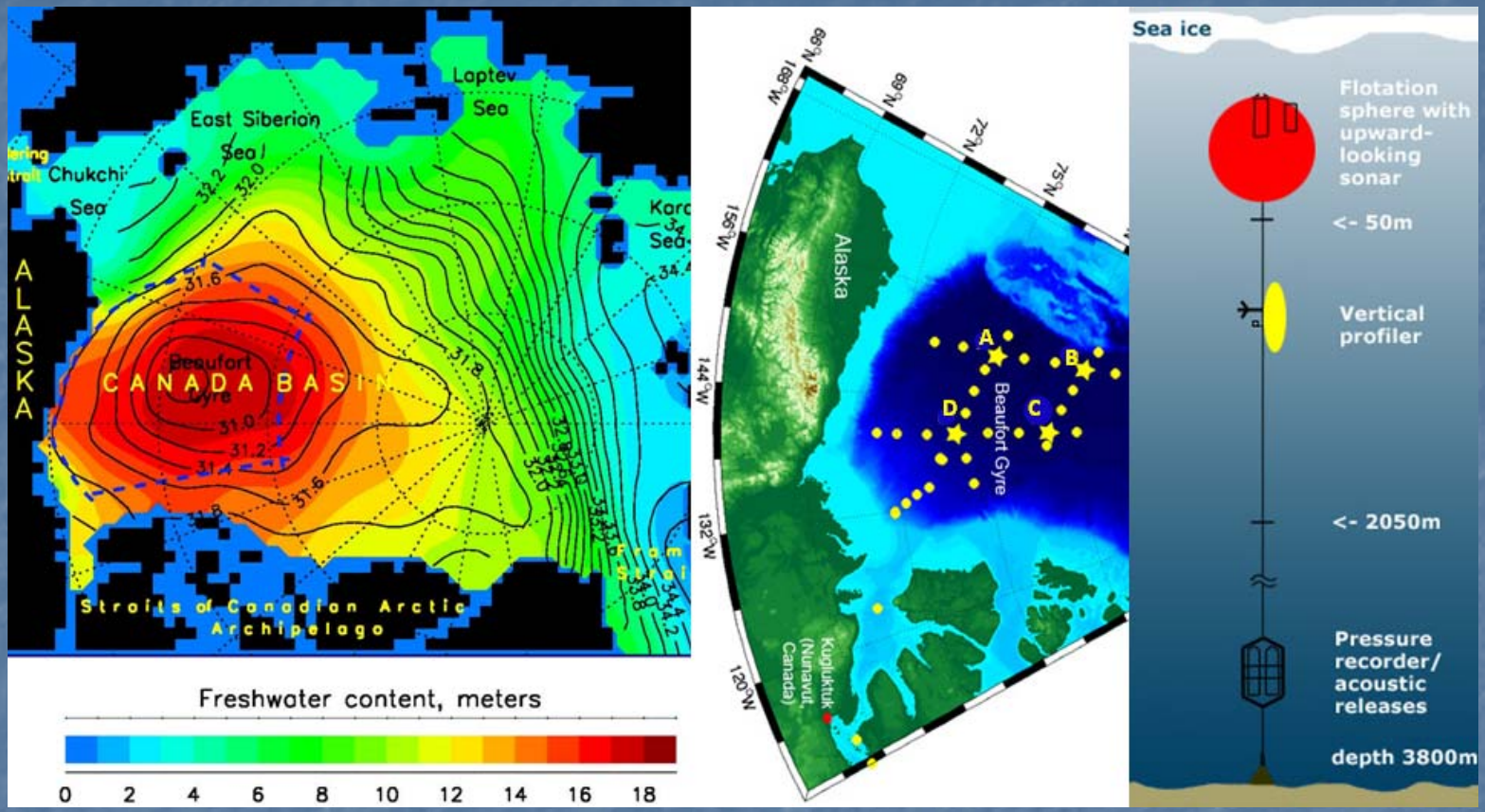


ITPs enable the study of ocean phenomena across a wide range of spatial scales: from the basin-scale circulation and properties (left: Atlantic Water temperatures across the Arctic measured by ITPs operating between 2004 – 2012), to mesoscale motions (middle: an Atlantic Water eddy of radius about 15 km sampled by an ITP), to the very small scales relevant to ocean mixing (right: ITPs resolve the finestructure of a double-diffusive staircase at the top boundary of the Atlantic Water layer.).



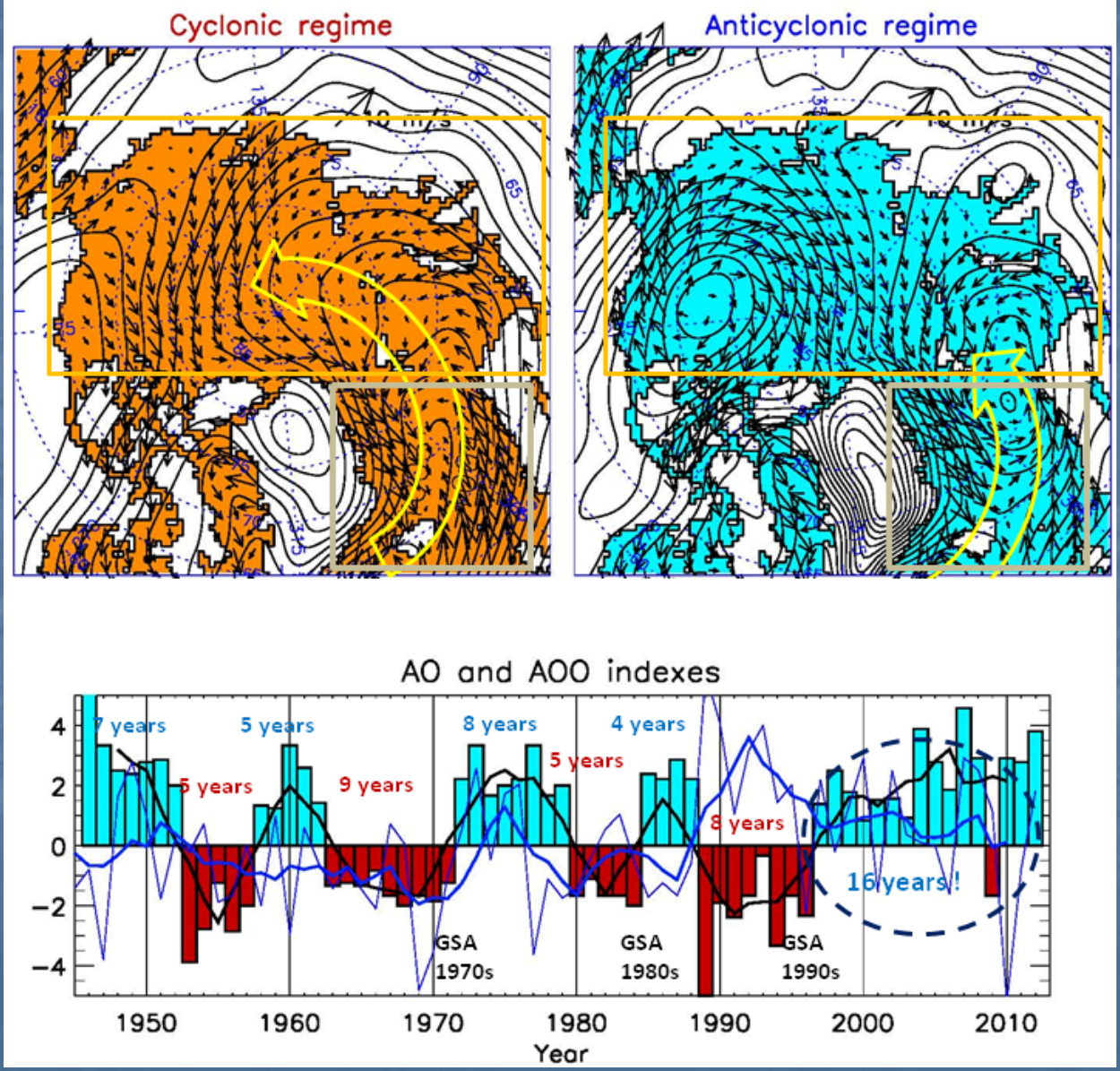
High resolution section through an upper-ocean anticyclonic eddy of potential temperature (a), salinity (b), buoyancy frequency (c) and cyclogeostrophic velocity relative to a deep level of no motion (d), from Timmermans et al., 2008a.

The Beaufort Gyre Observing System (BGOS) 2003-2013

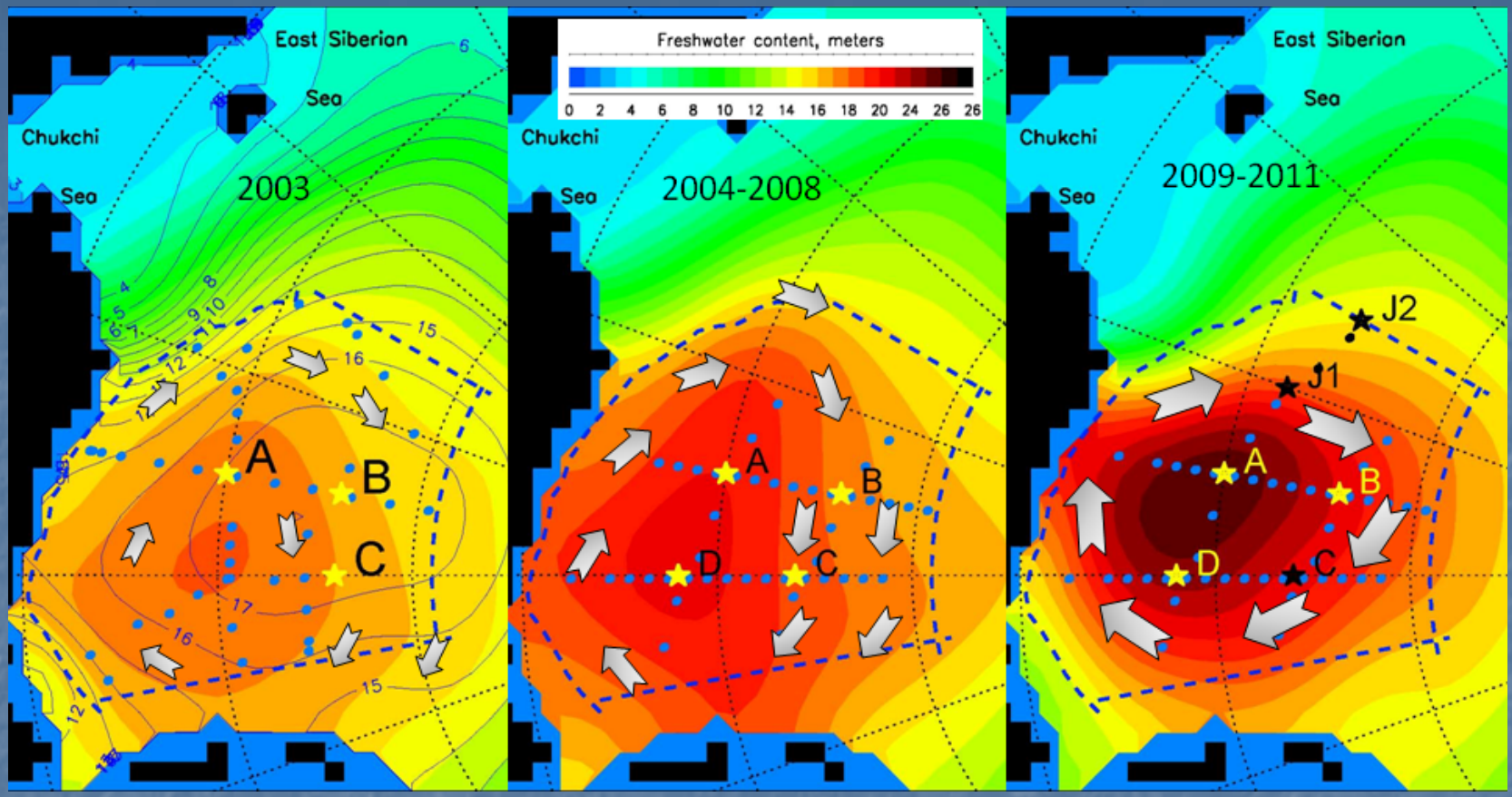


Climatology of Arctic freshwater content (m, colors). Solid lines depict summer 1950–1980 mean salinity at 50 m. Middle: BGOS field program with moorings (stars) and sites of CTD casts (circles); Right: Mooring diagram with: (a) floatation-mounted Upward Looking Sonar, and ADCP; (b) McLane Moored Profiler (MMP) measuring T, S and currents between 50 and 2050m, (d) anchor, (e) acoustic releases and (f) anchor-mounted Bottom Pressure Recorder (BPR).

Circulation regimes and freshwater accumulation and release history



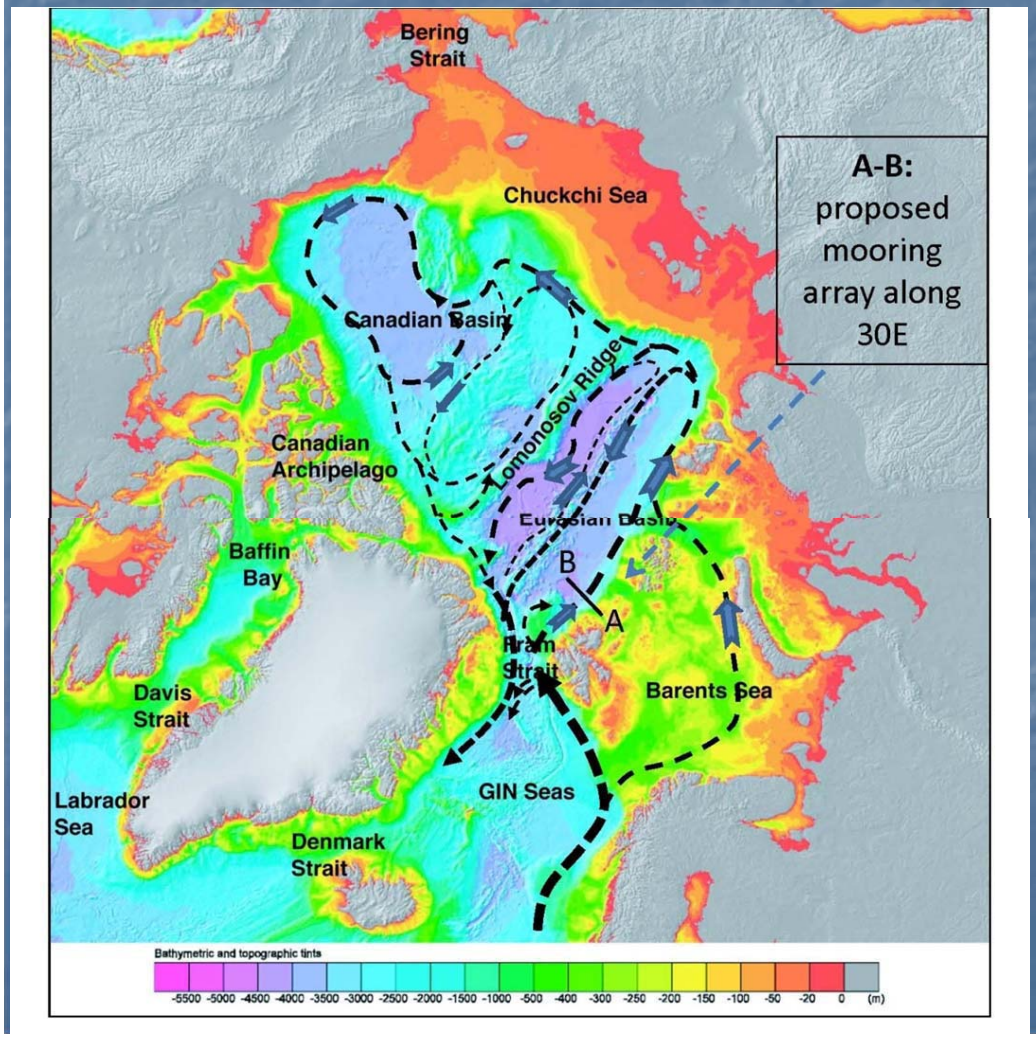
During cyclonic circulation regime the Arctic Ocean (Beaufort Gyre) releases freshwater to the North Atlantic and during anticyclonic regime it accumulates freshwater.
Since 2003 the Beaufort Gyre accumulated 5,000 cubic kilometers of fresh water and its release can result in a new Great Salinity Anomally (GSA)



By 2013, a full decade of observations, supported by NSF, Woods Hole Oceanographic Institution and the Department of Fisheries and Oceans, Canada, will have been obtained in the Beaufort Gyre (BG) region. To date, over 100 peer-reviewed publications by authors from different countries and institutions have utilized BG Observing System (BGOS) data. Some of the results suggest that the BG freshwater (FW) reservoir may be entering a period of freshwater release

The Atlantic Water Boundary Current in the Eastern Arctic: Composition, Transport, Variability, and Dynamics

Co-PIs: Robert S. Pickart (WHOI),
Randi Ingvaldsen and Harald Loeng (IMR, Bergen, Norway)



Schematic diagram showing the inferred circulation in the Arctic Ocean of the Atlantic layer and intermediate depth waters between 200m and 1700 m (adopted from Rudels *et al*., 1994).

The WHOI/IMR mooring array is designed to measure the Atlantic Water charactristics downstream of the complex chokepoint at Fram Strait.

This mooring array was deployed in October 2012 from R/V “Lance”