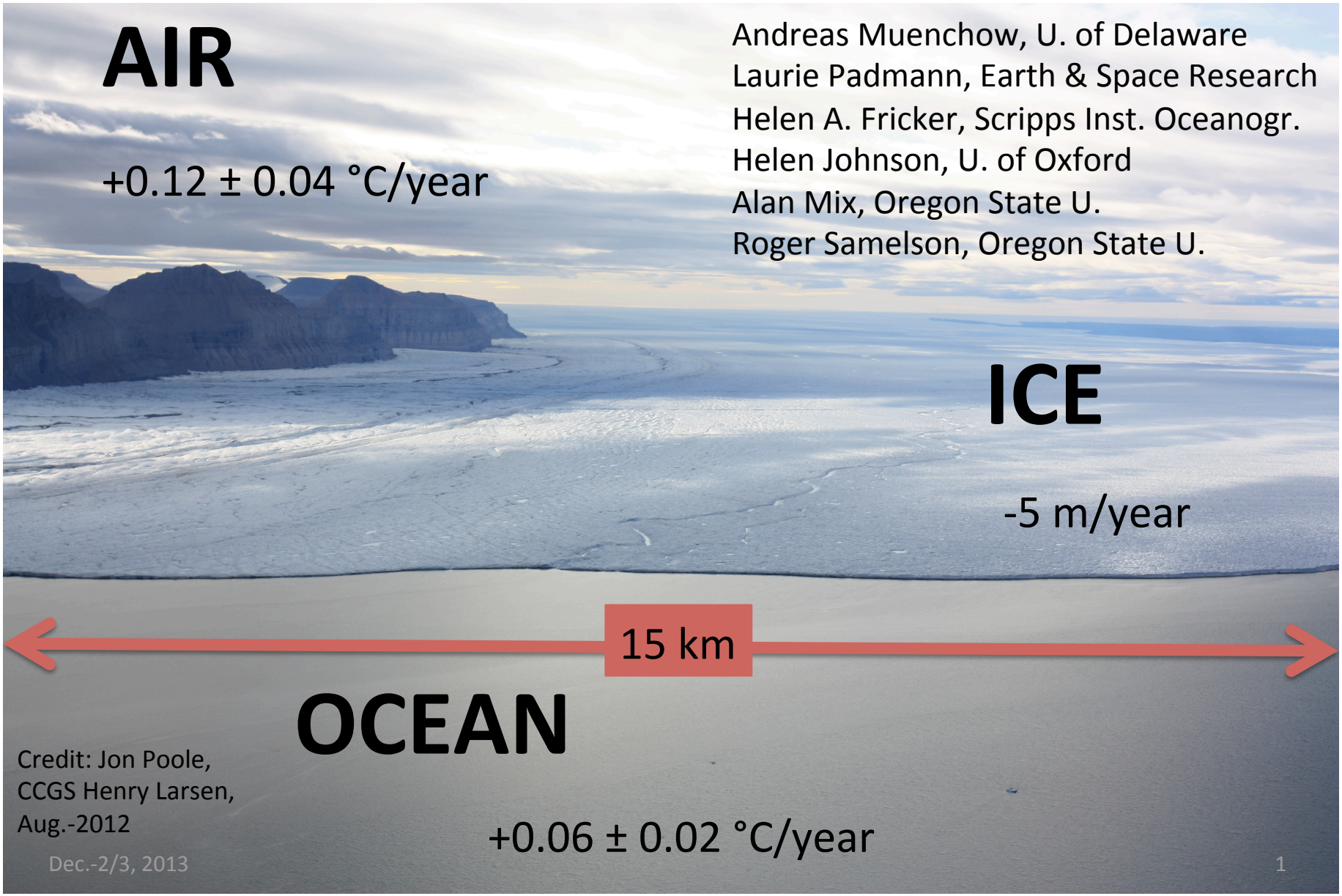
Decadal Variability of Petermann Gletscher, North Greenland from Observations of Ice, Ocean, and Atmosphere

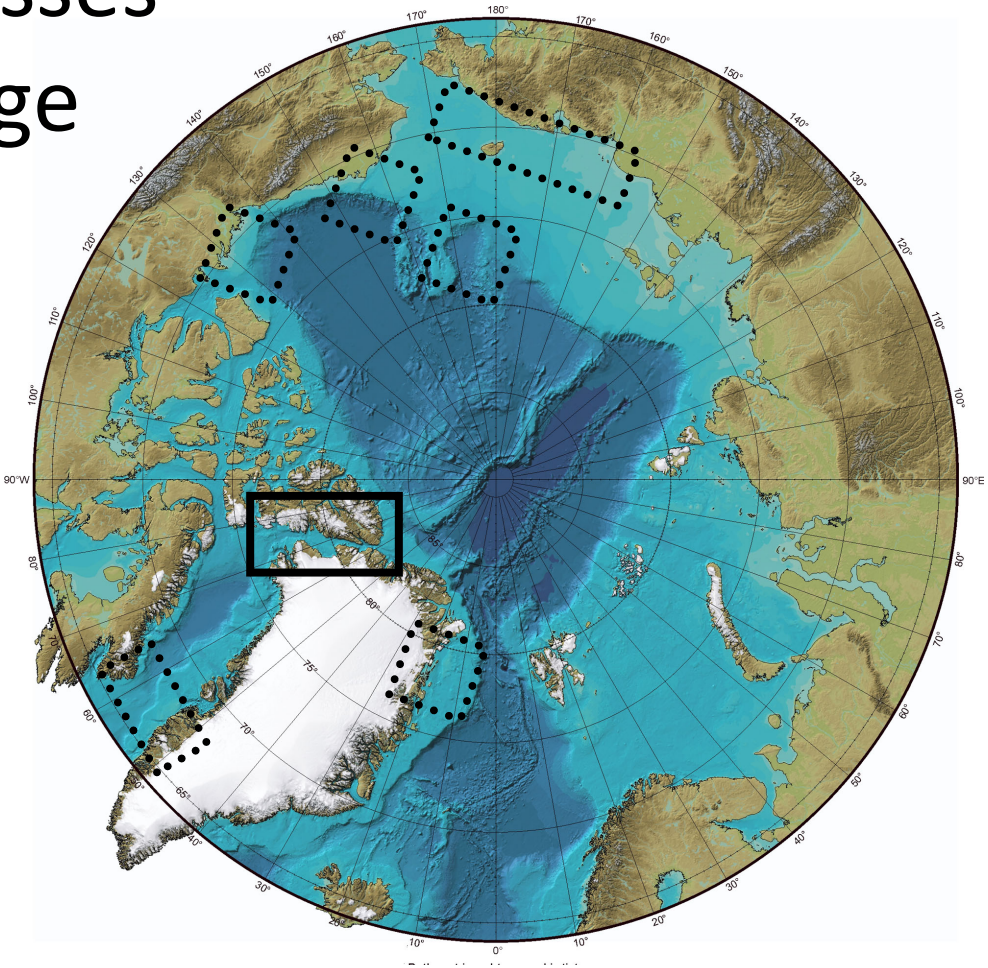


Arctic Coastal Processes and Climate Change

Andreas Münchow

University of Delaware

http://IcySeas.org

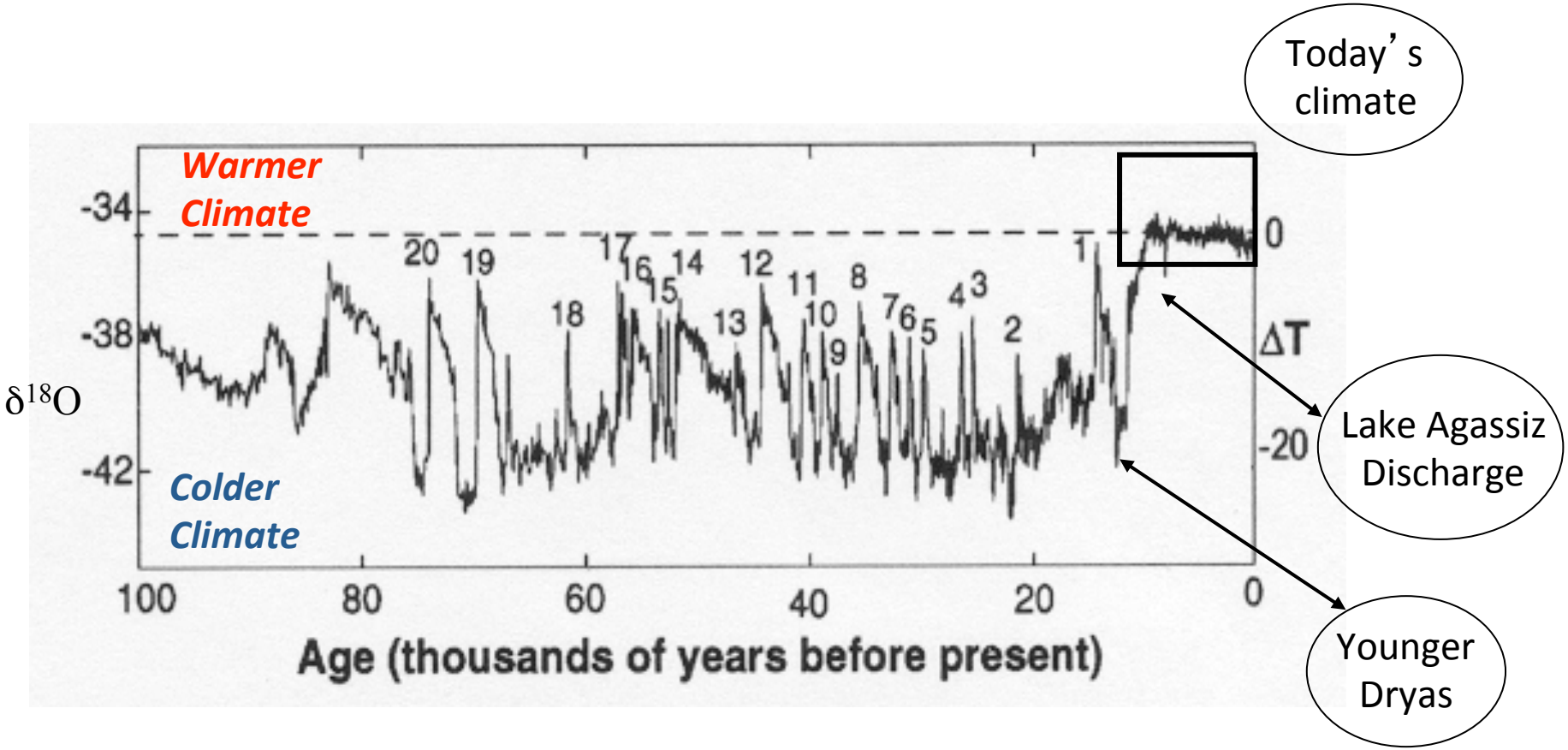


~50 weeks @ sea
since 1992

Collaborators: Drs. Melling (Canada), Johnson (England), Falkner, Samelson, Padman (Oregon), Fricker (California), Rabe (Scotland), Schauer (Germany), Pimenta (Brazil), Garvine, Song, Badiey, Huntley and Ms. Ryan (Delaware)

Greenland Ice Core Data:

Oxygen isotopes $\delta^{18}O$ ~ ΔT temperature

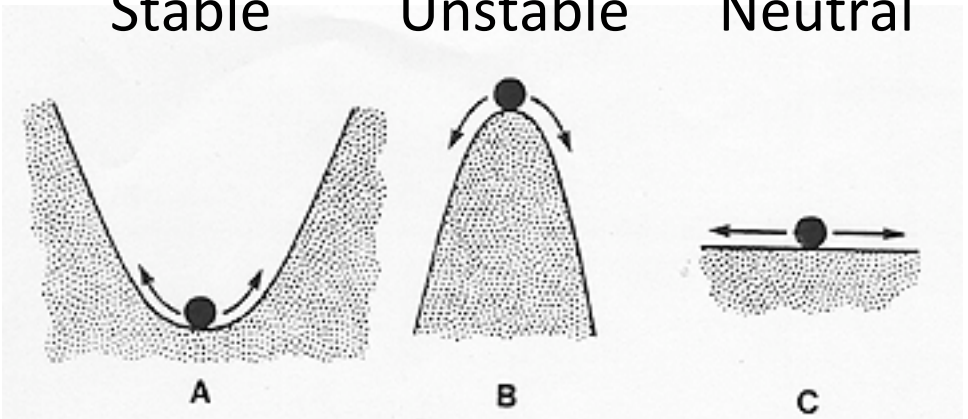


from Alley et al. (2001)

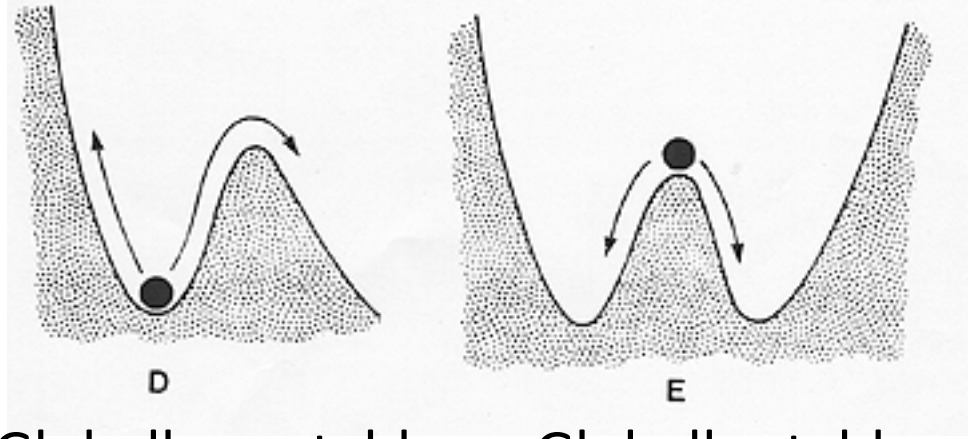
Dynamic Equilibria:

Stable Unstable Neutral

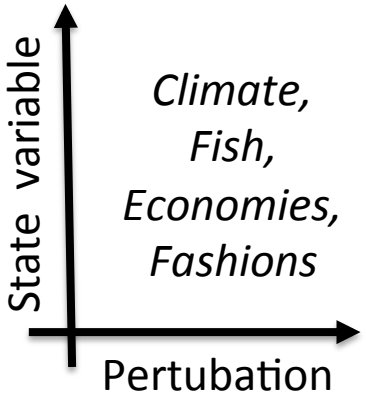
Single states:



Multiple states:



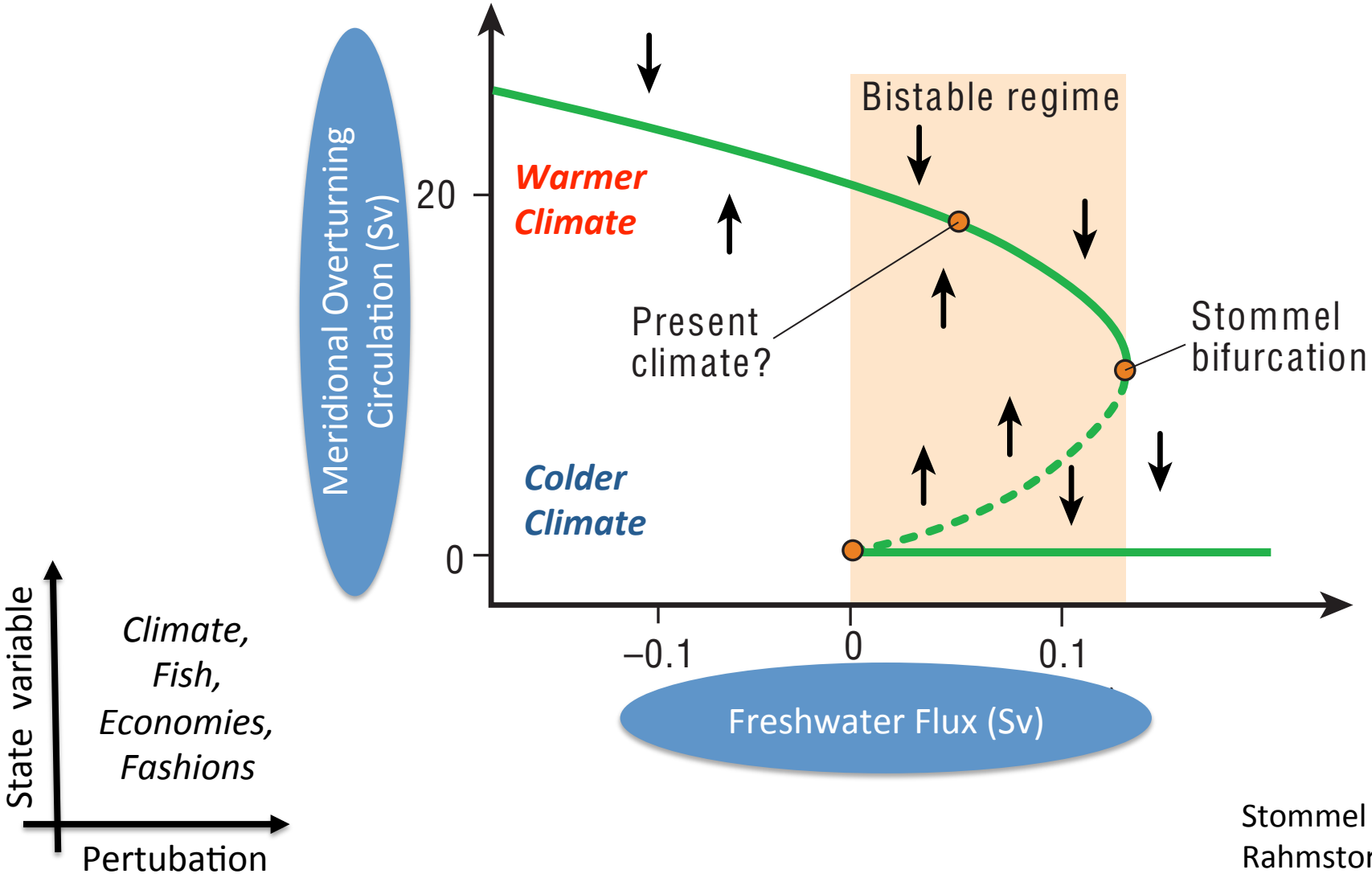
Globally unstable Globally stable



Climate, Fish, Economies, Fashions

Adapted from Dr. Berryman, WSU-529 "Population Theory"

Hysteresis Loop of Climate Change



Stommel (1961)
Rahmstorf (2002)

Arctic Coastal Processes and Global Climate Change

1. Arctic freshwater *flux* and the global thermohaline *circulation* (nonlinear, multiple equilibria).

2. Insulation of the Arctic ice-cover from deep warm Atlantic water, i.e., "maintenance of the Arctic halocline"

Need *Velocity* Observations:

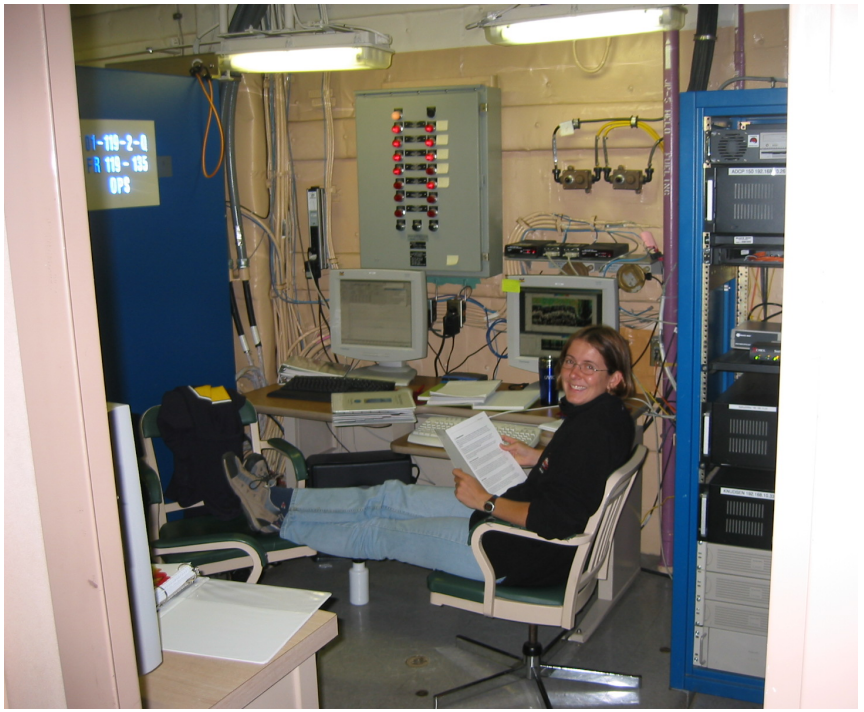
Nares Strait Freshwater Flux Experiment

USCGC Healy ADCP system:

1. Healy in snowy Seattle dry-dock

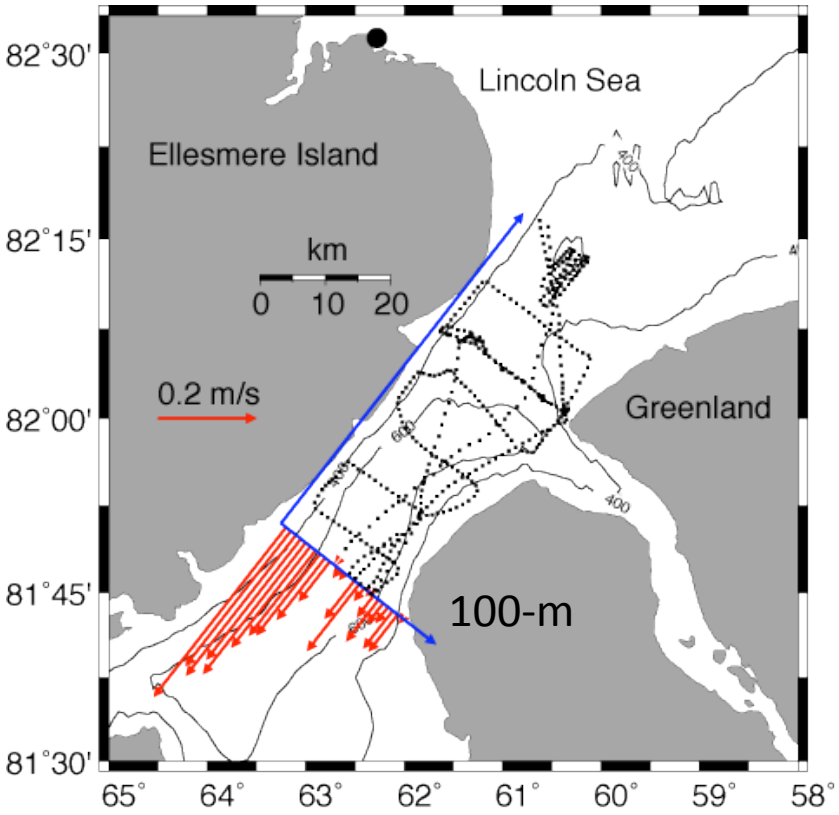
3. Bilge rat in the back

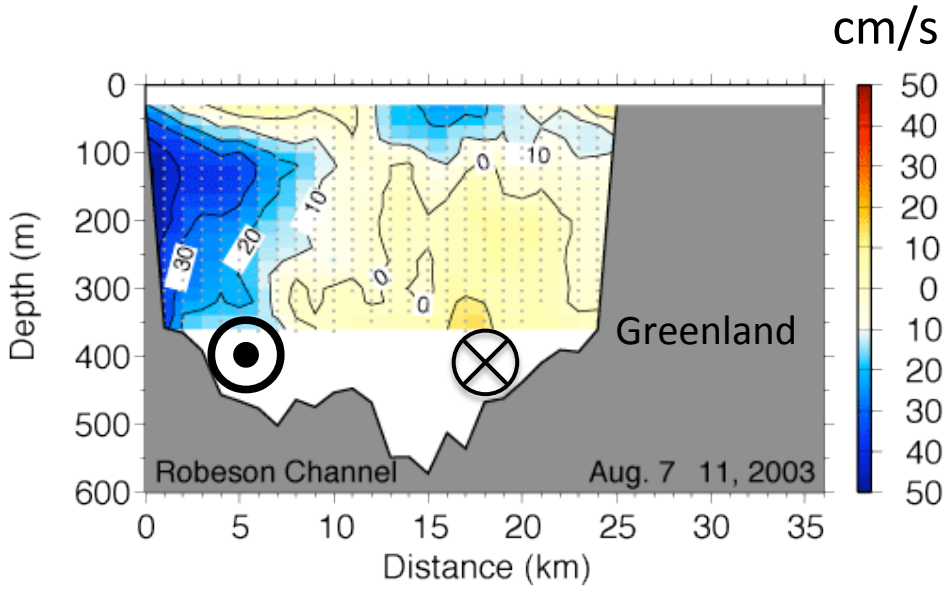
2. Well of the 75-kHz phased array ADCP



4. Command and Control

Velocity Surveys





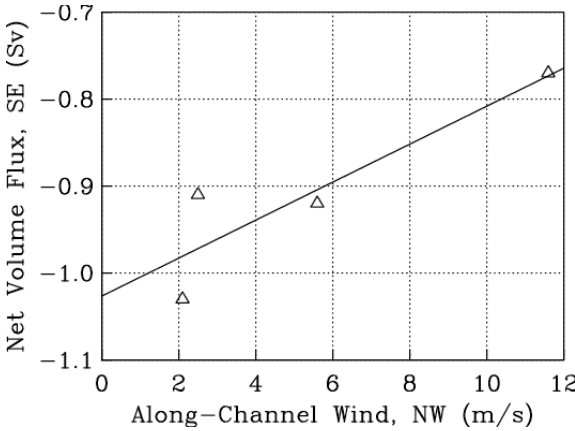
L_D~ *10 km* internal Rossby Radius

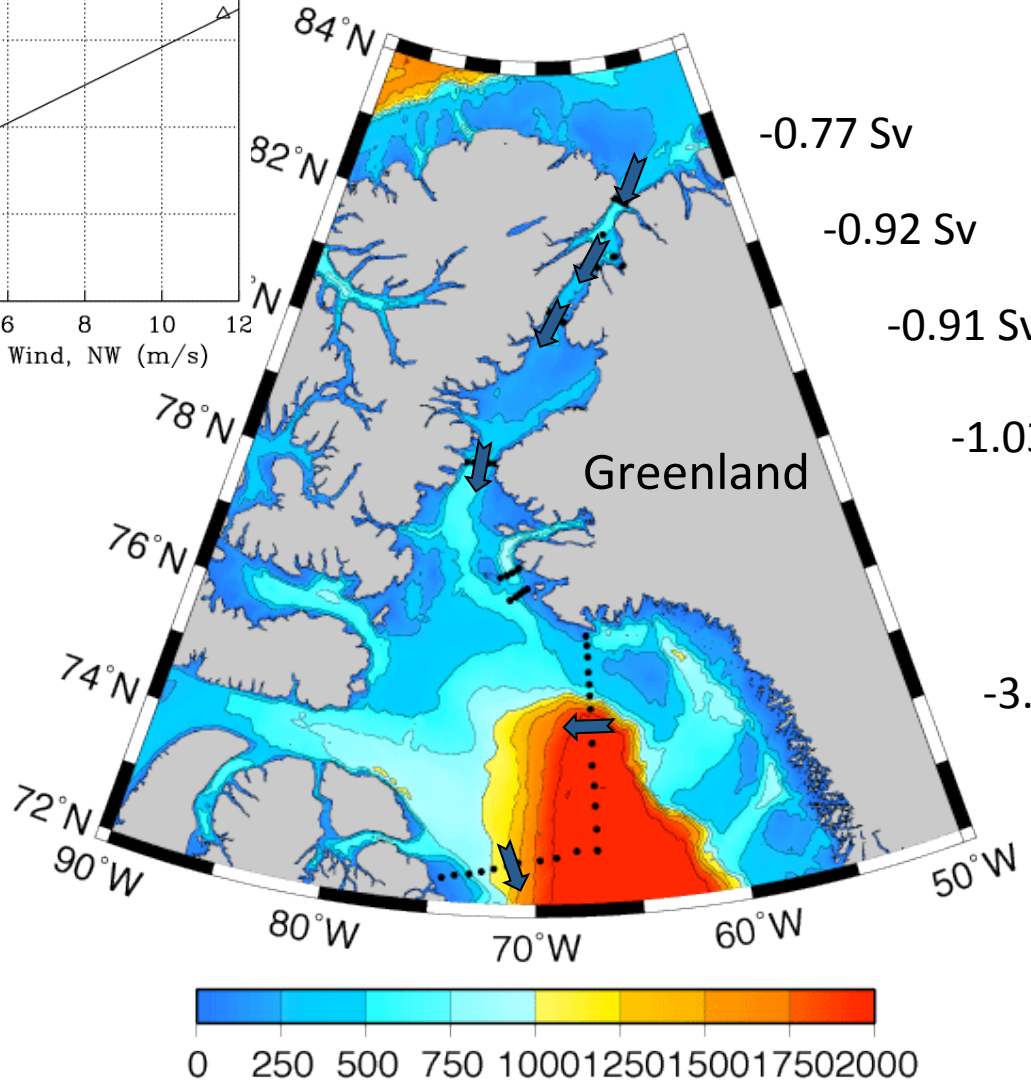
Volume Flux: 0.77 ± 0.10 Sv

Fresh Water Flux: 28 ± 4 mSv

USGGC Healy 2003 ADCP surveys

Flux vs. Wind:





-0.77 Sv

-0.92 Sv

-0.91 Sv

-1.03 Sv

0.9±0.10 Sv

-3.8 +/- 0.3 Sv

5.1 +/- 0.2 Sv

Velocity Moorings

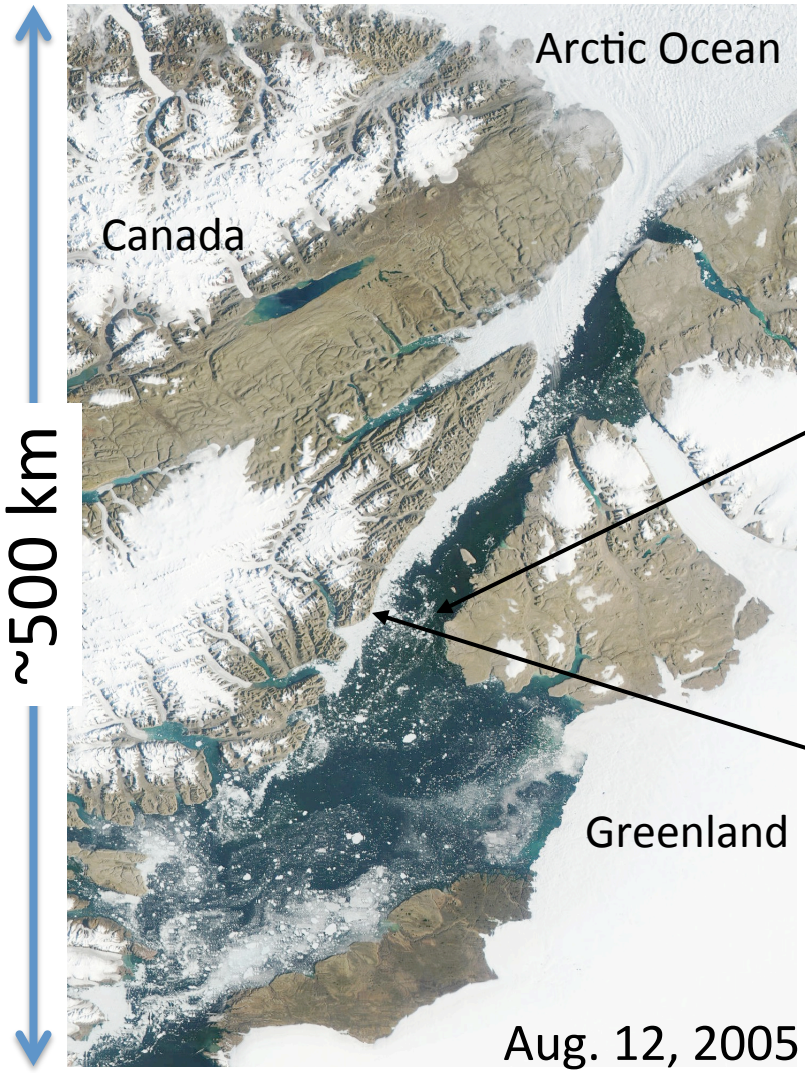
Magnetic Compass not always reliable:

Nares Strait (2003-12):	~ 3800 nT
Fram Strait (2014-16):	~ 6700 nT
Barents Sea:	~ 6700 nT
Required:	>10,000 nT

horizontal magnetic field strength.

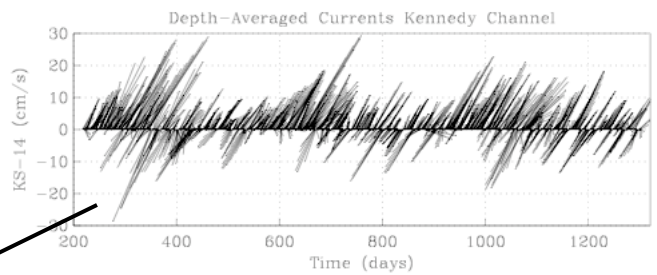
Rigid Backbone allows
Pitch and Roll, but
NO Heading Change

2003-06	Nares Strait	US-ASOF
2007-09	Nares Strait	CA-IPY
2009-12	Nares Strait	private
2014-16	Fram Strait	with AWI
2017-	Barents Sea	with IMR?

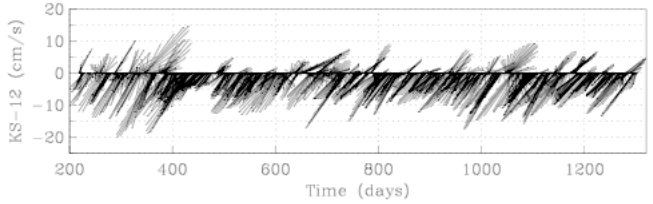


Along-Channel Currents, cm/s

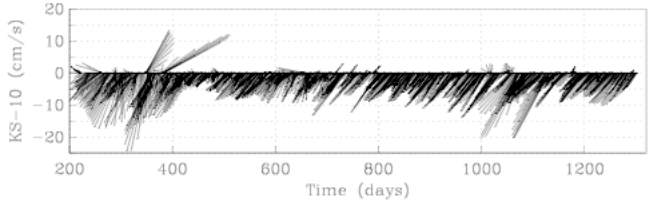
30
cm/s
-30



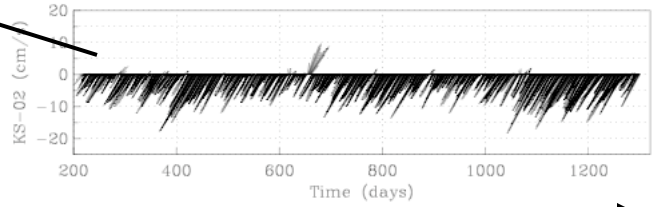
km-34, Greenland



km-30



km-24

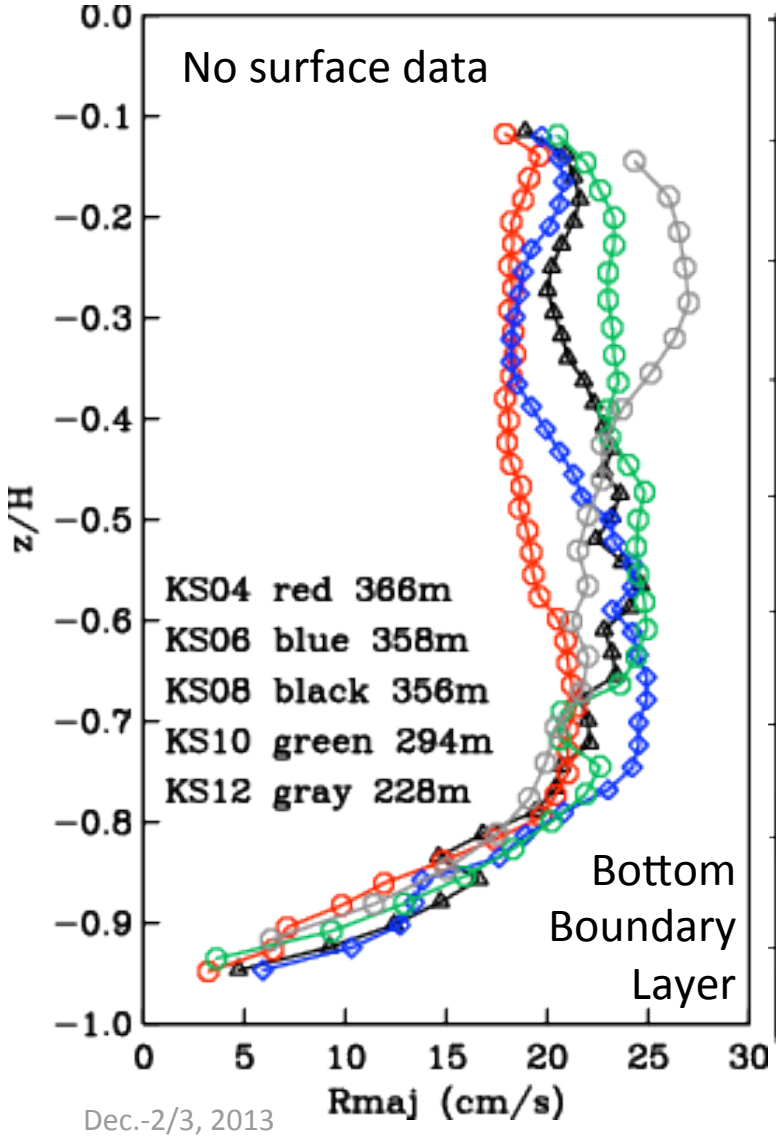


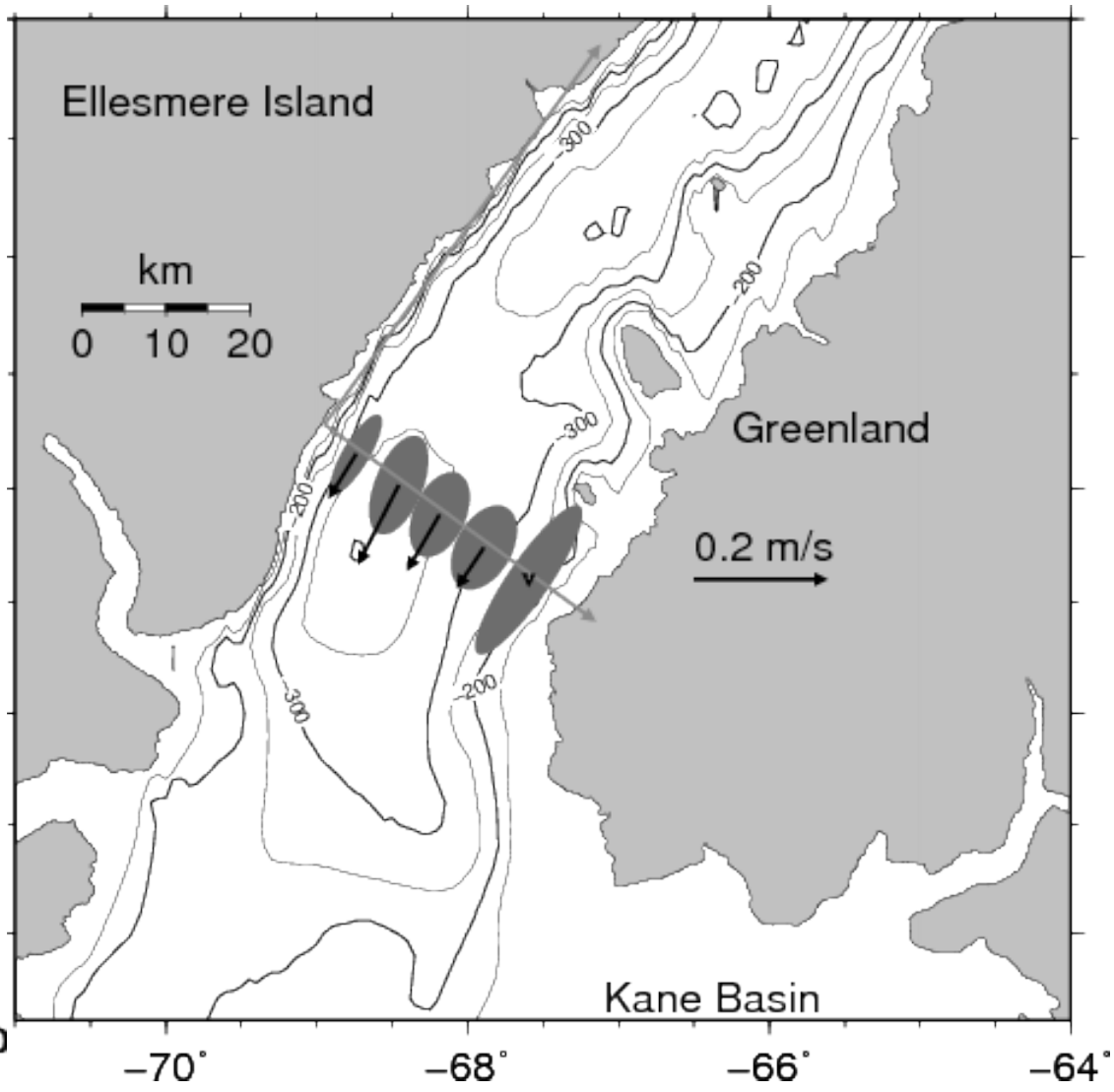
km-03, Canada

2003 Time 2006

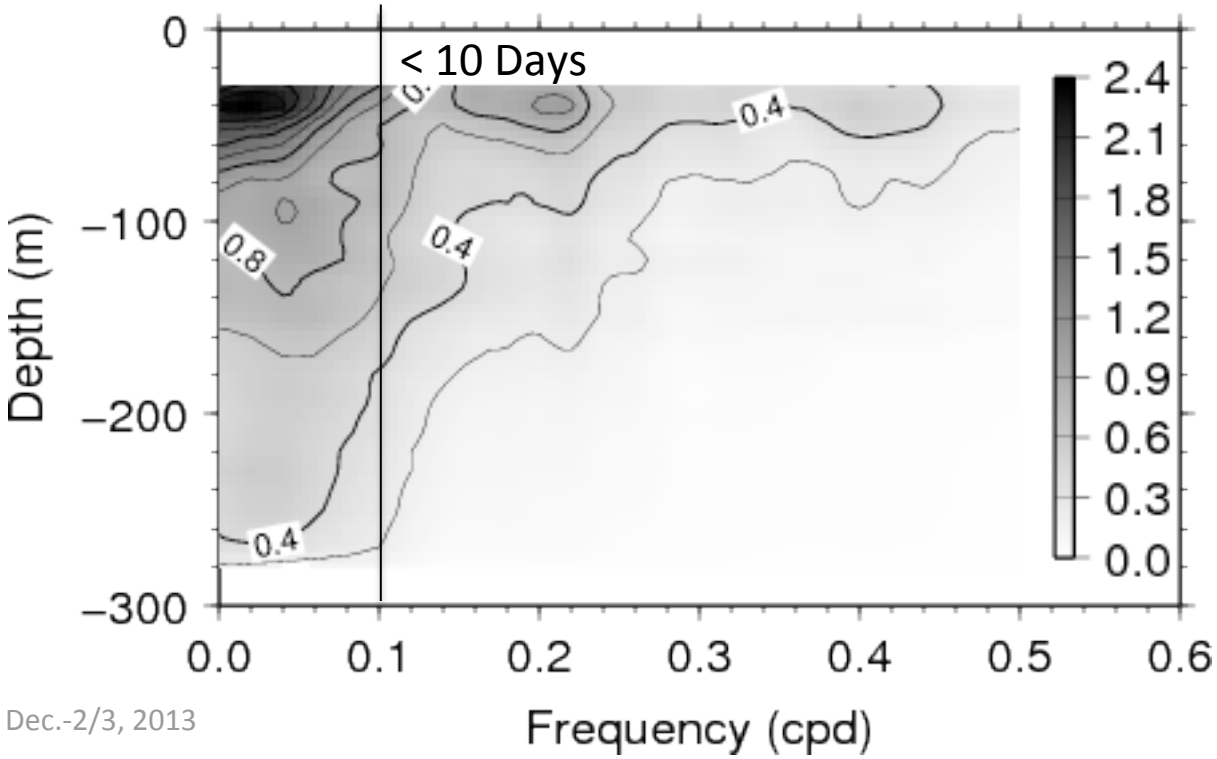
M_2 Tidal Amplitude

Mean and Subtidal Variability

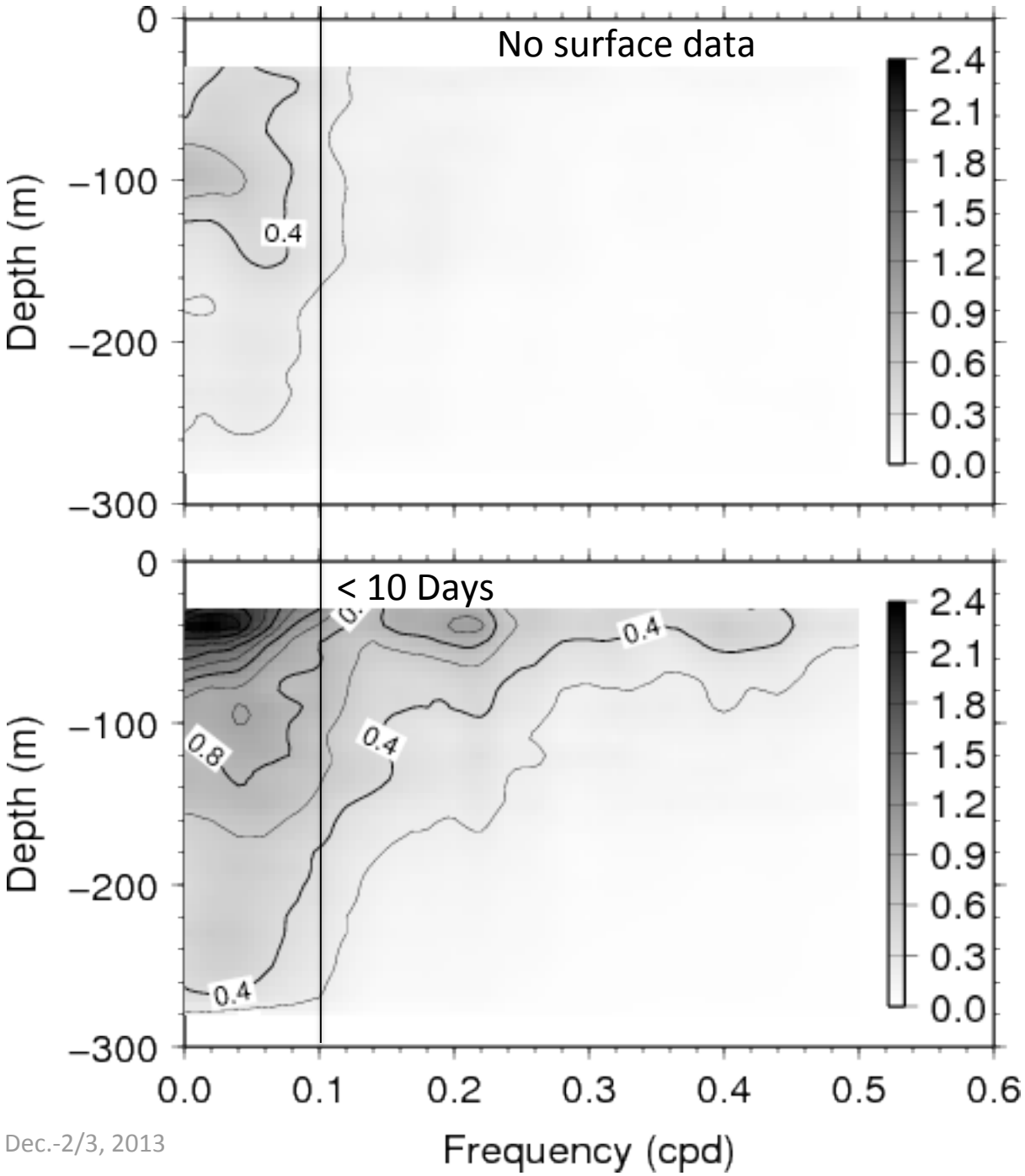




Spectral Density
$(cm/s)^2$ per cpd



Summer
(Mobile Ice)

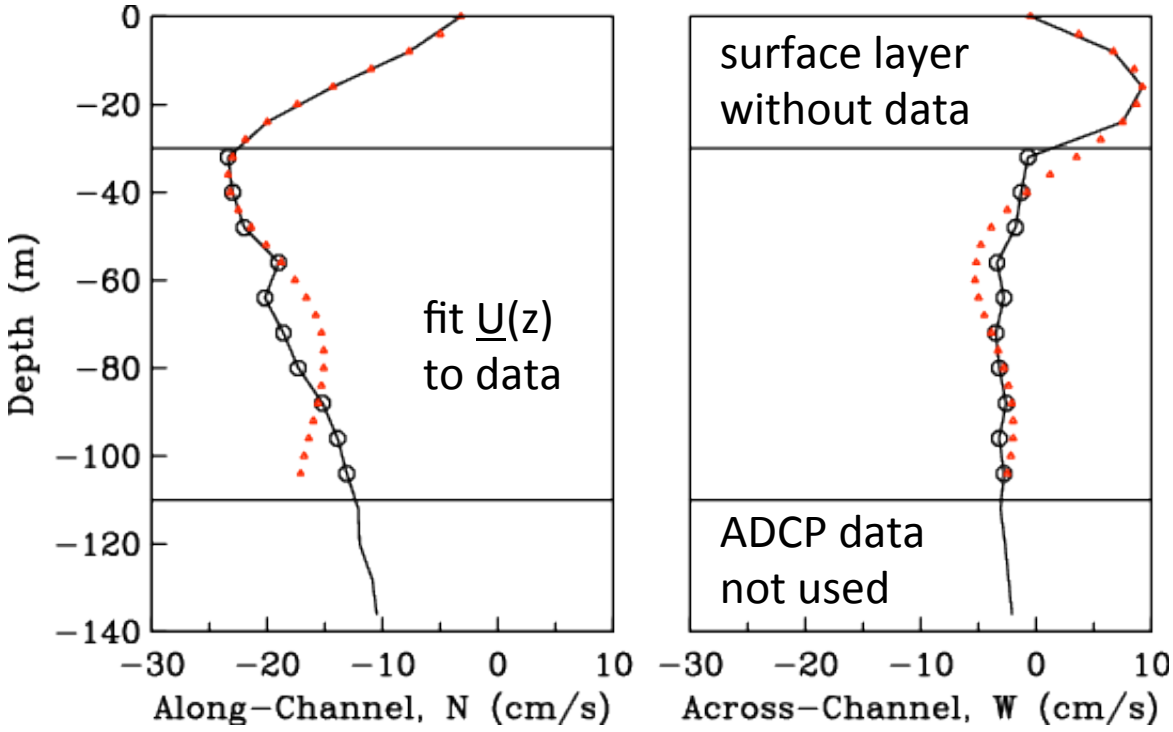


Spectral Density
$(cm/s)^2$ per cpd

Winter
(Landfast Ice)

Summer
(Mobile Ice)

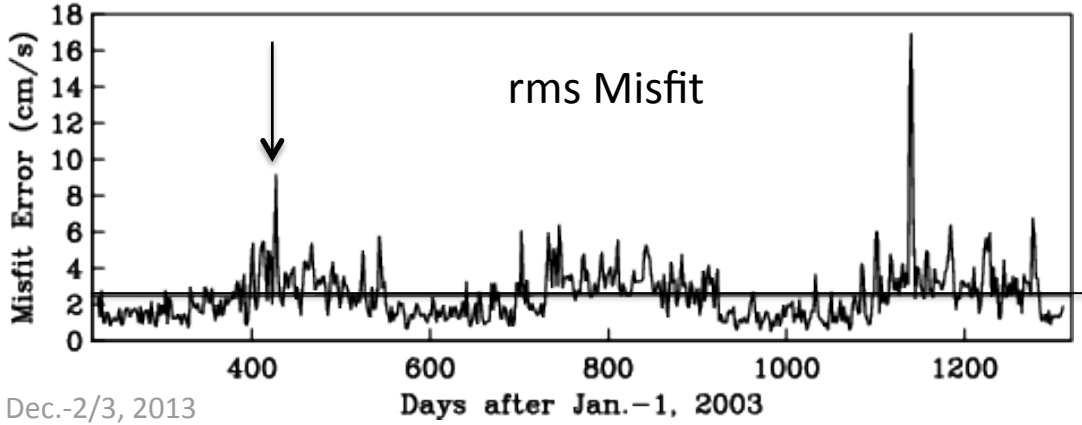
Surface Layer Extrapolation/Interpolation



Least-Square Fit (red)

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

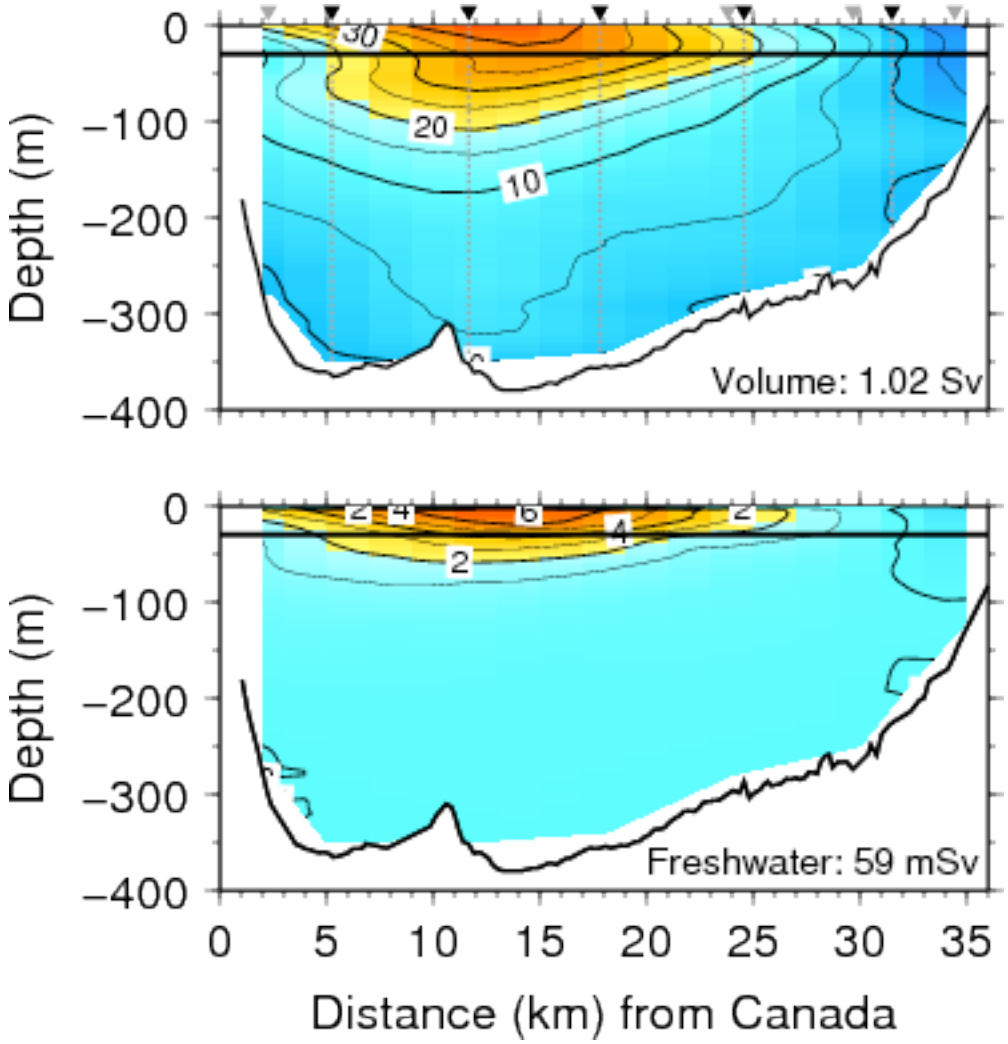
Data (black circles)



Root mean square Misfit
Data-Fit:

2.3 cm/s average

Mean Flux 2003-2009:



Mean Along-Channel Velocity (cm/s)

$$\iint u \, dArea$$

=

1.02 Sv

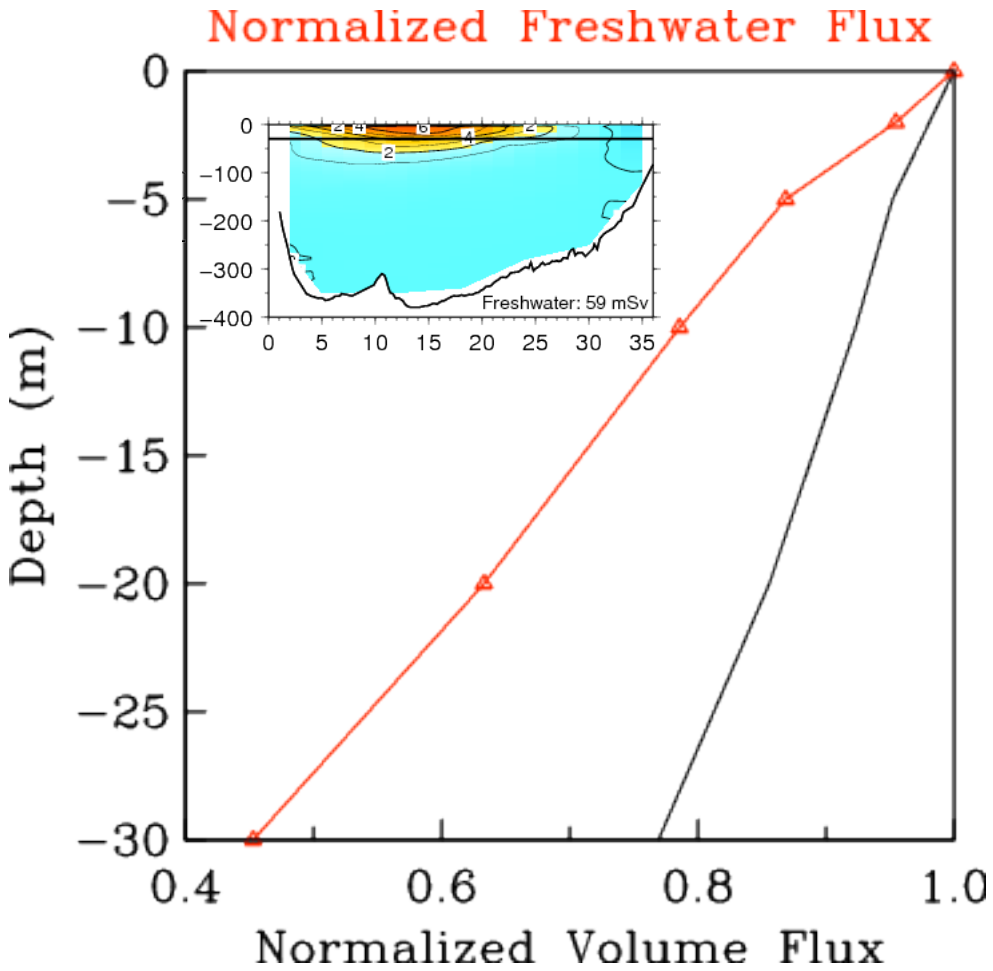
Along-Channel Freshwater Flux (mSv/km/m, 34.8 psu)

$$\iint u(s-s_0)/s_0 \, dArea$$

=

59 mSv

Cummulative Flux Integral scaled by Total Flux:



>50 % of Freshwater Flux

and

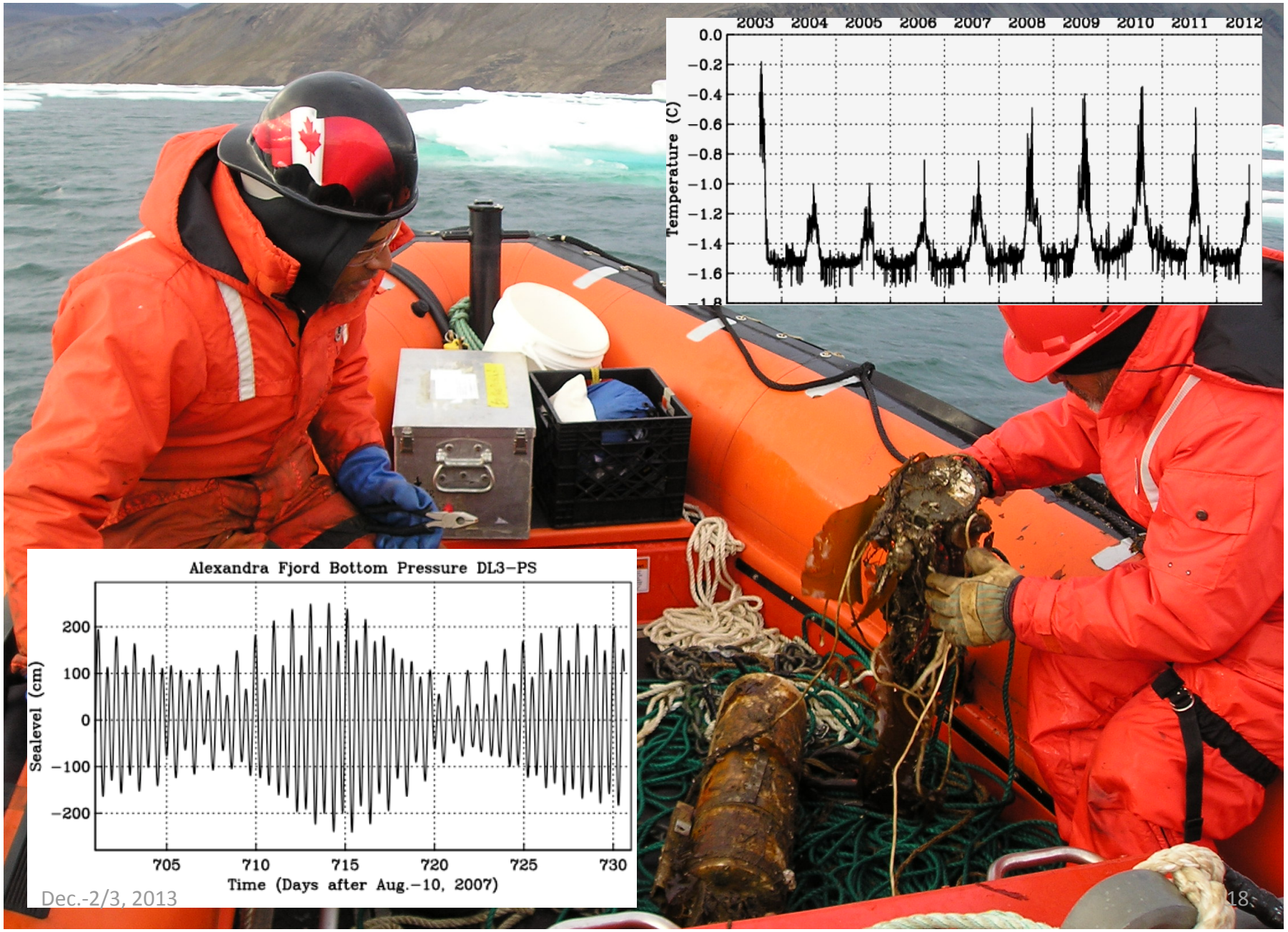
~20 % of Volume Flux

reside in

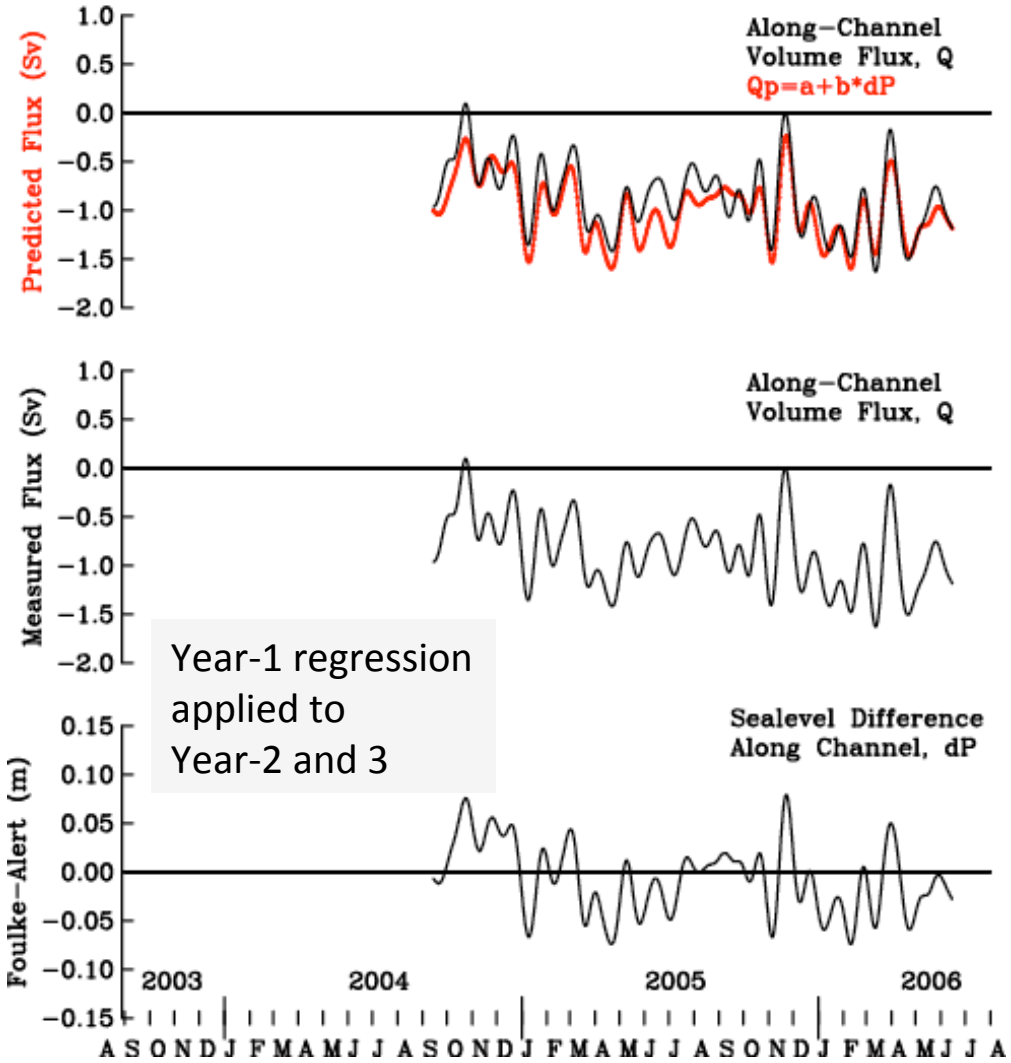
Top 30-m of Water Column

Correlate flux with
along-channel pressure gradient →

Nares Strait Tide Gauges: 9 Year Deployment



Volume Flux vs. Along-Channel Pressure Grad.

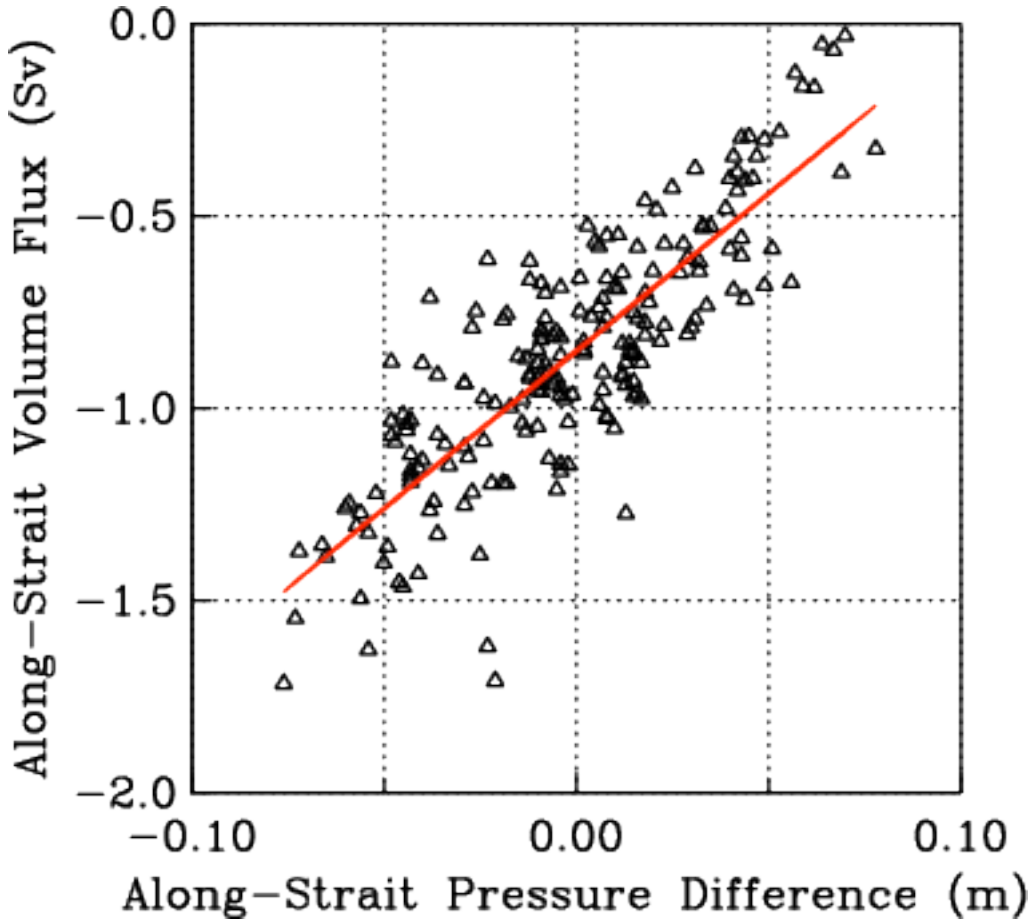


Correlation: r^2=0.64

Flux = a + b* press. diff.

Regression:

a = -0.94 Sv
b = 8.86 Sv/m

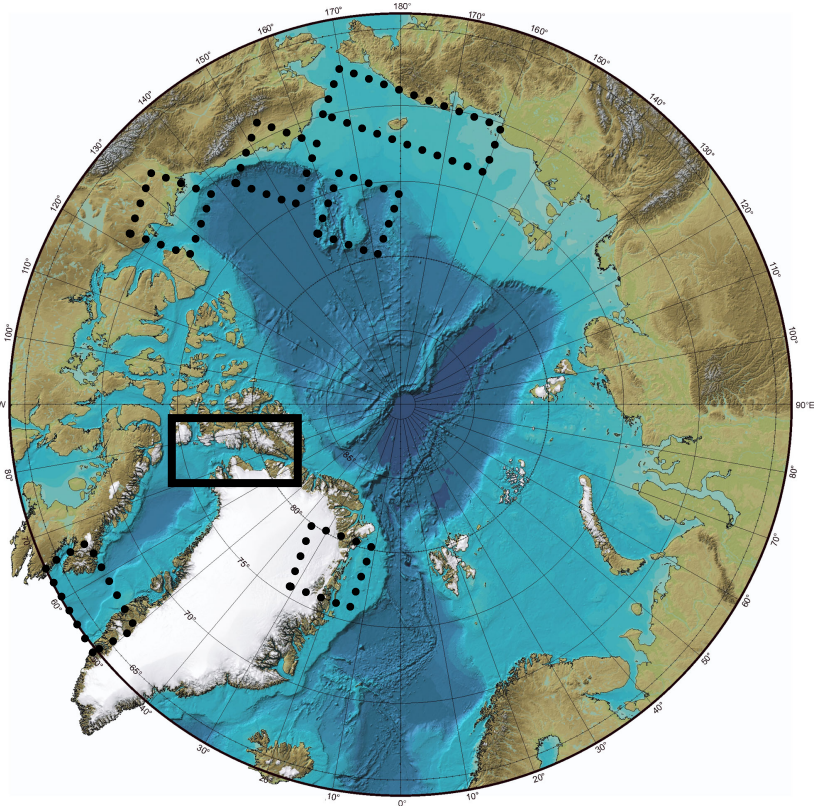

0.0
−0.5
−1.0
−1.5
−2.0
Along−Strait Volume Flux (Sv)
−0.10
0.00
0.10
Along−Strait Pressure Difference (m)

Conclusions:

Arctic velocity measurements challenging:
Careful experimental design essential.

Nares Strait 2003-09 freshwater flux 59 mSv:
Half reside unmeasured in surface 30-m.

Nares Strait dynamics largely linear:
Driven by along-channel pressure gradient.



Challenges:

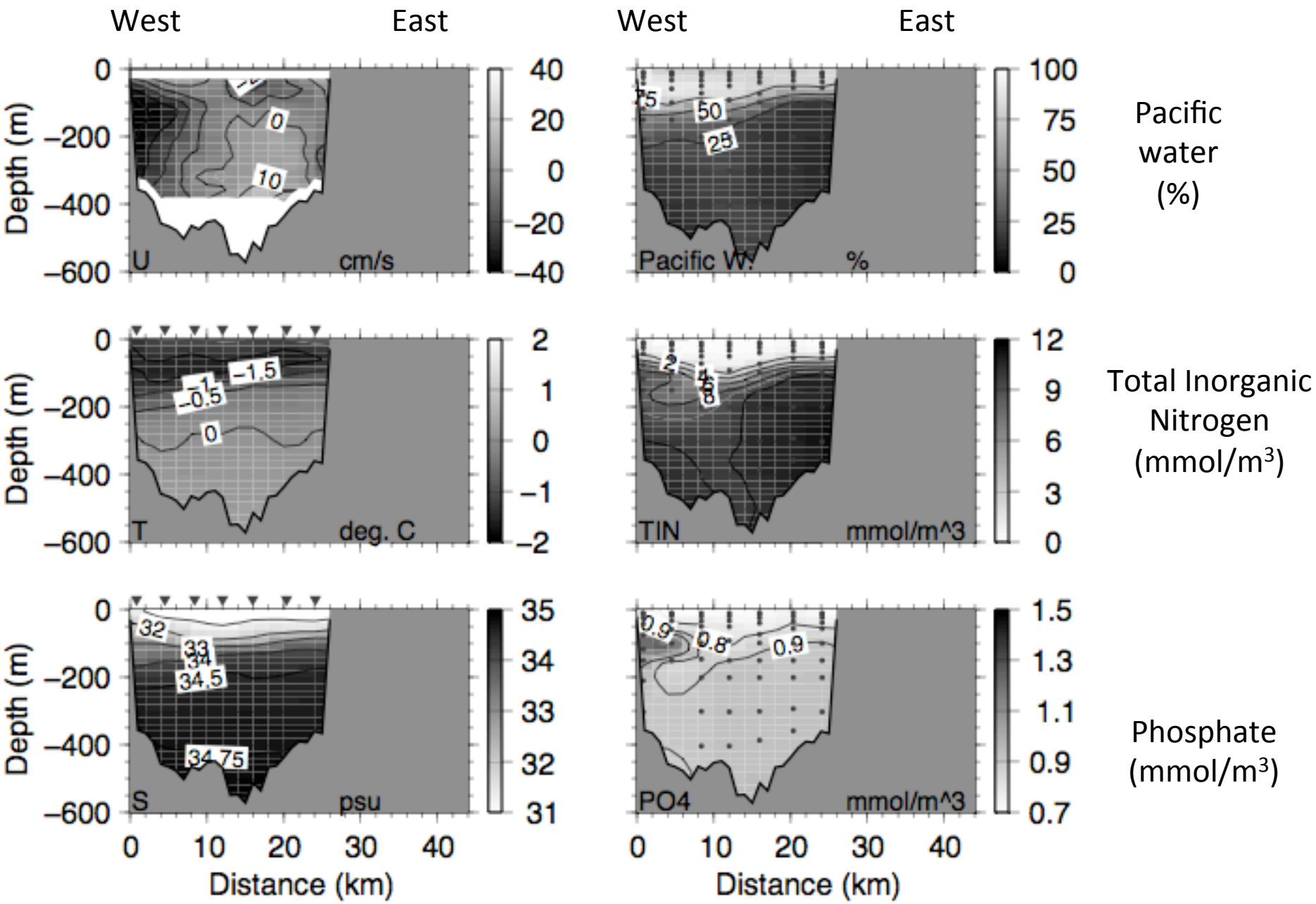
Long time scales of climate variability:
How to maintain climate time series?

Nonlinear physics within Complex Systems:
Equilibria, Tipping Points, Turbulence;

Under ice/water data communication:
Acoustic “cell phone” towers;

Envisioning Information (Edward Tufte):
How to escape Flatland?

Petermann Gletscher →



Pacific water (%)

Total Inorganic Nitrogen ($mmol/m^3$)

Phosphate ($mmol/m^3$)