UNIVERSITY OF GOTHENBURG

The Arctic Ocean Carbon Cycle in a Changing Environment

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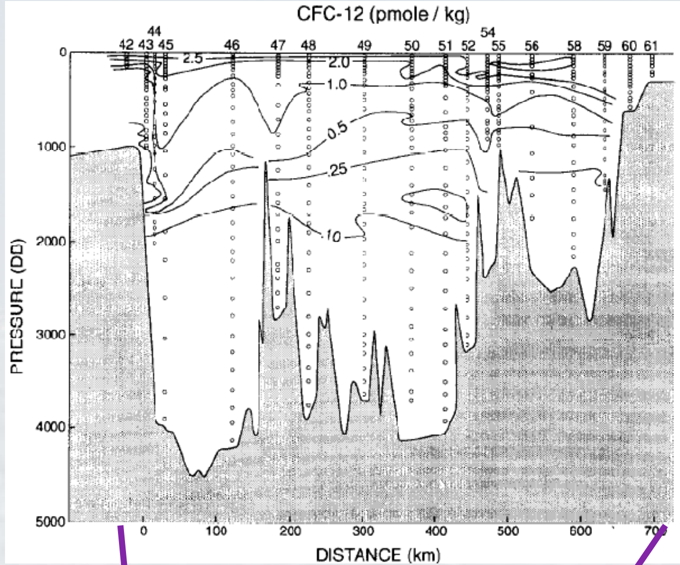
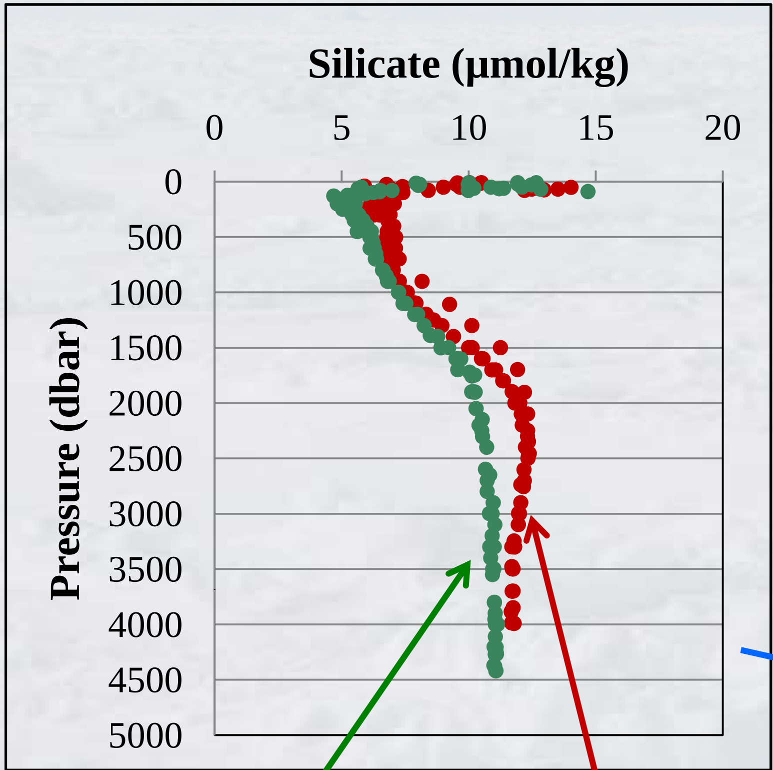
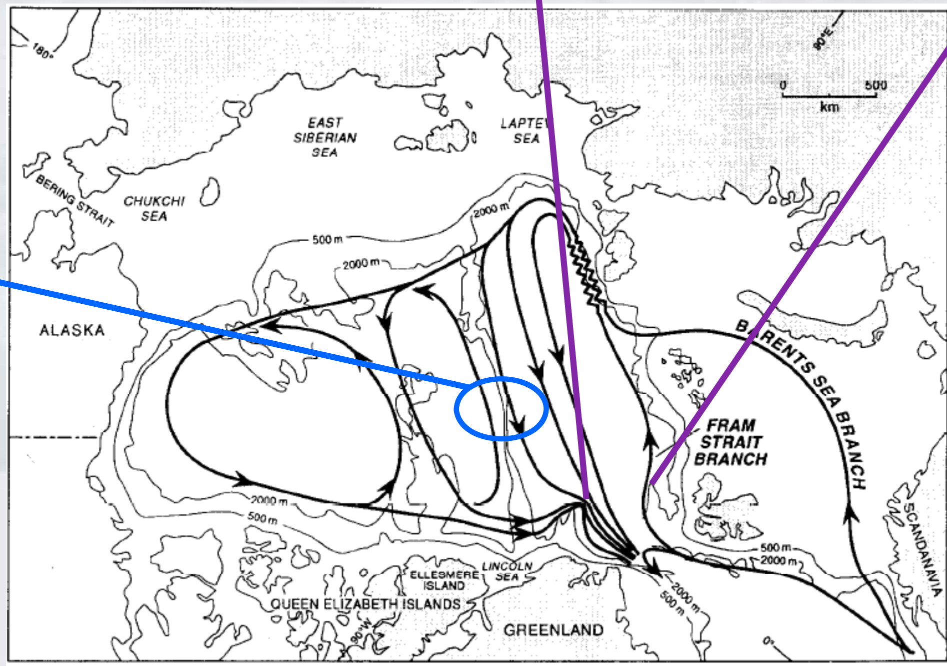
Faculty of Science

Arctic Ocean circulation

Intermediate & deep waters follows the topography counter-clockwise.







Amundsen Basin

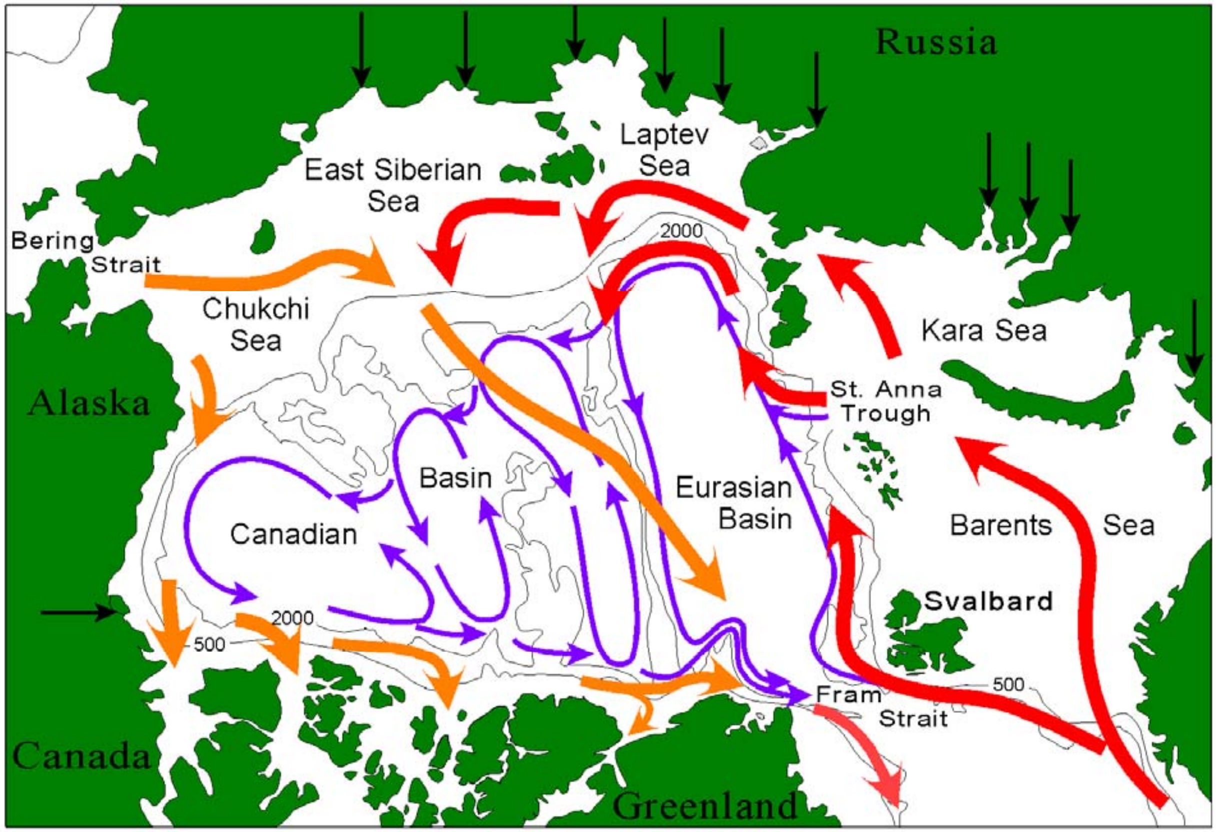
Makarov Basin

Rudels et al.

Arctic Ocean circulation

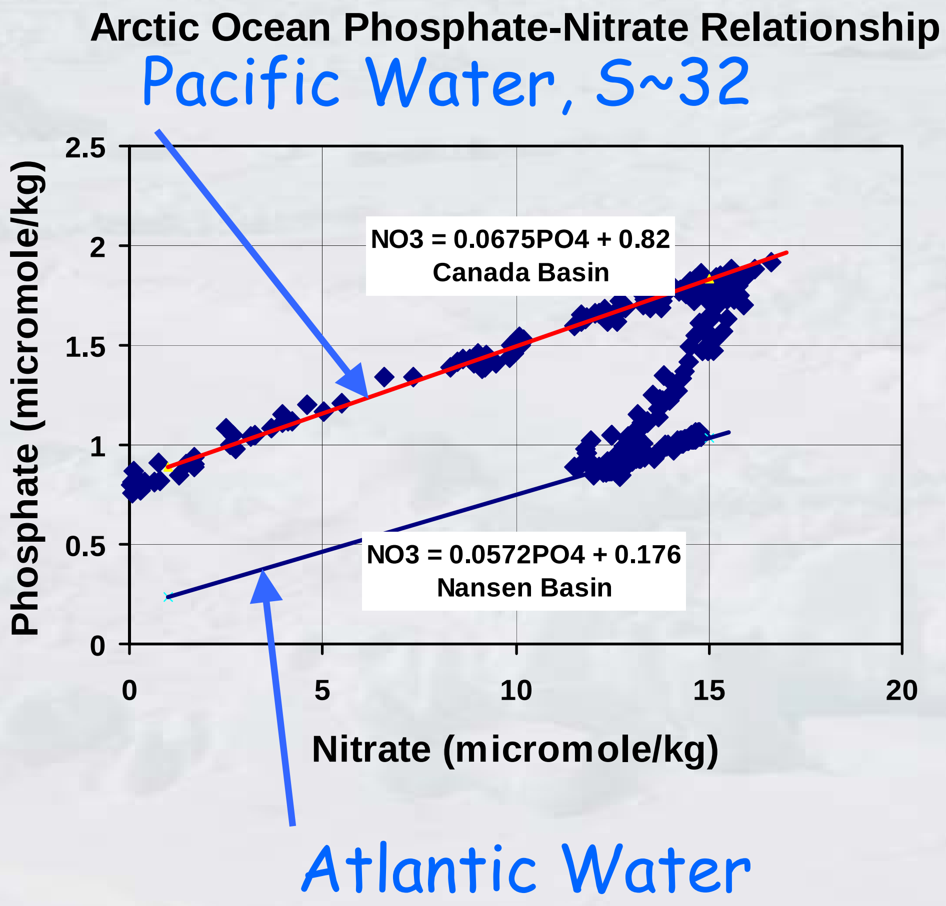
Surface water circulation

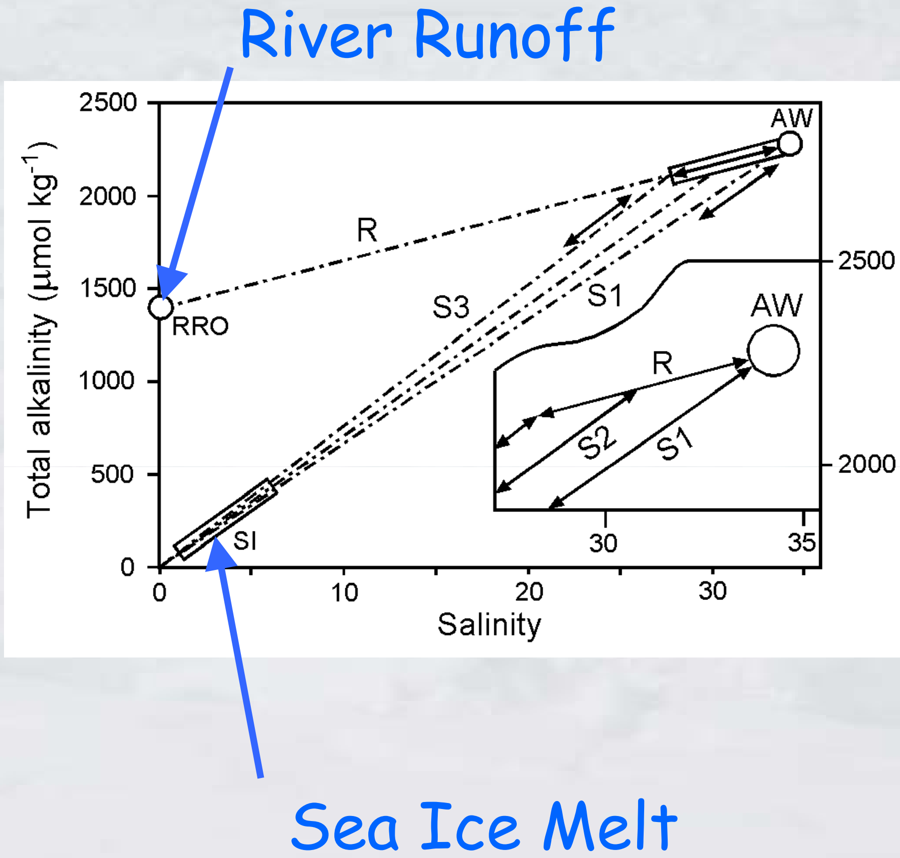
Much of the Pacific and Atlantic waters enter over the shelves and adds to the surface waters of the central basins, but what are their flow paths?



Chemical signatures solve this question

Tracing surface water sources by applying relationships of phosphate - nitrate, and total alkalinity - salinity. ($\delta^{18}O$ - S)





Jones et al.

Pacific freshwater is
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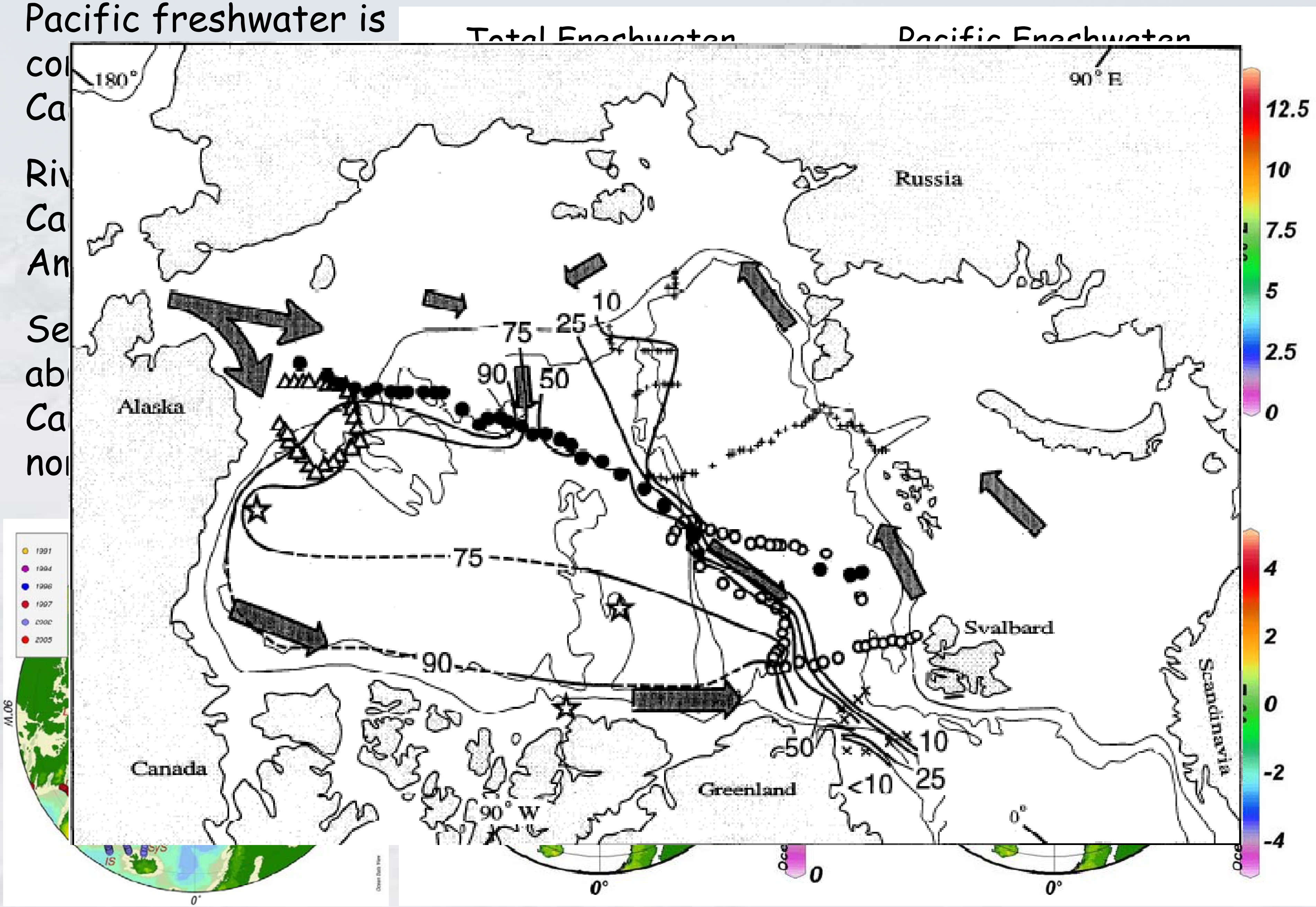
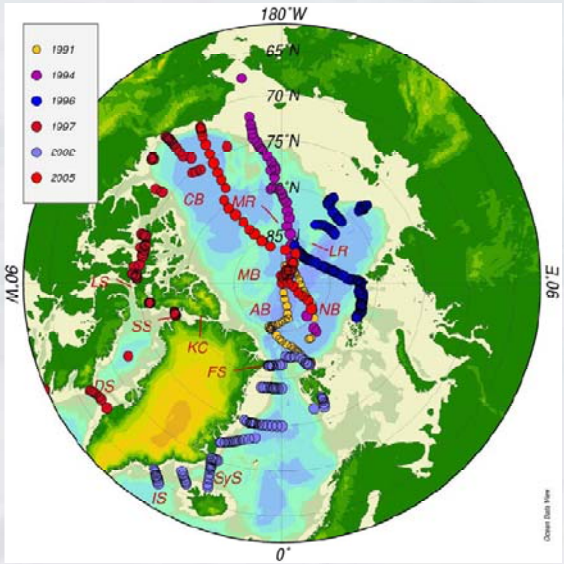


Except for circulation this approach also gives the source waters

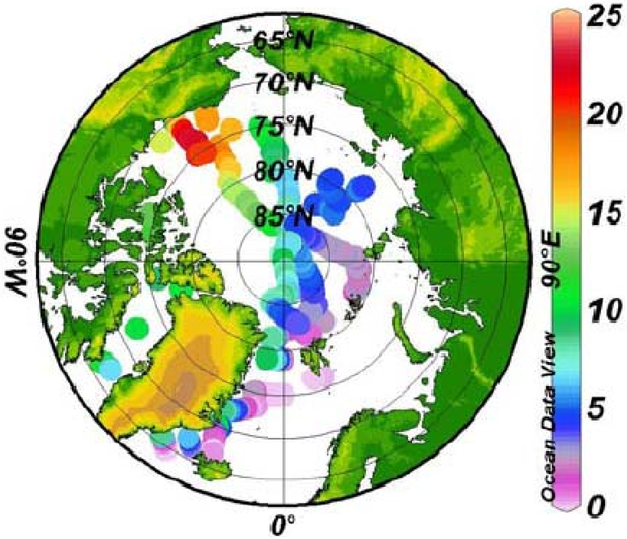
Pacific freshwater is confined to the Canada Basin.

River runoff to the Canadian and Amundsen Basins.

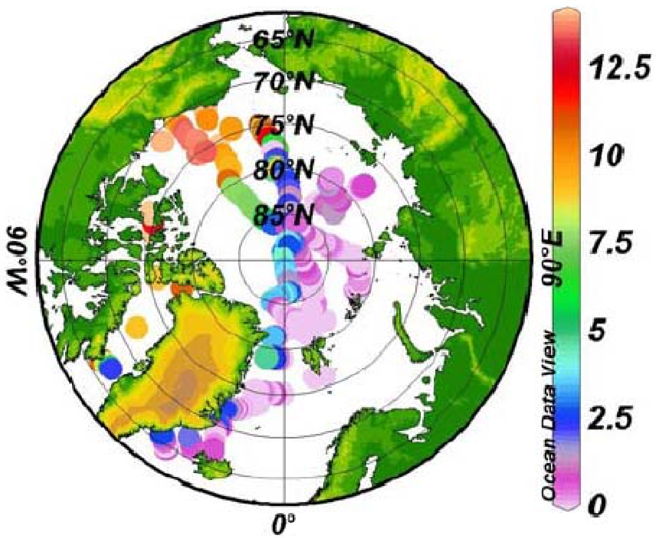
Sea ice melt is abundant in the Canada Basin and north of Svalbard.



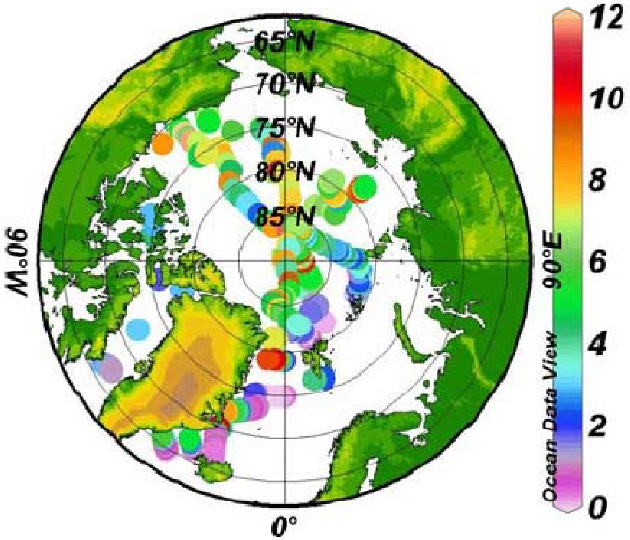
Total Freshwater



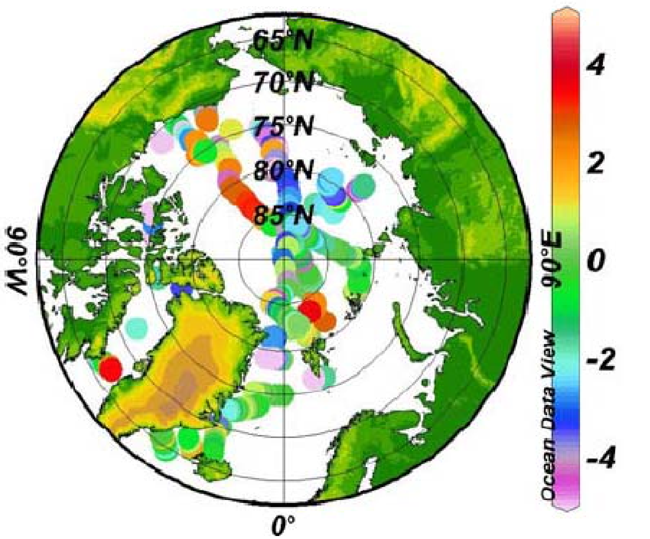
Pacific Freshwater



River Runoff

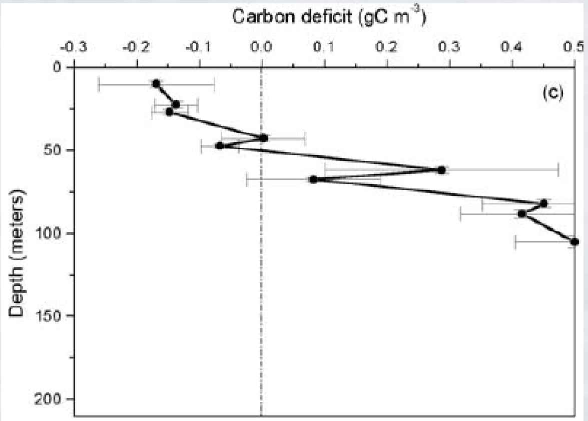


Sea Ice Melt

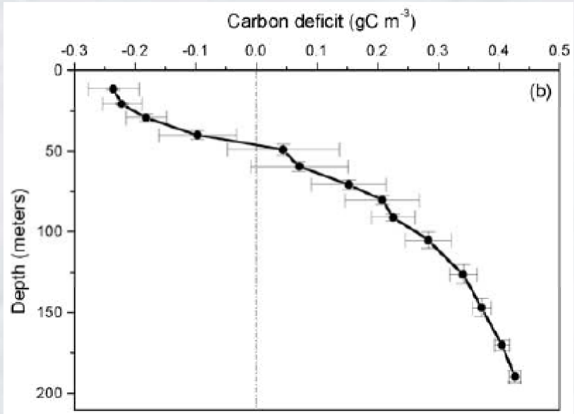


This information of surface water sources can be used to determine export production.

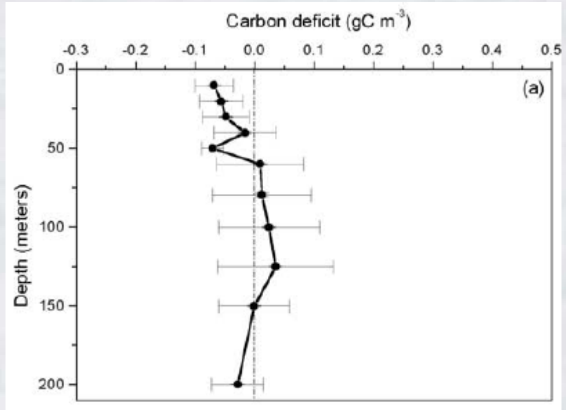
- Knowing the source waters contributing to a water makes it possible to determine the preformed concentration of e.g. phosphate.
- Comparing this to the measured concentration one can compute the deficit, i.e. what has been consumed.
- As the only sink of phosphate is primary production this deficit can be converted to new production (assuming residence time >> 1 year).



Canada Basin
5.8 gC m^{-2}



Makarov Basin
8.4 gC m^{-2}



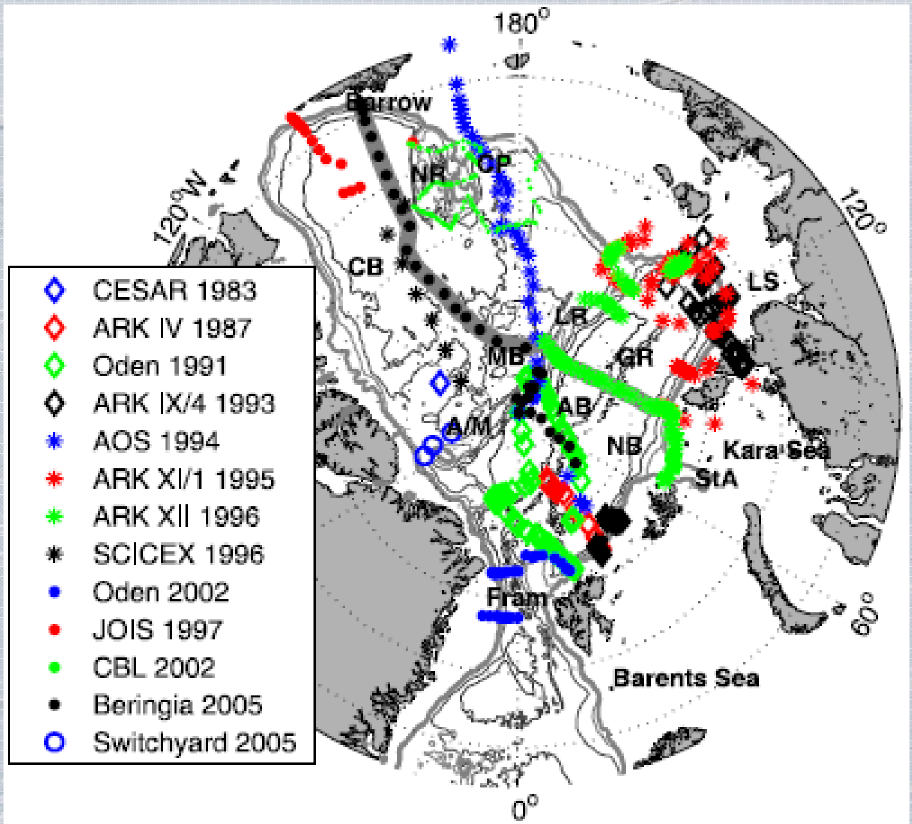
Eurasian Basin
2.9 gC m^{-2}

With 15 years residence time this correspond to ~0.5 gC m^{-2} in the central Arctic Ocean

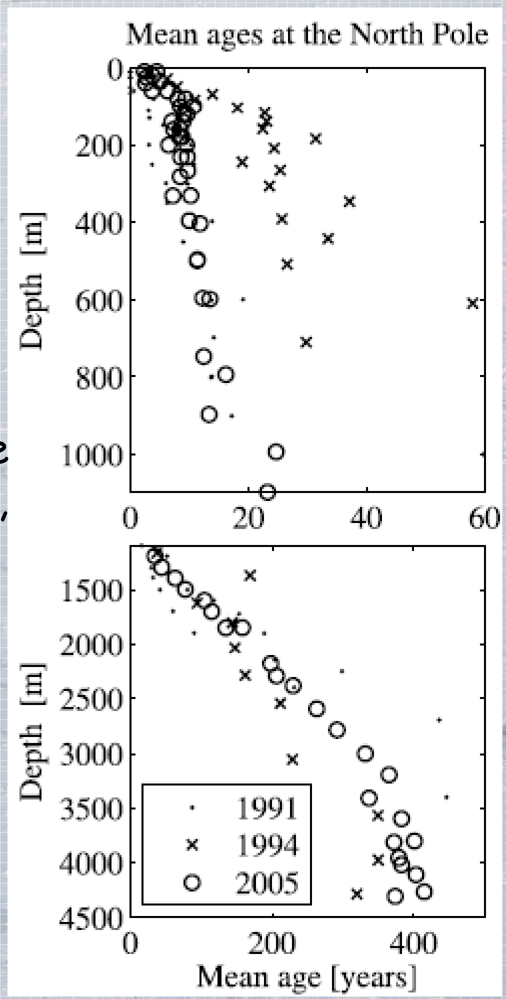
The anthropogenic carbon concentration by applying the transit time distribution (TTD) method.

It is done by determining the concentration, *c*, of a passive tracer at any point, r, at any time, t, with knowledge of the TTD and the input function of the tracer at the sea-surface, with G(r,t) being is the TTD.

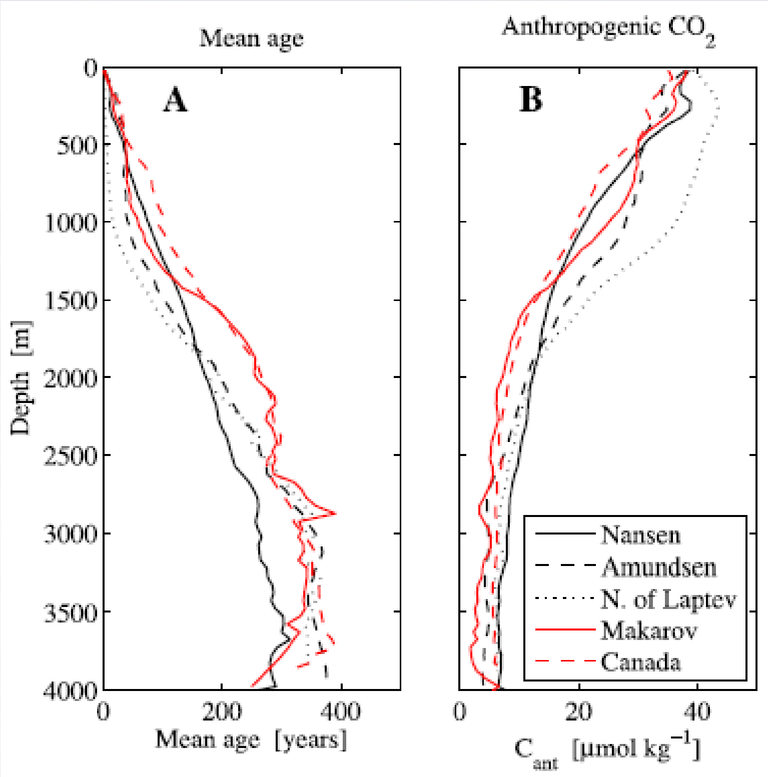
$$c(r,t) = \int_0^\infty c_0(t-t')G(r,t')dt'$$

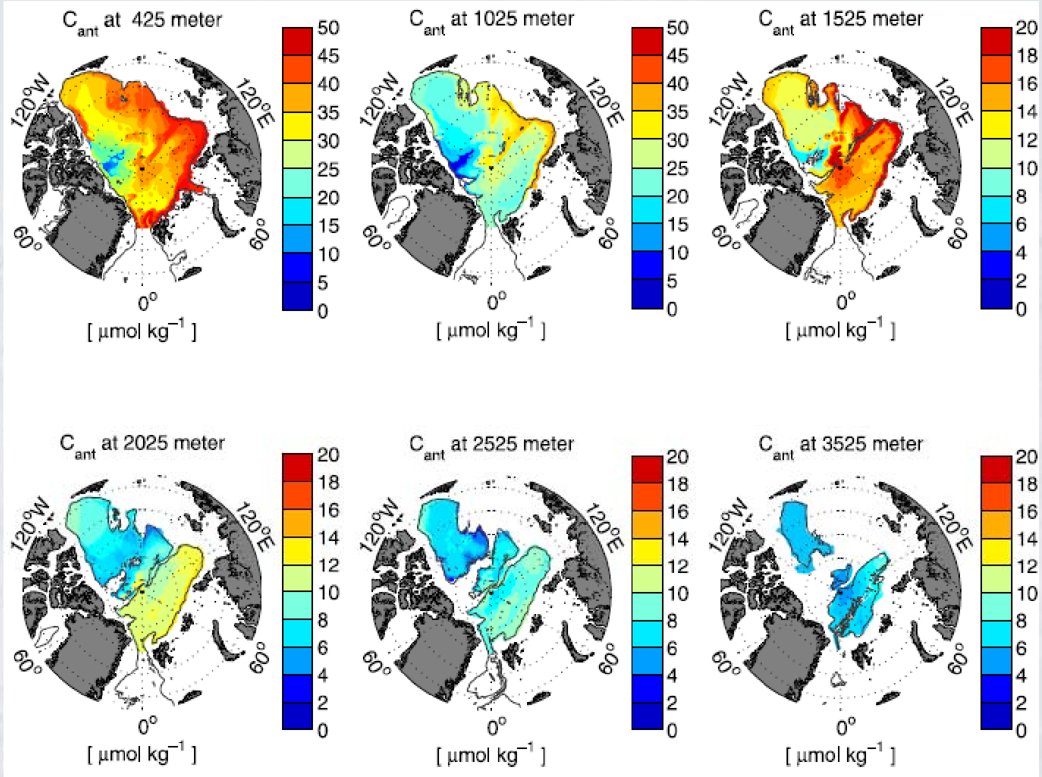


Mean ages at the North Pole: 1991, 1994 and 2005.



Tanhua et al. JGR, 2009

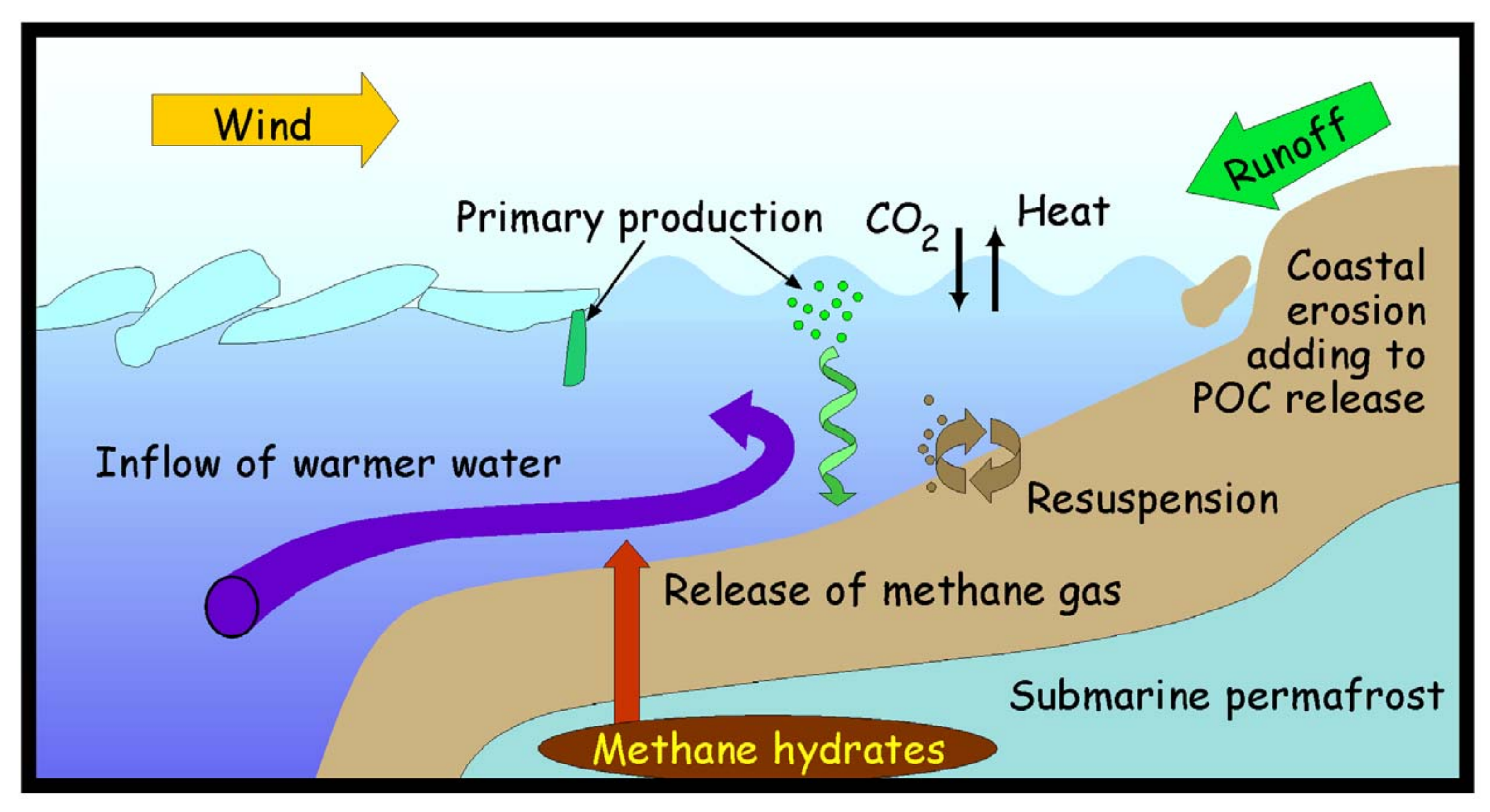




Applying the TDD method gives an inventory in the Arctic Ocean of 2.5±0.4 x 10^{15} gC including the shelf seas, which is ~2% of all oceanic sinks.

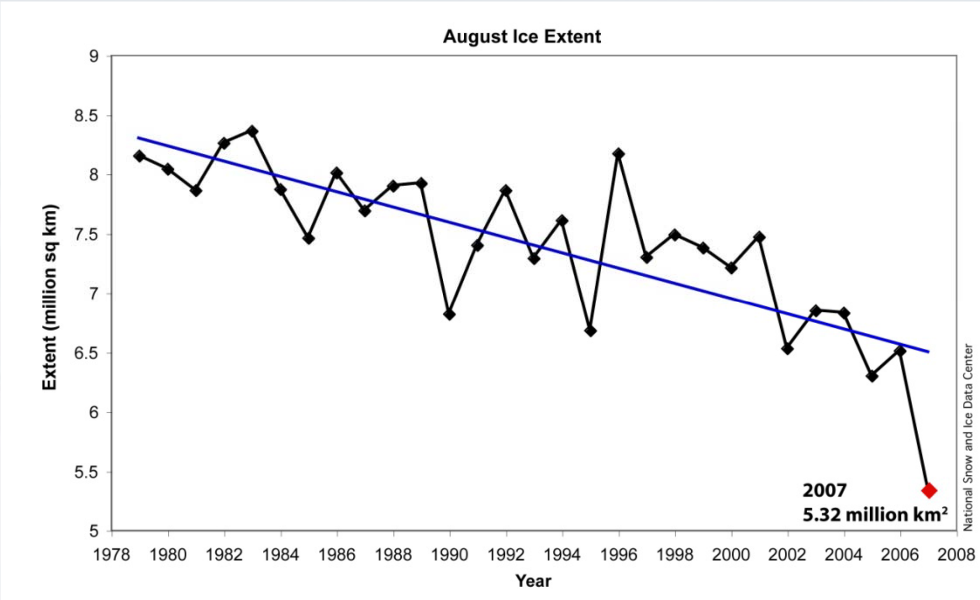
Tanhua et al.
JGR, 2009

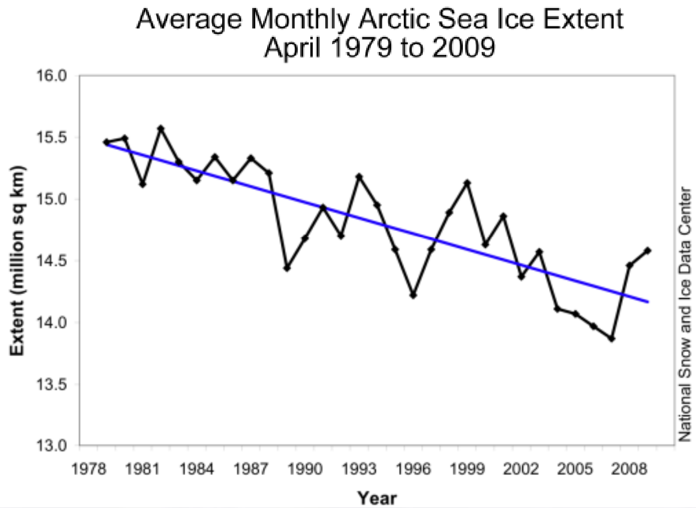
Most C-transformation occurs over the shelves

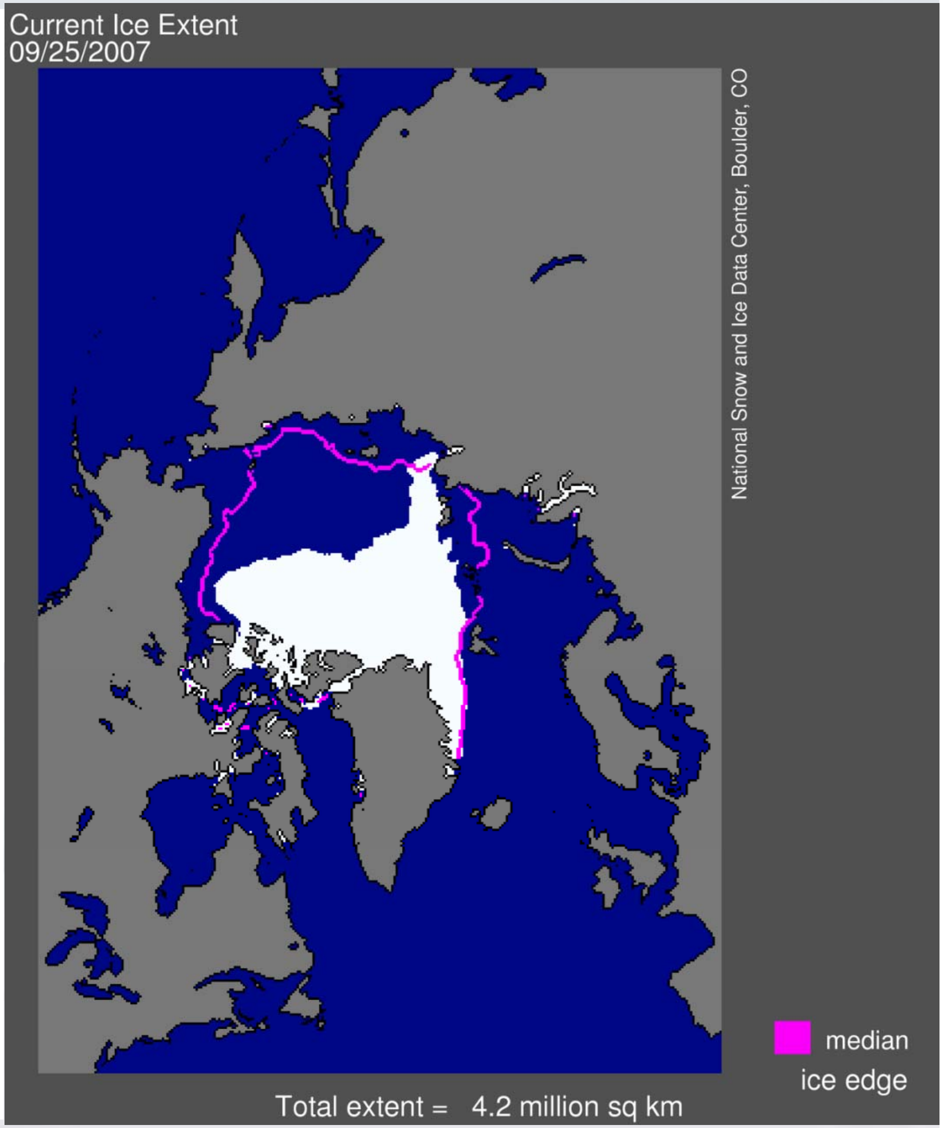


Includes biological production and decay, water mass modification, air-sea exchange, sedimentation and resuspension, terrigenous input, etc.

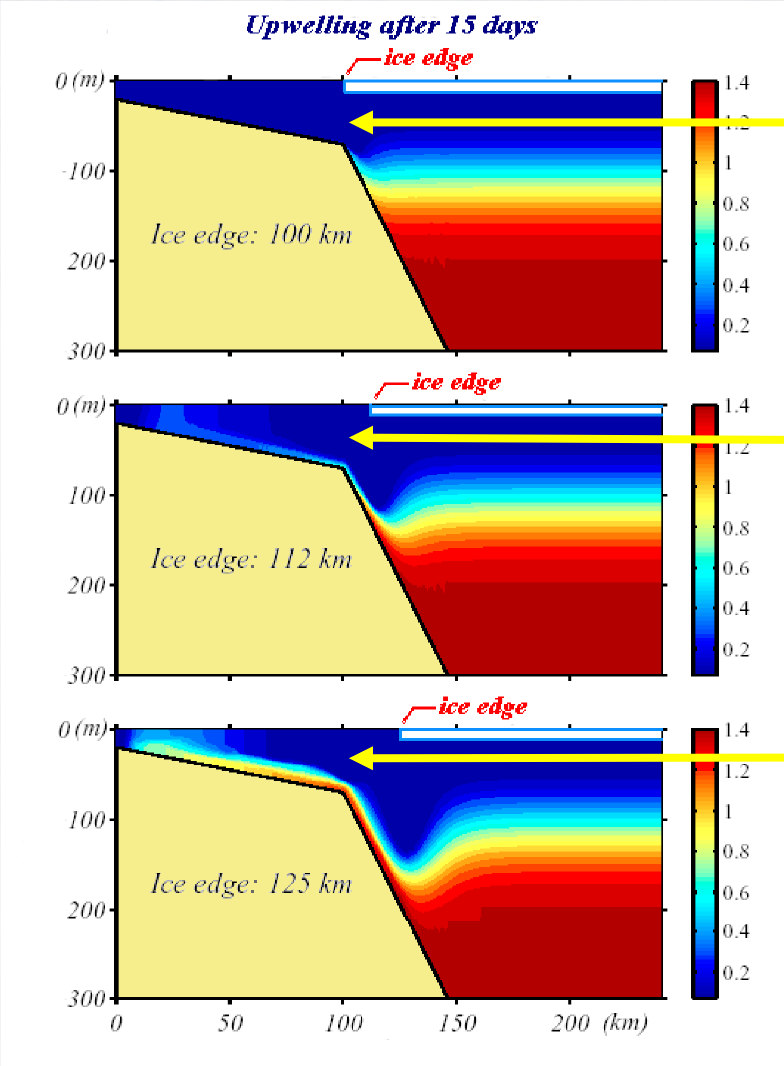
Will decreasing summer ice coverage impact the carbon transformation and fluxes?







Decreased ice cover will potentially increase upwelling, and thus also increase nutrient supply to the photic zone.



Model Results:

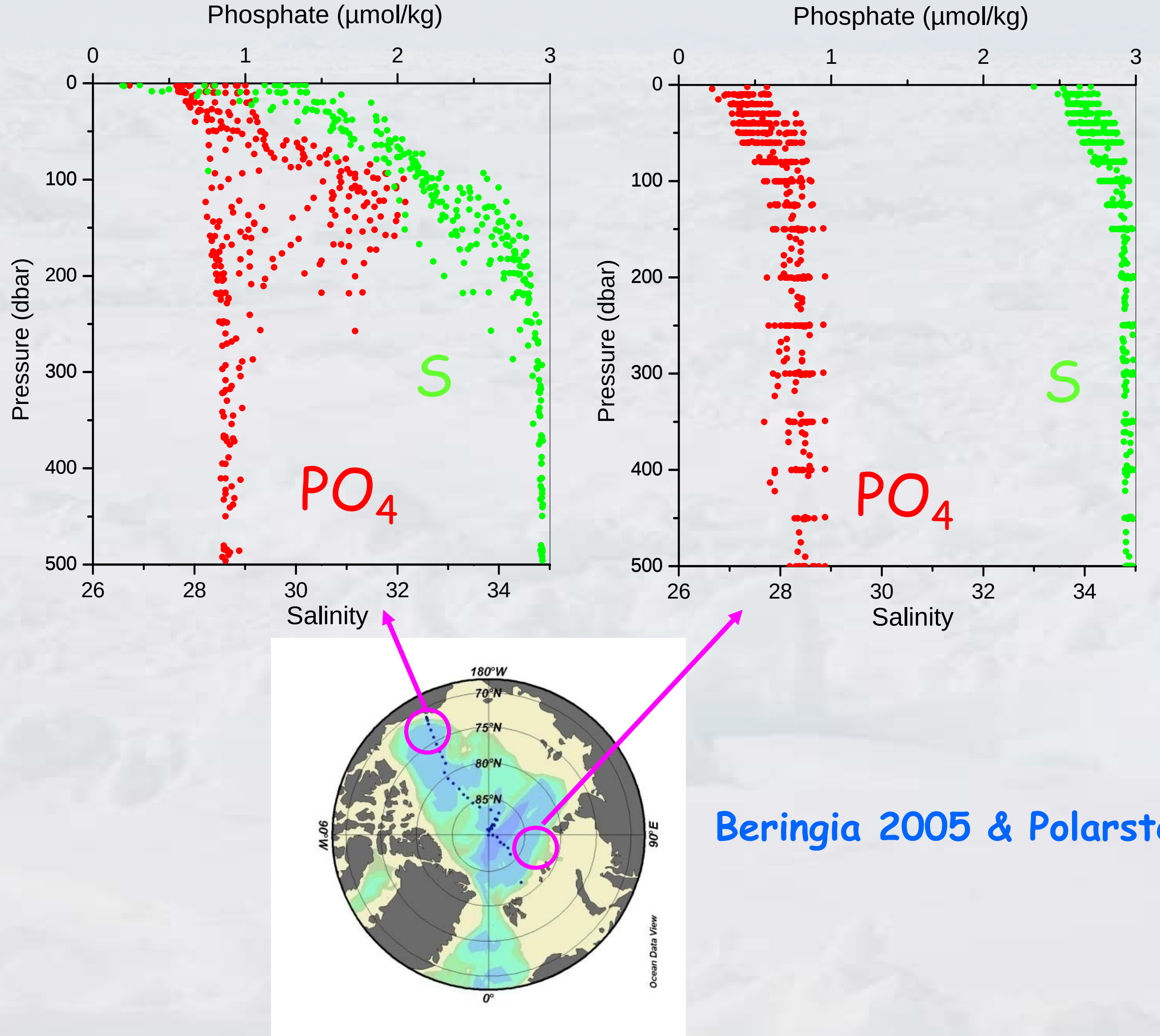
A circulation 'cell' forms with upwelling at the coast and downwelling at the ice edge. Only shelf water circulates if the shelf-break is ice-covered.

Continued retreat of summer ice cover exposes more and more of the shelf-break for longer periods of time to upwelling favorable winds.

Upwelling depth increases as slope waters become ice-free. Salty, nutrient-rich water can now cross the whole shelf in a thin bottom boundary layer.

Carmack & Chapman, GRL, 2003

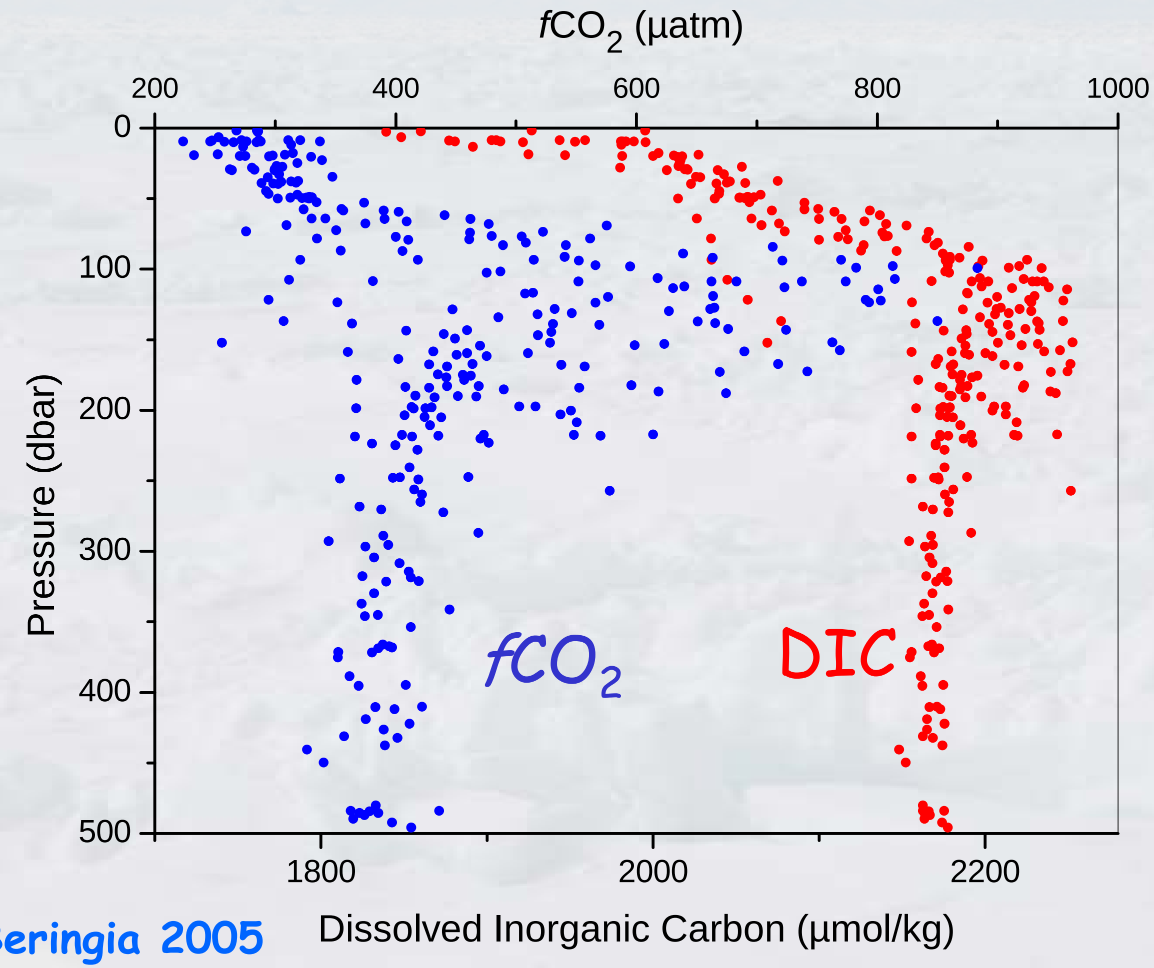
Decreased ice cover → increased upwelling → increased nutrient supply



Pacific side; nutrients higher at ~100 m, but profile more stratified compared to Atlantic side.

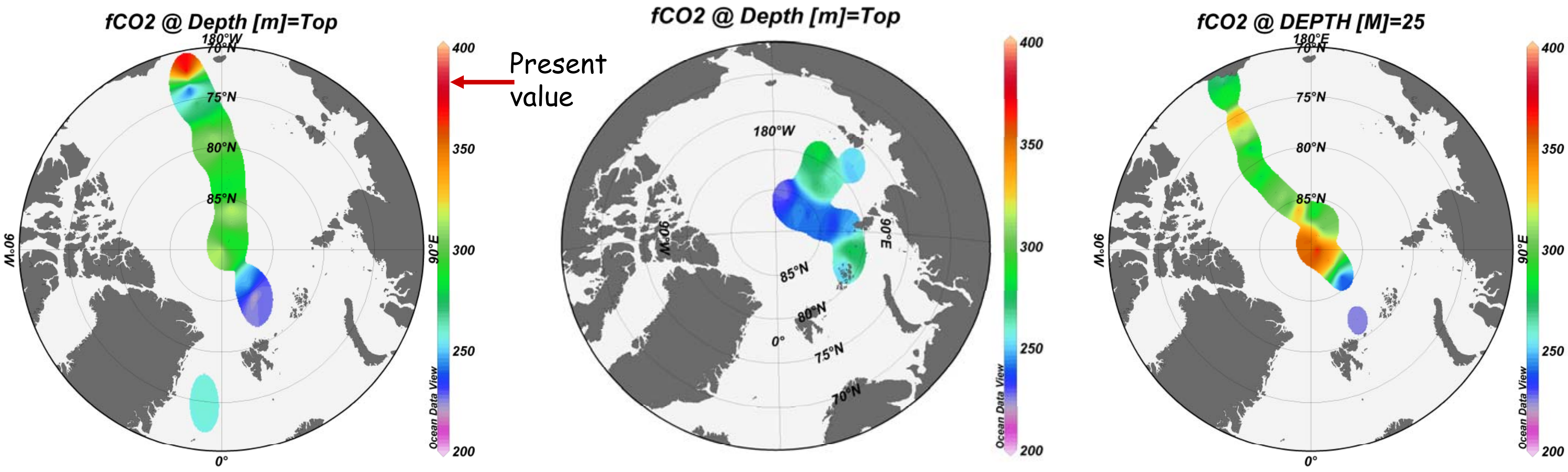
Beringia 2005 & Polarstern 1996

Decreased ice cover → increased upwelling → increased nutrient supply, but also → increased pCO_2 supply, which compensate the oceanic C-uptake!

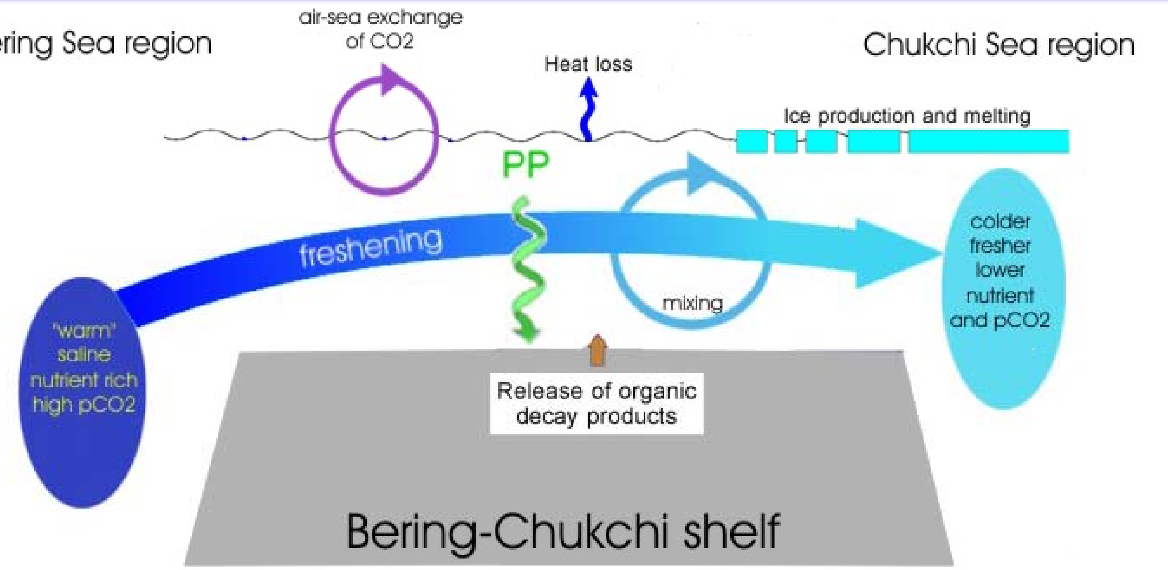


Beringia 2005

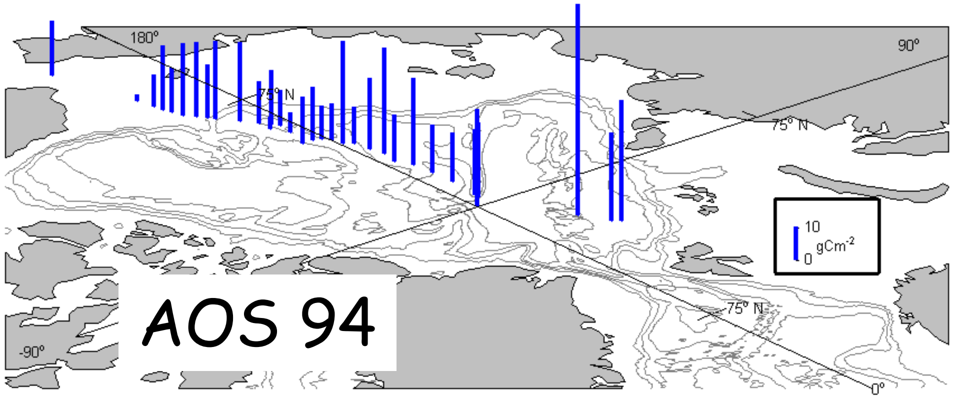
Also, if nutrients are mixed up at the Pacific side it will be followed by DIC, which compensate the effect of a potential increase in PP.

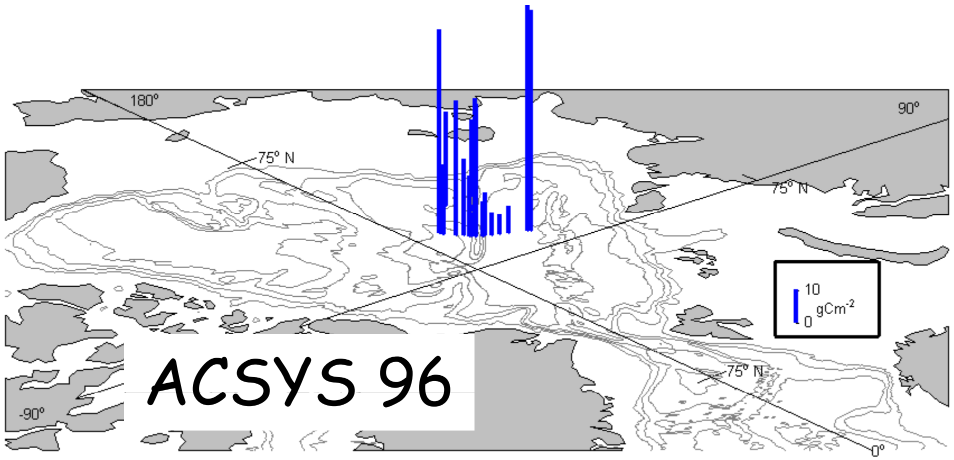


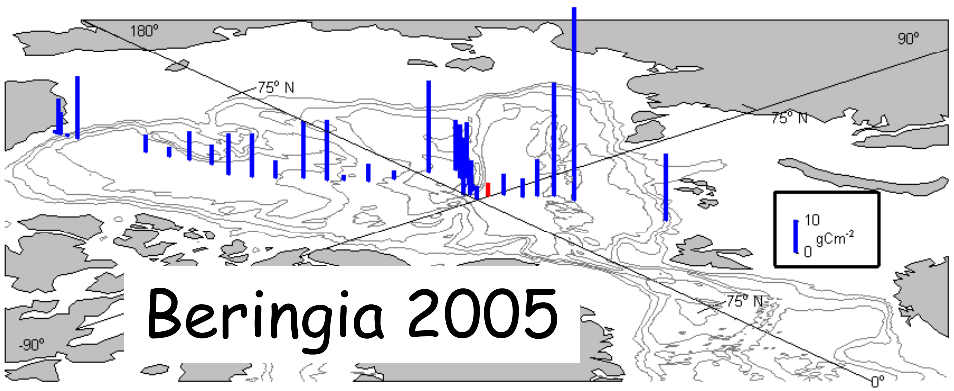
The pCO_2 of the surface waters in the Arctic Ocean calculated with data collected during the cruises from left: AOS 94, ACSYS 96, & Beringia 2005.



Or Barents Sea

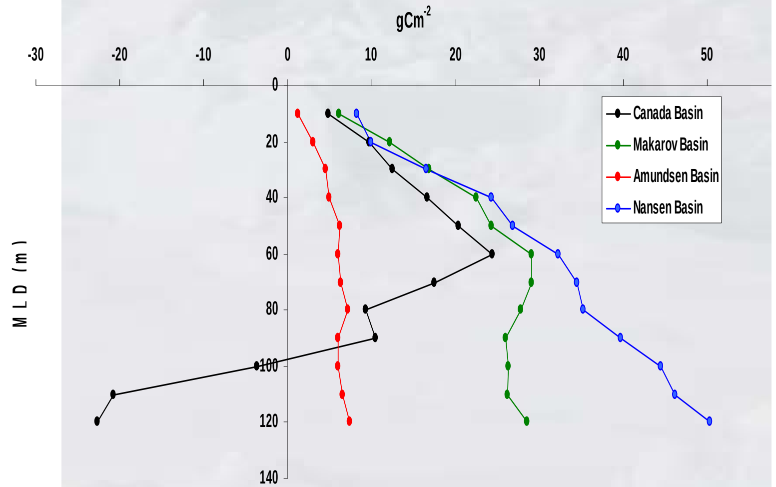






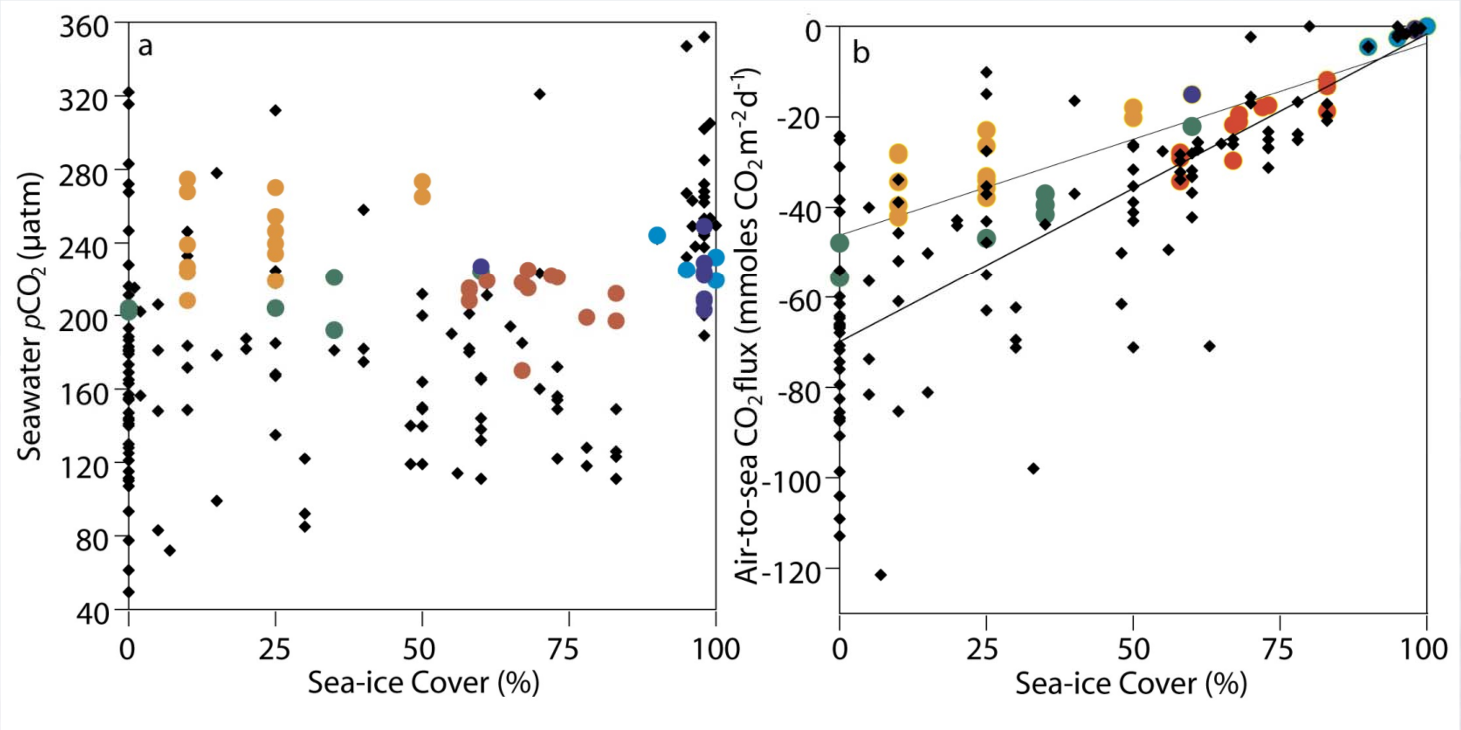
The <u>potential uptake capacity of carbon</u> in the winter mixed layer of the Arctic Ocean based on the pCO_2 under-saturation.

The potential uptake varies with time and location, but the average is close to 10 gC m^{-3}, which corresponds to about 50×10^{12} gC over the deep central basins.



pCO_2 in the Chukchi Sea region and the impact of Ice Cover on Air-Sea flux

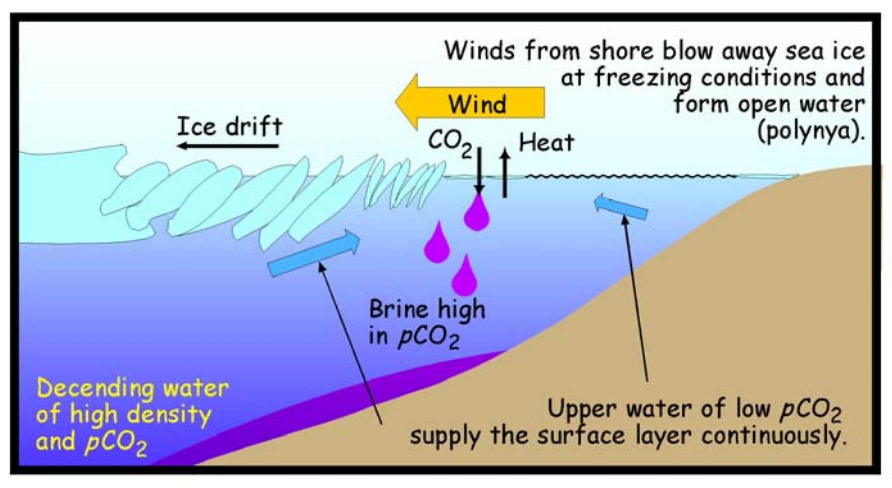
Bates et al. GRL 2006

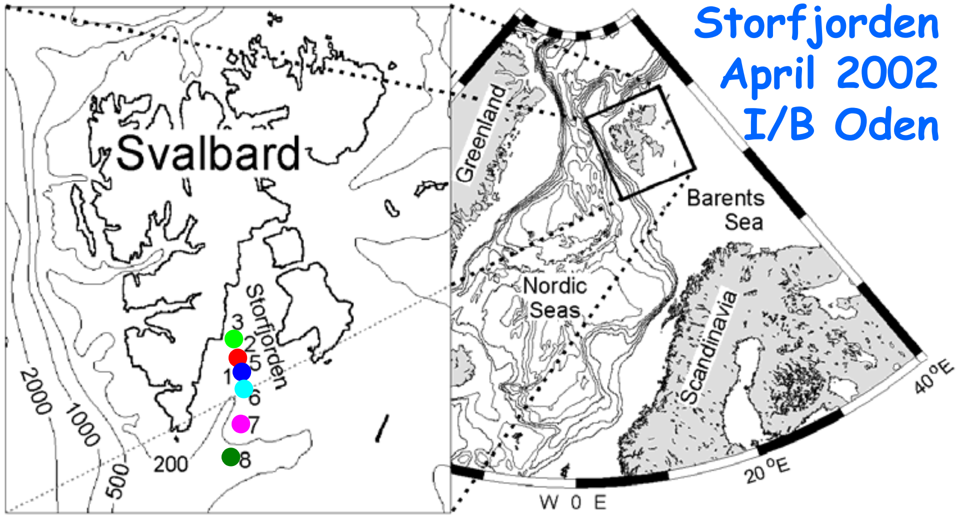


Large areas of under-saturated surface water, but no trend with ice cover. But as the flux much depends on the transfer energy at the sea surface it varies from zero in ice covered regions to ~60 mmol CO_2 $m^{-2}d^{-1}$ (~0.7 gC $m^{-2}d^{-1}$) in ice free waters.

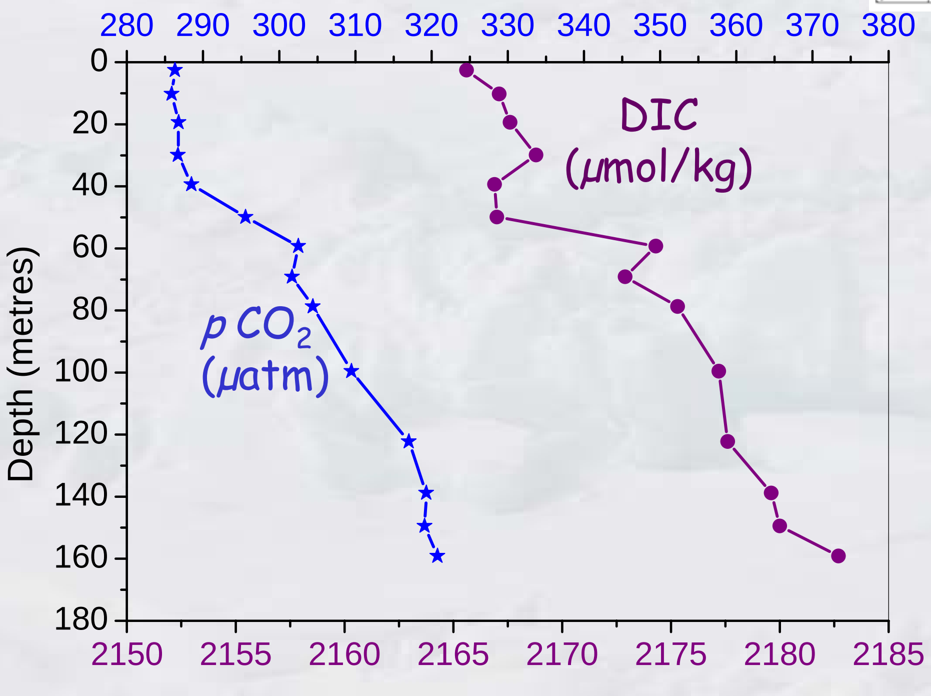
<u>Hence a decrease in ice cover has a major impact on the flux!</u>

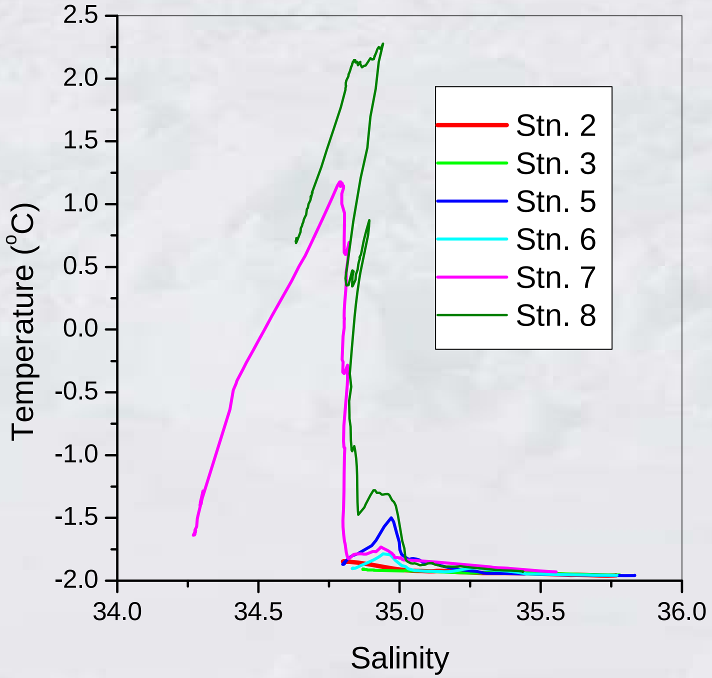
Sea Ice production, brine formation and gas exchange



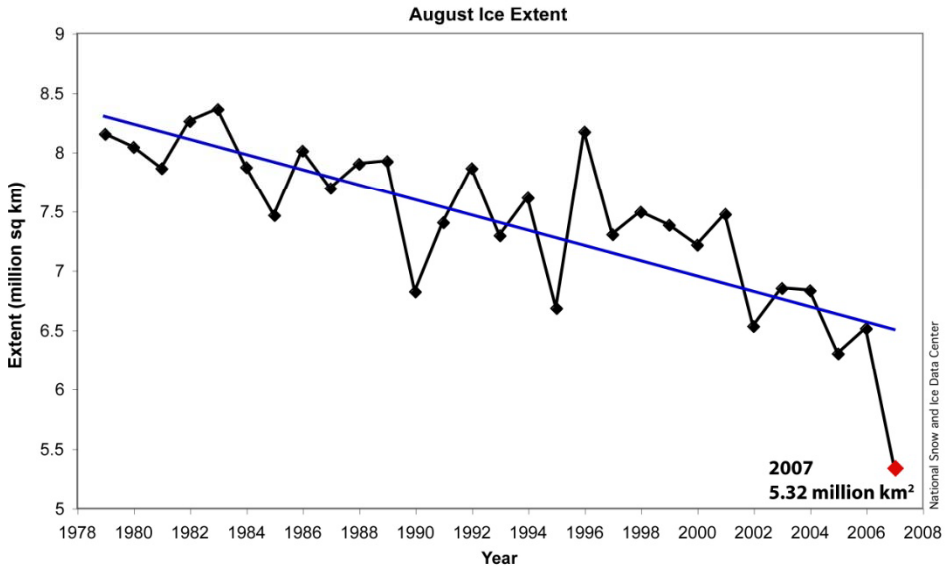


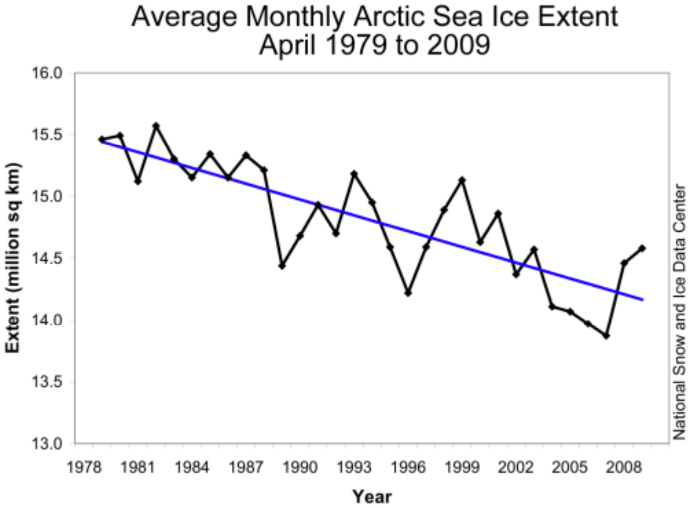
Storfjorden
April 2002
I/B Oden

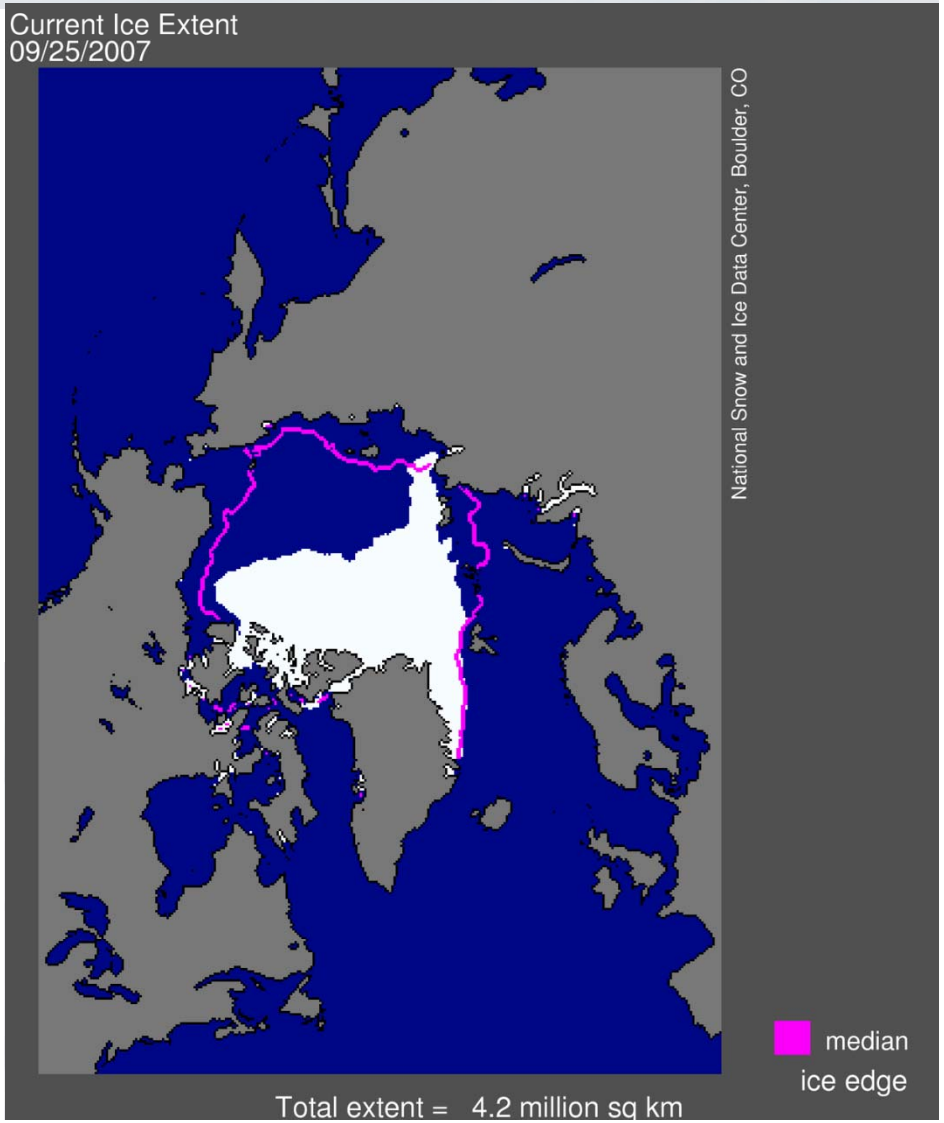




Decreased summer ice coverage → larger ice production during freezing season → more brine production → increased CO_2 uptake → increased ventilation







Arctic Ocean carbon fluxes and Climate Change

Effects on C-flux:

√ more runoff $\Rightarrow$
- $\uparrow$ stratification
- $\uparrow$ nutrient supply
- ? light condition

$\Rightarrow$ Primary Production?

√ less sea ice $\Rightarrow$
- $\uparrow$ light condition
- $\uparrow$ nutrient supply by increased vertical mixing

$\Rightarrow$ PP?

√ increased T $\Rightarrow$ changed biology(?)

Future research:

- There is a data deficit in the Arctic Ocean and hence all new data is welcome
- Seasonal signal is substantial over the shelves and thus there is a need for seasonal data
- This also goes for the surface of the central basins
- Specific area with no (nearly) data is where the Lomonosov Ridge meet Greenland/Canada
- Any specific data that is missing? Probably....