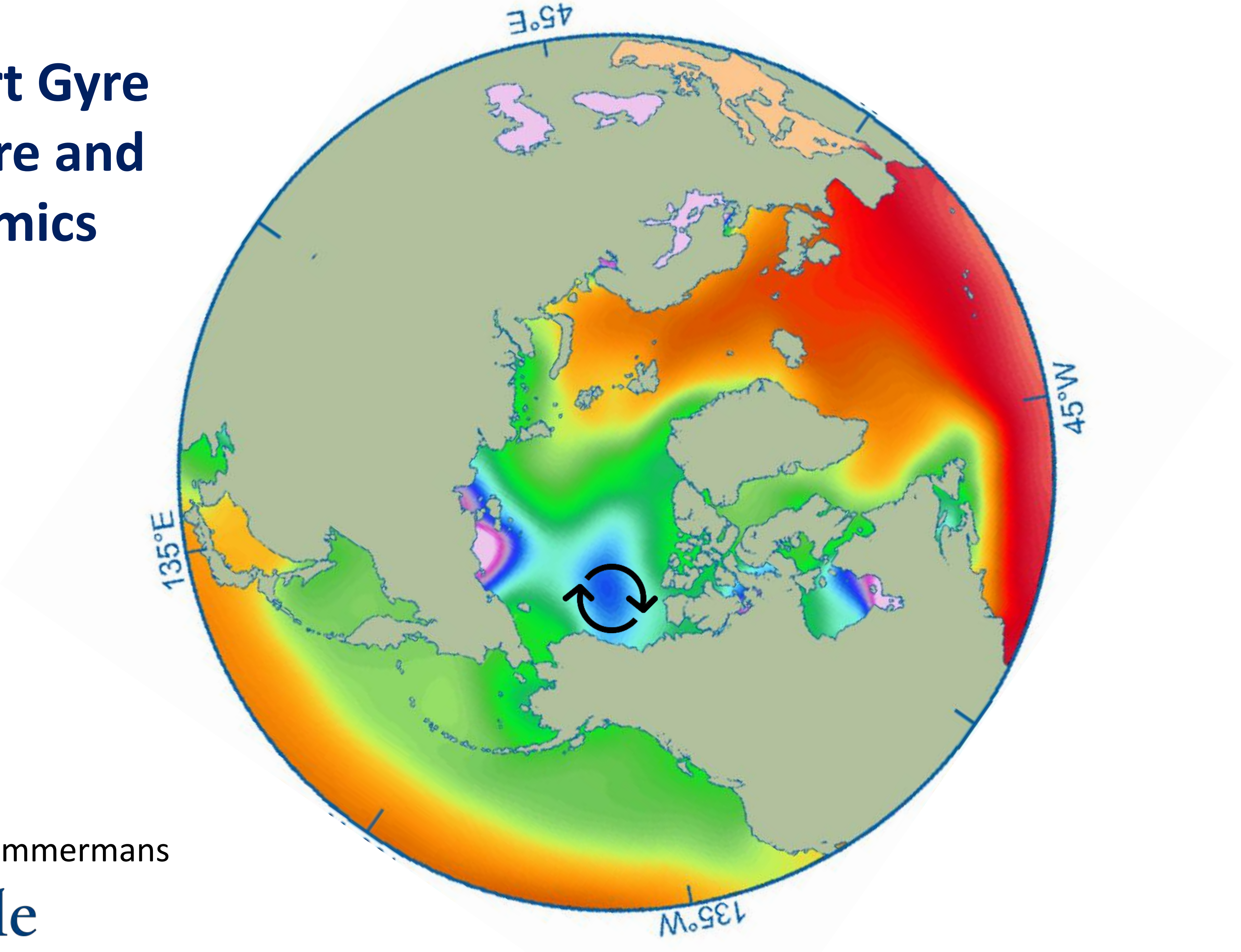
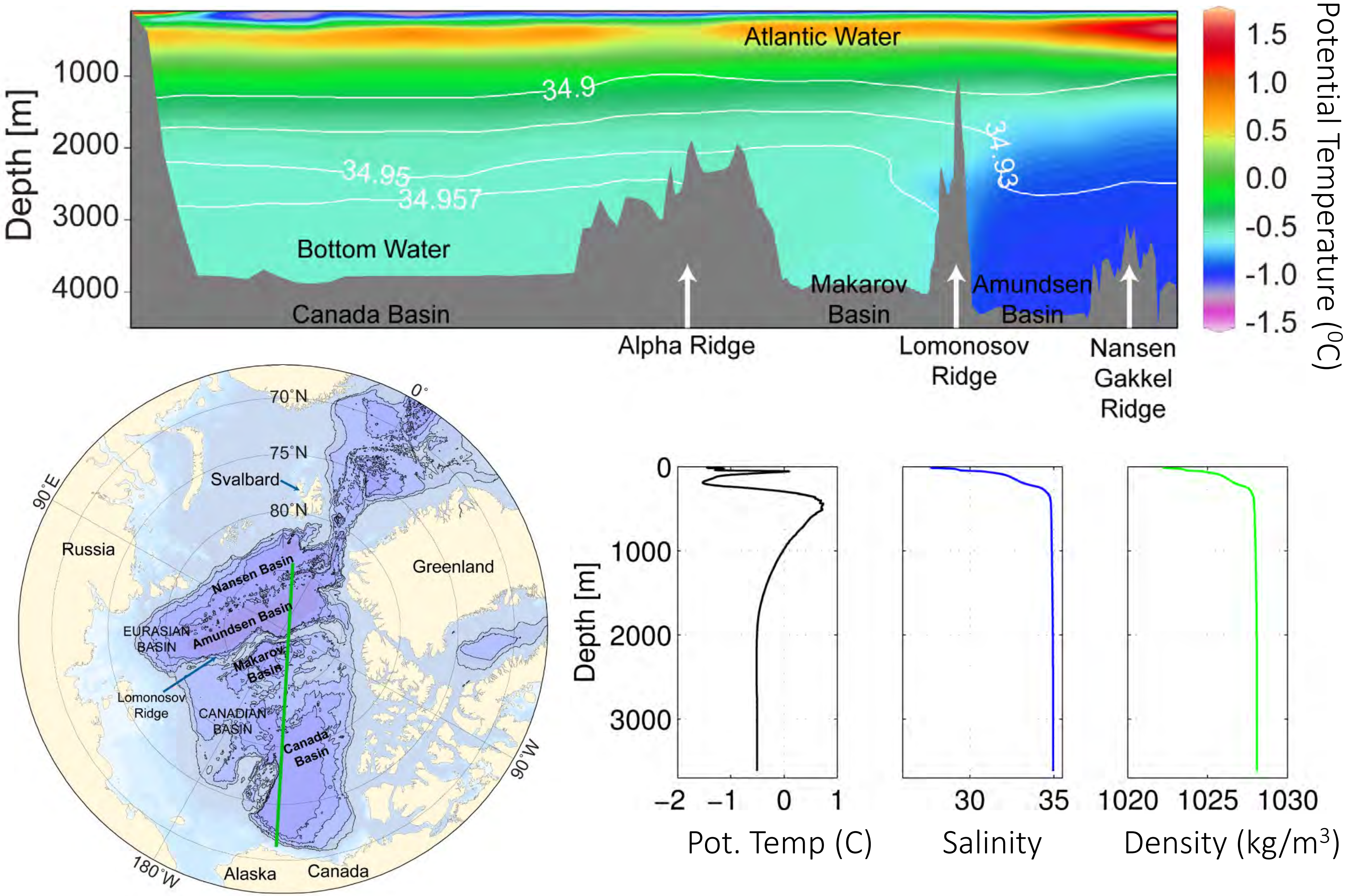
Beaufort Gyre Structure and Dynamics

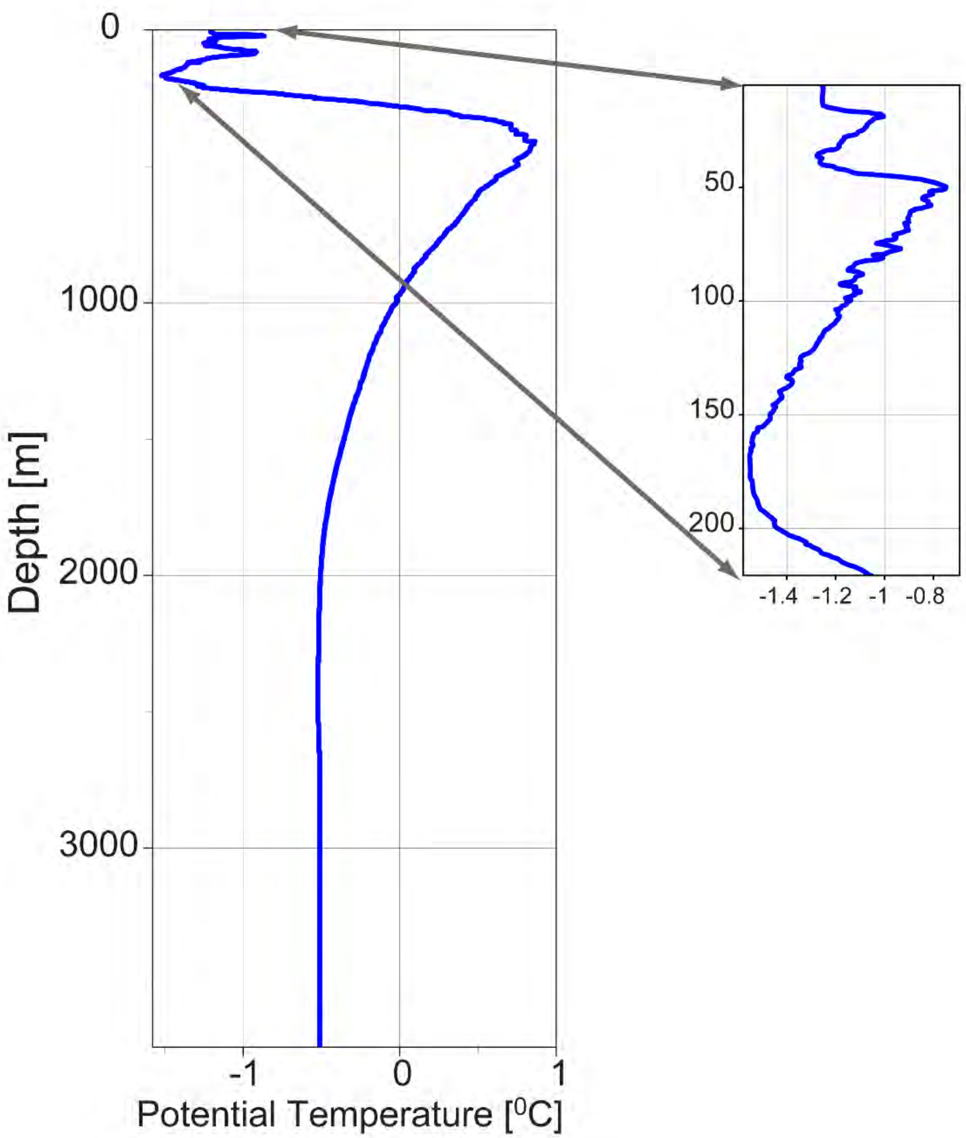


Mary-Louise Timmermans
Yale

Arctic Ocean Stratification

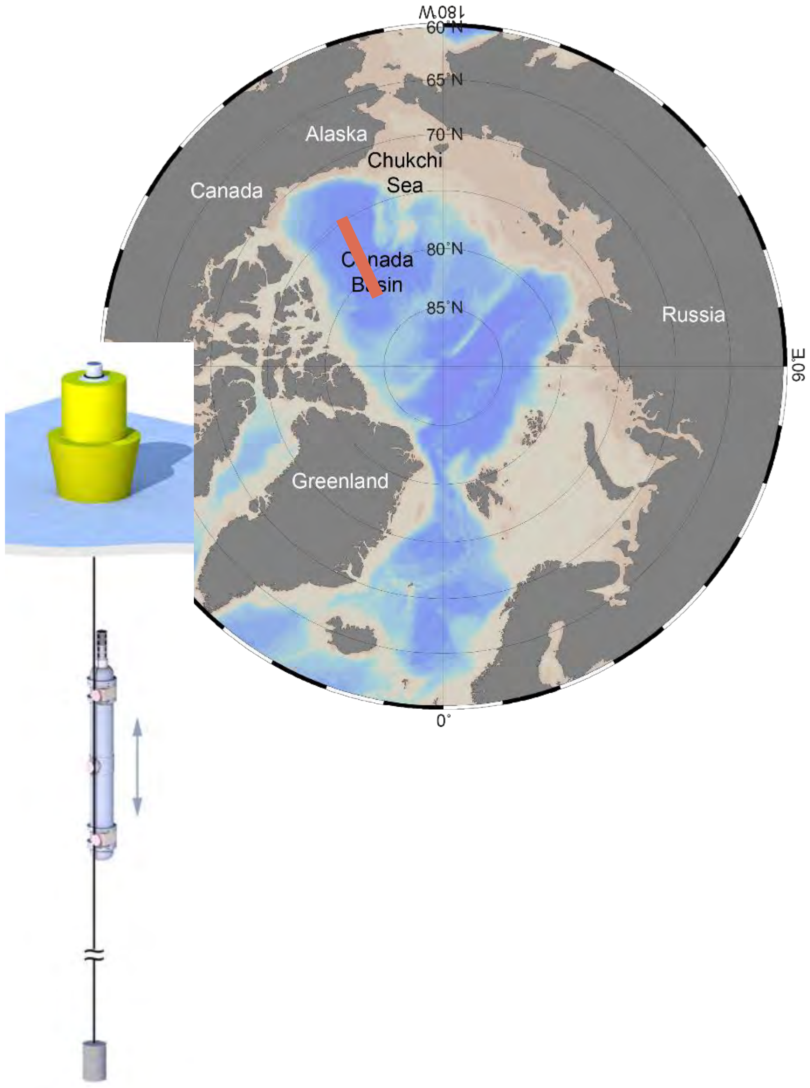


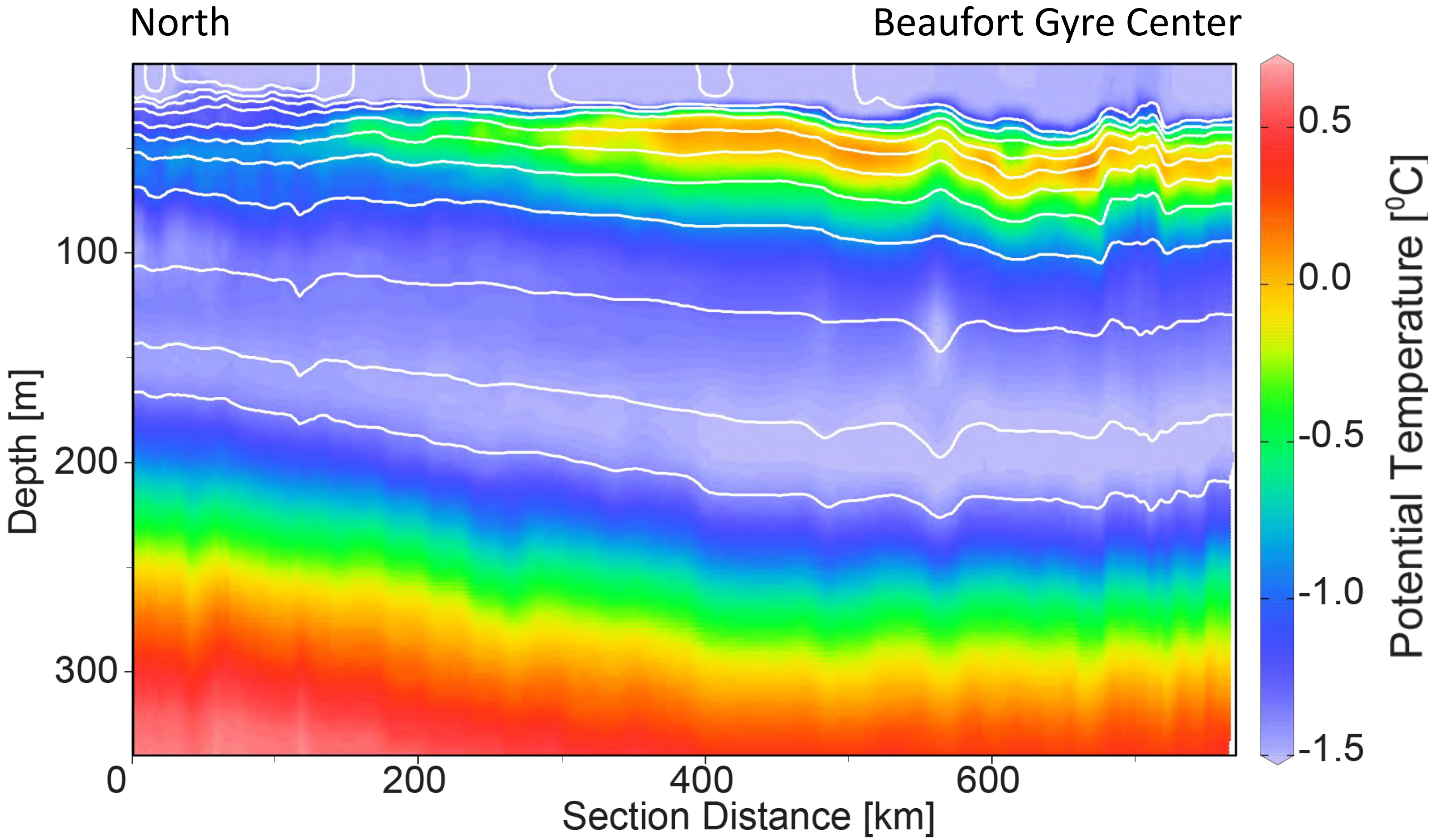
Arctic Ocean Temperature Profile



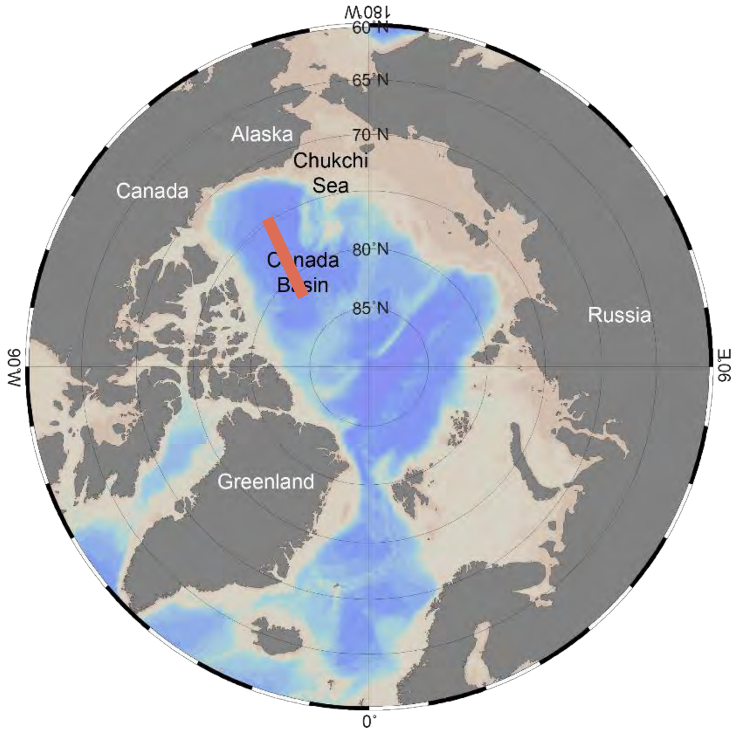
Interleaving warm layers
in the Arctic halocline

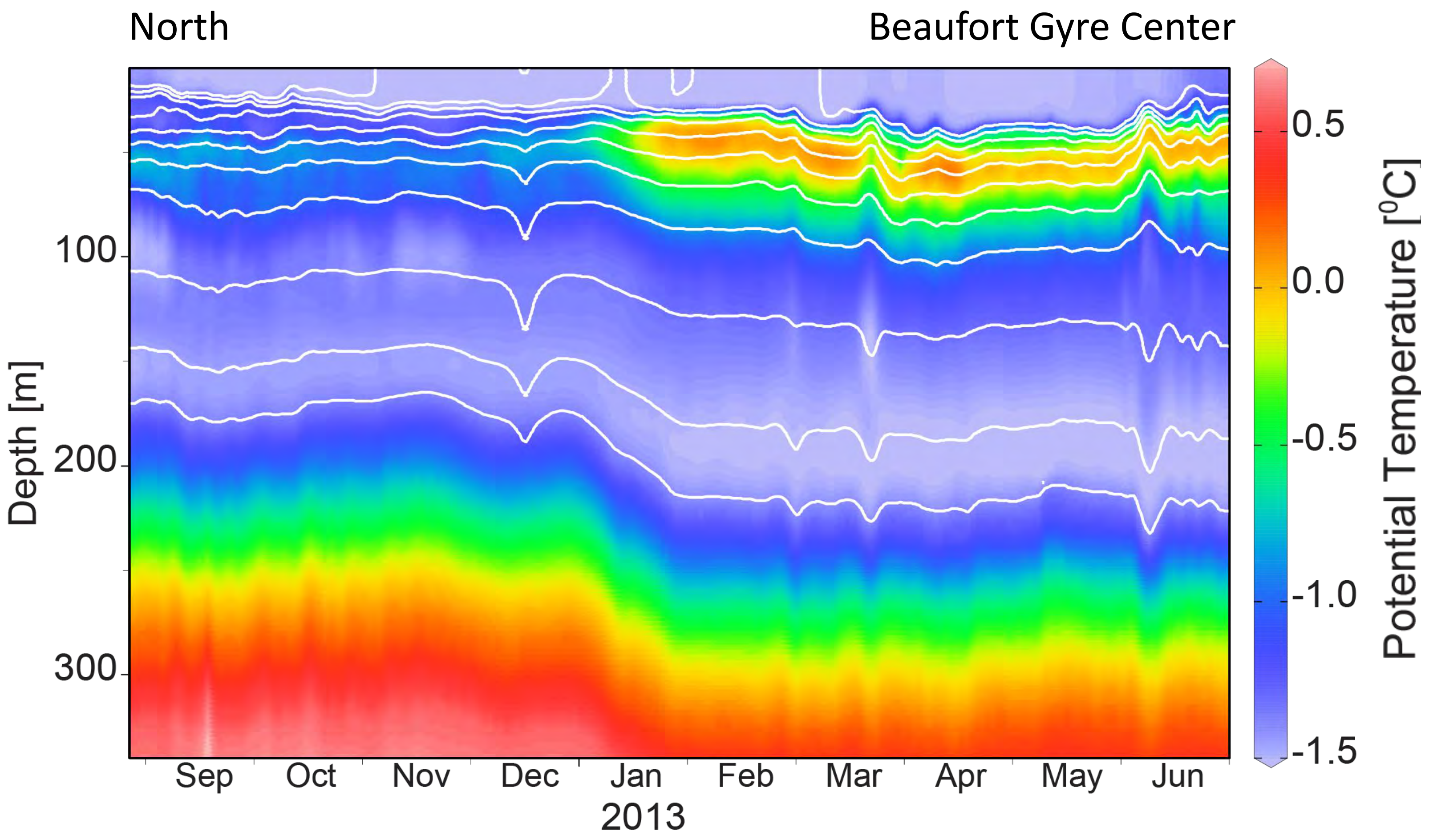
The Beaufort Gyre Halocline





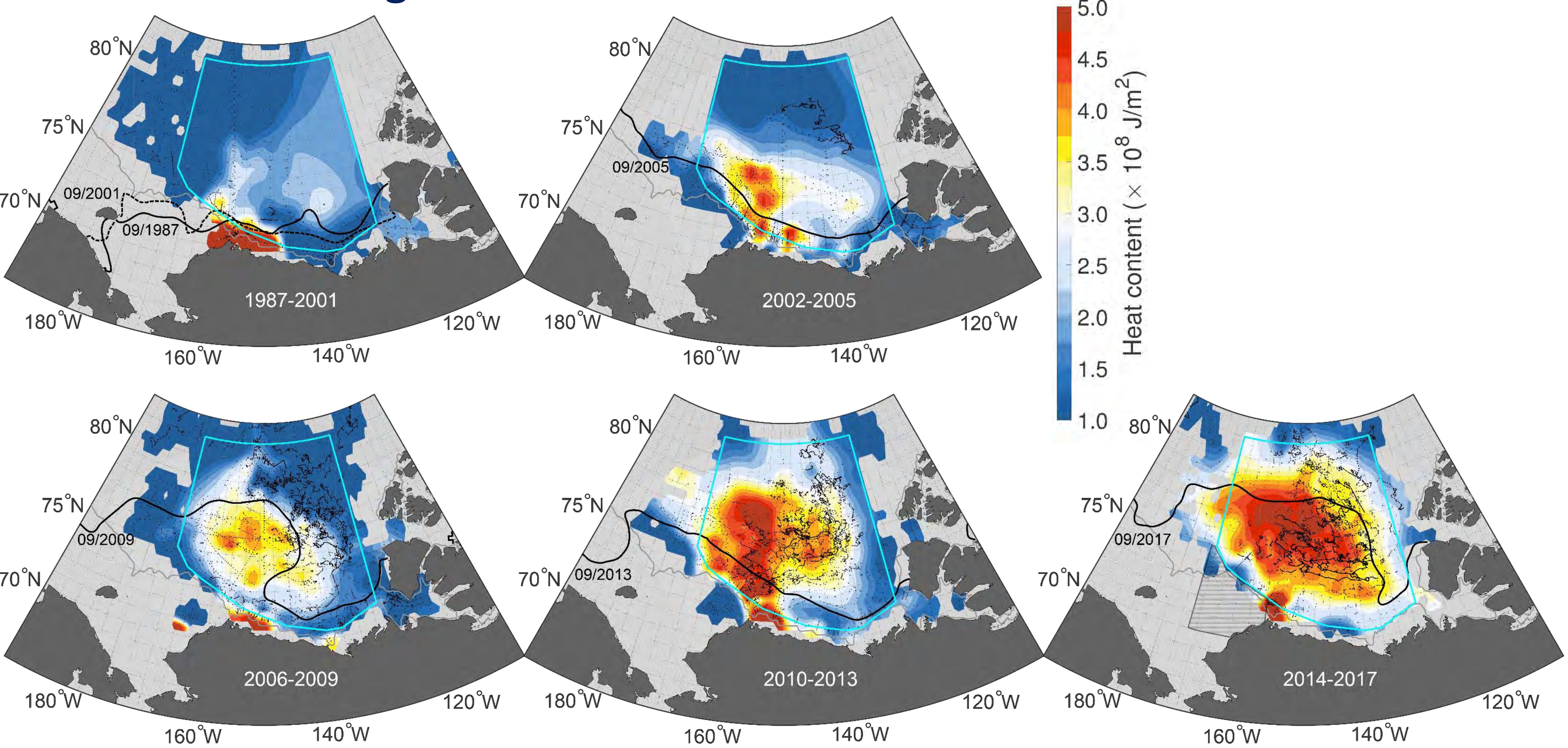
The Beaufort Gyre Halocline





Integrated Ocean Heat

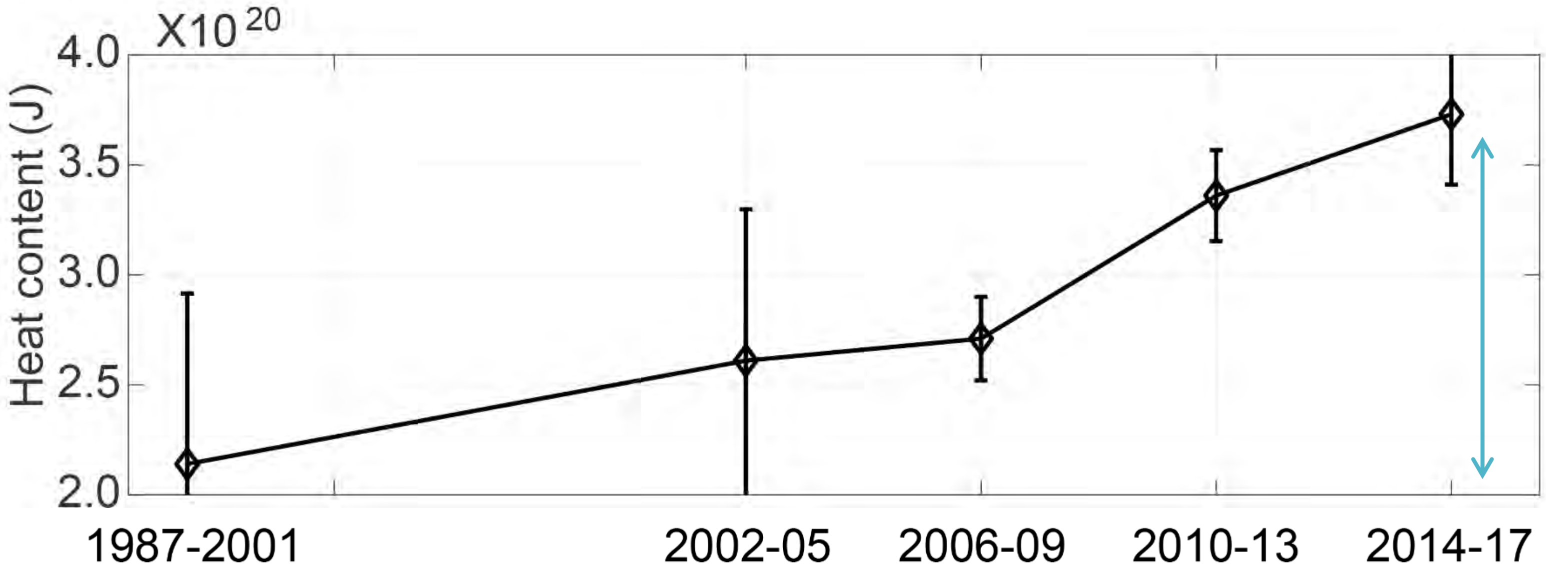
$$Q = \int_{d_{31}}^{d_{33}} \rho(z) c_p(z) [T(z) - T_f(z)] dz$$



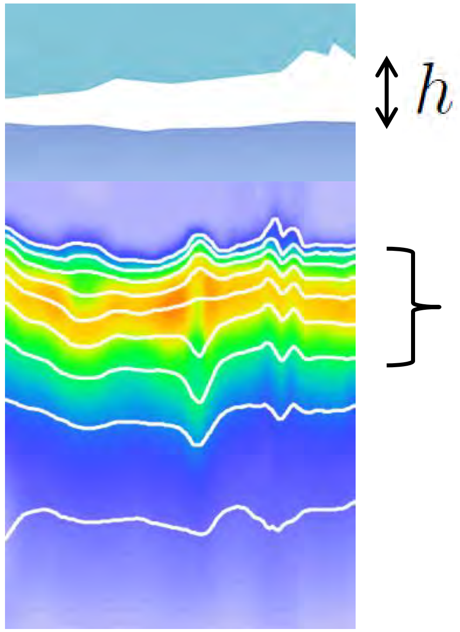
Timmermans, Toole and Krishfield (2018)

Warm Halocline Heat Content

Total heat content in the warm halocline layer:
near doubling in ocean heat content over the past 3 decades



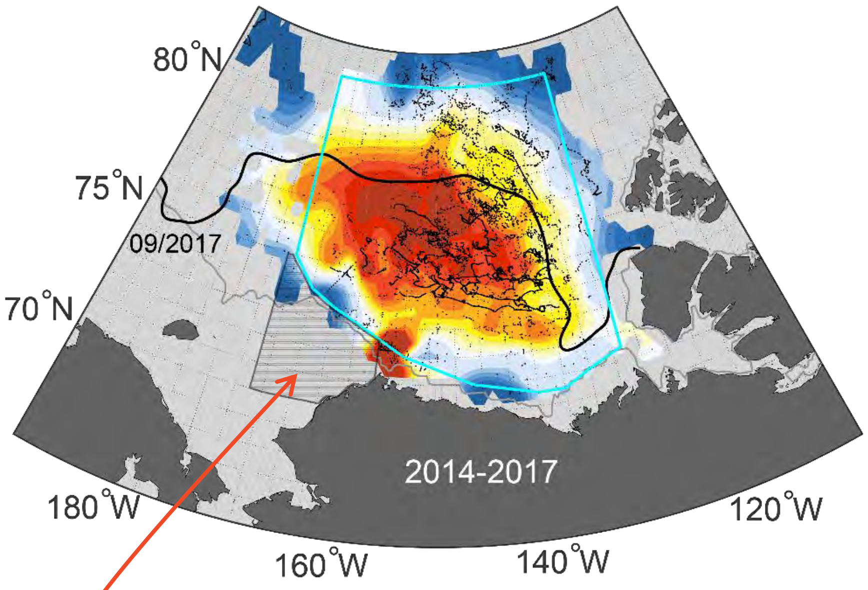
Sea-ice melt equivalent?



The capacity for sea ice melt of the additional heat content:

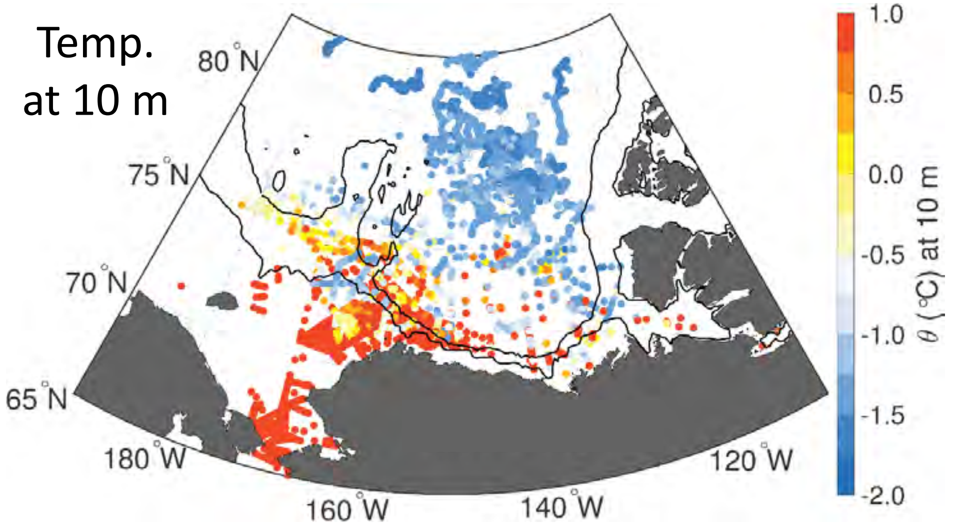
$$h = \frac{2 \times 10^8 \ [\mathrm{J\ m^{-2}}]}{L \ [\mathrm{J\ kg^{-1}}] \rho_{\mathrm{ice}} \ [\mathrm{kg\ m^{-3}}]} \approx 0.8 \mathrm{\ m}$$

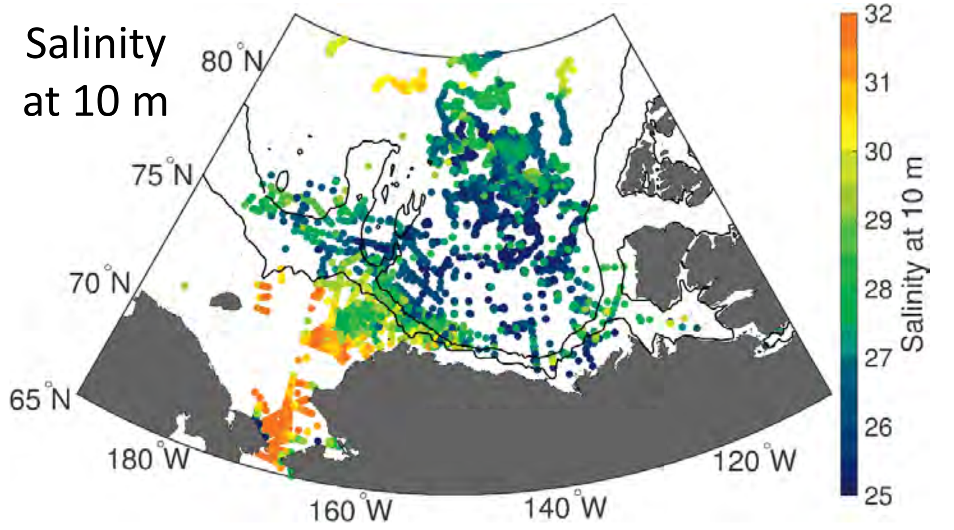
Source of Halocline Heat



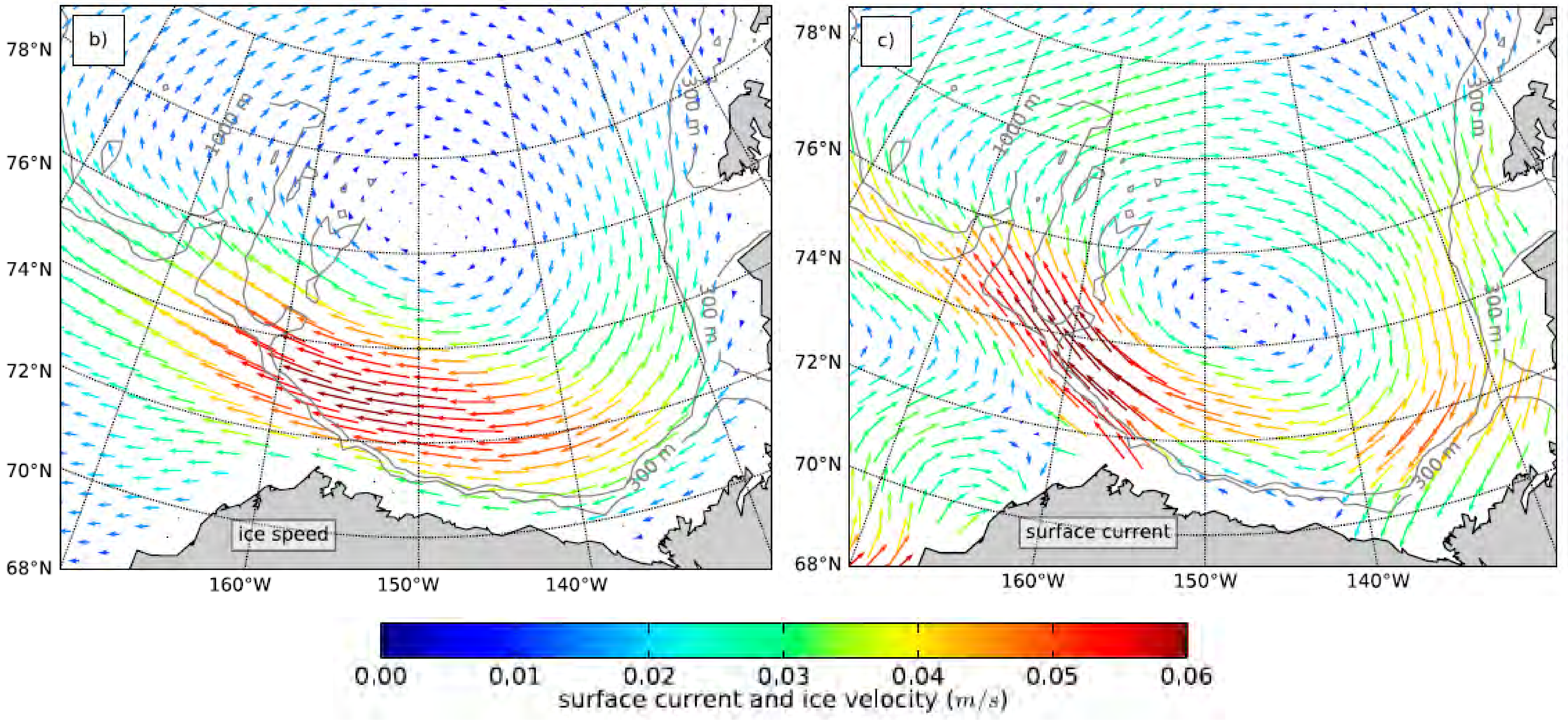
Chukchi Sea Region

Summer 2003-2013





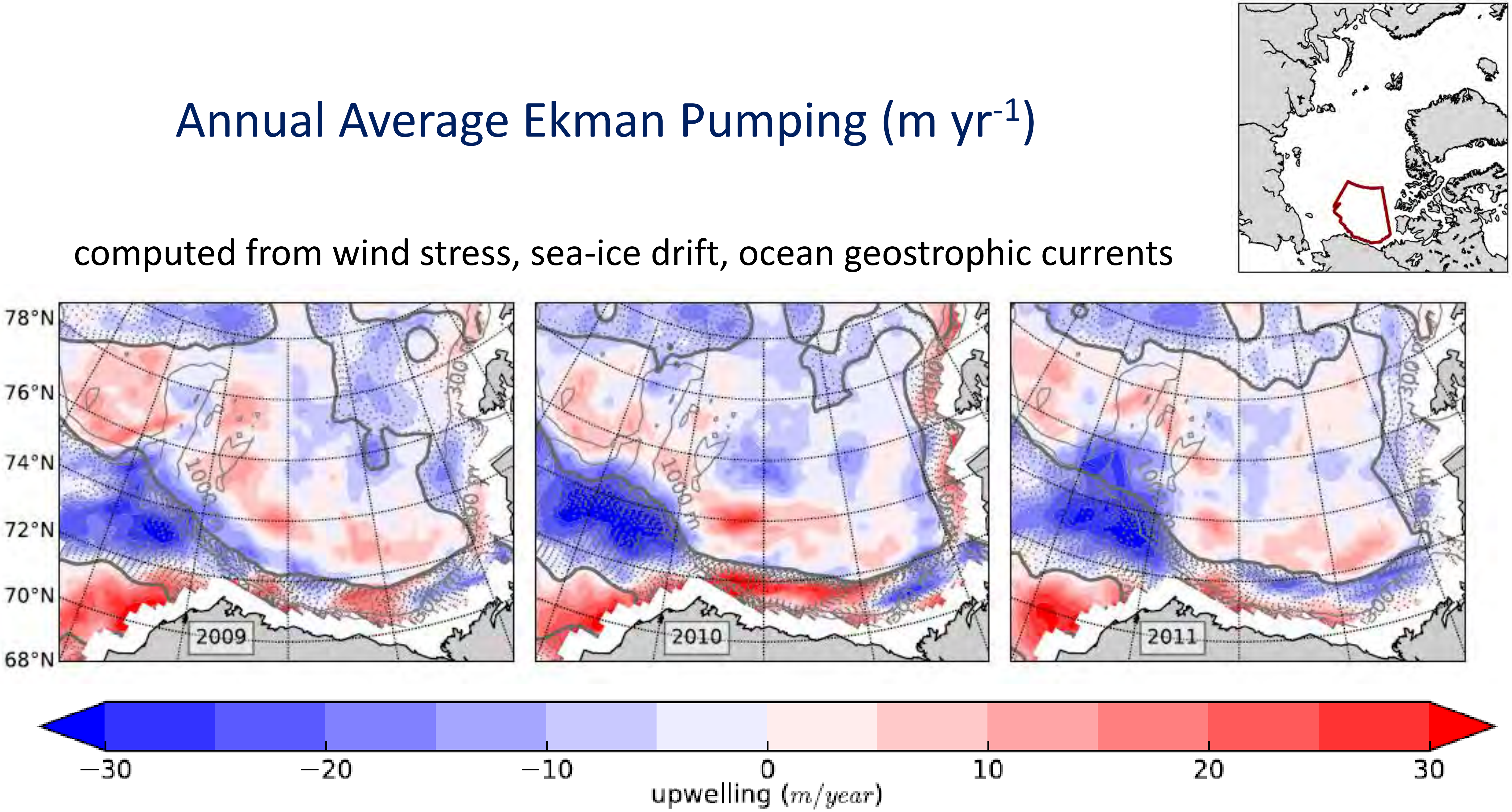
Ice Speed and Surface Geostrophic Currents: 2003-14



Meneghello, Marshall, Timmermans, Scott (2018)

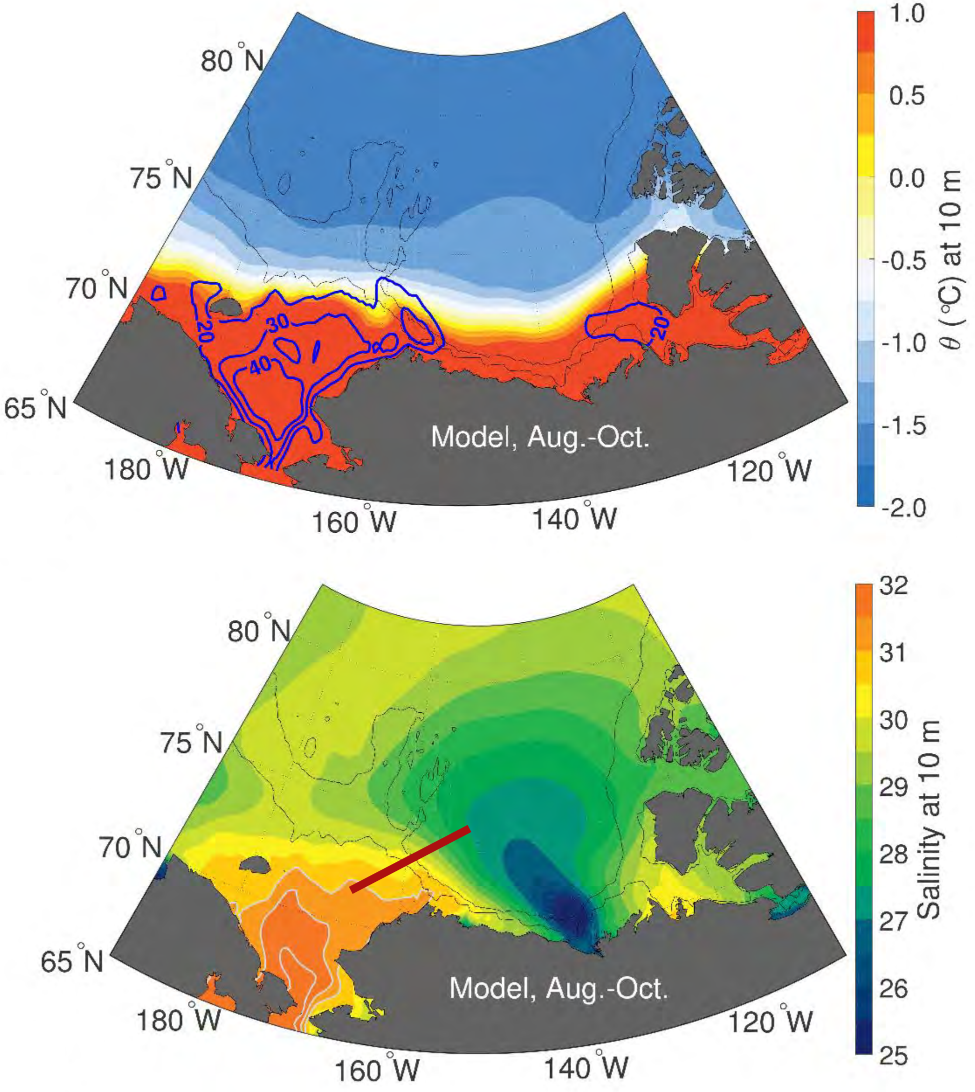
Annual Average Ekman Pumping (m yr^{-1})

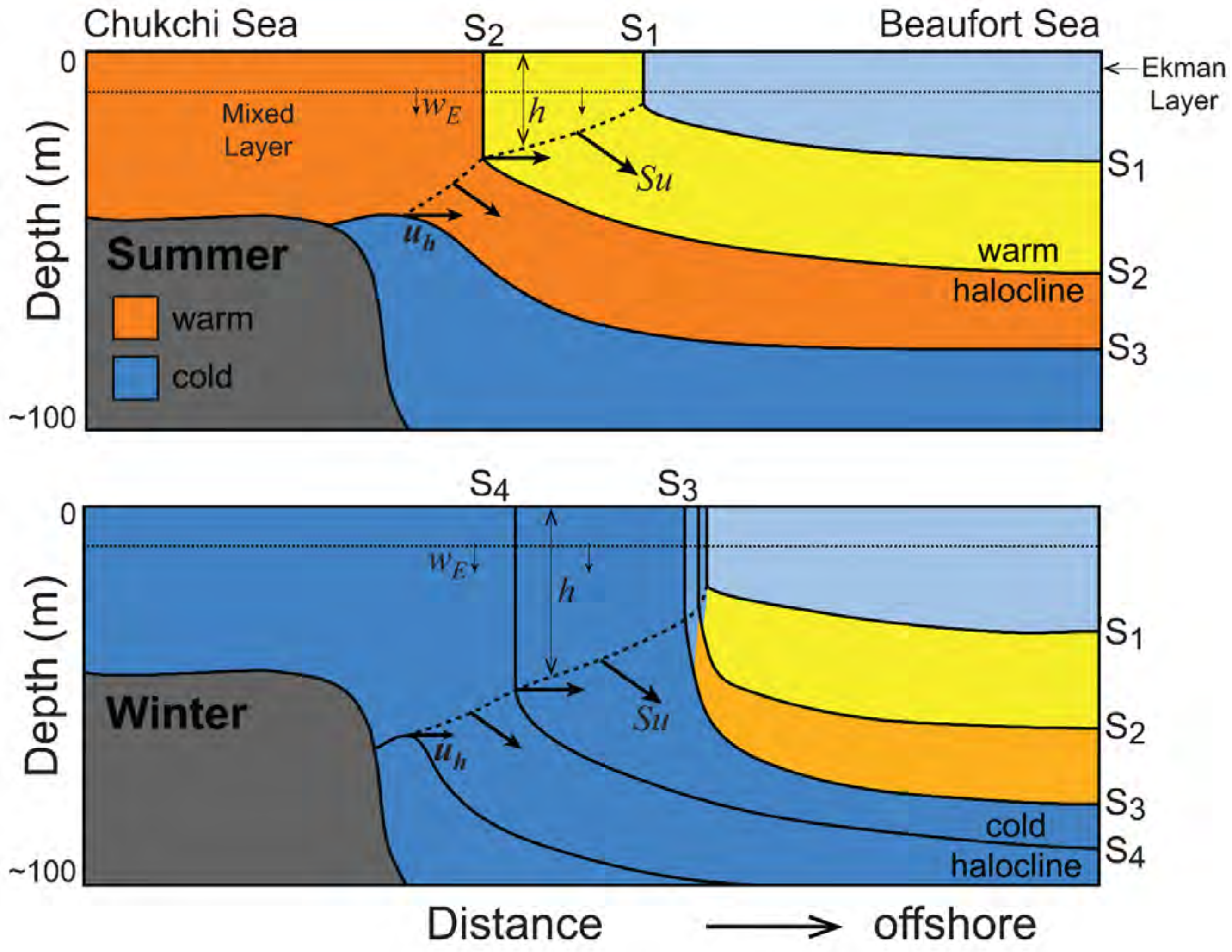
computed from wind stress, sea-ice drift, ocean geostrophic currents



Meneghello, Marshall, Timmermans, Scott (2018)

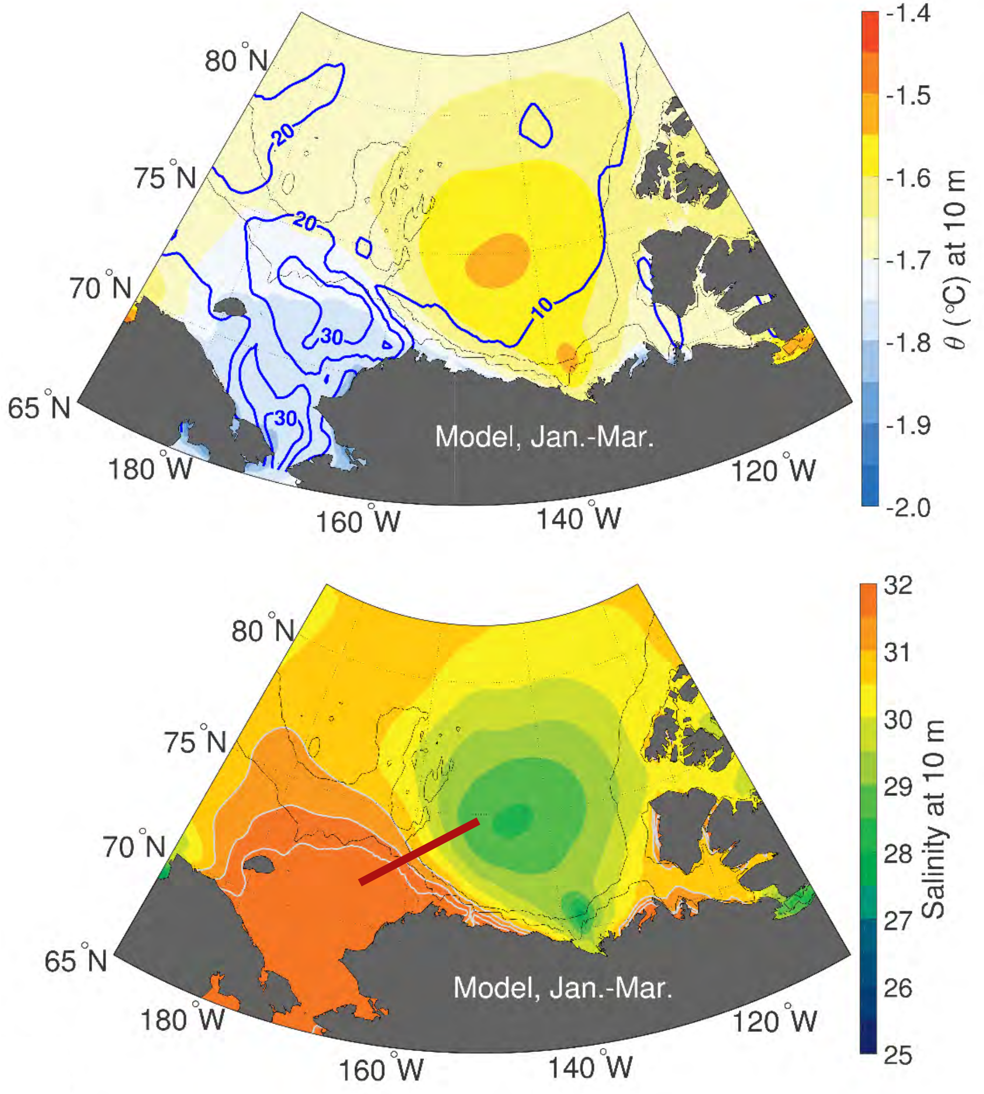
Northern Chukchi Sea: Entryway for Halocline Waters

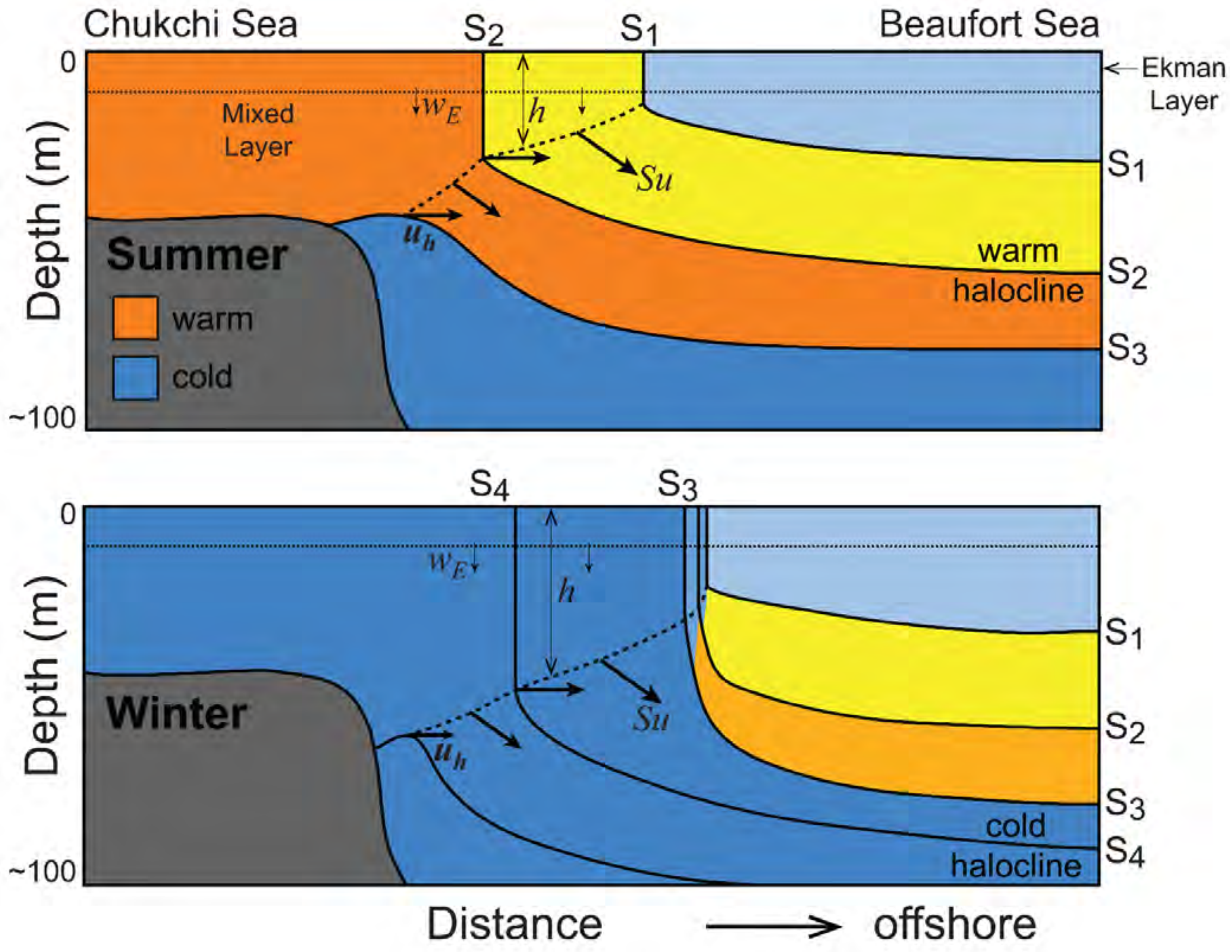




Timmermans, Marshall, Scott & Proshutinsky (2017)

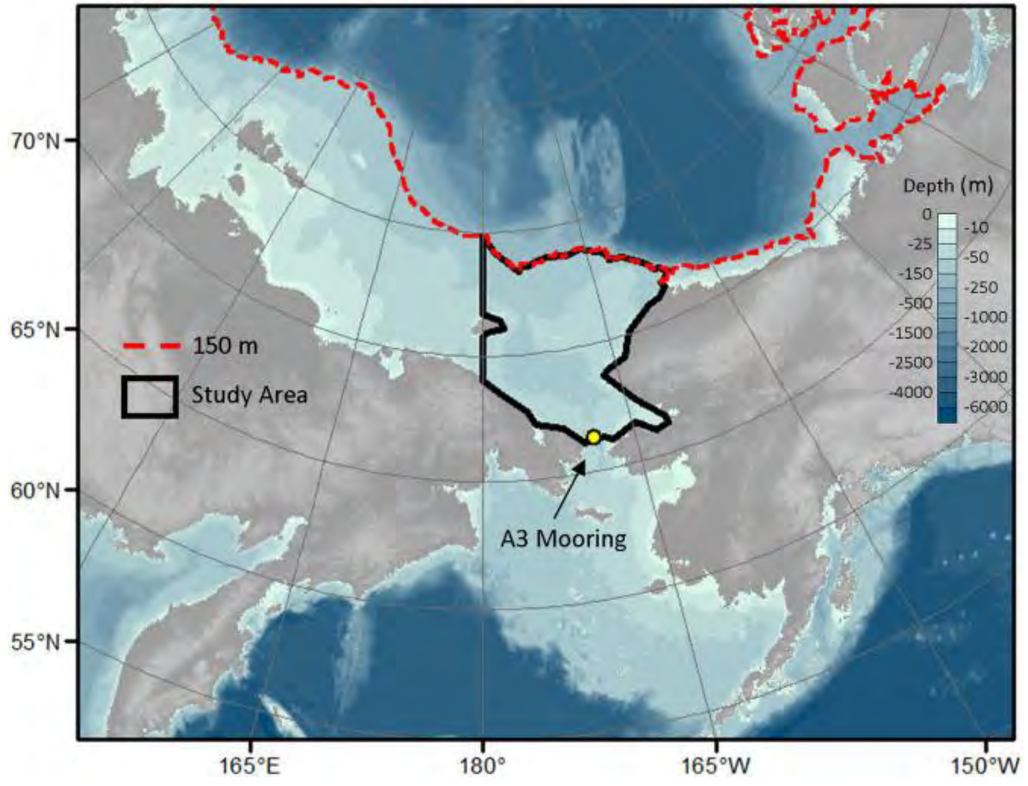
Ventilation of the Halocline: Trapping the Heat



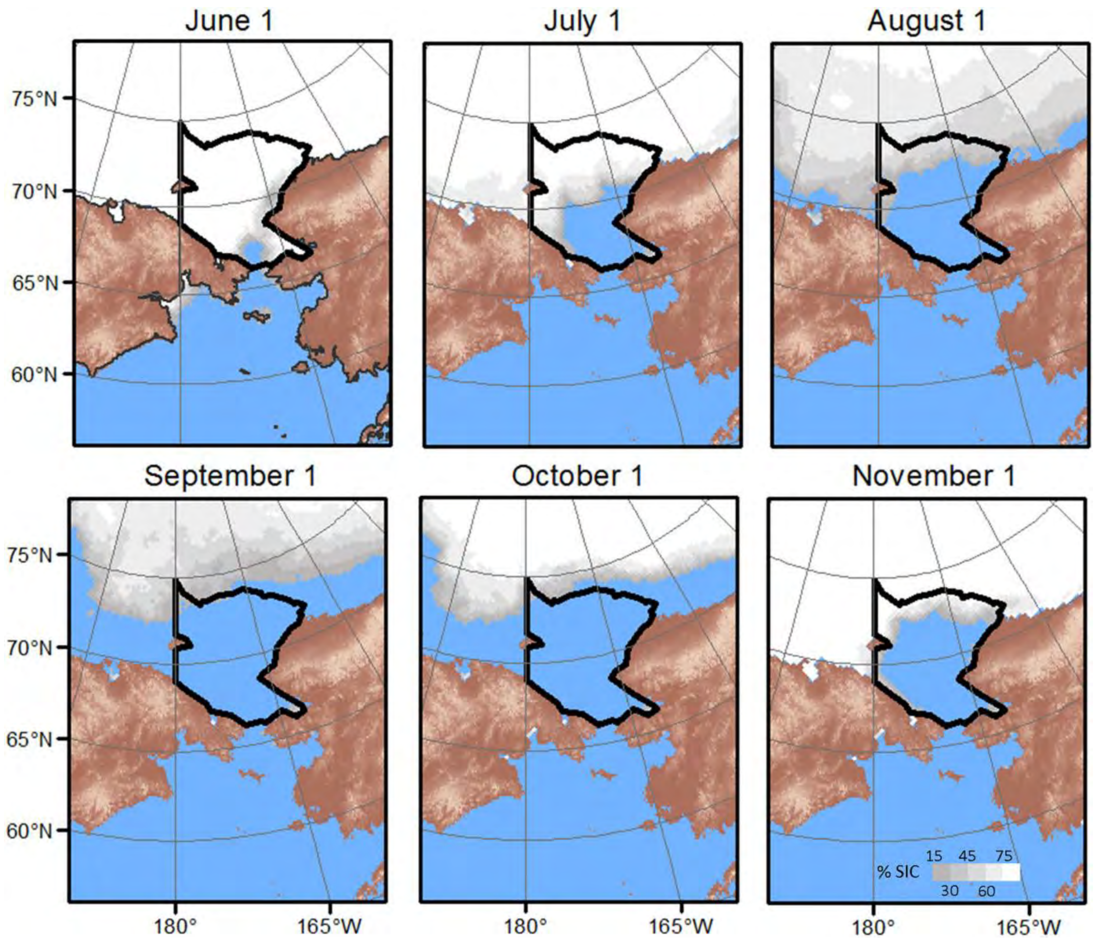


Timmermans, Marshall, Scott & Proshutinsky (2017)

Sea ice in the Chukchi Sea

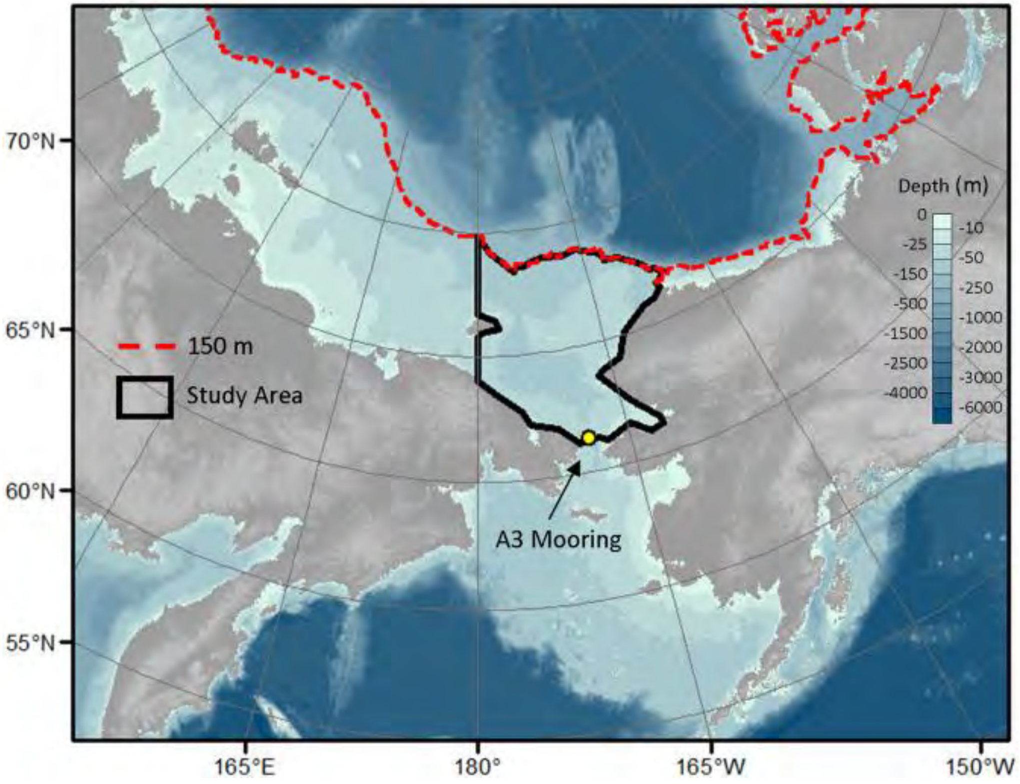


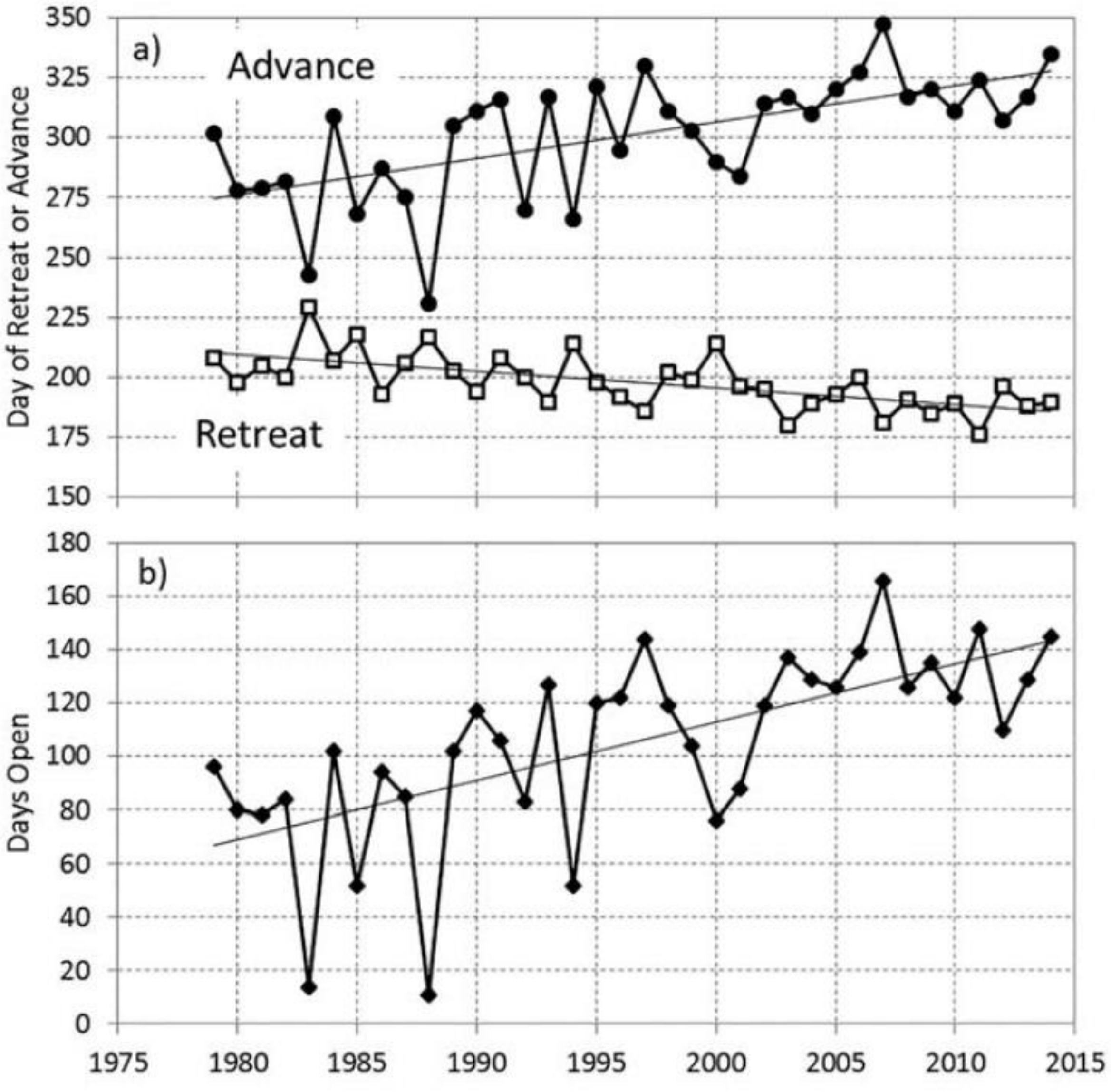
Serreze et al. (2016)



Median ice conditions in the Chukchi Sea: 1979–2014

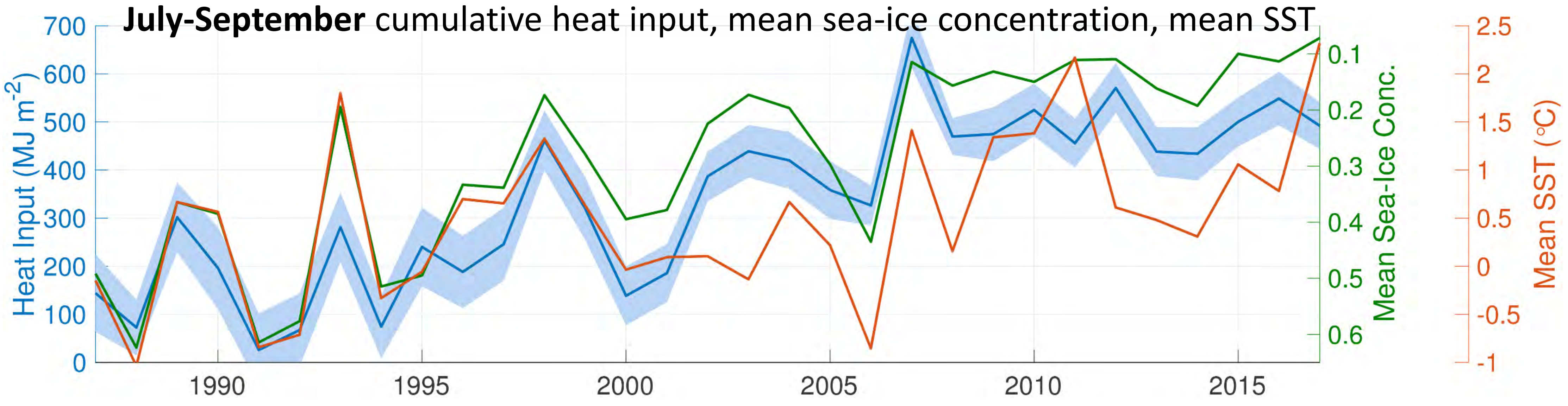
Sea ice in the Chukchi Sea

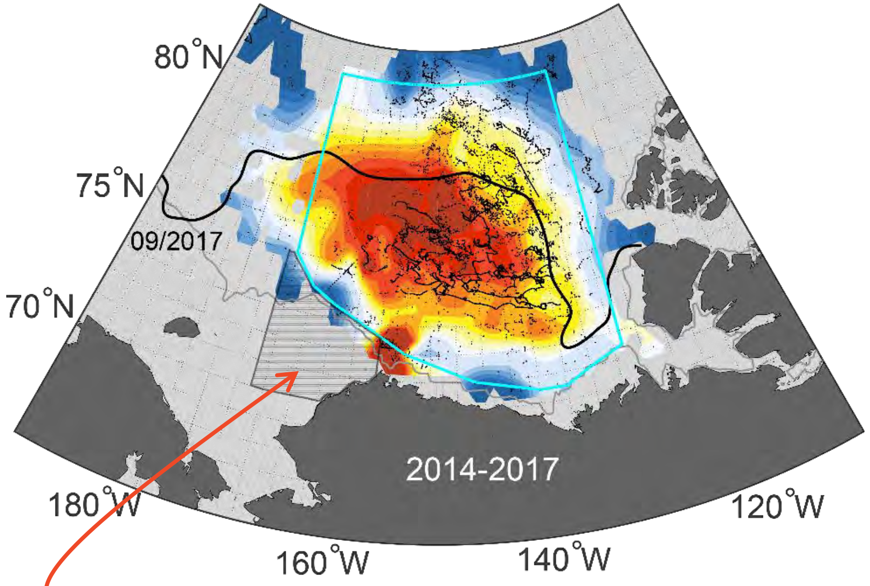




Serreze et al. (2016)

Time series in the Chukchi Sea Region





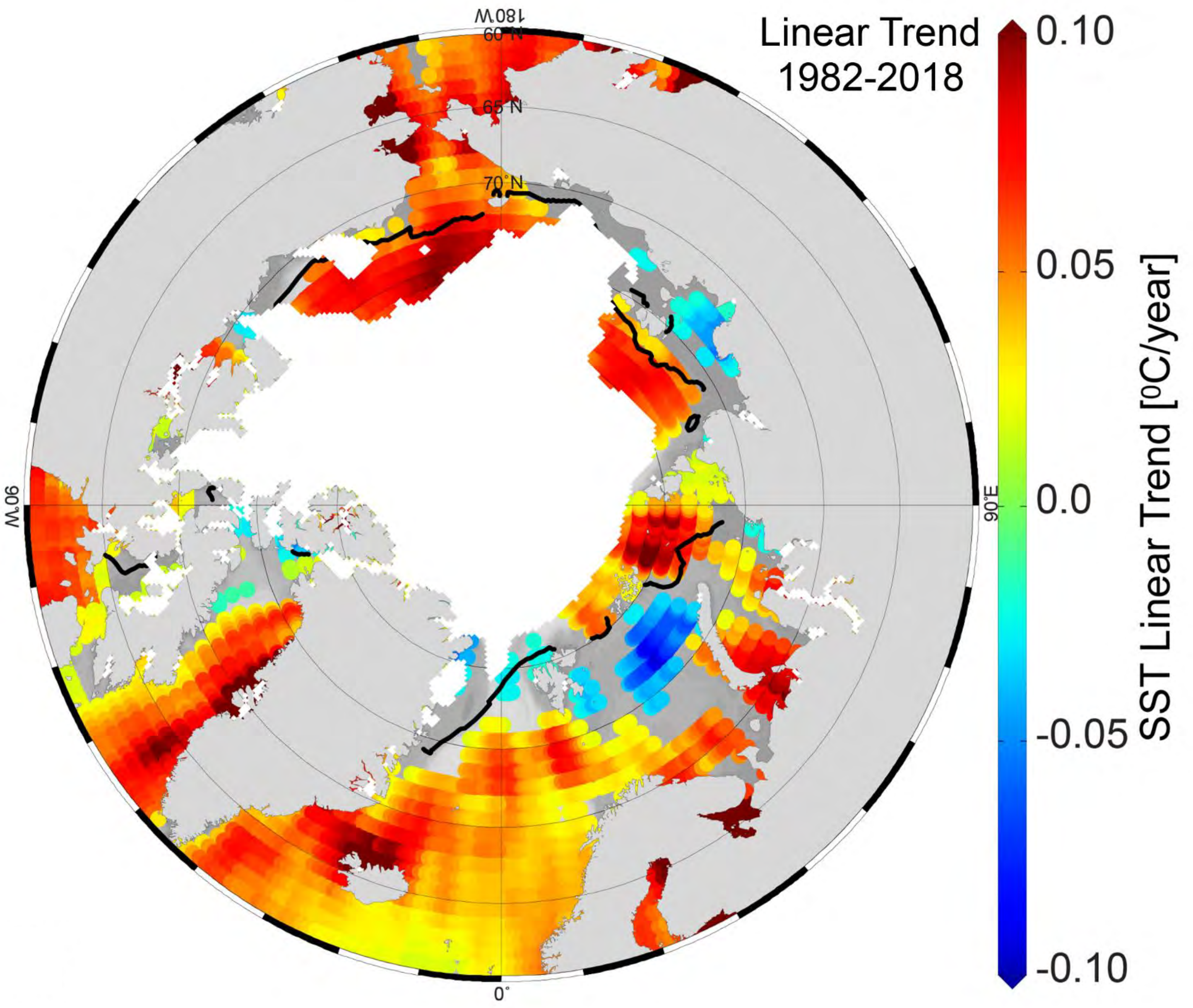
Chukchi Sea Region

Cumulative net heat flux for July to September has a main component of surface solar absorption.

~ 400 MJ m^{-2} heat input increase primarily due to sea ice loss.

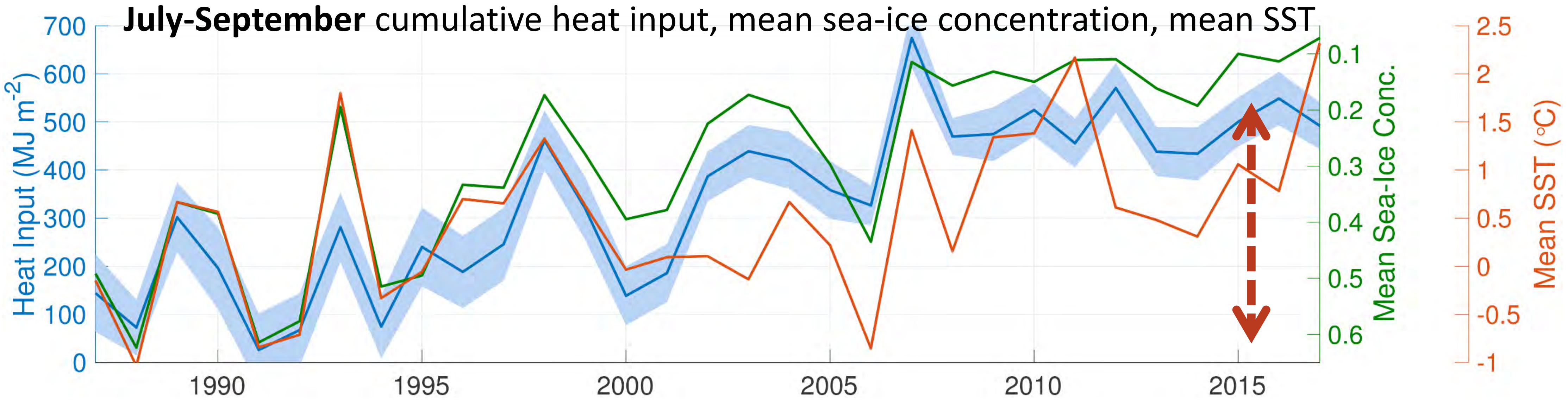
Surface Arctic Ocean: Sea Surface Temperature

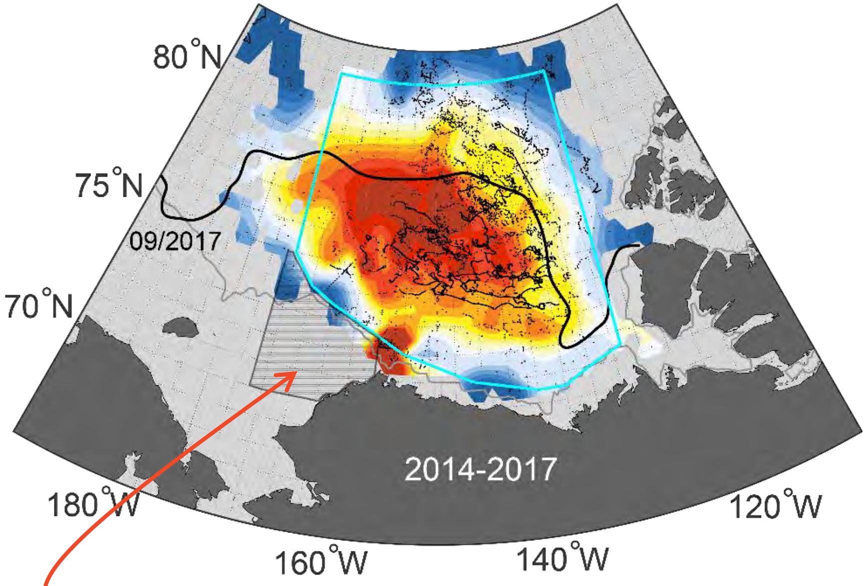
1982-2018
Linear Trend
August
Sea-Surface
Temperature



SST is increasing at rates of 0.5°C per decade over large sectors that are ice-free in summer.

Time series in the Chukchi Sea Region





Chukchi Sea Region

Late summer SSTs should be $\sim$ 5°C warmer in recent years compared to three decades ago.

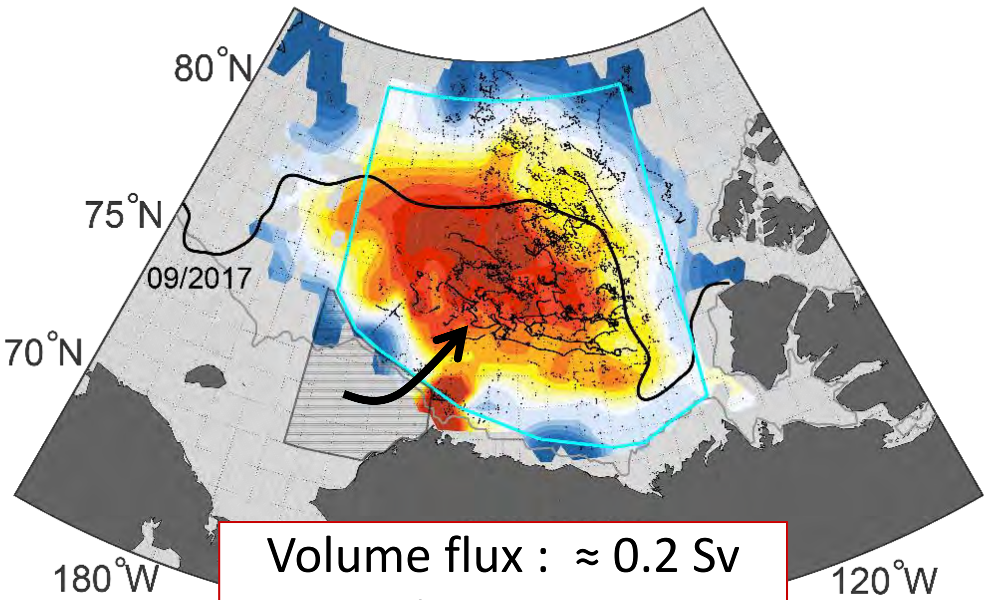
$$\frac{\partial T}{\partial t} = \frac{F}{\rho c_p D}$$

$$D \approx 20 \text{ m}$$

Cumulative heat input can account for observed SST increase.

Heat Entering the Halocline

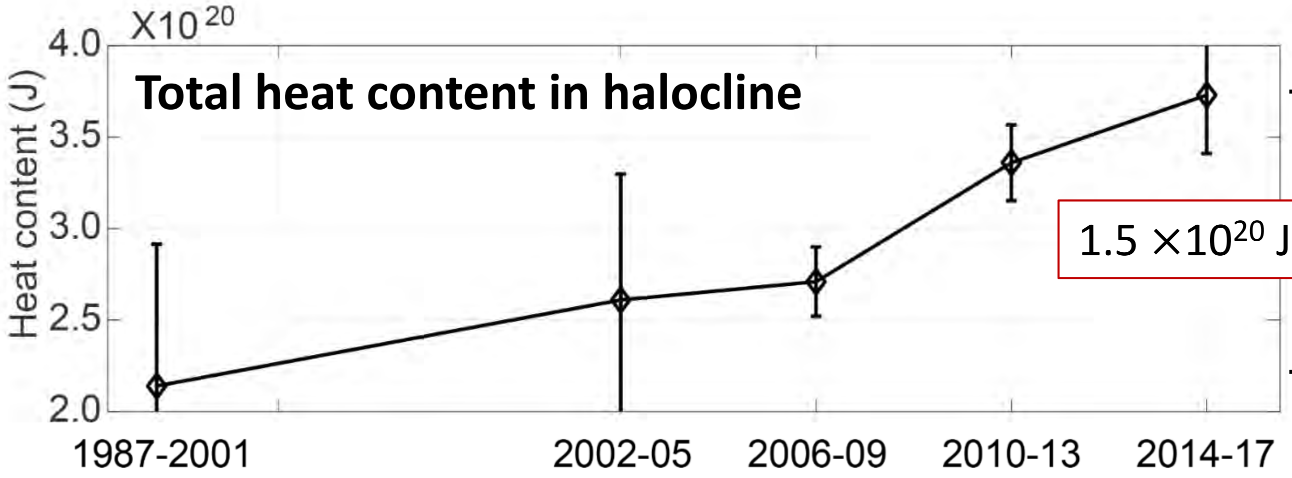
heat entering halocline = energy density in Chukchi × volume flux into halocline



Volume flux : ≈ 0.2 Sv steady over JAS ⇒ volume influx: 1.6×10^{12} m^3

Energy density: $\rho c_p \, [\mathrm{SST} - T_f]$ Heat content/volume relative to freezing

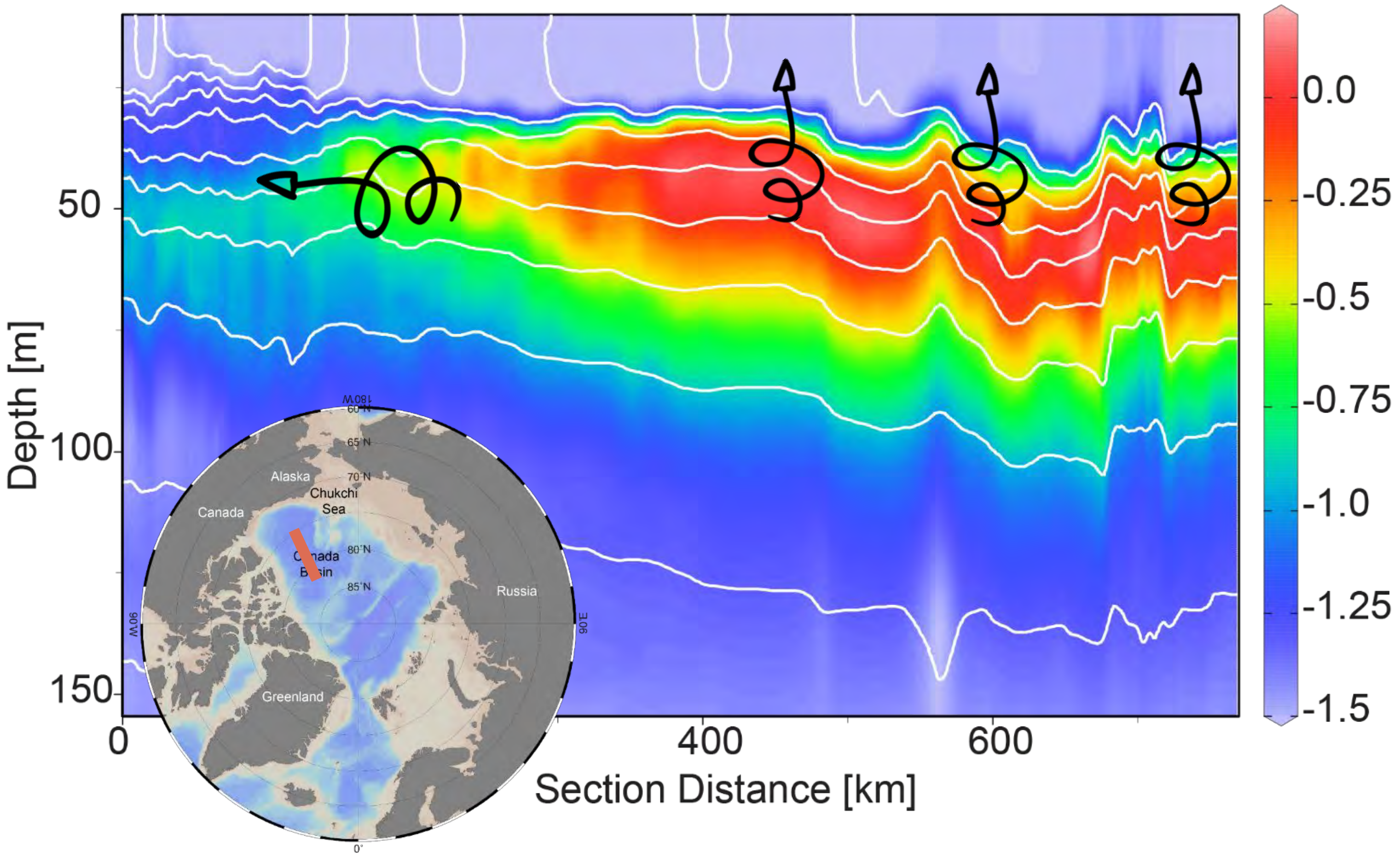
Area averaged summer SST time series yields **cumulative heat input to halocline: 4 $\times 10^{20}$ J**.



1.5×10^{20} J

Increased heat in the Chukchi region can account for interior basin halocline warming.

Fate of the Halocline Heat



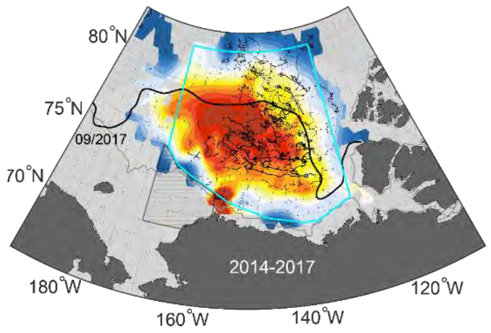
Range of estimated diffusivities:
$\sim 10^{-7}$-10^{-6} $m^2\ s^{-1}$

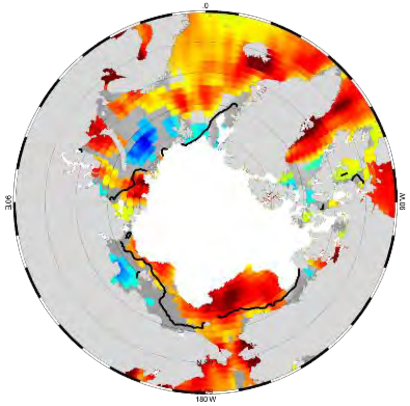
$\Rightarrow$ upward heat fluxes: 0.03 to 0.3 W m^{-2}

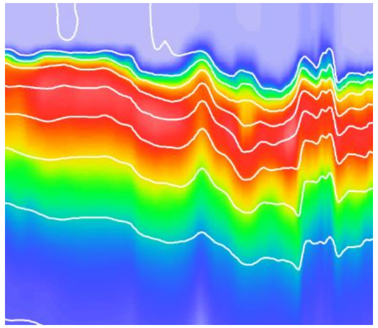
These fluxes $\Rightarrow$ diffusive removal of heat would take 40-400 years

Eddy fluxes also transport heat laterally out of the region in a dynamical response to the wind-energy input.

Summary and needs for viable decadal projections







- Heat content increases in Beaufort Gyre interior due to sea ice losses at the basin margins
- Effects of ice-albedo feedback have consequences far beyond the summer season
- How will mixing change as sea ice cover declines? Will stratification continue to suppress turbulent mixing?
- How do episodic mixing events and their timing influence the system?
- Will we see a shift to α conditions, or will freshwater dominate?
- How does/will the Beaufort Gyre/Freshwater equilibrate?