Health of Polar Oceans Observing System

by
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for
CLIVAR Summit
POS-PSMI Breakout Session
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at
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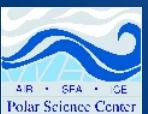
Baltimore, MD
Acknowledgements: Ron Kwok, Ignatius Rigor, Matt Alkire, Cecilia Peralta-Ferriz, Roger Andersen, Sarah Dewey, Suzanne Dickinson, David Morison, and many more



Overview Arctic

Arctic Ocean Observing System

- Largely motivated by changes that started in the early 1990s
- In situ observations benefitted greatly from AON 2000-2015
- AON consisted of drifting buoys, moorings, and repeated sections with ships and aircraft, and it greatly improved our understanding of the marine Arctic
- A weakness has been that nature, geopolitics, and practicality biased in situ measurements to Beaufort-Gyre-Transpolar-Drift view that does not capture connection to global climate indices
- Since 2015, AON ocean observing system has been degraded
- Remote sensing of the ocean will be critical to understanding the relation of the Arctic Ocean change to climate.

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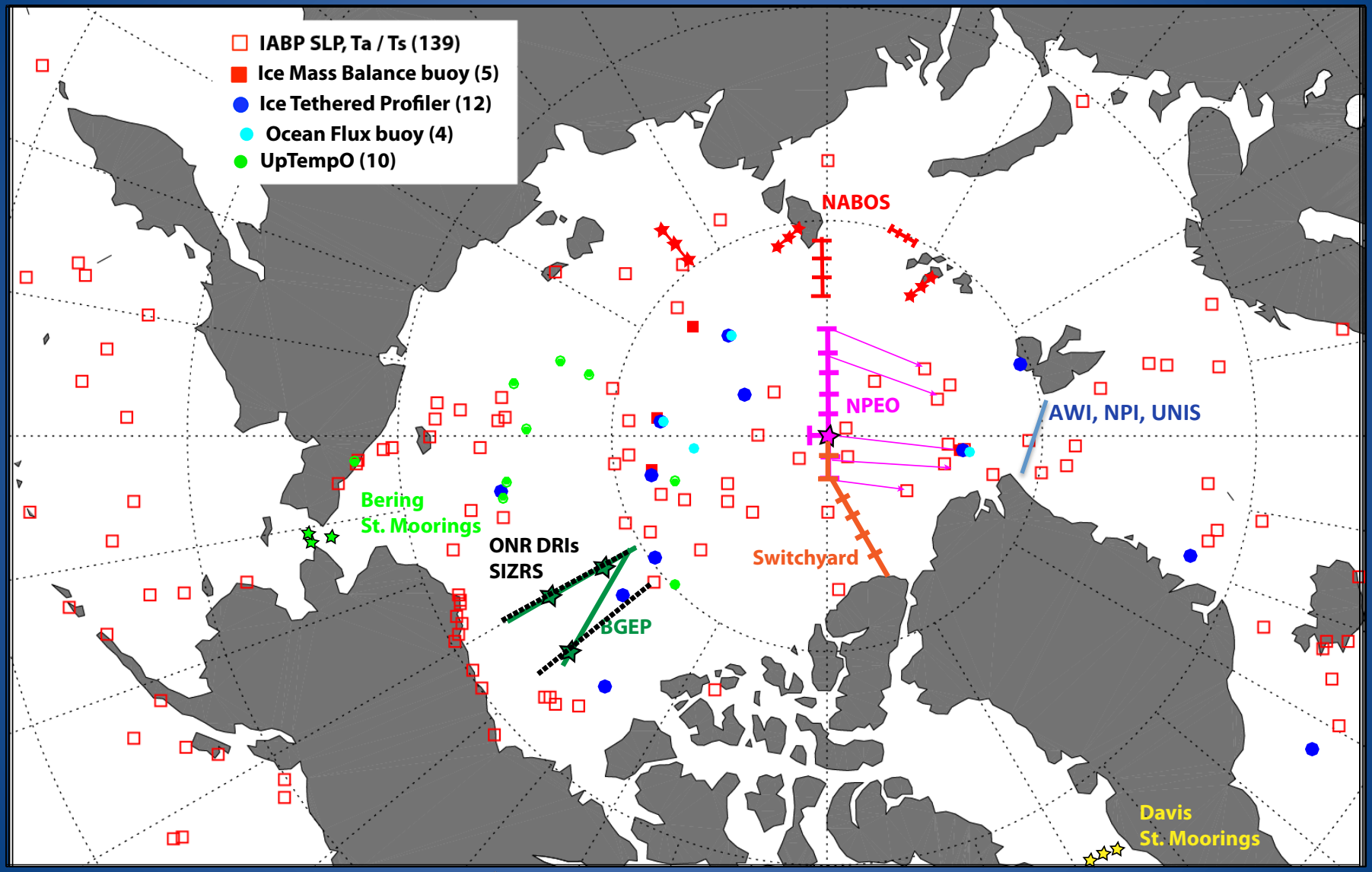
Arctic Ocean Observations in 2015



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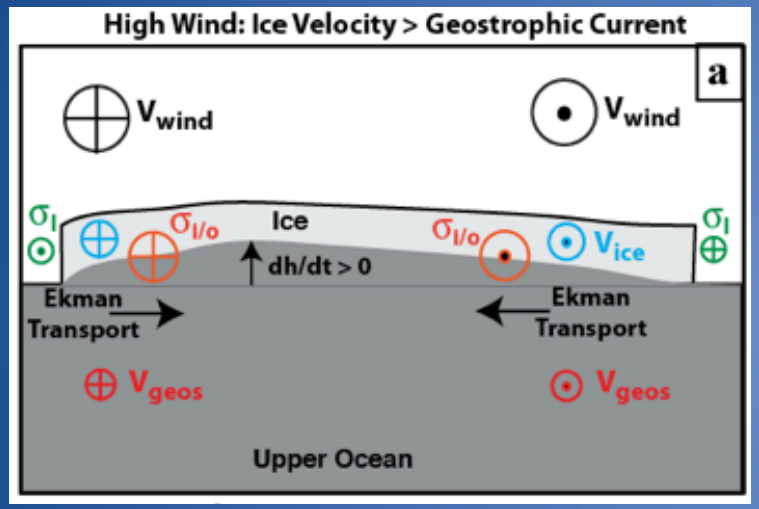
Arctic Ocean in Situ Observing: Strengths and Weaknesses

- The combination of AON, IABP, ONR DRIs and SIZRS, and the German and Norwegian ASOF monitoring of Fram Strait improved observations of the marine Arctic by an order of magnitude.
- It included everything from standard T&S profiles, SLP, and SAT, to bottom pressure, ice draft, ice-ocean fluxes, and ice surface imagery.
- The only problem with these in situ measurements has been limited spatial extent; they are predominantly in the Canada Basin and drifting measurements tend to sample the same water repeatedly.
- Why is that? Because the ice moves with the water.

Sea Ice Moves With the Upper Ocean

Because it responds to sea surface tilt identically to the upper ocean, sea ice moves with the geostrophic surface water velocity,

More **or** **Less**

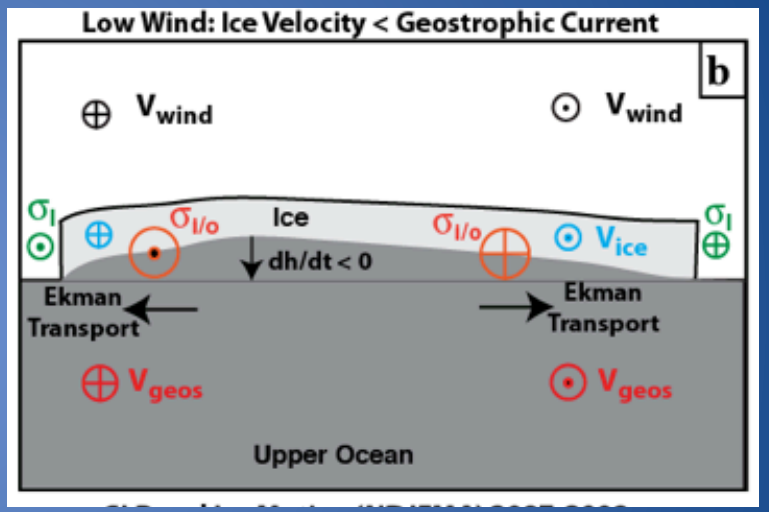


Wind > Internal Ice Stress

$V_{ice} > V_{water}$

Ekman pumping increases tilt,

geos V_{water}, and geos V_{ice}



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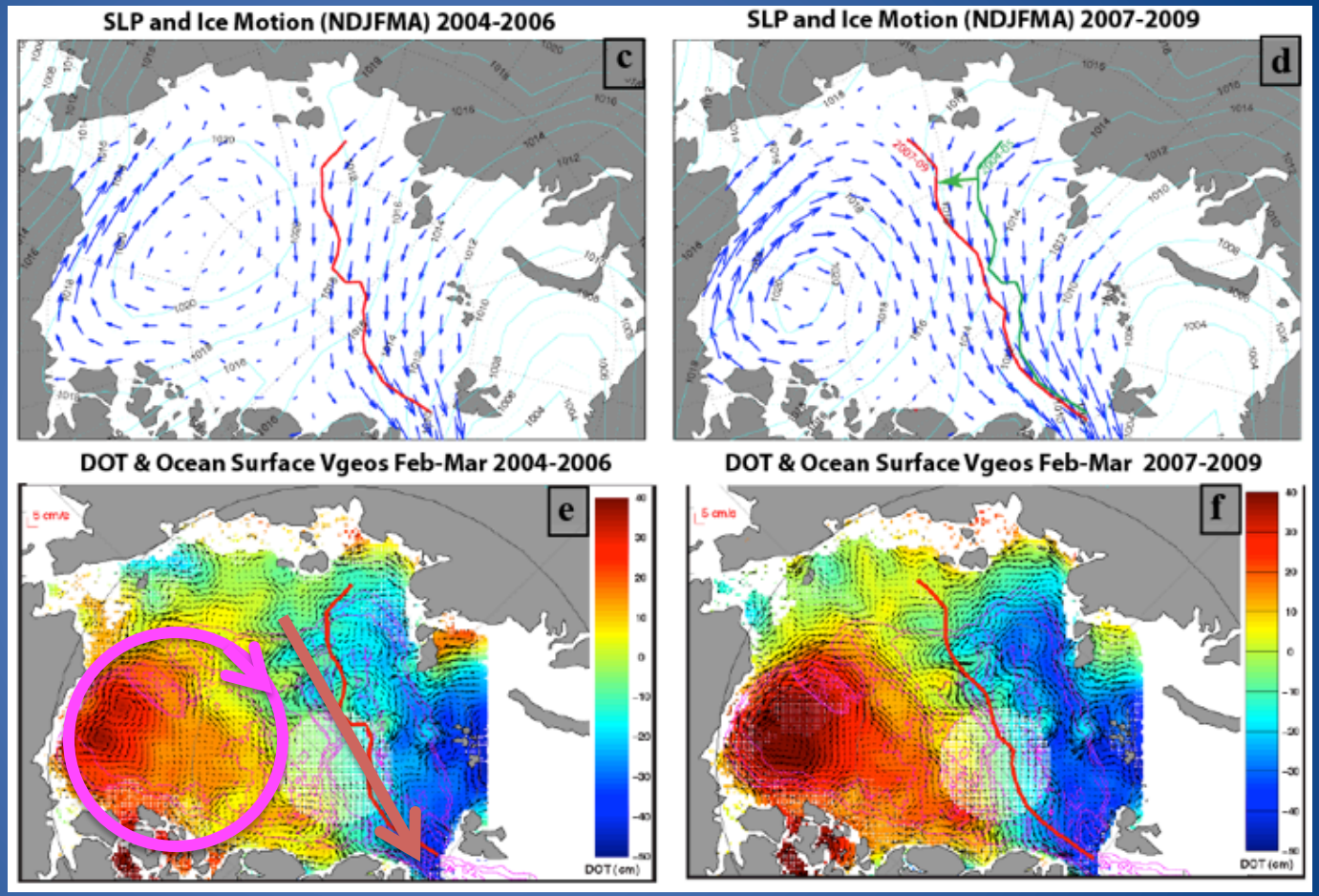
Sea Ice Moves With the Upper Ocean

With the result that ice velocity patterns (c and d) are similar to surface geostrophic water velocity (e and f).

Consequently, buoys and ships that drift with the ice tend to stay in the Beaufort Gyre or follow the Transpolar Drift, paralleling ocean fronts, and repeatedly sampling the same water masses.



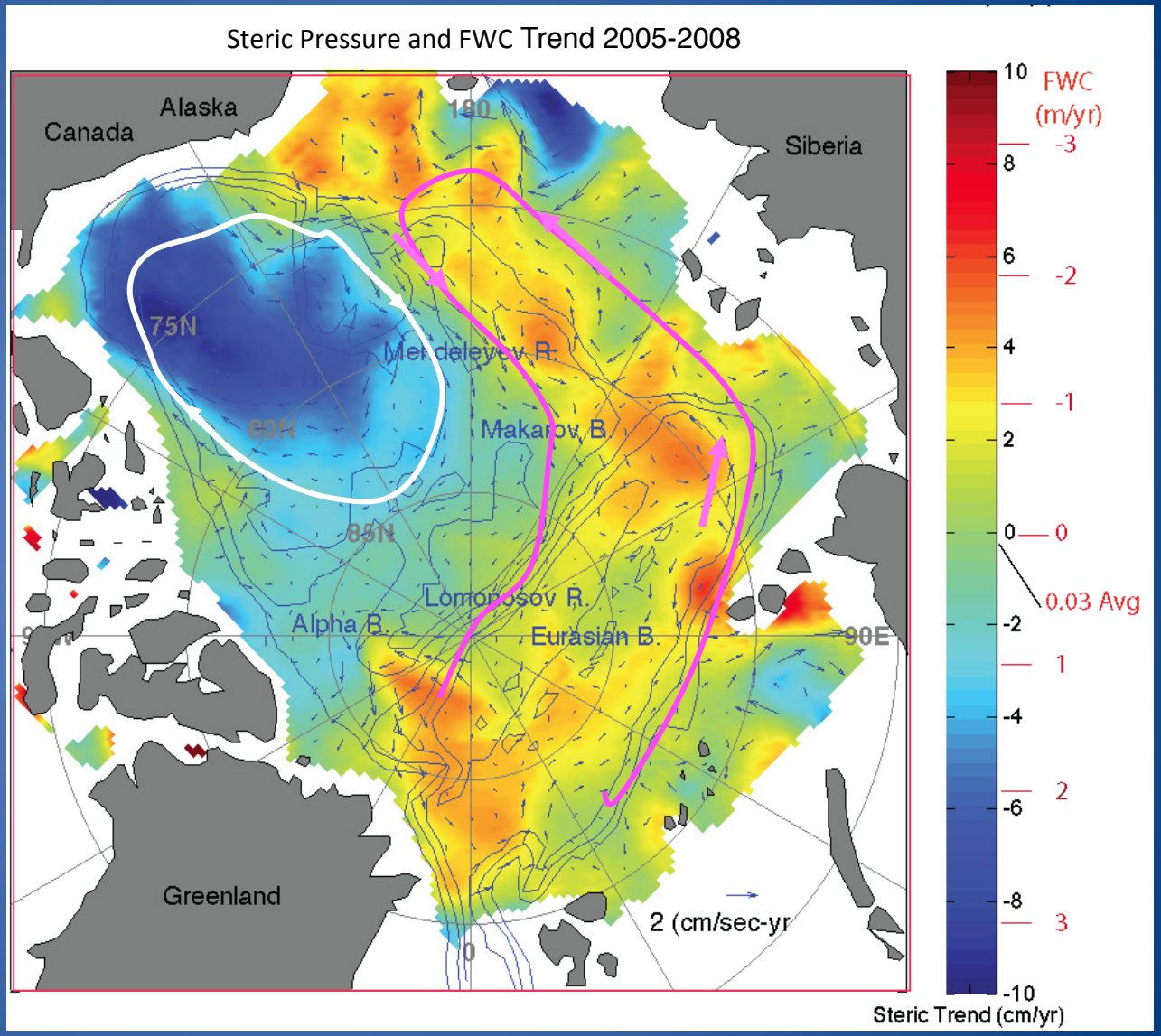
Ship cruise tracks often parallel the Transpolar Drift with the same result.

Figure S13 from: Morison, J. H., R. Kwok, C. Peralta-Ferriz, M. Alkire, I. Rigor, R. Andersen, and M. Steele, 2012: Changing Arctic Ocean freshwater pathways. *Nature*, **481**, 66-70.

Steric Pressure (-Steric Height) ~ Freshwater Trend 2005-08 ~ -36 x (GRACE Bottom Pressure - ICESat DOT)

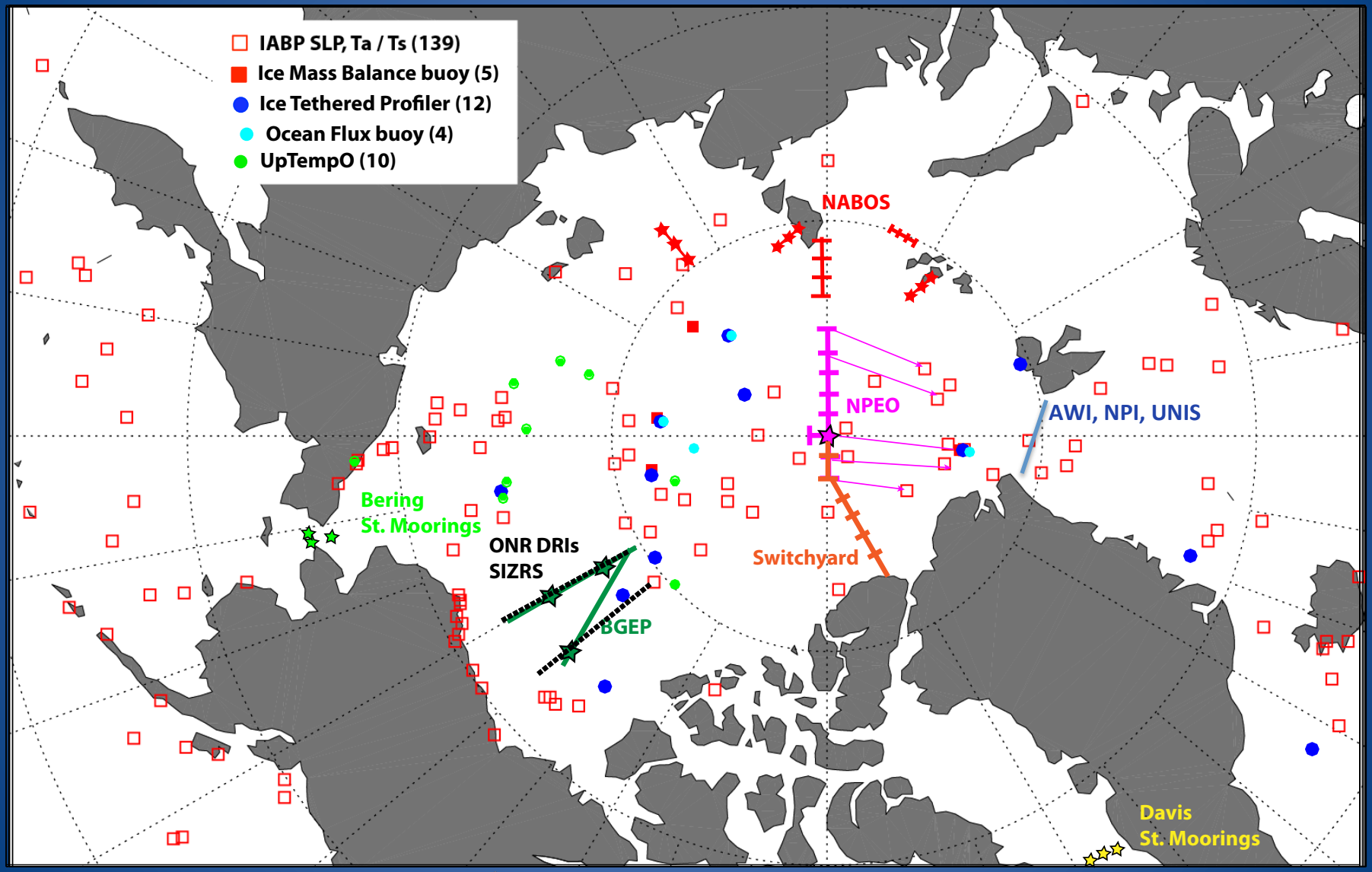
This limitation is overcome with remote sensing of SSH (e.g., ICESat, CryoSat), ocean bottom pressure (GRACE), ice velocity, etc.

Example is the trend 2005-08 in steric pressure (GRACE OBP-ICESat DOT) ~ -FWC that tracks shift in FWC from Eurasian Basin to the Canada Basin using remote sensing.



[Morison, J., R. Kwok, C. Peralta-Ferriz, M. Alkire, I. Rigor, R. Andersen, and M. Steele (2012), Changing Arctic Ocean freshwater pathways, *Nature*, *481*(7379), 66-70.]

What's happened to the Arctic Ocean observing system?



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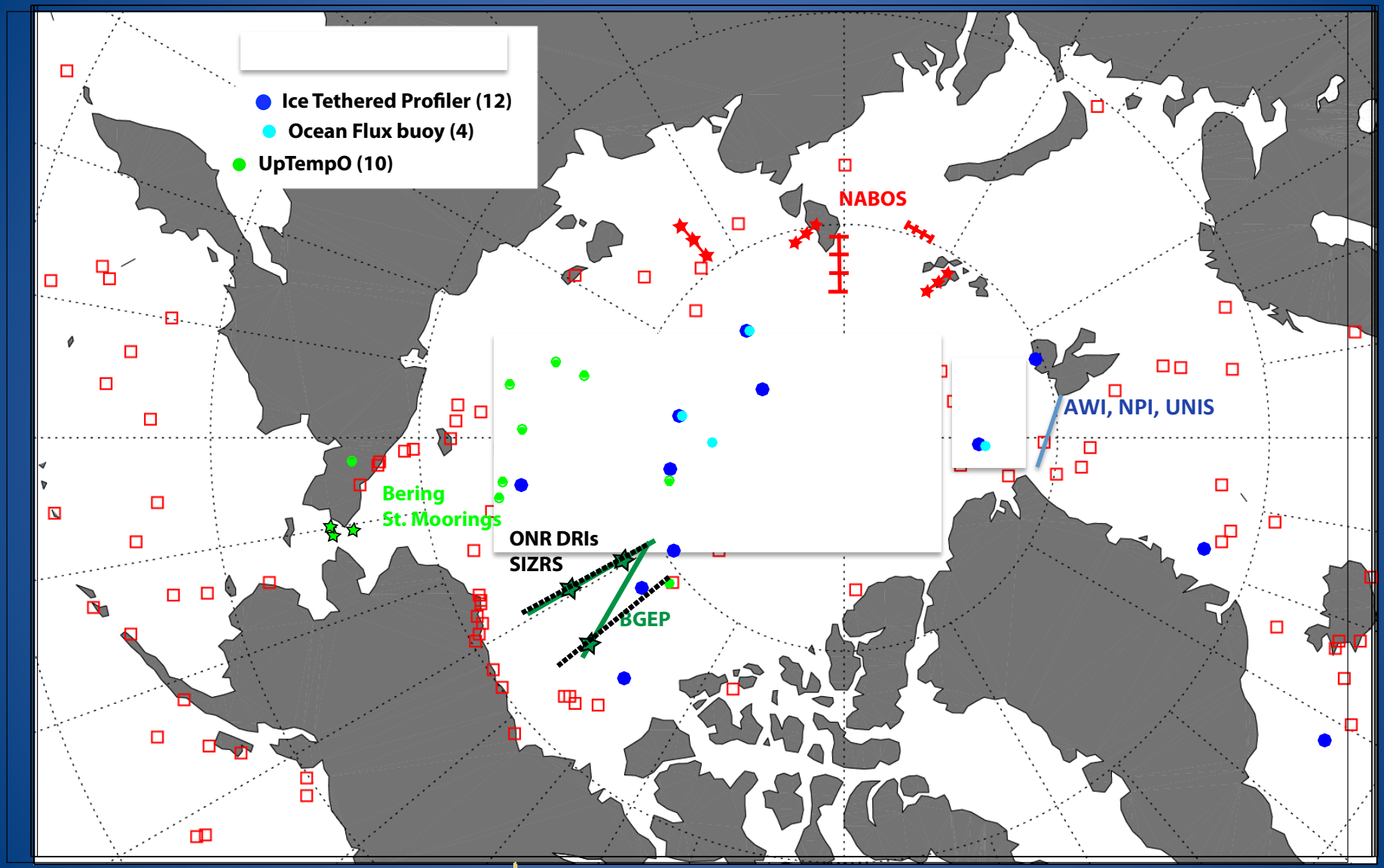
Most of the AON ocean observatories ended in 2015.



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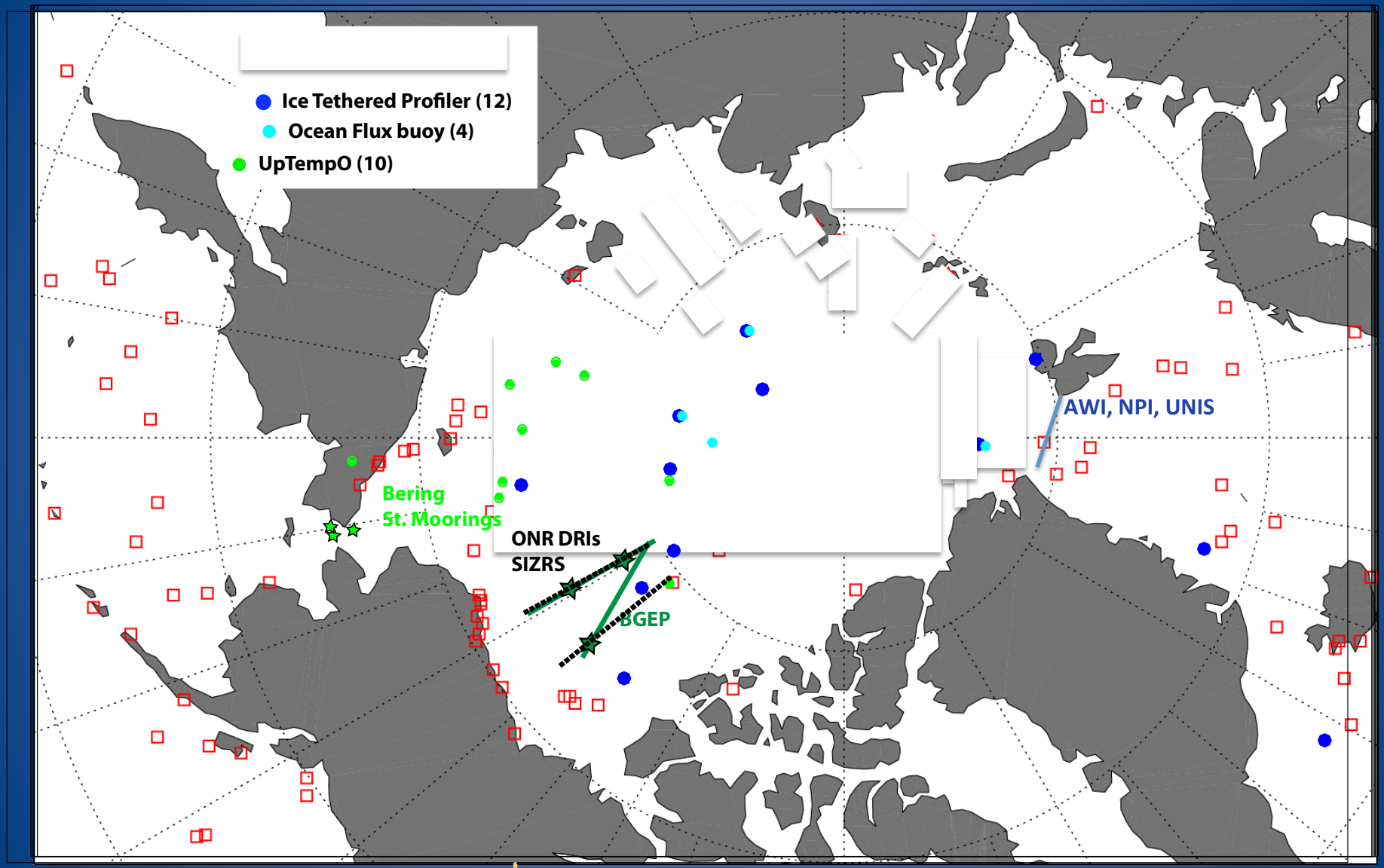
NABOS 2017 Cancelled by Russian Government



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We need to reverse this degradation of in situ Arctic Ocean observations and facilitate their better coordination with remote sensing

Overview Antarctic

Antarctic Ocean Observing System

- Southern Ocean Argo floats cover the ice-free areas
- For ice covered region, systematic programs of ocean observations seem moribund (e.g., International Program for Antarctic Buoys) or undeveloped (Southern Ocean Observing System)
- As in the Arctic and remote sensing is critical for understanding the relation of Antarctic ocean change to climate change

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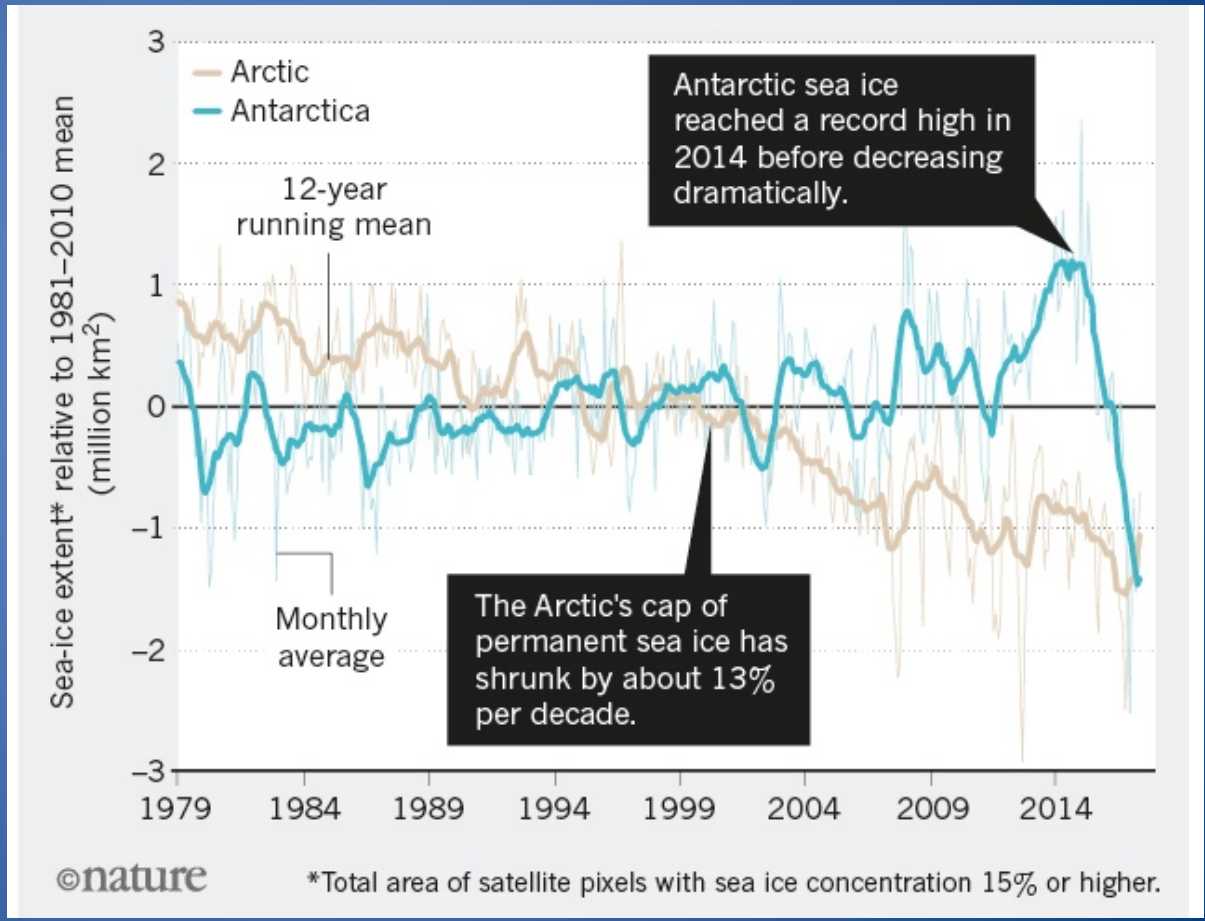
New Antarctic Ocean Imperative

- **Recent comment in Nature by Turner and Comiso [2017] cites the recent and sudden record minimum in Antarctic sea-ice extent and calls for a new emphasis on understanding the Southern Ocean seasonal ice zone.**



Turner, J., and J. Comiso (2017), Solve Antarctica's sea-ice puzzle, *Comment in Nature*, *547*, 19–21.

Floats and Buoys in the Antarctic

- Argo float coverage in the Southern Ocean appears to be good.

- However, although some Argo floats are equipped to avoid surfacing under ice, coverage in seasonally ice-covered areas seems sparse.

- The lack of a coherent buoy program measuring ocean, ice, and atmospheric variables is surprising.

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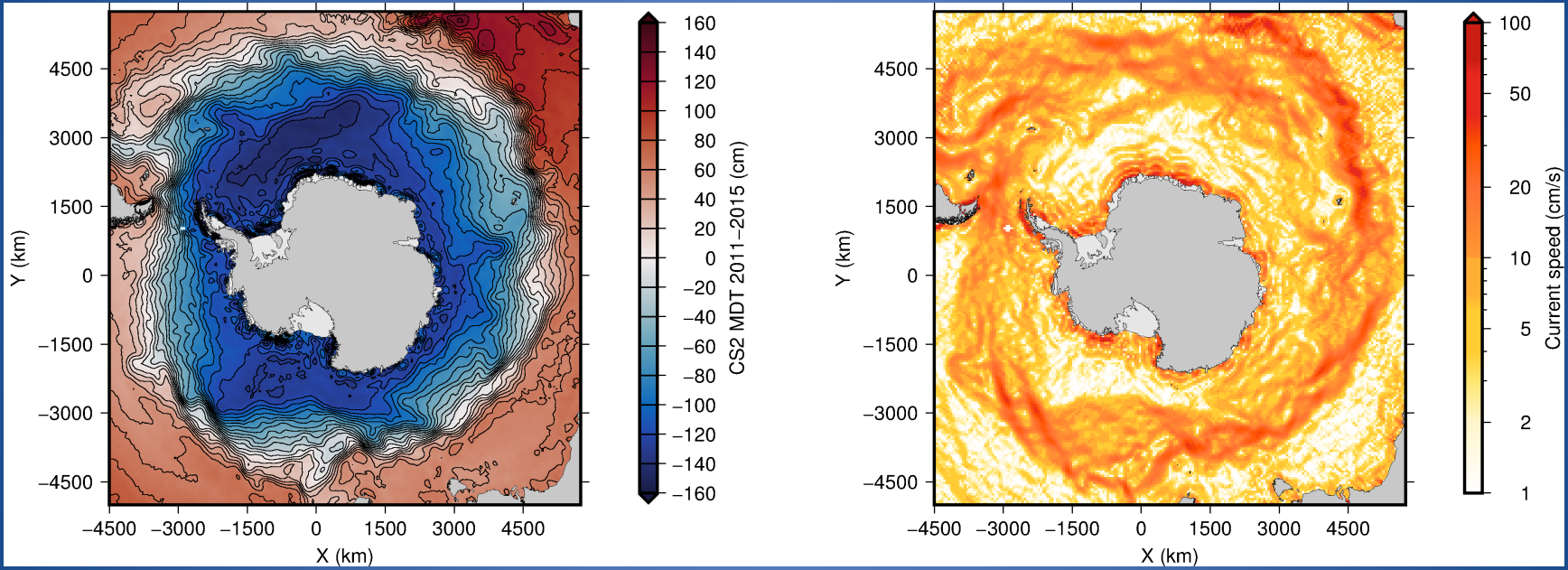
Remote Sensing for Antarctic Oceanography

- As in the Arctic, remote sensing e.g., passive microwave, altimetry, and gravity, are keys to the future of Antarctic oceanographic observing.

Armitage and Kwok, 2017



- We should have repeat in situ observations in seasonally ice covered regions to enable us to validate and interpret the remote sensing the observations.

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The needs are the same for Arctic and Antarctic marine observations.

U.S. CLIVAR should take a strong position that:

- **In situ observations should be enhanced in the ice-covered seas to provide for measurement of air-ice-ocean interaction, basic hydrography, ocean mixing, and for comparisons to remote sensing, bottom pressure and precision GPS determination of SSH.**
- **In situ observation should be coordinated with remote sensing. Through coordination, the whole of remote sensing and surface observations will be very much greater than the sum of its parts**
- **To improve sampling in the sea-ice environment, we should increase the use of aircraft for both remote sensing (e.g., IceBridge) and deployment of in situ instruments (e.g., SIZRS, OMG).**

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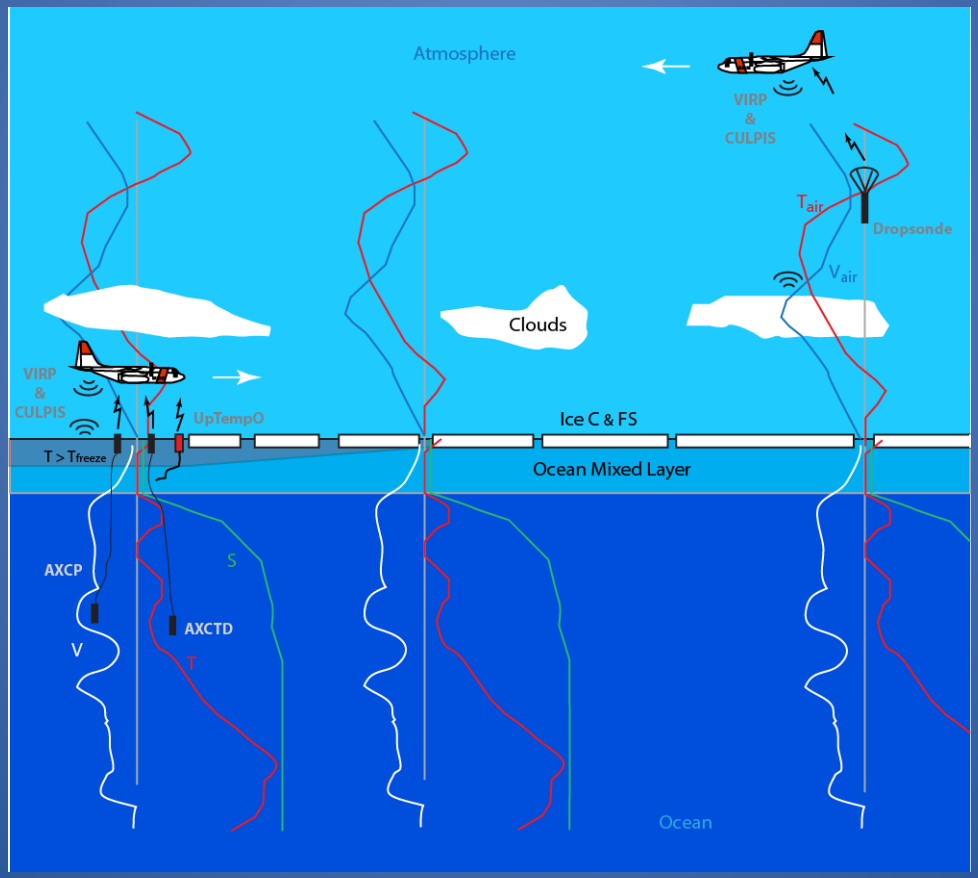
Aircraft Oceanography for Polar Oceans

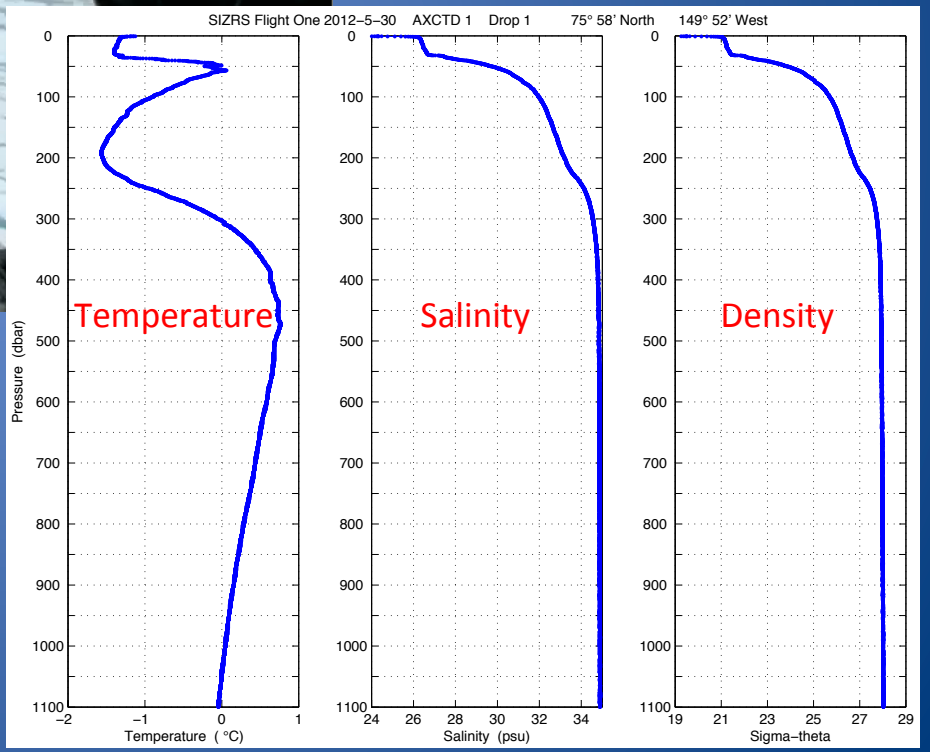
Repeat Long-range aircraft sections using expendable ocean and atmospheric probes and deploying drifting buoys could give the repeat in situ measurements we need.



Ocean Profiles From AXCTD, AXCP

Launch AXCP and AXCTD from ramp in open water leads between ice floes

Example AXCTD Profile May 30, 2012 at 76°N, 150°W



Receive and record data onboard circling C-130

Before region accessible to ships!

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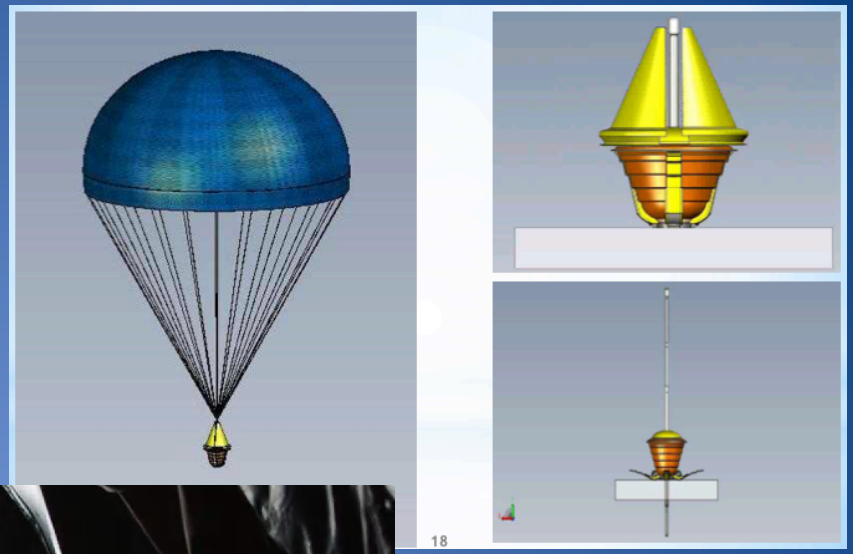
IABP AXIB Buoys

SIZRS and International Arctic Buoy Program (IABP) team to deploy self-erecting Aircraft eXpendable Ice Buoys (AXIB) during SIZRS missions.



AXIB Deployment

Thank You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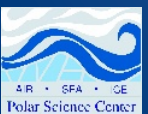
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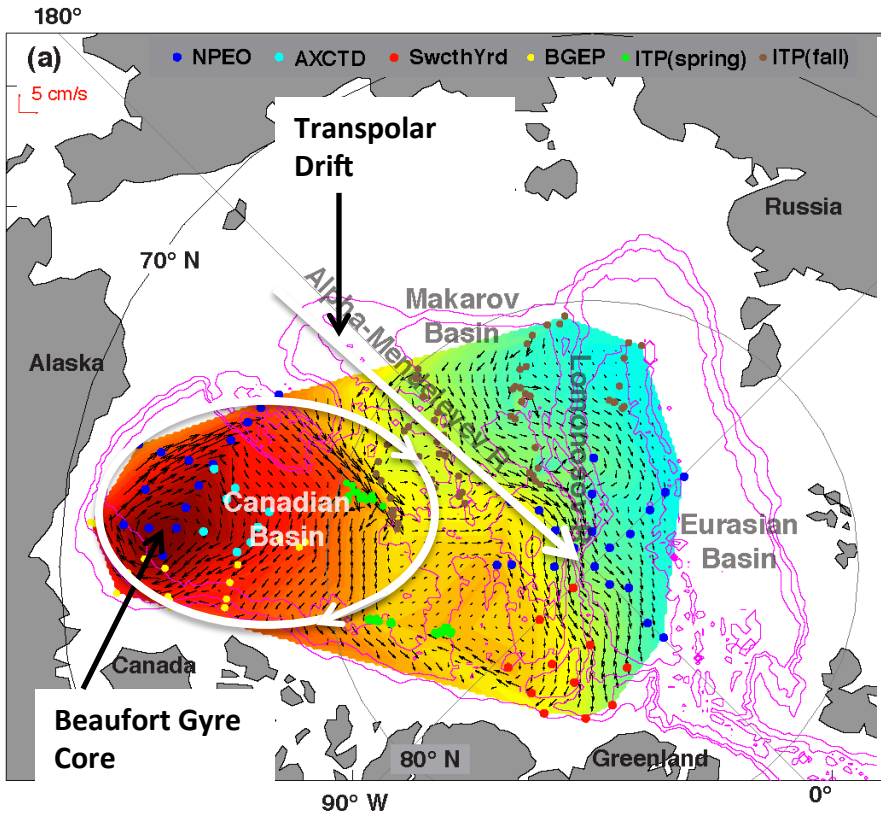
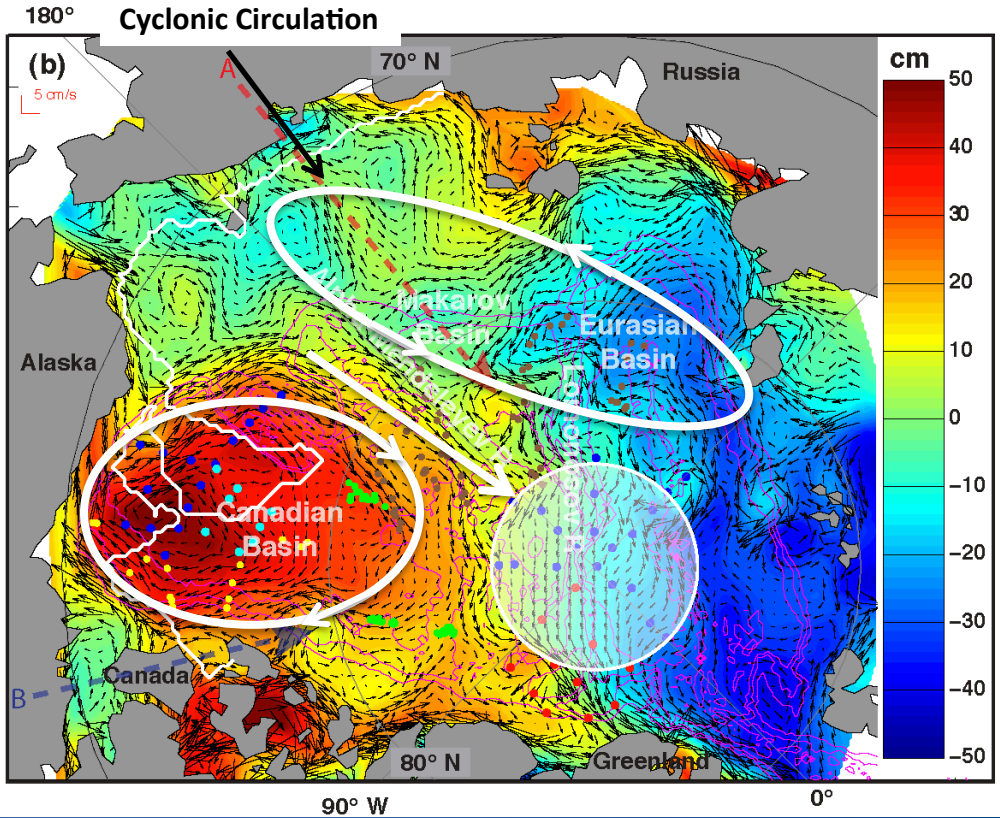
Anticyclonic view is a natural outcome of measurements concentrated in west longitudes

Spring 2008 dynamic height and surface geostrophic current relative to 500 dbar from available hydrographic profiles show the Beaufort Gyre and Transpolar Drift

ICESat dynamic ocean topography (DOT) and surface geostrophic current reveal DOT trough and cyclonic circulation on the Russian side of the Arctic Ocean





- **Agreement between dynamic height and DOT (r = 0.92) => mostly baroclinic**

Kwok, R., and J. Morison (2011), Dynamic topography of the ice-covered Arctic Ocean from ICESat, *Geophysical Research Letters*, *38*(L02501), L02501.

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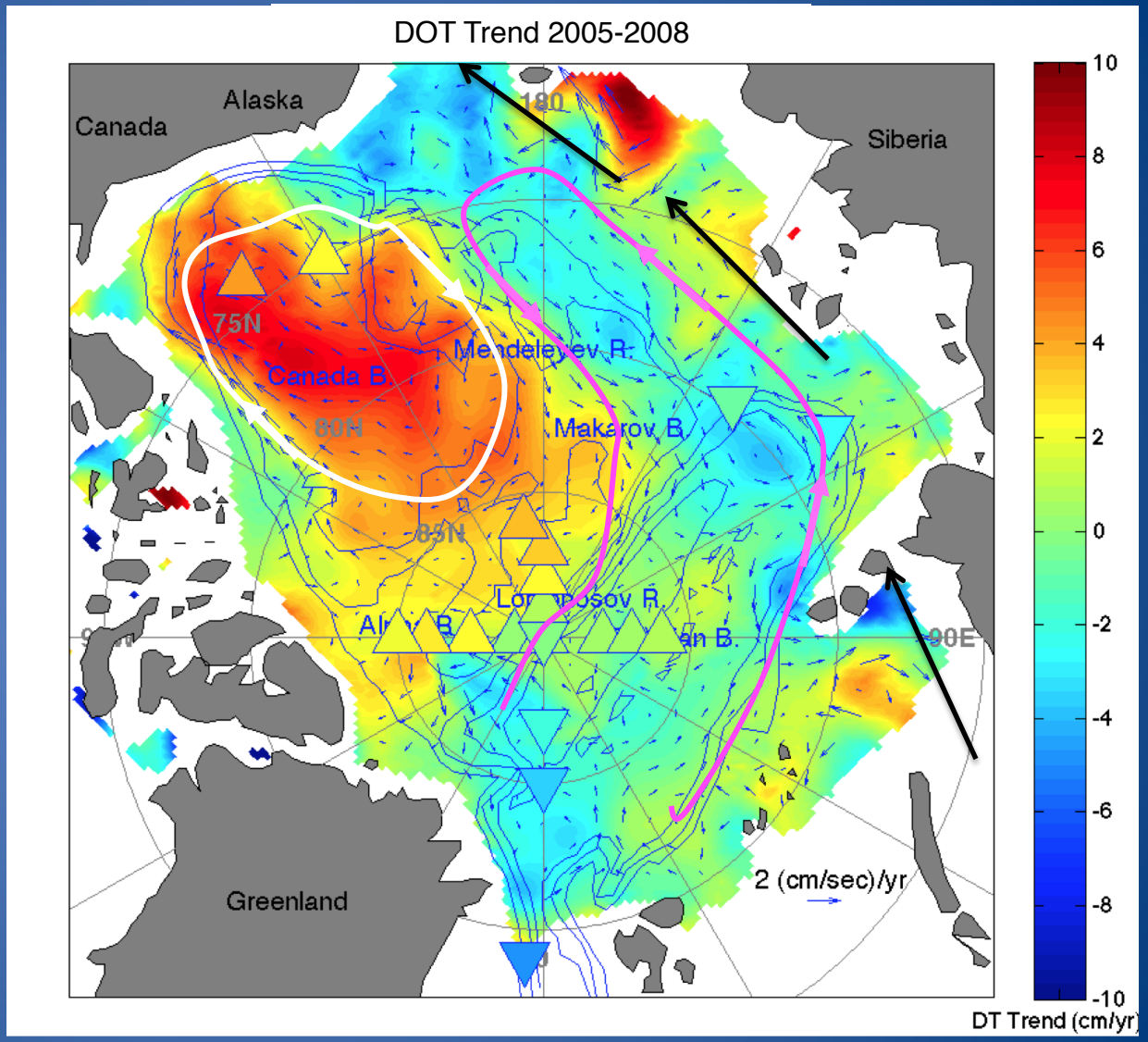
DOT Trend 2005-08 From ICESat Altimetry And From GRACE Bottom Pressure + CTD Steric Height (triangles)

DOT change 2005-2008 => shift to cyclonic mode.

More important for this presentation, the agreement between DOT and GRACE OBP plus Steric Height from repeat hydrography illustrates how the remote sensing (GRACE and ICESat) and in situ measurements combine to increase the scope of polar ocean observations.



ICESat & GRACE

In Situ Hydro

[Morison, J., R. Kwok, C. Peralta-Ferriz, M. Alkire, I. Rigor, R. Andersen, and M. Steele (2012), Changing Arctic Ocean freshwater pathways, *Nature*, *481*(7379), 66-70.