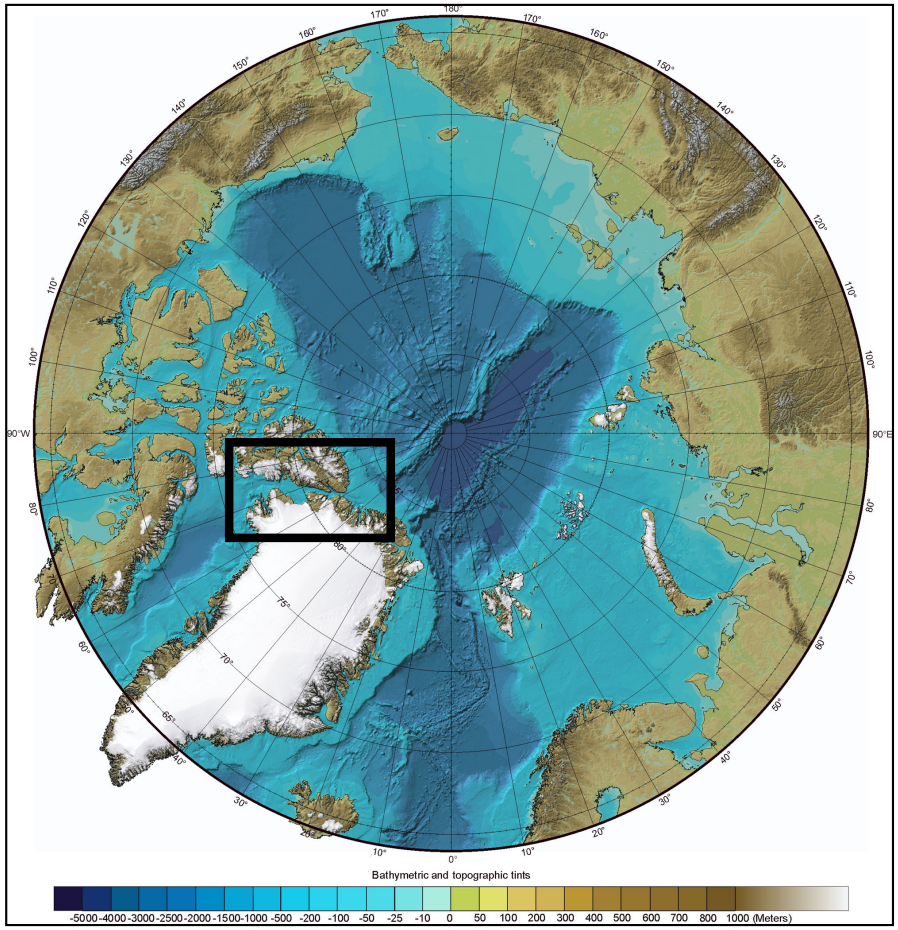
Observed Volume and Freshwater Flux to the West of Greenland *2003-12*

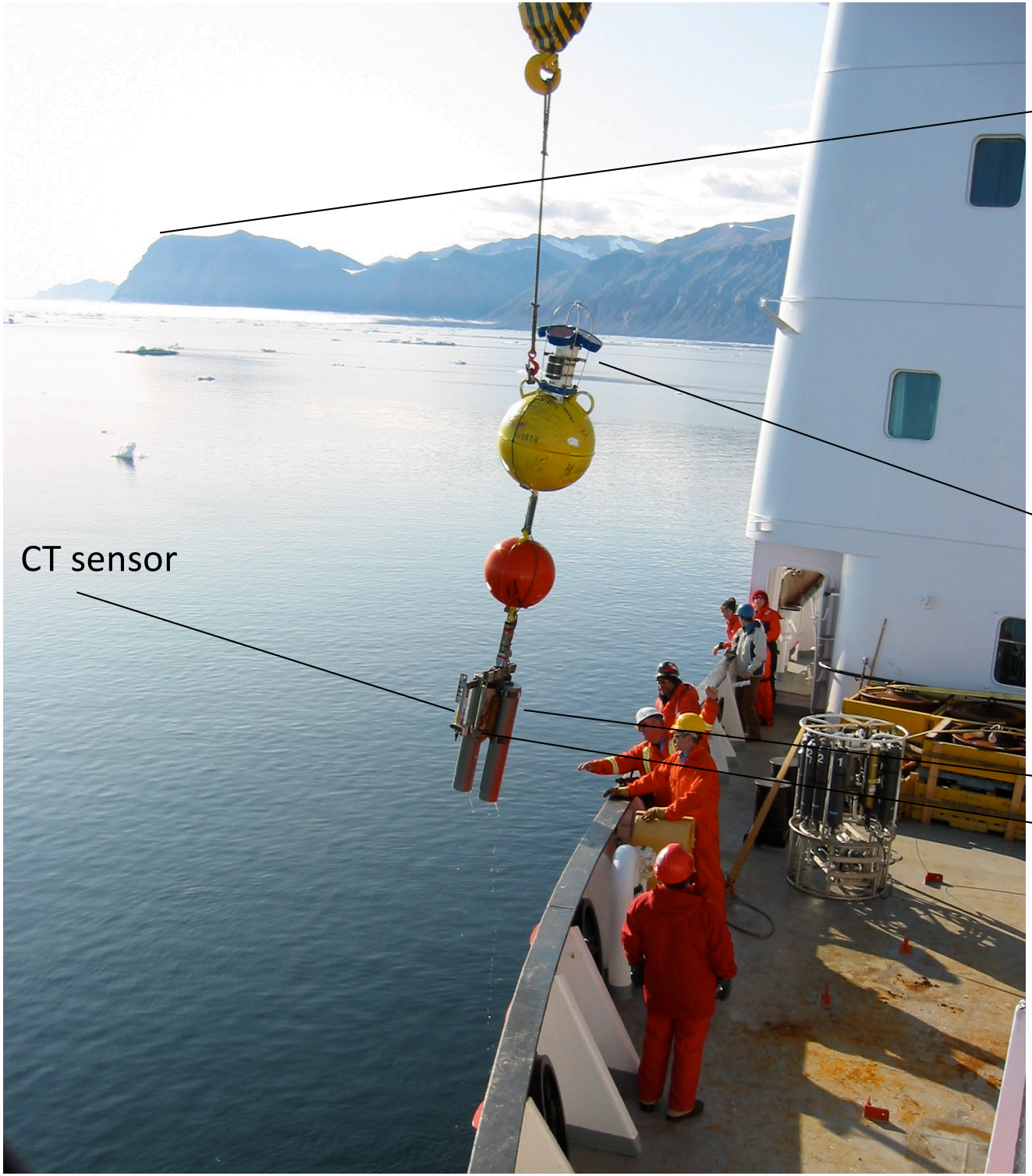
Andreas Műnchow, University of Delaware

http://muenchow.cms.udel.edu/
http://IcySeas.org



1. Introduction: Surveys 1876-2003
2. Nares Strait Moorings 2003-20012
3. Nares Strait Ocean Flux and Dynamics
4. Ice Arches, Land-fast Ice

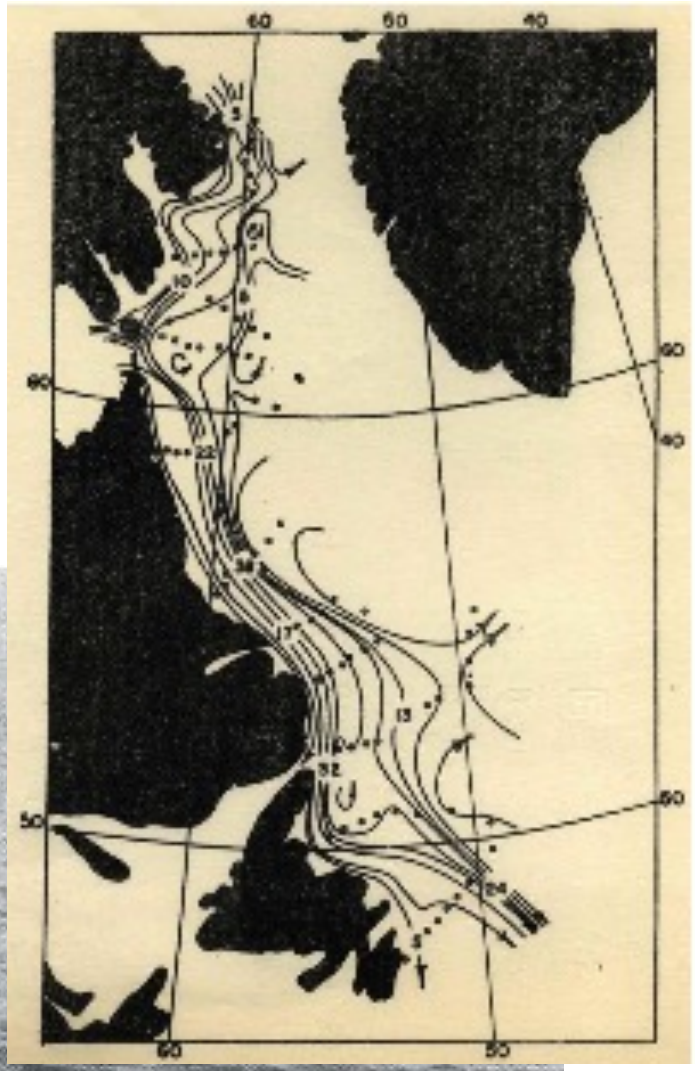
Past Nares Strait Collaborators:
Humfrey Melling (Canada), Helen Johnson (England), Kelly Falkner (Oregon), Berit Rabe (Scotland), Helga Huntley and Pat Ryan (Del.)

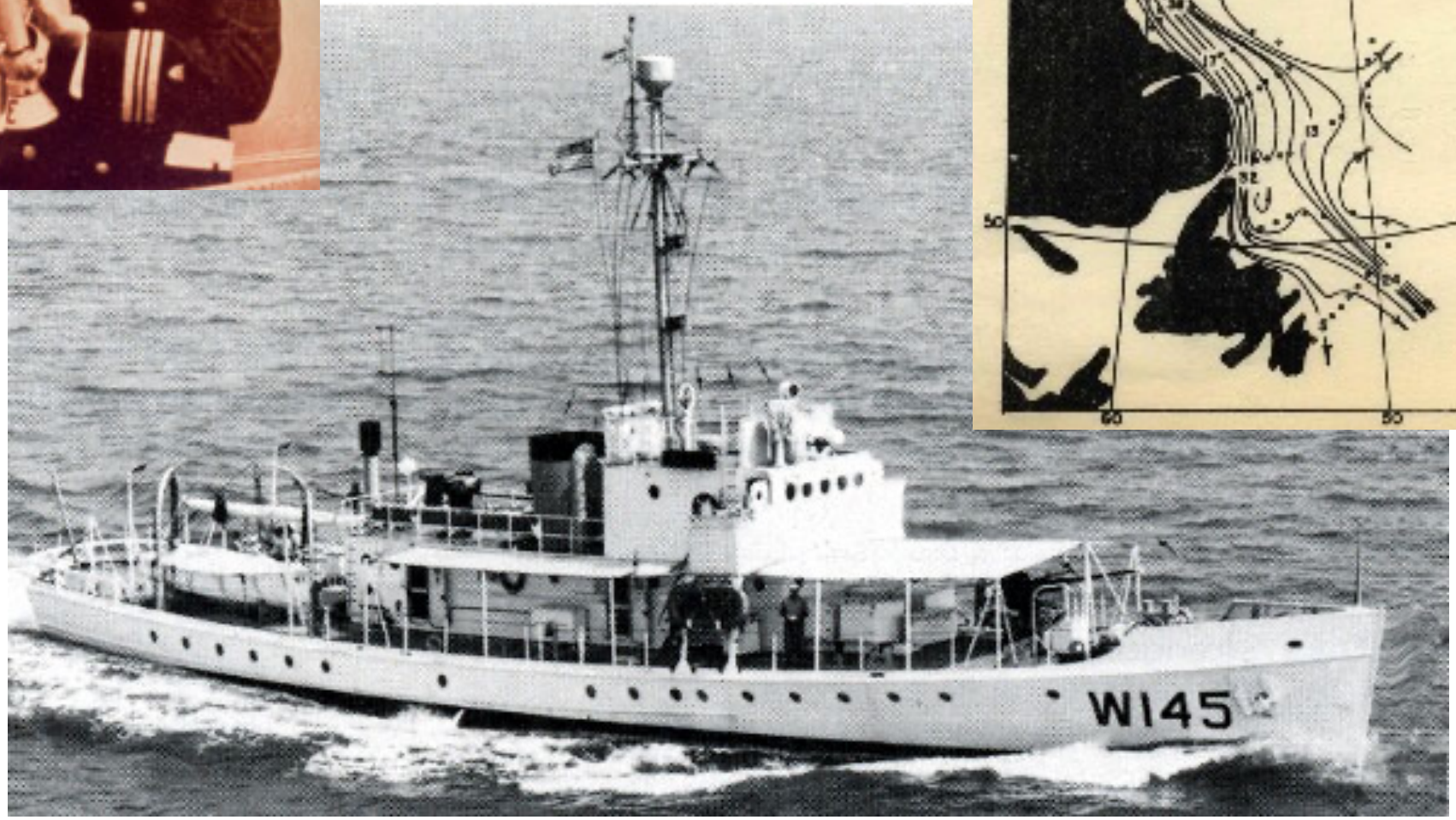

Cape Wilkes,
Ellesmere Island,
~ 70 km south
CT sensor
ADCP transducers
Battery packs (3 years)
Acoustic releases (2)

1928 Marion Expedition

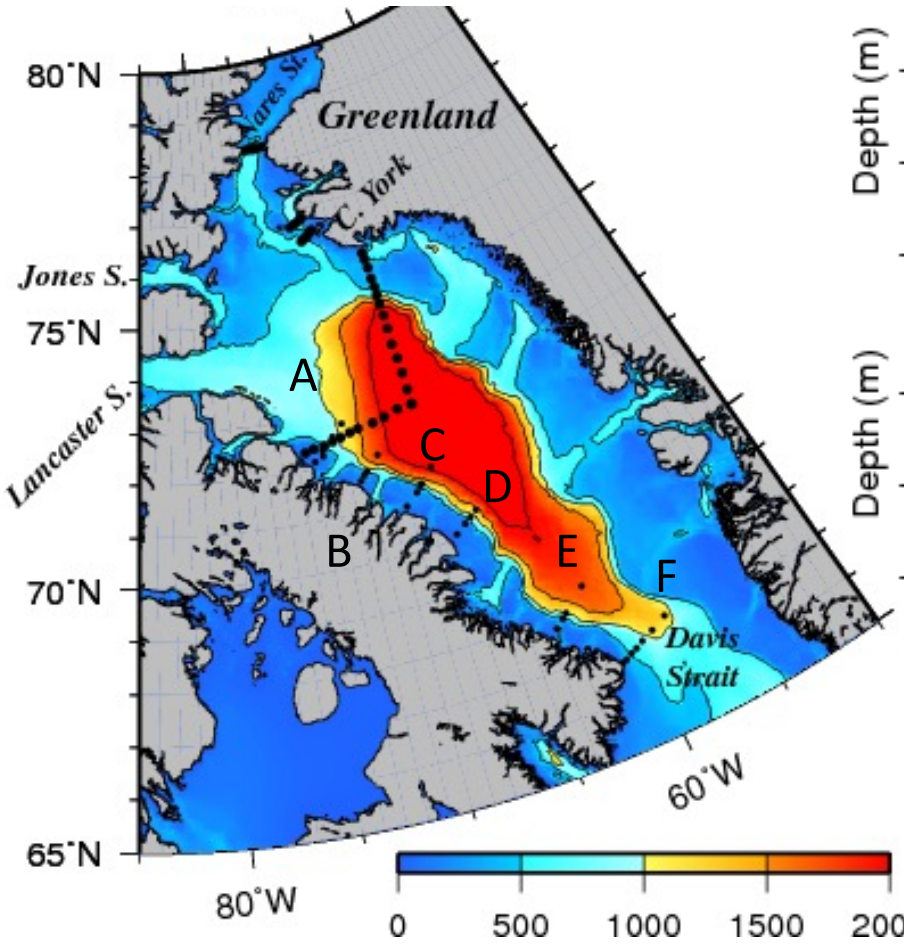
Labrador Shelf Current

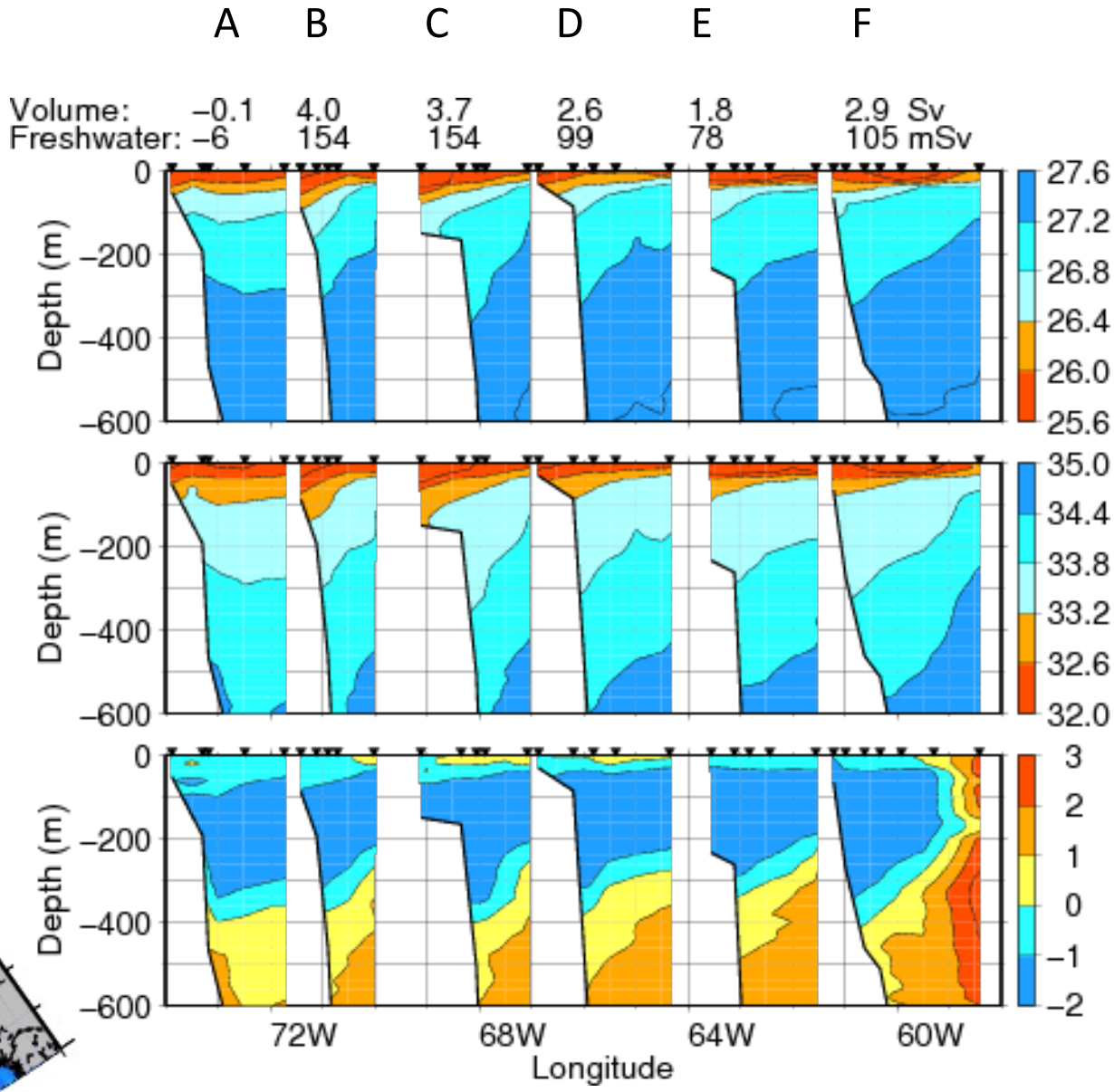
Smith (1931)



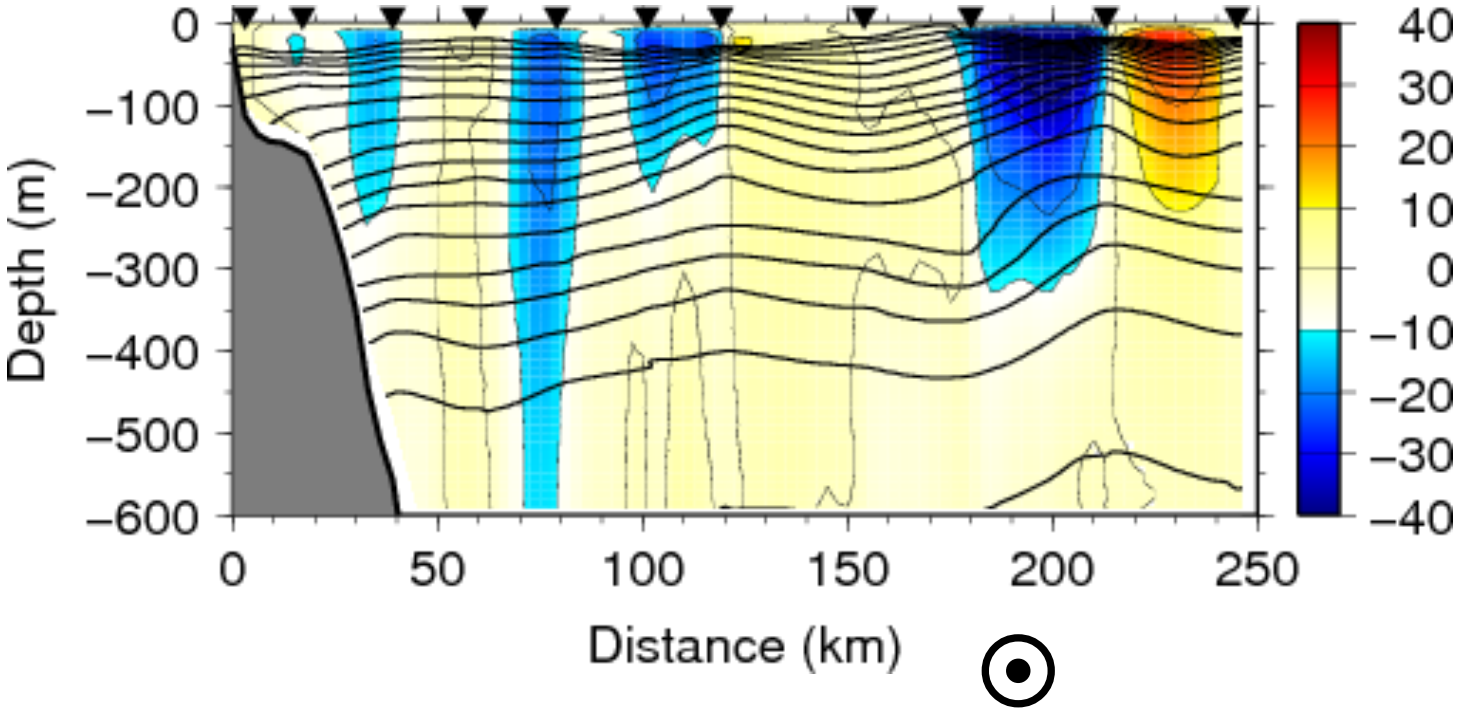


1979 Baffin Island CTD Survey
Geostrophic Flux Estimates

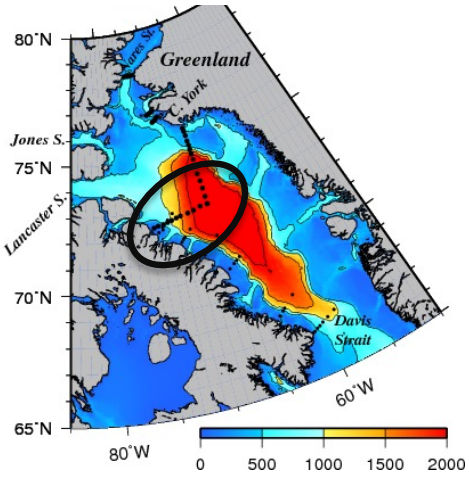


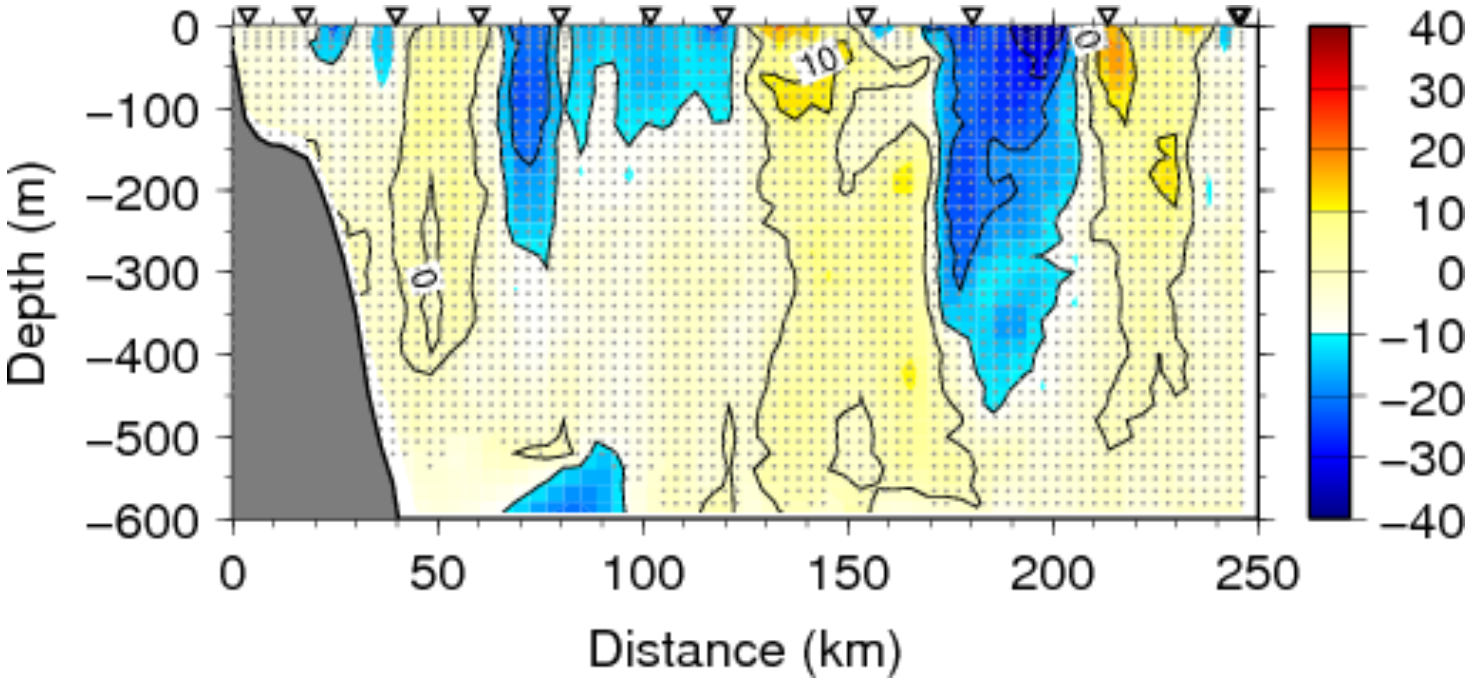


From Muenchow et al. (2013)



Geostrophic Velocity
From CTD section



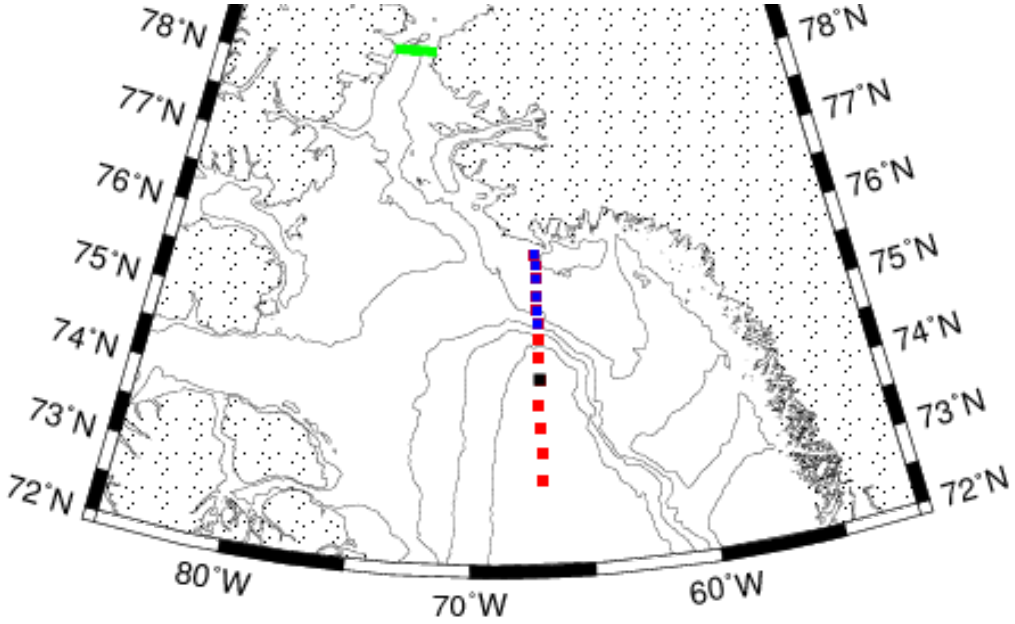


Measured Velocity
From ship ADCP

5.1 +/- 0.2 Sv

187 +/- 30 mSv

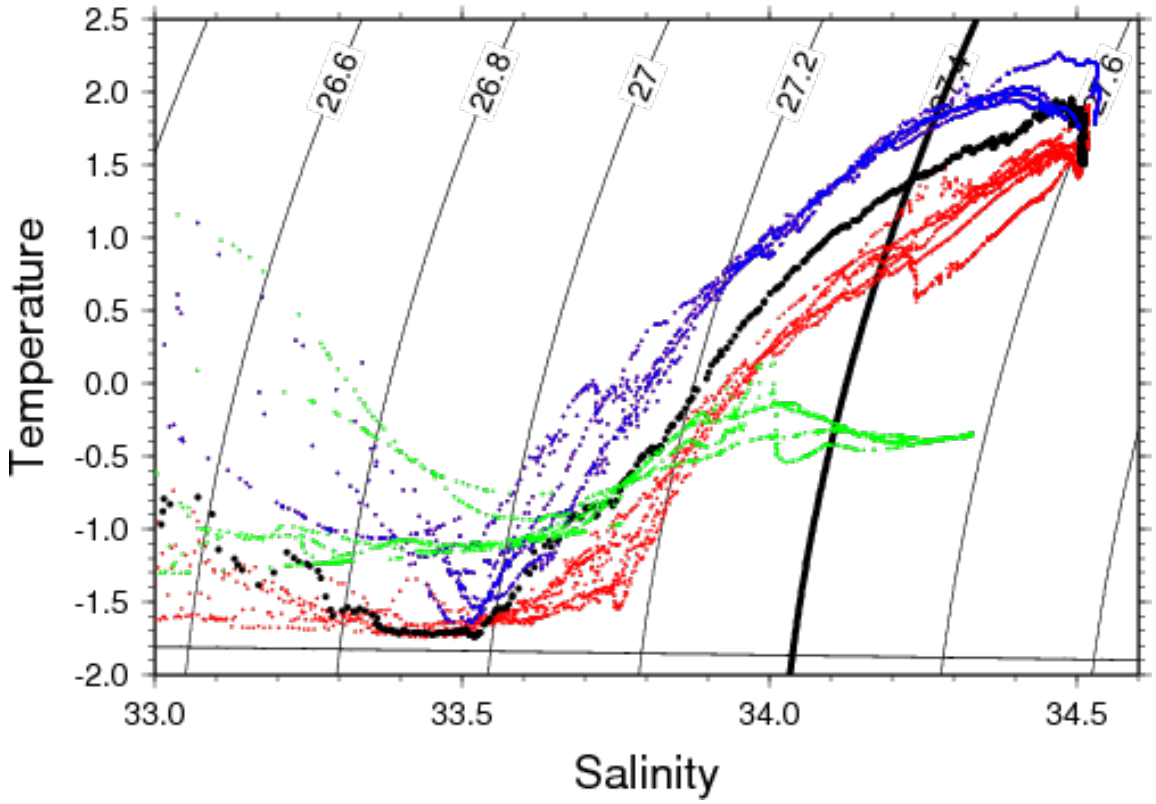
From Muenchow et al. (2015)



Nares Strait

West-Greenland Shelf

West Greenland Slope and Basin



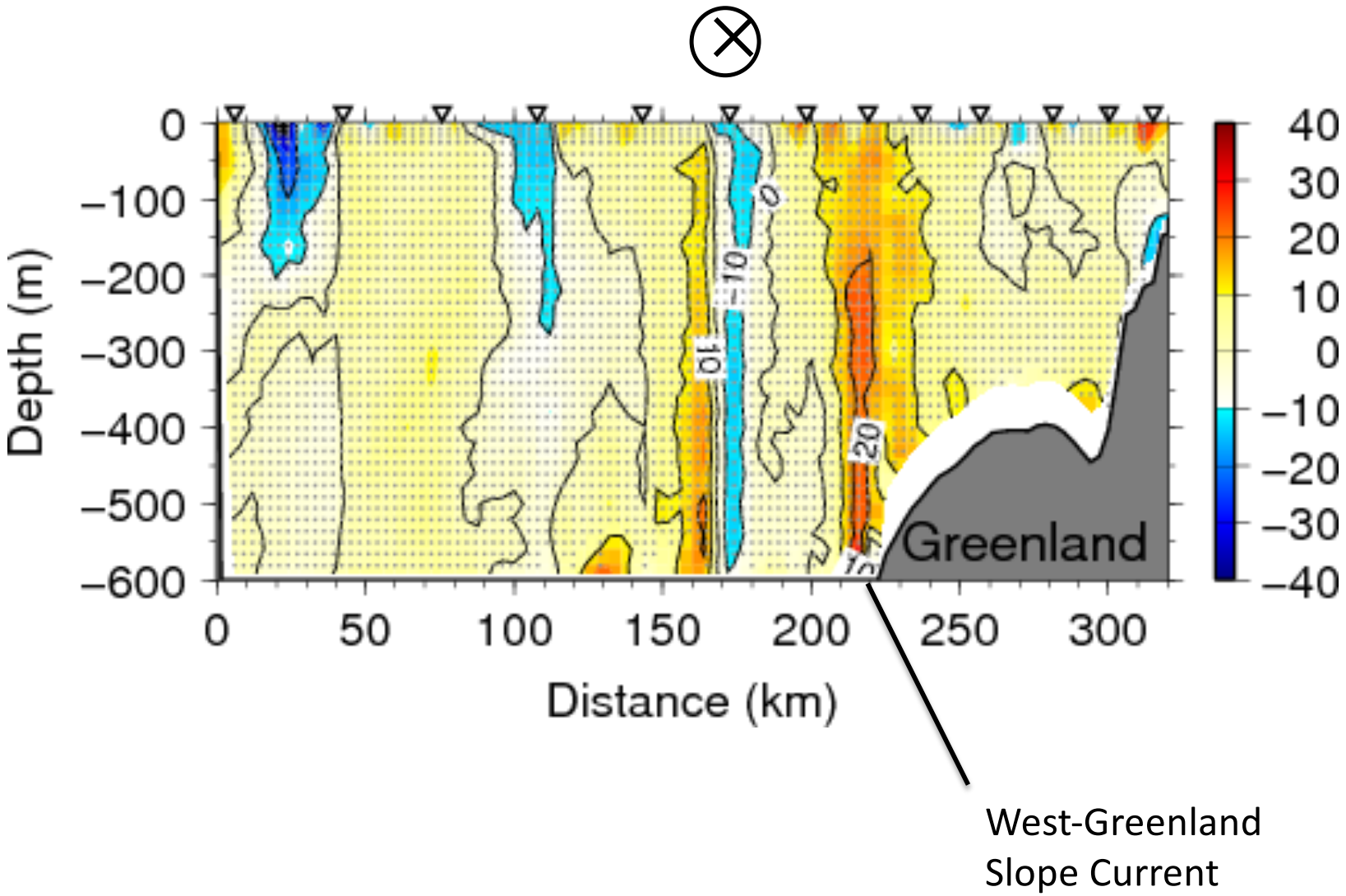
West-Greenland Shelf

West Greenland Slope and Basin

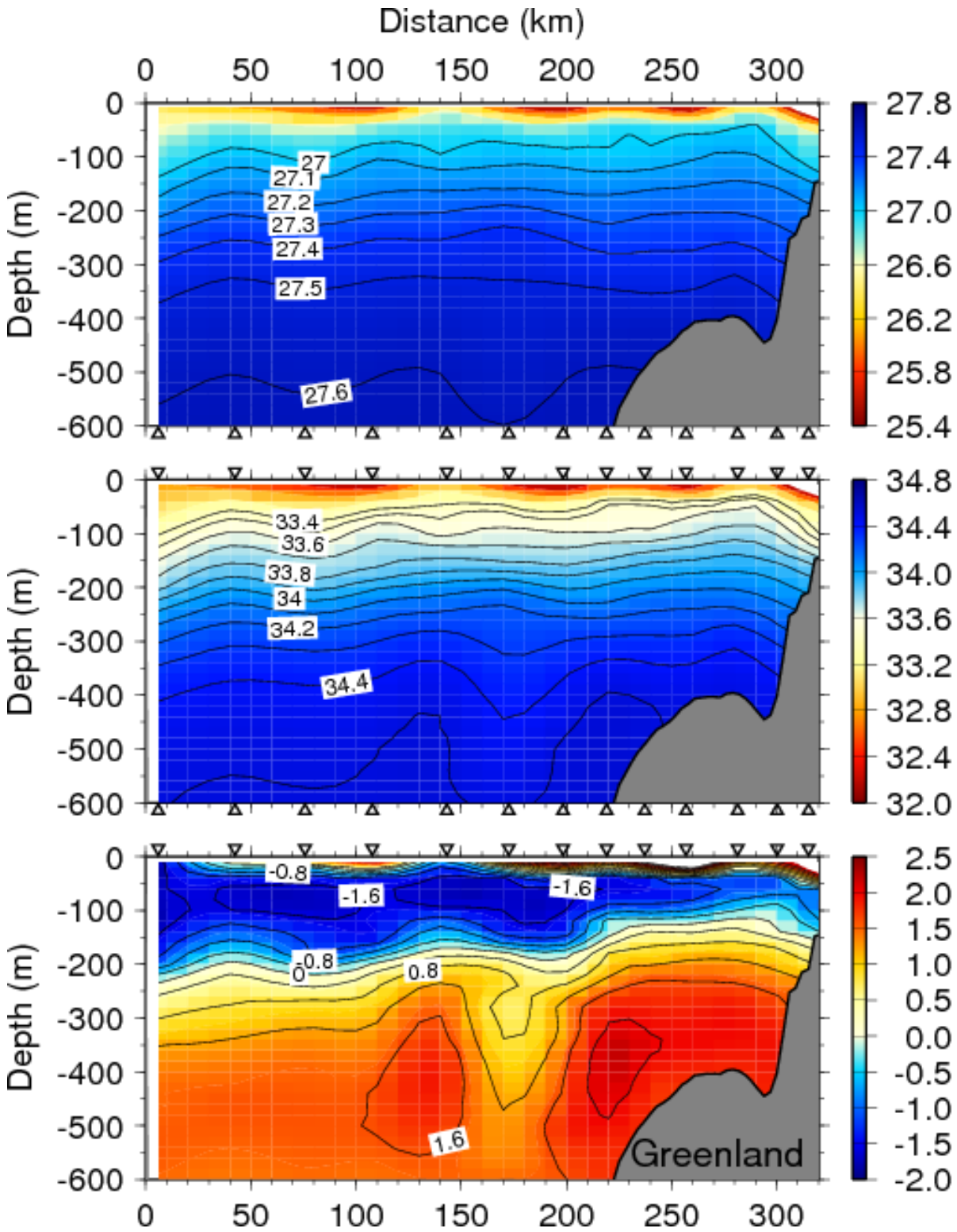
Nares Strait

From Muenchow et al. (2015)

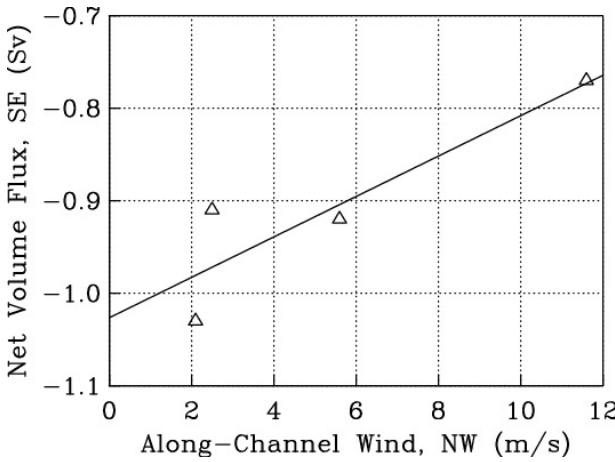
West-Greenland vmADCP section



From Muenchow et al. (2015)


Distance (km)
0
50
100
150
200
250
300
Depth (m)
0
-100
-200
-300
-400
-500
-600
27
27.1
27.2
27.3
27.4
27.5
27.6
27.8
27.4
27.0
26.6
26.2
25.8
25.4
33.4
33.6
33.8
34
34.2
34.4
34.8
34.4
34.0
33.6
33.2
32.8
32.4
32.0
-0.8
-1.6
-1.6
0
0.8
0.8
1.6
Greenland
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0

Nares Strait Freshwater Flux Experiment



USGGC Healy 2003
vessel-mounted ADCP

-0.77 Sv

-0.92 Sv

-0.91 Sv

-1.03 Sv

0.9±0.10 Sv

Greenland

-3.8 +/- 0.3 Sv

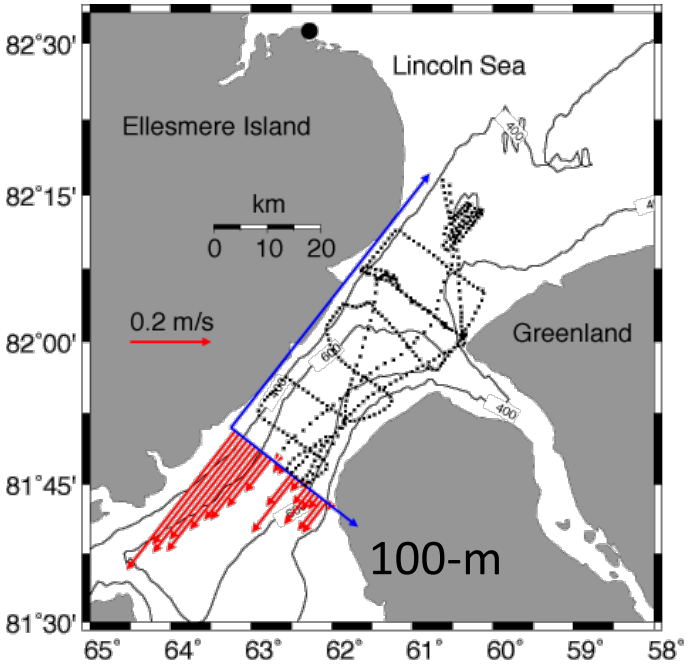
5.1 +/- 0.2 Sv

84°N
82°N
78°N
76°N
74°N
72°N
90°W
80°W
70°W
60°W
50°W

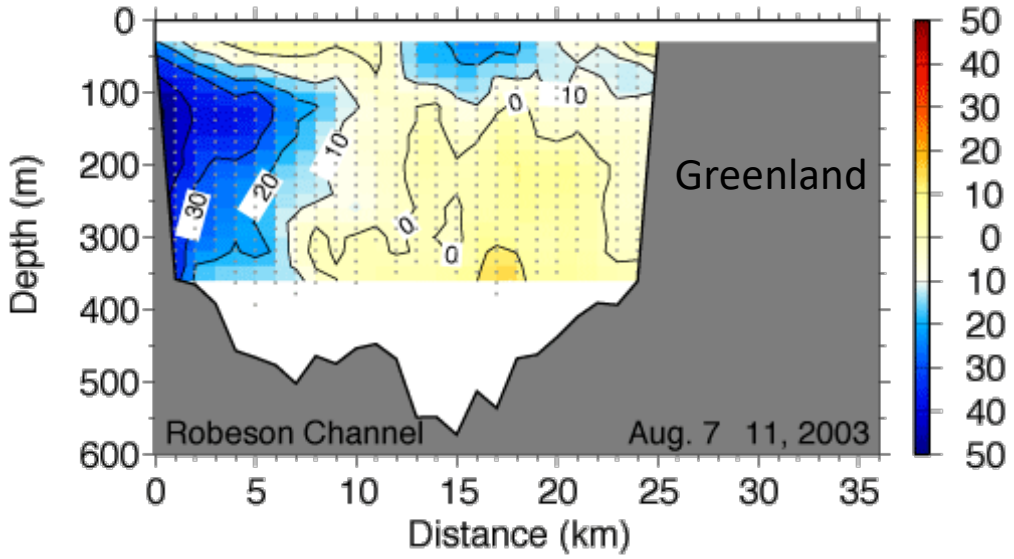
0 250 500 750 1000 1250 1500 1750 2000

Münchow et al. (2007, 2015)

Nares Strait Freshwater Flux Experiment



Velocity Snapshot (4-days) cm/s



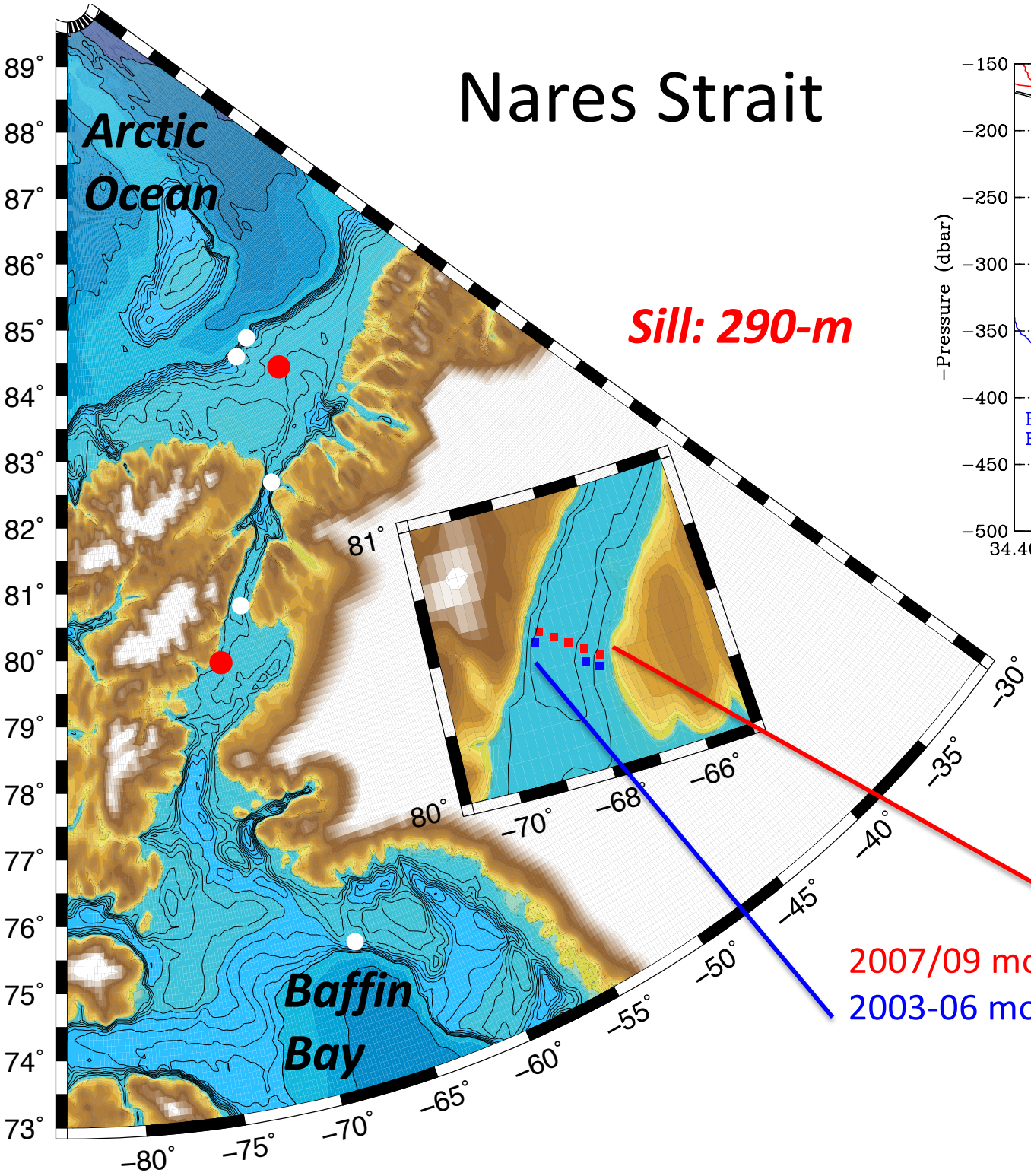
L_D

Volume Flux: $0.77 \pm 0.10 \times 10^6$ m^3/s

Fresh Water Flux: $28 \pm 4 \times 10^6$ m^3/s

from Münchow et al. (2007)

Nares Strait

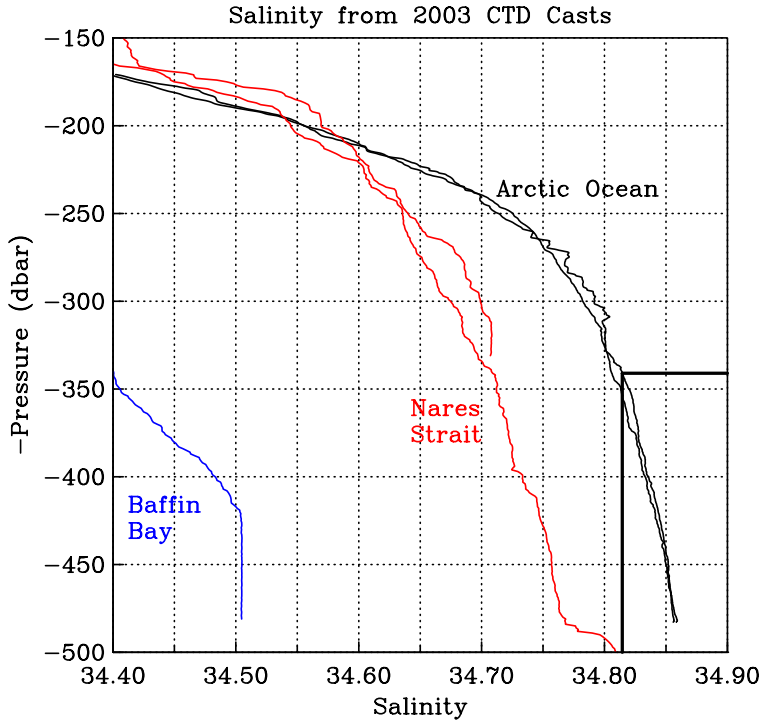


Sill: 290-m

Sill: 225-m

2007/09 moorings

2003-06 moorings



Velocity:

Long-Range Sonars

- Sonars send and receives acoustic waves
- Measured Doppler shift proportional to velocity
- 75 kHz transducers

Rigid Backbone allowed to Pitch and Roll, but NOT Change Heading

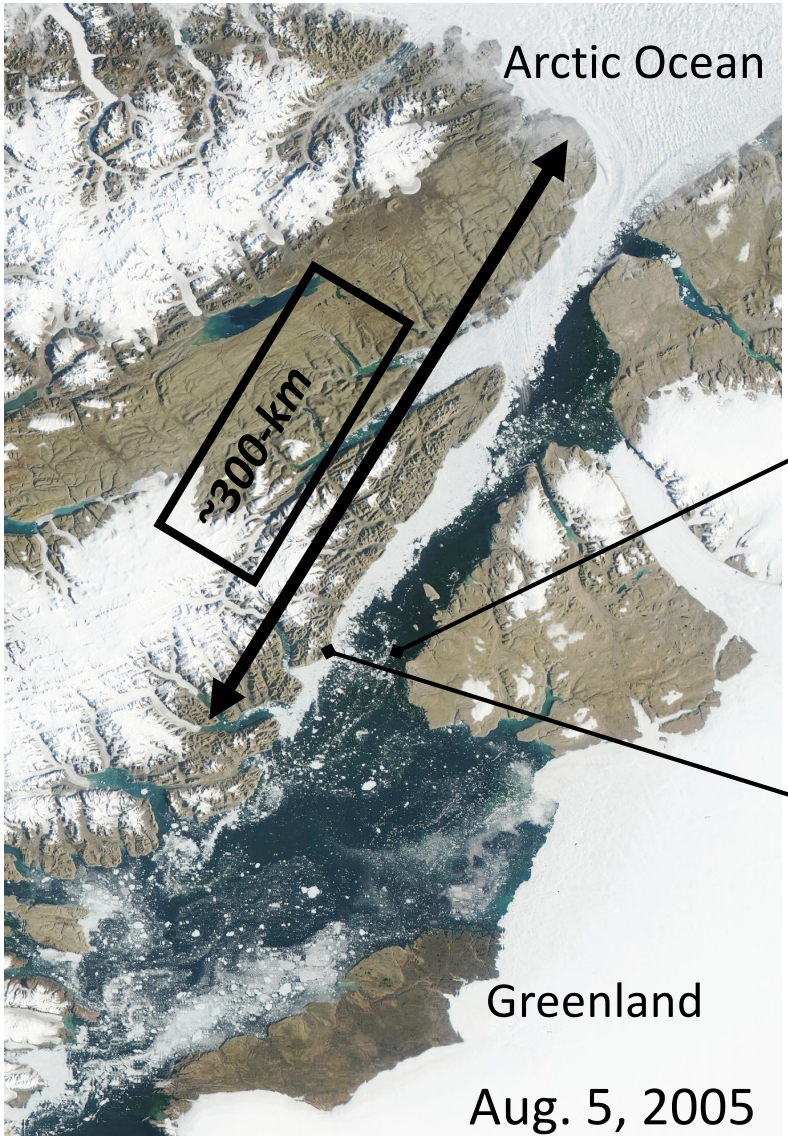
Magnetic Compass unusuable:

Kennedy Channel ~2800 nT
Fram Strait ~ 5800 nT

magnetic field strength

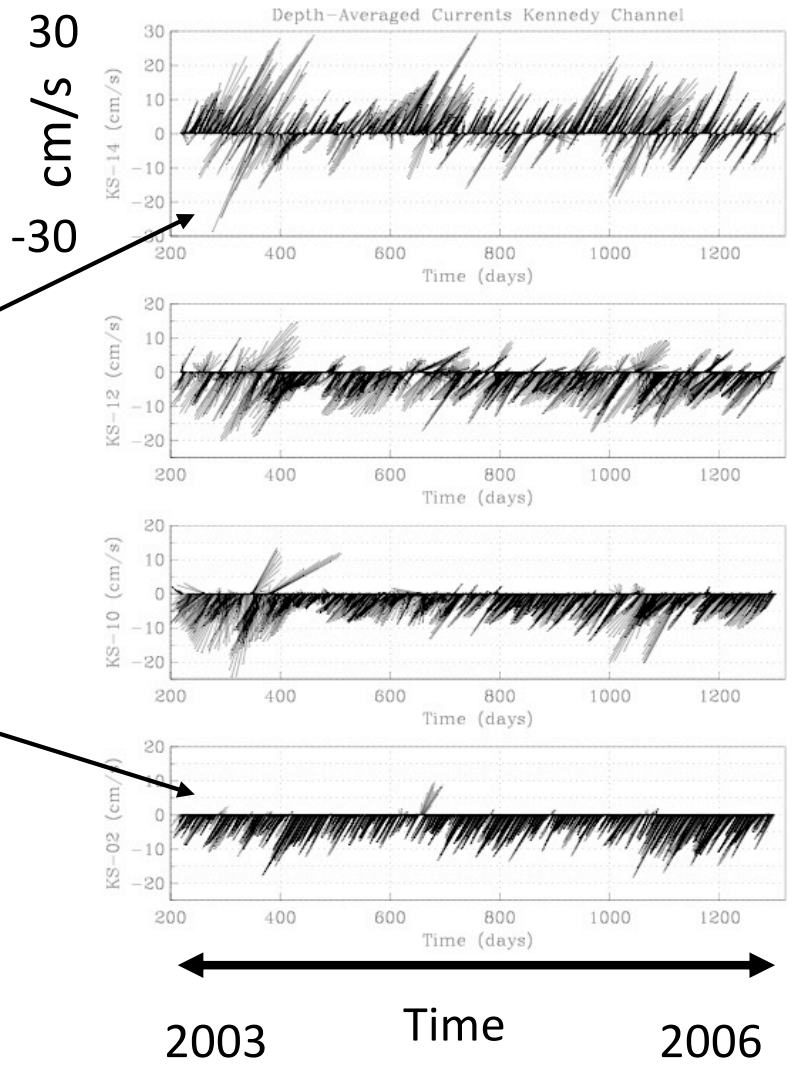
75 kHz ADCP Mooring Deployment from CCGS Henry Larsen

Nares Strait Freshwater Flux Experiment

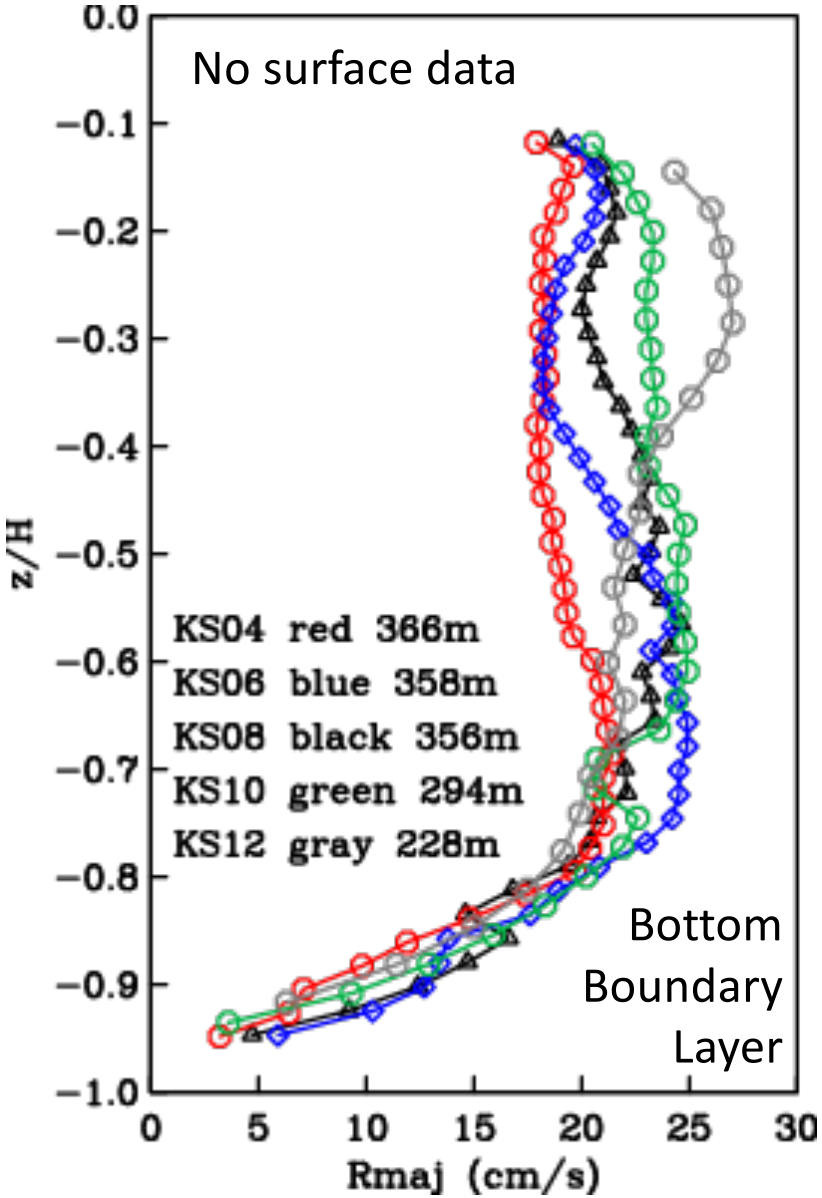


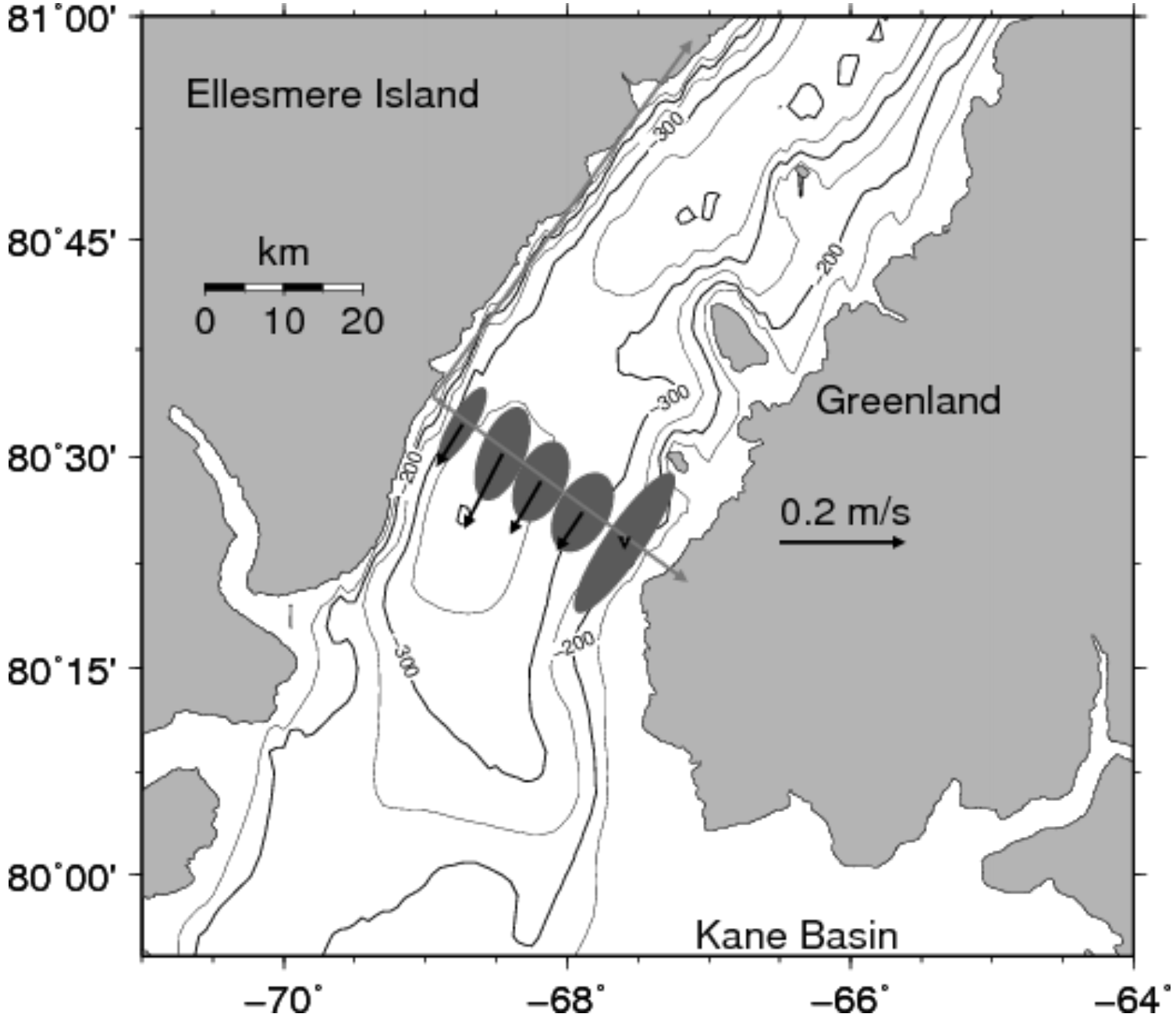
Velocity Time Series (3-years)

Along-Channel Currents, cm/s

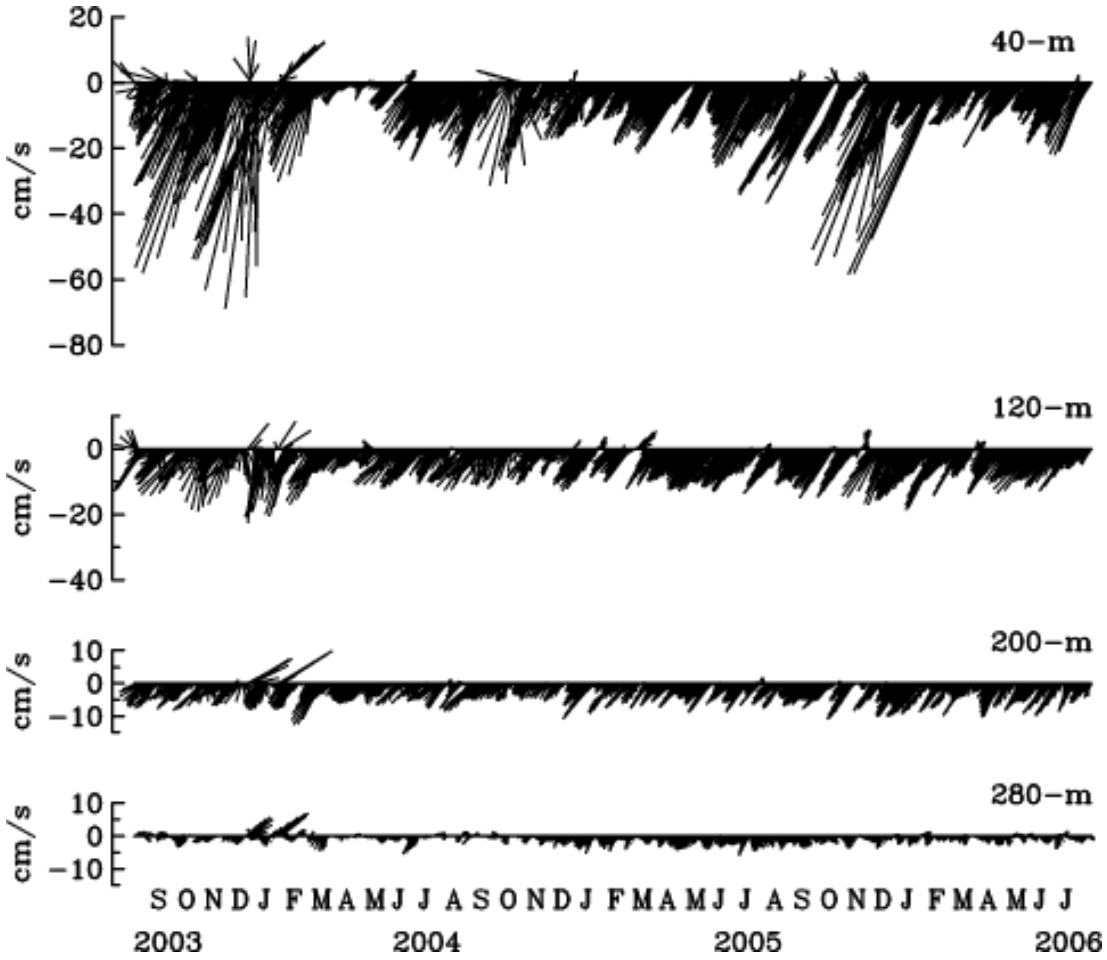


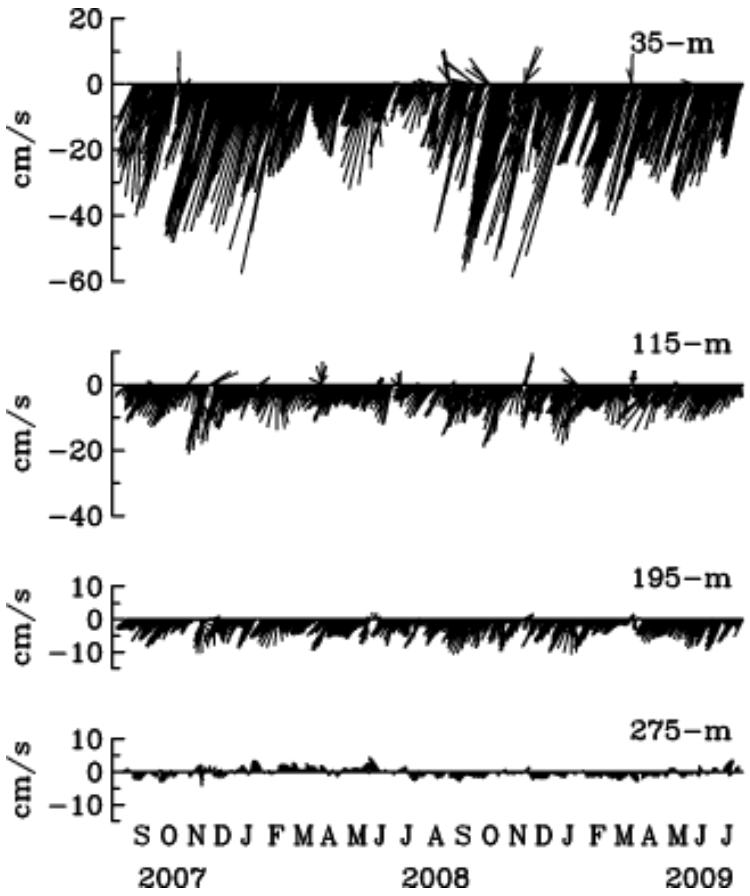
M_2 Tidal Amplitude

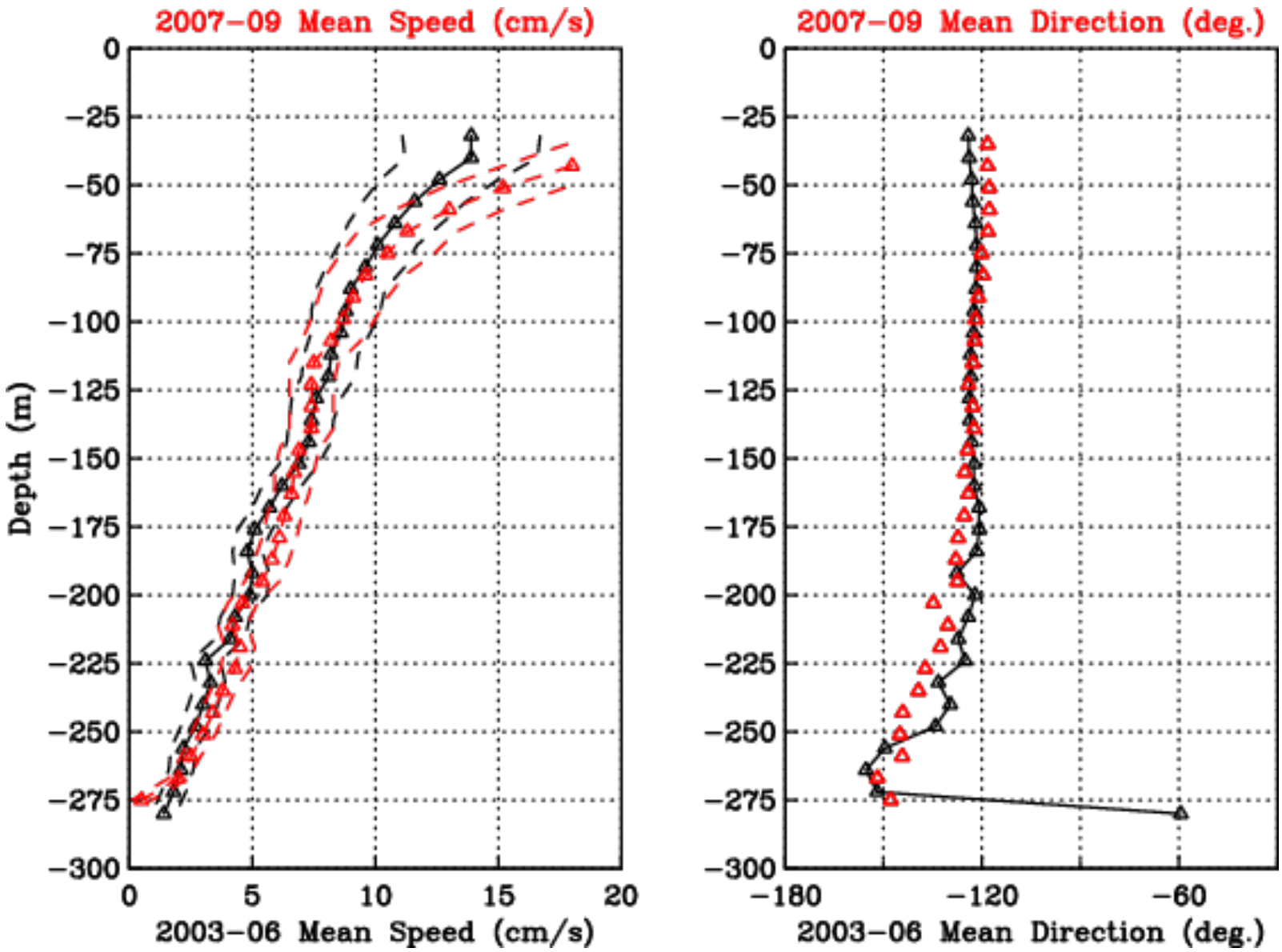



81˚00'
80˚45'
80˚30'
80˚15'
80˚00'
−70˚
−68˚
−66˚
−64˚
Ellesmere Island
Greenland
Kane Basin
km
0 10 20
0.2 m/s
300
200
300
200
300
200

Low-Pass Filtered Current Vectors at Center of Channel



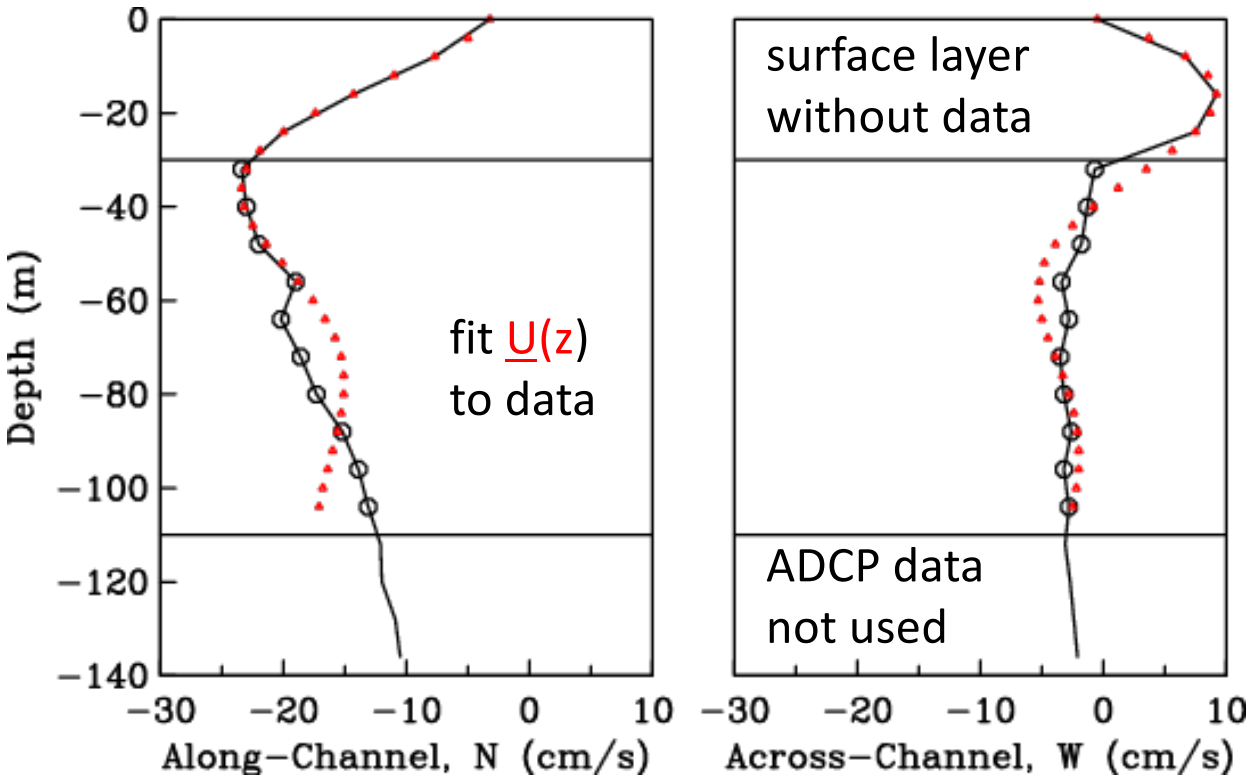




2003-06 Land-fast ice-cover dominant (wind-stress weak)

2007-09 Mobile ice-cover dominant (wind-stress strong)

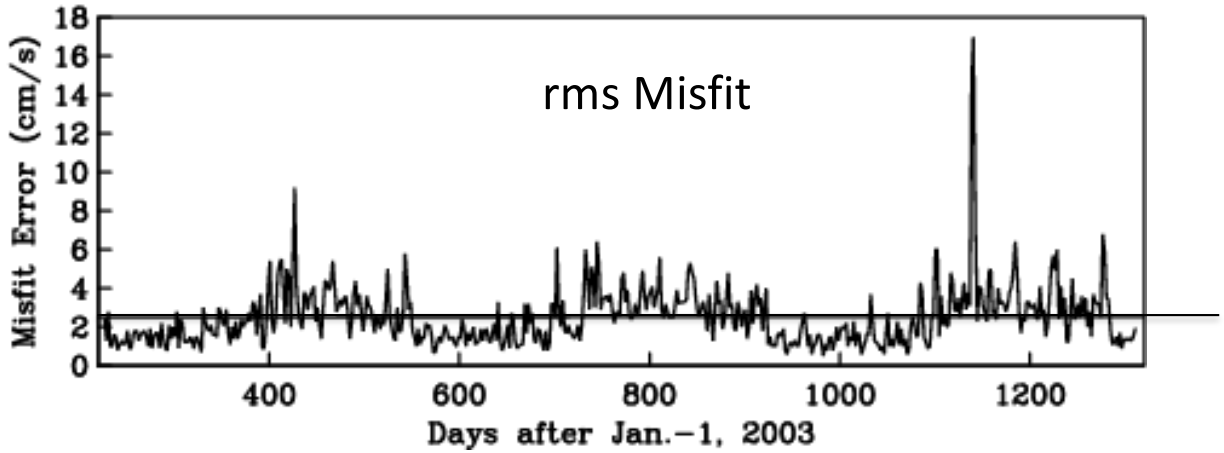
Surface Layer Extrapolation/Interpolation



Least-Square Fit (red)

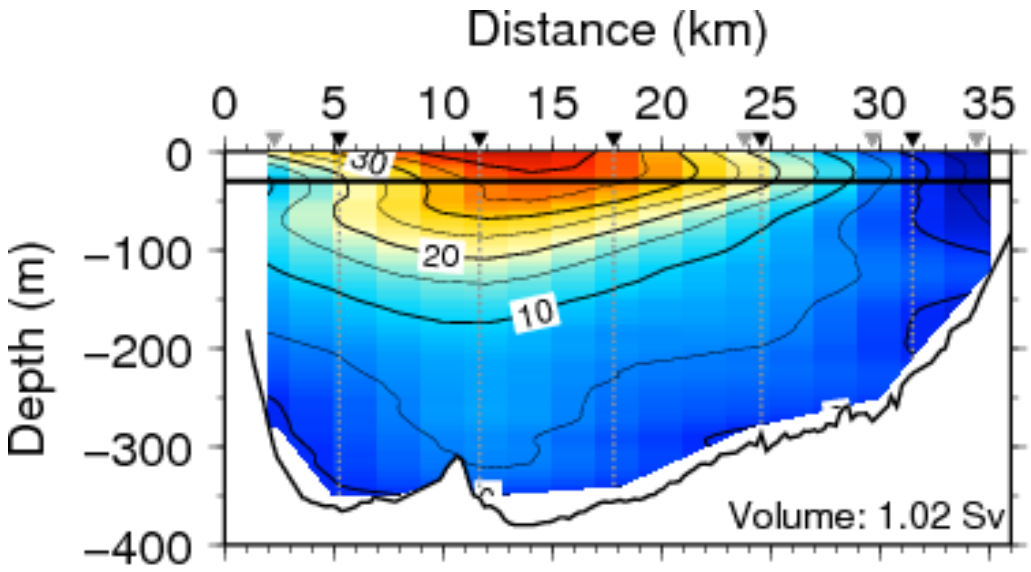
U(z) = const. + linear shear
+ Ekman layer

Data (black circles)

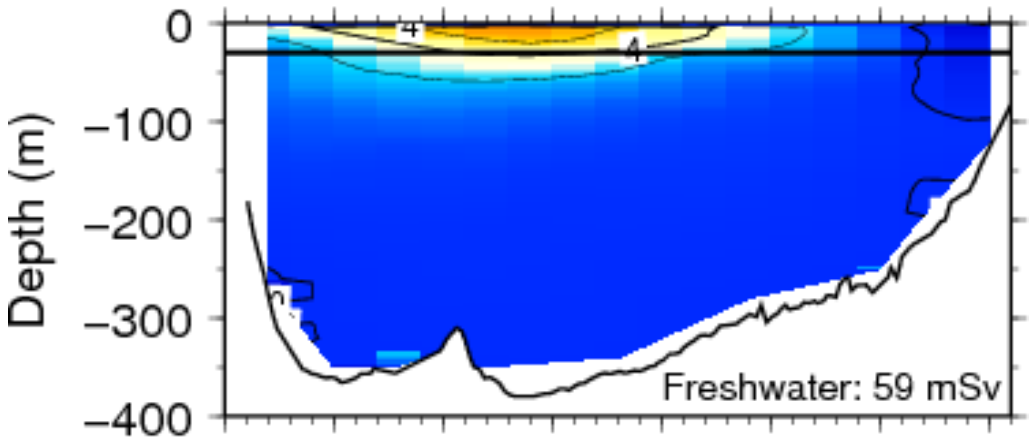


Root mean square Misfit
Data-Fit:

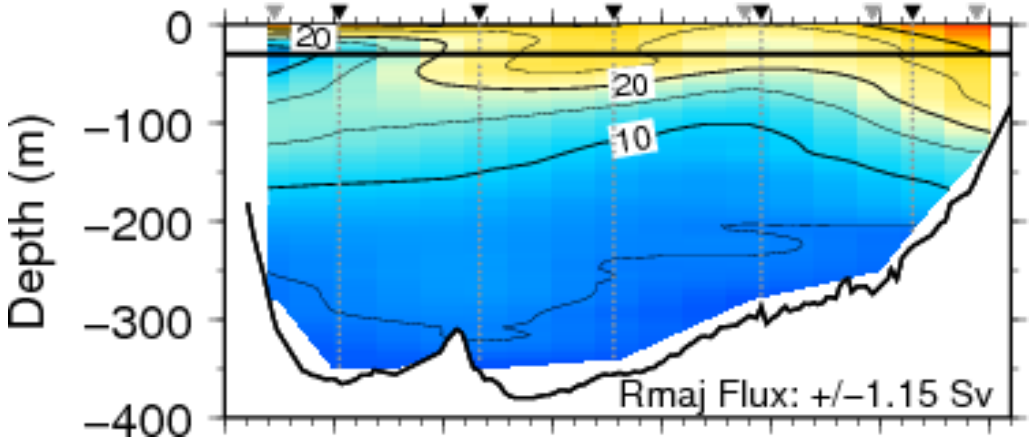
2.3 cm/s average



Mean Along-Channel Velocity (cm/s)

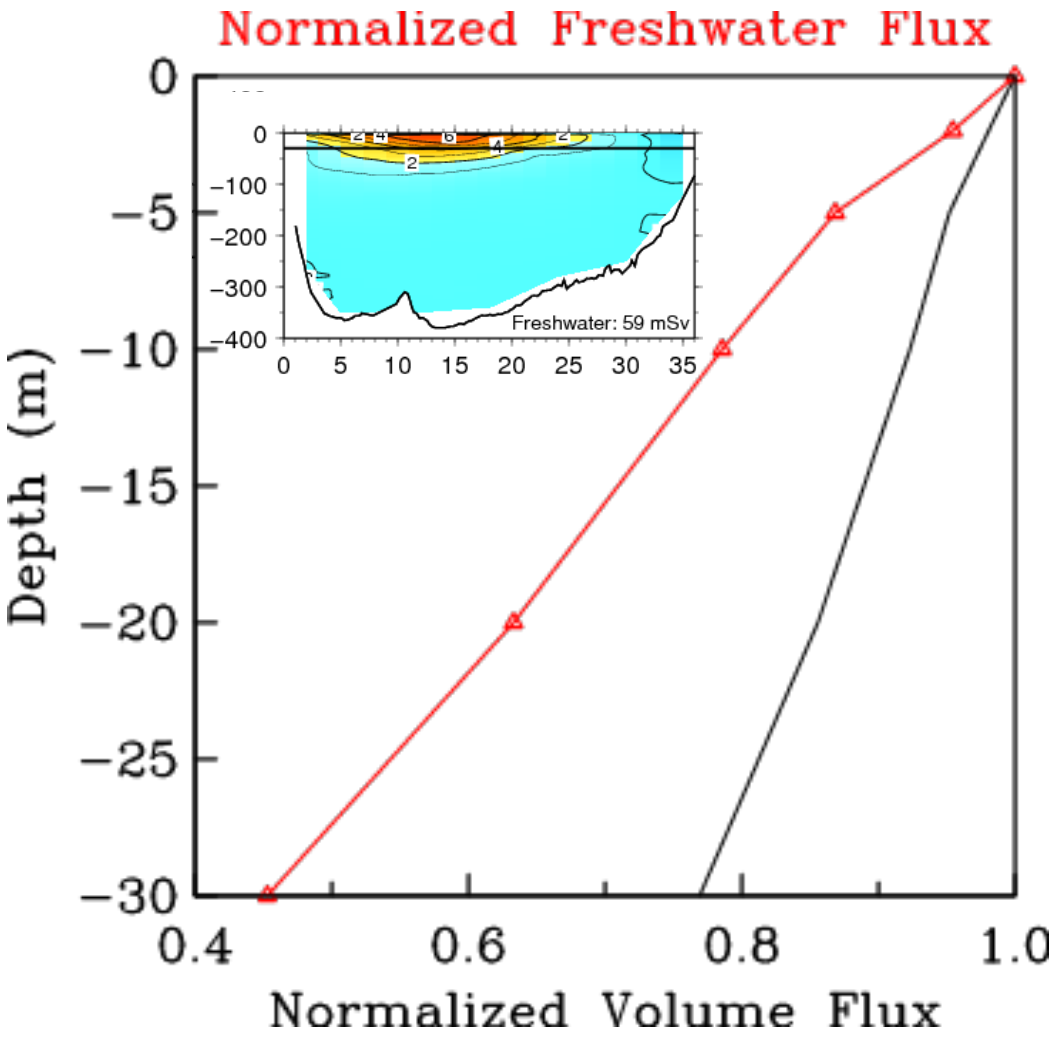


Along-Channel Freshwater Flux (mSv per km per meter rel. to 34.8)



Along-Channel velocity fluctuations (cm/s)

Cummulative Flux Integral scaled by Total Flux:



>50 % of Freshwater Flux

and

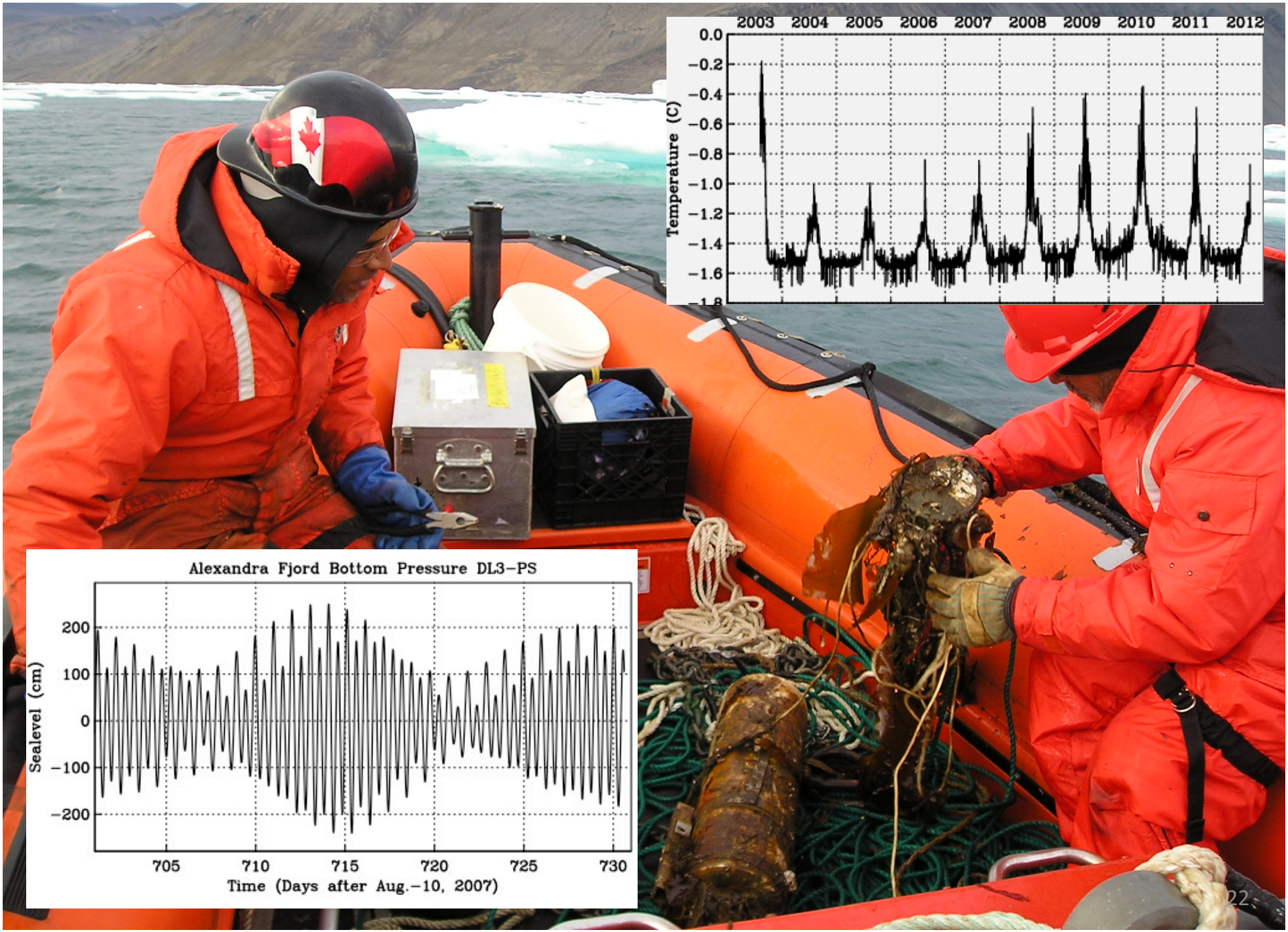
~20 % of Volume Flux

reside in

Top 30-m of Water Column

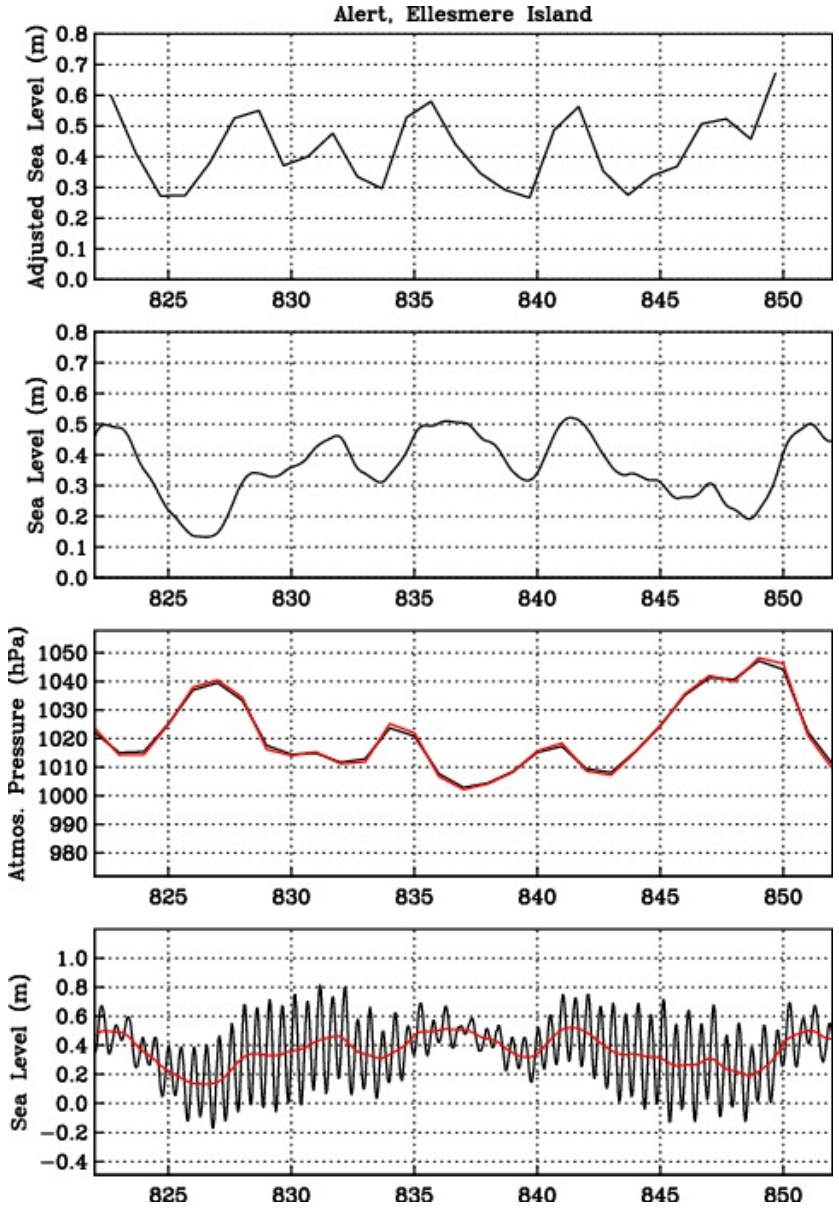
Correlate flux with
along-channel pressure gradient →

Nares Strait Tide Gauges: 9 Year Deployment



Tides and Filters

Alert, northern Ellesmere Island

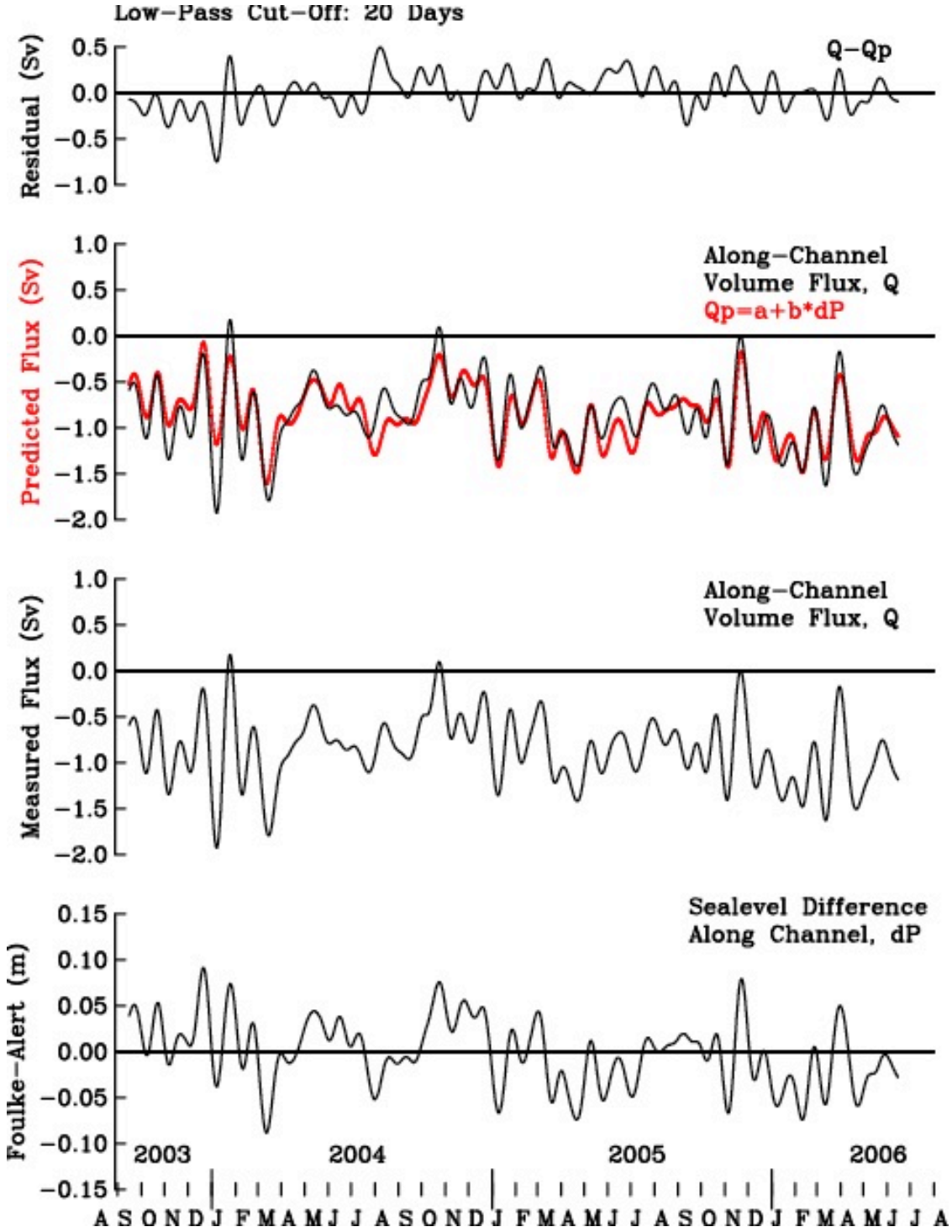


Adjusted sea level

Filtered sea level

Atmospheric pressure

Sea level



Residual root mean square:
0.19 Sv

Correlation: r^2=0.71

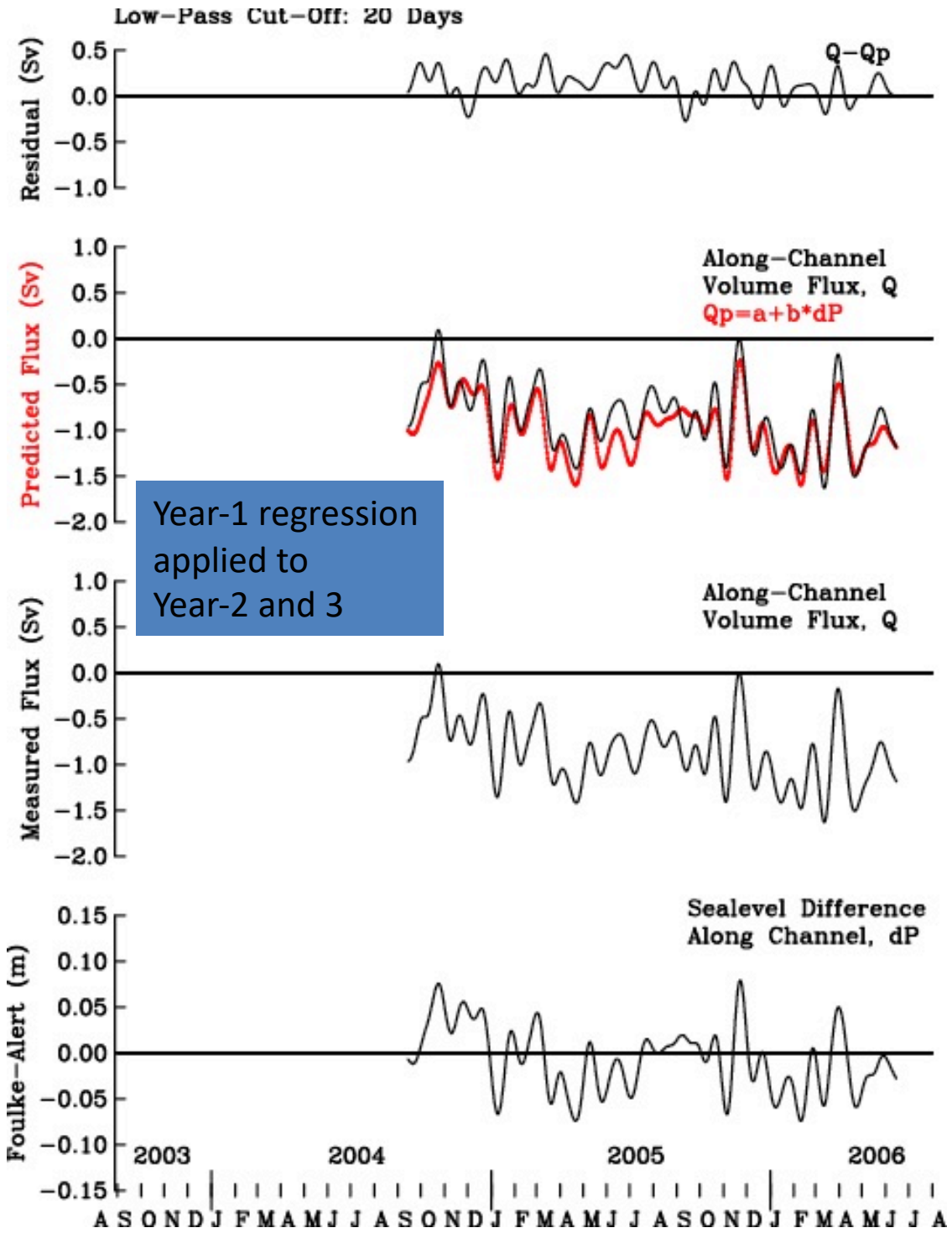
Q_p = a + b*dP

a= -0.84 Sv

b=+8.54 Sv/m

Kliem and Greenberg (2003):
0.5 Sv per 0.1 m

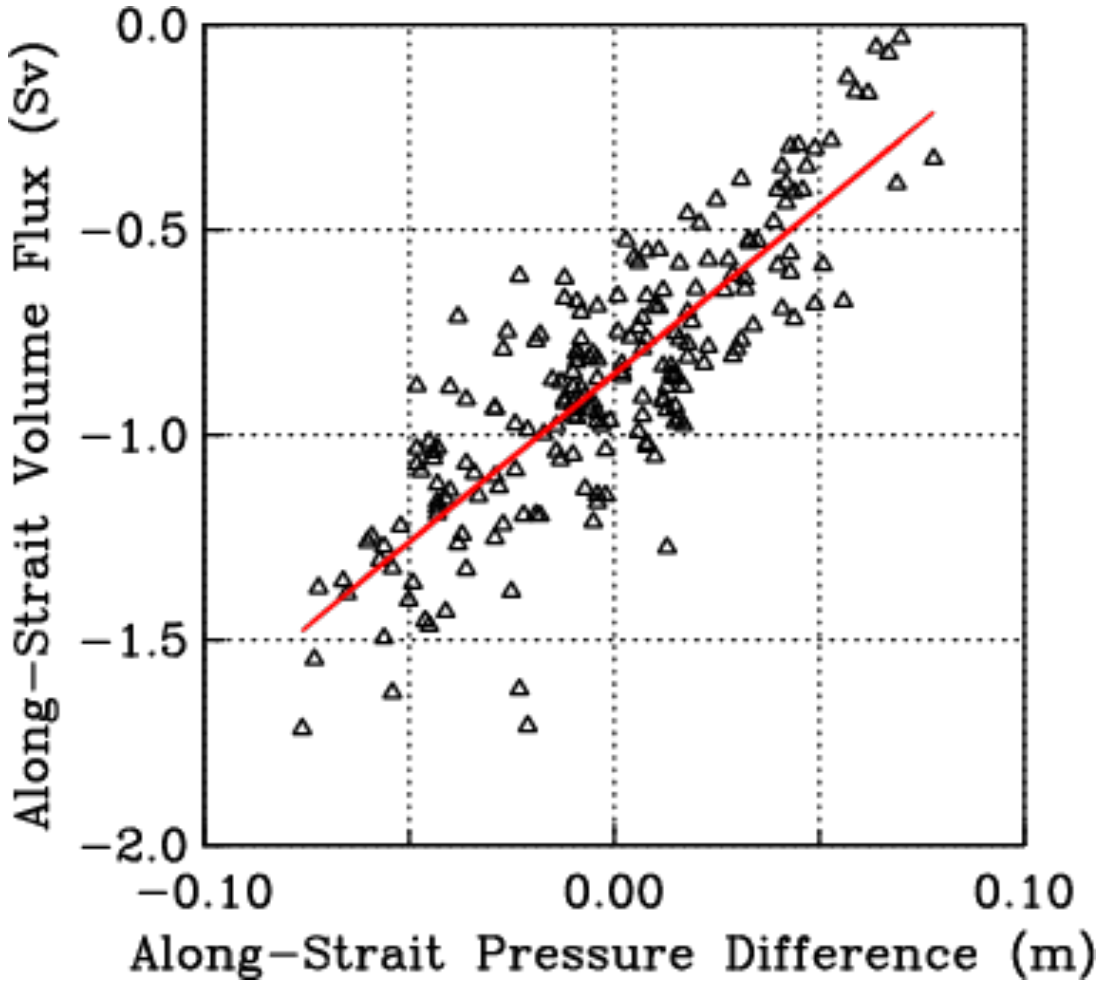
Observations:
0.85 Sv per 0.1 m

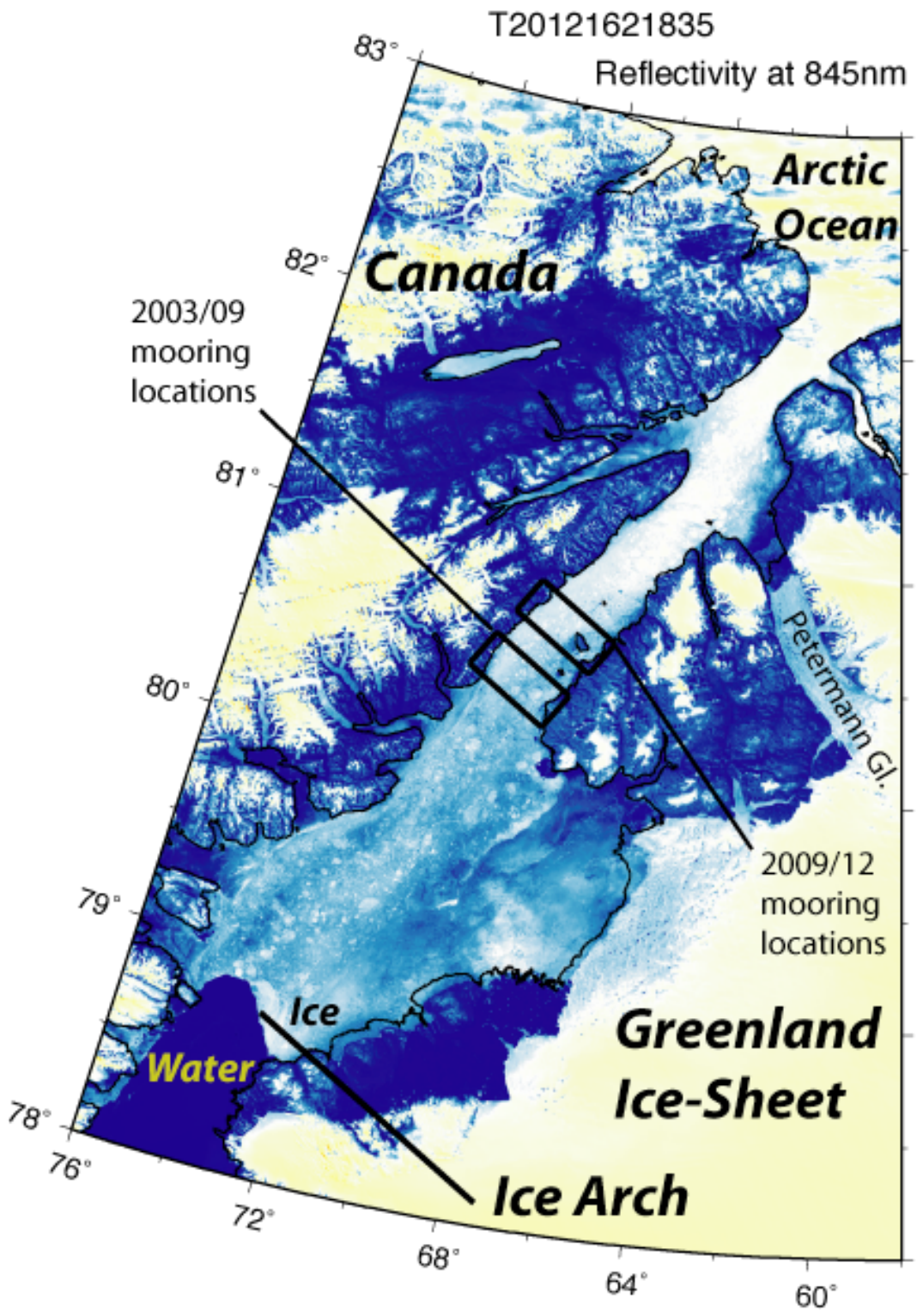


Residual root-mean squares:
0.21 Sv

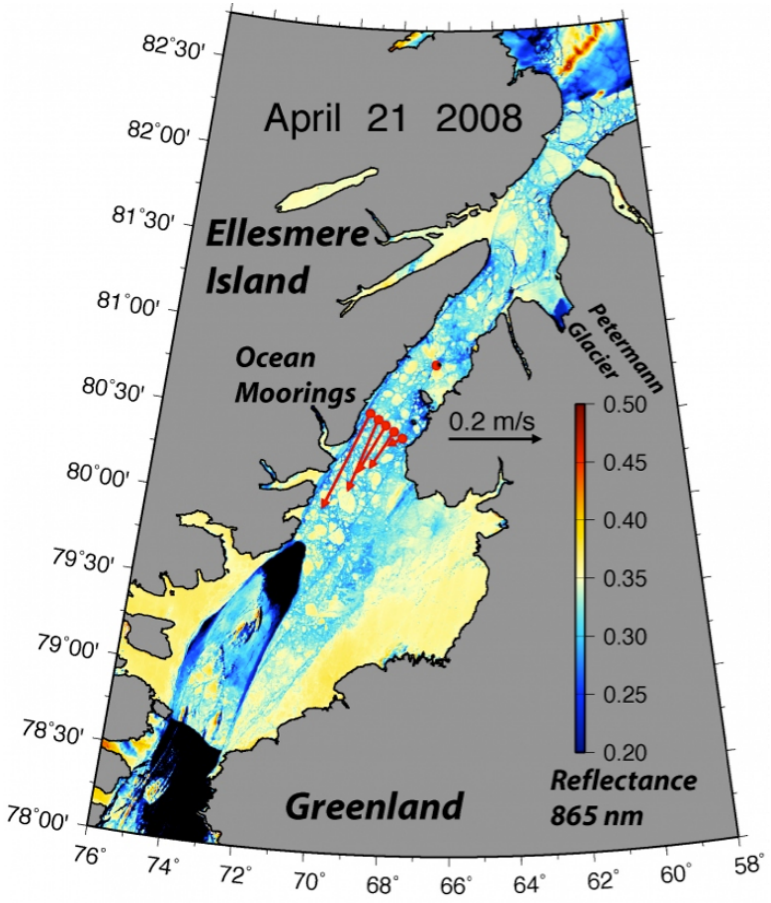
Correlation: r^2=0.64
Regression: a= -0.94 Sv
Regression b=8.86 Sv/m

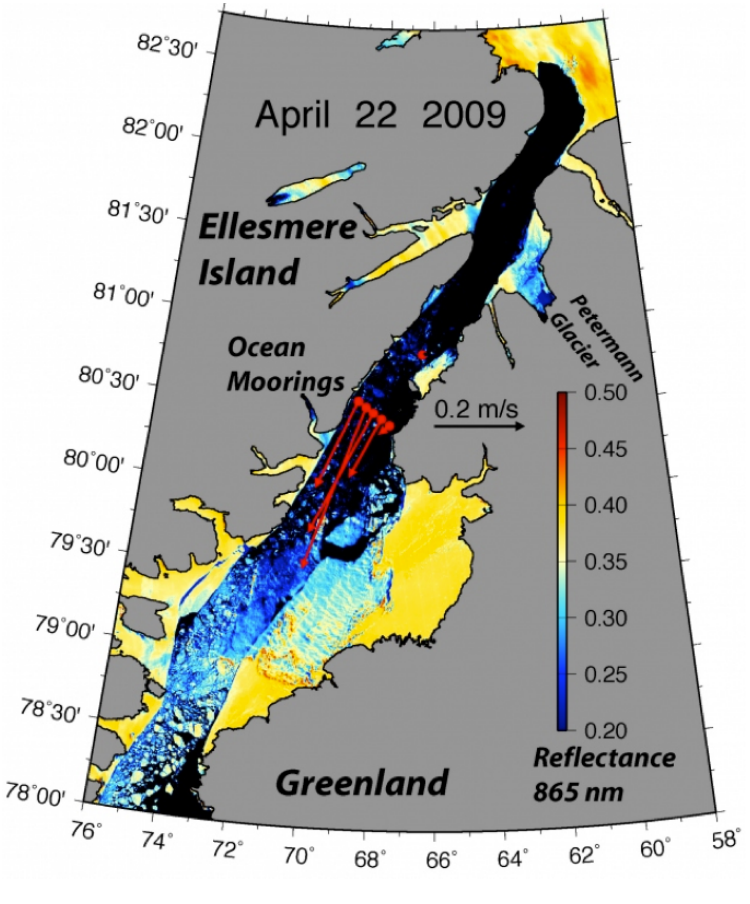
Predict Volume Flux from Along-channel Pressure Difference:

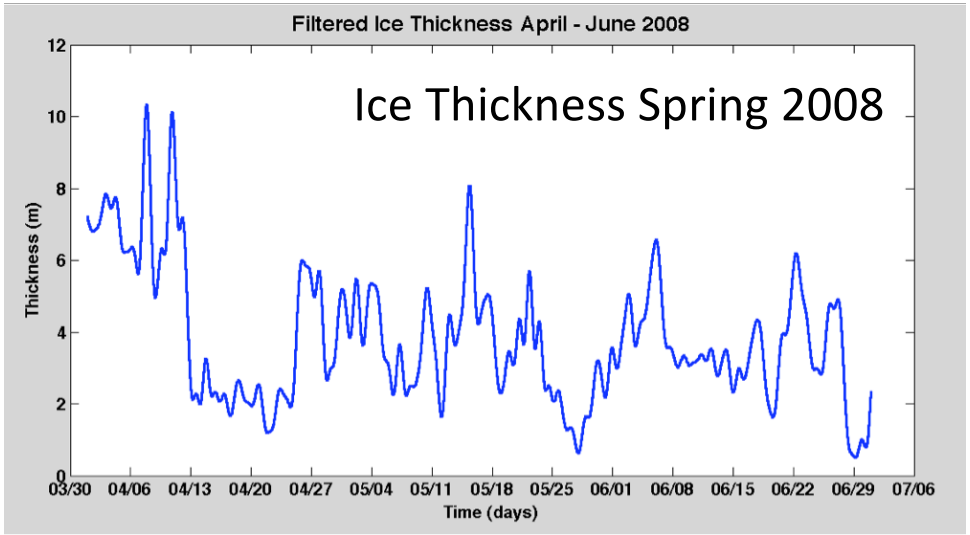


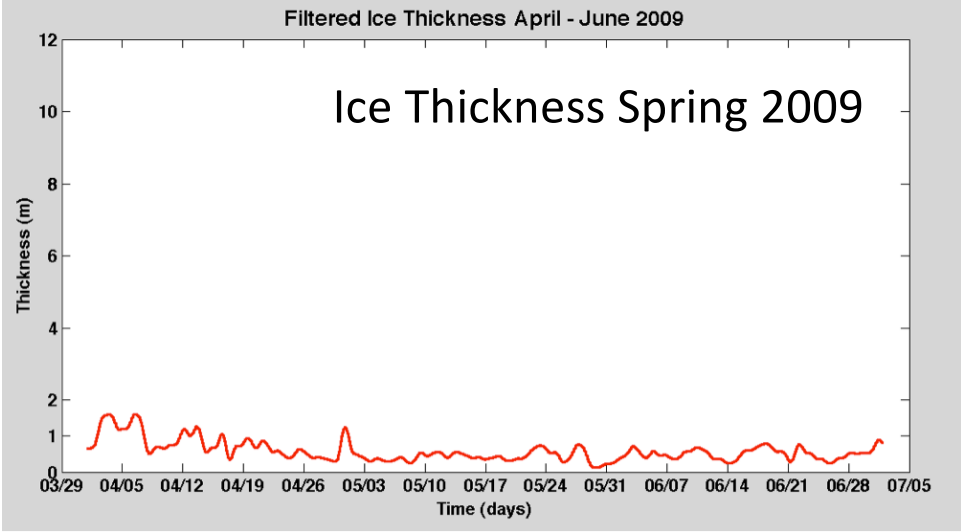

T20121621835
Reflectivity at 845nm
Arctic
Ocean
Canada
2003/09
mooring
locations
Petermann Gl.
2009/12
mooring
locations
Ice
Water
Greenland
Ice-Sheet
Ice Arch
83°
82°
81°
80°
79°
78°
76°
72°
68°
64°
60°

Ice Profiling Sonars after impact with Petermann Ice Island 2010

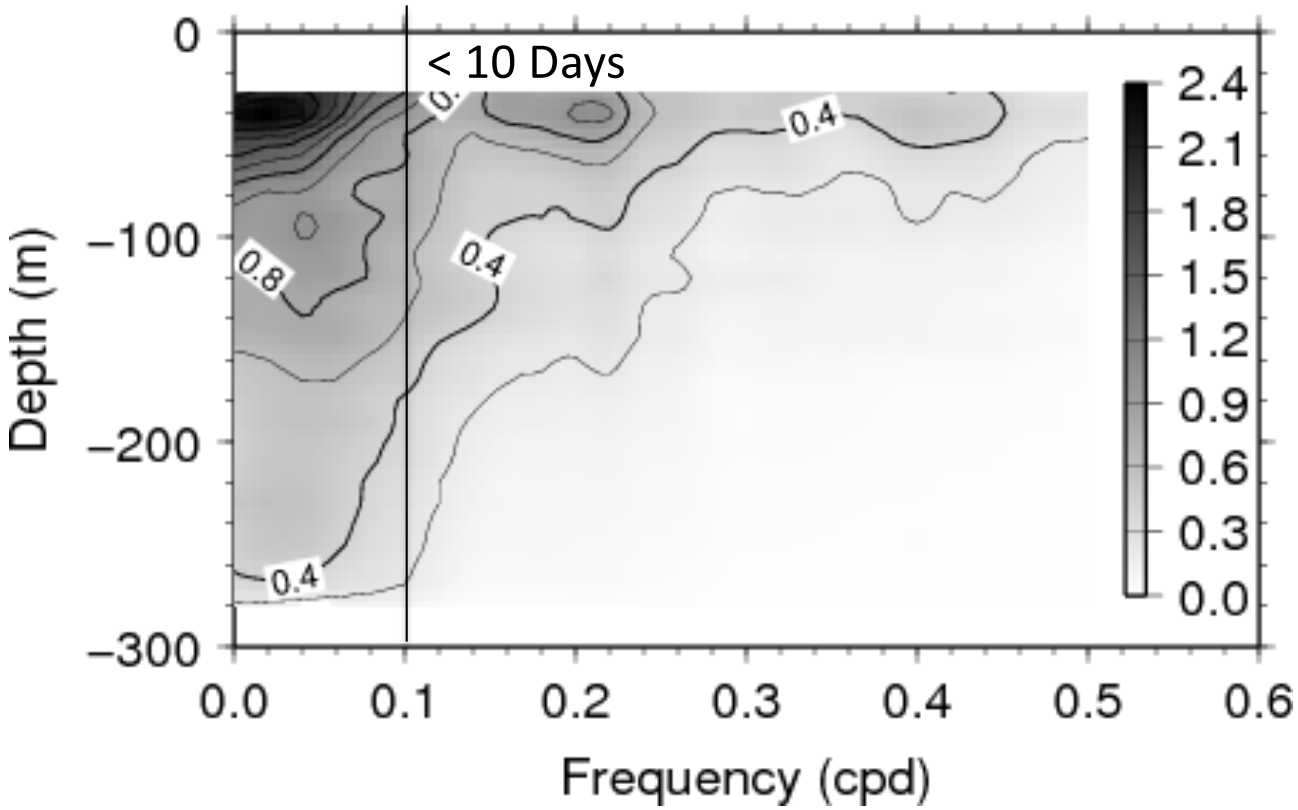

April 21 2008
Ellesmere Island
Petermann Glacier
Ocean Moorings
0.2 m/s
0.50
0.45
0.40
0.35
0.30
0.25
0.20
Reflectance 865 nm
Greenland
82°30'
82°00'
81°30'
81°00'
80°30'
80°00'
79°30'
79°00'
78°30'
78°00'
76°
74°
72°
70°
68°
66°
64°
62°
60°
58°


April 22 2009
Ellesmere Island
Petermann Glacier
Ocean Moorings
0.2 m/s
0.50
0.45
0.40
0.35
0.30
0.25
0.20
Reflectance 865 nm
Greenland
82°30'
82°00'
81°30'
81°00'
80°30'
80°00'
79°30'
79°00'
78°30'
78°00'
76°
74°
72°
70°
68°
66°
64°
62°
60°
58°

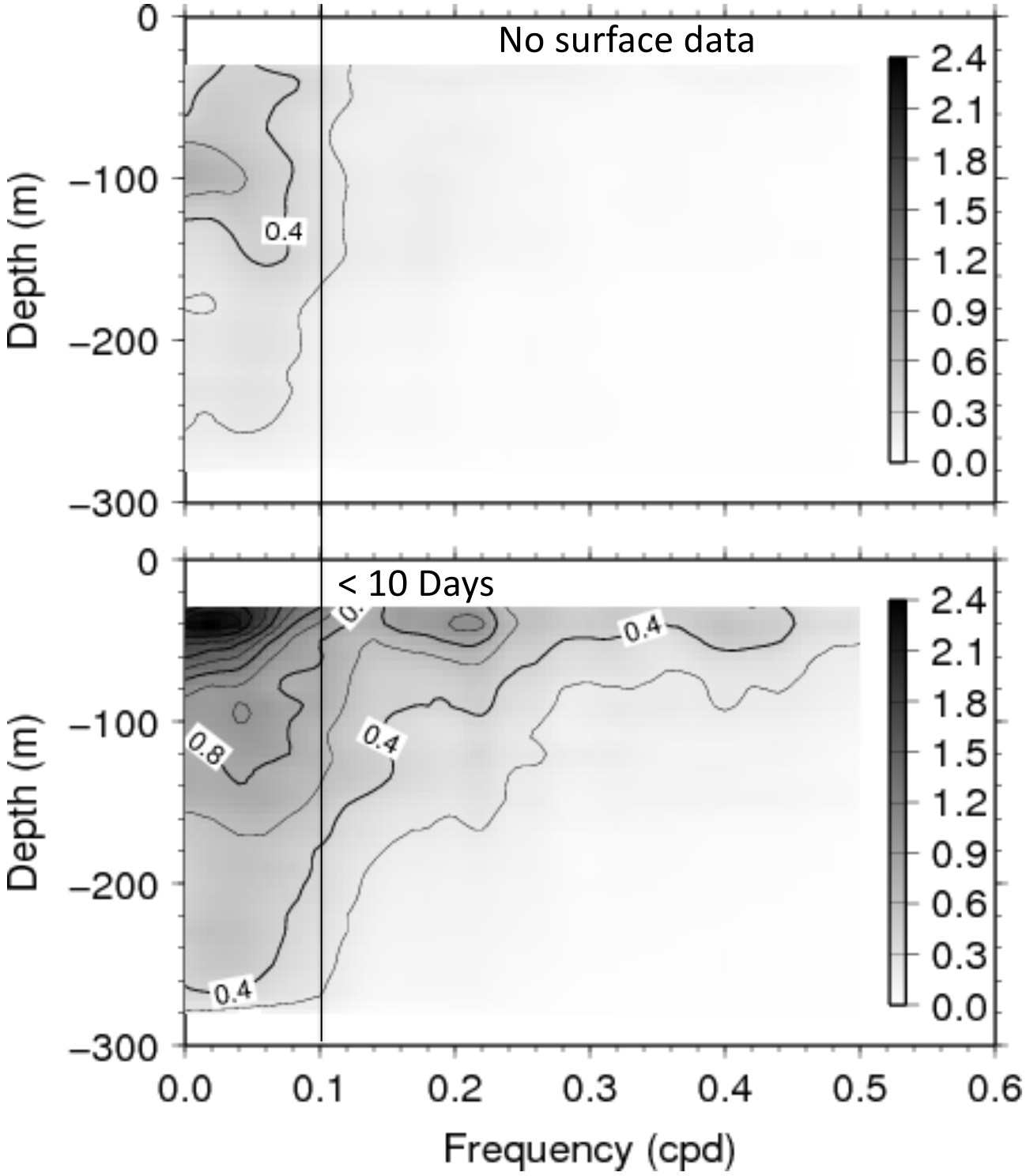

Filtered Ice Thickness April - June 2008
Ice Thickness Spring 2008
Thickness (m)
0
2
4
6
8
10
12
03/30
04/06
04/13
04/20
04/27
05/04
05/11
05/18
05/25
06/01
06/08
06/15
06/22
06/29
07/06
Time (days)


Filtered Ice Thickness April - June 2009
Ice Thickness Spring 2009
Thickness (m)
0
1
2
4
6
8
10
12
03/29
04/05
04/12
04/19
04/26
05/03
05/10
05/17
05/24
05/31
06/07
06/14
06/21
06/28
07/05
Time (days)

Spectral Density
$(cm/s)^2$ per cpd



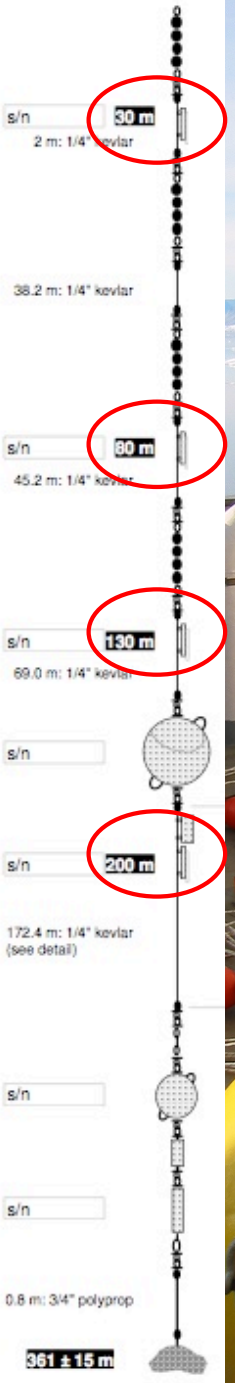
Summer
(Mobile Ice)

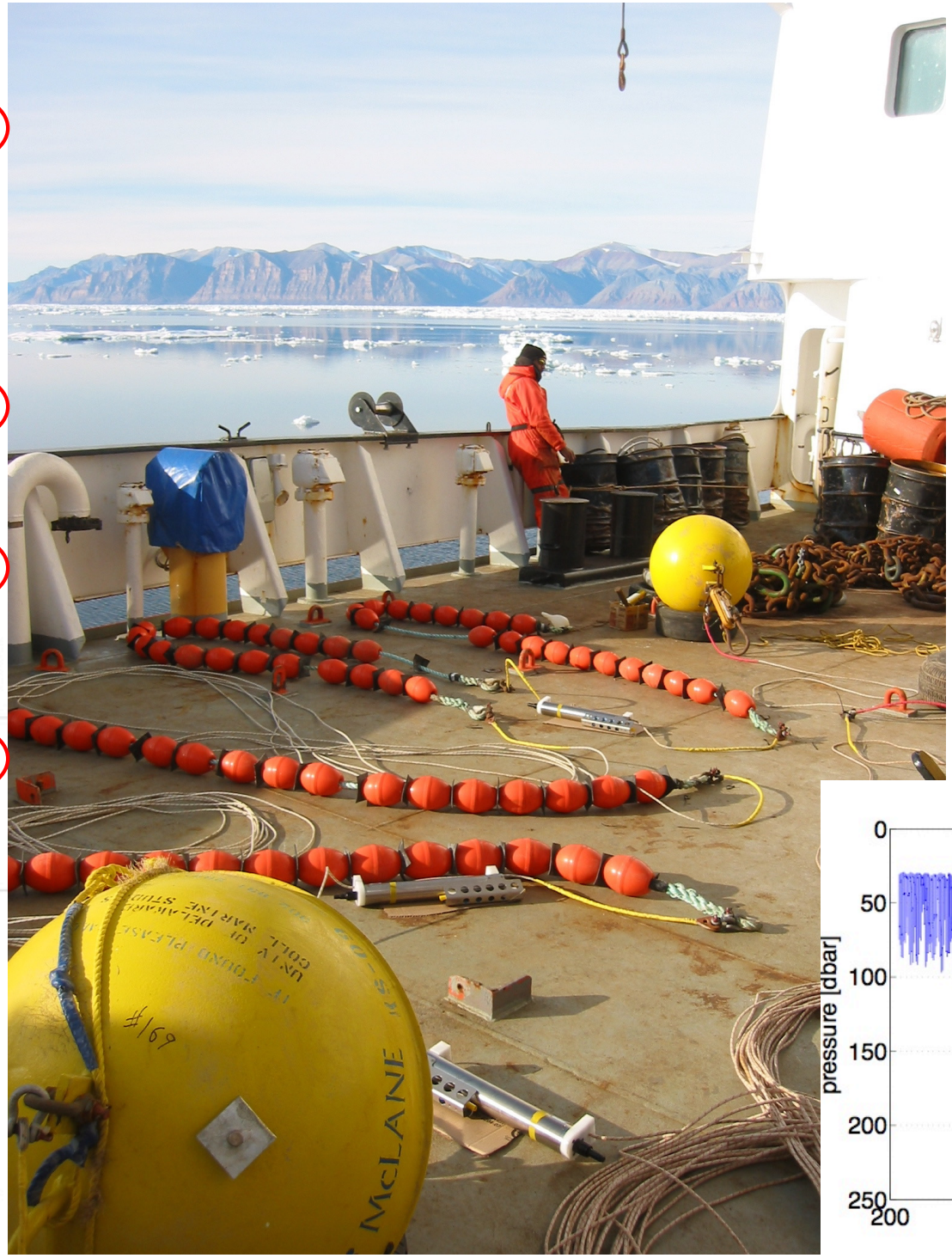


Spectral Density
$(cm/s)^2$ per cpd

Winter
(Landfast Ice)

Summer
(Mobile Ice)



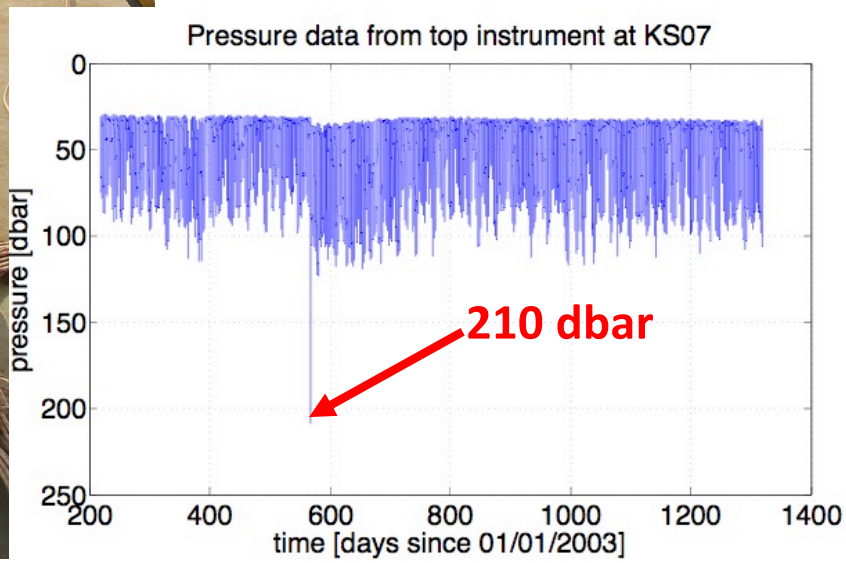


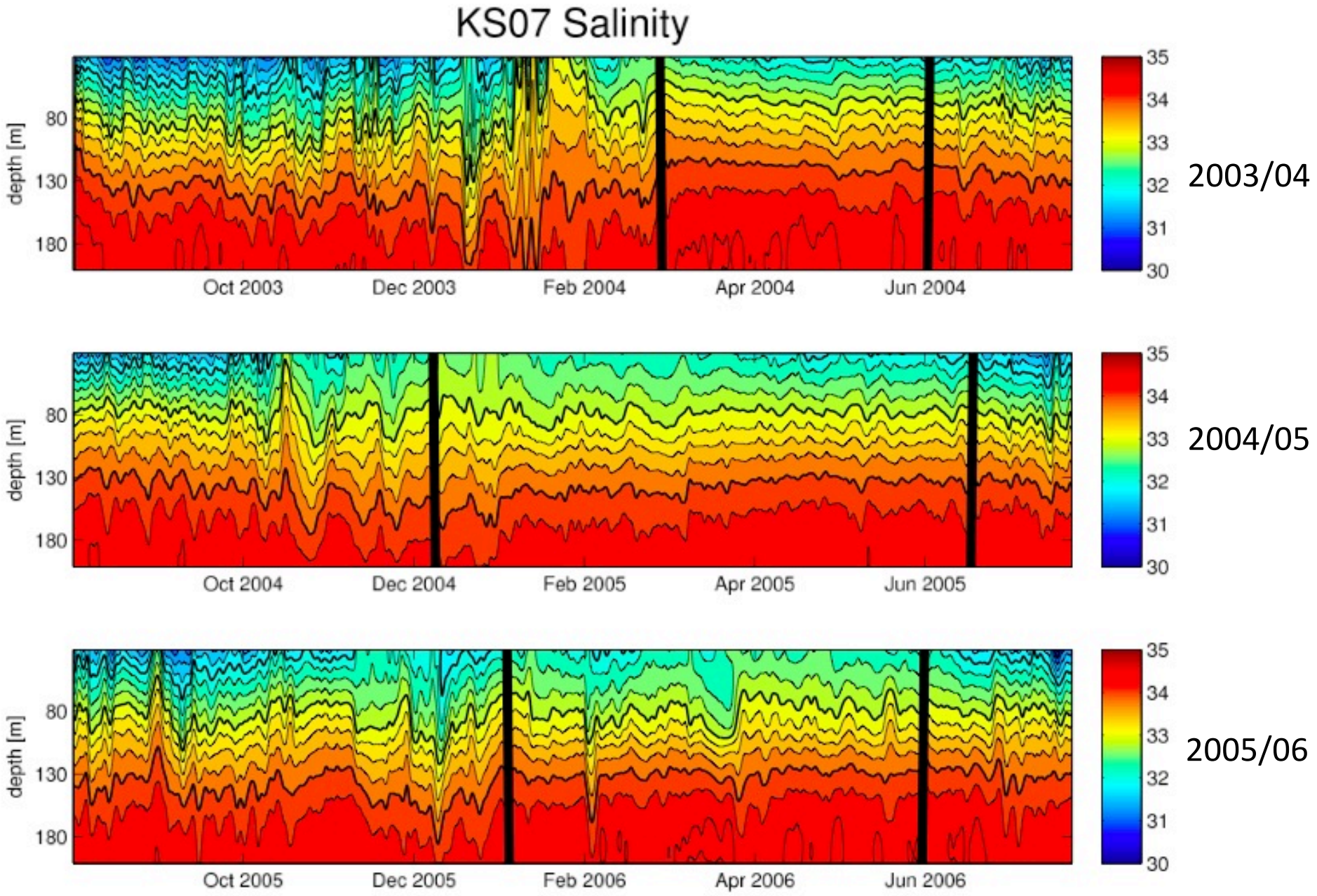
Temperature, salinity,
And pressure moorings

Work with ice and currents

Do not fight it.

Tidal Mooring Lean-Over
Provides Ice avoidance and
vertical profiles





mobile ice
(“summer”)

landfast ice
(“winter”)

Rabe et al. (2012)

Conclusions

- Mean Nares Strait volume flux is 1 Sv to the south
- Mean Nares Strait freshwater flux is ~55 mSv to the south
- >50% of freshwater flux in top 30-m
- Along-Channel dynamics almost linear (friction ~ pressure gradient)
- Ice-arches impact both landfast ice duration and ocean dynamics