Observing Tidewater Glacier Variability: Progress and Challenges
Motivation and Challenges

- Transfer of mass at the glacier-ocean boundary plays a significant role in ice sheet dynamics, mass balance and sea level rise.

- Processes operating at the ice-ocean boundary operate on a range of temporal (seconds to years) and spatial (mm to km) scales.

- Some processes are known to be important but are poorly understood; other important processes might still be unknown.
What parameters *(do we think)* are important?

**glaciology**
- ice flow
- calving
- surface balance
- hydrology

**oceanography**
- hydrography
- circulation
- mélange

**geometry**
- ice thickness
- bathymetry

**climate/meteorology**
- temperature
- winds

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[GRISO, 2012]
How do we observe these parameters?

**Glaciology**
- Ice flow: **RS, in situ**
- Calving: **RS, in situ**
- Surface balance: **RS, in situ**
- Hydrology: **in situ**

**Oceanography**
- Hydrography: **RS, in situ**
- Circulation: **in situ**
- Mélangé: **RS, in situ**

**Oceanography**
- Hydrography: **RS, in situ**
- Circulation: **in situ**
- Mélangé: **RS, in situ**

**Geometry**
- Ice thickness: **surveys**
- Bathymetry: **surveys**

**Climate/Meteorology**
- Temperature: **in situ**
- Winds: **RS, in situ**

**Notes:**
- Bold = well-developed
- Italic = less well-developed

[GRISO, 2012]
Problem of Scale (spatial and temporal)

Network velocities

[Nettles et al, 2008]
in situ vs. remote sensing observations

**in situ:**
- *continuous sampling*
- *spatially limited*
- *difficult to incorporate into models*
- *expensive, challenging*

**remote sensing:**
- *spatially extensive*
- *easier to incorporate into models*
- *cheap and ‘easy’*
- *periodic sampling*
continuous sampling vs. spatial extent

[Moon et al., 2012]
How important is temporal resolution?

[Schild, 2011] [Stearns, 2008]

minimum position each year

~daily positions
How important is temporal resolution?

1-Aug-2008; 1000-1530 UTC; 4 minutes between frames
continuous sampling vs. spatial extent

mechanisms that initiate acceleration and retreat:

1. increased submarine melting
   - ice geometry and roughness
   - subglacial discharge of surface melt
   - oceanic properties and circulation
2. reduction/weakening of ice melange
   - ice properties/thickness
   - atmospheric and thermodynamic forcing
   - oceanic mechanical or thermodynamic forcing
3. increased crevassing and reduced ice strength due to surface warming
   - surface melt

[GRISO, 2012]
Where do we need innovation and improvement?

**in situ** methods:
- robust, low-cost GPS receivers
- radio/satellite telemetry
- innovative data processing/analysis methods
Where do we need innovation and improvement?

Riegl LPM-321

wavelength: 1550 um
range: 1 - 6 km (not ice)
accuracy: 25 mm
precision: 15 mm
msmt. rate: 10 - 1000 Hz
field of view: 360°h x 150°v

near situ methods:

• unattended operation
• high spatial and temporal resolution
• TLS, GBRI, time-lapse cameras
Where do we need innovation and improvement?

- **wavelength:** 1064 um
- **range:** 6 - 10 km
- **accuracy:** 15 mm
- **precision:** 10 mm
- **msmt. rate:** 222 kHz
- **field of view:** 360°h x 60°v
Where do we need innovation and improvement?
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ground-based radar interferometer
Where do we need innovation and improvement?

**wavelength:** Ku-band and C-band

**range resolution:** 75 cm

**azimuthal resolution:**
- **1 km:** 7m (Ku-band); 24 m (C-band)
- **10 km:** 70 m (Ku-band); 240 m (C-band)

**scan rate:** 1 min/scan
1-minute interferograms from September 10-13, 2012.

Ku-band radar (~16 mm wavelength)

Where do we need innovation and improvement?

(24 hours = 1440000)

(2 cm/min ≈ 10 km/yr)
Conclusion

Our ideal ice-ocean observing platform should combine *in situ*, *near situ* and satellite remote sensing measurements.

In some cases, improved remote sensing techniques and platforms reduce the need for extensive networks of *in situ* instruments (e.g. ice flow, calving).
Problem of Scale (spatial and temporal)

Andersen et al., 2010