LAMONT-DOHERTY EARTH OBSERVATORY
THE EARTH INSTITUTE AT COLUMBIA UNIVERSITY

Changing Freshwater Sources to the Canadian Basin: 1989-2005

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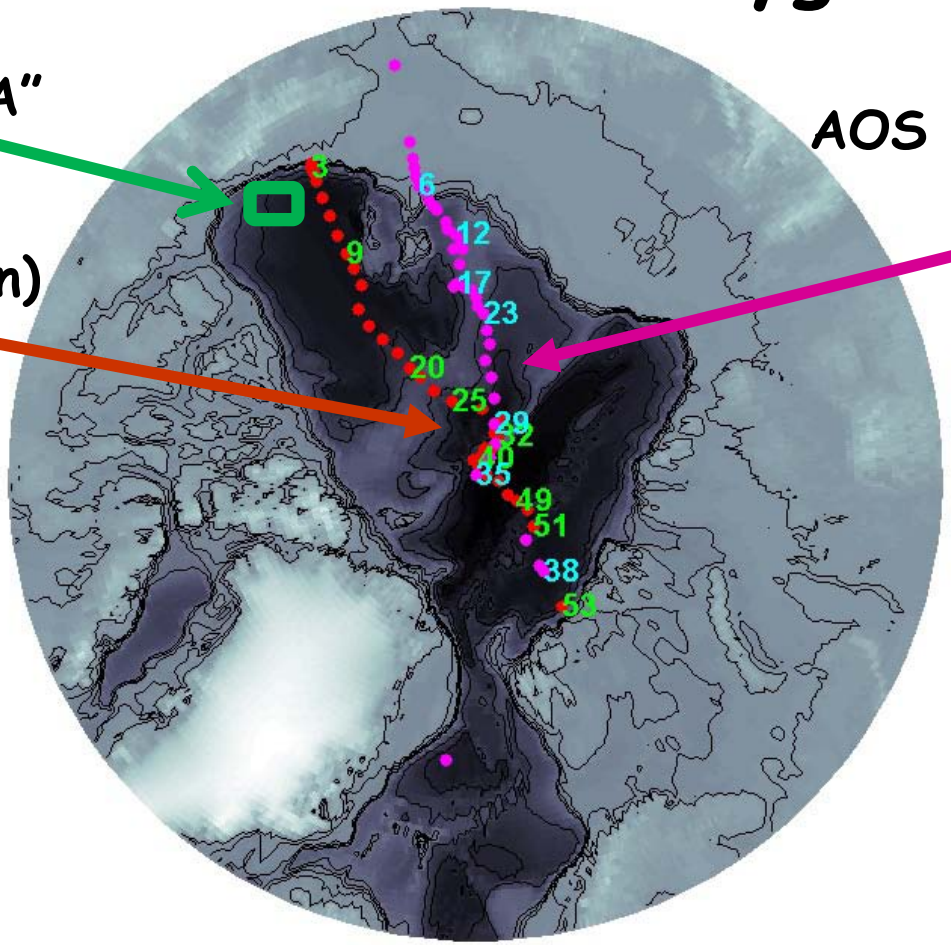
1: Columbia, 2: Rutgers, 3: Princeton

Suitable hydro Profiles with water-mass tracer measurements: (Requires nutrients and oxygen isotopes)

IOS Station "A"
1987-1991

AOS 2005 (Oden)

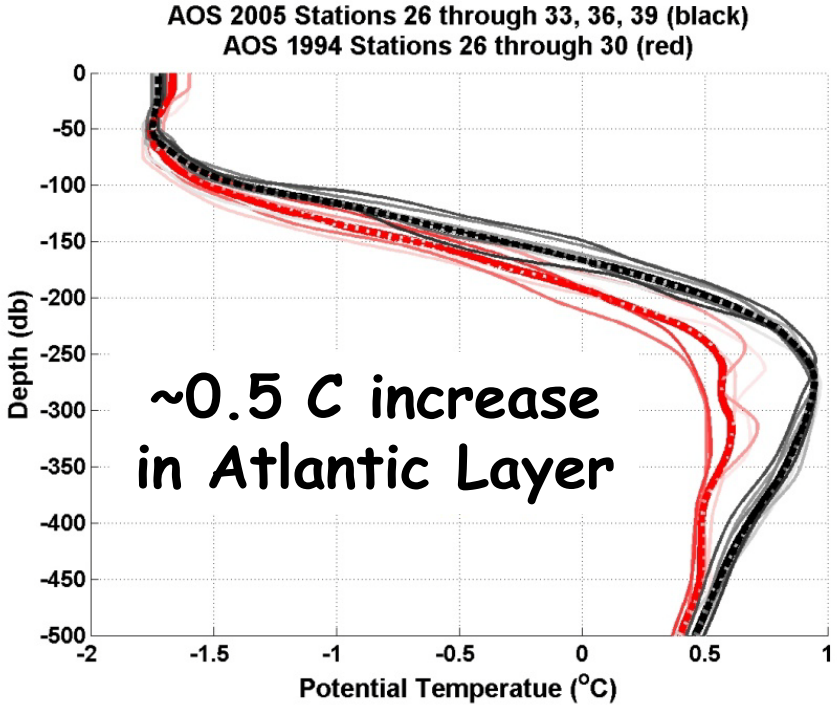
AOS 1994 (Polarstern)

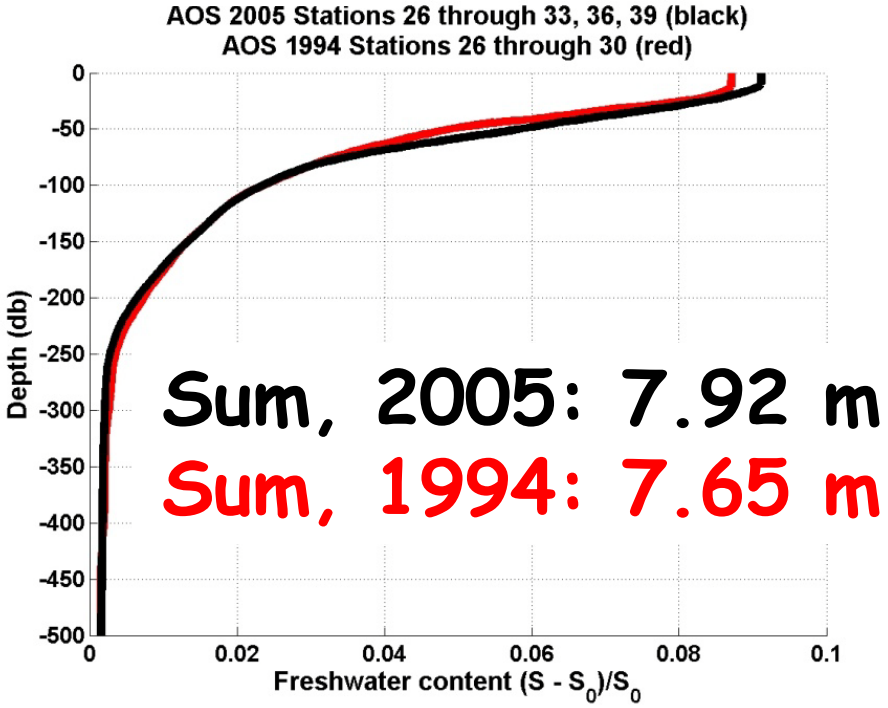


Changes in the Makarov Basin: 2005 vs. 1994:

Black: 2005 Stns 26-39

Red: 1994: Stns 26-30



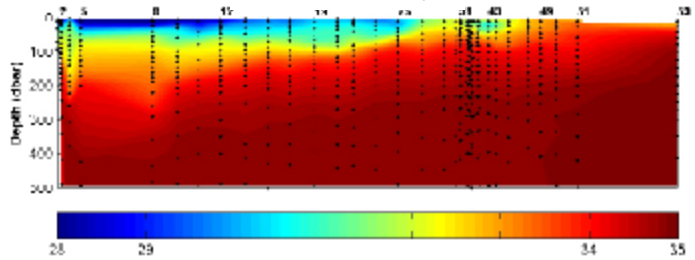


Temperature

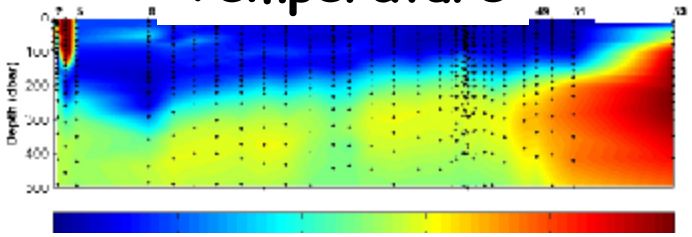
Freshwater = $(S-S_0)/S_0$

AOS2005 Upper 500 m

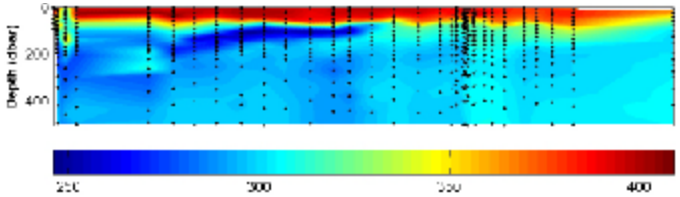
Salinity



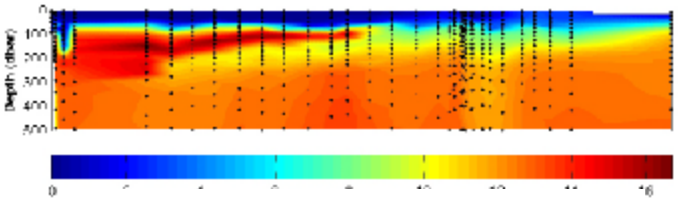
Temperature



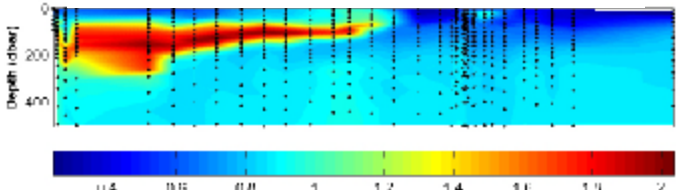
Dissolved Oxygen 240-400 μM



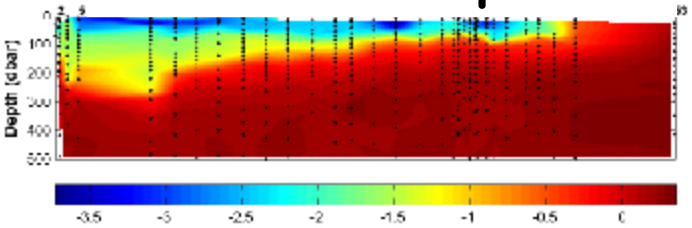
Nitrate < ~16 μM

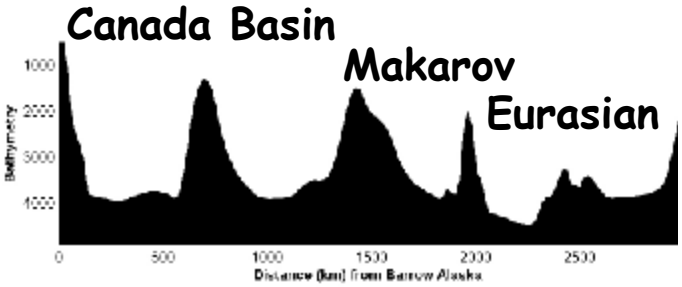


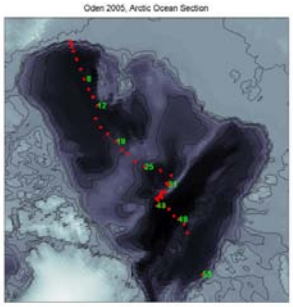
Phosphate 0.2-2 μM

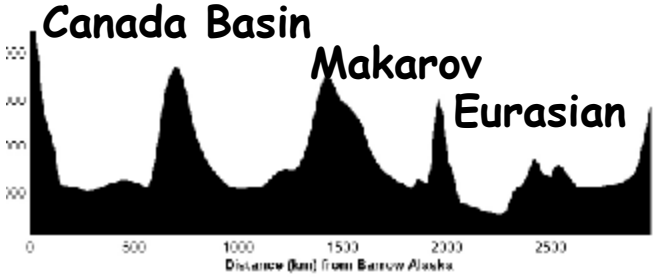


$\delta^{18}O$ > ~-3.5 per mil



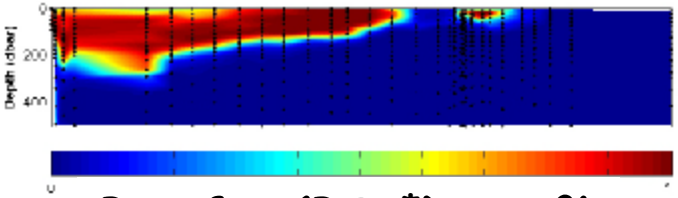




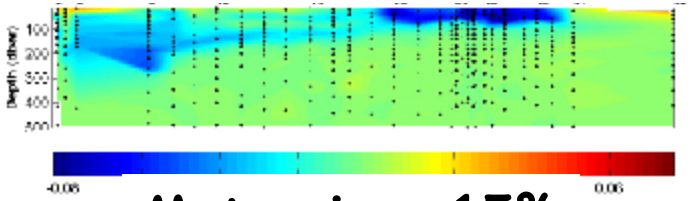


Freshwater Contributions: 2005 Track

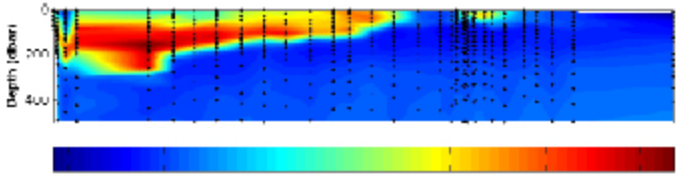
Pacific (Arctic N/P) < 7%



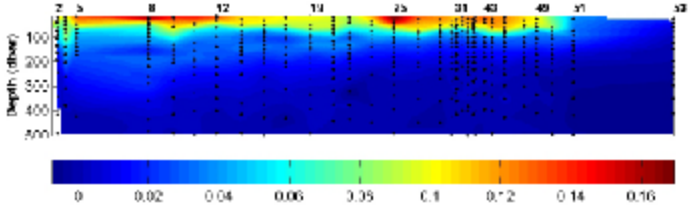
Sea-ice Melt -8 to +5 %



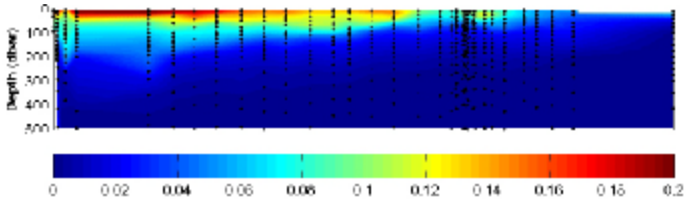
Pacific (PO_4^*) < 7%

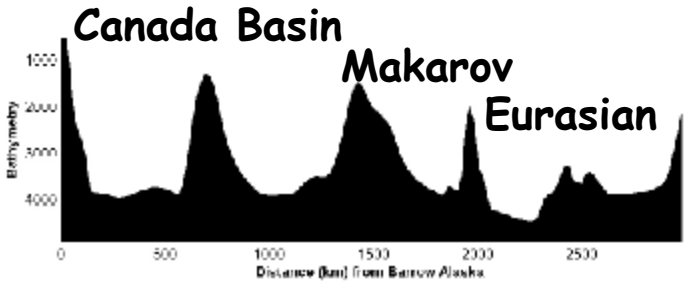


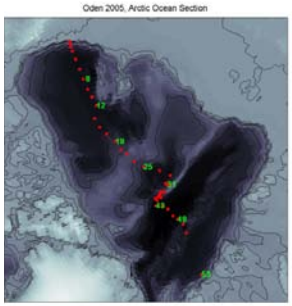
Meteoric < 15%

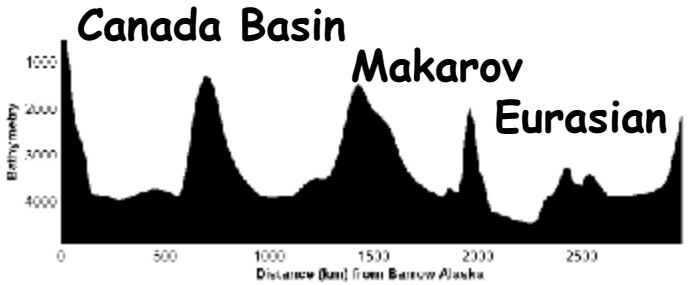


Total Freshwater < ~ 20%



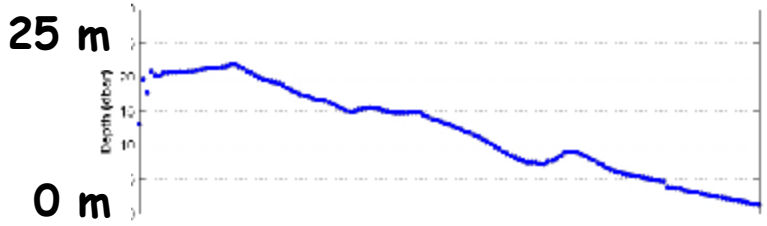




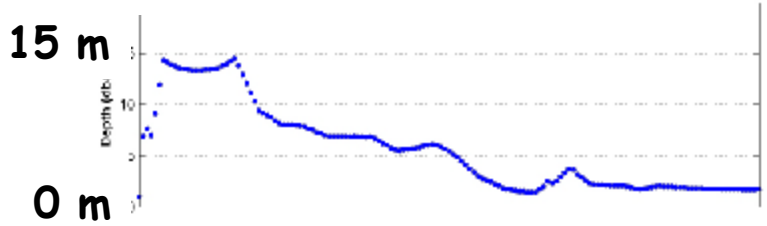


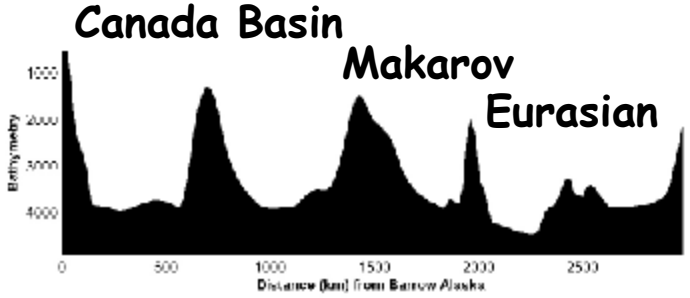
Vertical sums: water-column content of components (m^3/m^2):

Total Freshwater = $(S-S_0)/S_0$

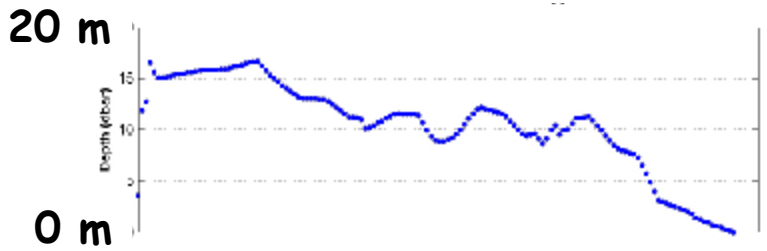


"Pacific" Freshwater

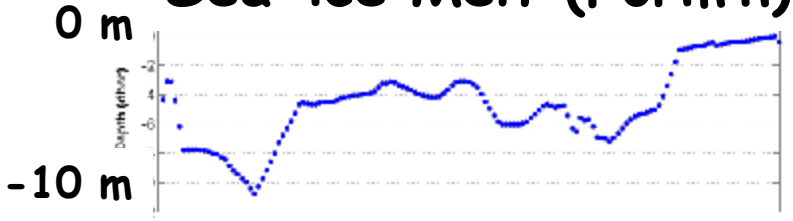




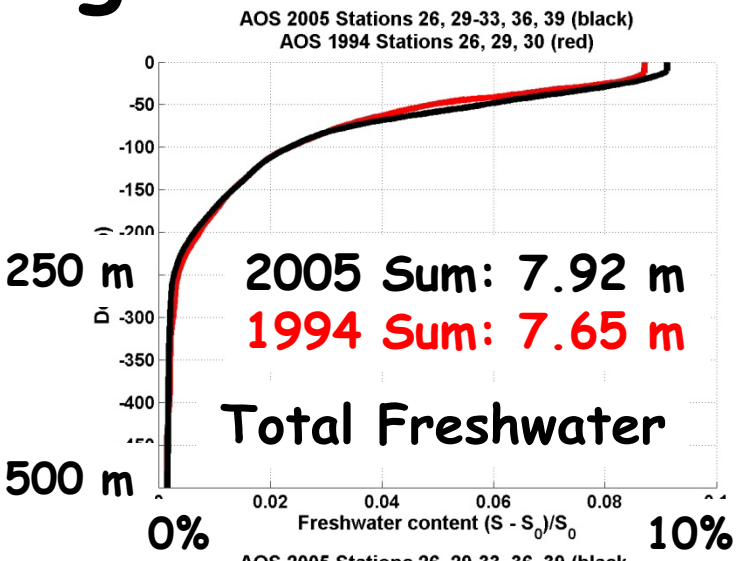
Meteoric (precip+runoff)

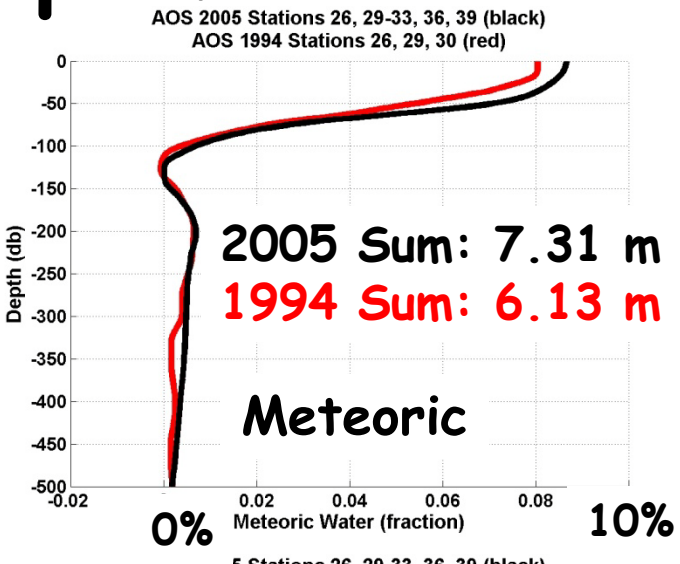


Sea-ice Melt (Form'n)

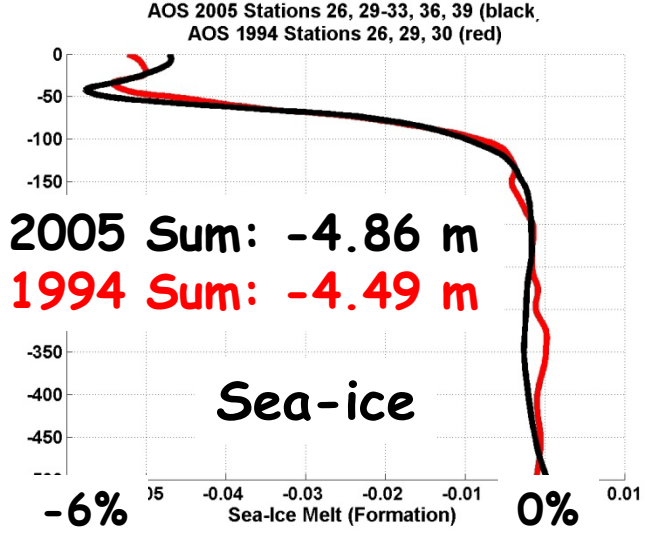


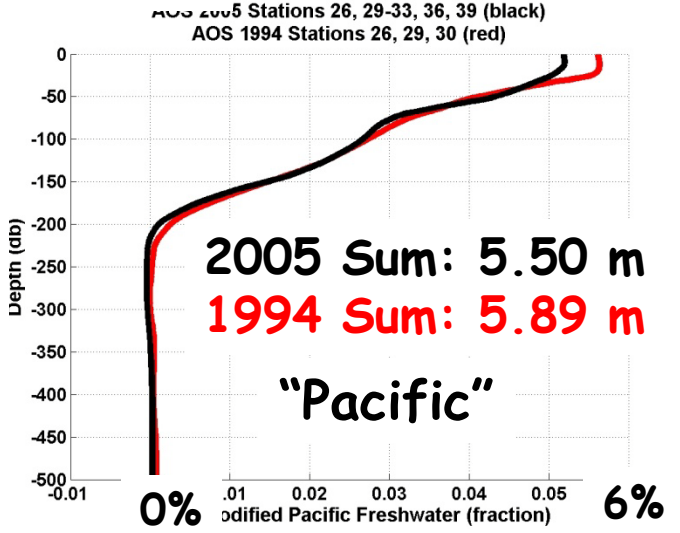
Makarov Basin: 2005 vs 1994 average water-mass profiles:





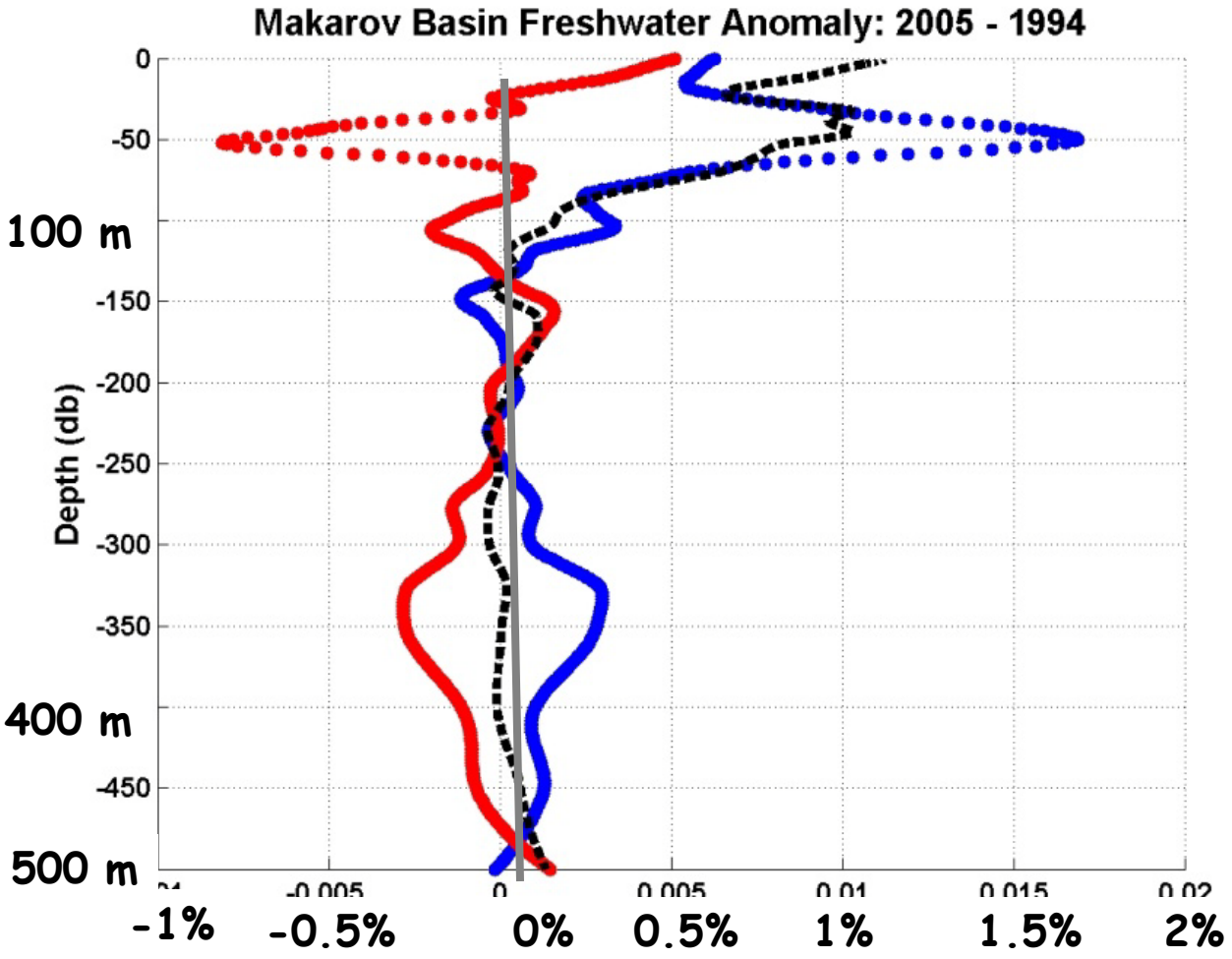
Small change in the vertical sum.
But change in specific layers is significant.
Esp. increased stratification in winter mixed layer and increased brine in Atlantic layer.





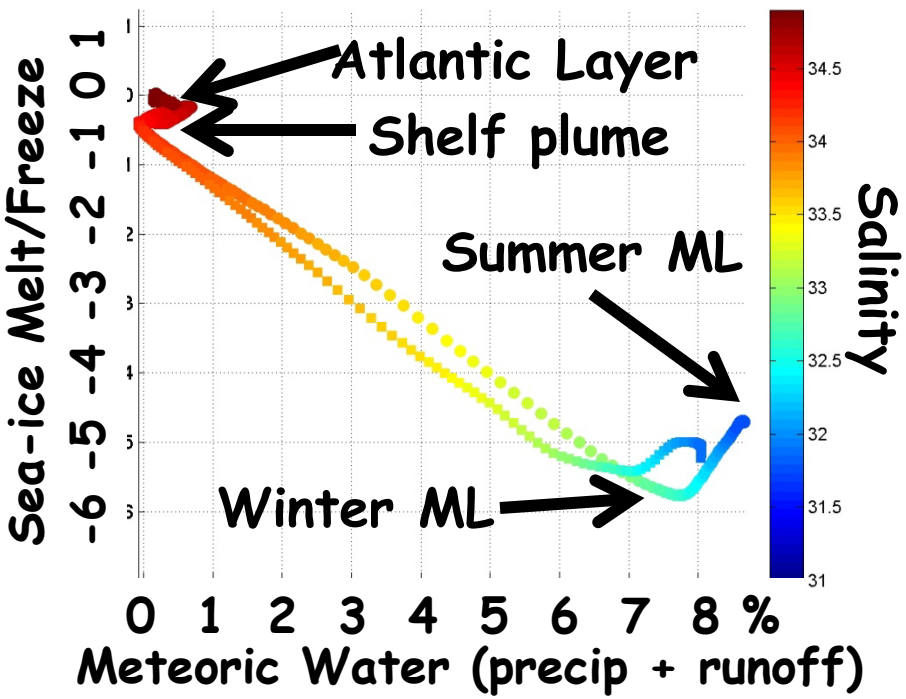
Vertical structure of the 2005-1994 anomalies:

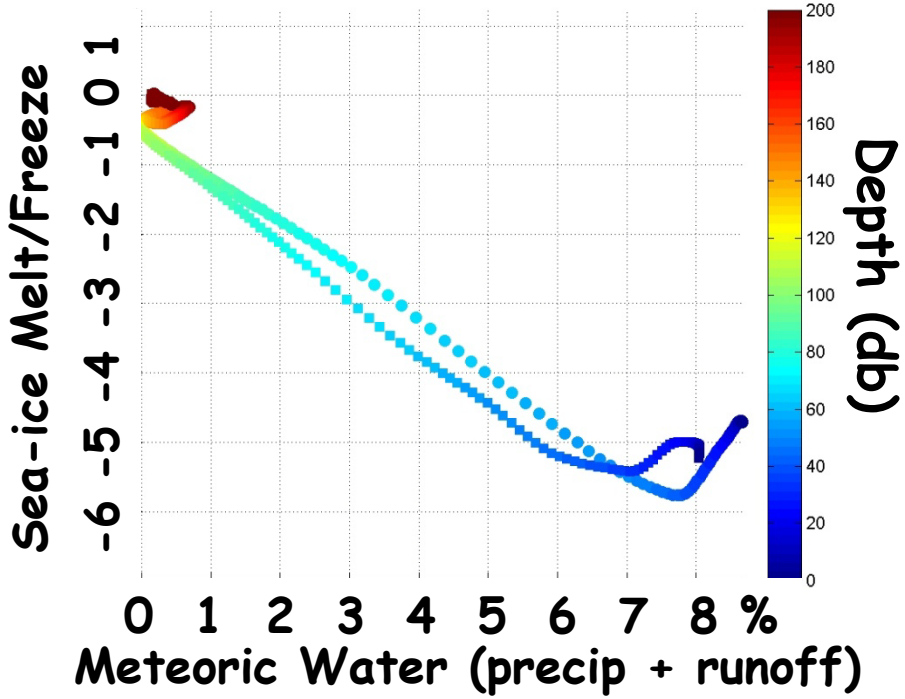
Red: Sea-ice
Blue: Meteoric
Black: Sum



- Injection of shelf-derived brine+runoff at S = 33.1
- Winter convection mixes down meteoric water+melt.
- Mixing between local w.m.l. and shelf-derived plume.

Makarov Basin Averages: Circles-2005, Triangles-1994

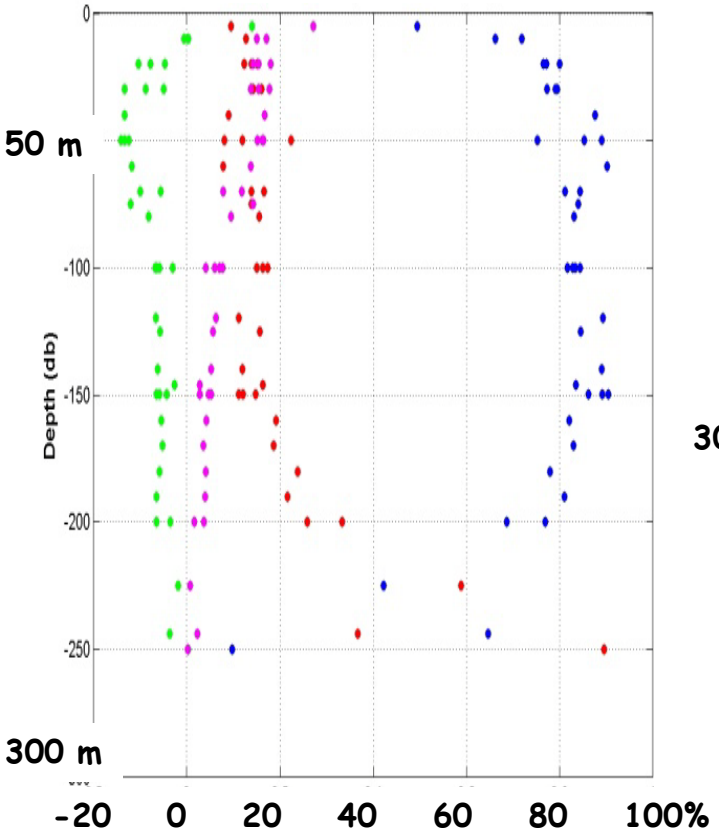




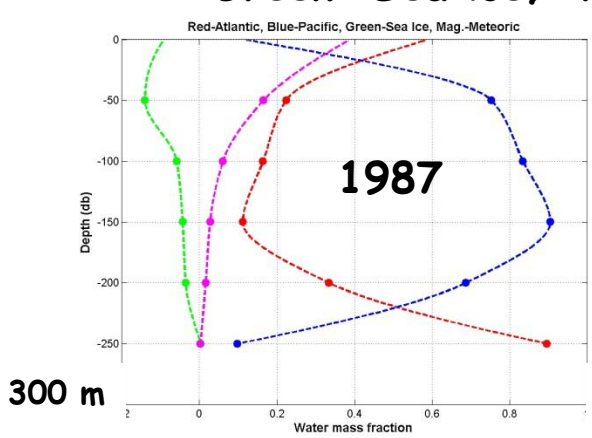
- 2005 winter mixed layer ~ 20% deeper (42 vs 35 m)
- 2005 w.m.l. ~ 0.1 psu more saline.
- 2005 surface water ~ 0.14 psu fresher.

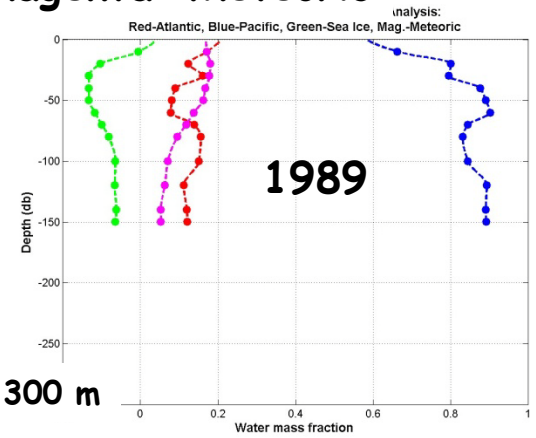
Southern Canada Basin: IOS "Station A": 1987-1991

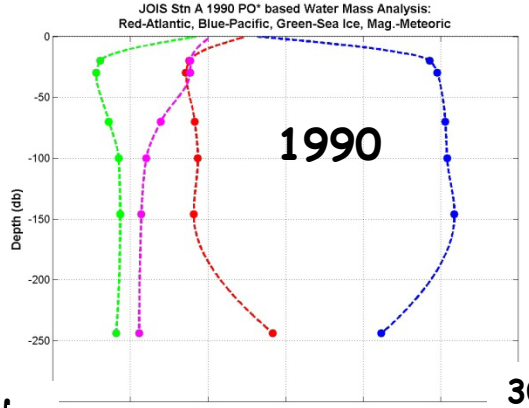
All Years

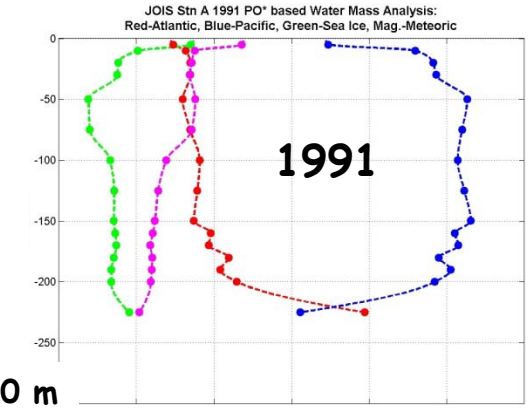


Red: Atlantic; Blue: Pacific;
Green: Sea ice; Magenta: Meteoric









300 m

-20 0 20 40 60 80 % -20 0 20 40 60 80 100%

Data courtesy of Robie MacDonald

Southern Canada Basin: AOS 2005 vs IOS "Station A"

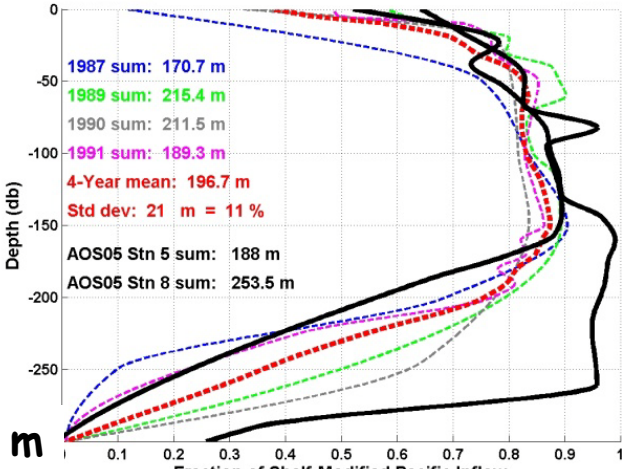
Black: AOS 2005

Red: Station A, 1987-91 Average

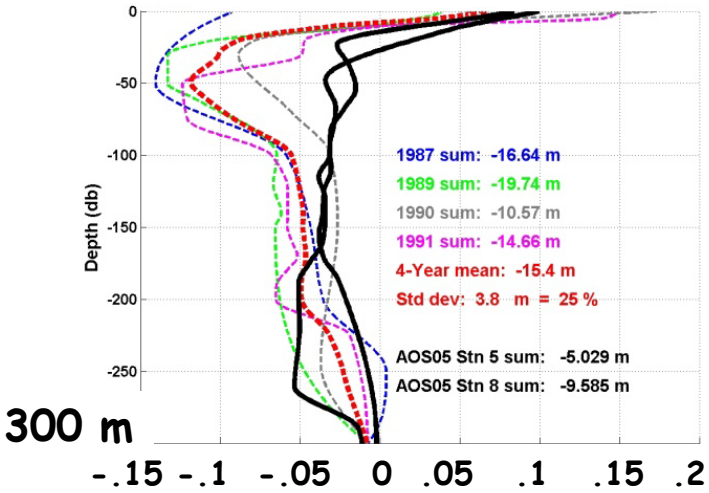
Vert. Sum	IOS A	STD	AOS05	Diff
Sea Ice	-15.4	3.8	-7.3	4.6
Meteoric	20.6	2.9	11.3	0.9
Pacific	13.6	1.5	15.3	4.5

Significant interanaul variability, but decadal still stands out.

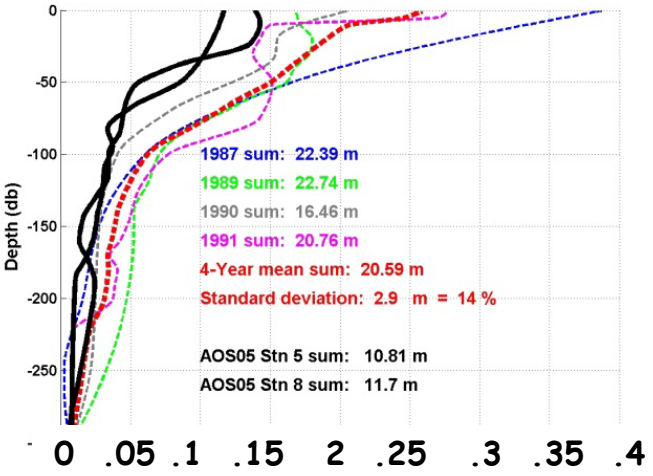
Pacific



Sea Ice

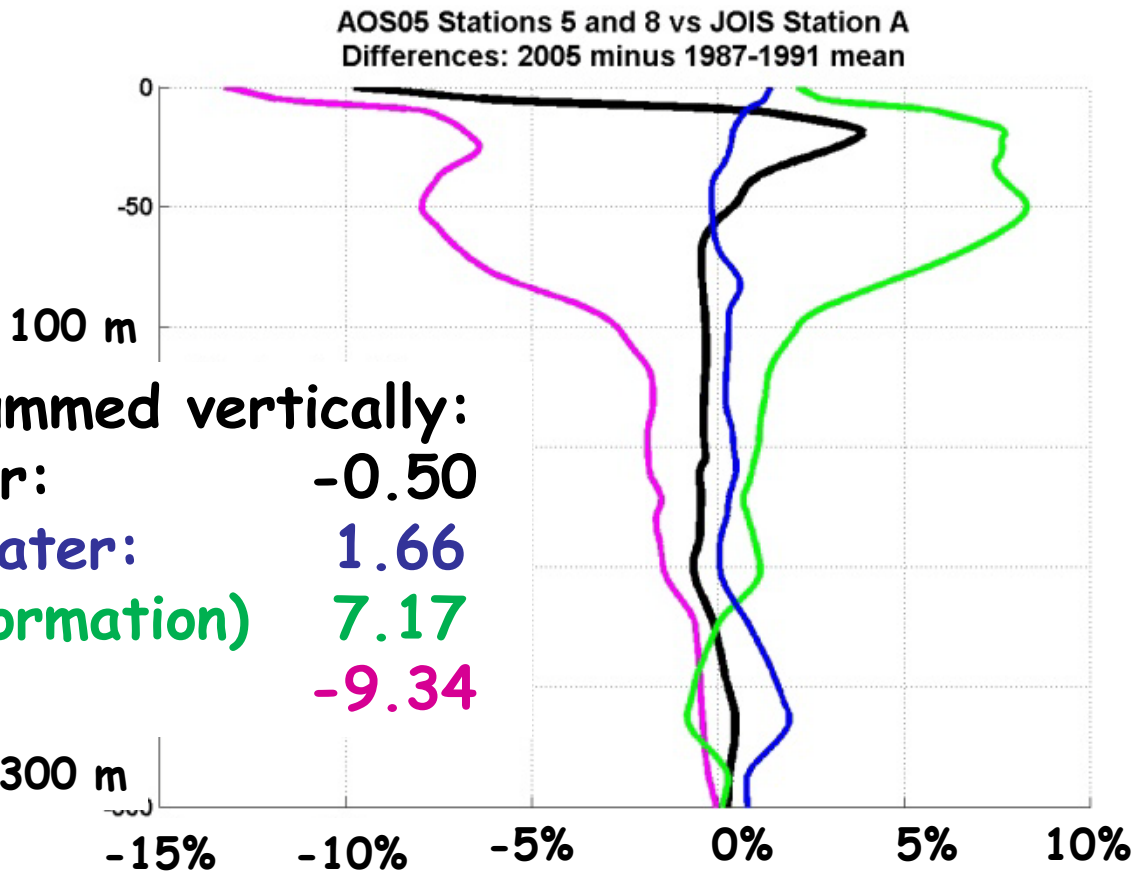


Meteoric



Differences: AOS 2005 minus Station A 1987-1991 (mean component profiles)

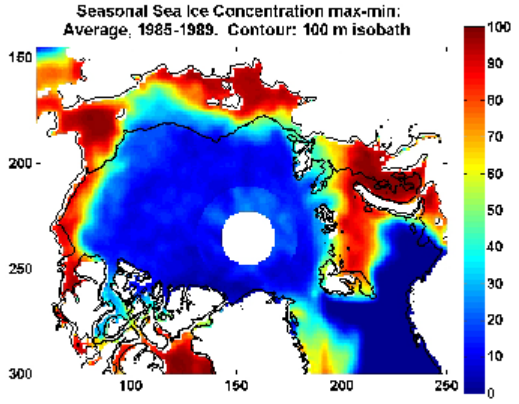
Black: Total freshwater
Blue: "Pacific" freshwater
Green: Sea-ice melt (form'n)
Magenta: Meteoric water



Differences (m^3/m^2) summed vertically:

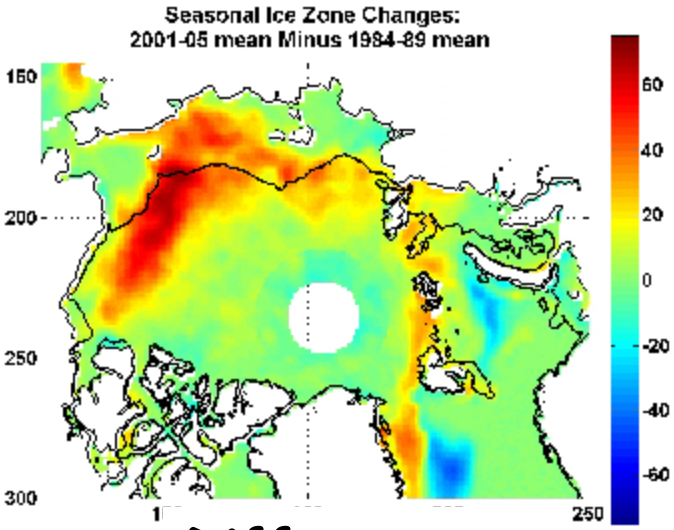
Total freshwater:	-0.50
"Pacific" freshwater:	1.66
Sea-ice melt (formation)	7.17
Meteoric water	-9.34

In the periods preceding the 1987-1994 and the 2005 sampling, the Seasonal Ice Zone expanded dramatically:



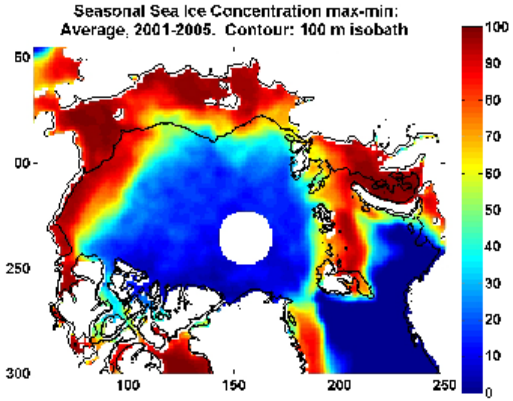
Seasonal Ice Zone (September – March sea-ice conentration): 1985-1989 Average

SIZ Change



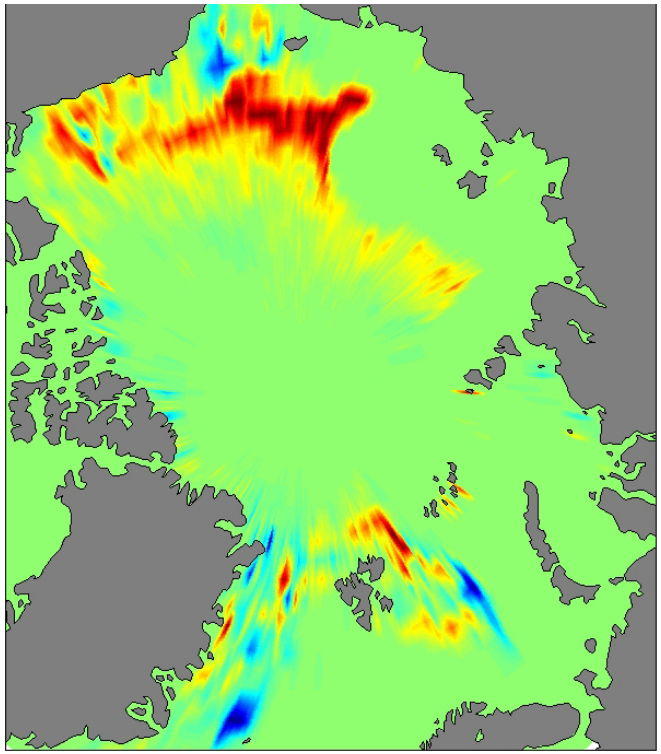
Difference: 2001-05 Minus 1985-1989

Seasonal Ice Zone (September – March sea-ice conentration): 2001-2005 Average



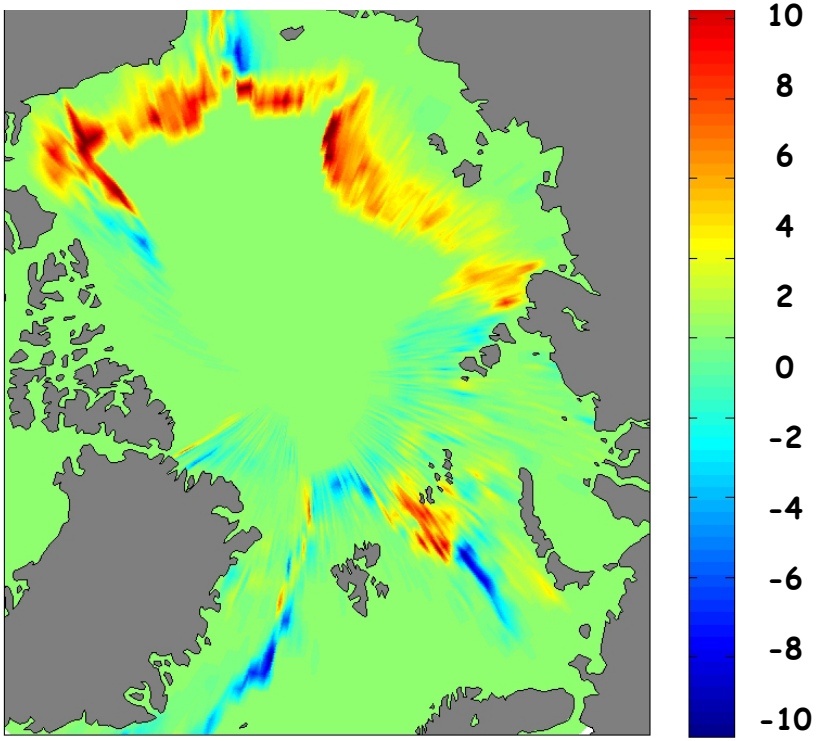
As the SIZ expands, both ice melt and formation dramatically increase:

ICE MELT
1999-2008 minus 1979-1988



Melt Area Increased 28%
Melting floes increased 30%

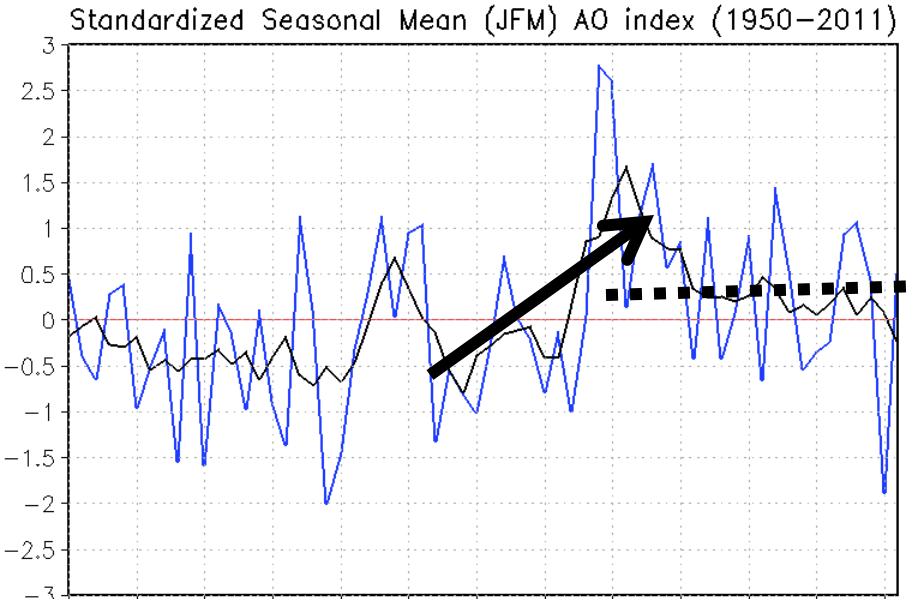
ICE FORMATION
1999-2008 minus 1979-1988



Formation Area Increased 4%
Formation floes increased 18%

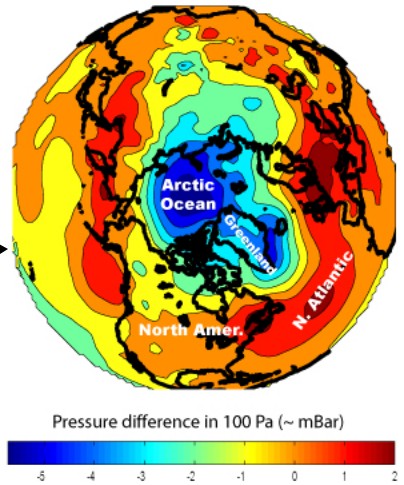
Ice floe tracking data courtesy Maslanik/Fowler/Meier

In the Arctic, the wind-stress curl gradient varies in time:



Cold season (JFM) Arctic Oscillation Index, 1950 to 2011

TREND:



Point-by-point tendency in SLP during the upward trend of the Arctic Oscillation from 1981-1993

http://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_ao_index/season.JFM.ao.gif

Conclusions

- Between the late 1980s and the mid 2000's, sea-ice meltwater up dramatically in the southern Canada Basin, but slightly down in the Makarov.
- Relative to changes in sea-ice thickness, meltwater is "missing" from the central Arctic; broader tracer surveys needed to identify meltwater pathways.
- Increased ice/melt cycle is increasing stratification and deepening the winter mixed layer over the Makarov.
- Met. Fraction down dramatically in southern Canada Basin; up moderately in Makarov. Volume is hard to explain from observed moderate precipitation increases.
- … but fits with "recovery" of wind-stress curl gradient, evident in the decrease of the AO (or NAO) leading up to the 2005 cruise, as compared with the early 1980s.