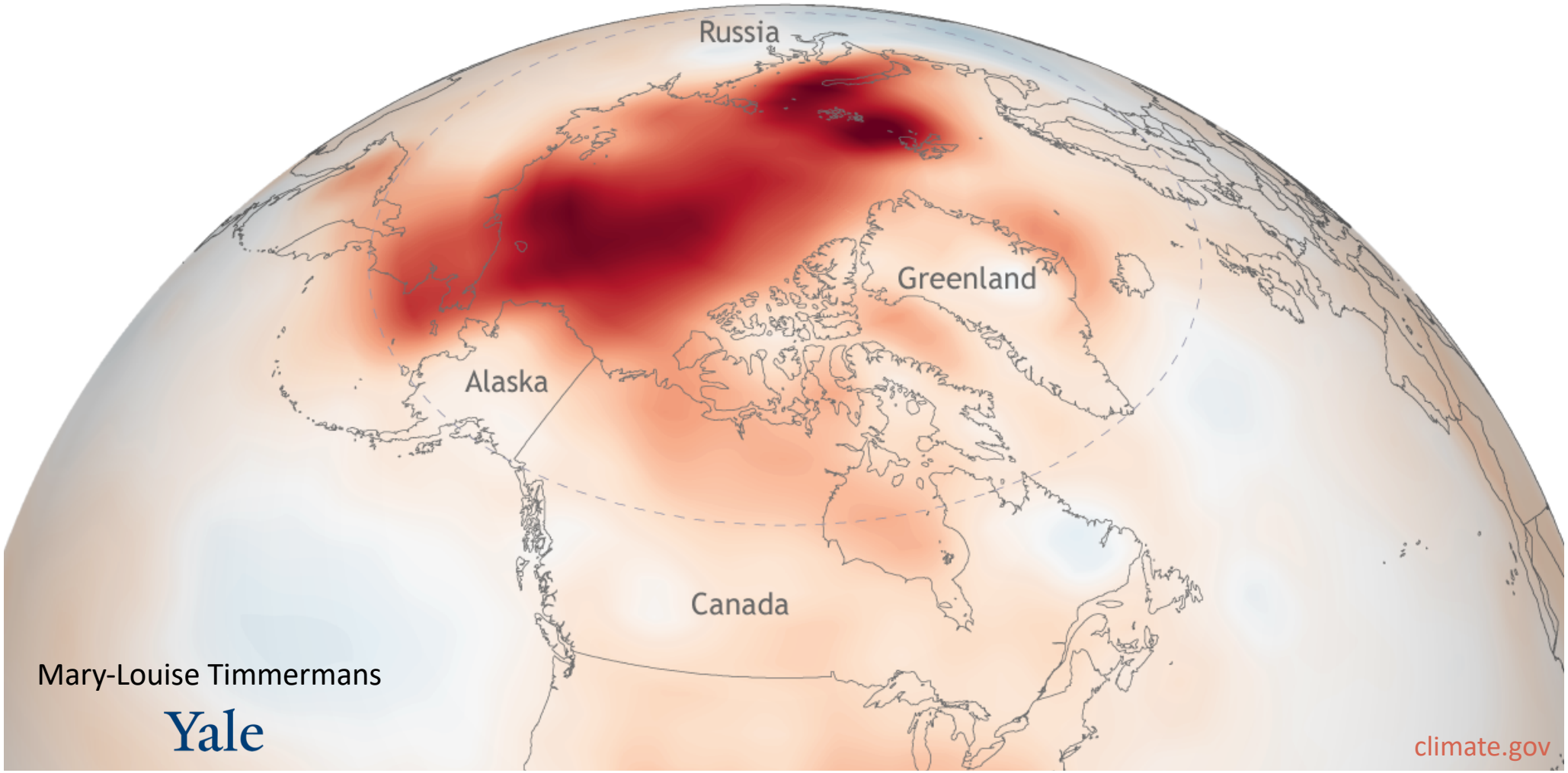
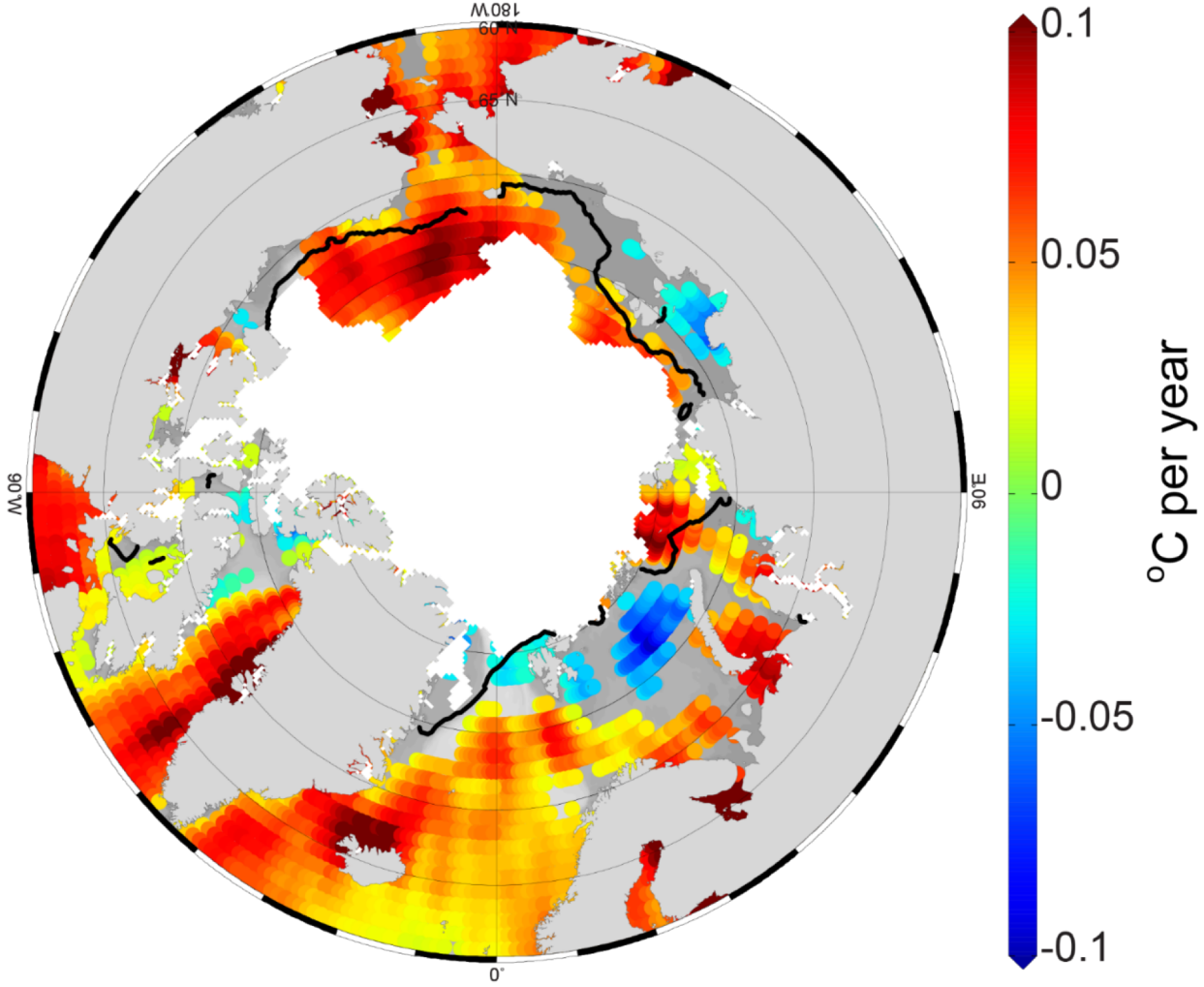
Consequences of a warming Arctic Ocean



Mary-Louise Timmermans
Yale

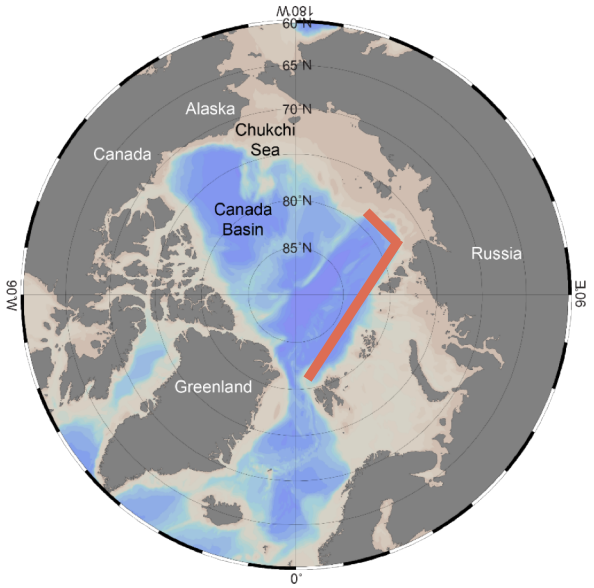
Surface Ocean Warming

1982-2017
Linear Trend
August
Sea-Surface
Temperature

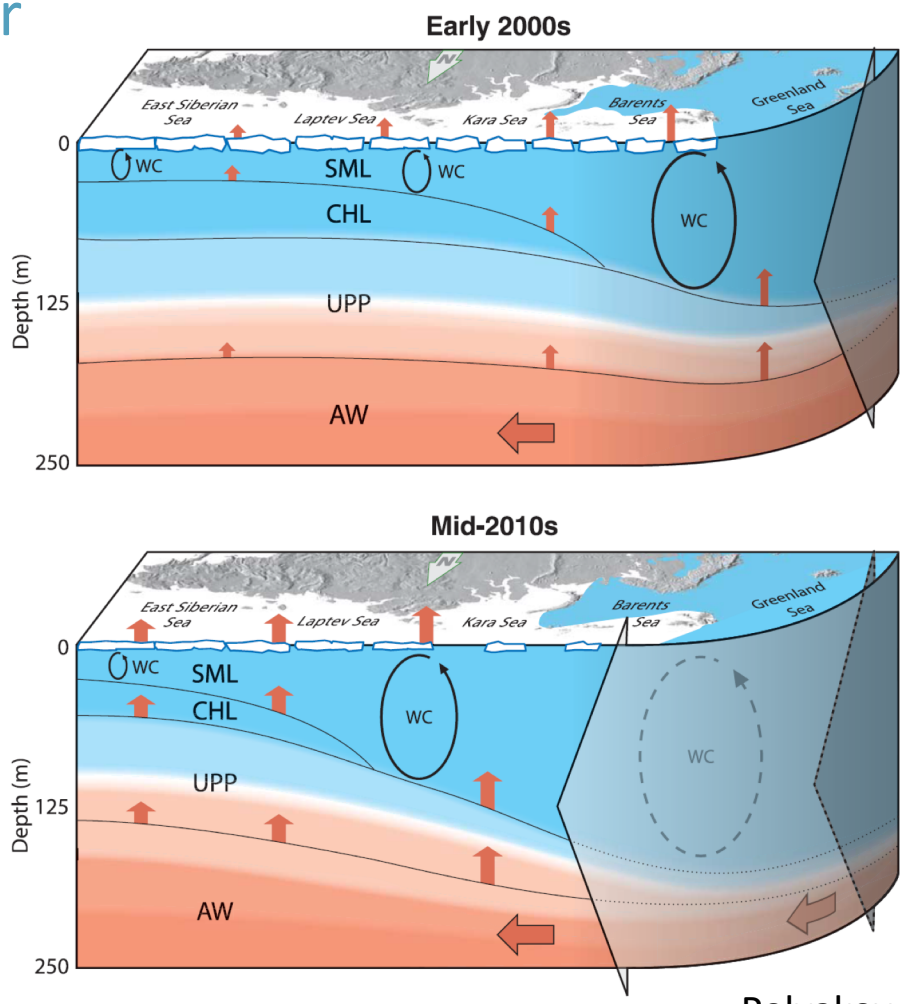


SST is increasing at rates of 0.5°C per decade over large sectors that are ice-free in summer.

Warming in the Atlantic Sector

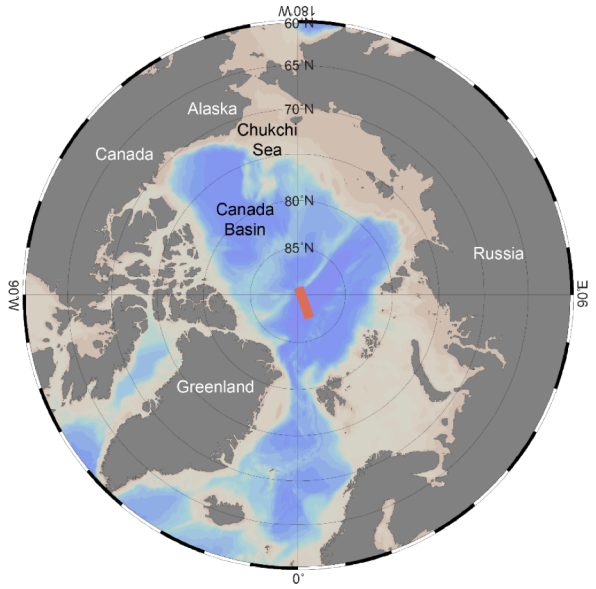


2 to 4 times larger Atlantic Layer heat fluxes in 2014-2015 compared to 2007-2008

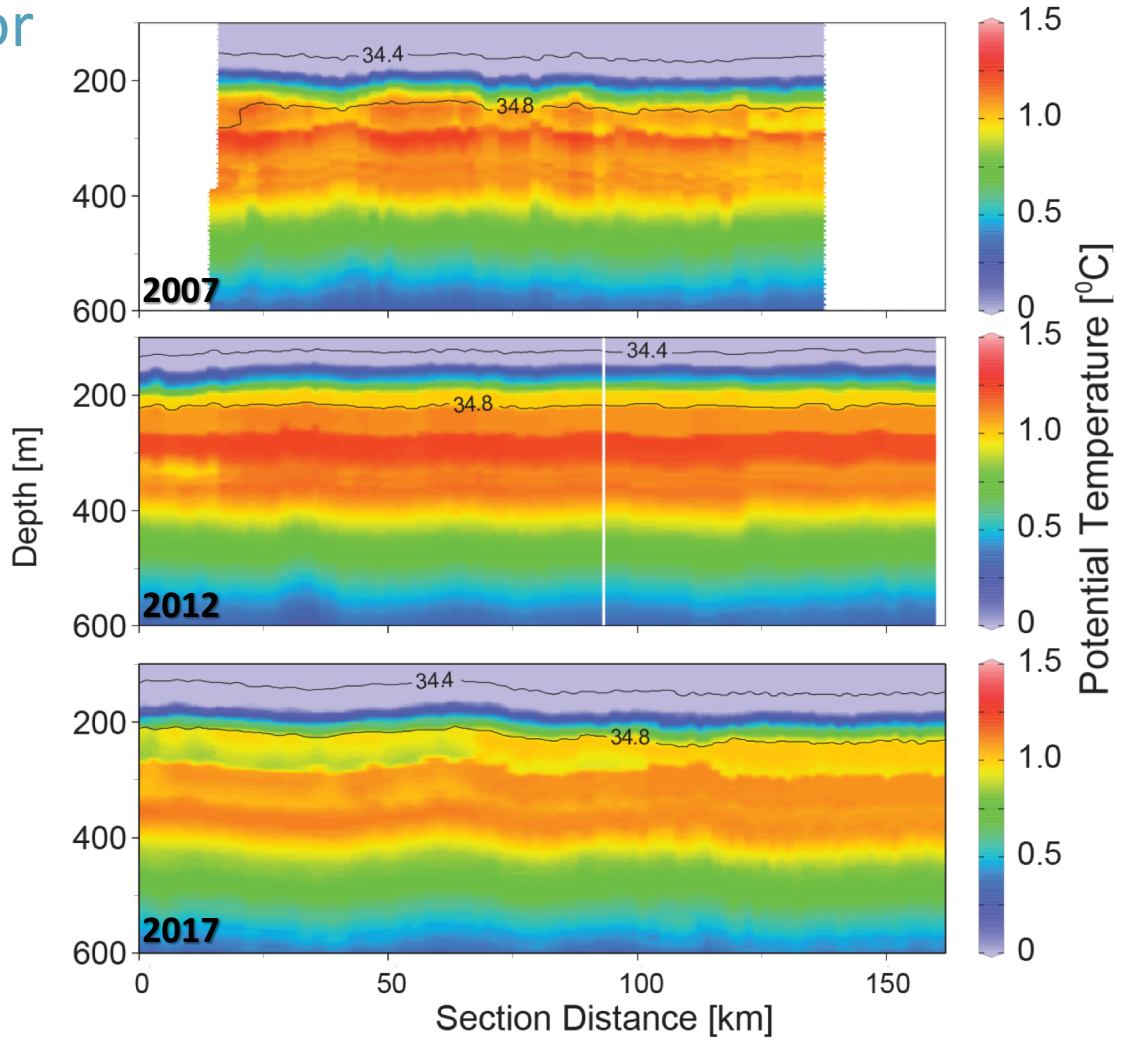


Polyakov et al., 2017

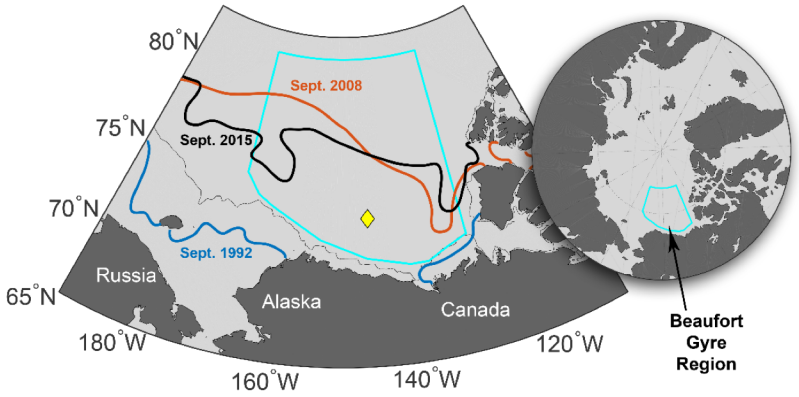
Warming in the Atlantic Sector

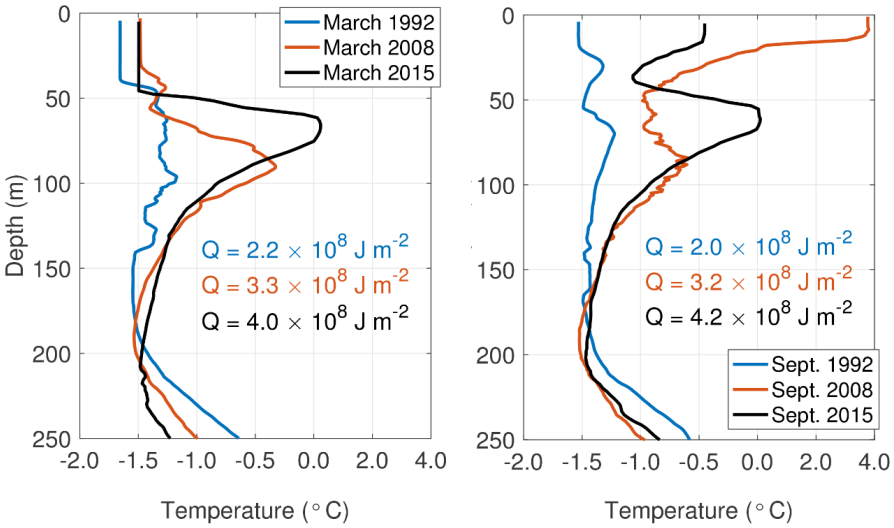


Central regions show little change in Atlantic Layer core temperature over a decade.

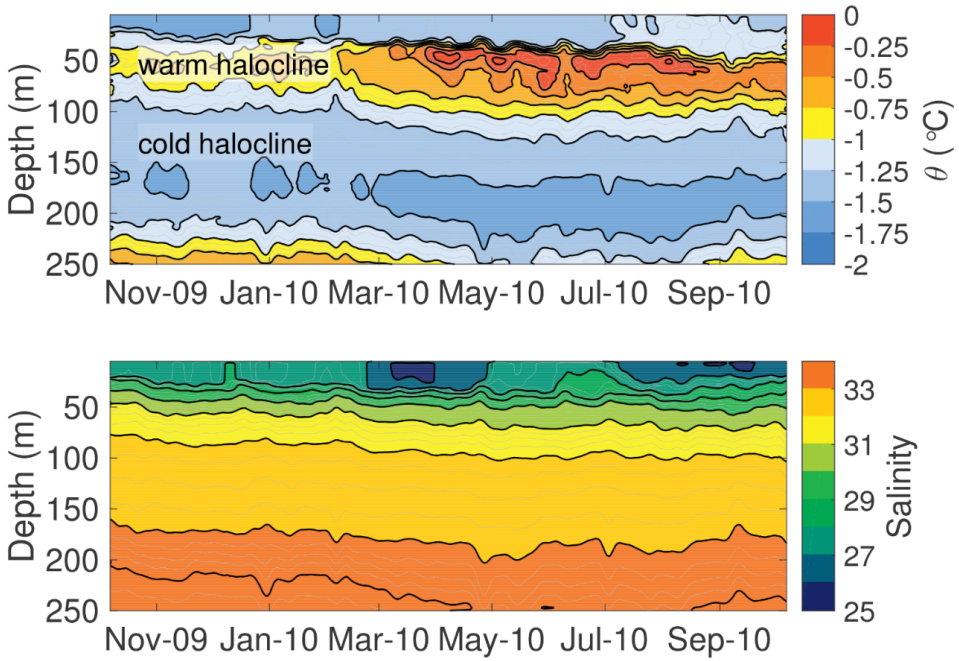


Warming in the Pacific Sector



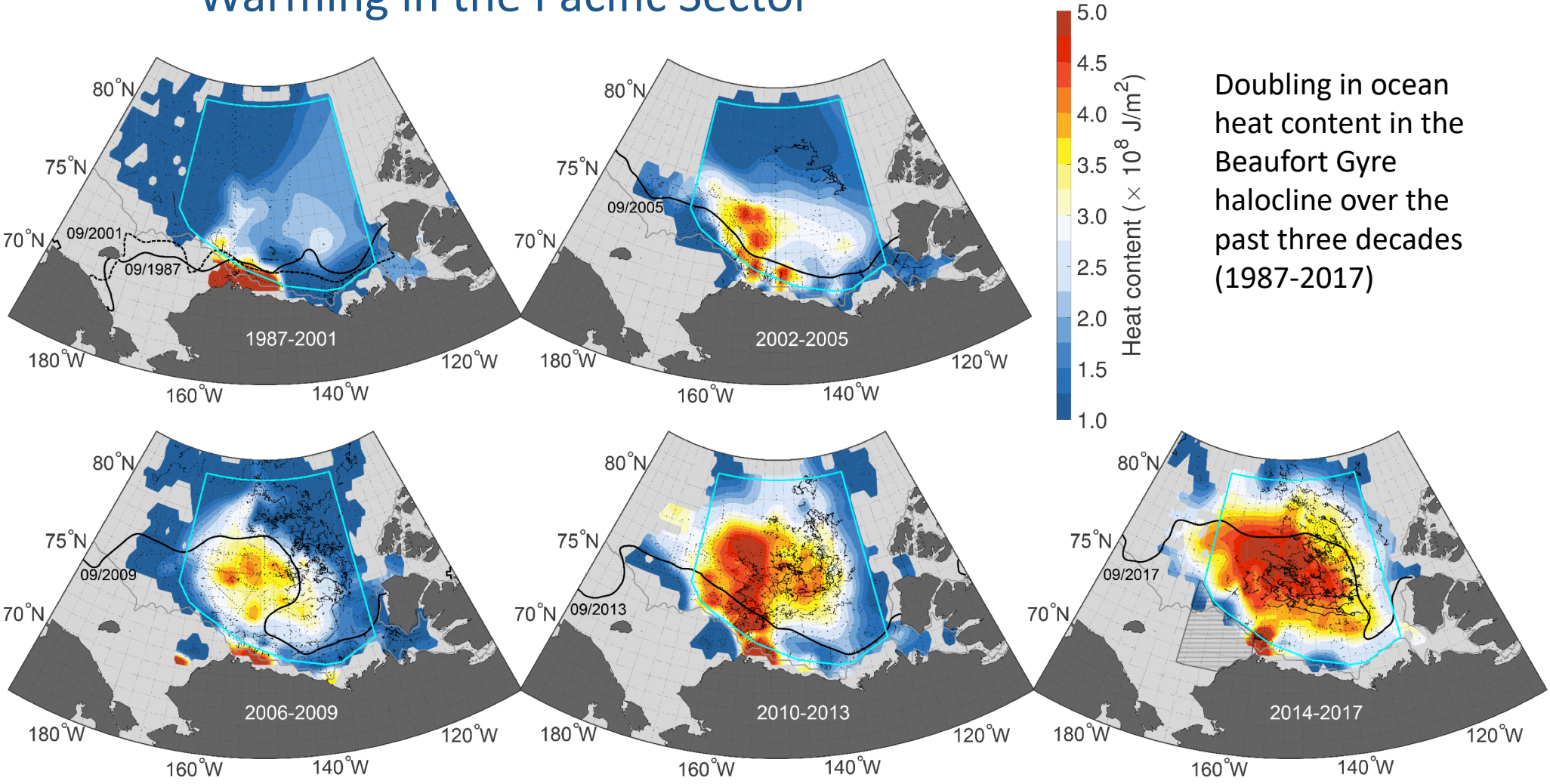


Warm halocline



Over the past three decades Pacific Water max temperature has increased by about 1^0C.

Warming in the Pacific Sector

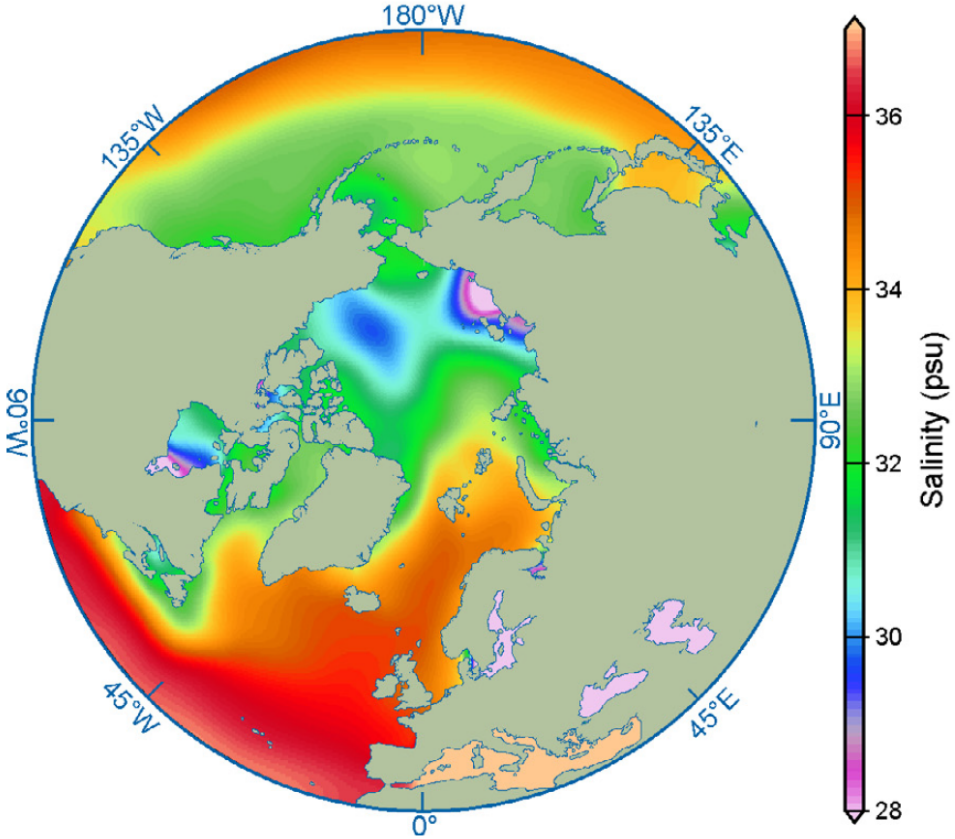


Doubling in ocean heat content in the Beaufort Gyre halocline over the past three decades (1987-2017)

Timmermans, Toole, Krishfield, 2018

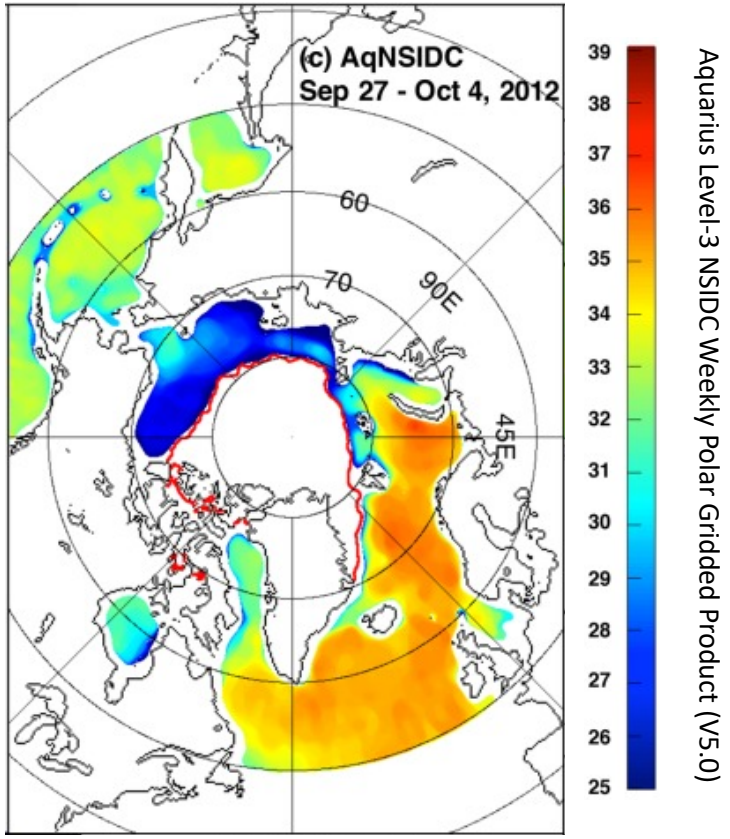
Arctic Ocean Salinity

Annual Mean 20 m salinity from climatology



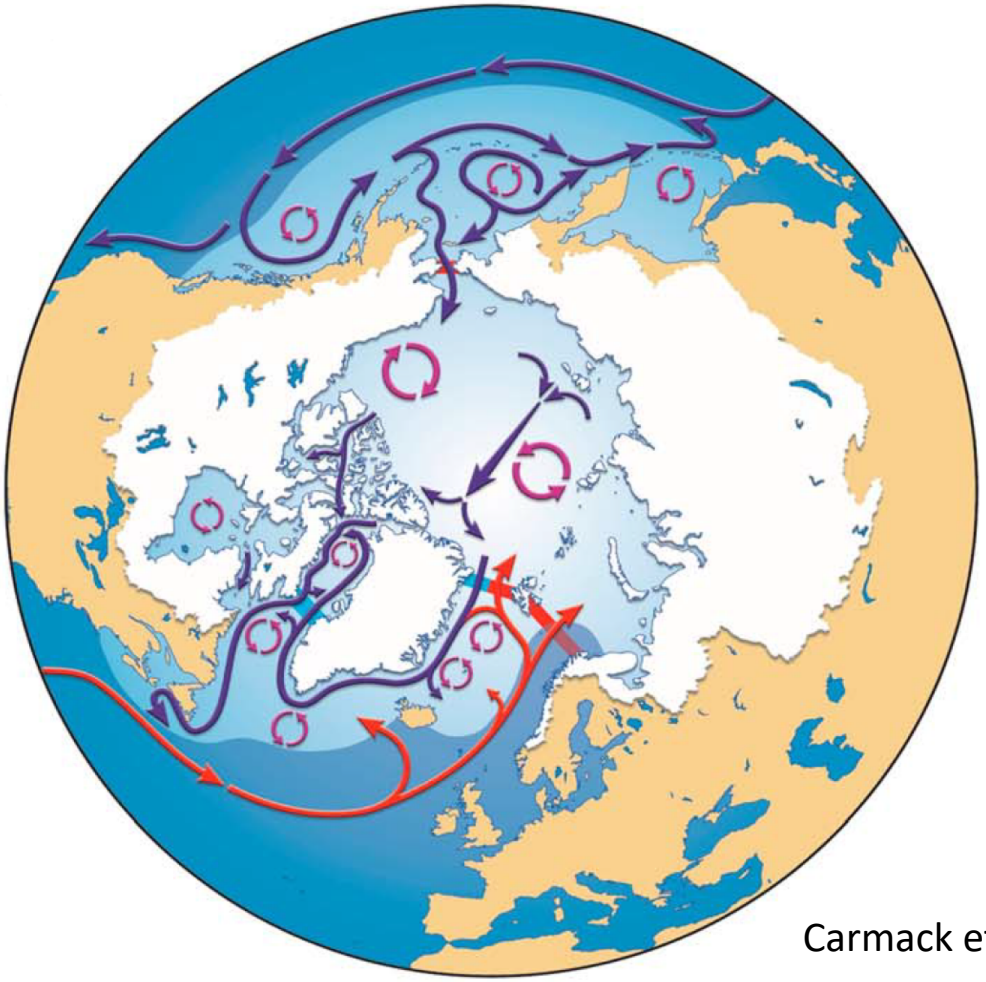
Blum et al. 2015

Satellite derived SSS



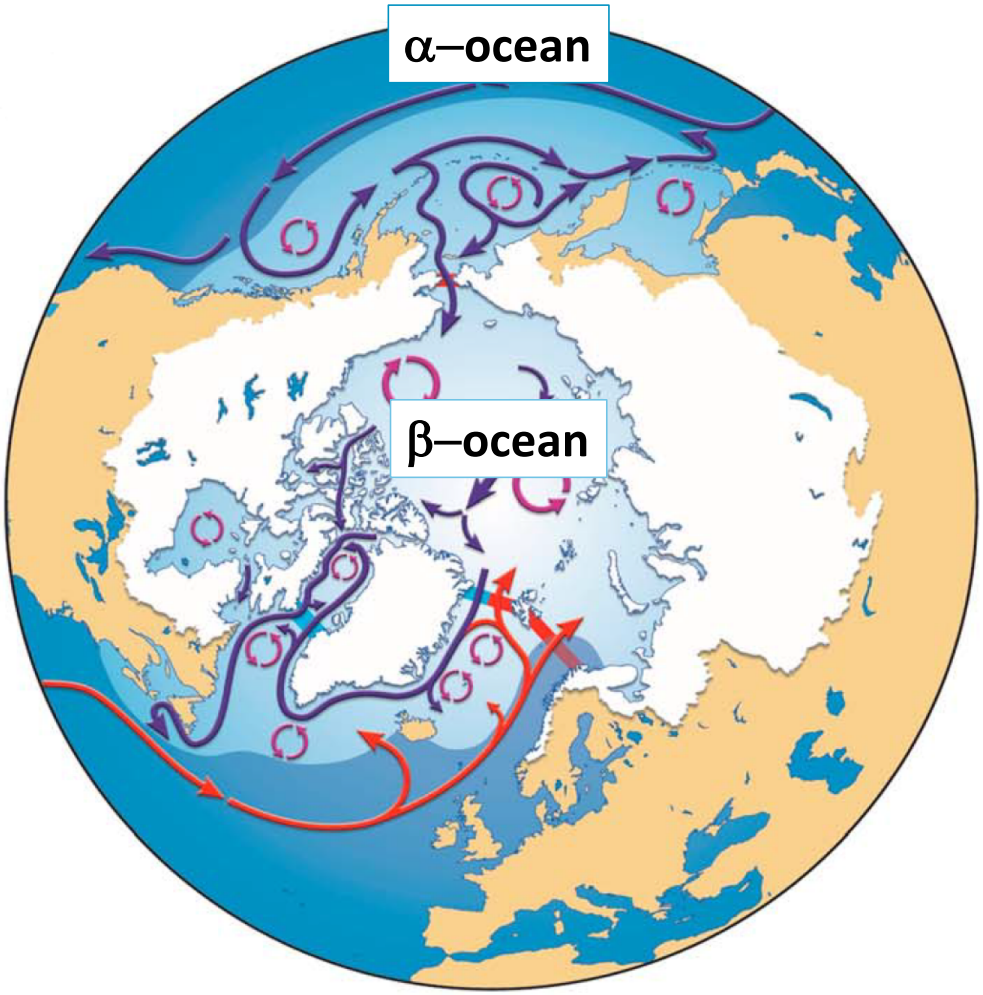
Garcia-Eidell et al. 2017

Ocean Transitions



Carmack et al. 2016

Ocean Transitions



$$\frac{1}{\rho}\frac{d\rho}{dz} = \beta\frac{dS}{dz} - \alpha\frac{dT}{dz}$$

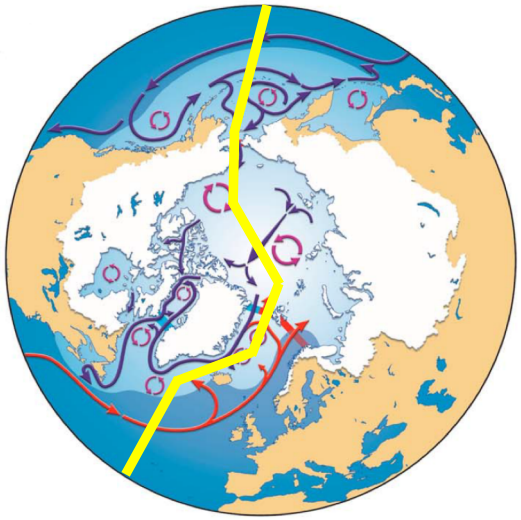
Alpha-ocean: stratified by T

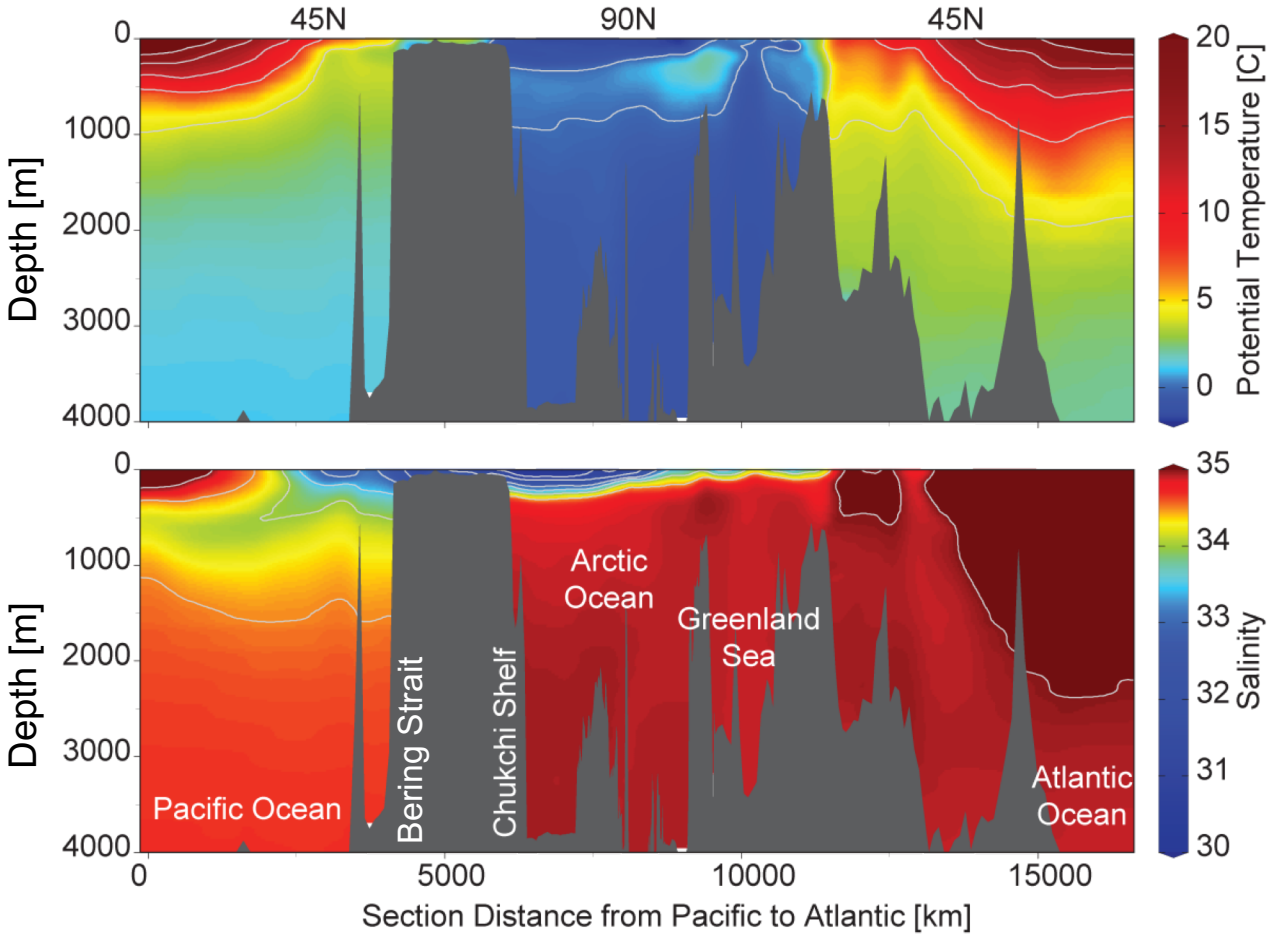
coefficient of thermal expansion → $\alpha\dfrac{dT}{dz} < 0$

Beta-ocean: stratified by S

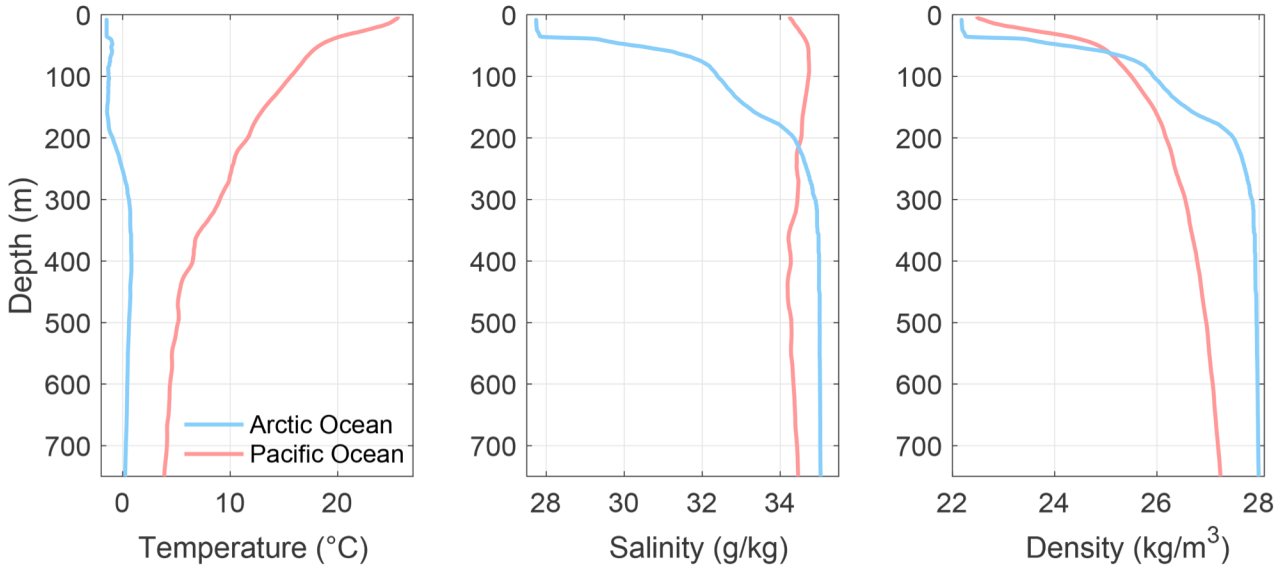
coefficient of haline contraction → $\beta\dfrac{dS}{dz} > 0$

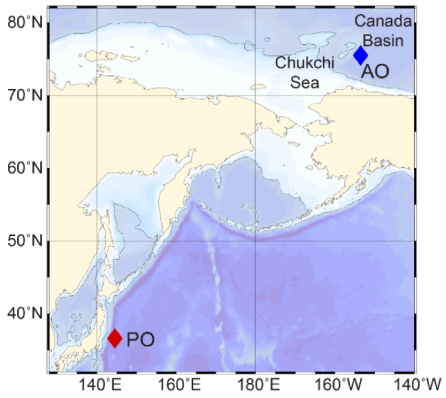
Stratification Transitions



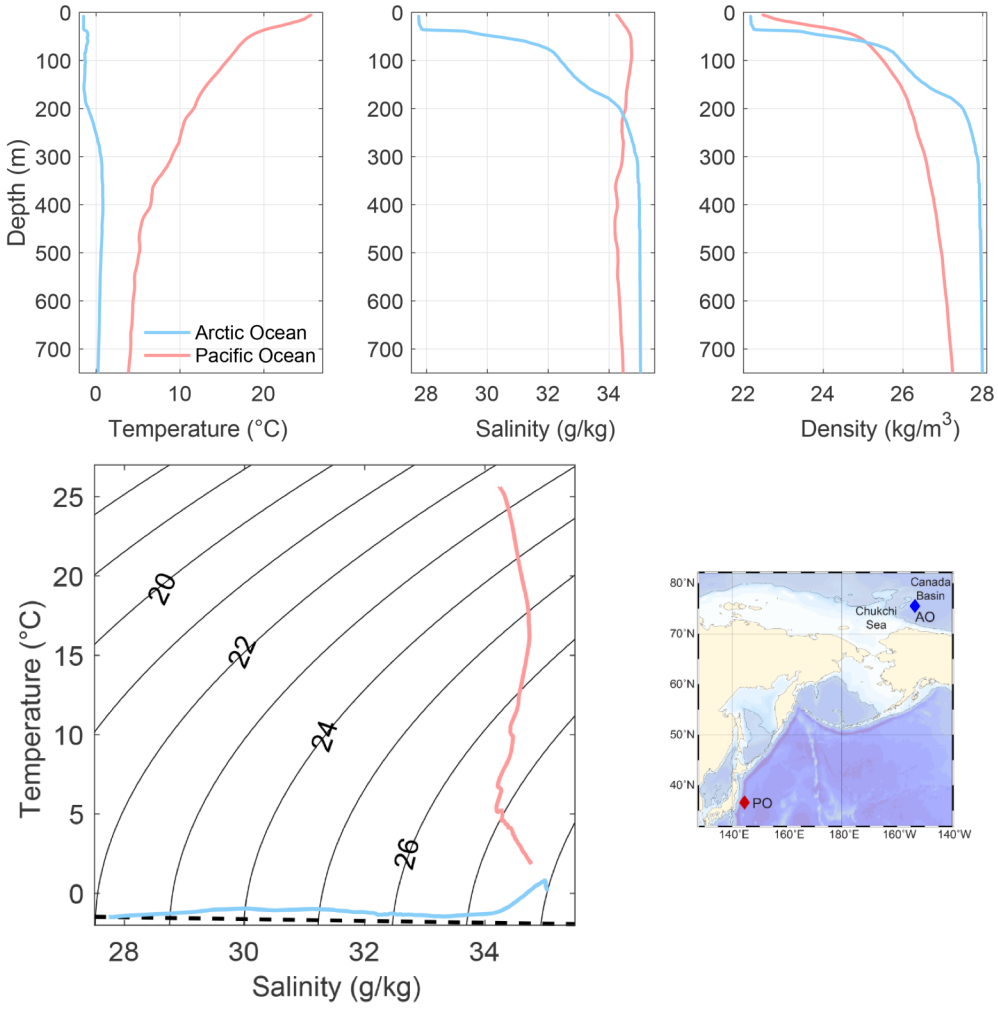


Water-column structure: Pacific vs Arctic Ocean

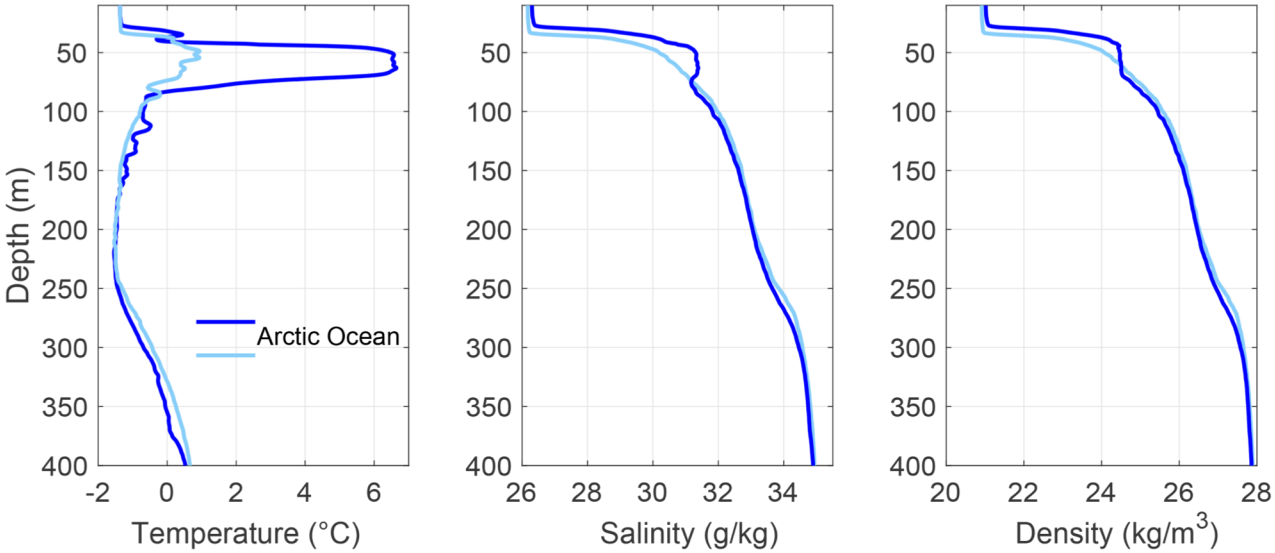


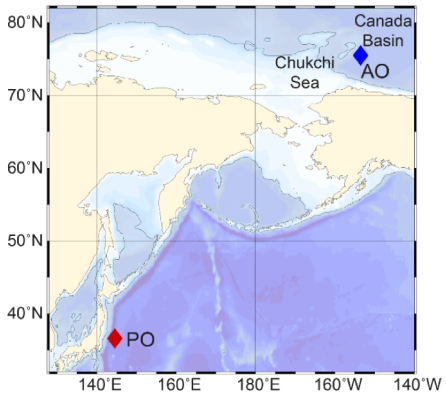


Water-column structure: Pacific vs Arctic Ocean

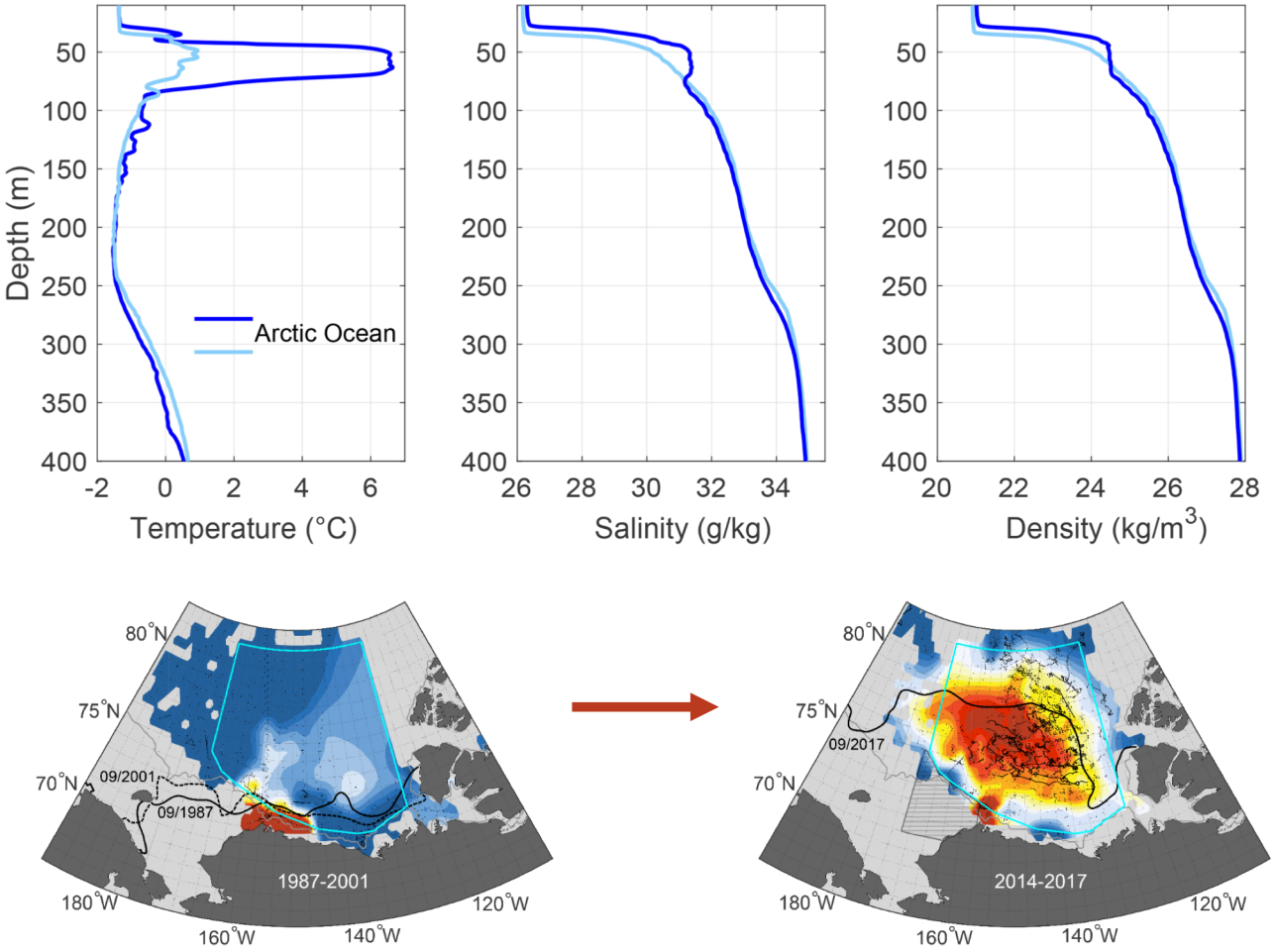


Very warm waters in the Arctic Ocean

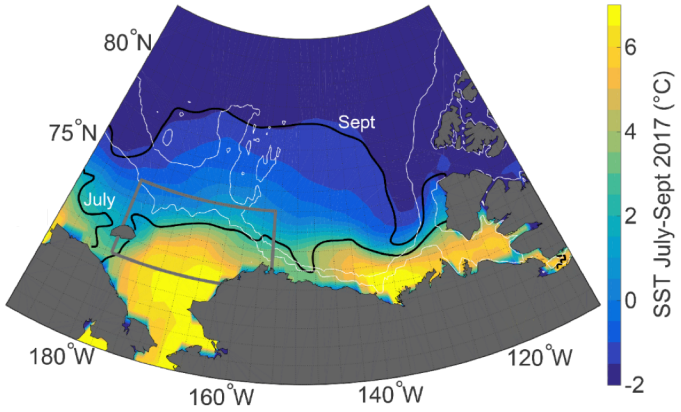


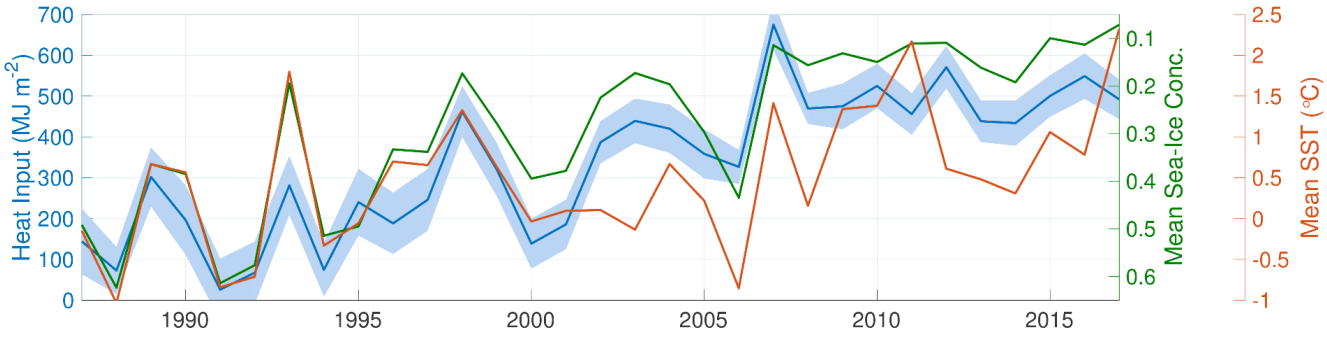


Very warm waters in the Arctic Ocean

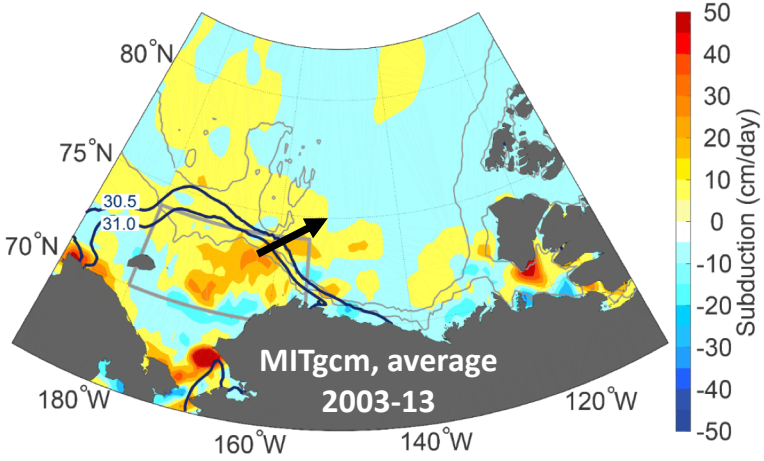


A source of halocline warming



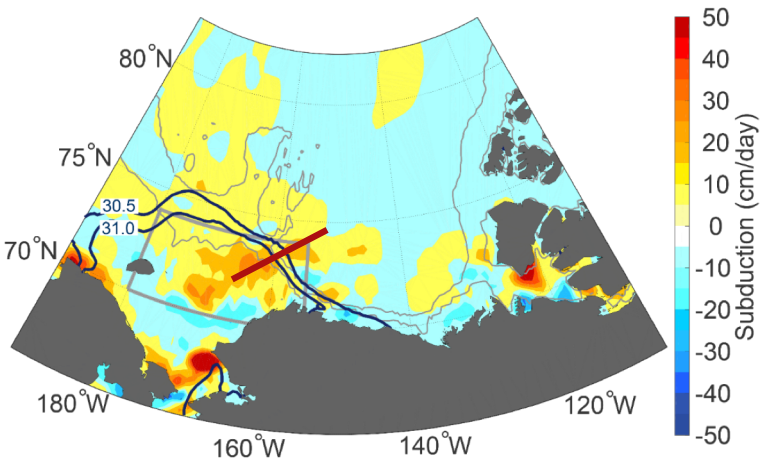


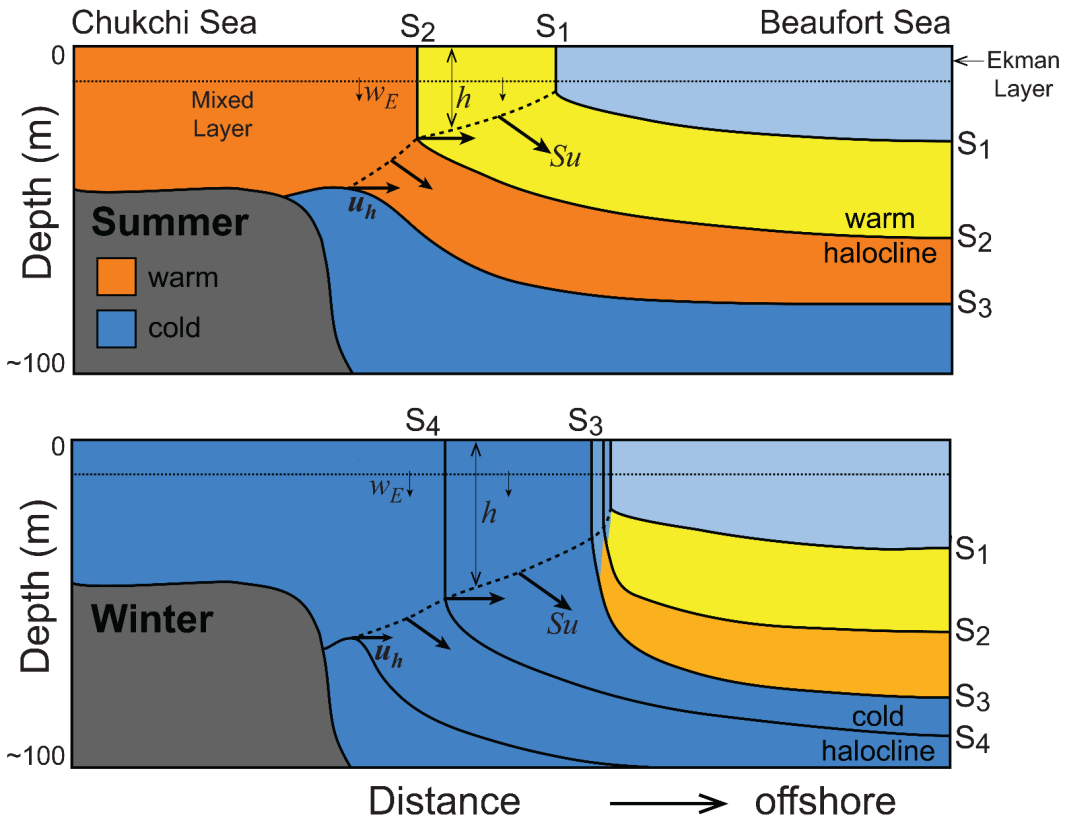
- Warm Beaufort Gyre halocline layers originate from the Pacific Ocean via the Chukchi Sea and Alaskan Coastal Current.
- Cumulative heat input to Chukchi region can account for the observed SST increase there.
- Increased heat in the Chukchi region can account for Canada Basin halocline warming.



Volume flux : ≈ 0.2 Sv

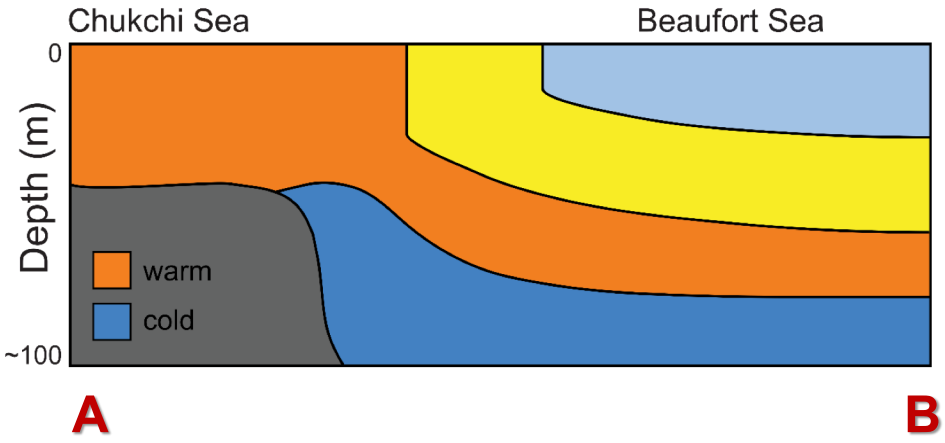
Ventilation of the Halocline: Trapping the Heat

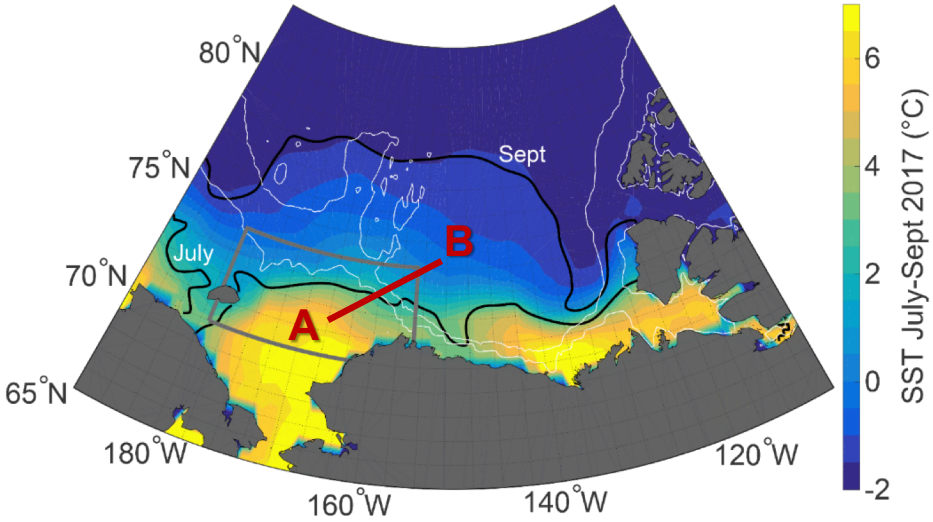




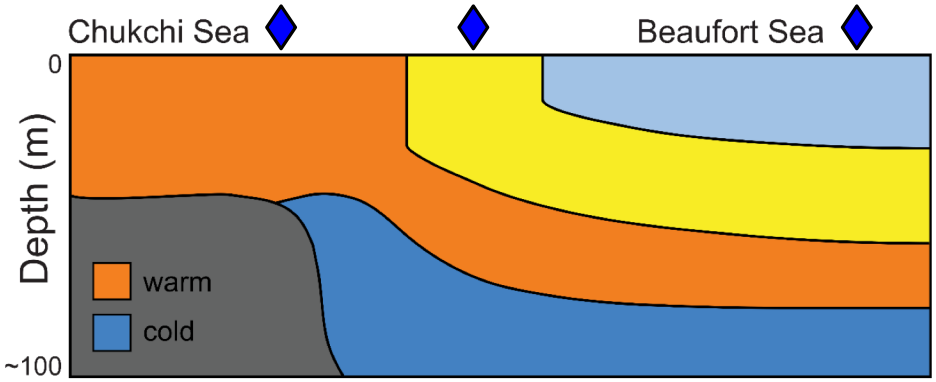
Timmermans, Marshall, Scott & Proshutinsky, 2017

A limit on the temperature of waters that can be pumped to depth?

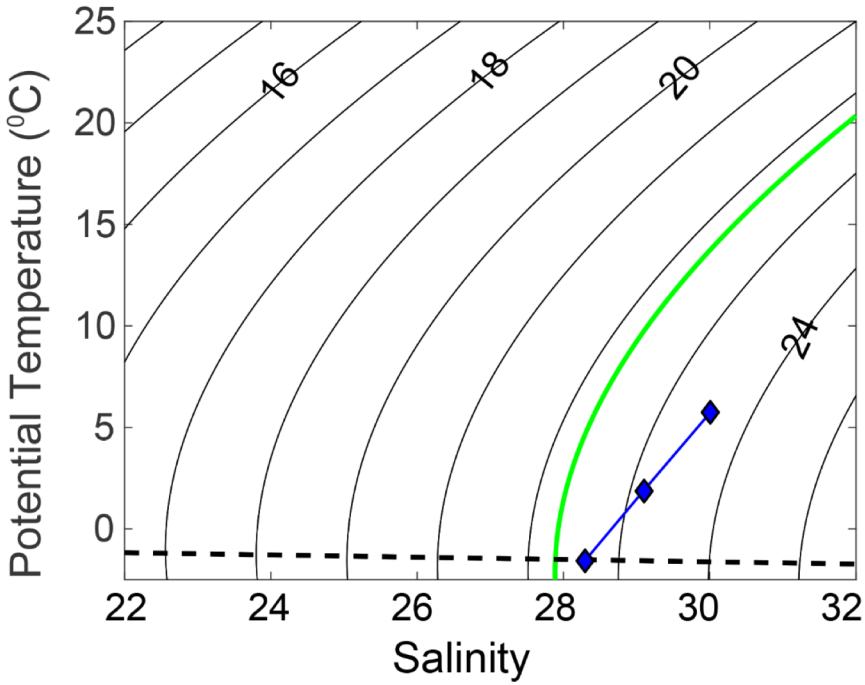




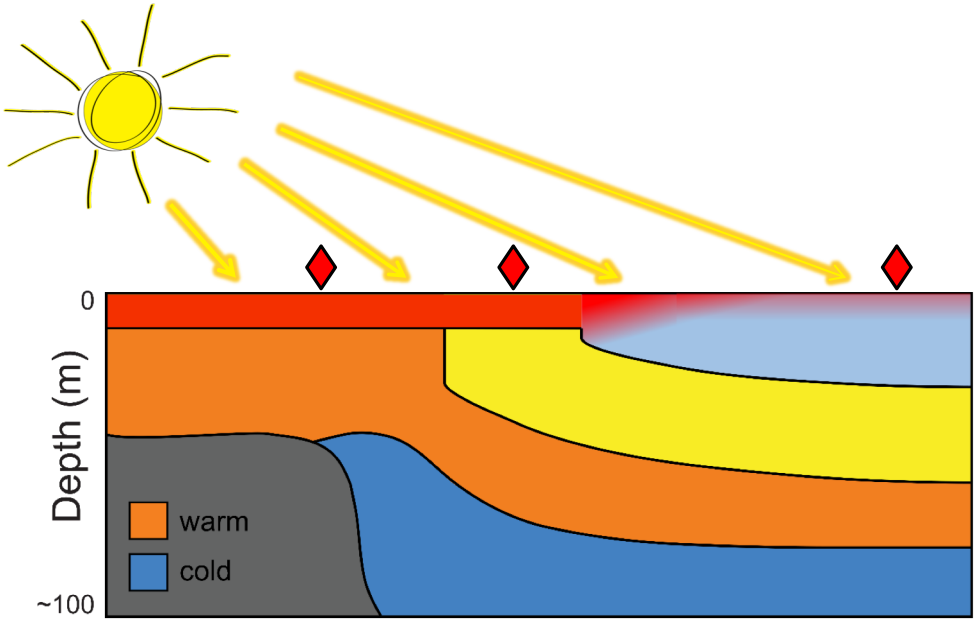
A limit on the temperature of waters that can be pumped to depth?



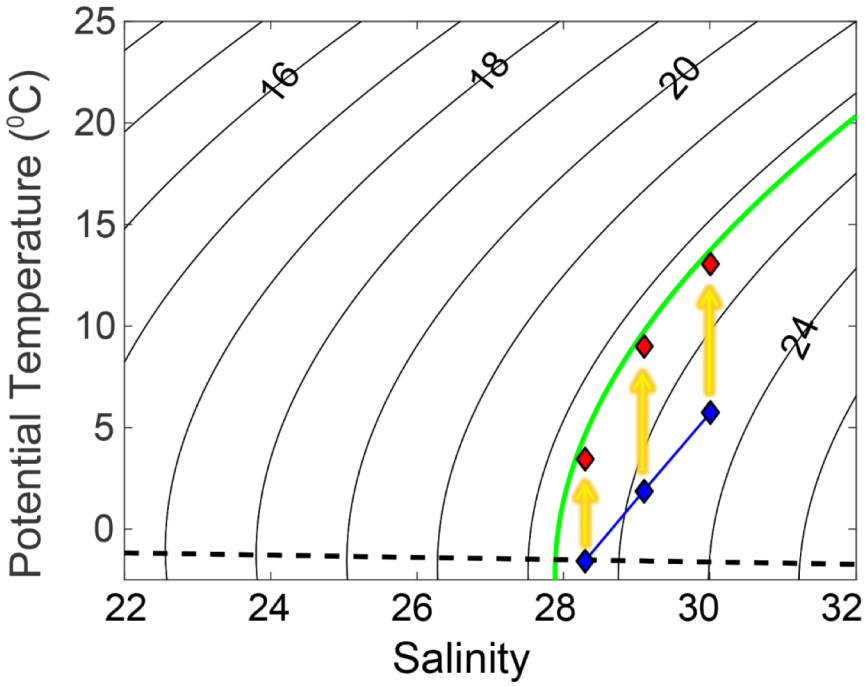
Temperature-Salinity plane



A limit on the temperature of waters that can be pumped to depth?

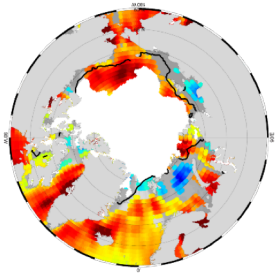


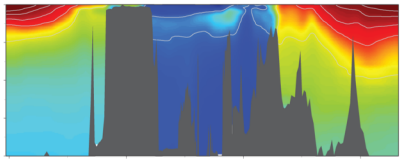
Temperature-Salinity plane

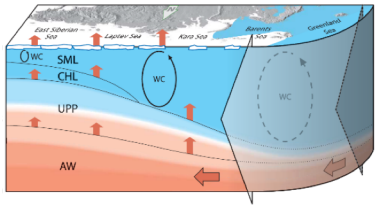


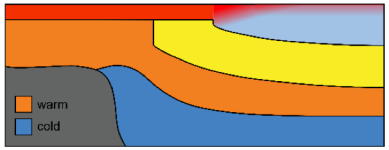
Solar absorption may be sufficiently intense that the lateral surface density gradient is eliminated.

Summary









- There is a general warming of all layers of the upper Arctic Ocean.
- In the β-Arctic, sea ice growth is possible, and warm water has a pathway to ventilate the halocline.
- A shift towards α conditions may be underway at Pacific and Atlantic gateway regions.
- Under continued warming, ocean temperature will play an increasingly dynamic role; halocline ventilation could be shut off during the warmest periods.