Largest River Discharges (annual averages)

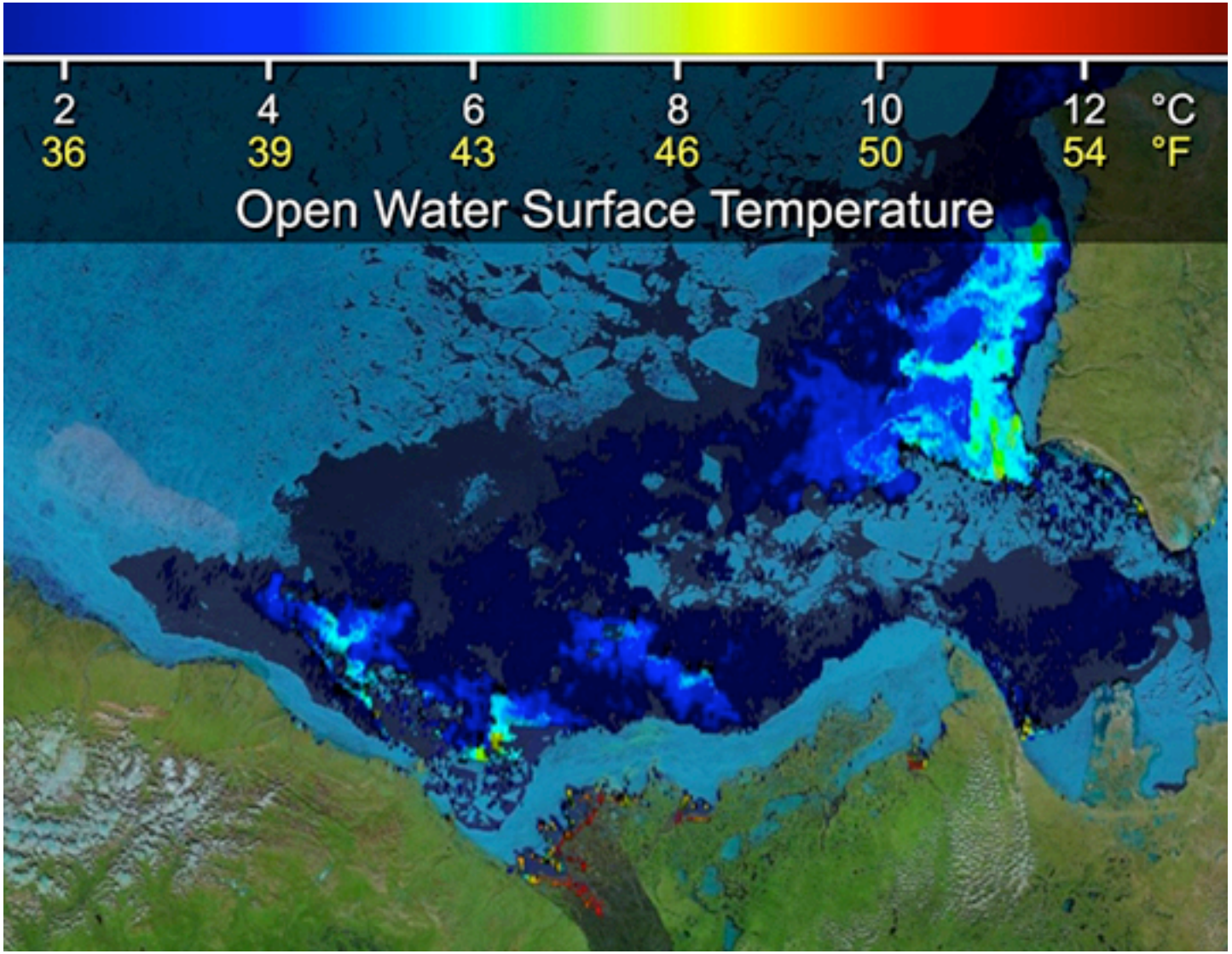
River	Discharge m^3/s
1. Amazon, South America	220,000
2. Ganges, India	44,000
3. Congo, Africa	41,000
4. Orinoco, South America	32,000
5. Yangtze, China	32,000
6. La Plata, South America	26,000
7. Yenisei, Arctic	20,000
8. Lena, Arctic	17,000
9. Mississippi, North America	16,000
10. Mekong, Asia	16,000
11. Ob, Arctic	13,000
12. Amur, Asia	11,000
13. Mackenzie, Arctic	10,000
…	
Delaware	330

Show YouTube video

2012 Mackenzie River Plume

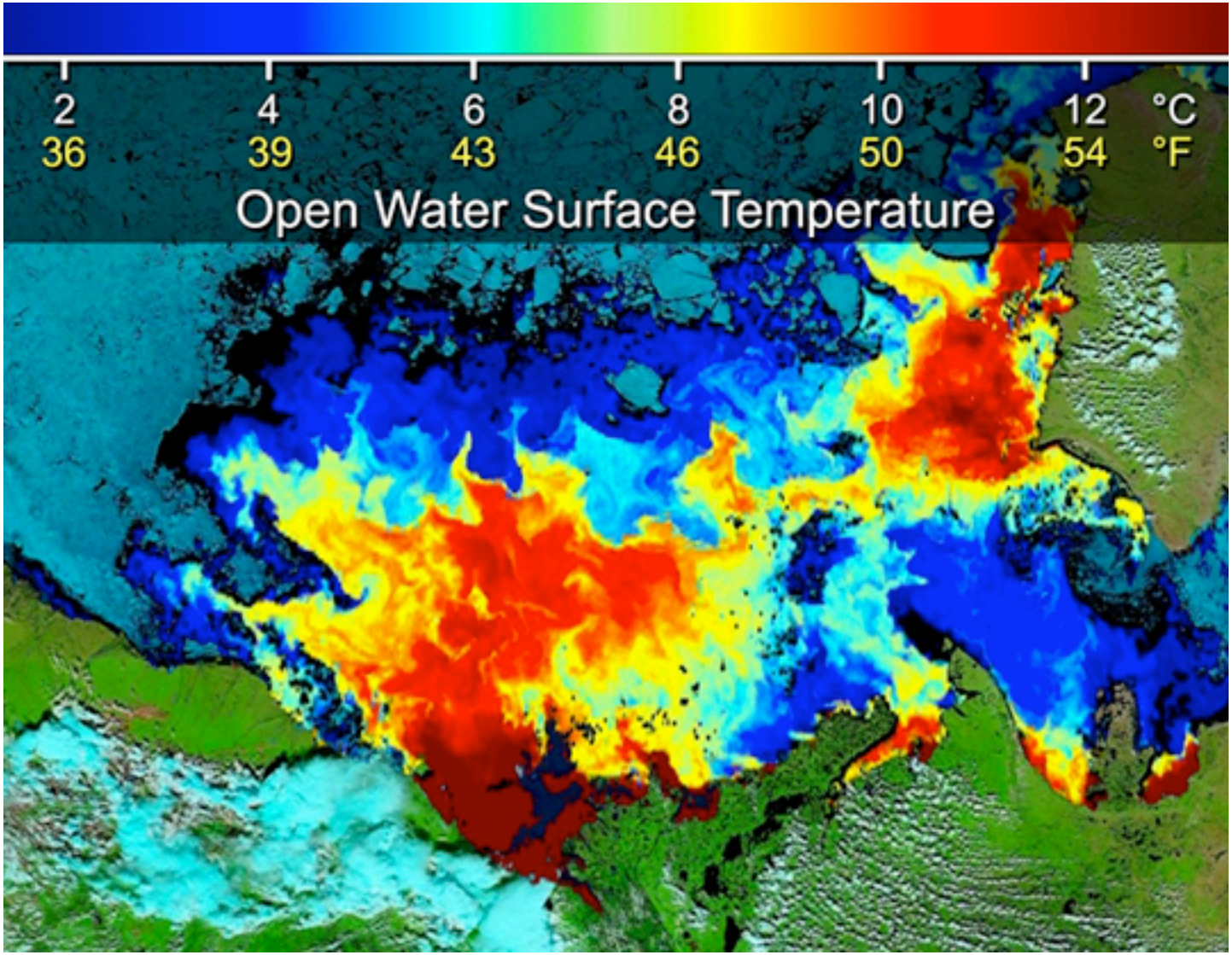
http://www.youtube.com/watch?v=pSHieLVTROk

Mackenzie Shelf and River Plume: June 14, 2012



http://climate.nasa.gov/news/1046/

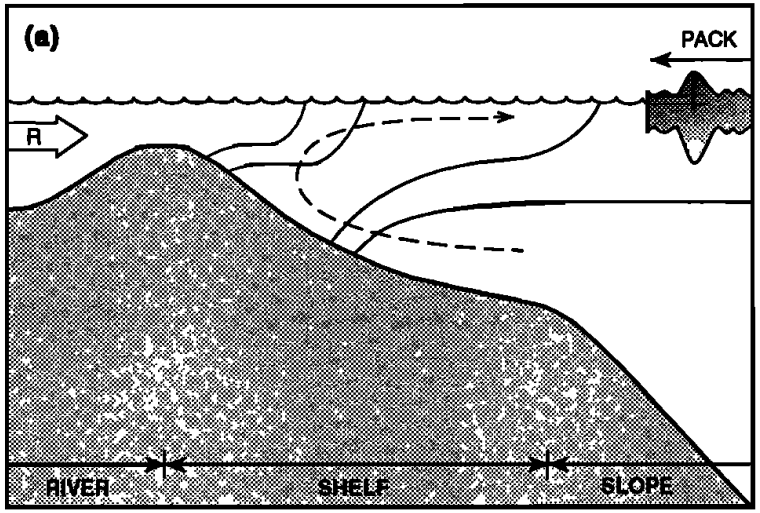
Mackenzie Shelf and River Plume: July 5, 2012



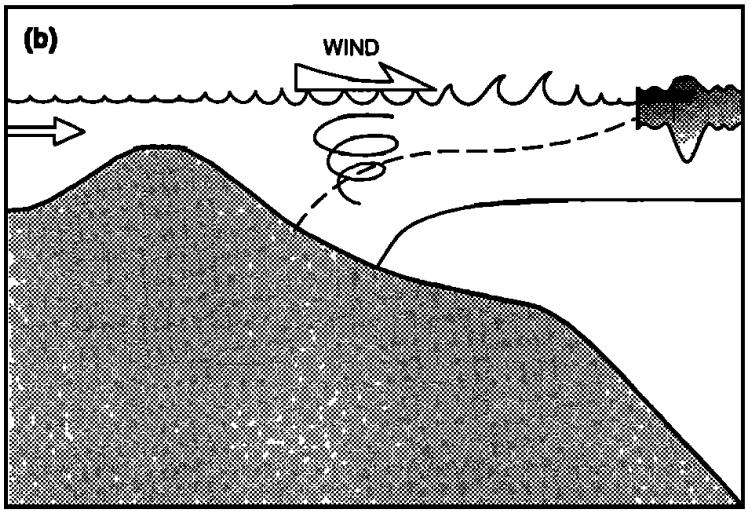
http://climate.nasa.gov/news/1046/

Schematic of Mackenzie Estuary-Shelf of Seasonal Ice-Discharge Interactions

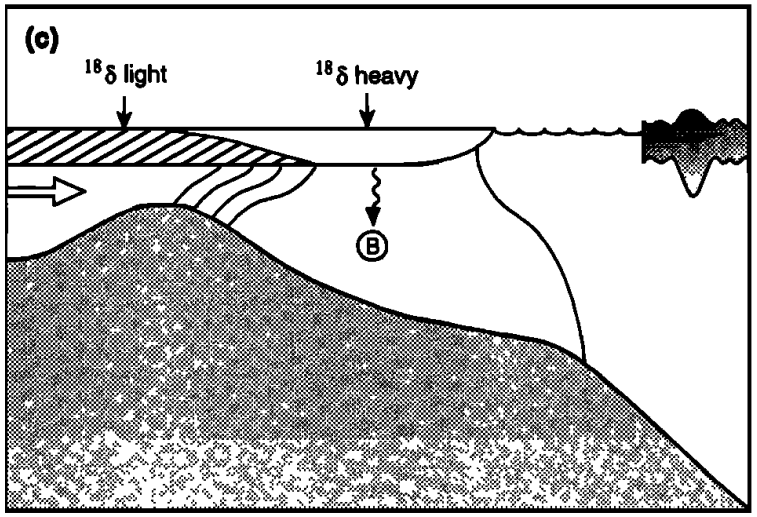
Summer Freshet



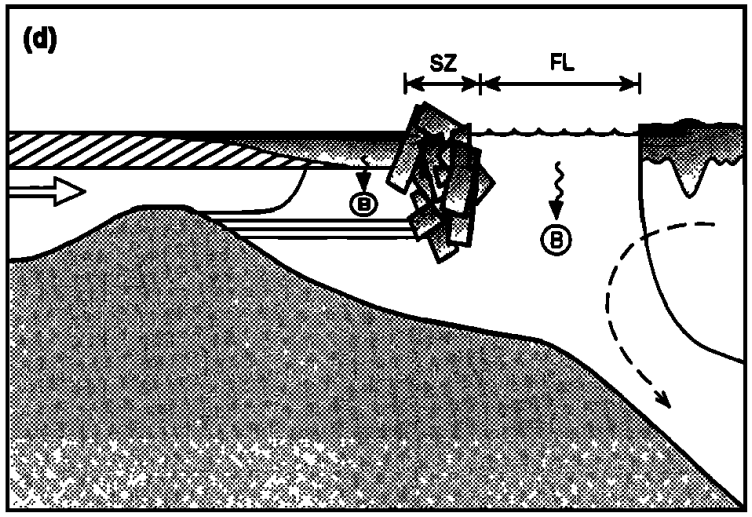
Autumn Storms



Winter Freeze Early

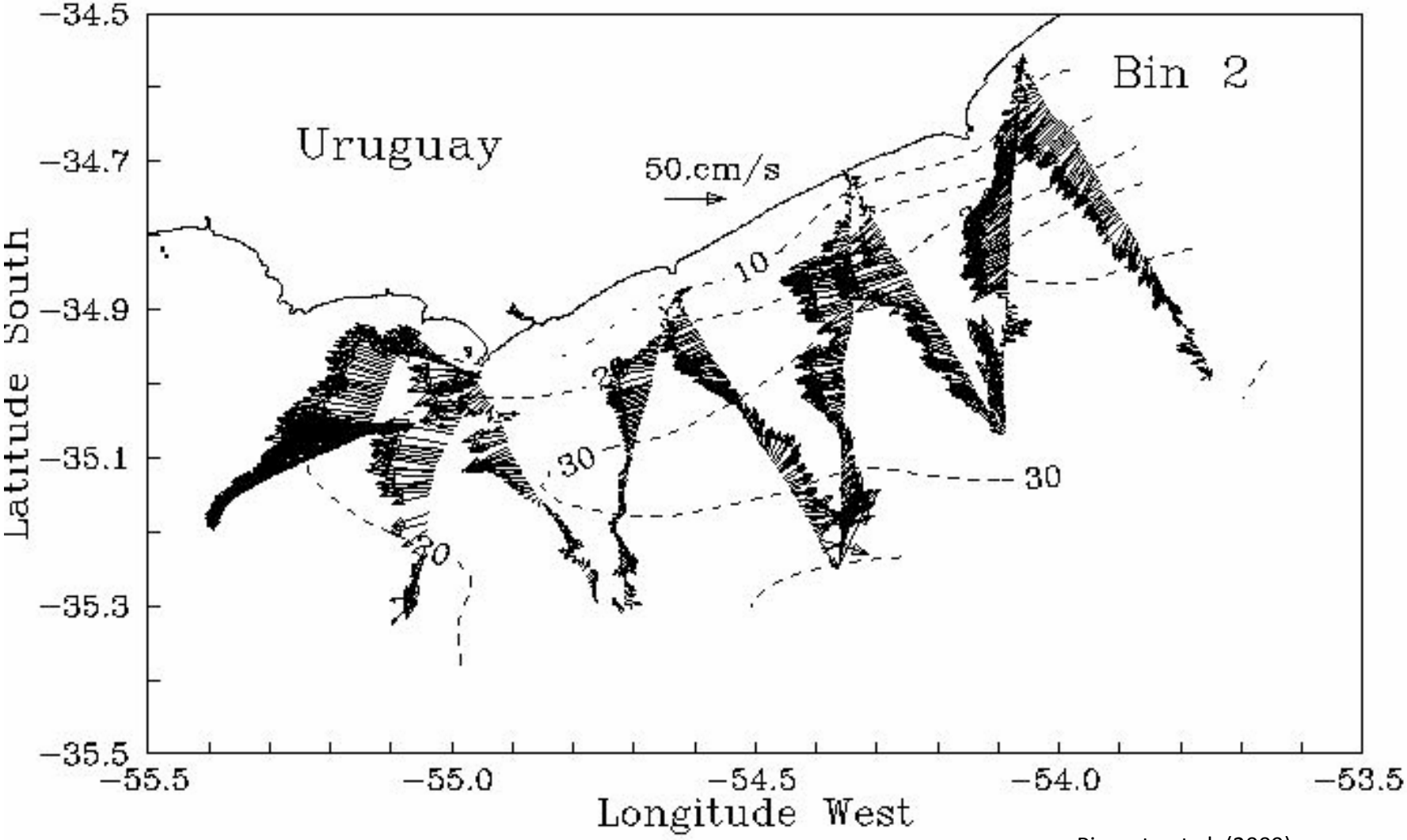


Winter Ice Barrier and Lead



Macdonald et al. (1995)

Surface Currents Aug.-1999



Pimenta et al. (2009)

Rio de la Plata

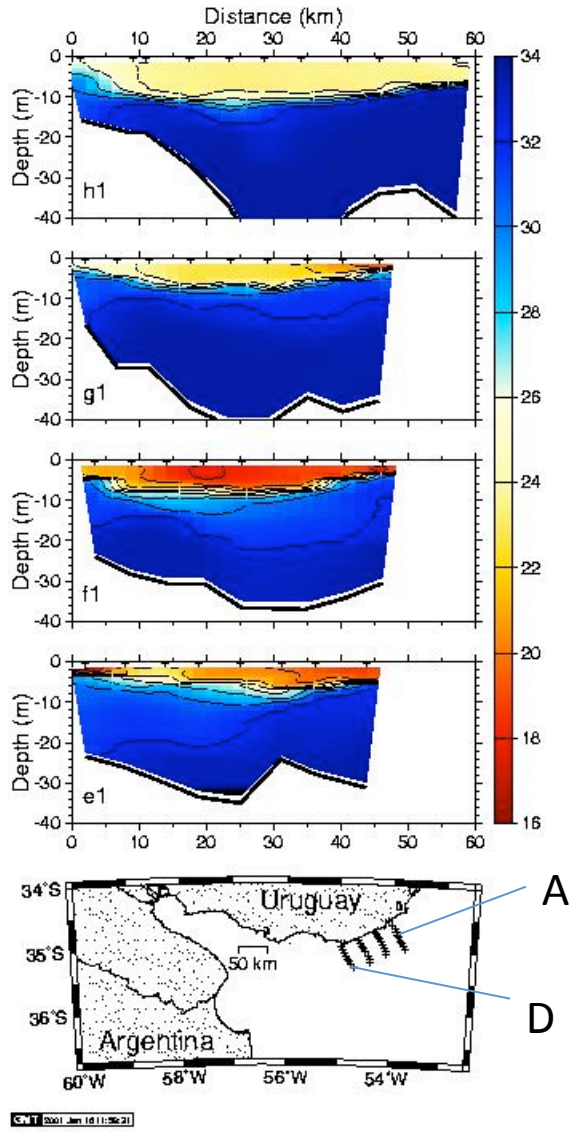
Salinity Aug.-1999

A

B

C

D

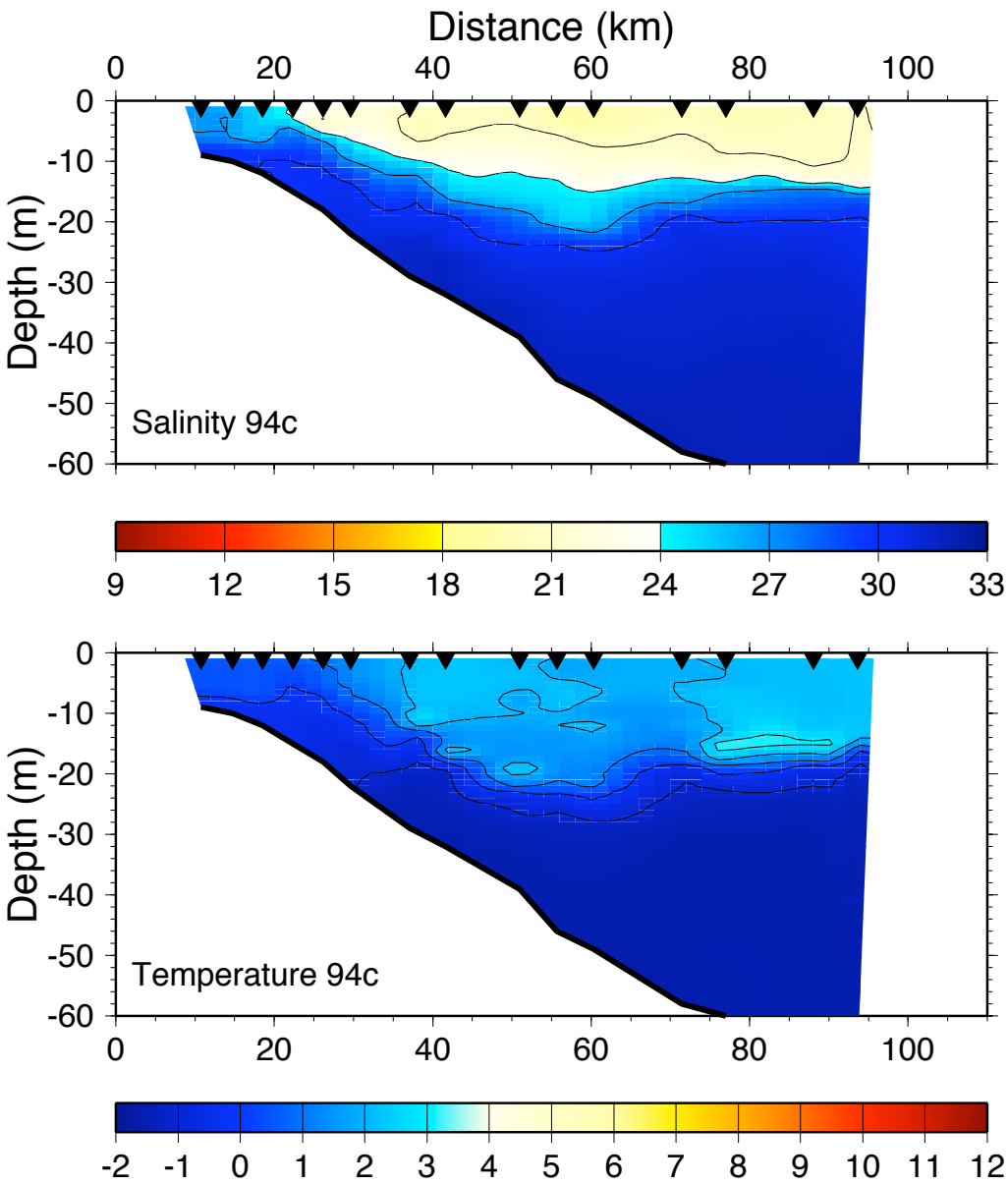


Time

- Strong Upwelling
- Onset of Upwelling
- Onset of Upwelling
- Weak Winds

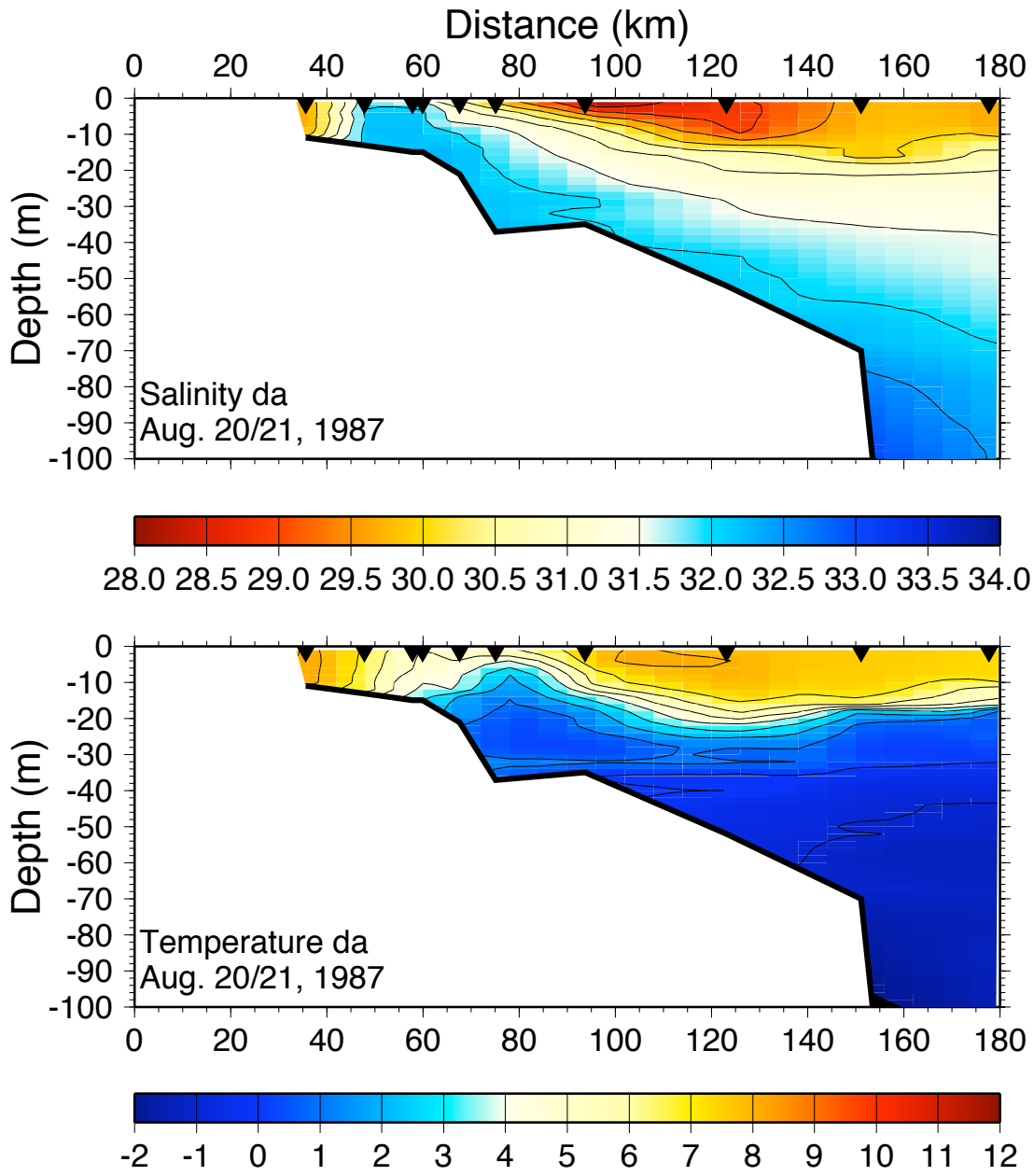
Pimenta et al. (2009)

Mackenzie Shelf with River Plume Sept.-1994



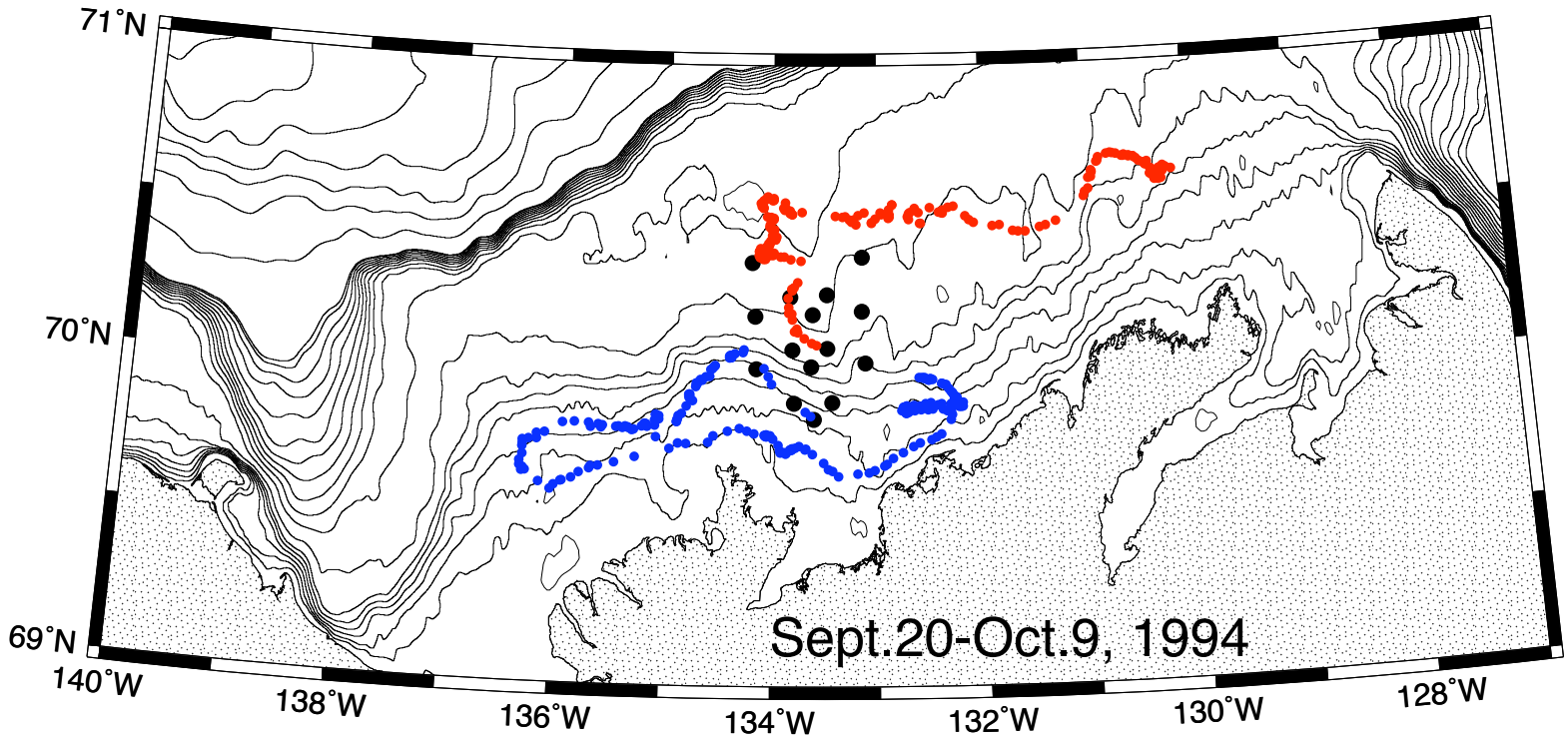
Unpublished own work

Mackenzie Shelf with River Plume Aug.-1987



Unpublished own work

Two Surface Drifters on the Mackenzie Shelf 1994



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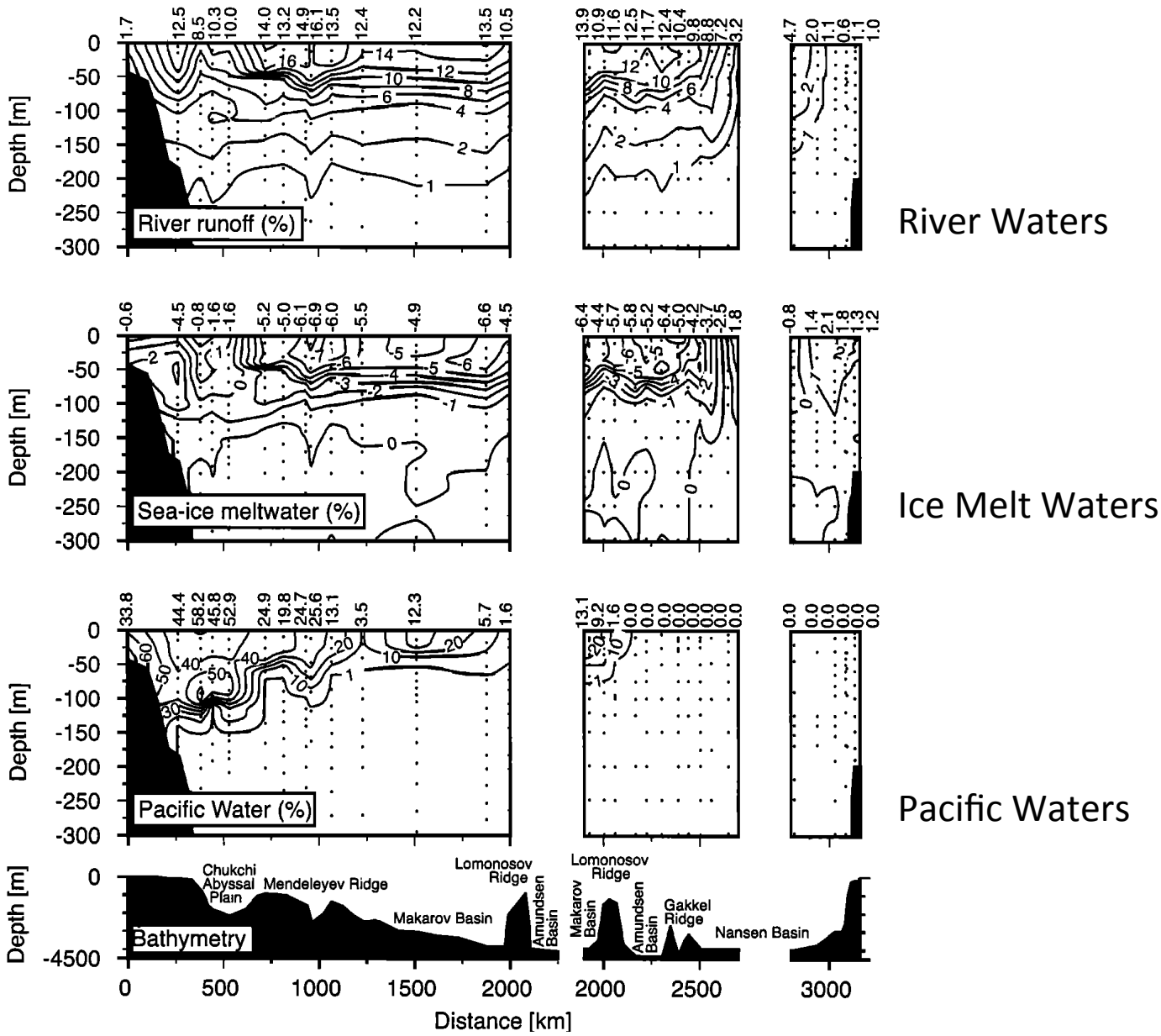


River Waters

Ice Melt Waters

Pacific Waters

Ekwurzel et al. (2001)

Water Mass Analysis via Tracers (Linear Algebra)

1. Conservation of Mass: $f_a + f_p + f_r + f_i = 1,$

2. Conservation of Salinity: $f_a S_a + f_p S_p + f_r S_r + f_i S_i = S_m,$

3. Conservation of Oxygen: $f_a \delta^{18}O_a + f_p \delta^{18}O_p + f_r \delta^{18}O_r + f_i \delta^{18}O_i = \delta^{18}O_m,$

4. Conservation of Phosphate: $f_a PO_4{}^*{}_a + f_p PO_4{}^*{}_p + f_r PO_4{}^*{}_r + f_i PO_4{}^*{}_i = PO_4{}^*{}_m,$

Unknowns:

1. Atlantic Water Fraction f_a
2. River Water Fraction f_r
3. Ice melt Fraction f_i
4. Pacific Water Fraction f_p

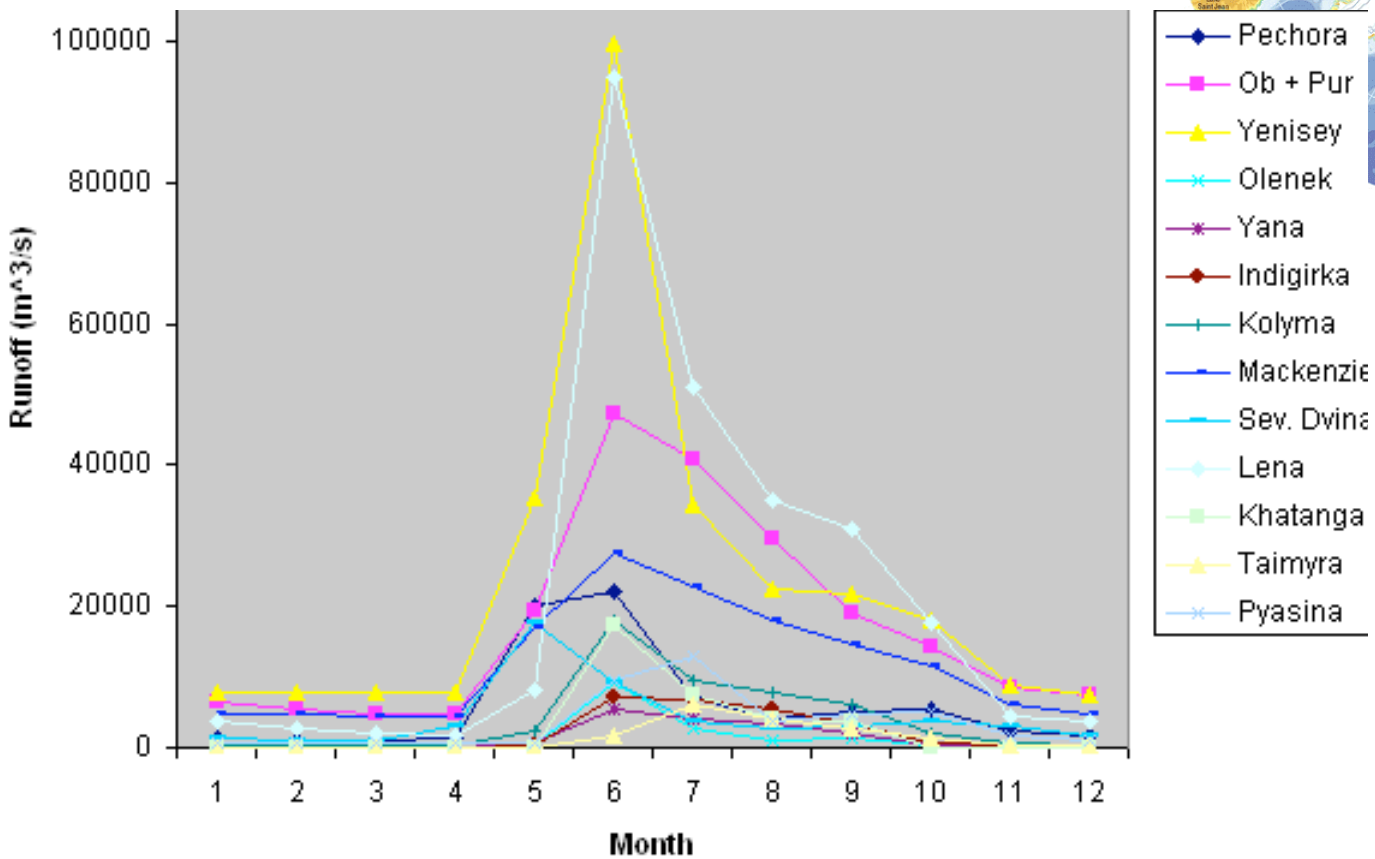
Knowns:

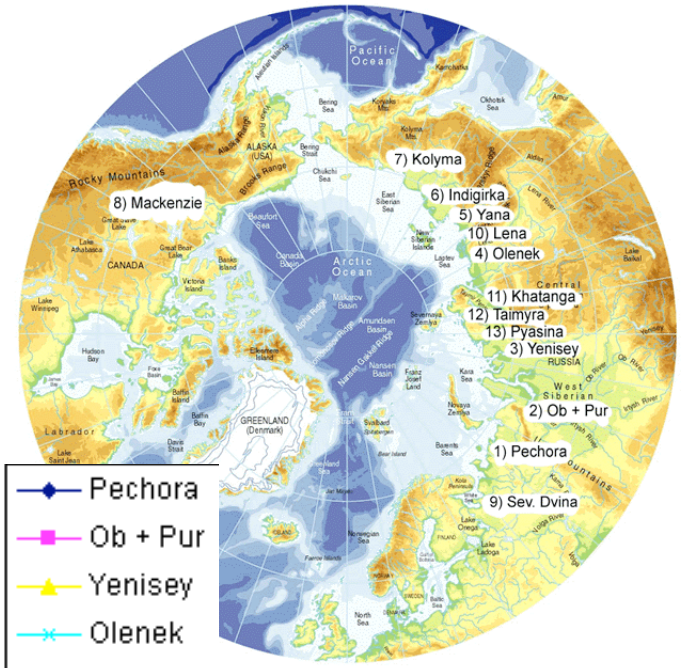
Table 1. Parameters Used in Three-Component and Four-Component Mass Balance

	Salinity	$\delta^{18}O$, ‰	$PO_4{}^*$, μmol kg^{-1}
Atlantic water	35 ± 0.05	0.3 ± 0.1	0.7 ± 0.05
River runoff	0	-18 ± 2	0.1 ± 0.1
Sea ice	4 ± 1	surface + (2.6 ± 0.1)[a]	0.4 ± 0.2
Pacific water	32.7 ± 1	-1.1 ± 0.2	2.4 ± 0.3

Ekwurzel et al. (2001)

Arctic River Discharges





WHOI Arctic Ocean Model
Intercomparison Project

Mean Annual River Discharge in km^3/s

(31.7 m^3/s)

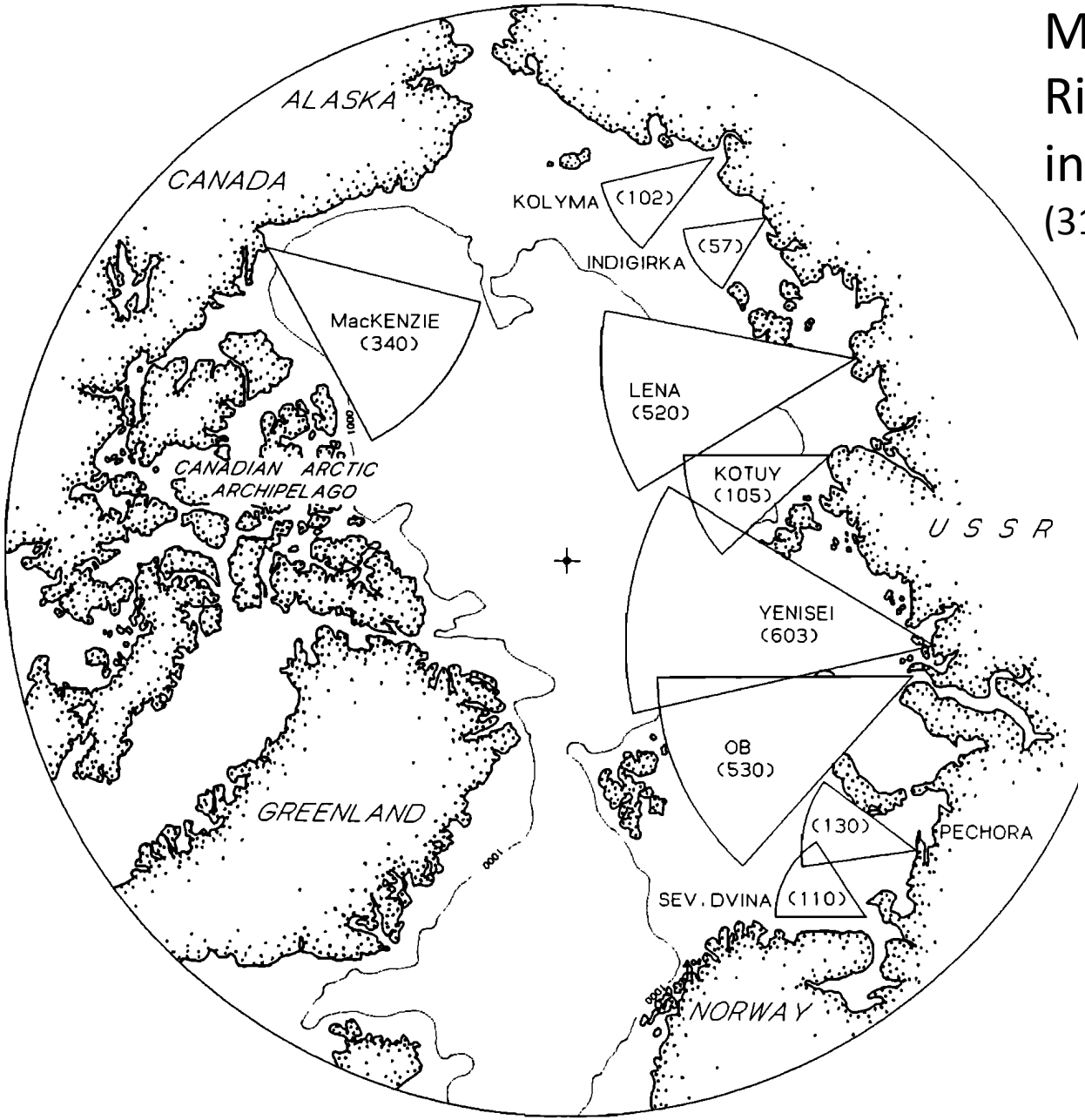
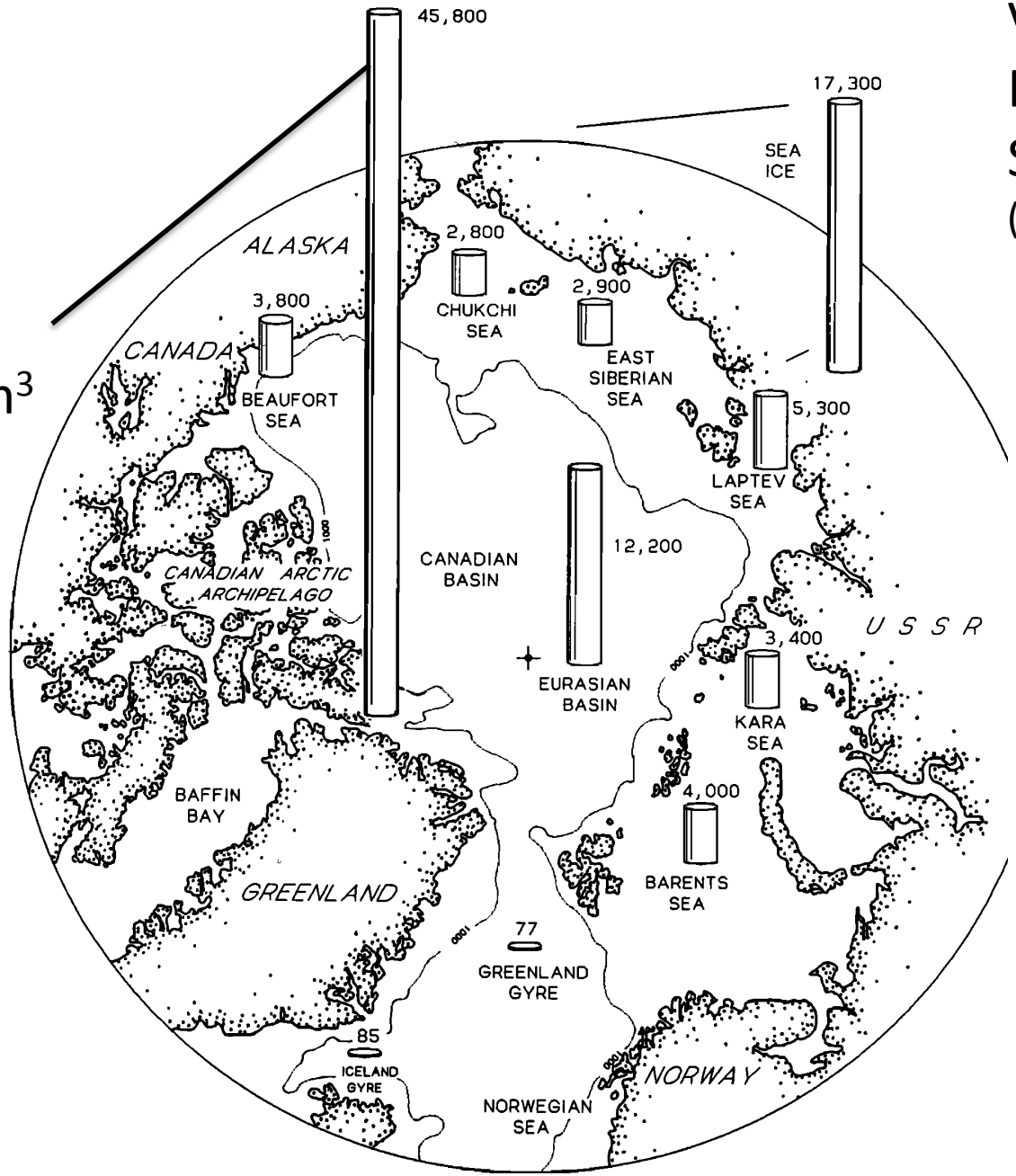


Fig. 3. Mean annual runoff to the Arctic Ocean in cubic kilometers per year. Only the nine largest rivers are shown.

Aagaard and Carmack (1989)

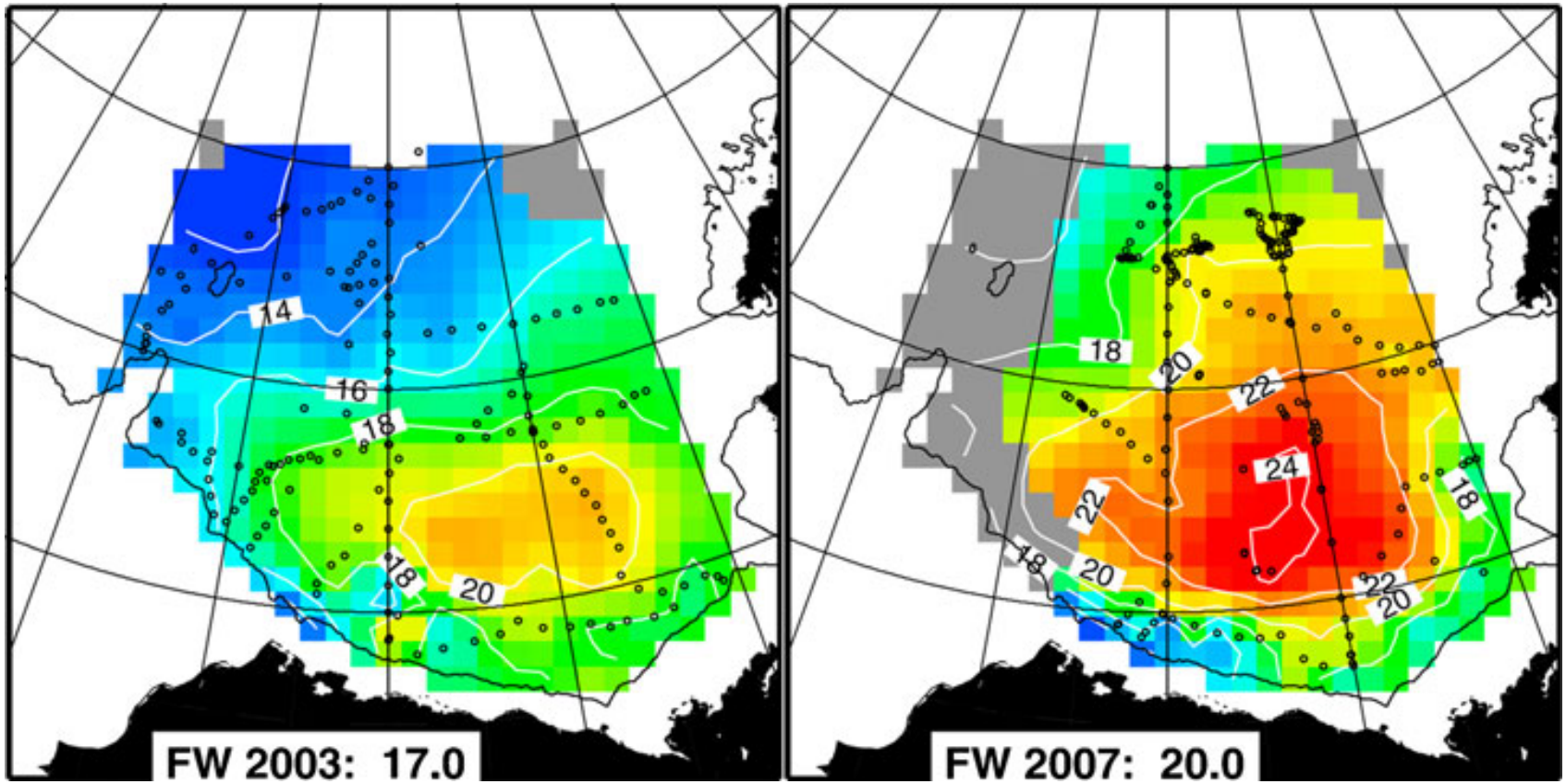
Beaufort Gyre 46,000 km^3

Volume of Freshwater Storage, km^3 (rel. to 34.93)



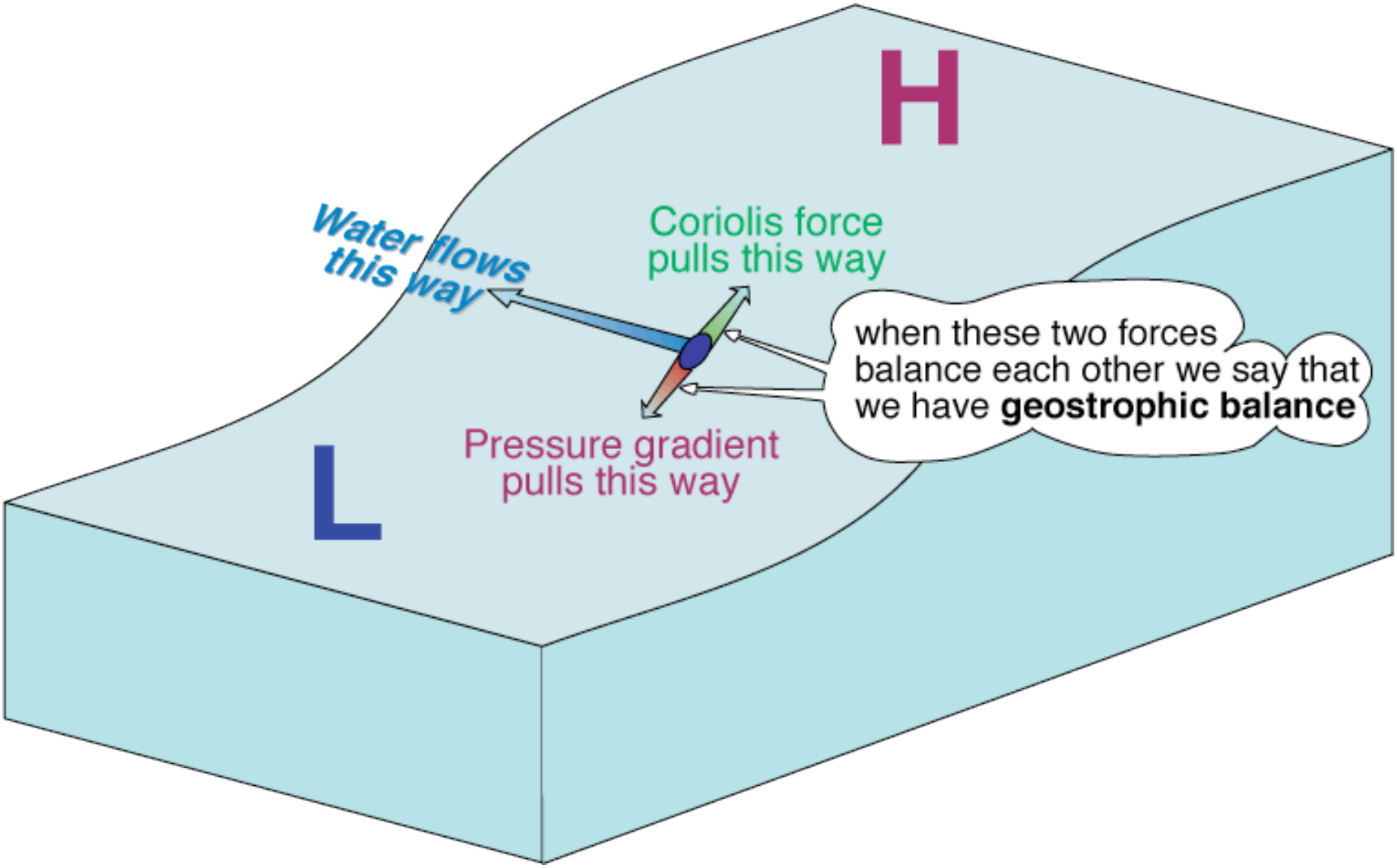
Aagaard and Carmack (1989)

Freshwater Content in Canada Basin (m)

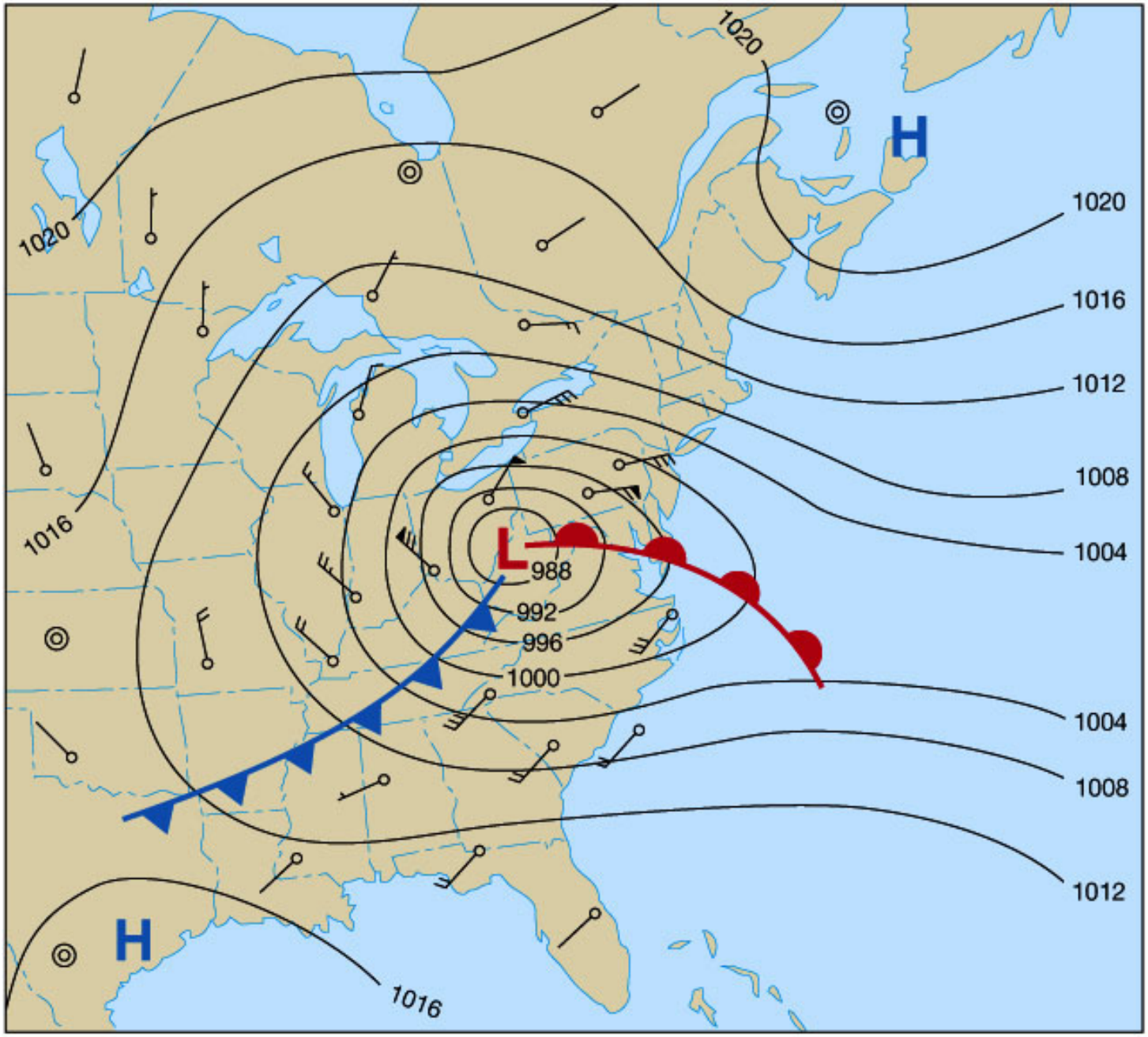


Proshutinsky et al. (2009)

Geostrophic Balance – Without Freshwater



http://www.seos-project.eu/modules/oceancurrents

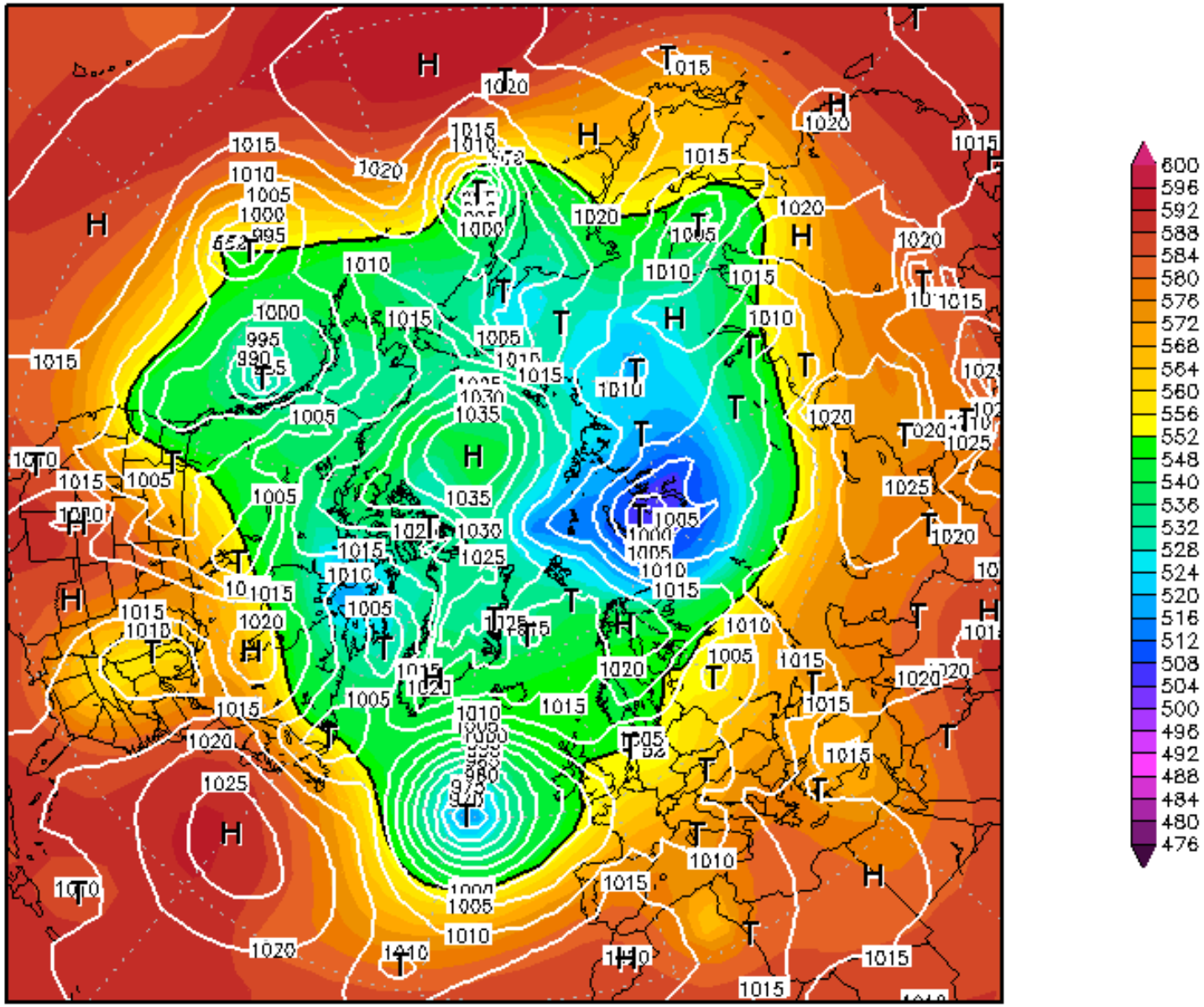


ff	Miles per hour
◎	Calm
	1–2
	3–8
	9–14
	15–20
	21–25
	26–31
	32–37
	38–43
	44–49
	50–54
	55–60
	61–66
	67–71
	72–77
	78–83
	84–89
	119–123

http://www.ux1.eiu.edu/~cfjps/1400/pressure_wind.html

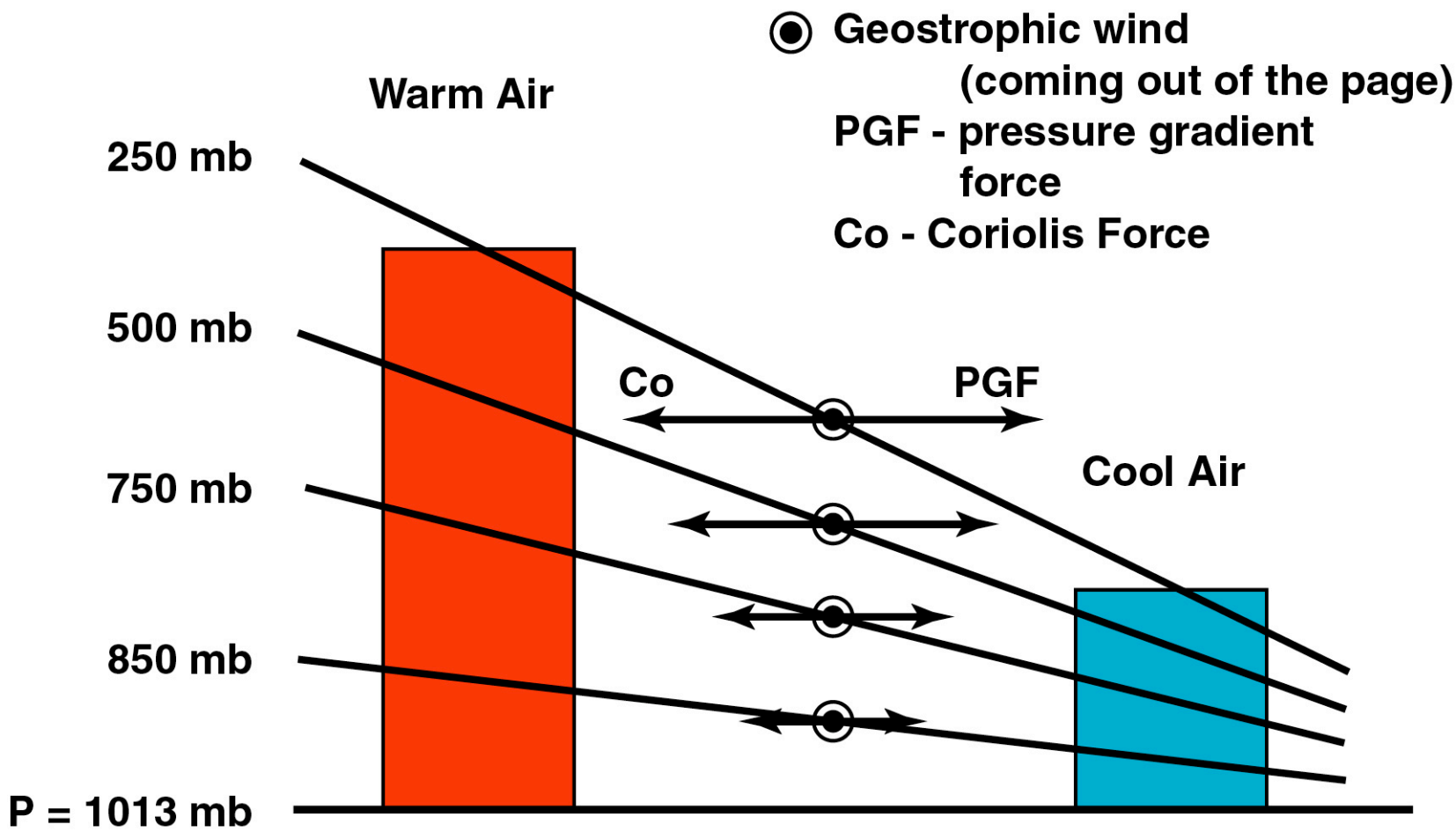
Init : Tue,14OCT2014 12Z Valid: Wed,15OCT2014 12Z

500 hPa Geopot. (gpdm) und Bodendruck (hPa)



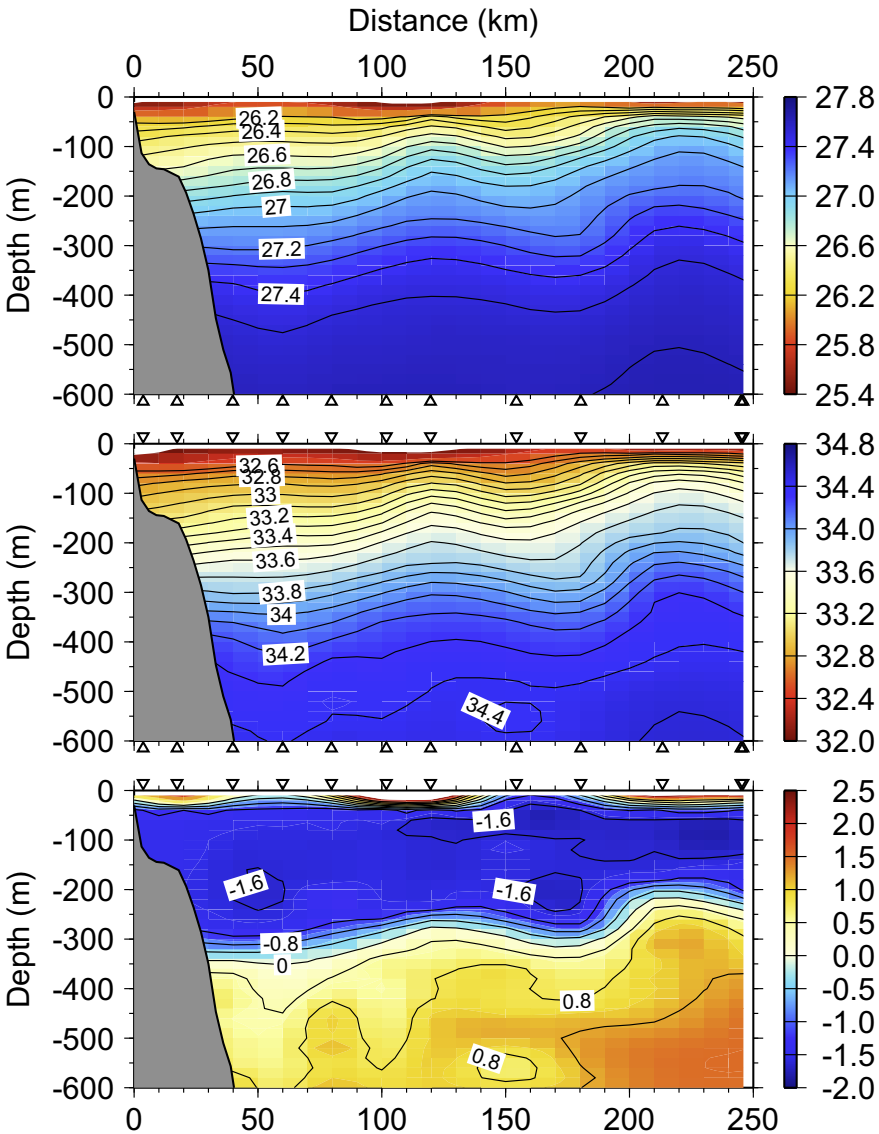
Daten: ECMWF
(C) Wetterzentrale
www.wetterzentrale.de

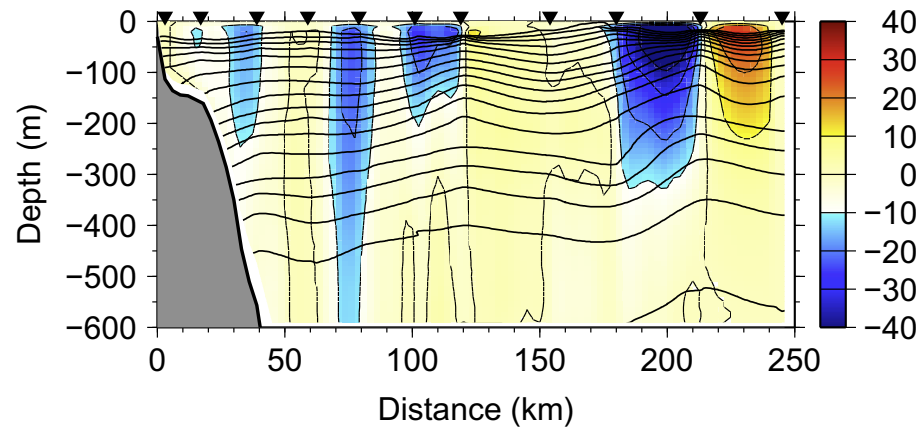
Geostrophic Balance – With Freshwater
(Thermal Wind Balance, Baroclinic Shear)



http://www.ux1.eiu.edu/~cfjps/1400/pressure_wind.html

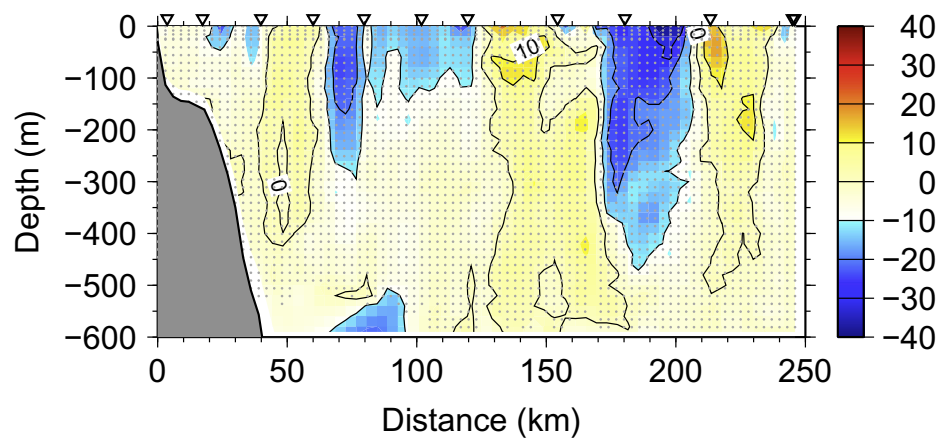
Thermal Wind, Ocean Example: Baffin Island Current





Thermal Wind

ADCP Measured Flow



Muenchow et al, 2014)