PICES Annual Science Meeting
S9: Variability in advection and its biological consequences for Subarctic and Arctic ecosystems
Yeosu, Korea October 21, 2014

Some effects of advection between the Arctic and Subarctic

Ken Drinkwater
IMR & BCCR, Bergen

INSTITUTE OF MARINE RESEARCH

Ecosystem Studies of Sub-Arctic Seas
ESSAS

IMBER

PICES Annual Science Meeting
S9: Variability in advection and its biological consequences for Subarctic and Arctic ecosystems
Yeosu, Korea October 21, 2014

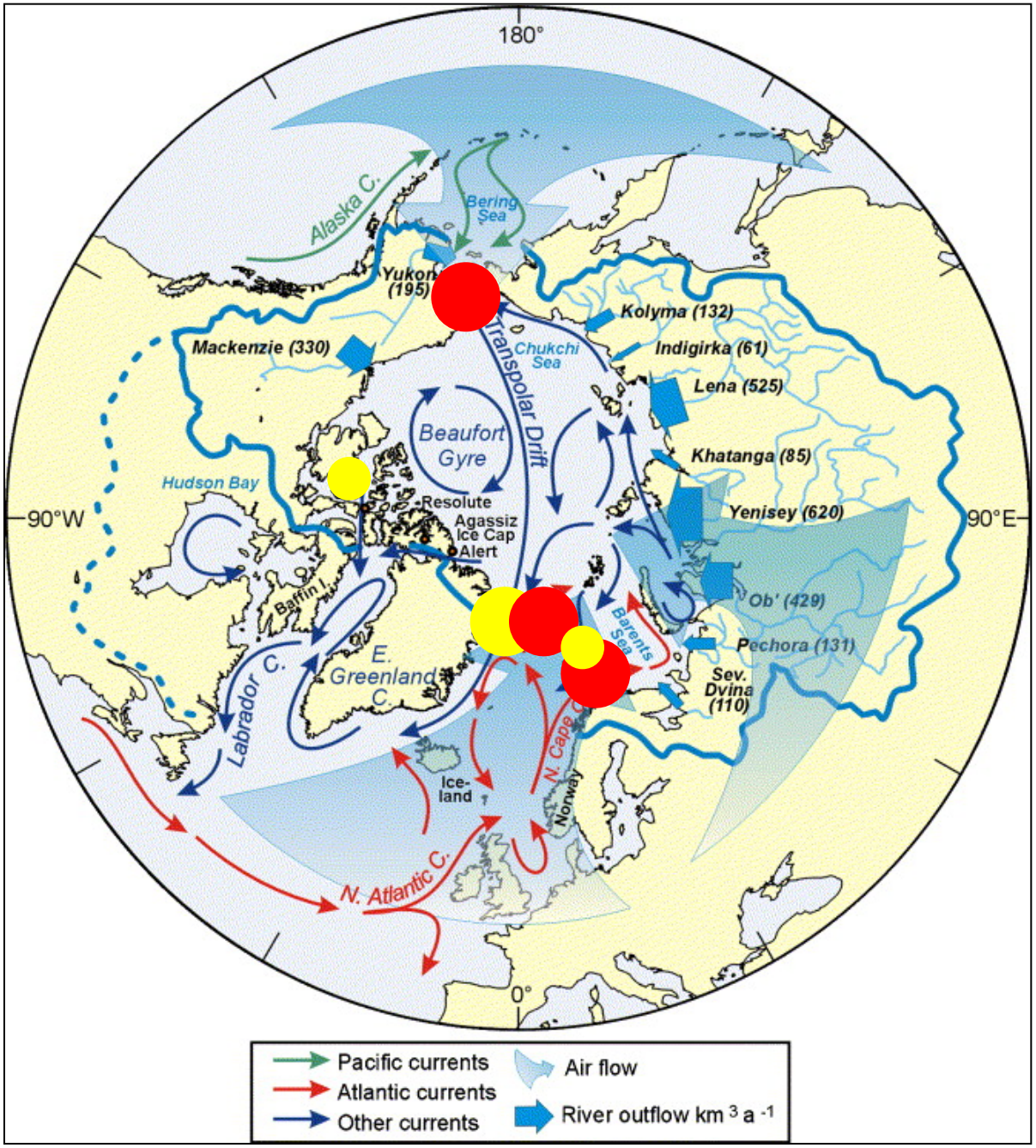
Some effects of advection from the Arctic to the Subarctic

Ken Drinkwater
IMR & BCCR, Bergen

INSTITUTE OF MARINE RESEARCH

Ecosystem Studies of Sub-Arctic Seas
ESSAS

IMBER

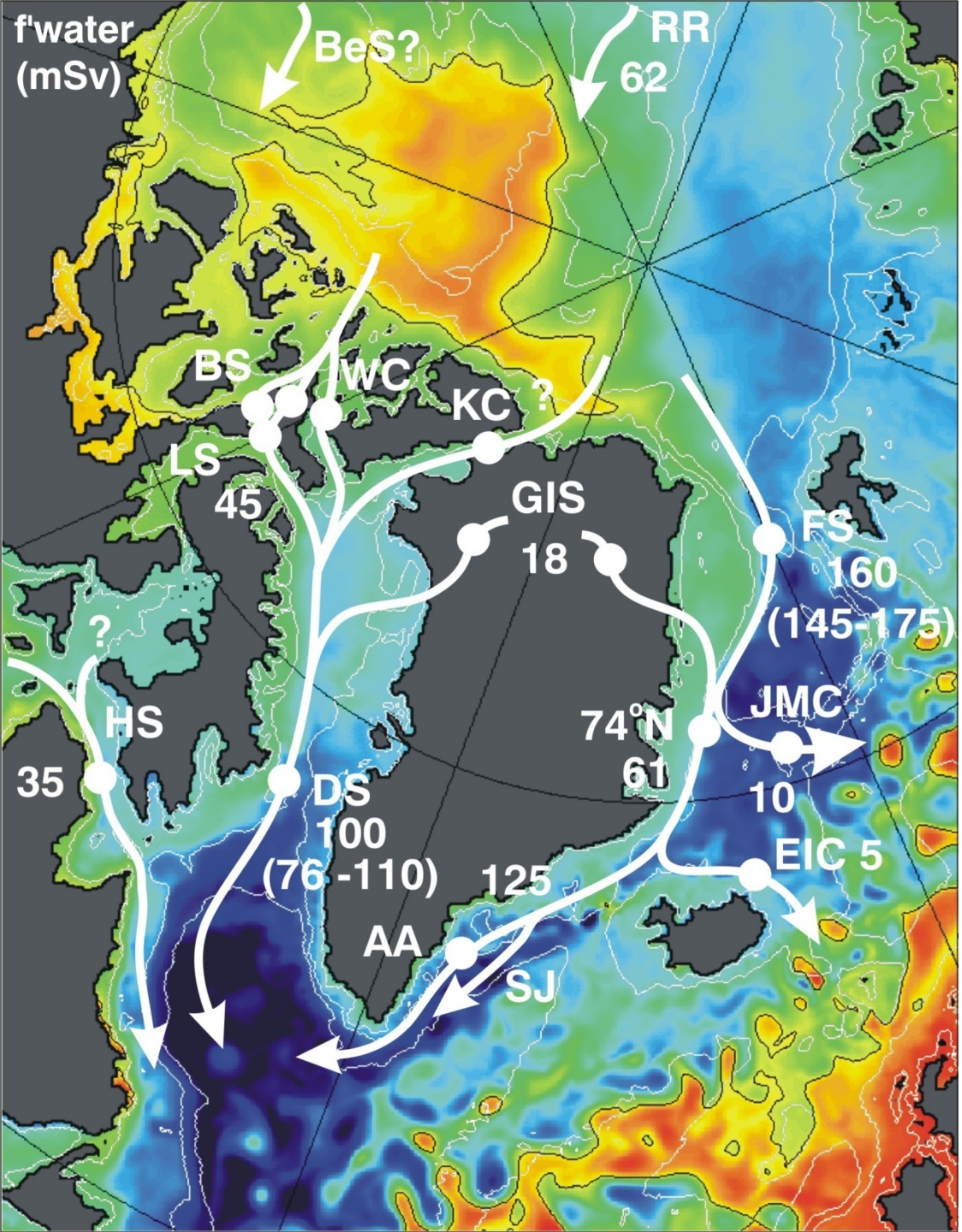


Advection between the Arctic and Subarctic

Inflow

Outflow

Note: Bering Strait flow is mostly one way and shallow while in Fram Stait it is two-way and deep.



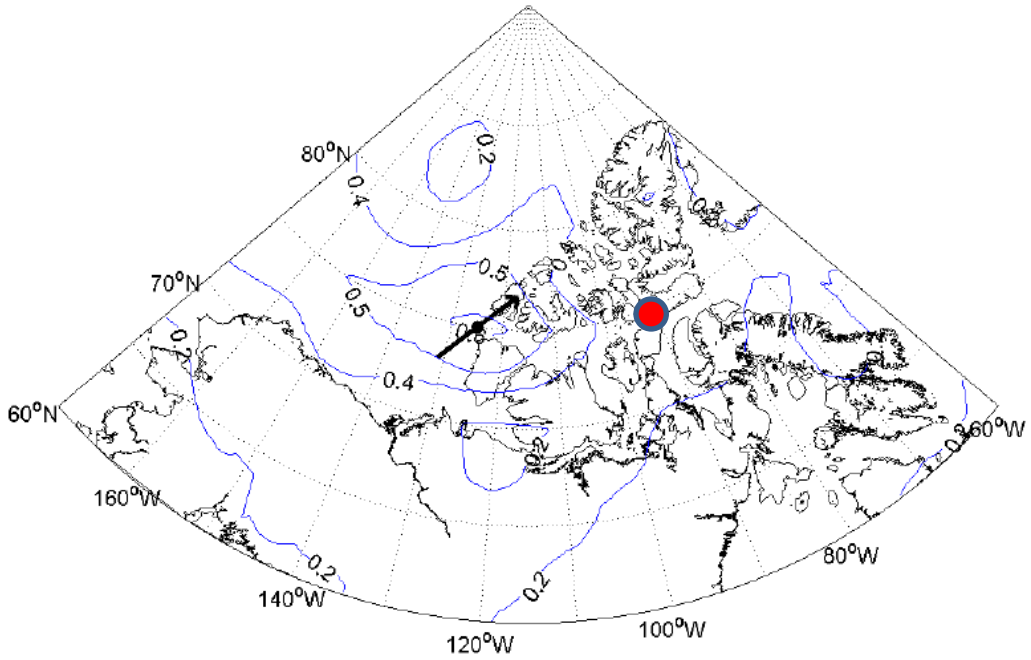
Freshwater Outflows

Fram Strait: 160 mSv
Canadian Archipelago: 82 mSv

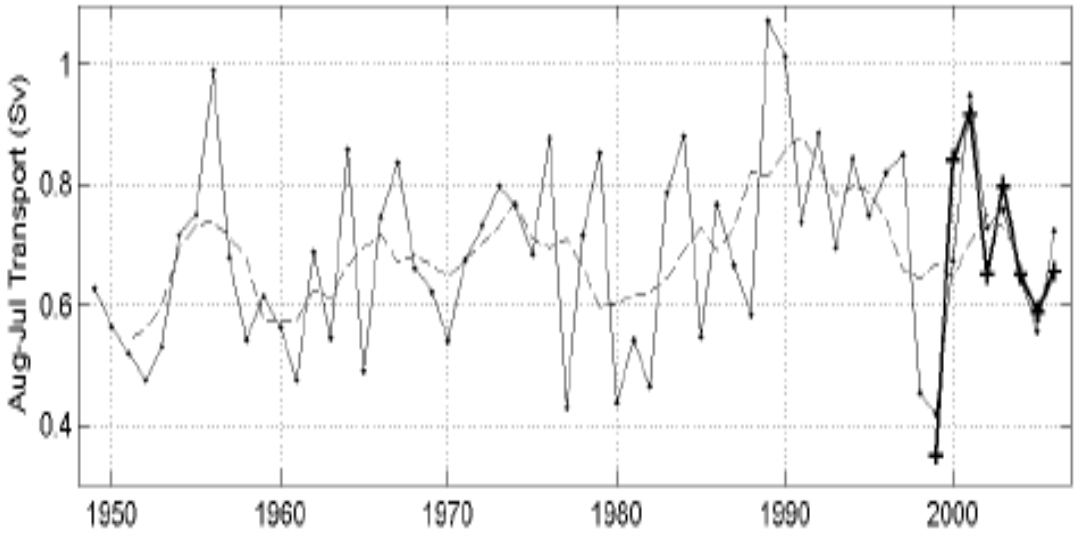
In recent years there has been a build up of freshwater in Beaufort Sea in association with a change in Arctic circulation pattern.

Dickson et al., 2008

Circulation through the CAA



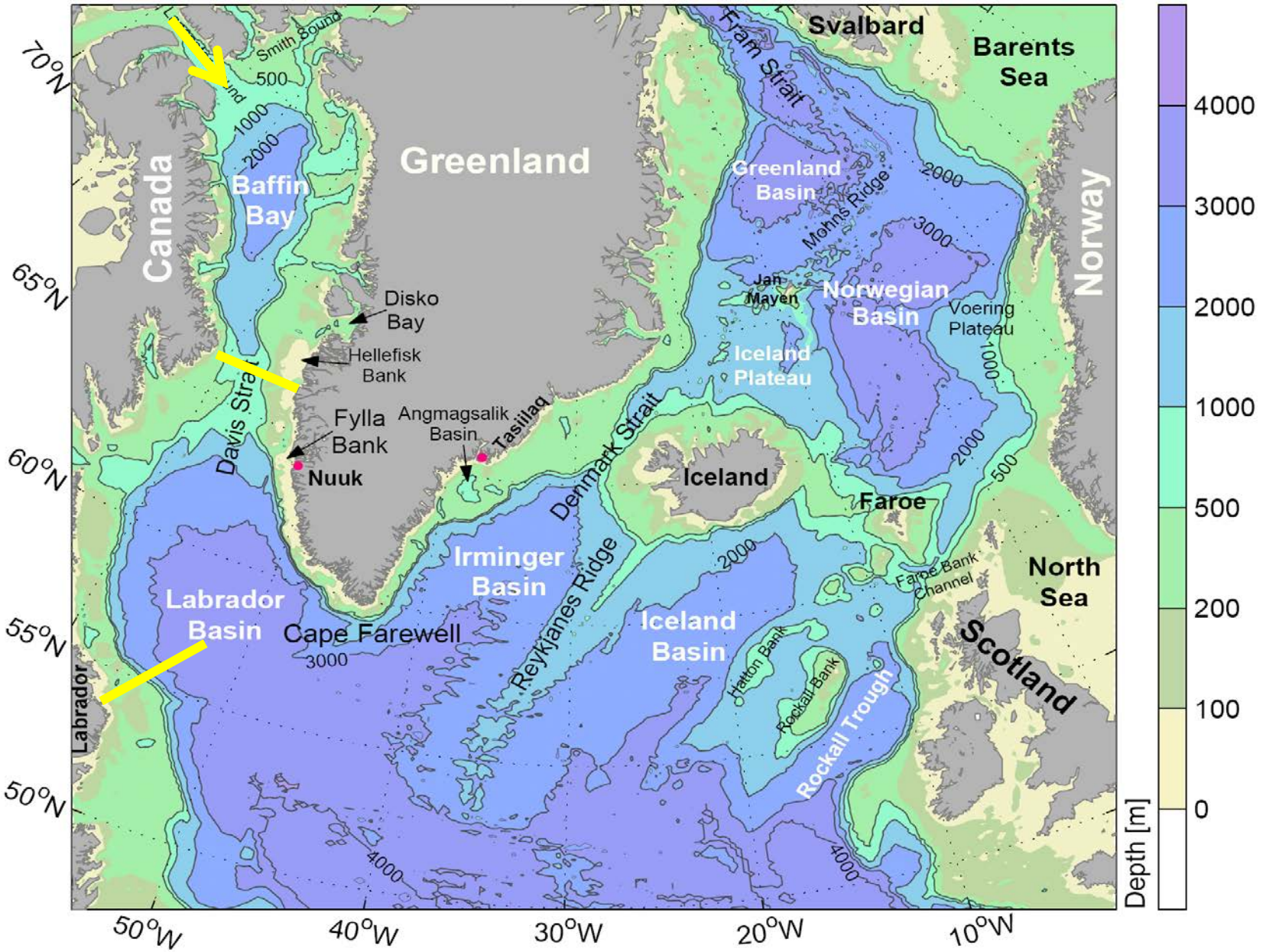
Correlation between monthly mean NCEP winds and volume transport in Barrow Strait (at red dot). Arrow represents direction that maximizes correlation.



Modelled transport (through Barrow Strait solid line) with 5 yr running mean (dashed line) with observations (heavy solid line)

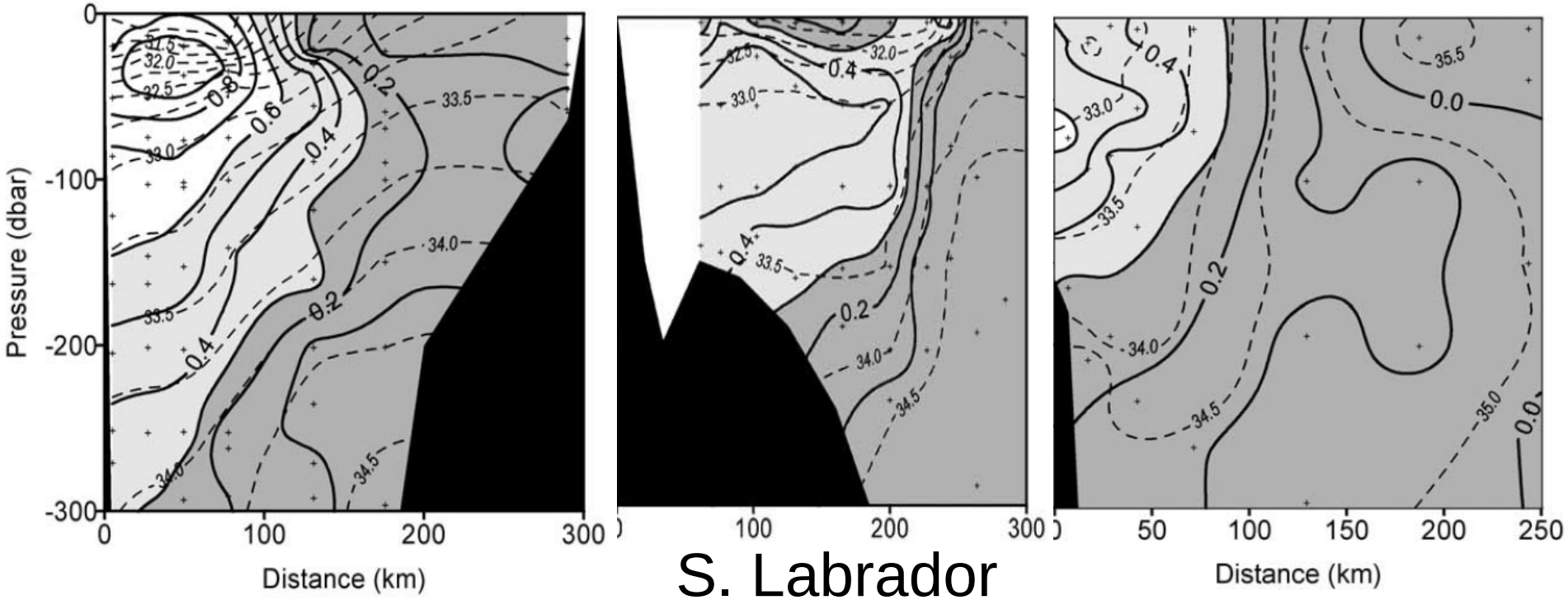
Peterson et al., 2008

Tracing the CAA through flows



Mads Ribbergaard, DMI

Tracing the CAA through flows

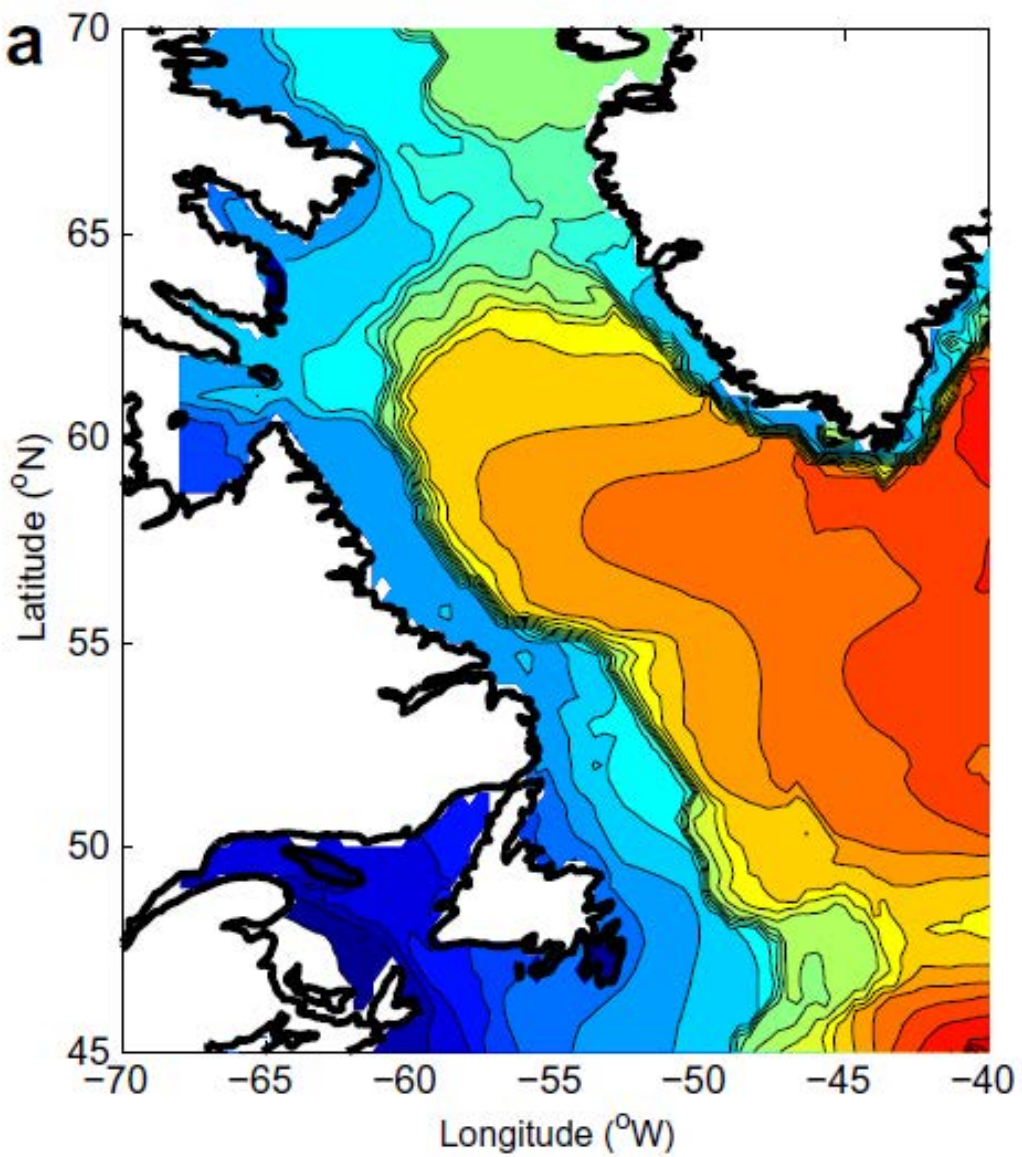


Davis Strait S. Labrador Shelf Grand Banks

Pacific source waters in the Arctic can be traced through their N:P ratios. Panels show salinity and percent Pacific Water. As far south as off Newfoundland and on the Grand Banks, they still make up ~40-60% of the shelf water mass.

Jones et al., 2003

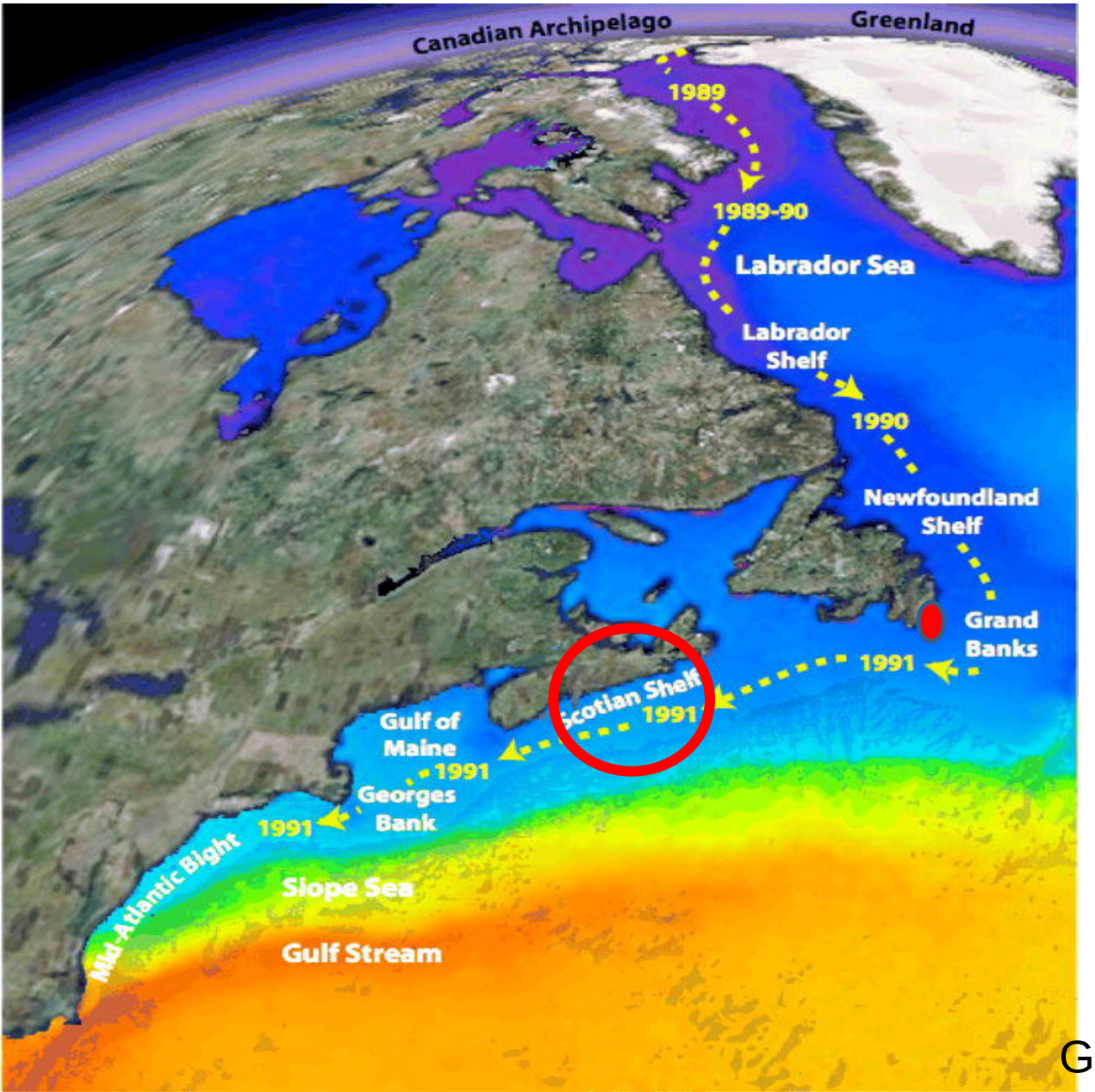
Labrador Sea Surface Salinity



Salinities reflect the circulation pattern with the coldest and freshest waters on the Labrador coast. The low salinities in the Gulf of St. Lawrence are due to the runoff from the St. Lawrence River system. Note low salinities off West Greenland.

Myers et al., 2009

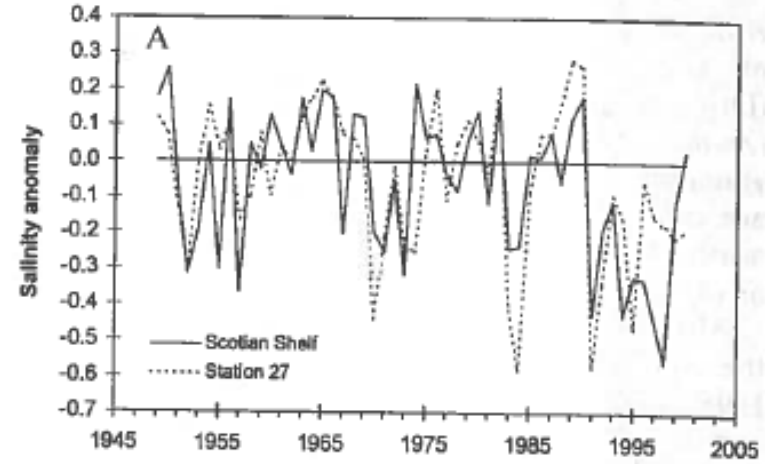
Advection of Freshwater

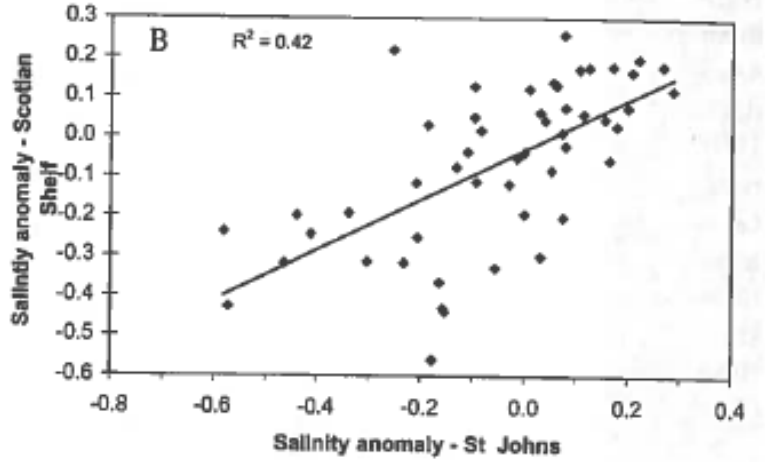


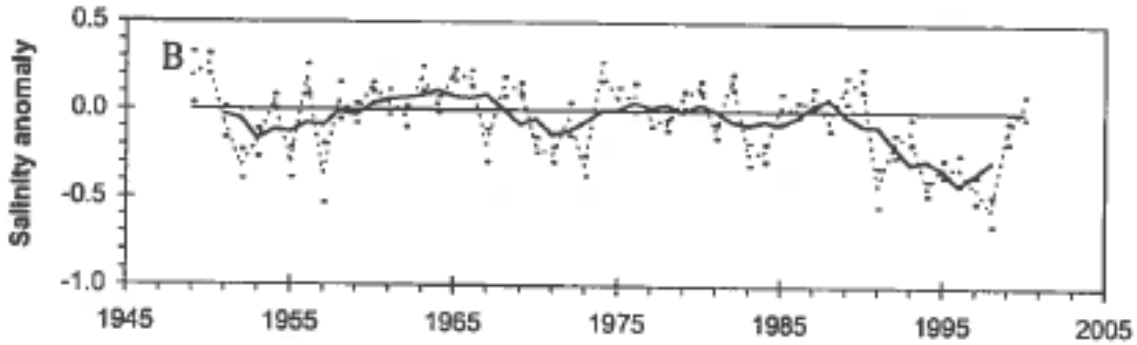
Freshwater from Arctic has been traced even farther south to the Scotian Shelf, Gulf of Maine and the Middle Atlantic Bight where it has been suggested that it affects stratification.

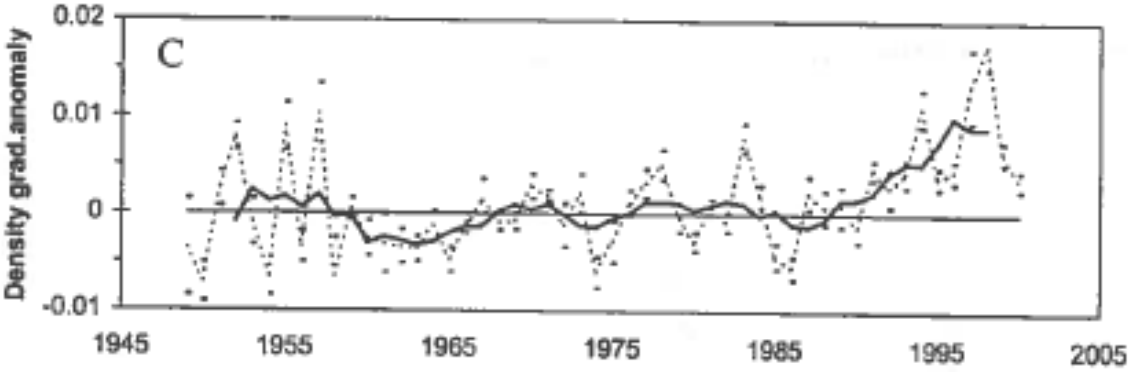
Greene et al., Ecology, 2008

Effects on Scotian Shelf Stratification



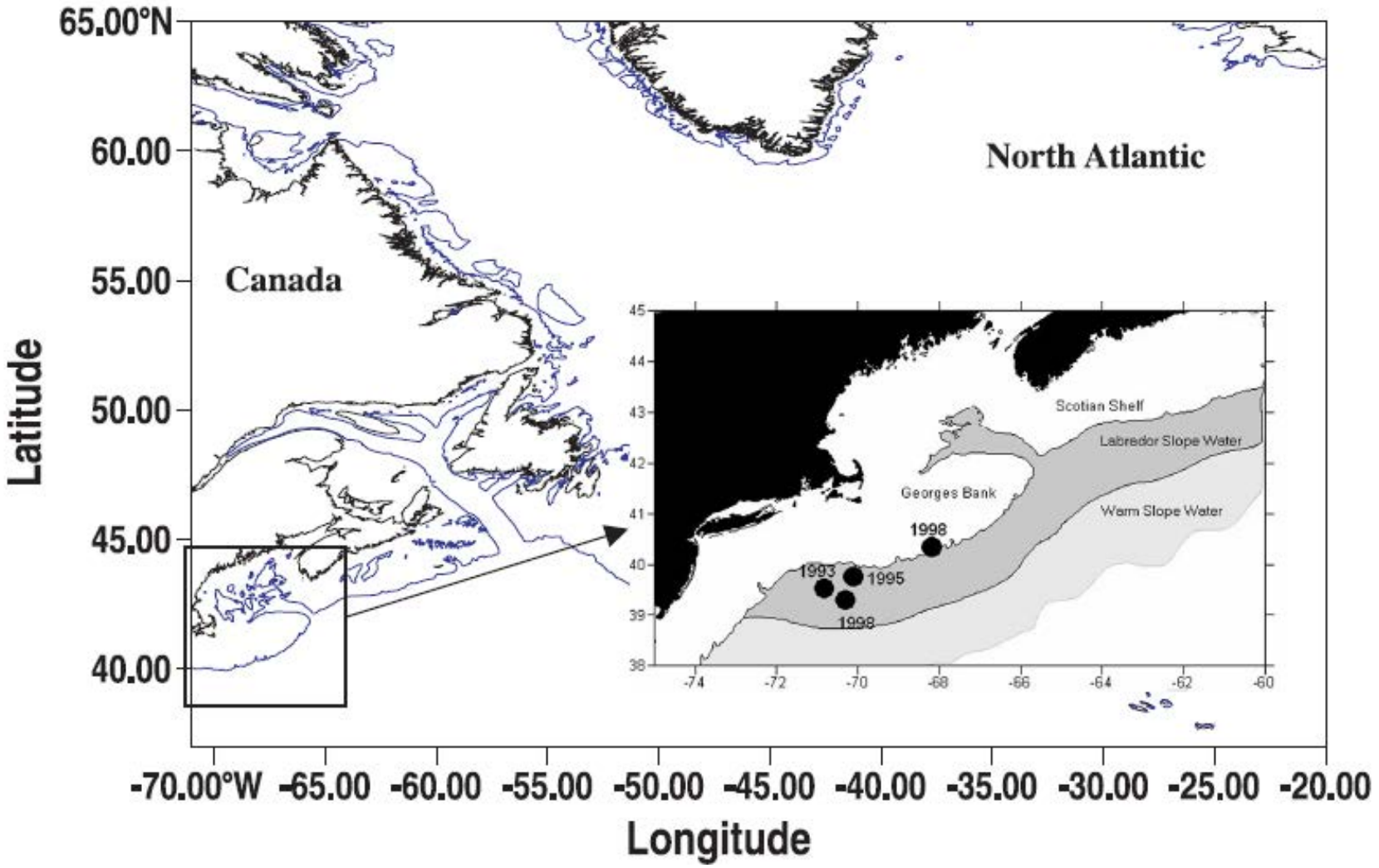






Salinity on the Scotian Shelf is determined to a large extent by advection from upstream (off Newfoundland) as indicated by the similarity in salinity anomalies. Salinity mainly determines the density stratification, hence stratification on the Scotian Shelf is largely controlled by advective processes.

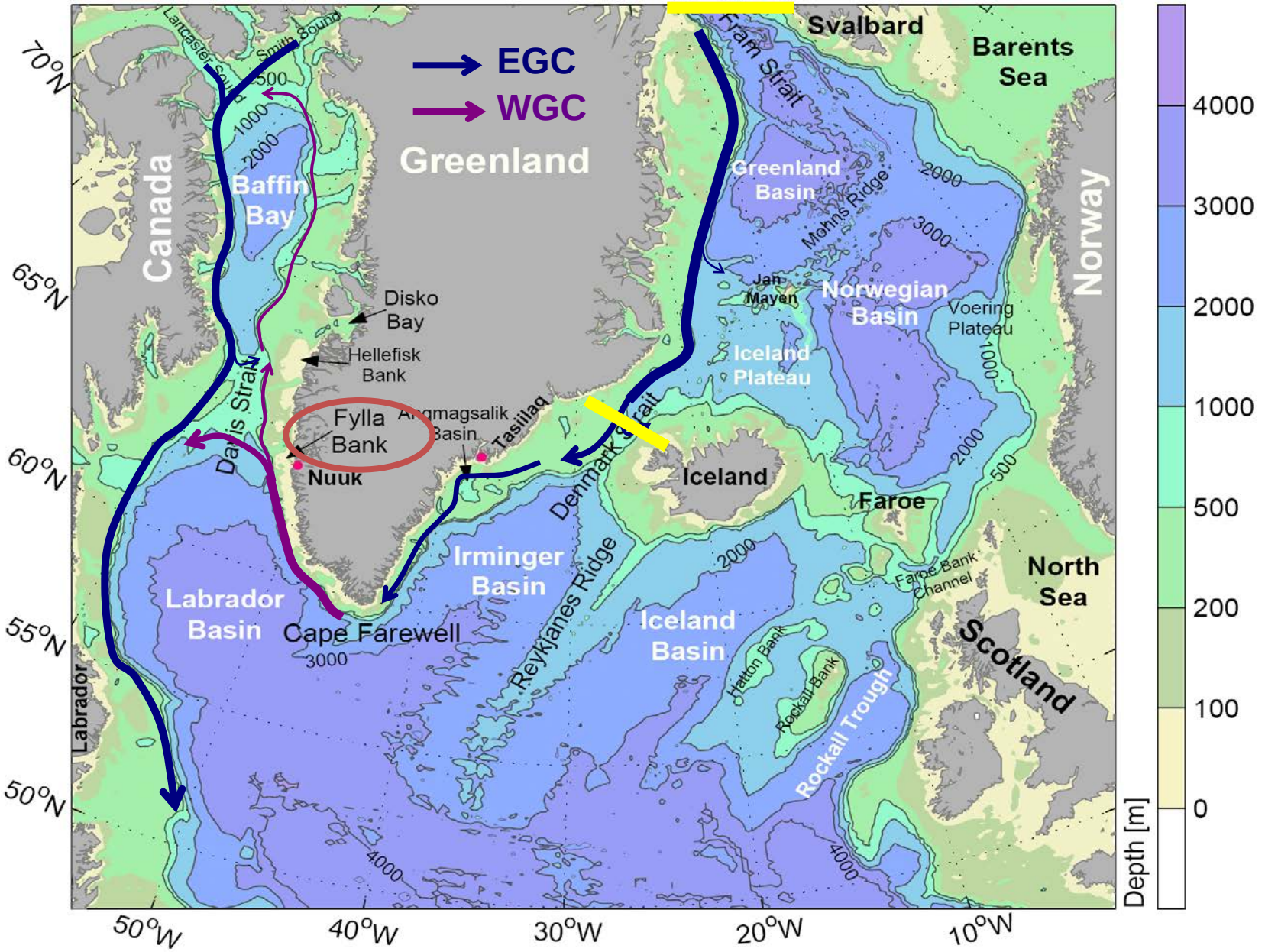
Effects on Zooplankton Distribution



The southern most extent of the *Calanus hyperboreous* in late 1990s.

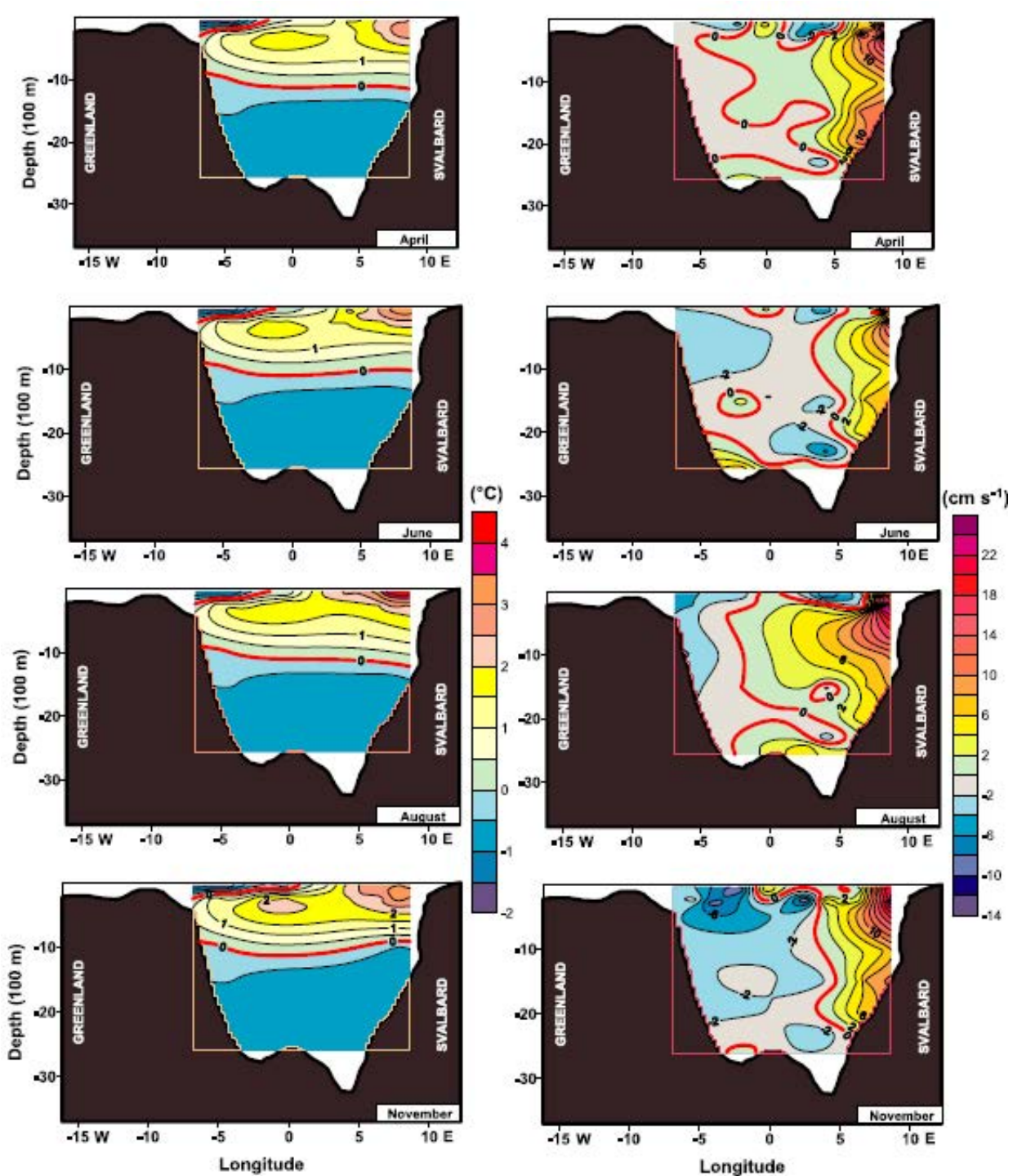
Johns et al., 2001

Tracking the Arctic Waters from Fram Strait



Mads Ribbergaard, DMI

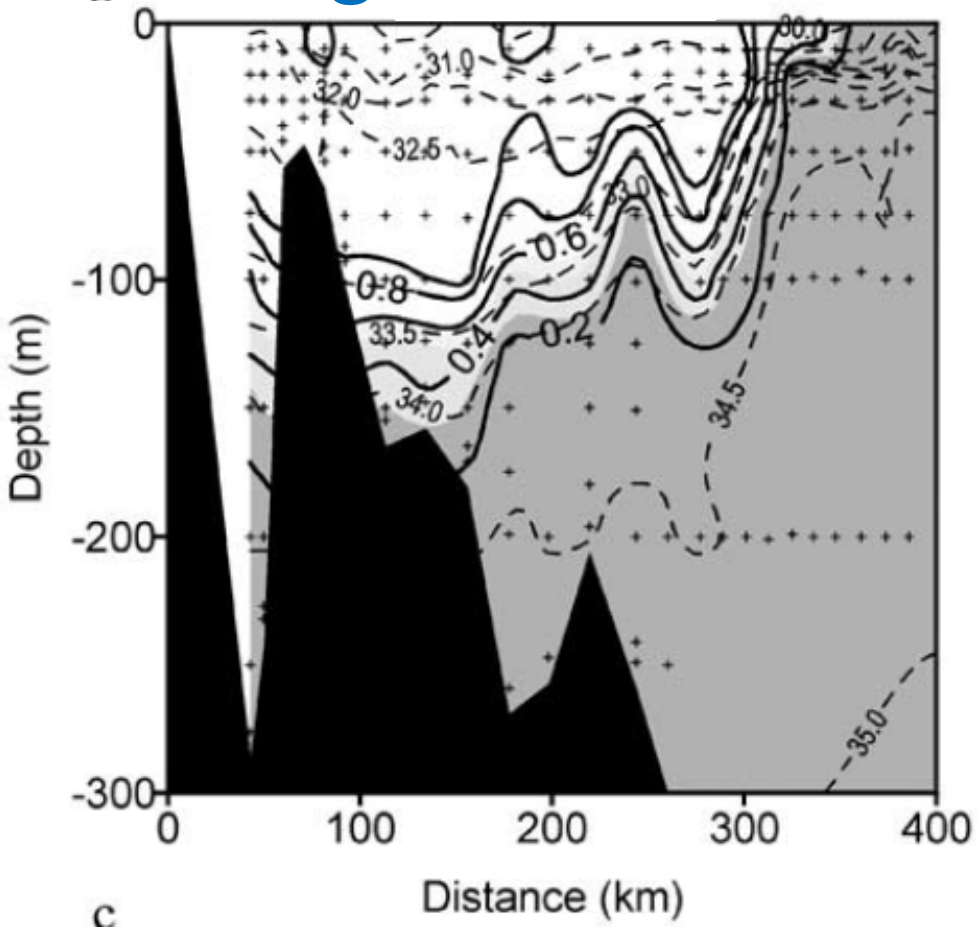
Fram Strait

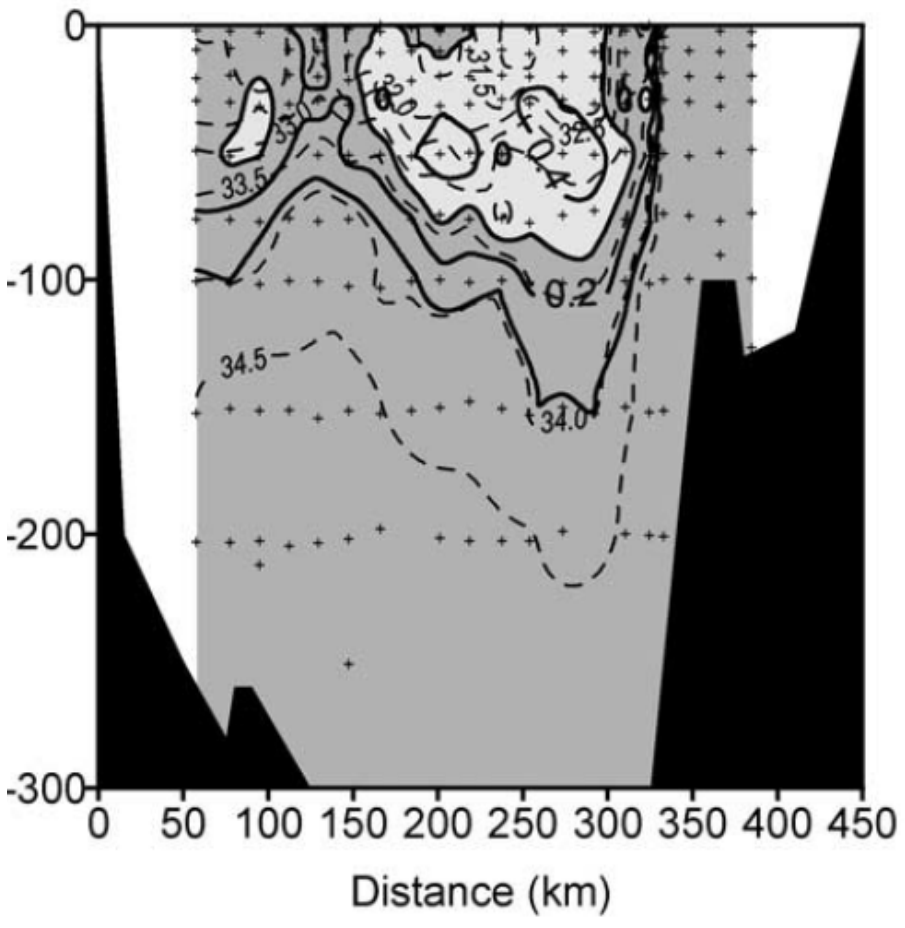


Coldest water coming through Fram Strait (left panels) is in upper layers towards the Greenland Shelf. The flow south on the western side of the Strait (right panels) shows no seasonality.

Hop et al., 2006

Tracking the Arctic Waters from Fram Strait



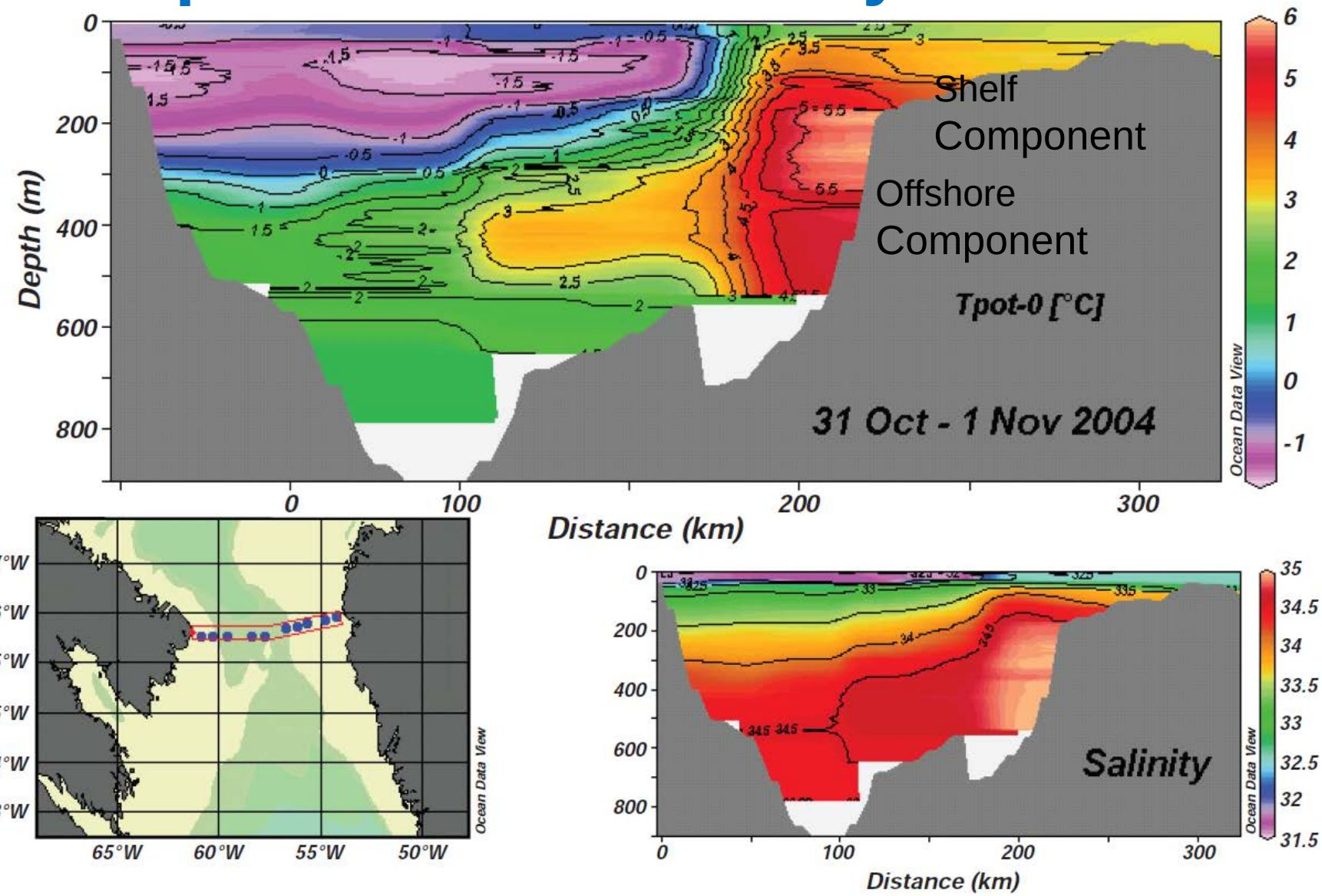


Fram Strait Denmark Strait

Little Pacific Water makes it past Cape Farewell however ice does influence W Greenland Current.

Jones et al., 2003

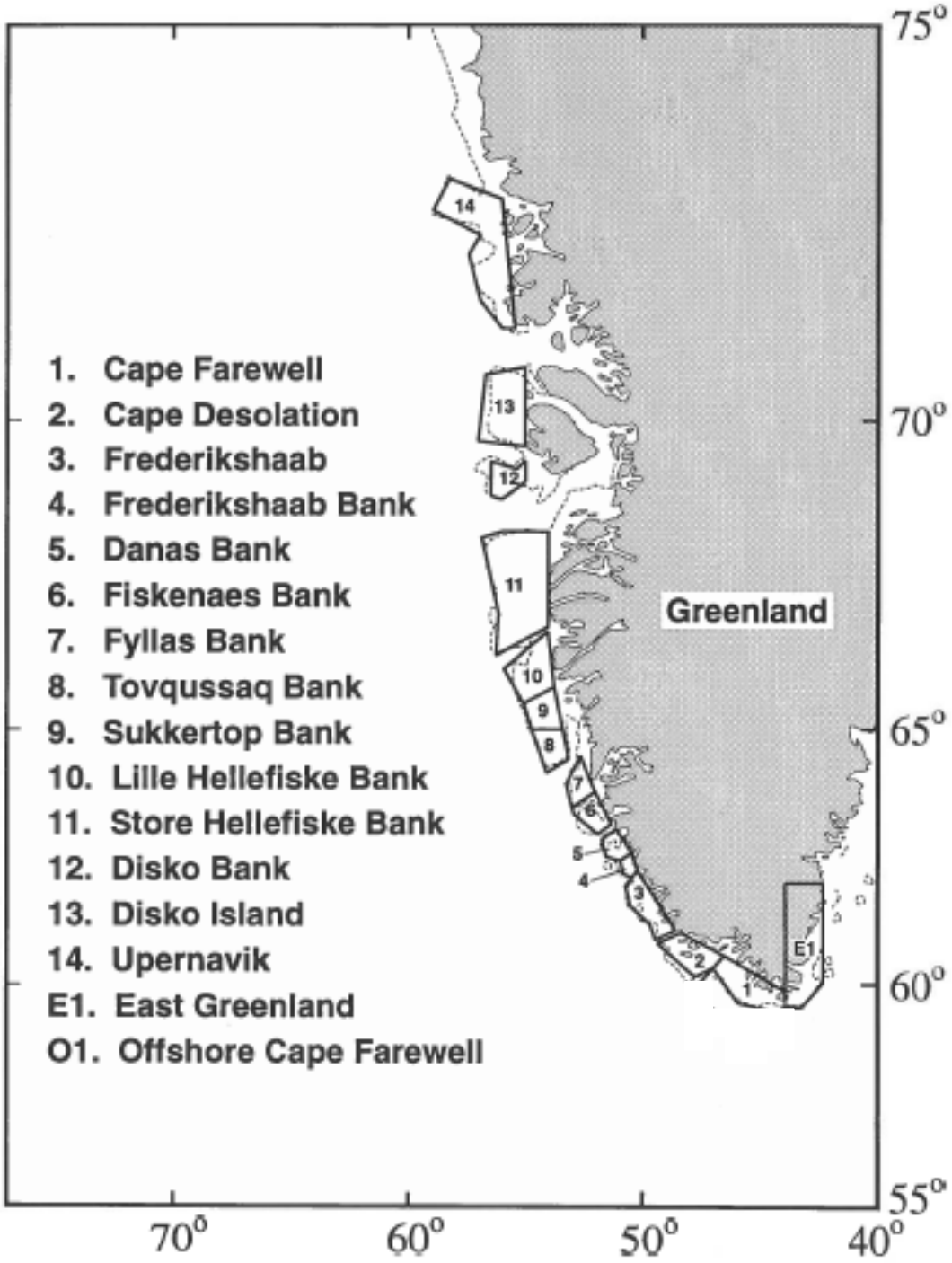
Temperature and Salinity Structure



Hydrographic Section across Davis Strait

Stein, 2005

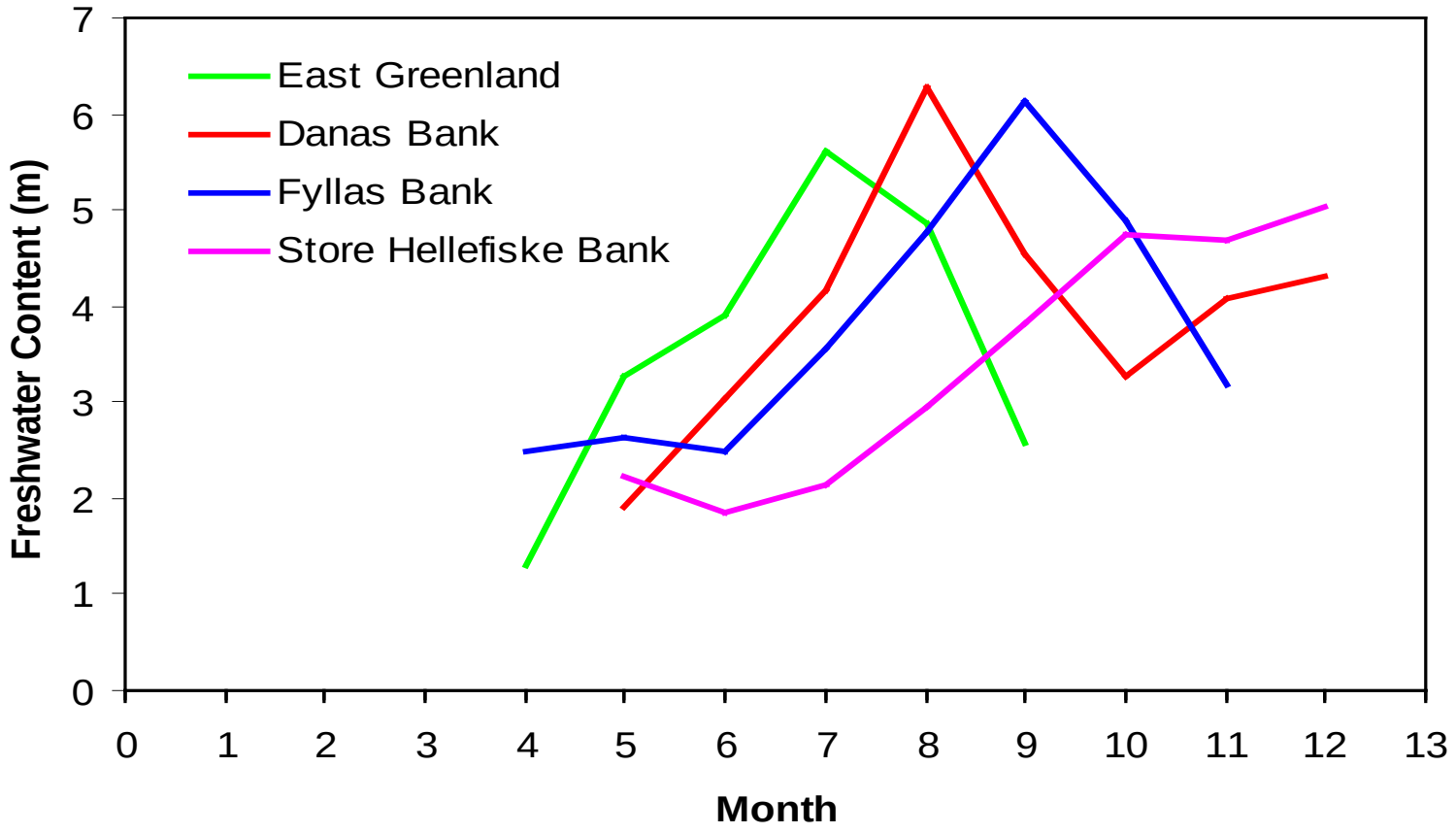
Hydrographic Data



Divided the West Greenland Shelf into 14 areas by topography and 1 area off East Greenland. Stations 200 m or less to ensure shelf data.

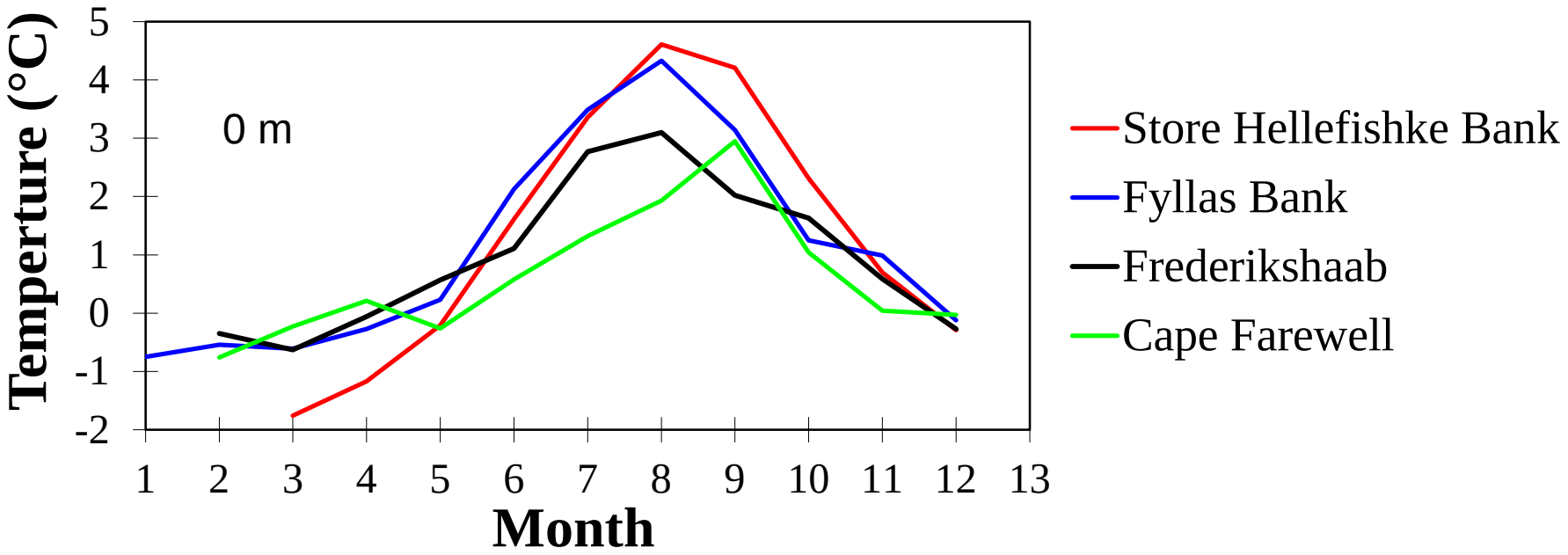
Assembled all hydrographic data from 1920s to 2002 in these areas, averaged within areas by month for each available year and then averaged all available years to estimate monthly mean temperature, salinity and density.

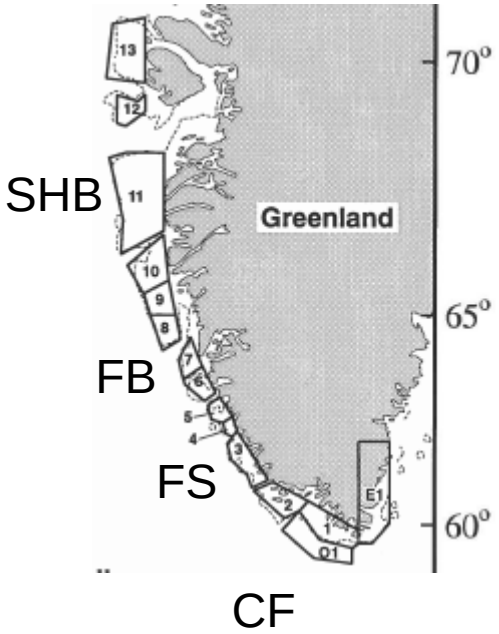
Monthly change in Freshwater Content



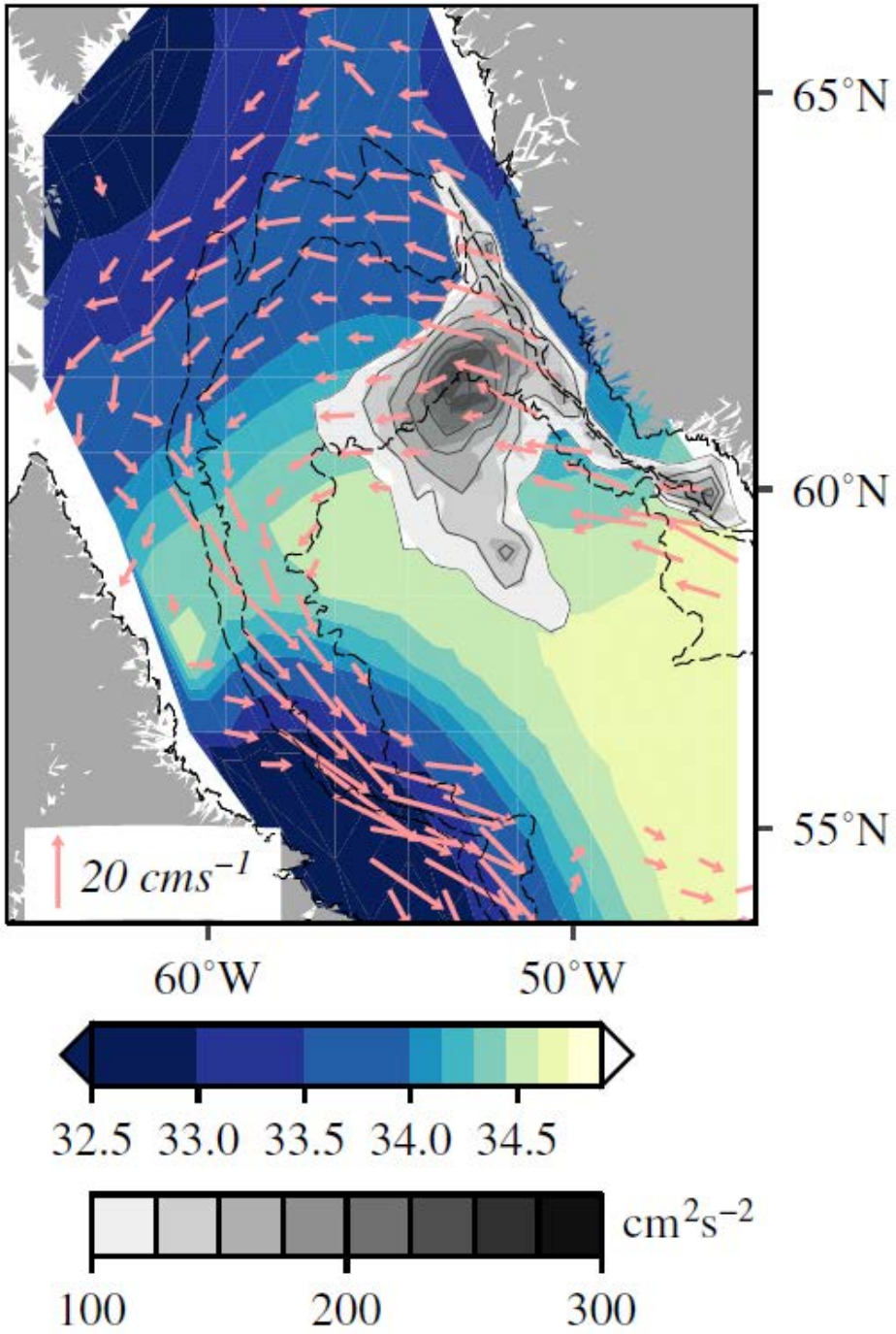
The freshwater content in top 100 m (relative to 34.5) shows strong seasonality peaking later in the year as one moves northward indicating advection. The peak off East Greenland is due to ice melt. There appears to be little loss of freshwater from East Greenland northwards through to at least Fyllas Bank.

Advection off West Greenland





Peak temperatures in top 50 m increase northward. Estimates of heat fluxes from COADS dataset suggest that the temperature increase is caused by atmospheric heating as water is advected north.

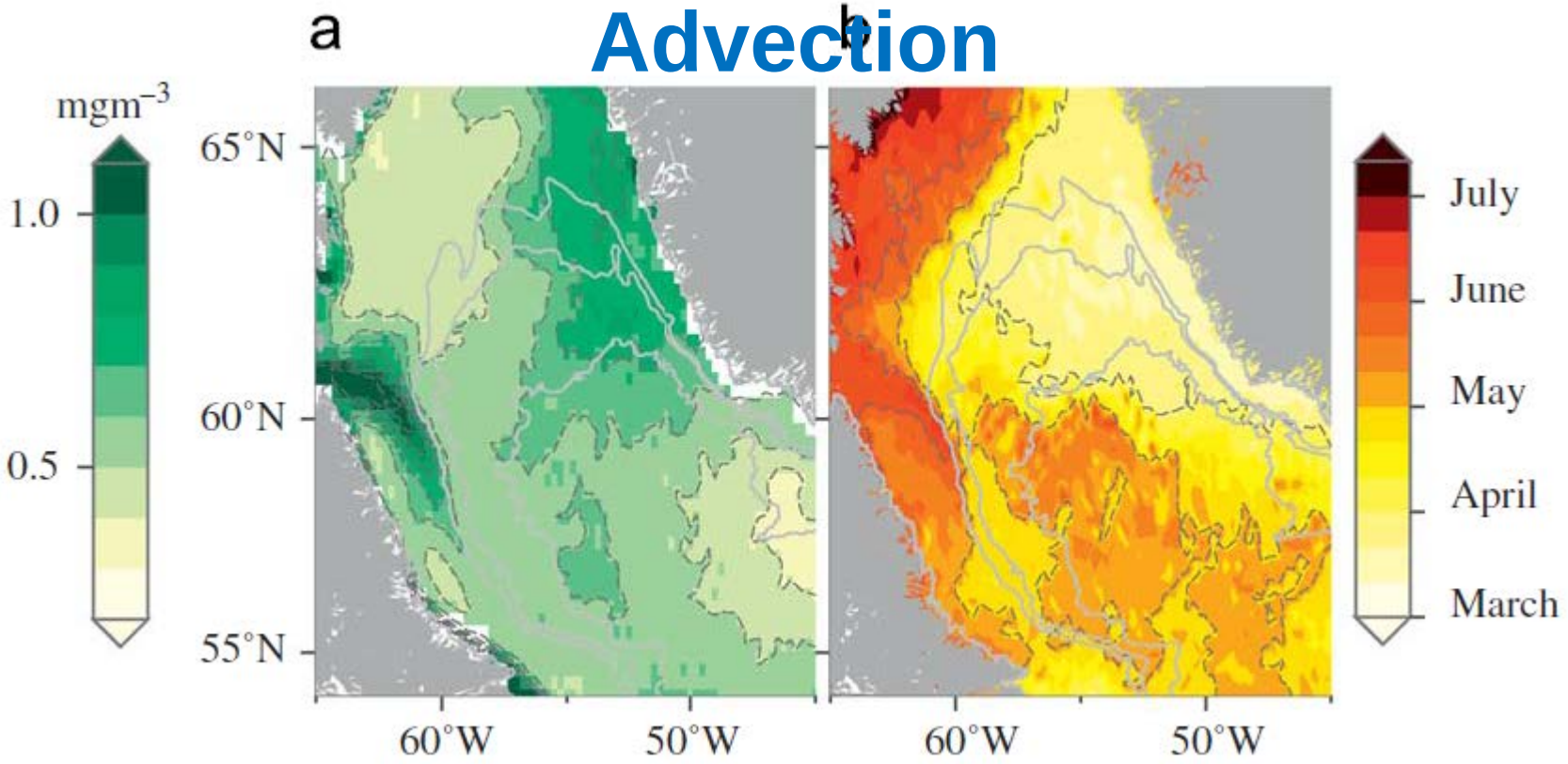


Circulation and Eddy Kinetic Energy

Strong eddy activity off West Greenland acts to advect low salinity waters from the shelf out into the Basin.

Frajka-Williams et al., 2009

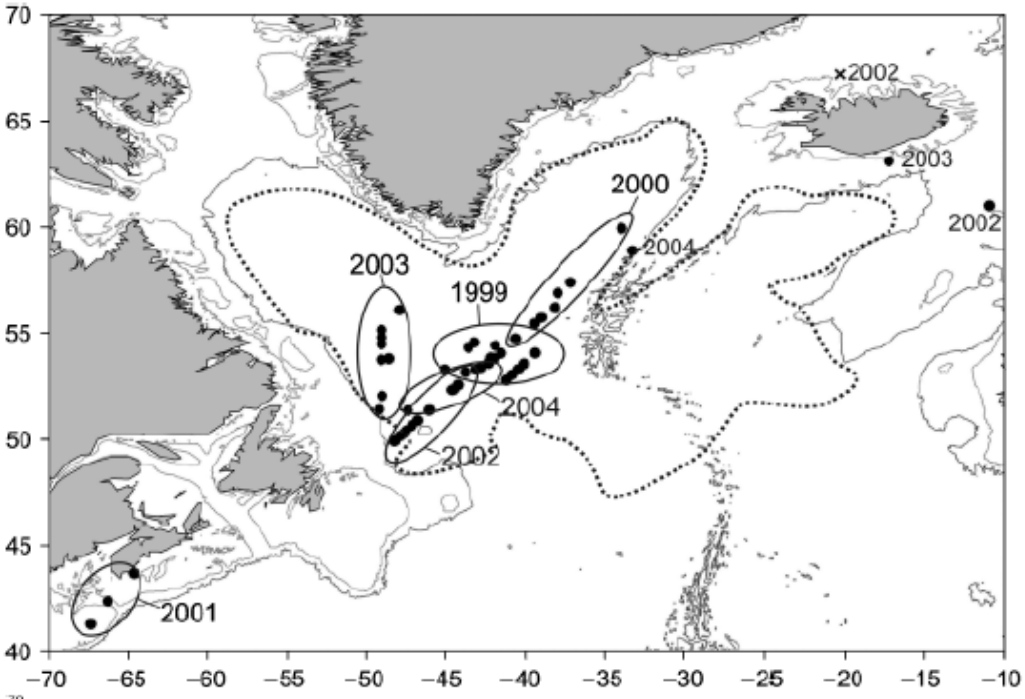
Implications of Offshore Freshwater Advection

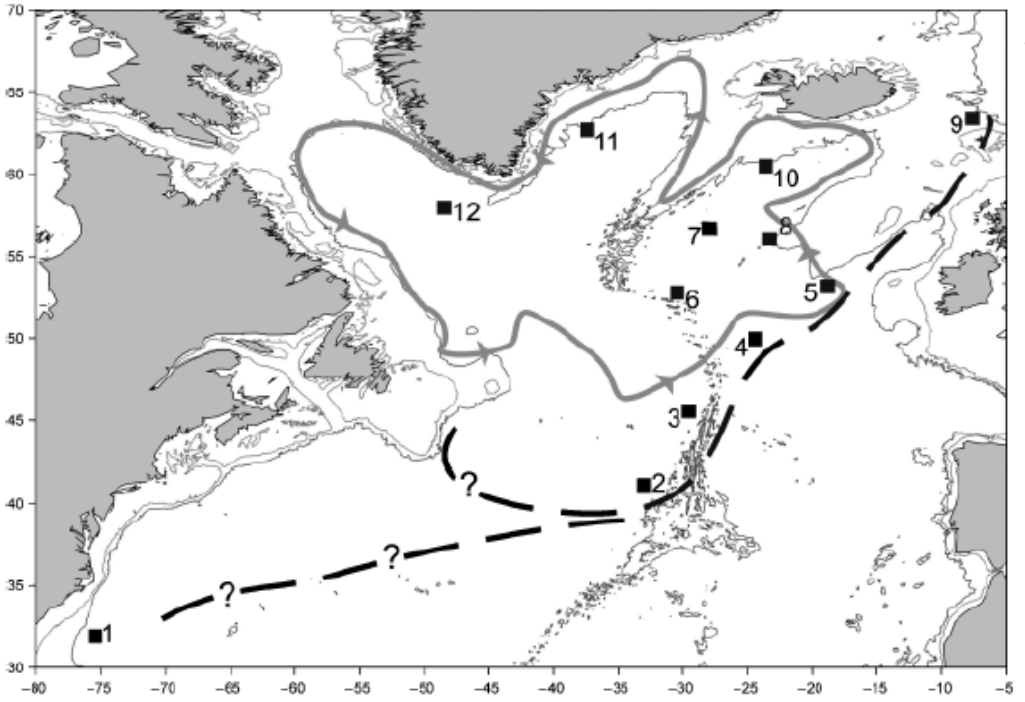


(a) Mean chlorophyll and (b) median start day of the phytoplankton bloom, from 1998 to 2008. Freshwater flux off the shelf provides stratification for initiation of the bloom.

Frajka-Williams and Rhines, 2010

Advection of Neodenticula Seminae



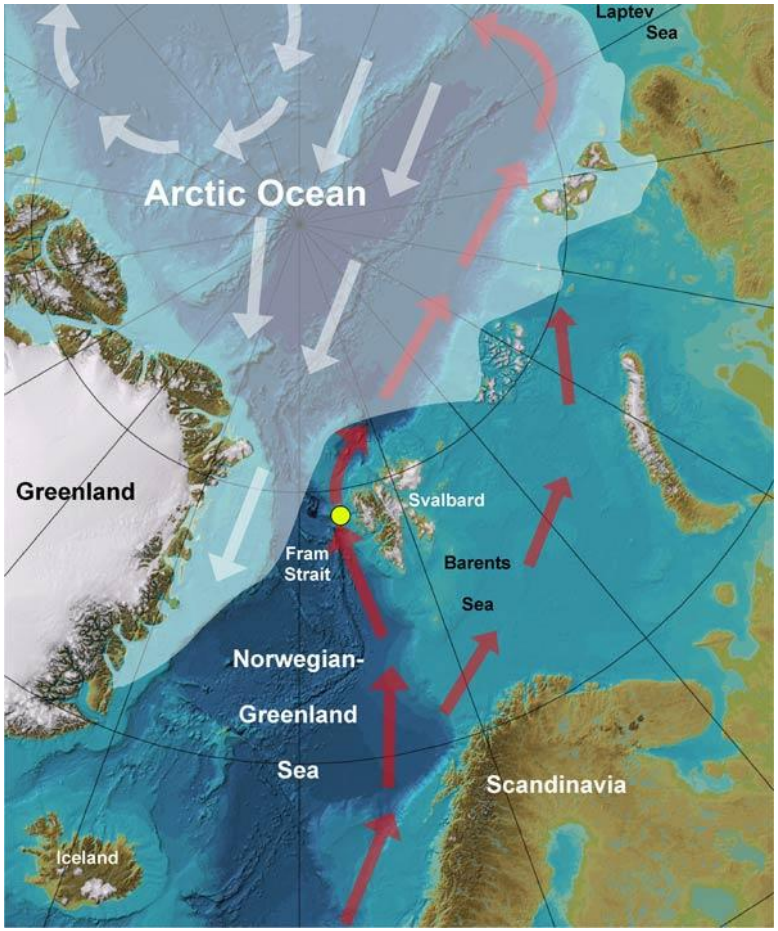


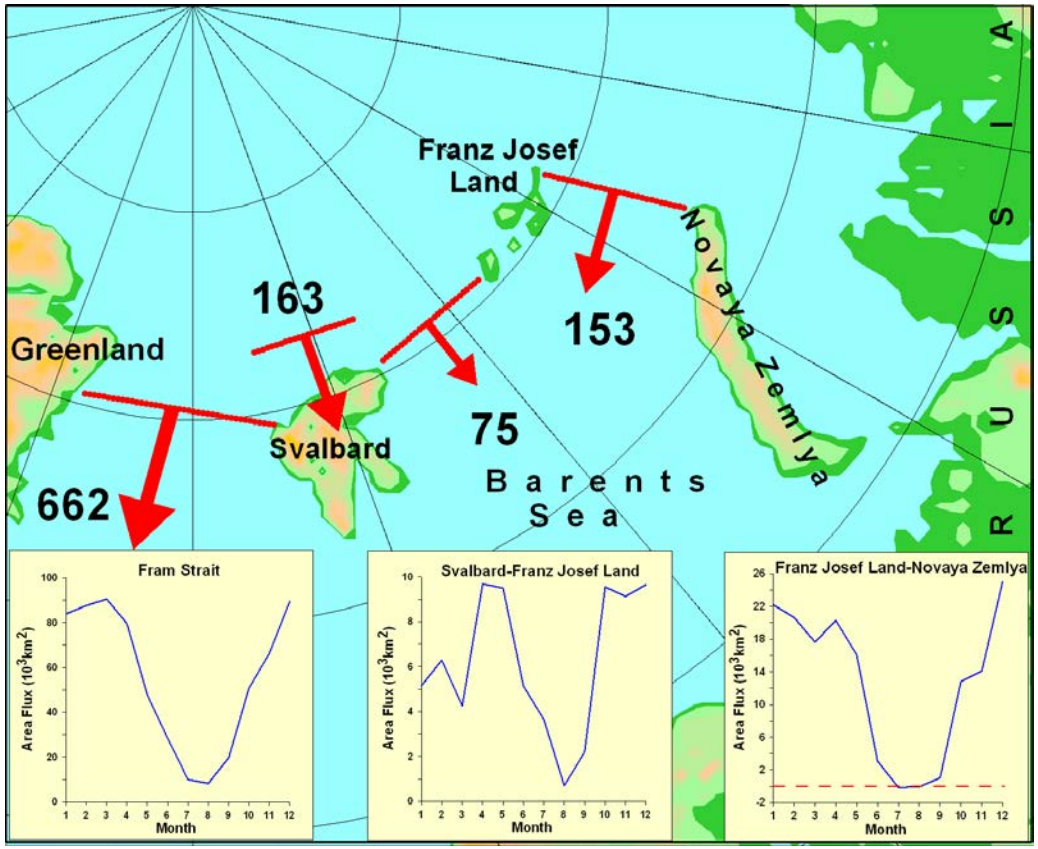
In late 1990s and early 2000s, the Pacific phytoplankton species Neodenticula Seminae was observed in the Atlantic for the first time in over 850,000 years.

Bottom panel shows southern distribution from paleo records (dashed line) and more recent data (solid line).

Reid et al., 2007

Ice advection out of the Arctic



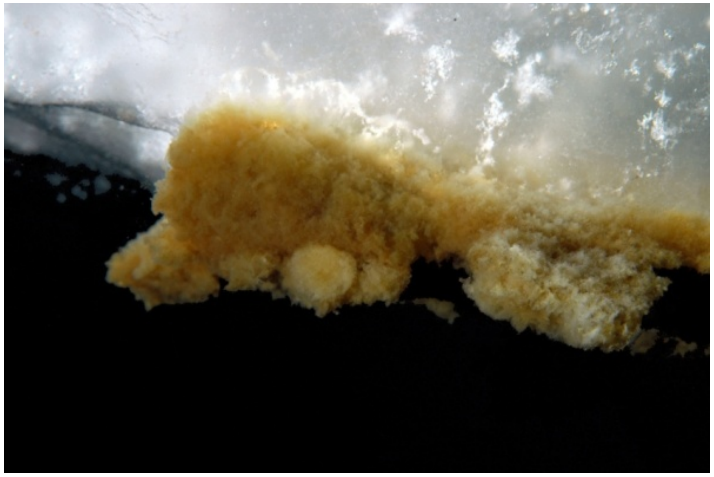


Mean annual sea ice area flux averaged for the period 1979-2006 (10^3 km^2)

Little to no ice transported out through Bering Strait.

Hop, H. & O. Pavlova. 2008. *Deep-Sea Research II 55*: 2292-2307.

Ice-associated Biomass Export from Arctic



Annual ice-associated biomass export from the Arctic Ocean:

Fram Strait: 922 × 10^3 t wet weight (106 × 10^3 t C)

Barents Sea: 99 x 10^3 t wet weight (12 x 10^3 t C)

Hop, H. & O. Pavlova. 2008. *Deep-Sea Research II 55*: 2292-2307.

Summary

- Flows from the Arctic into the North Atlantic advects significant amounts of freshwater which influences its salinity and stratification.
- This water extends far south on the western side of the North Atlantic and influences Arctic zooplankton distributions
- Sea ice from the Arctic also is advected into the Atlantic mainly through Fram Strait.
- This carries ice biota along East Greenland.
- Advection of freshwater from off West Greenland Shelf influences phenology of the phytoplankton production.

Bergy Bits off Cape Farewell,
Greenland, May 2013