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

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http://lcySeas.org

1. Introduction: Surveys 1876-2003
2. Nares Strait Moorings 2003-2012
3. Nares Strait Ocean Flux and Dynamics
4. Ice Arches, Land-fast Ice

Collaborators:
Humfrey Melling (Canada), Helen Johnson (England), Kelly Falkner (Oregon), Berit Rabe (Scotland), Helga Huntley and Pat Ryan (Del.)
1928 Marion Expedition

Labrador Shelf Current

Smith (1931)
1979 Baffin Island CTD Survey
Geostrophic Flux Estimates

From Muenchow et al. (2013)
Measured Velocity From ship ADCP

Geostrophic Velocity From CTD section

5.1 +/- 0.2 Sv

187 +/- 30 mSv

From Muenchow et al. (2013)
From Muenchow et al. (2013)
West-Greenland vmADCP section

From Muenchow et al. (2013)
Nares Strait Freshwater Flux Experiment

**USGGC Healy 2003 vessel-mounted ADCP**

-0.77 Sv
-0.92 Sv
-0.91 Sv
-1.03 Sv
-3.8 +/- 0.3 Sv
5.1 +/- 0.2 Sv

0.9 +/- 0.10 Sv

Münchow, Falkner, Melling (2007, 2013)
Nares Strait Freshwater Flux Experiment

Velocity Snapshot (4-days) cm/s

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)
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 unusable:

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

Velocities Time Series (3-years)

Along-Channel Currents, cm/s

-30 cm/s

30 cm/s

Greenland km-34

km-30

km-24

km-03, Canada

Aug. 5, 2005

Arctic Ocean

~300-km

2003

2006

Time
Discovery Harbor
Tide Gauge at 30-m depth:
Recovered 2012 after 4 failed prior attempts

Photo Credits: Derrick Stone
Temperature, salinity, and pressure moorings work with ice and currents. Do not fight it.

Tidal Mooring Lean-Over provides ice avoidance and vertical profiles.

Pressure data from top instrument at KS07:

210 dbar
Ice Profiling Sonars after impact with Petermann Ice Island 2010
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)
Vector Empirical Orthogonal Functions:

Mode-1: 60% (black) of total Variance
Mode-2: 20% (blue)
Mode-3: 11% (green)
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)
55% of Freshwater Flux and 22% of Volume Flux reside in Top 30-m of water column.
Tides and Filters

Alert, northern Ellesmere Island

Adjusted sea level

Filtered sea level

Atmospheric pressure

Sea level

Time (days), April 2005
Residual root mean square: 0.19 Sv

Correlation: $r^2=0.71$

$Q_p = a + b \cdot dP$

$a = -0.84$ 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
Year-1 regression applied to Year-2 and 3

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:
Estimate of Rossby Numbers

Ro ~ 0.2
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
Geostrophic volume and freshwater estimates 2003-2006

Volume flux

Summer: Mobile Ice
Winter: Landfast Ice
Summer Freshwater Flux 50% larger than Winter Freshwater Flux
Winter (Landfast Ice)

Summer (Mobile Ice)

Spectral Density (cm/s)^2 per cpd

10 Days
KS07 Salinity

2003/04
2004/05
2005/06

mobile ice ("summer")
landfast ice ("winter")

Rabe et al. (2012)
Internal Rossby Radius of Deformation $L_D$

Freshwater driven flows generally scale with the internal Rossby radius of deformation, the “eddy” scale

\[ \sqrt{\Delta \rho / \rho_0 \ g \ D / f} \approx 10 \text{ km} \]

- $f$ is Coriolis “force”
- $\rho$ is density
- $D$ is vertical scale of motion
Nares Strait Hydrography, Aug.-2003

\[ \text{Internal Rossby radius of deformation} \]

\[ L_D = \left( \frac{\Delta \rho}{\rho_0 g D} \right)^{1/2} / f \sim 10 \text{ km} \]

from Münchow et al. (2006)
From radar backscatter:
NASA’s Quick and ESA’s Advanced Scatterometers

**Evolution of Multi-Year Ice**

Kwok and Untersteiner (2011)
Frederica de Laguna with Therkel Mathiassen in 1929 near Upernavik, West-Greenland
malaria in the tropics has made it much more challenging to reduce regional or local disease, particularly compared with the successful eradication in many cooler temperate regions where disease transmission historically and for climate/geographic factors has been less robust.

Sachs and Malaney (2002) have shown a striking correlation between malaria and poverty. Moreover, they show that malaria-endemic countries also have a lower rate of economic growth compared with nonmalaria countries, an average growth in per capita GDP of 0.4% per year versus...
Figure 5.13. Annual averages of the global mean sea level (mm). The red curve shows reconstructed sea level fields since 1870 (updated from Church and White, 2006); the blue curve shows coastal tide gauge measurements since 1950 (from Holgate and Woodworth, 2004) and the black curve is based on satellite altimetry (Leuliette et al., 2004). The red and blue curves are deviations from their averages for 1961 to 1990, and the black curve is the deviation from the average of the red curve for the period 1993 to 2001. Error bars show 90% confidence intervals.
When the earth warms, ice sheets and glaciers shrink, and sea level rises.

Impact of 1-meter sea level rise:

- Land area (thousand km²)
- Population (millions)
- GDP (US$ billion)

<table>
<thead>
<tr>
<th>Region</th>
<th>Land area</th>
<th>Population</th>
<th>GDP</th>
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<tbody>
<tr>
<td>Africa</td>
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<td>Global (total)</td>
<td>2,223,000</td>
<td>145 million</td>
<td>US$944 billion</td>
</tr>
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From Anthoff et al., 2006
ADCP transducers
Cape Wilkes, Ellesmere Island, ~ 70 km south

CT sensor
Battery packs (3 years)
Acoustic releases (2)