Monitoring fjord circulation

and ice mélange and shelf circulation

using GPS-tracked icebergs

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....and many others

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KISS workshop
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(photo: D. Carroll 2013)
Greenland Ice Sheet variability

- Accelerating rate of mass loss
- Change is most rapid at edges

ICESat (Schenk and Csatho, 2012)

GRACE (Harig and Simons, 2012)

- Icebergs decreasing on Labrador Shelf and Grand Banks (Timco, Canadian Ice Service, 2007)
Outlet glacier variability

- 200+ outlet glaciers: where change is happening
- Surge in interest in ice-ocean processes (*e.g.*, US CLIVAR working group)
- **Not just Greenland:** SE Alaska, Patagonia, Antarctic Peninsula

What mechanisms link outlet glacier variability to climate system?

1) Atmospheric

2) Ocean

3) Glacier/fjord geometry and geology
Icebergs from Greenland

Impacts:
- global sea level rise
- freshwater distribution
- sediment distribution
- catalyst for biological processes
- shipping risks

Enderlin et al. 2014

Moon et al. 2012

and as a tool to “diagnose”
Fjord circulation: what do we expect?

Mechanisms:
• Estuarine circulation
• Intermediary circulation
• Along-fjord winds
• Tidal processes
• Internal waves
• Hydraulic control

Linked to 3 triggering mechanisms for glacier variability:
1) increased submarine melting
2) change in ice mélange
3) increased crevassing / surface effects

(modified from Straneo et al. 2013)
Observations in Greenland fjords: difficult!

Mooring pressure record on top sphere (64” diameter)
Observations in Greenland fjords: difficult!
Icebergs in Greenland

Rink Glacier, Greenland
June 15, 2007 - July 22, 2011

courtesy Ginny Catania; Extreme Ice Survey
To quantify icebergs’ impact, we need:

1) Iceberg distributions (size and number)

Helheim Glacier & Sermilik Fjord (SE Greenland)

Sermilik Fjord and 50 m vessel

MODIS
July 30, 2013

photo: N. Cobbings
To quantify icebergs’ impact, we need:

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2) Melt rate (dependent on $T(z)$, $S(z)$, velocity, waves, etc.)
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1) Iceberg distributions (size and number)

2) Melt rate (dependent on $T(z)$, $S(z)$, velocity, waves, etc.)

3) Residence time of icebergs in specific regions (e.g., fjord, shelf, mélange)

Helheim Glacier & Sermilik Fjord (SE Greenland)

MODIS
July 30, 2013
Iceberg trackers

Sermilik Fjord:
5 trackers deployed Sept. 2012
5 trackers deployed Aug. 2013

Rink and KS Fjords:
6 trackers deployed Jul. 2013
Iceberg trackers

**BENEFITS**
- Expendable and very cheap
- Hourly velocities, lifetimes > 1 year
- Can be used for more than fjord circulation:
  - ice mélange movement
  - coastal currents
  - iceberg melt

#4, deployed Sept. 2012, lost Dec. 2013
Ice mélange motion in Sermilik Fjord

[Graph showing ice mélange motion with distances and speeds indicated]

Distance from Helheim terminus (km)

Days since deployment

- 23.5 m/d
- 24.3 m/d
- 25.2 m/d
- 18.4 m/d
- 18.3 m/d
- 21.9 m/d
What you get from MODIS imagery

Example of along-fjord velocity, 2012-2013
Higher temporal resolution needed near terminus

Three case studies:

1) Uummannaq Fjord region, central west Greenland

1) LeConte Glacier, SE Alaska

2) Jorge Montt, Patagonia, Chile
1) Uummannaq Fjord region, central west Greenland

NASA project: Sutherland, Catania, Stearns, et al.
2) LeConte Glacier, SE Alaska

courtesy of J. Amundson and R. Motyka
3) Jorge Montt Glacier/Fjord, Chilean Patagonia

circulation primarily driven by along-fjord winds

C. Moffat, 2014
Icebergs are effective drifters (cost- and science-wise) giving unprecedented spatial and temporal information on scales of fjord circulation.

Expand network of iceberg trackers—explore rigidity of mélange, get vertical motion, and quantify FW impact.

Needs:
1) higher temporal and spatial resolution
2) 3-D reconstructions of above water ice surface
Iceberg trackers: a follow up on the destroyed float