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On the Role of Advection on the Interaction between Arctic and Subarctic Seas: Comparing the Atlantic and Pacific Sectors

Ken Drinkwater
IMR & BCCR, Bergen

INSTITUTE OF MARINE RESEARCH

Ecosystem Studies of Sub-Arctic Seas
ESSAS

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Effects of Advection

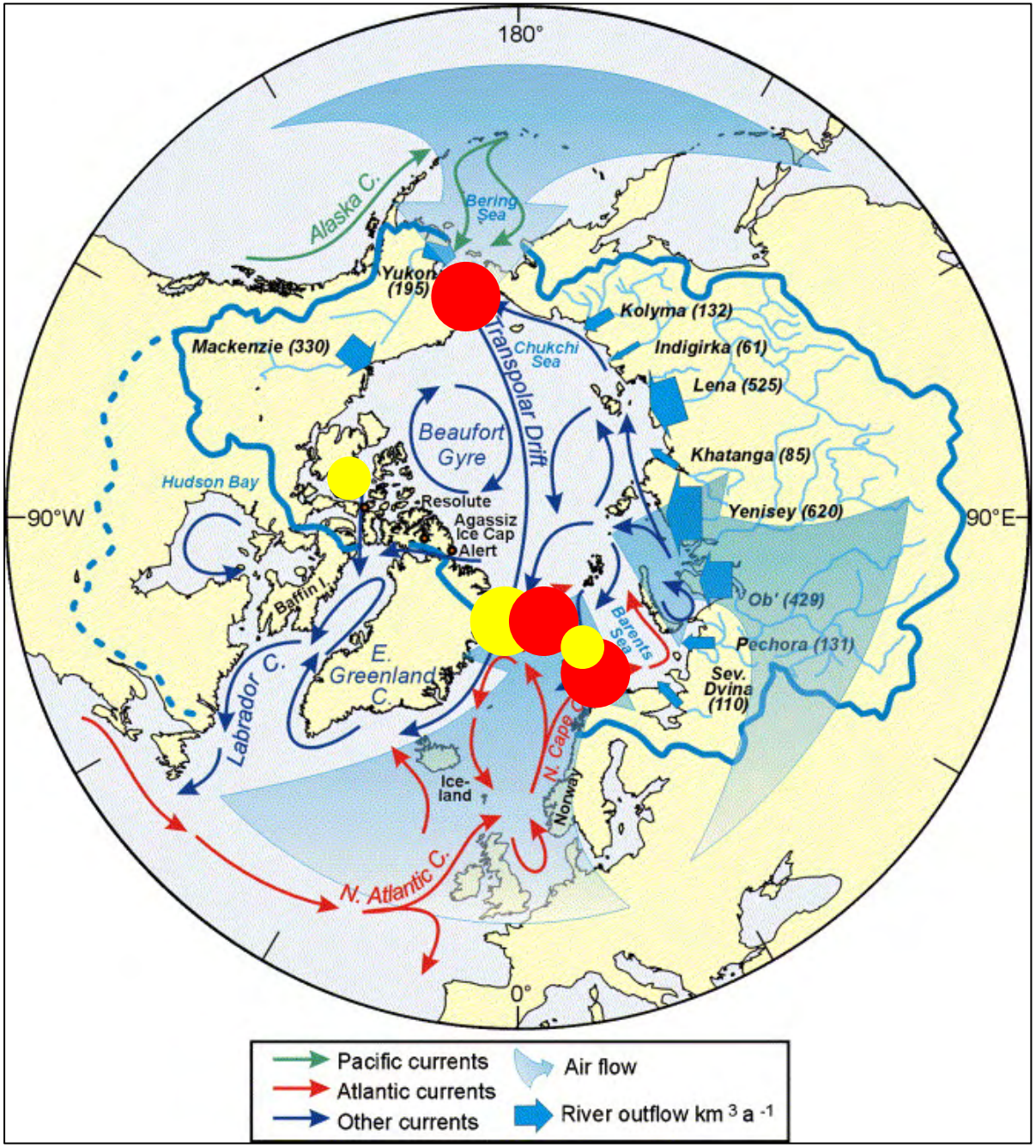
In this talk I will provide some examples of advective effects from both the Pacific and Atlantic.

Indirect effects of advection through:

- Water mass properties (heat, freshwater)
- Nutrients
- Sea ice
- Turbulence

Direct effects of advection on

- Carbon
- Plankton (Phytoplankton, Zooplankton, Benthos)
- Fish Larvae



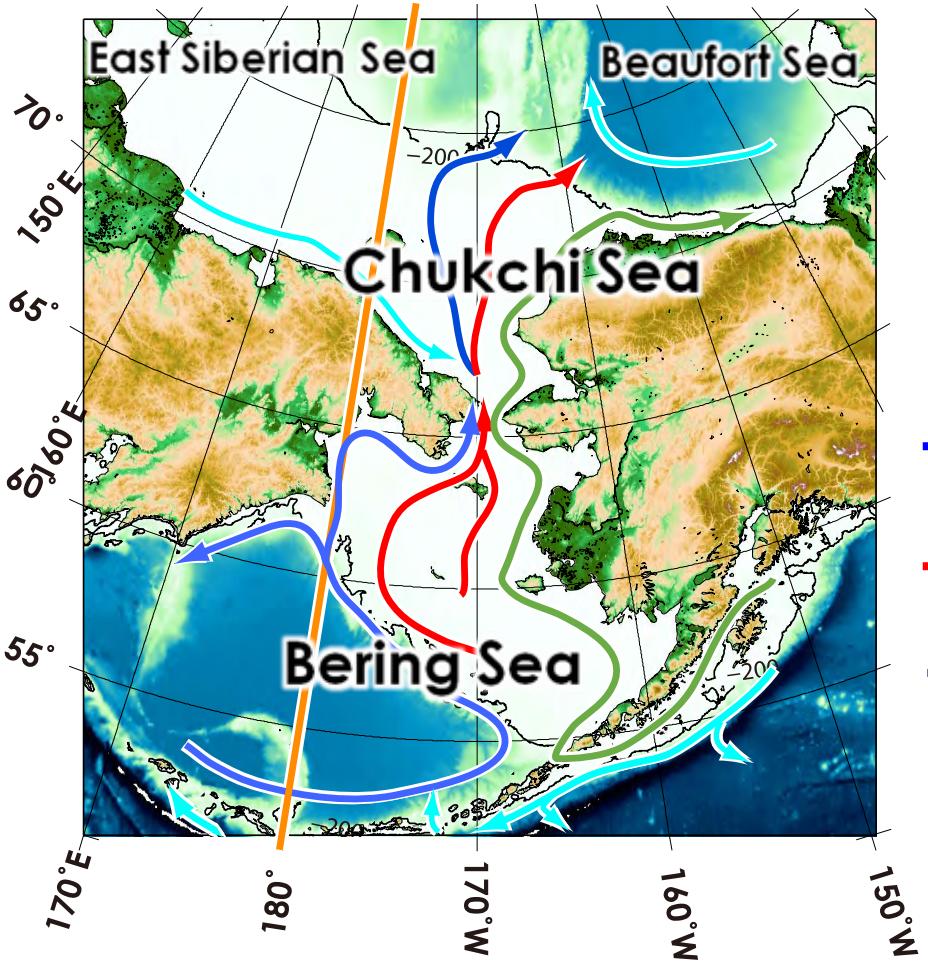
Advection between the Arctic and Subarctic

Inflow

Outflow

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

Bering Strait Inflow



(Coachman et al., 1975, Coachman, 1986, Springer and McRoy., 1993)

Western Arctic Shelf

Chukchi & Bering Sea

3 major inflows from the North Pacific

- Anadyr Water: Cold, Saline, Nutrient rich
- Bering Shelf Water: Cold, saline
- Alaska Coastal Water: Warm, less saline

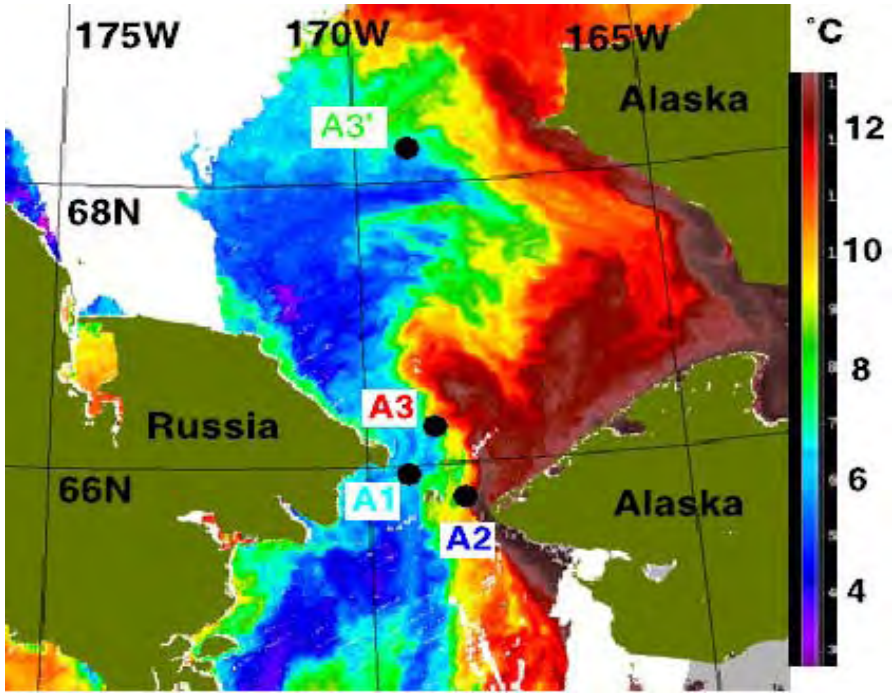
Seasonally ice covered

Oct–Jun（Chukchi Sea）
Nov–May（Bering Sea）

Slide from S.I. Saitoh

Advection of Warm Water

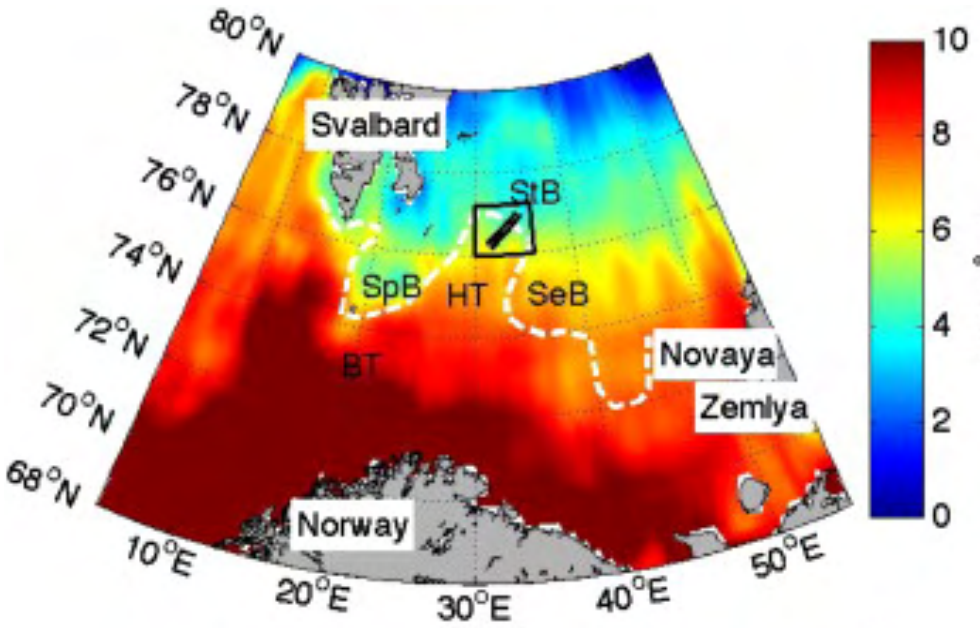
Bering and Chukchi Seas



SST 26 August 2004, Woodgate et al., 2005

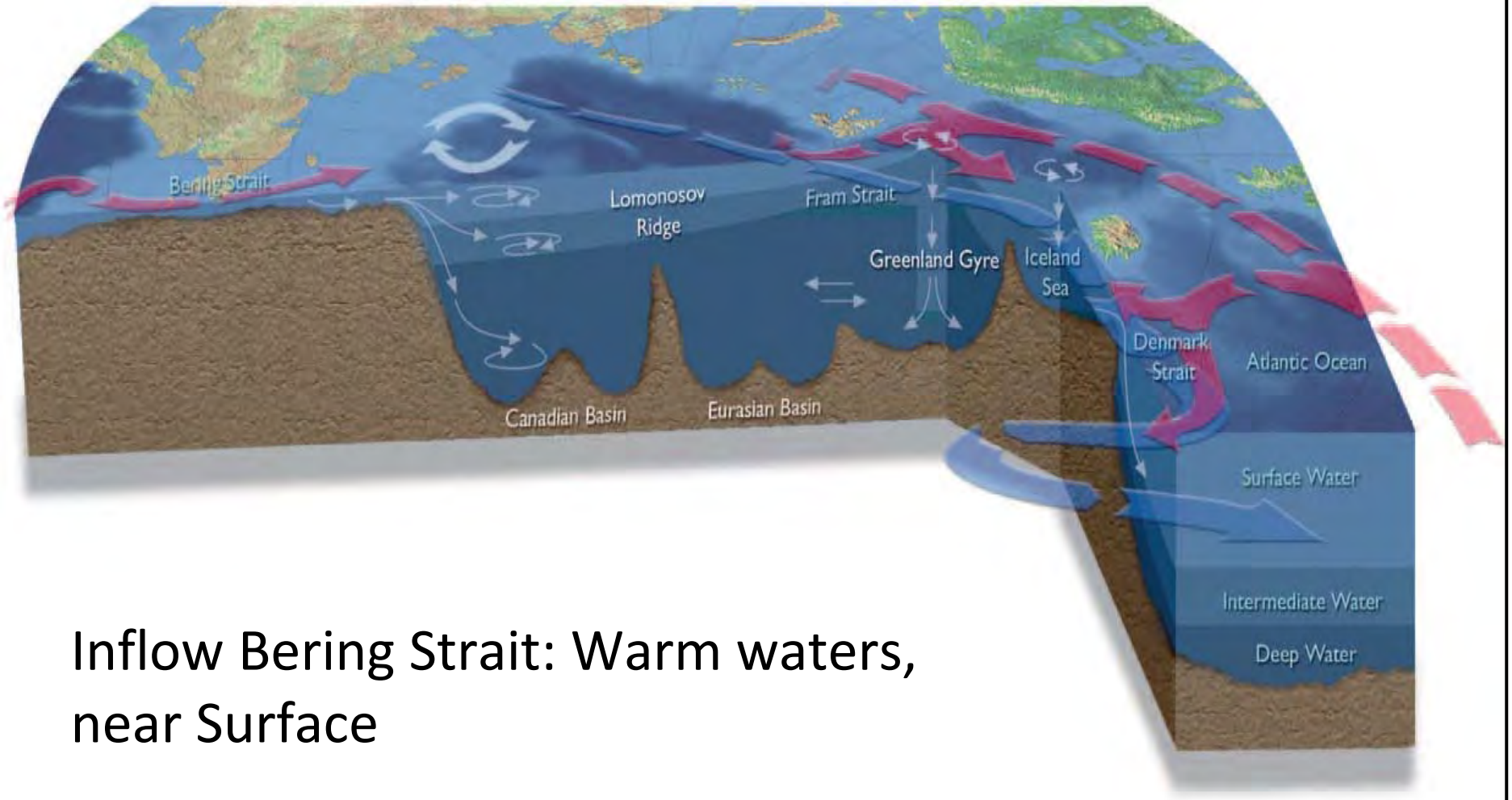
…but not in winter.

Barents Sea



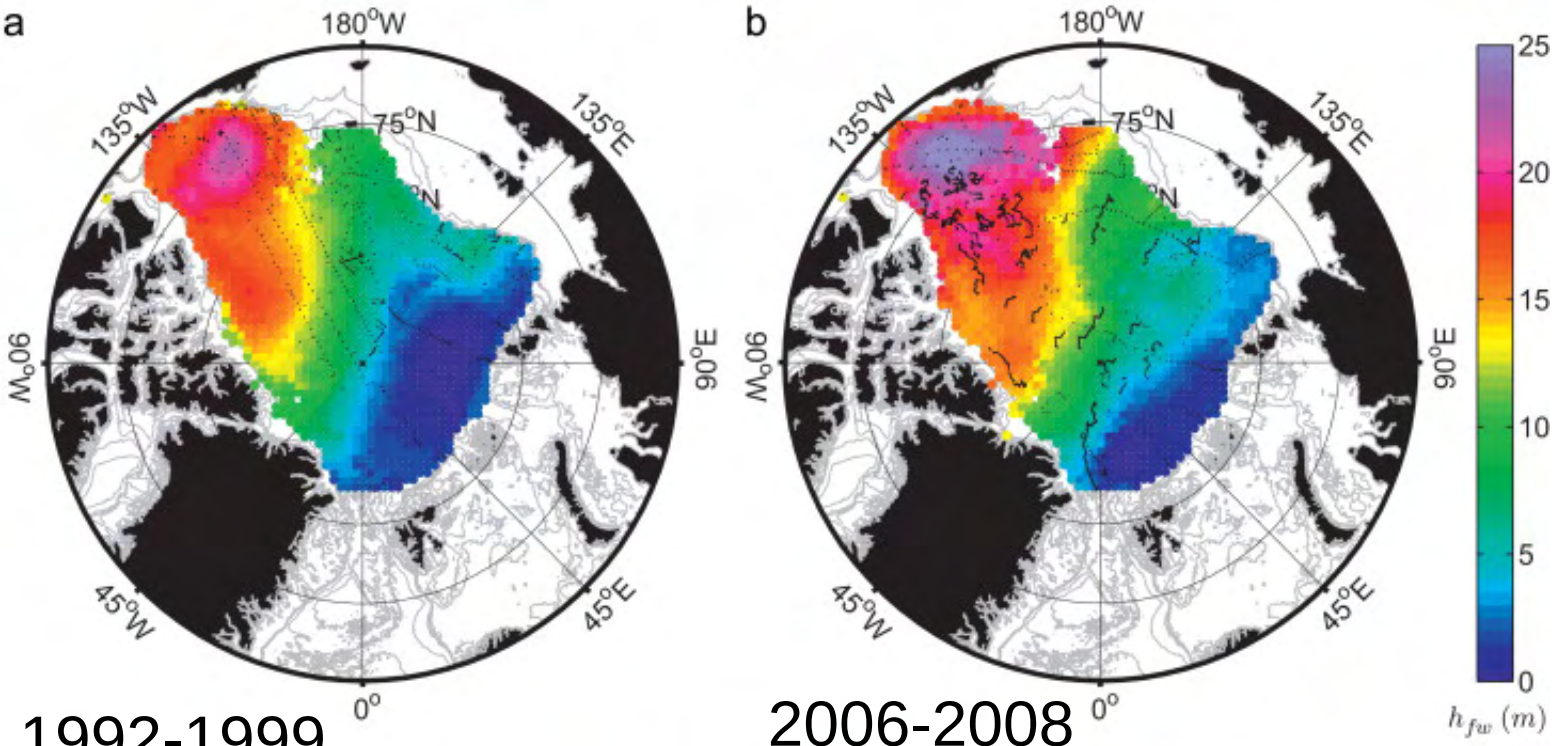
SST 15 August 2007, Våge et al., 2011

…warm water comes in year around.



Inflow Bering Strait: Warm waters, near Surface

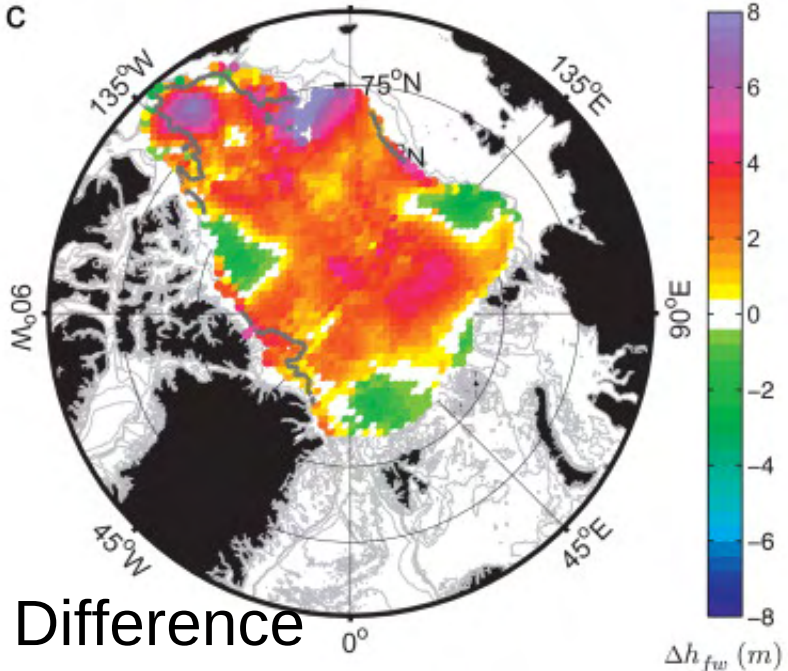
Inflow Fram Strait: Warm, High Saline waters, intermediate depths (200 m)



1992-1999

2006-2008

Source of FW from Bering Strait and Russian rivers and little from Atlantic.



Summer (JAS) observed height of freshwater from 34 relative to salinity of 35.

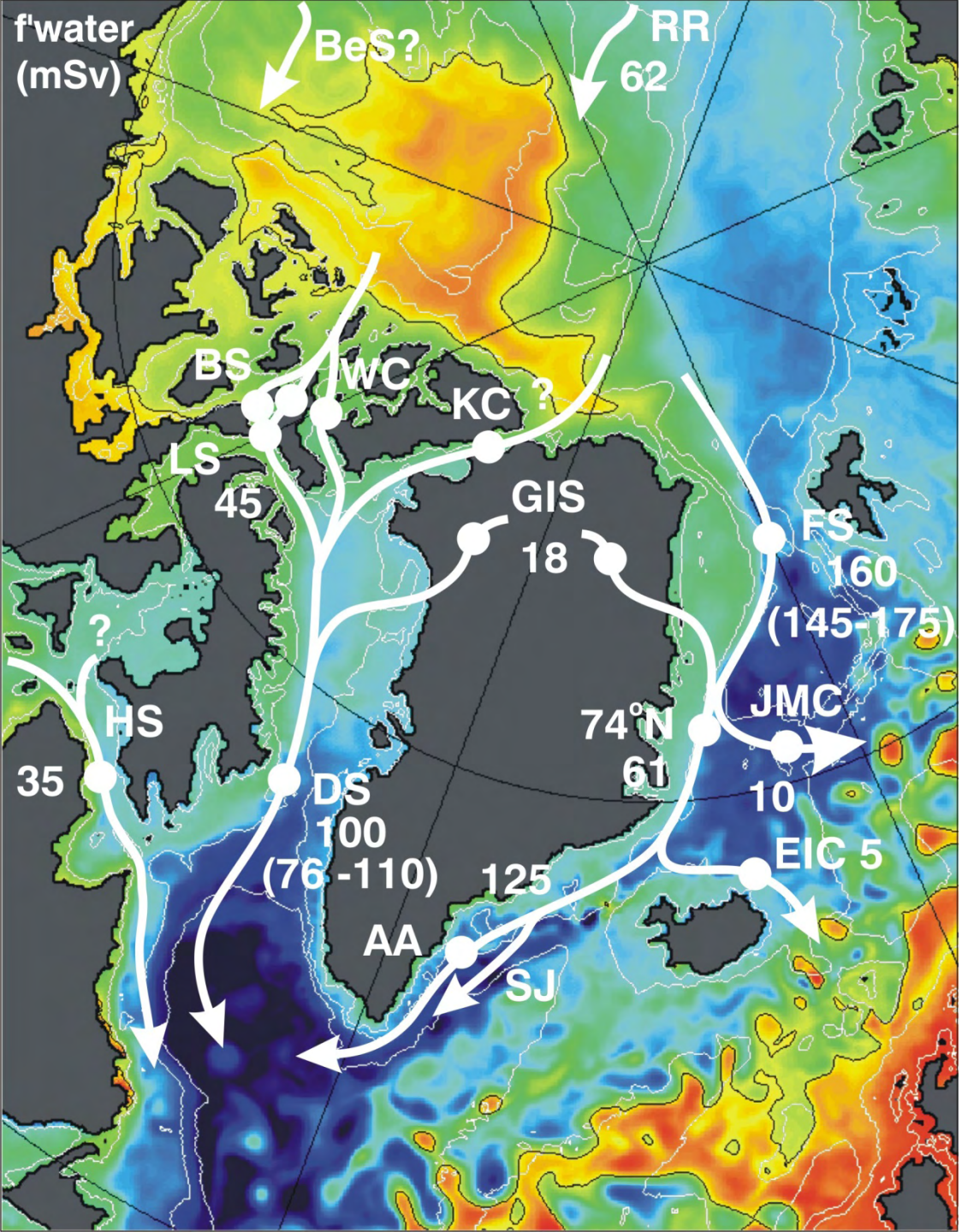
Difference

Increase in recent years due to increased ice melt, river runoff and inflow through Bering Strait.

Rabe et al., DSRII, 2011
Woodgate et al., GRL, in press

Riverine Input to the Arctic Ocean

Major input from the Siberian Rivers.



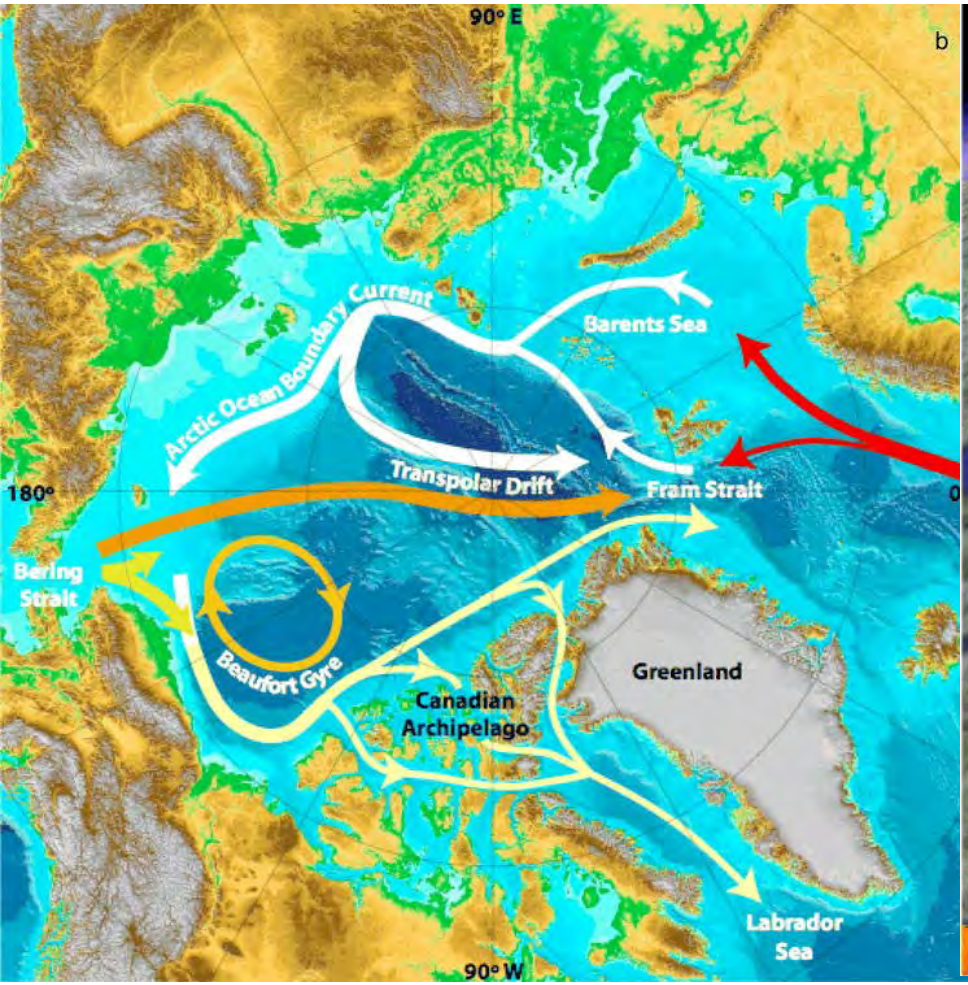
Freshwater Outflows

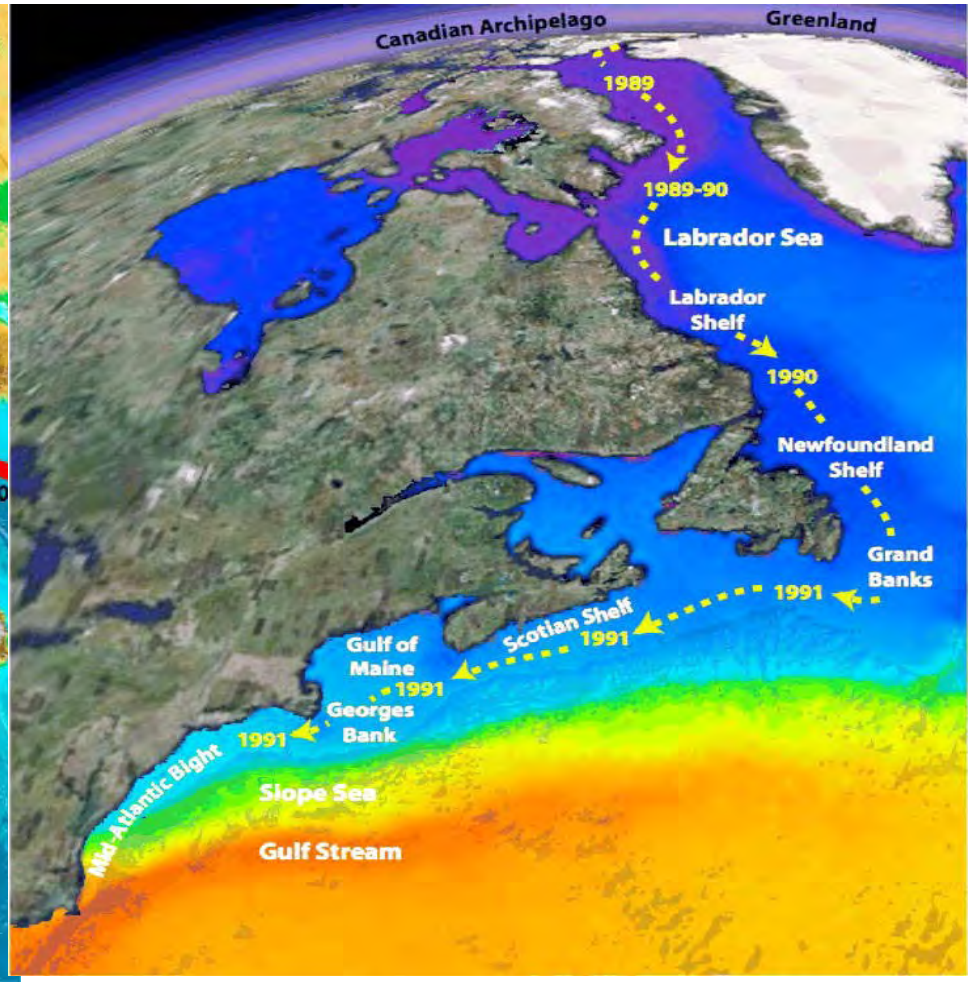
Fram Strait: 160 mSv

Canadian Archipelago: 82 mSv

Dickson et al., 2008

Advection of Freshwater





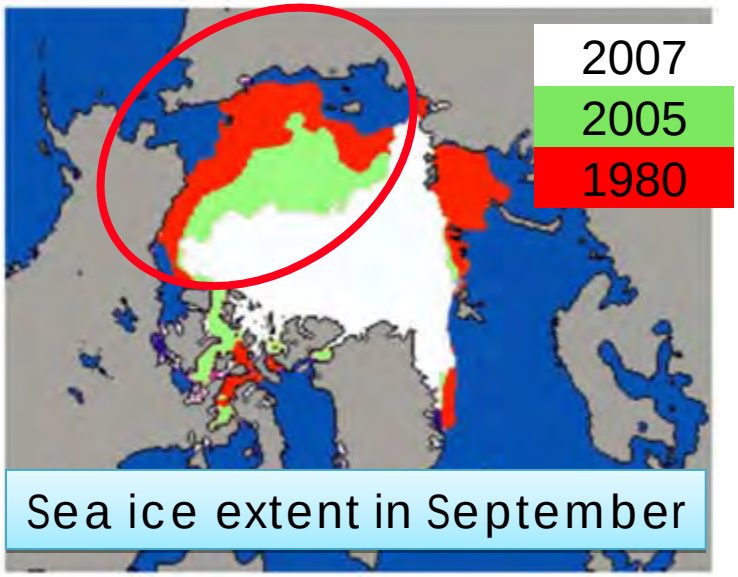
Freshwater from Arctic has been traced from the Arctic through the Canadian Archipelago into the NW Atlantic where it has affected zooplankton distributions.

Greene et al., Ecology, 2008

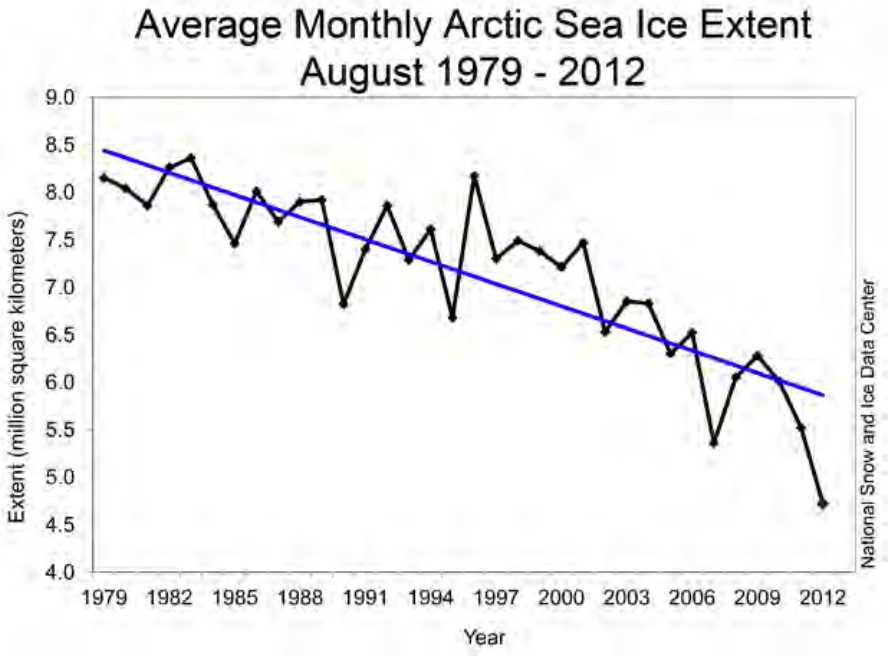
Advected Effect on Recent Sea-Ice Decline

Decreasing Arctic sea ice attributed to heat advected through Bering Strait (Woodgate et al., 2010).

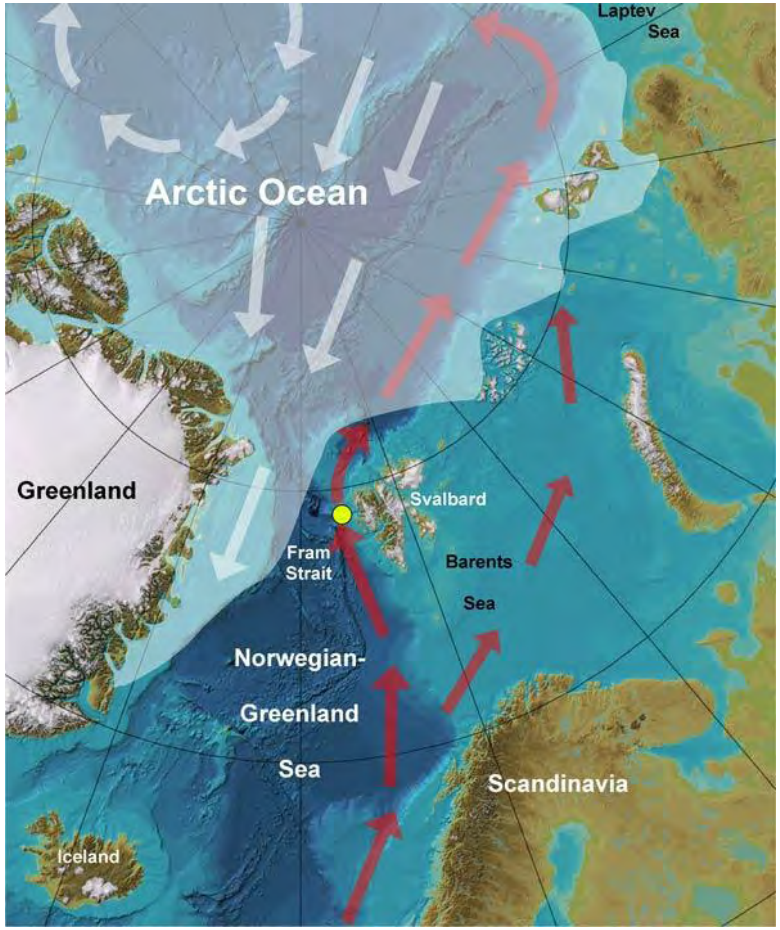
Atlantic heat input not as effective in melting sea ice due to being mainly subsurface.

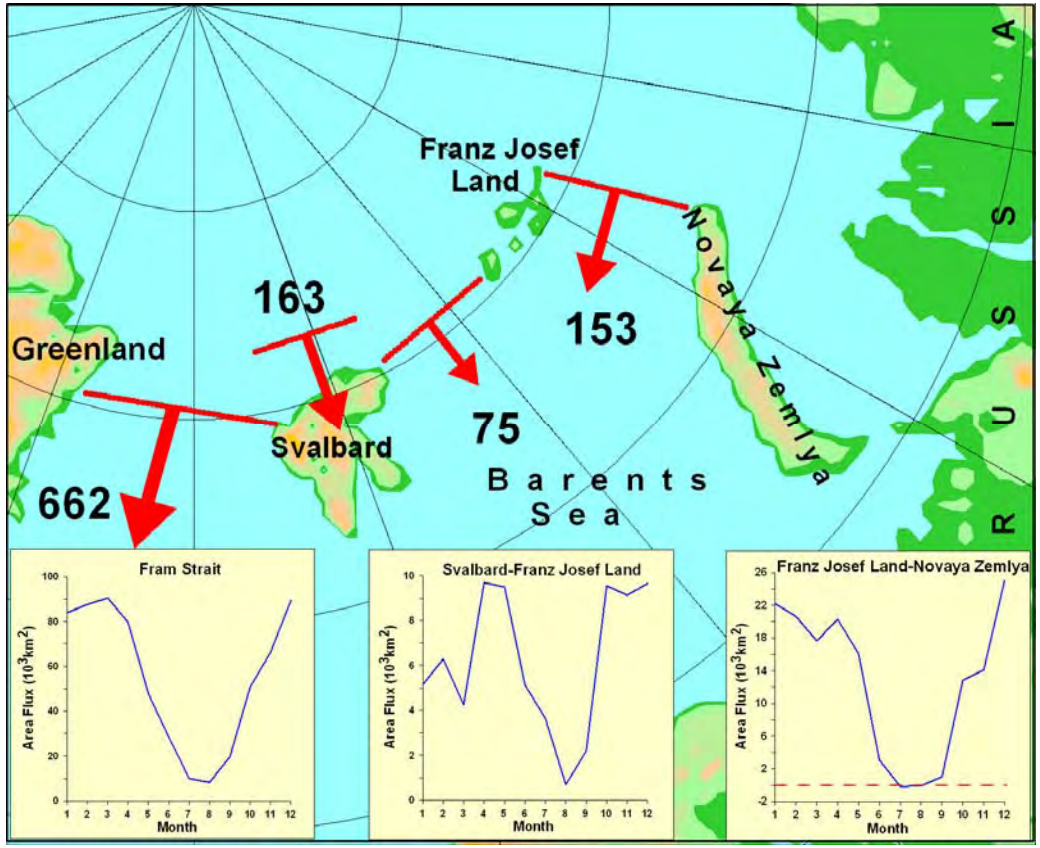


(Perovich & Ritcher-Menge, 2009)



Ice advection out of the Arctic



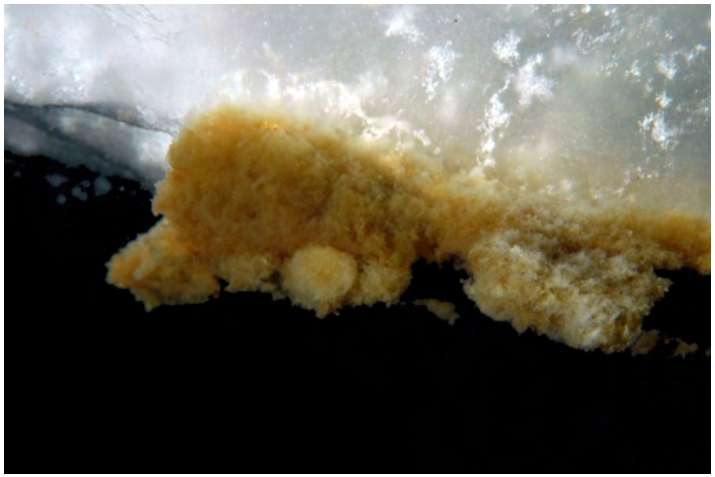


Mean annual sea ice area flux averaged for the period 1979-2006 (10^3 km^2)

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)

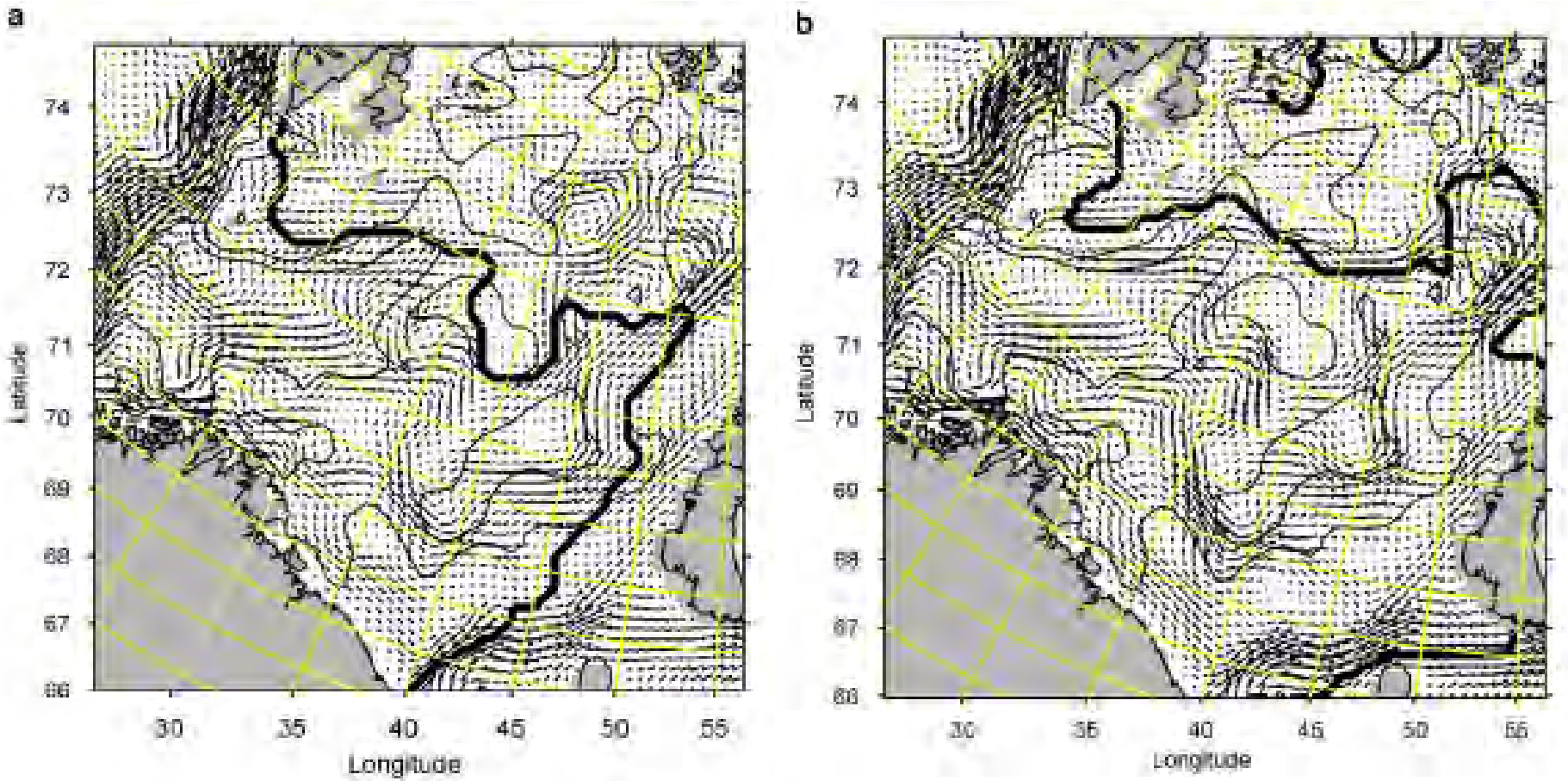
Barents Sea: 99 x 10^3 t wet weight (12 x 10^3 t C)

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

Fronts Move in Response to Advection

2000

2047



Modelled currents and Polar Front (thick black line) in the Barents Sea. Such movements have also been observed in response to variability of Atlantic inflow..

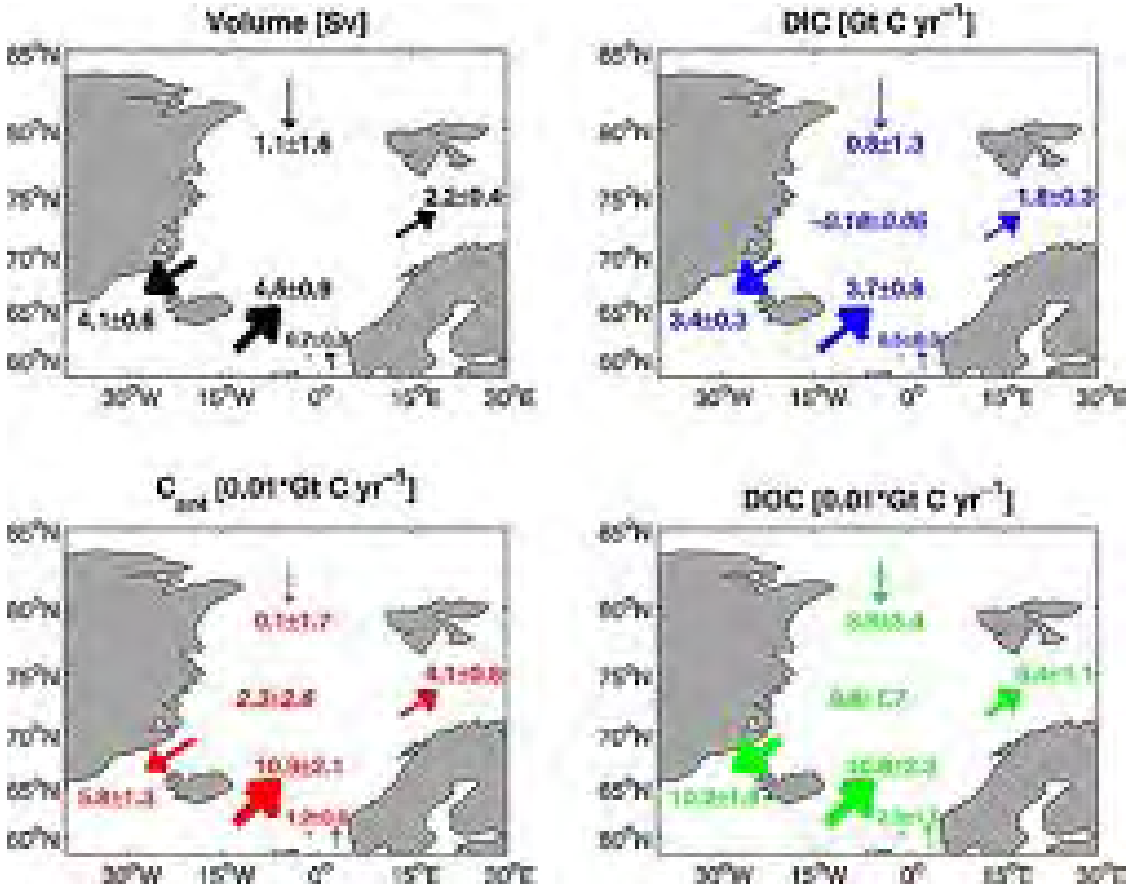
Huse & Ellingsen, 2008

In the Arctic

The front separating Atlantic and Pacific waters shifted from Lomonosov Ridge to the Mendeleyev-Alpha Ridge in mid-1990s due to greater advection of Atlantic Water into the Arctic.

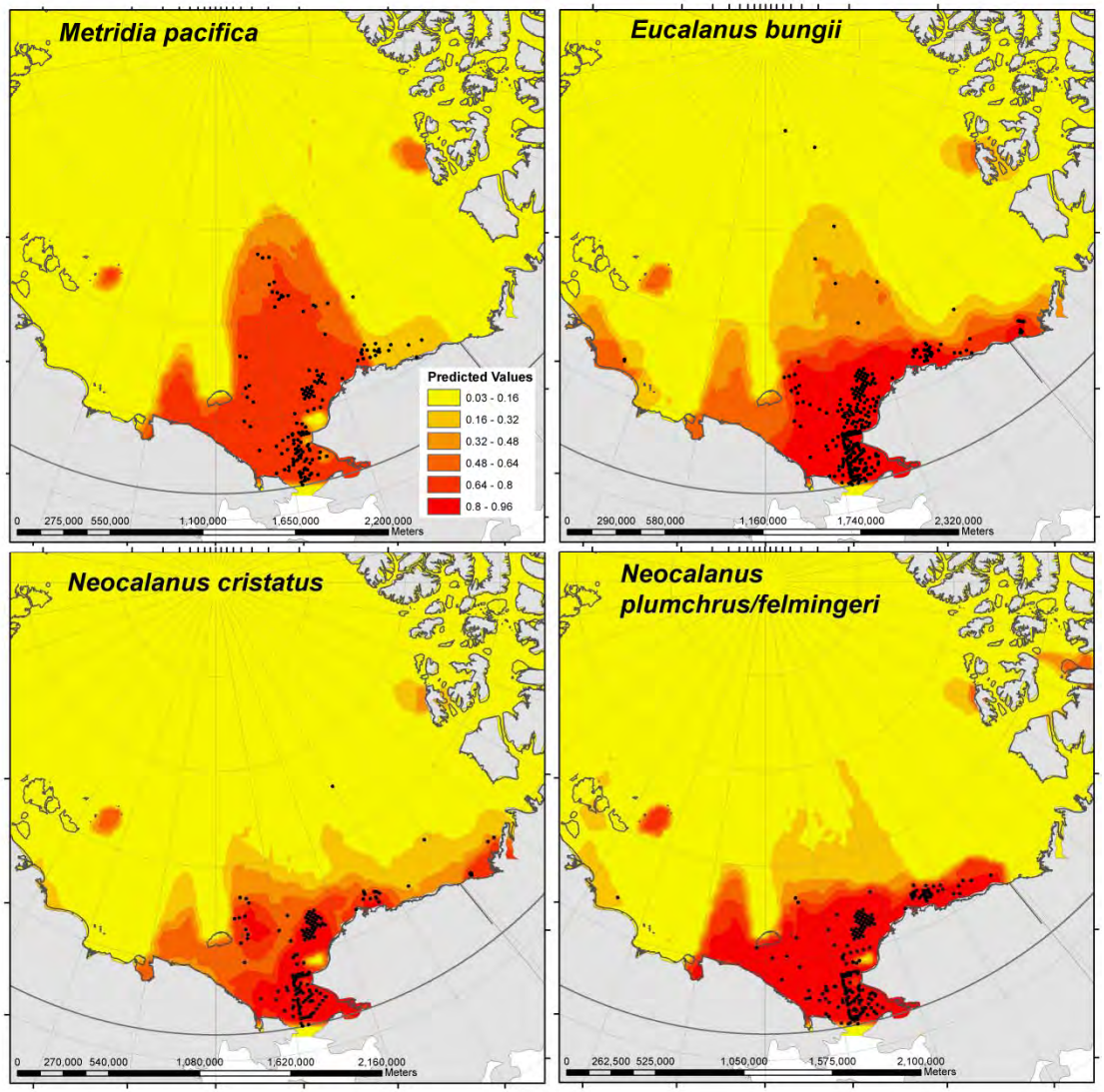
Carbon Budget: Nordic Seas

Advective C fluxes are 2 orders of magnitude larger than the CO_2 uptake from the atmosphere. Small changes in advective fluxes can have a big effect on the carbon budget within the Nordic Seas.



Jeansson et al., 2011, GCB

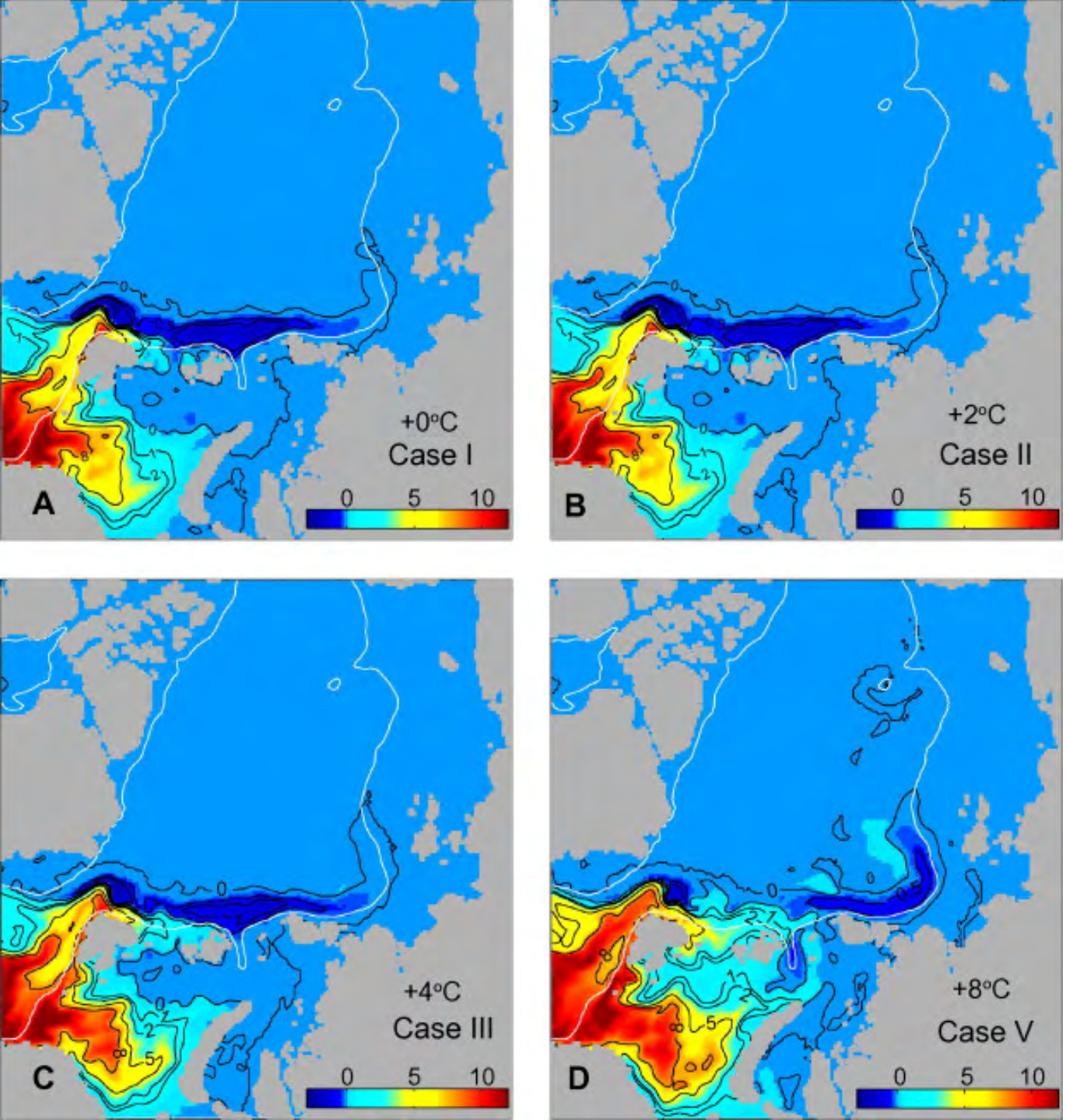
Influence of advection on zooplankton community composition



Observed (black) & niche-modeled probabilities (fills) of encountering Pacific species: Rutzen & Hopcroft, unpublished

- Chukchi Sea zooplankton is dominated by Bering Sea fauna during summer
- Pacific species are generally confined to shelves, but the larger more oceanic members have been observed as distant as the northern boundary of the Canada Basin

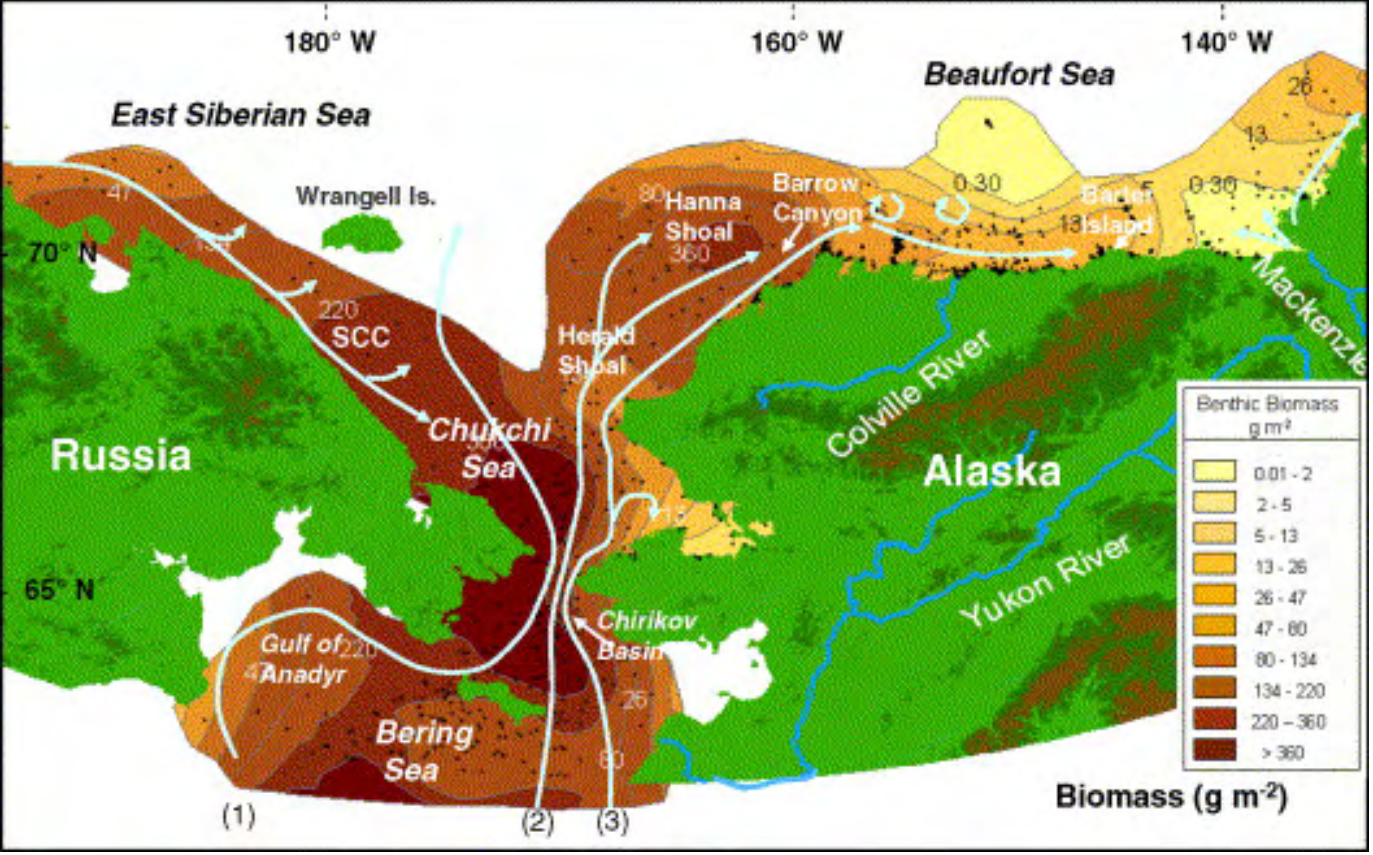
Atlantic Sector



Simulated annual production of the Atlantic species *C. finmarchicus* (g C m^{-2}) in the Arctic Ocean under different climate change scenarios. Note that it is advected into the Arctic but does not survive (negative production).

Slagstad et al., 2011

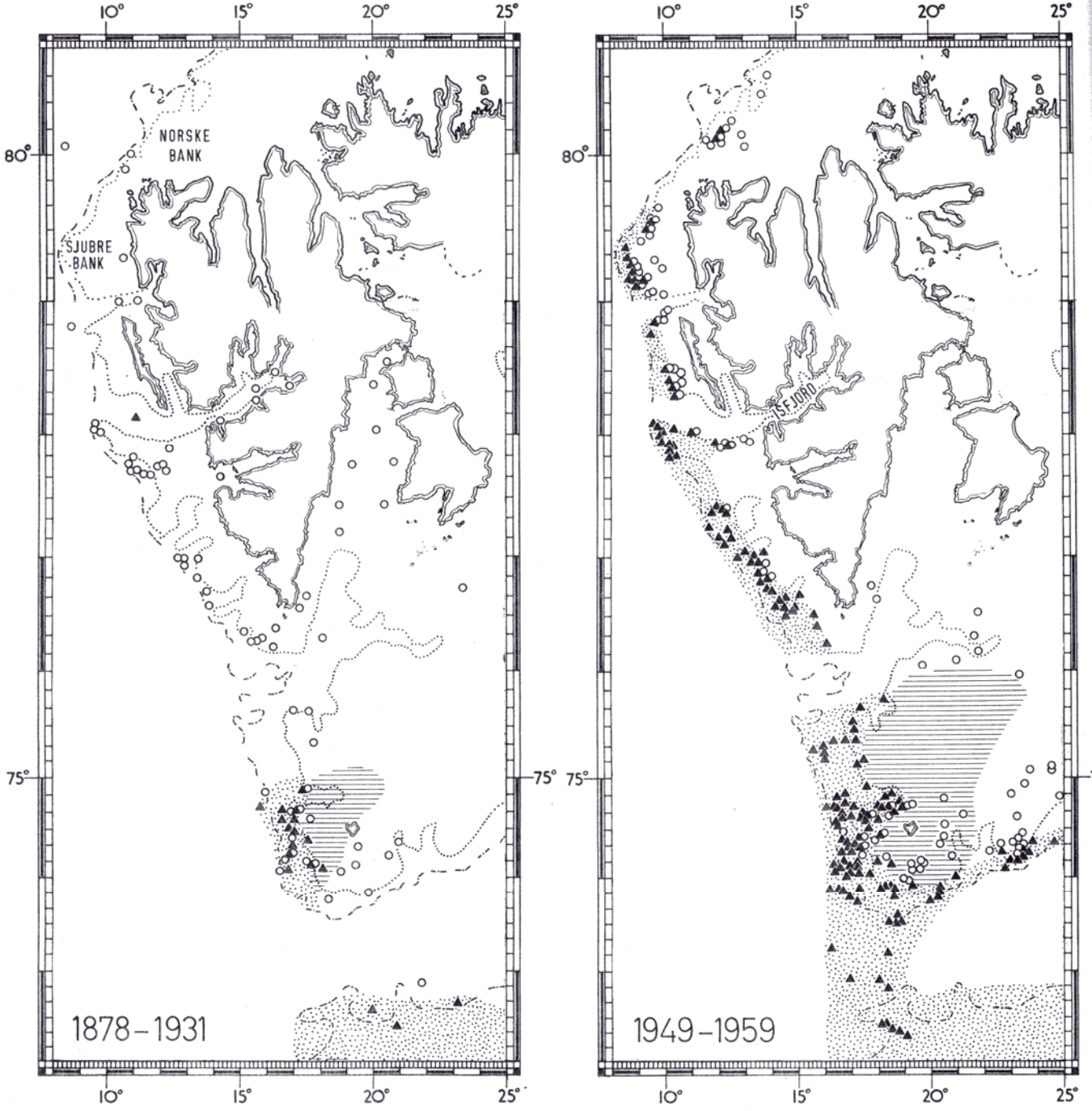
Benthos



The high benthic biomass (>300 g m^{-2}) and chlorophyll (>150 mg m^{-2}) on both the southern and northern Chukchi shelf are known as depositional centers for reduced organic matter that originates on the Bering Sea shelf and is advected northward in Anadyr and Bering shelf water masses.

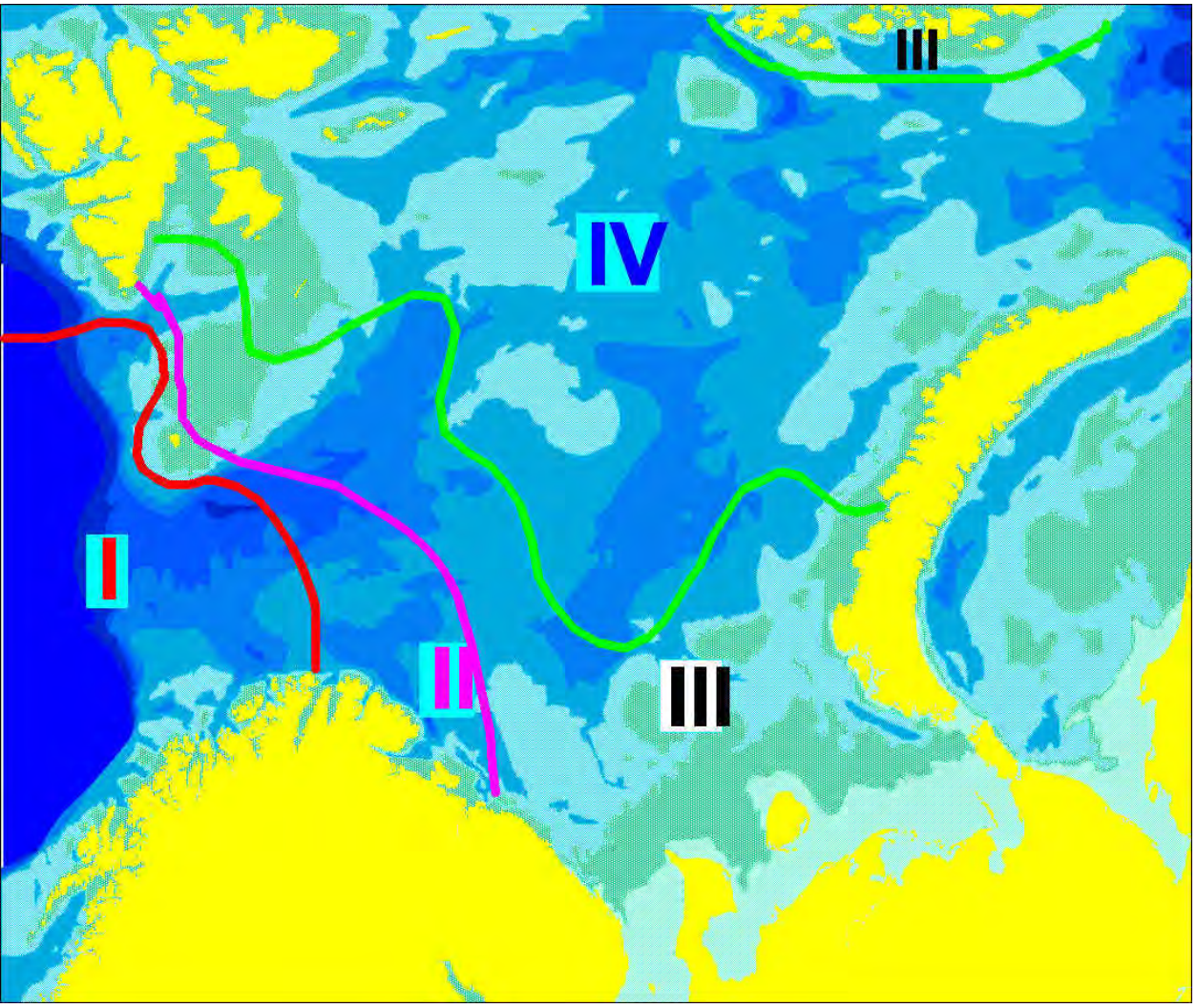
Dunton et al., DSRII, 2005

Off West Svalbard, comparison of benthos prior to the 1930s with those of the 1950s indicated that Atlantic species spread northward by approximately 500 km under increased Atlantic flow



Blacker, 1957

Zoobenthos



Biogeographic boundaries for zoobenthos in the Barents Sea in 20th century: I – maximal western penetration of Arctic species in cold periods; II – line of 50% average relation between boreal and arctic species; III – maximal eastern penetration of boreal species in warm periods; IV – transitional zone.

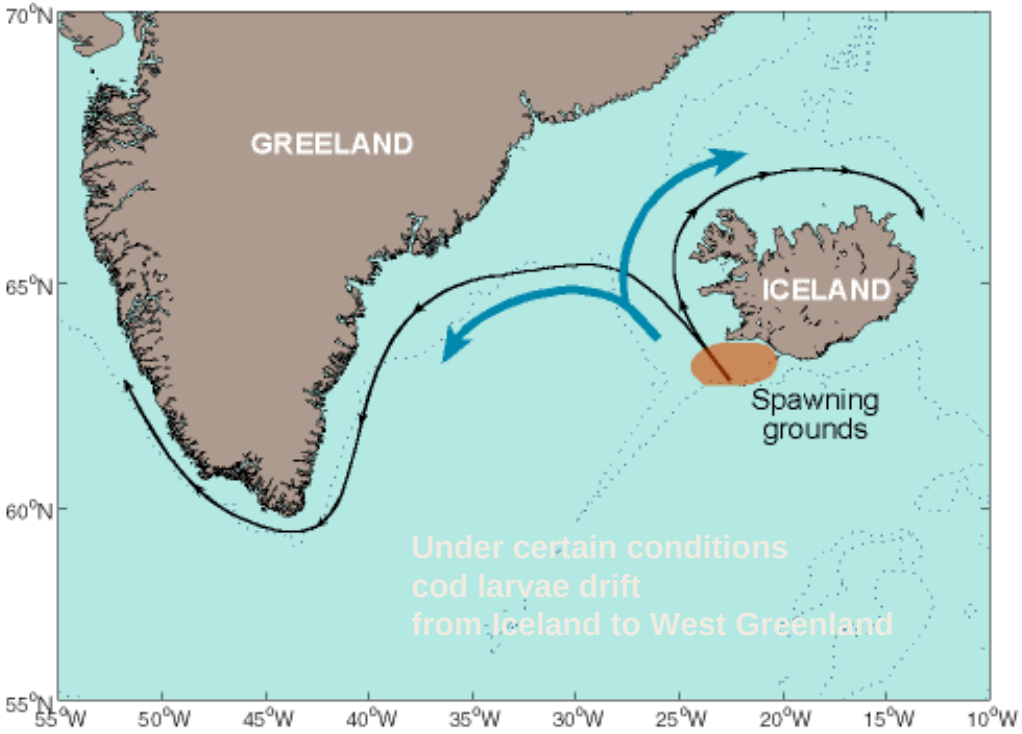
Results related to penetration of Atlantic waters.

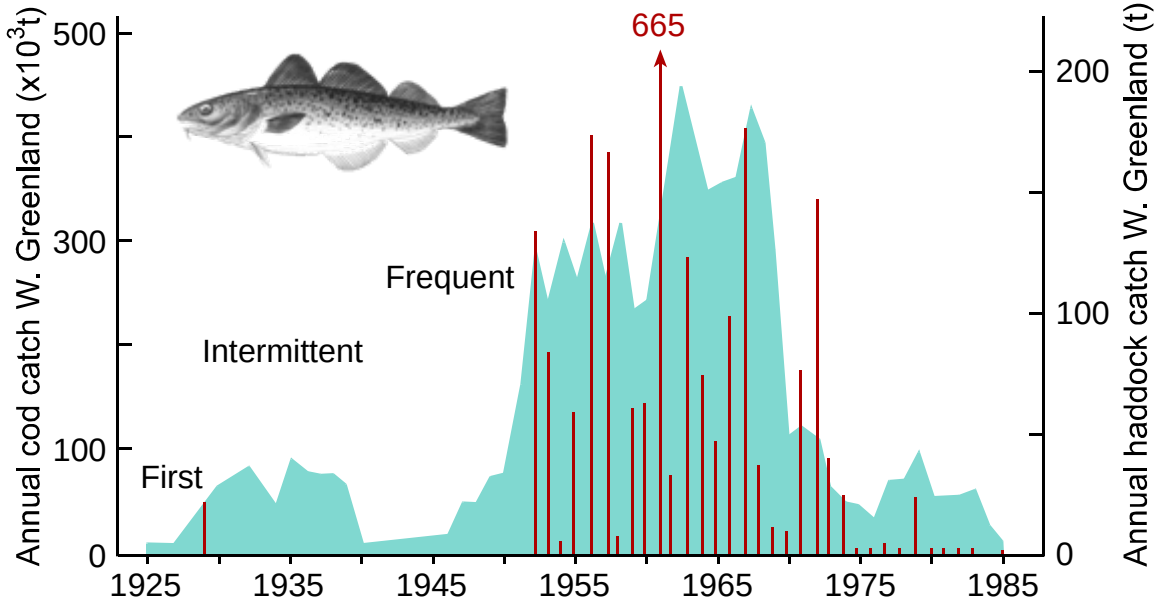
Loeng et al., 2005, ACIA

West Greenland

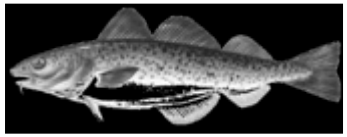
Iceland Connection

In the 1920s cod larvae drifted from Iceland to West Greenland and there was good survival once there.

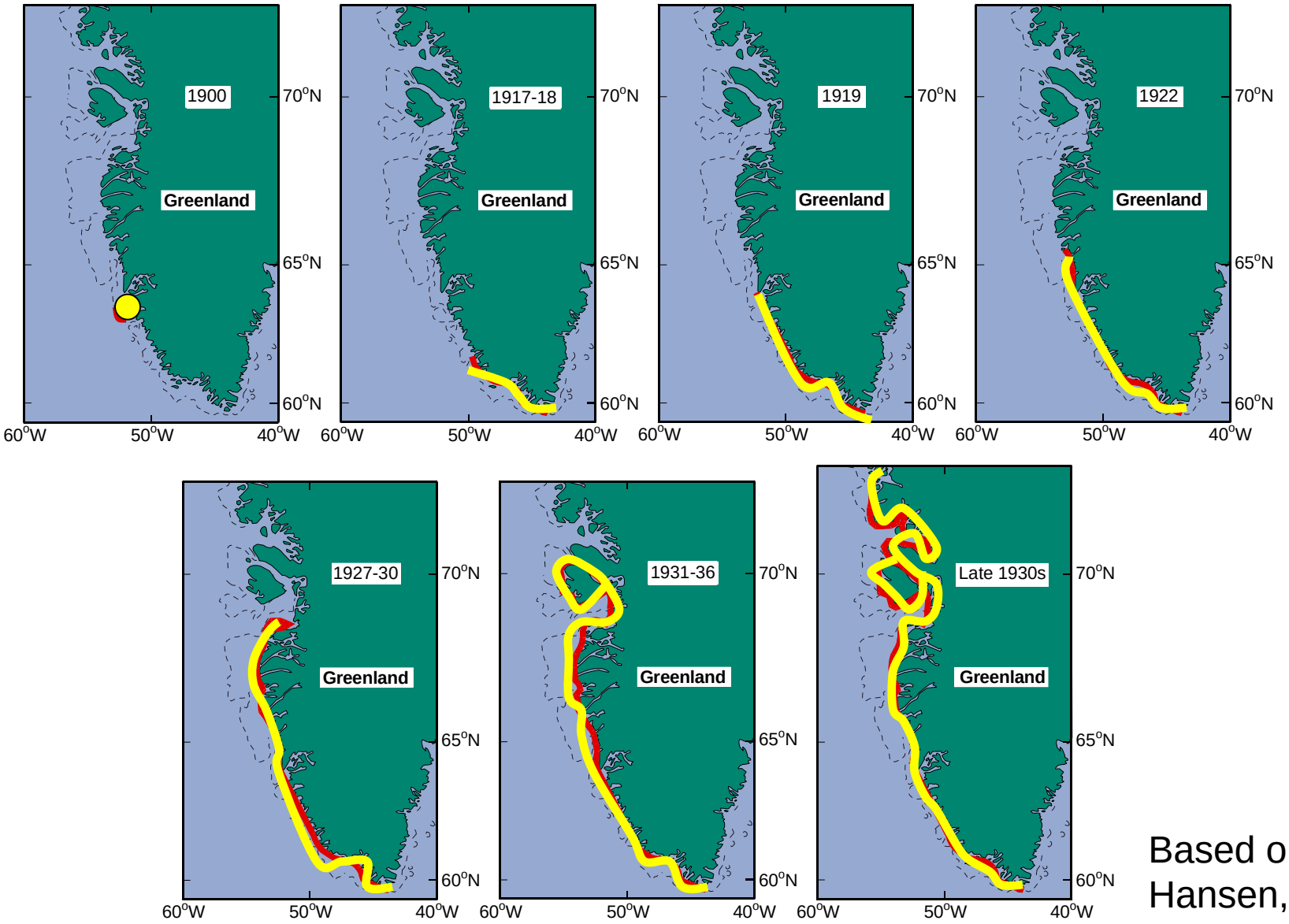




Increased abundance of cod through to the 1960s resulted in the development of a cod fishery that dominated the Greenland economy.



Atlantic cod moved northward by 1500 km in response to warming.



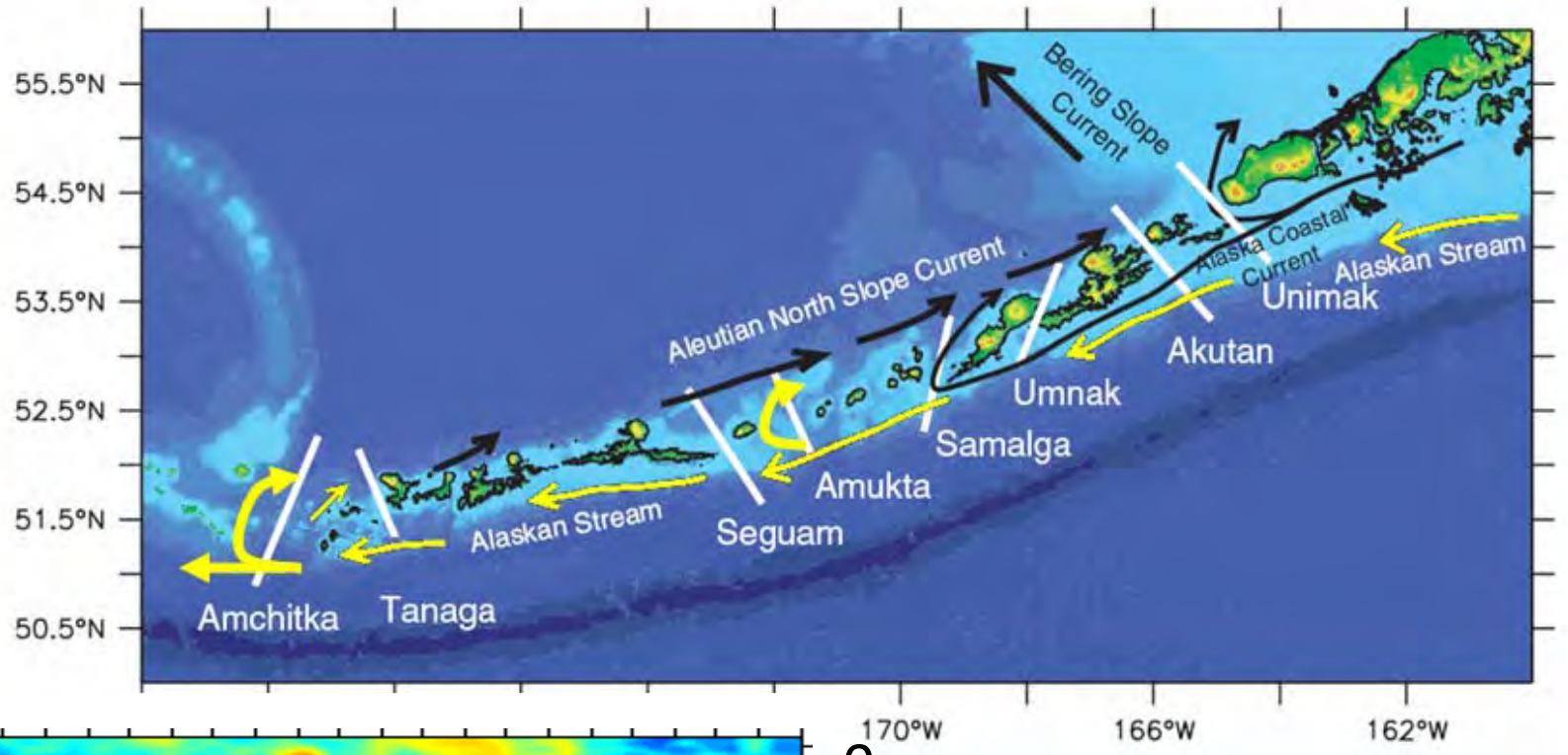
Based on Hansen, 1940

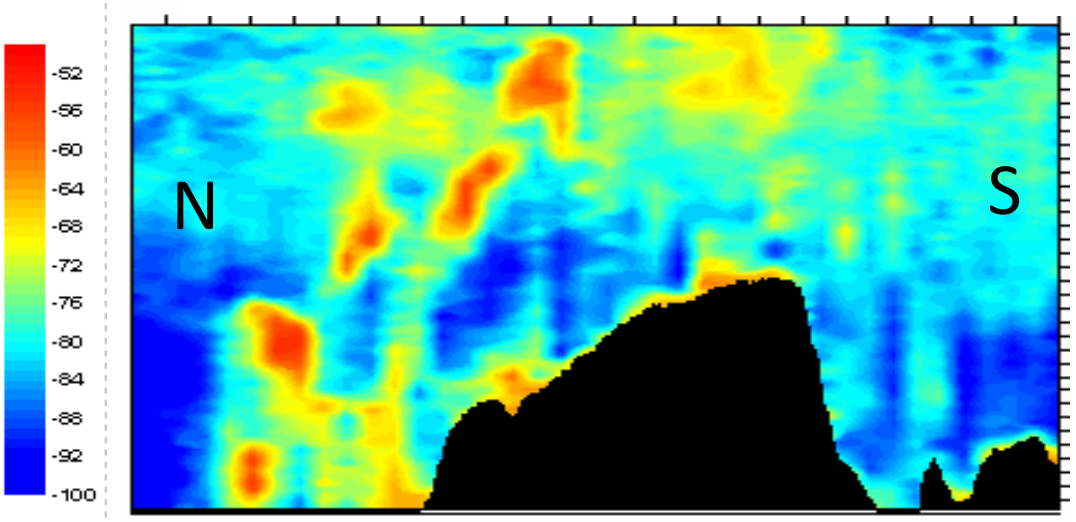
Hotspot for Predators Foraging on Krill

Shearwaters feeding with ~ 100 humpback whales in Unimak Pass.

Source of the Euphausiids?

Modified from Ladd et al., 2005 Fish. Oceanogr.





Krill Abundance

Summary

	Pacific-Bering St.	Atlantic-Fram St.
Topography	Shallow	Deep
Flow	Inflow (shallow)	Inflow (Deep)/ Outflow (Shallow)
Heat Inflow	Warm Summer/ Cold Winter	Warm
Freshwater	Inflow	Outflow
Ice/ice algae	Little to None	Outflow
Nutrients	High Nutrient Inflow	High Nutrients
Phytoplankton	Inflow of resting stages, cells	Inflow of resting stages (?), cells
Zooplankton	Inflow Community Structure	Inflow, Outflow Structure
Fish Larvae	Some species	Some species

Conclusions

- Advection plays an important role in the interaction of Arctic and Subarctic Seas, both in terms of physical properties and ecology.
- Ecological effects are both direct and indirect
- Effects range from carbon to marine mammals and seabirds

Still….

Thanks for your attention.


Thank you for your Attention!