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

AIR
+0.12 ± 0.04 °C/year

ICE
-5 m/year

OCEAN
+0.06 ± 0.02 °C/year

Credit: Jon Poole, CCGS Henry Larsen, Aug.-2012
Dec.-2/3, 2013
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)

Dec.-2/3, 2013
Greenland Ice Core Data:

Oxygen isotopes $\delta^{18}O \sim \Delta T$ temperature

from Alley et al. (2001)
Dynamic Equilibria:

Single states:

Multiple states:

Adapted from Dr. Berryman, WSU-529 “Population Theory”
Hysteresis Loop of Climate Change

- **Warmer Climate**
- **Colder Climate**
- **Bistable regime**

Meridional Overturning Circulation (Sv)

State variable:
- Climate,
- Fish,
- Economies,
- Fashions

Perturbation

Freshwater Flux (Sv)

Stommel (1961)
Rahmstorf (2002)
Arctic Coastal Processes and Global Climate Change

1. Arctic freshwater \textit{flux} and the global thermohaline \textit{circulation} (nonlinear, multiple equilibria).

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

Need \textit{Velocity} Observations:

Nares Strait Freshwater \textit{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

Dec.-2/3, 2013
Velocity Surveys

Volume Flux: $0.77 \pm 0.10 \text{ Sv}$

Fresh Water Flux: $28 \pm 4 \text{ mSv}$

$L_D \sim 10 \text{ km}$ internal Rossby Radius

Dec.-2/3, 2013
Flux vs. Wind:

-0.77 Sv
-0.92 Sv
-0.91 Sv
-1.03 Sv

-3.8 +/- 0.3 Sv
5.1 +/- 0.2 Sv

Greenland

0.9 +/- 0.1 Sv

Dec.-2/3, 2013
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

km-03, Canada

km-24

km-30

km-34, Greenland

Arc: Ocean

Aug. 12, 2005

~500 km

2003

Time

2006

Dec.-2/3, 2013
M₂ Tidal Amplitude

Mean and Subtidal Variability

No surface data

Bottom Boundary Layer

Ellesmere Island
Greenland
Kane Basin

0.2 m/s
Spectral Density
(cm/s)² per cpd

Winter (Sea Ice)

< 10 Days

Summer (Mobile Ice)
Winter (Landfast Ice)

Summer (Mobile Ice)

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

Dec.-2/3, 2013
Surface Layer Extrapolation/Interpolation

Least-Square Fit (red)

\[ \mathbf{U}(z) = \text{const.} + \text{linear shear} + \text{Ekman layer} \]

Data (black circles)

fit \( \mathbf{U}(z) \) to data

surface layer without data

ADCP data not used

Root mean square Misfit

Data-Fit:

2.3 cm/s average
Mean Flux 2003-2009:

Mean Along-Channel Velocity (cm/s)

\[ \iiint u \, d\text{Area} = 1.02 \text{ Sv} \]

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

\[ \iiint \frac{u(s-s_0)}{s_0} \, d\text{Area} = 59 \text{ mSv} \]
>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 = $a + b \times \text{press. diff.}$

Regression:

\begin{align*}
a &= -0.94 \text{ Sv} \\
b &= 8.86 \text{ Sv/m}
\end{align*}
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?