Airborne and Satellite Observations of the Distribution, Thickness, and Drift of Sea Ice Types and Extreme Ice Features in the Beaufort Sea

BREA Results Forum - Agenda Item 7.2

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Environment Canada Environnement Canada

Canada

BREA priority areas

- Coupled ocean-ice-atmosphere modeling and forecasting

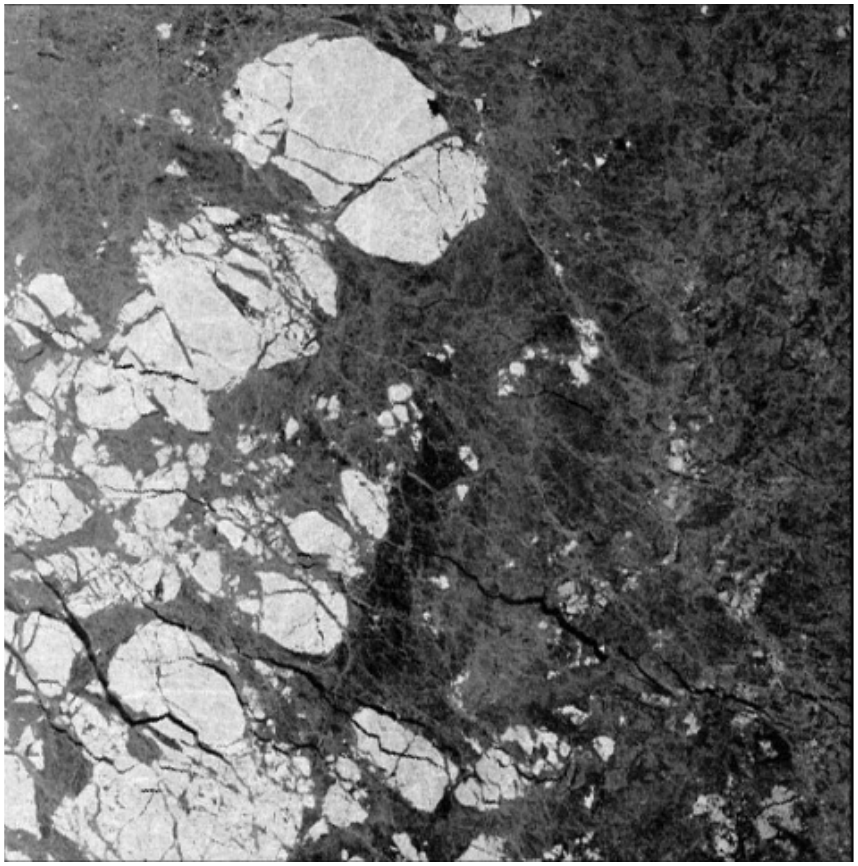
- Sea ice types and extreme ice features

Objectives

1. Provide BREA with information on regional changes in sea ice dynamics and thickness that have occurred within the context of recent changes in the sea ice regime of the Beaufort Sea region
2. Assess thickness and drift of extreme ice features and ice islands
3. Baseline information in preparation for design criteria and regulations for safe and environmentally responsible oil and gas activities
4. Validate new state-of-the-art atmosphere-ice-ocean model for operational sea ice forecasting in the Beaufort Sea, currently under development at Environment Canada.

Activities

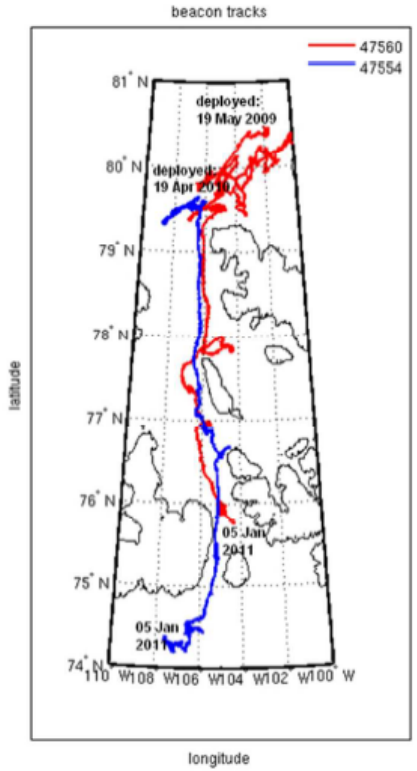
- Analysis of Canadian Ice Service (CIS) Ice Charts and Automated Sea Ice Tracking System (CIS-ASITS) using Radarsat data

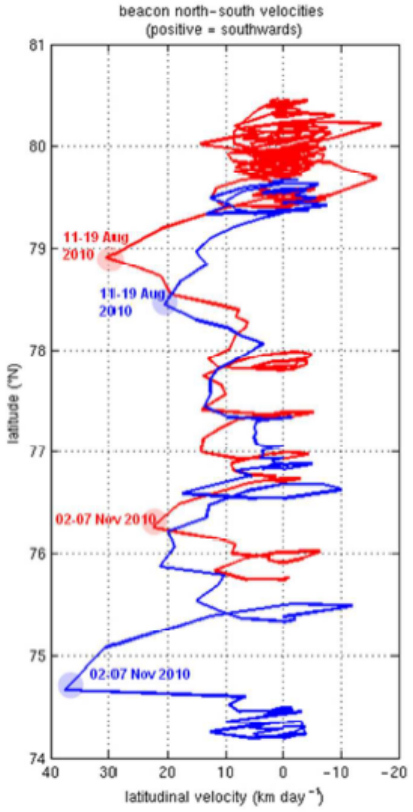


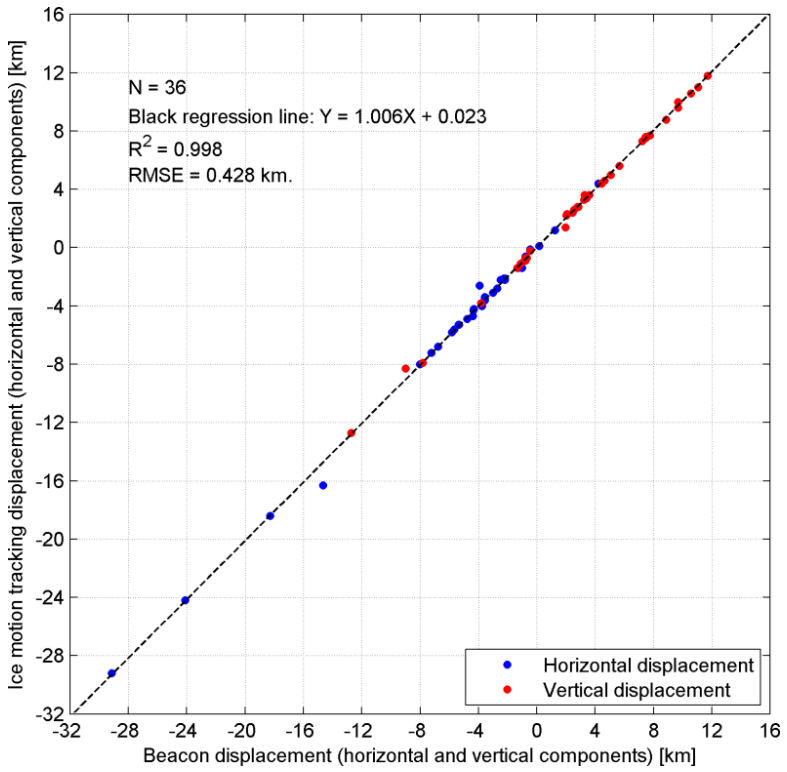
- Employs a phase-correlation approach to estimate both translation and rotational components of sea ice motion
- Limitations primarily during the melt season: i) large tone differences are a result of surface melt water on the ice and ii) lower ice concentrations with open water and wind

Canadian Ice Service Automated Sea Ice Tracking System (CIS-ASITS)

- RADARSAT derived ice drifts compared well with those from ice island fragments and MYI in the Beaufort Sea bearing CIS satellite-tracking beacons with errors ~0.5 km d^{-1}







Wohlleben et al. 2013
Komarov and Barber 2013-IEEE TGARS

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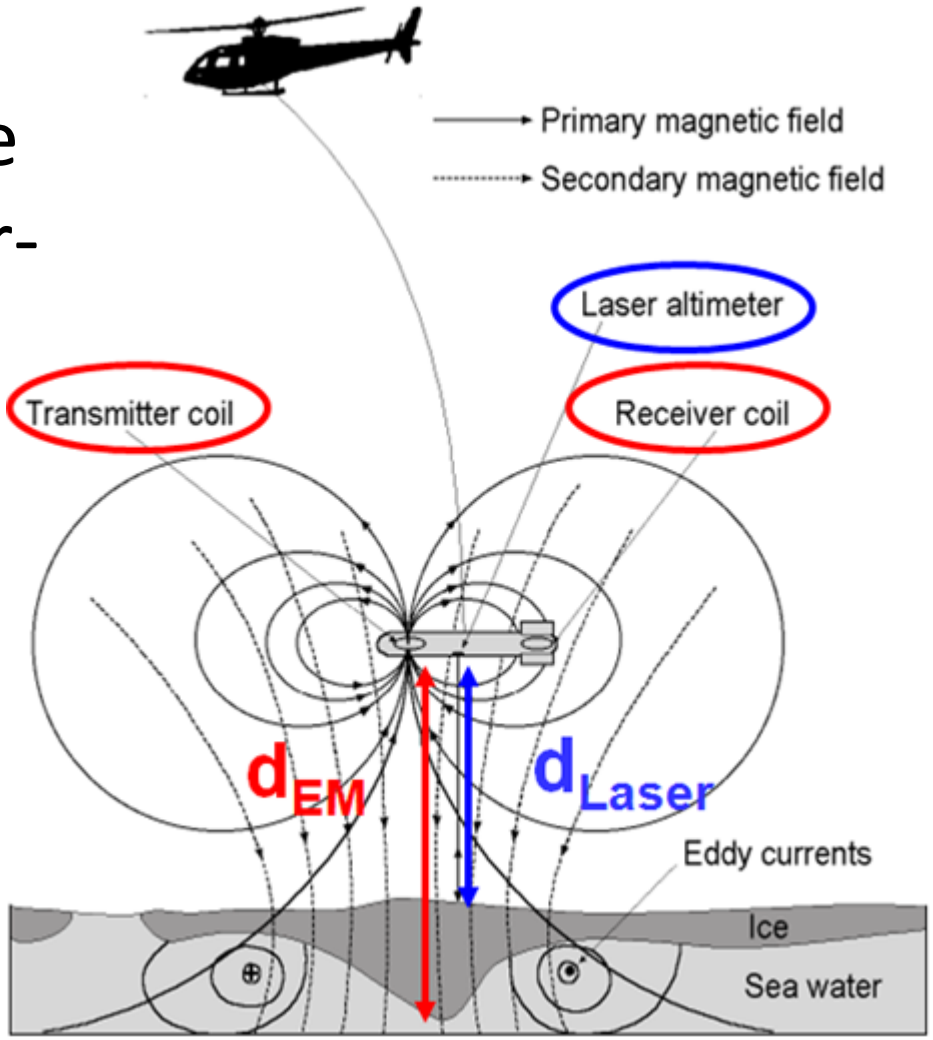
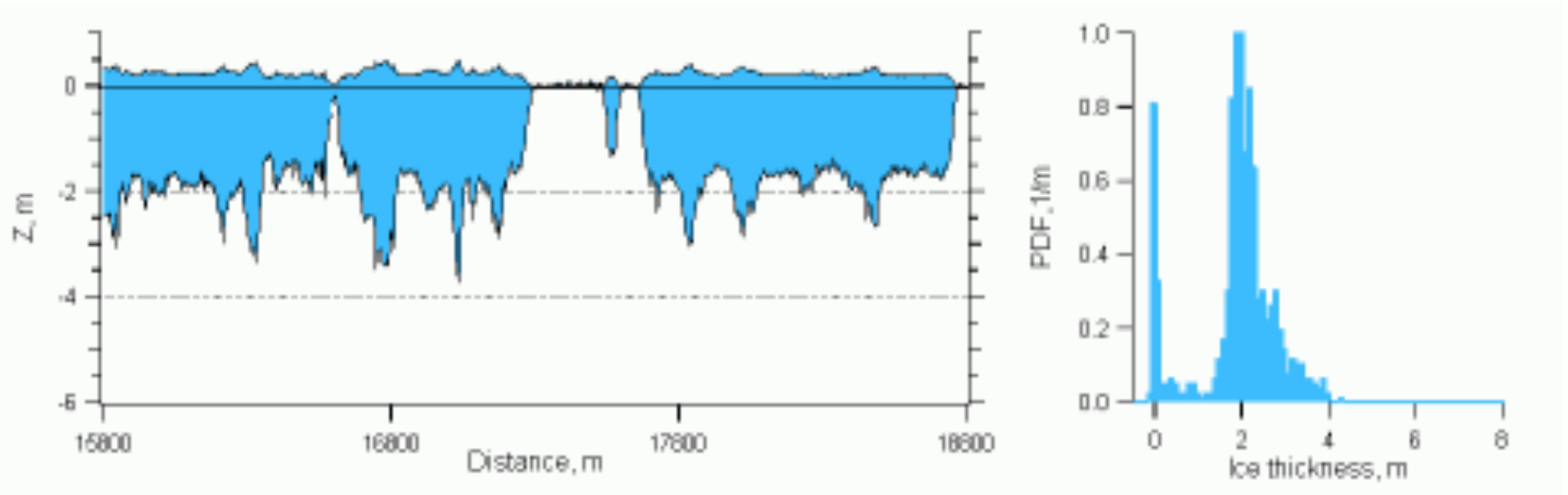
Activities

- Perform airborne electromagnetic (EM) ice thickness surveys and air-drop GPS beacons



$$Z_i = d_{EM} - d_{Laser} \text{ (snow + ice)}$$

Typical airborne EM thickness profile



- 0.1 m accuracy over level ice
- Smoothing of ridges due to footprint
- Independent ridge information from laser & INS & DGPS

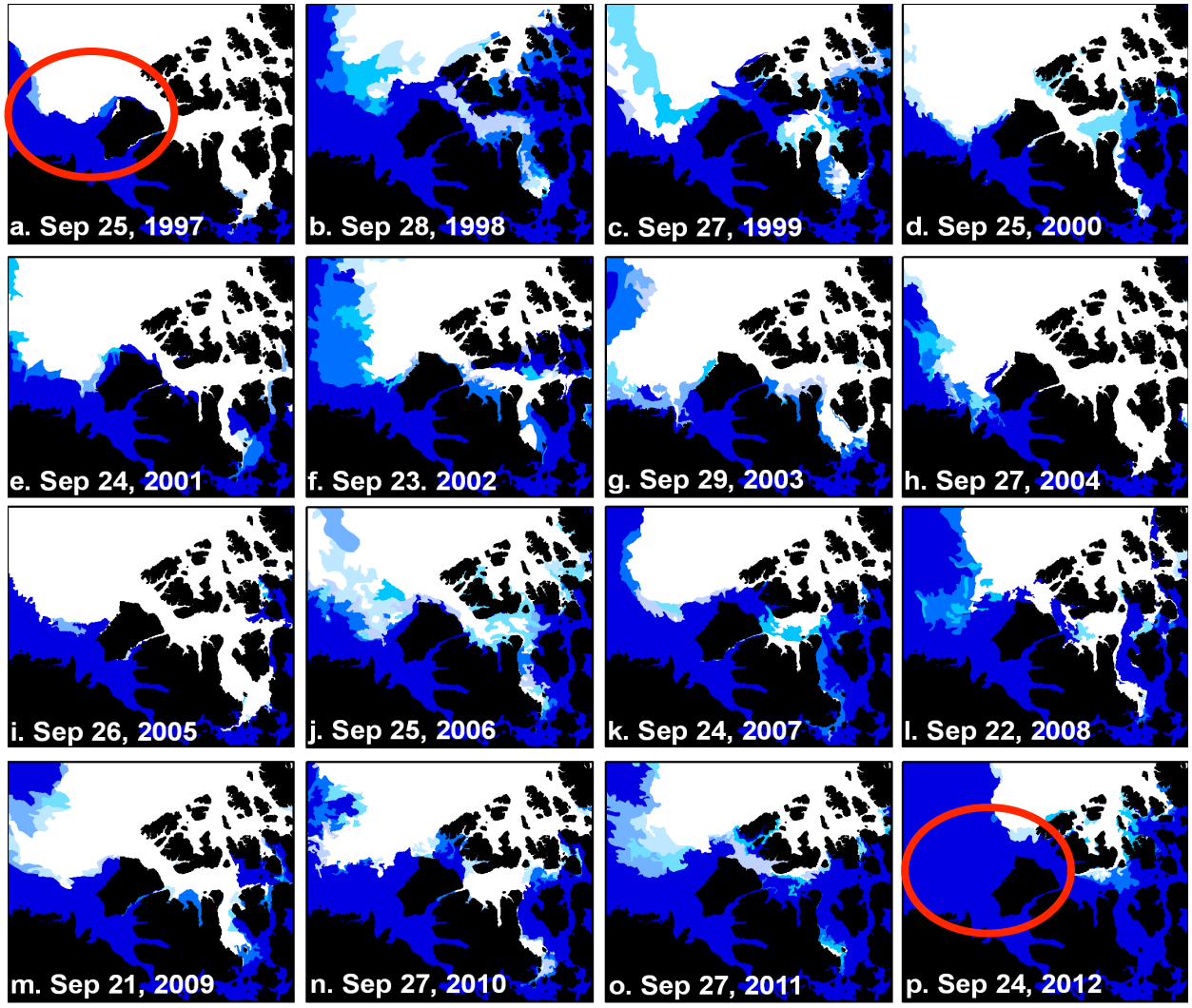
EM thickness sounding with DC-3/Basler BT67 airplane

Results

1. Ice motion and export from the Canadian Arctic Archipelago (CAA)

(Environment Canada results)

Beaufort Sea ice cover variation 1997-2012

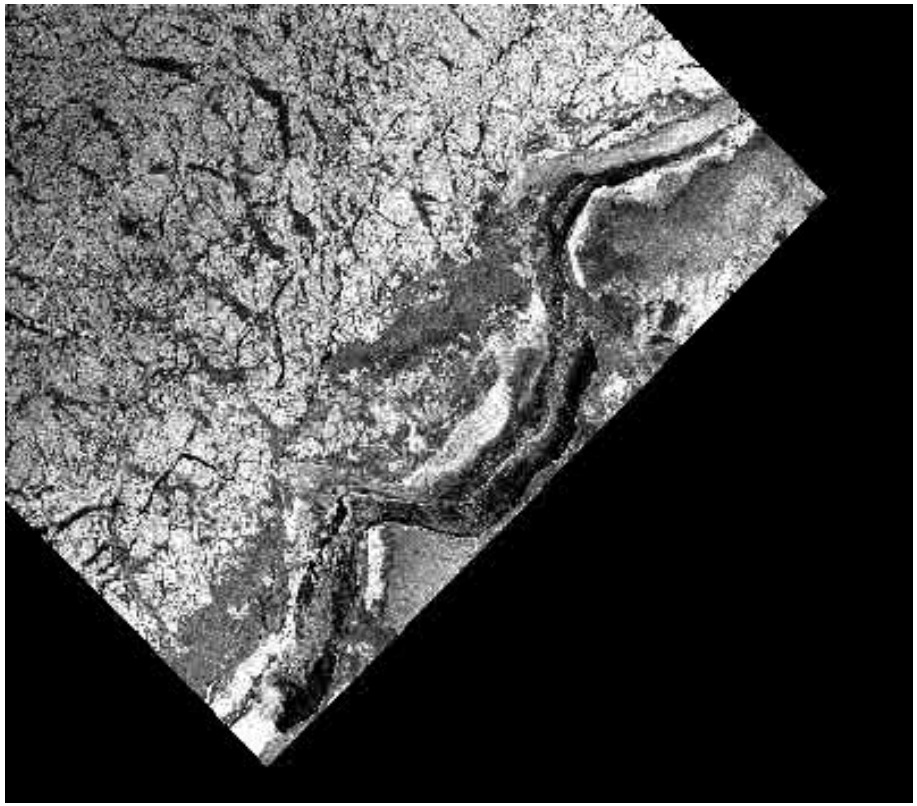


- Has there been a recent change in CAA-Arctic Ocean ice exchange given the changes in the ice cover of the Beaufort Sea over the past decade?

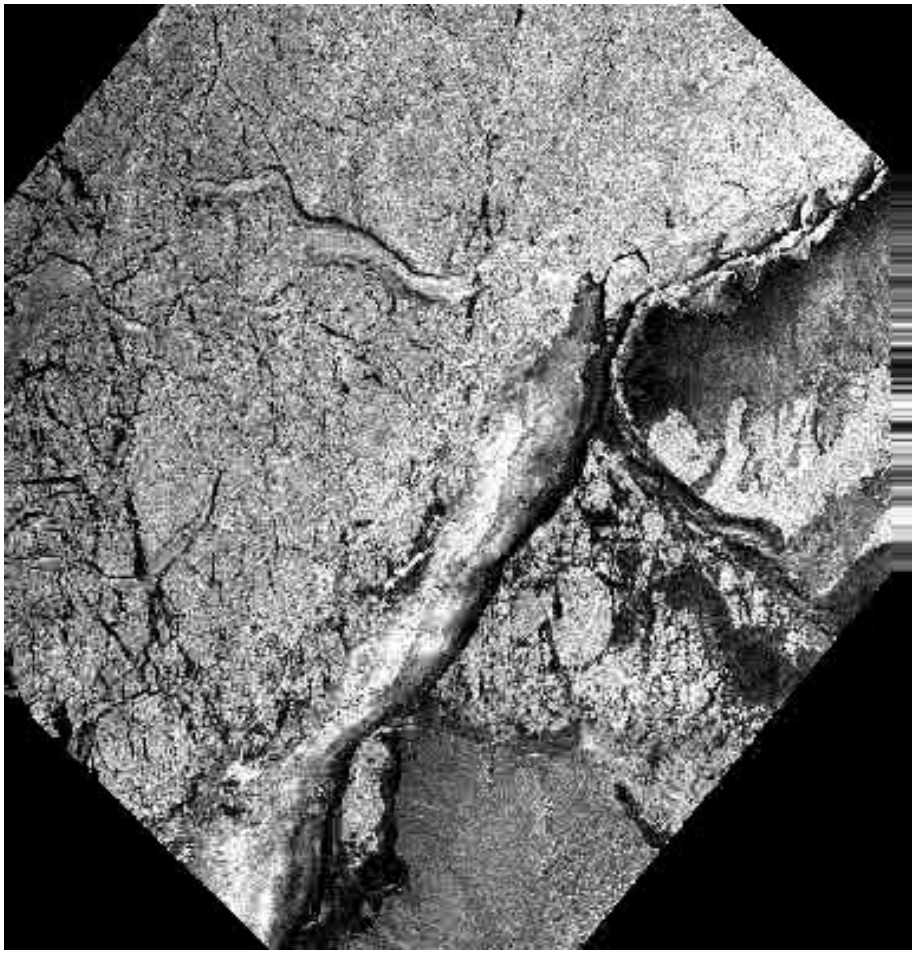
Canada

M’Clure Strait: Import and Export

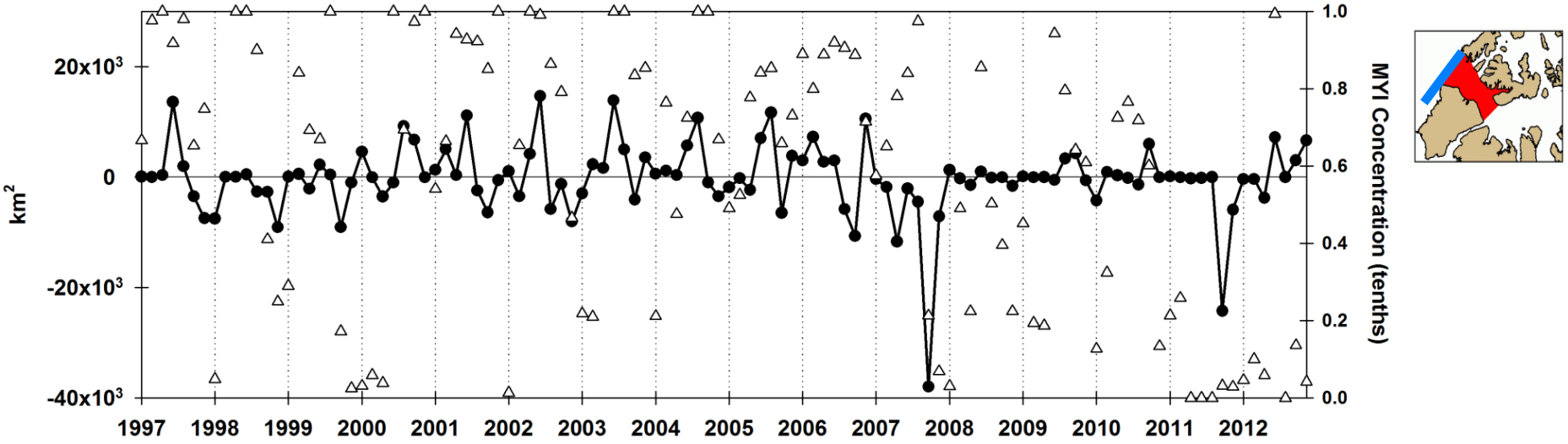
2003 (import)



2007 (export)



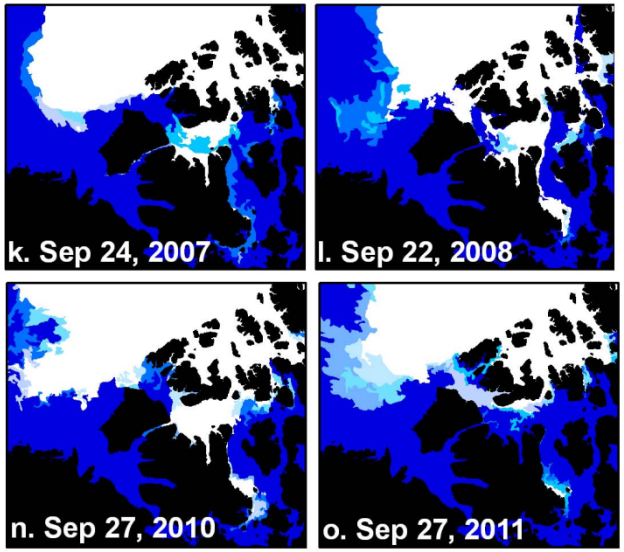
M'Clure Strait: Time Series of Monthly May to November Ice Area Flux, 1997-2012



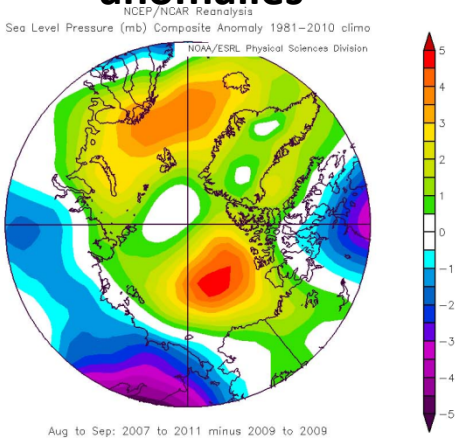
- Over the 16-year period there was variable ice inflow and outflow from May to Nov
- More May to Sep net positive Arctic Ocean ice inflow from ***1997-2006***
  - ***104x10³ km²***; high MYI concentration
- Less May to Sep net positive Arctic Ocean ice inflow from ***2007-2012***
  - ***-20x10³ km²***; low MYI concentration

Ice export and winds

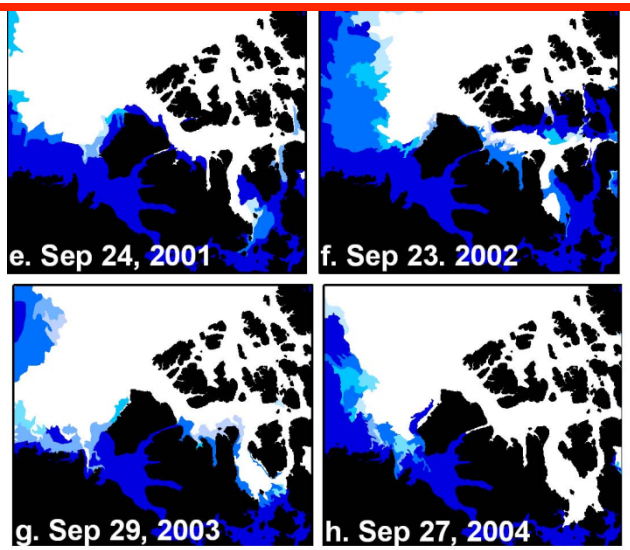
- High pressure over northern Beaufort: reduced/stagnant import into CAA

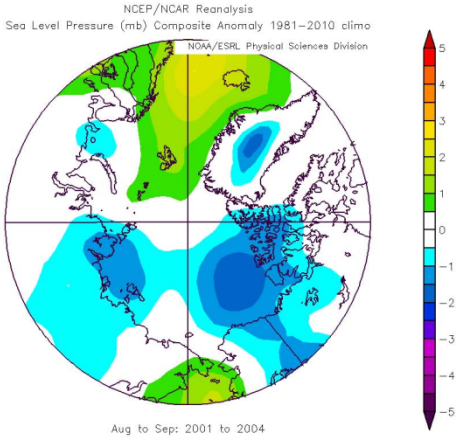


Sea level pressure anomalies



- Low pressure: import into CAA ("normal" situation)
- Intensity and location of pressure patterns important





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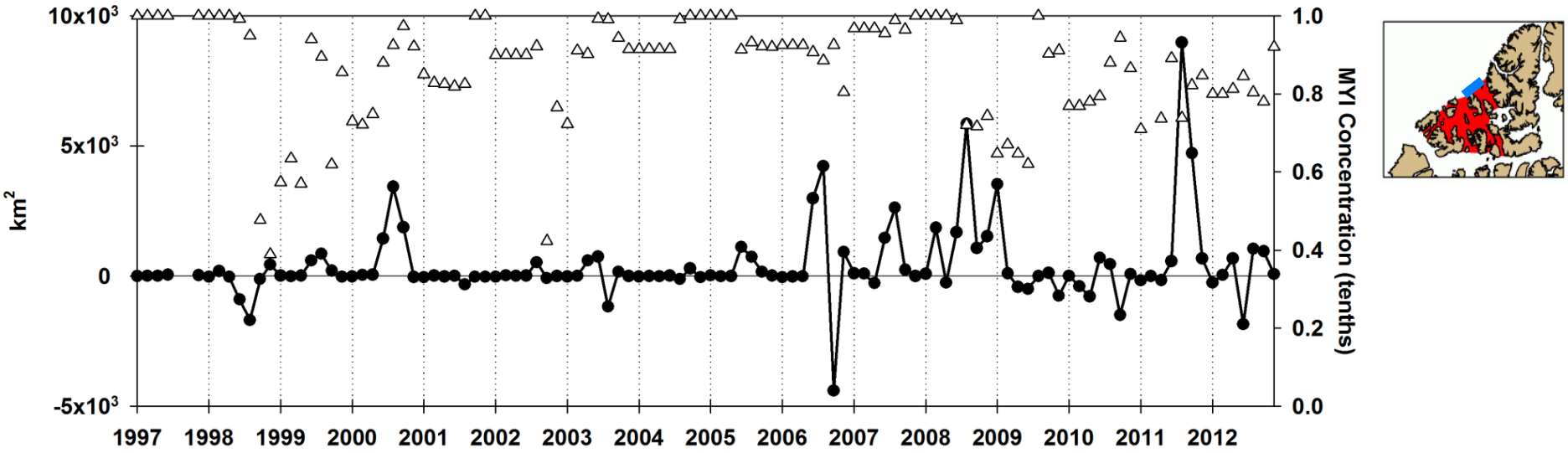
QEI-N: Time Series of Monthly May to November Ice Area Flux, 1997-2012



- Over the 16-year period there was mostly Arctic Ocean inflow from May to November
- More May to Sep more net positive Arctic Ocean ice inflow ***since 2006***
  - 1997-2005: ***9x10³ km²***
  - 2006-2012: ***35x10³ km²***
- Increased import into QEI does not offset losses through M'Clure

Results

2. Thickness of sea ice, multiyear hummock fields, and ice islands

- Data from 2009, 2011, and 2012

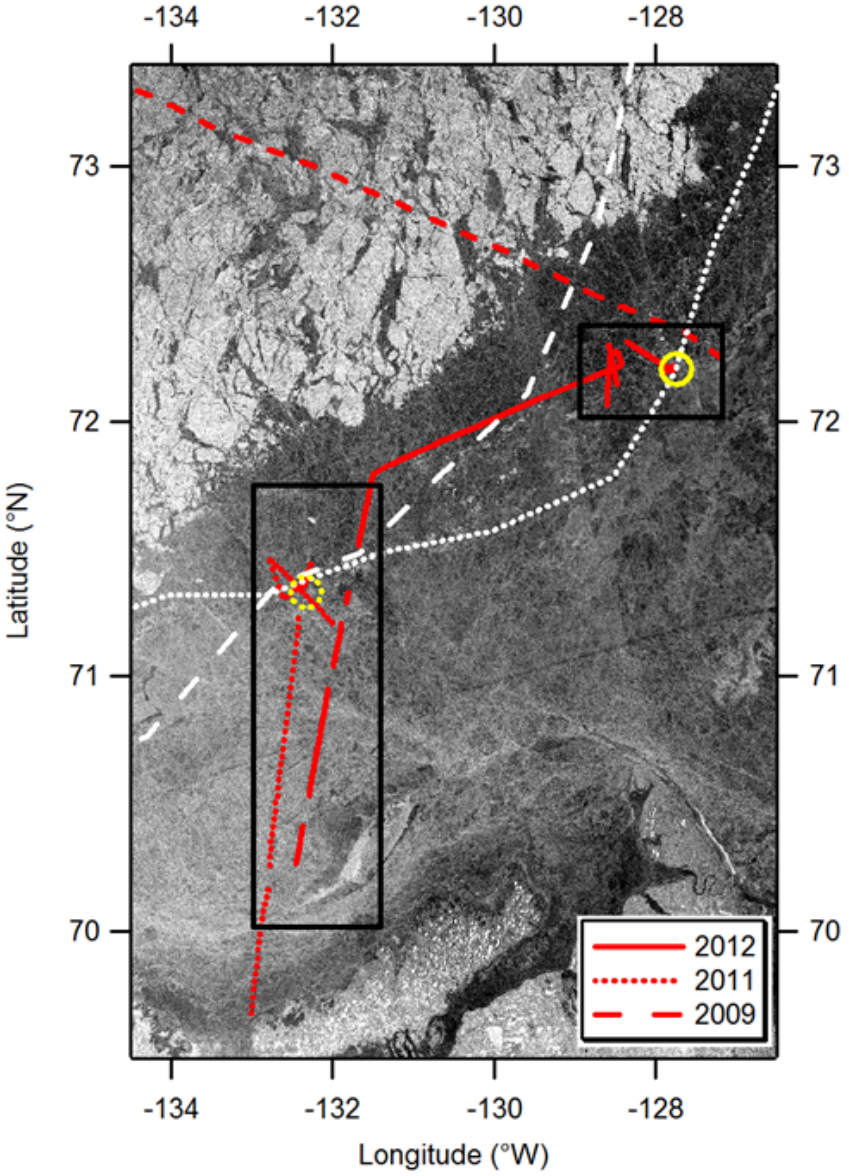
  (York University/University of Alberta results)

Publication:

Haas, C., (2012), Airborne Observations of the Distribution, Thickness, and Drift of Different Sea Ice Types and Extreme Ice Features in the Canadian Beaufort Sea, Proceedings of the Arctic Technology Conference ATC, Houston, Texas, December 3-5, 2012, Paper No. OTC 23812, 8 pp.

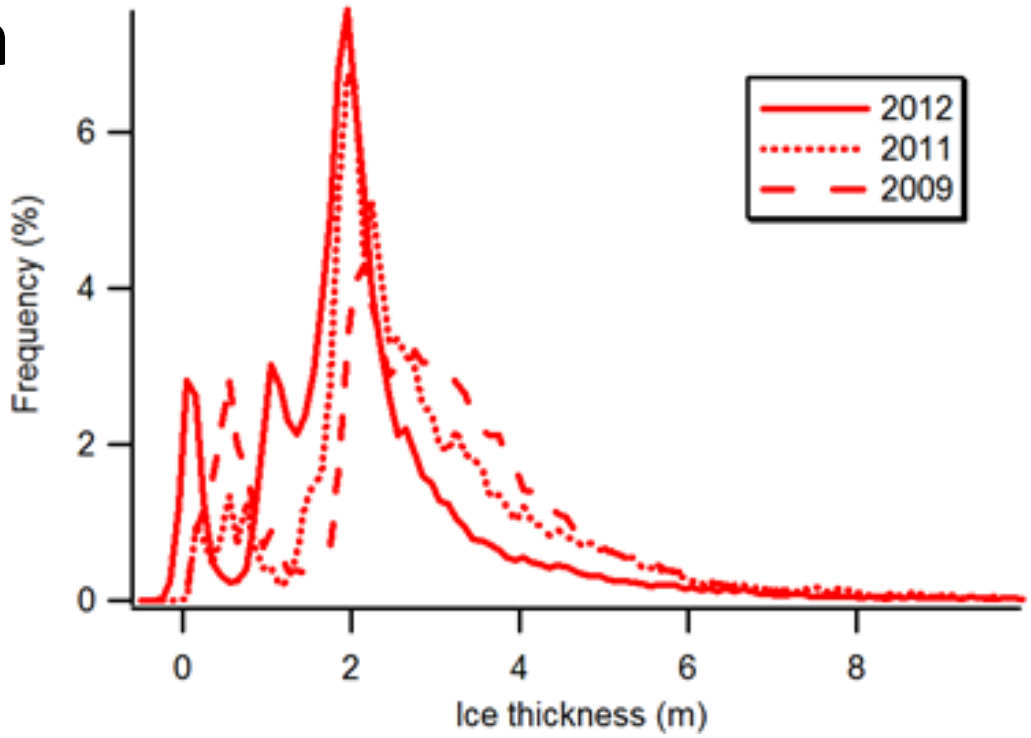
Ice conditions

- Three flights in 2009, 2011, 2012
- Different regions surveyed
- Note variability of multiyear ice edge
- Ice islands (yellow circles)



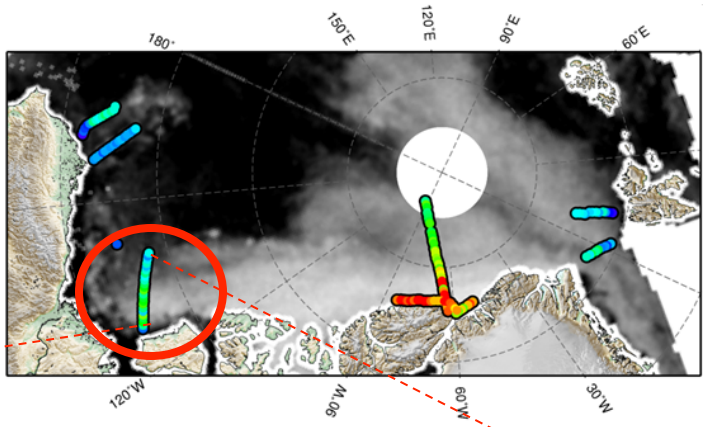
Ice thickness histograms

- Dominated by first-year ice, 2.0 – 2.2 m thick
- Multiyear ice represented by bulges, 3.0 – 3.7 m thick

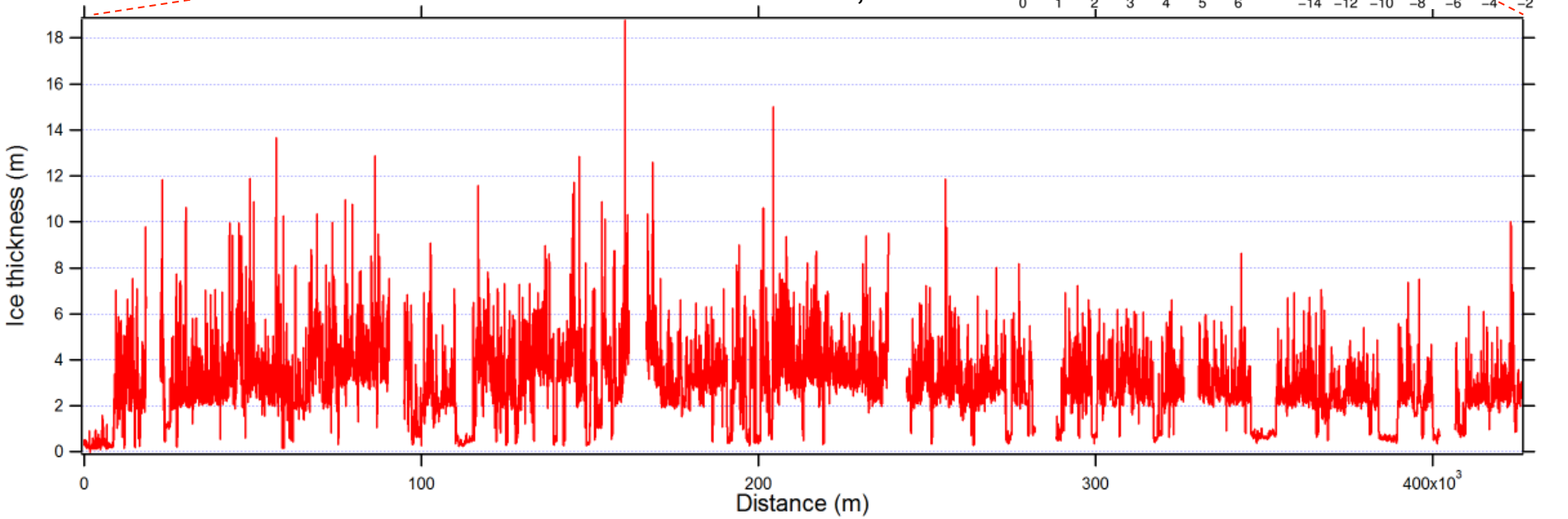


Cross section through Beaufort Gyre

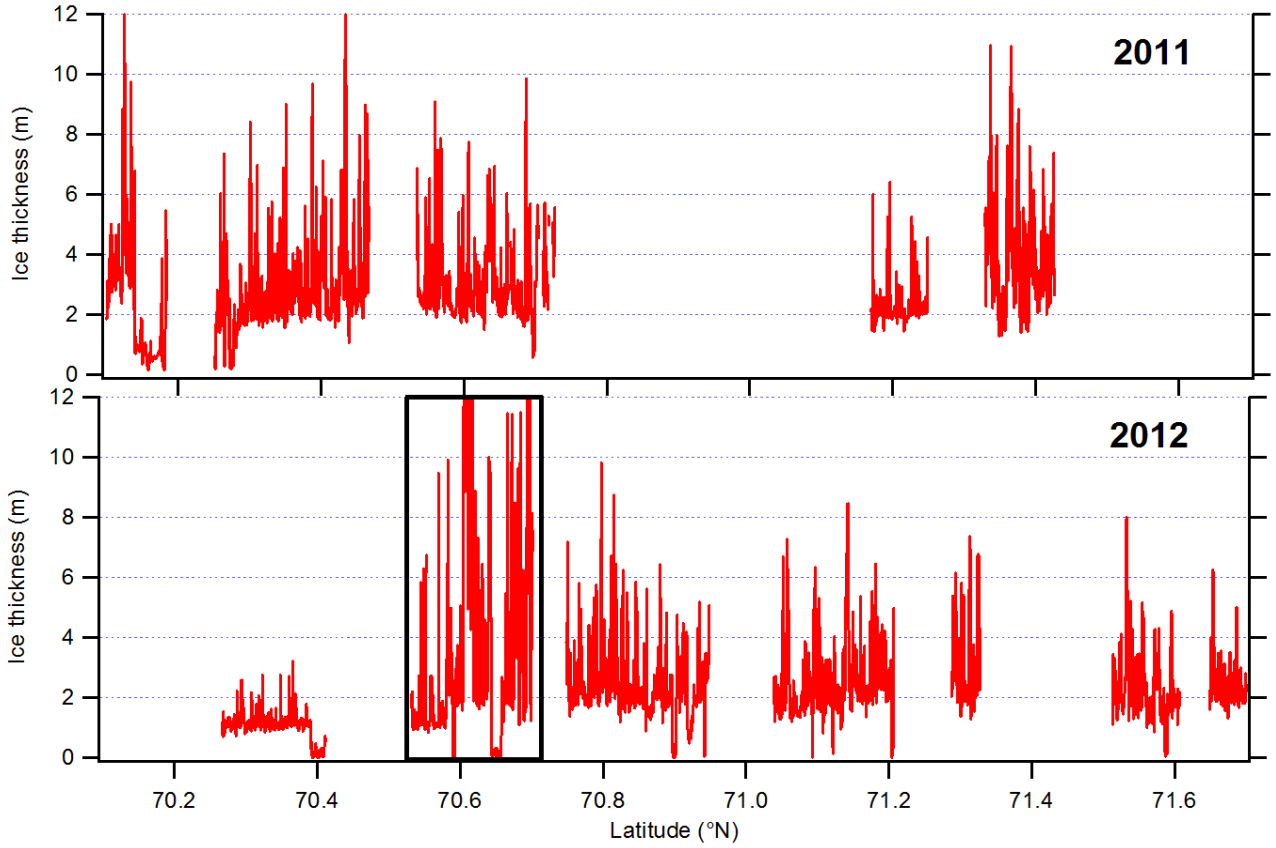
- Dispersed fields of > 4 m thick MYI in outflowing Beaufort Gyre branch

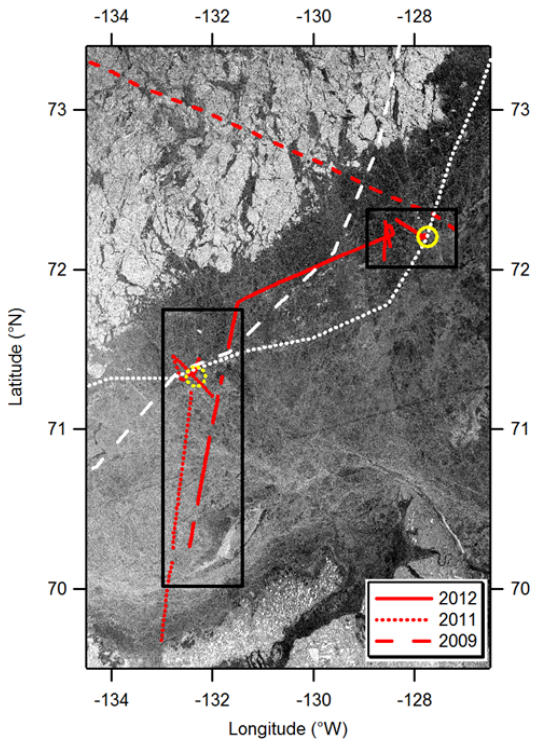


Haas et al., 2010



Extremely deformed first-year ice

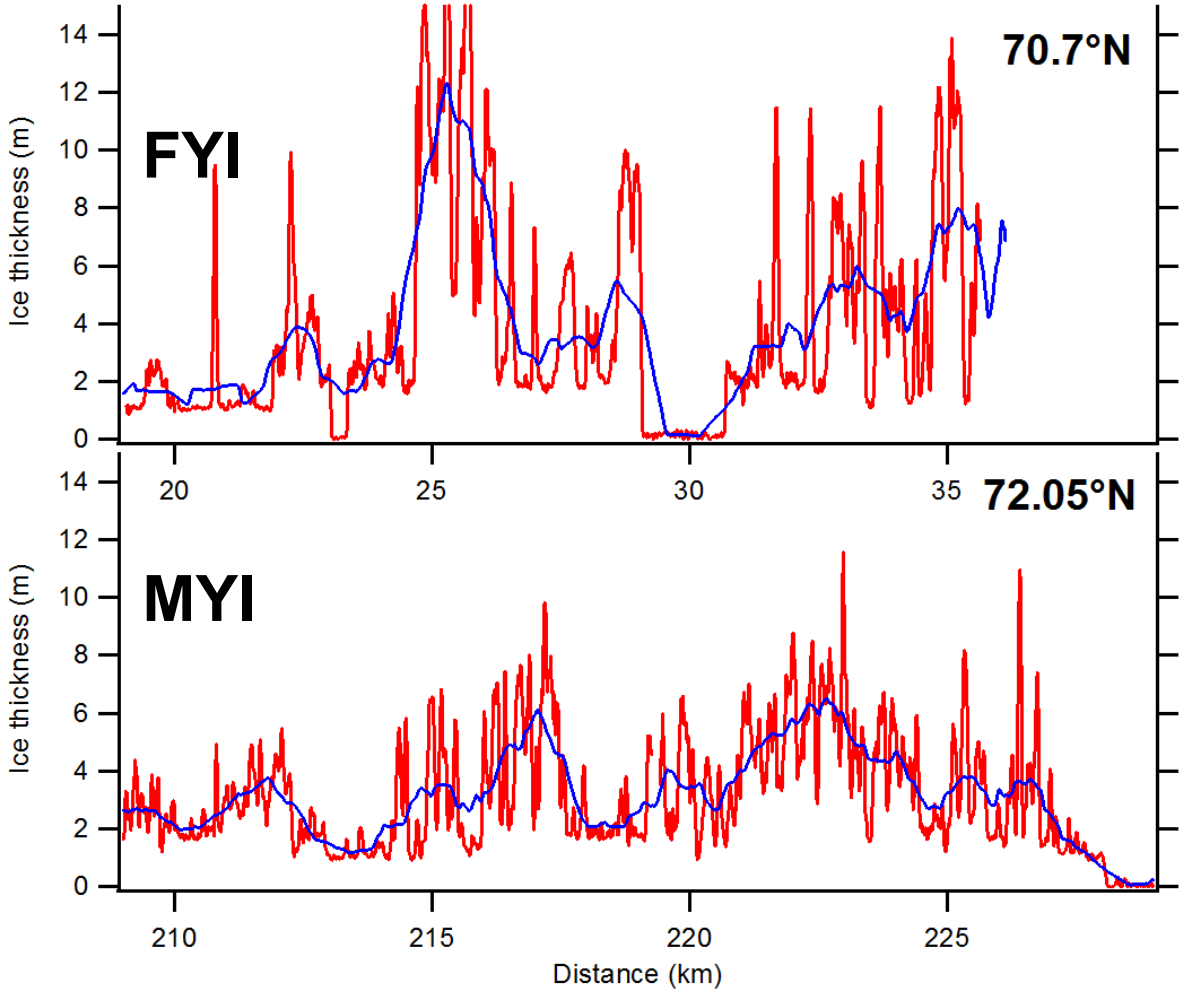




- Note highly deformed areas near flaw lead

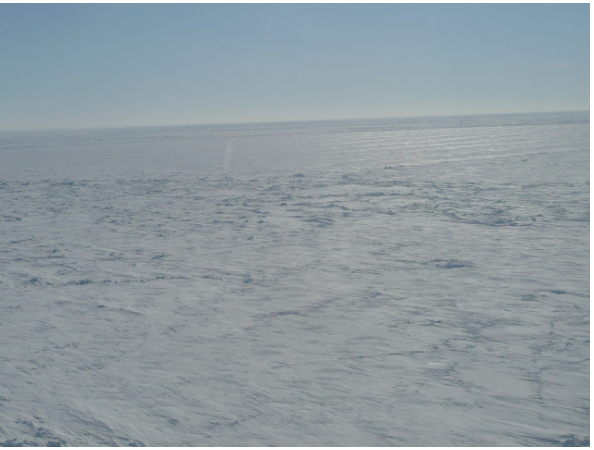
FYI vs. MYI hummock fields

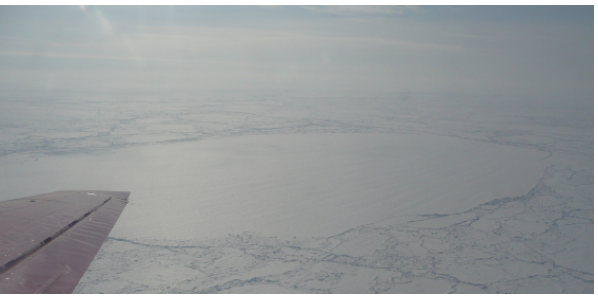
- FYI may be thicker than MYI as it has undergone no summer melting
- May have different keel properties

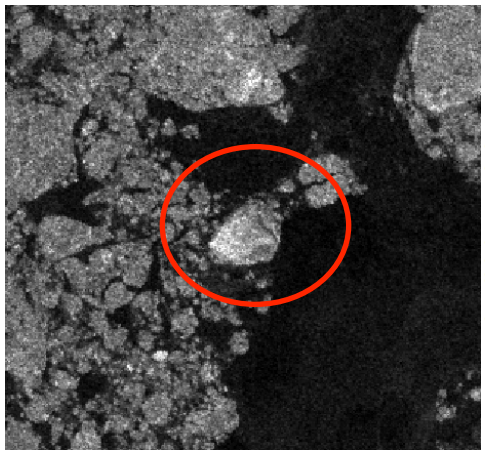


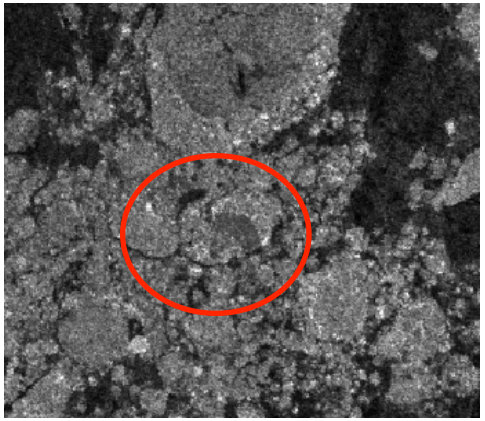
Blue line: 1 km moving average

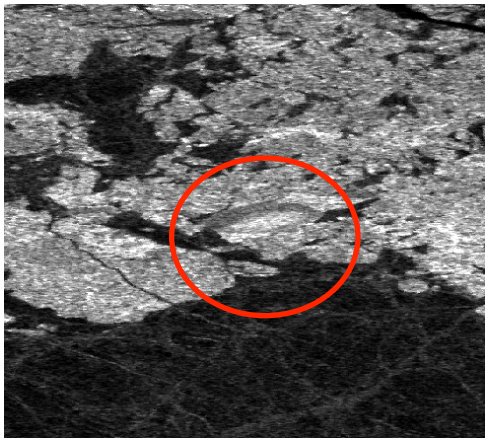
Ice Islands



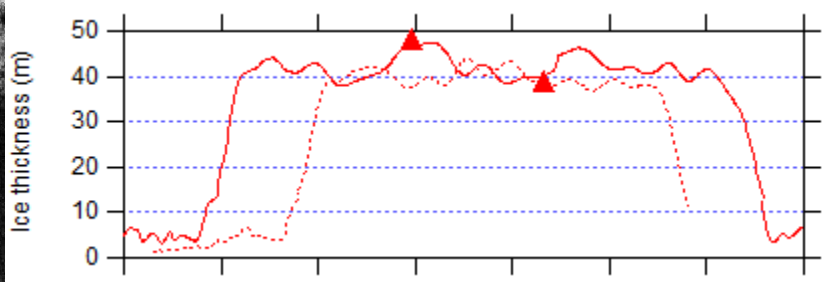




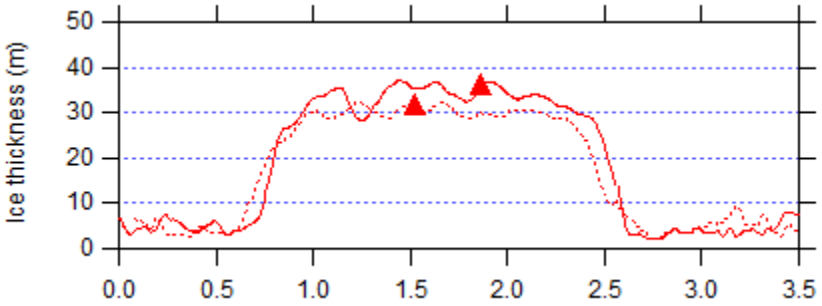




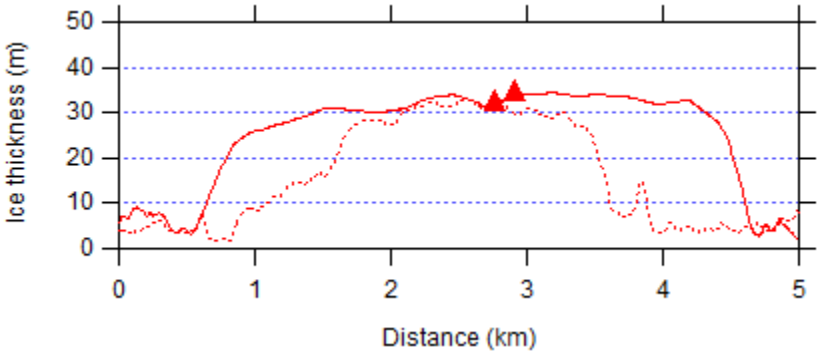
Byam Martin Channel



Viscount Melville Sound



Southern Beaufort

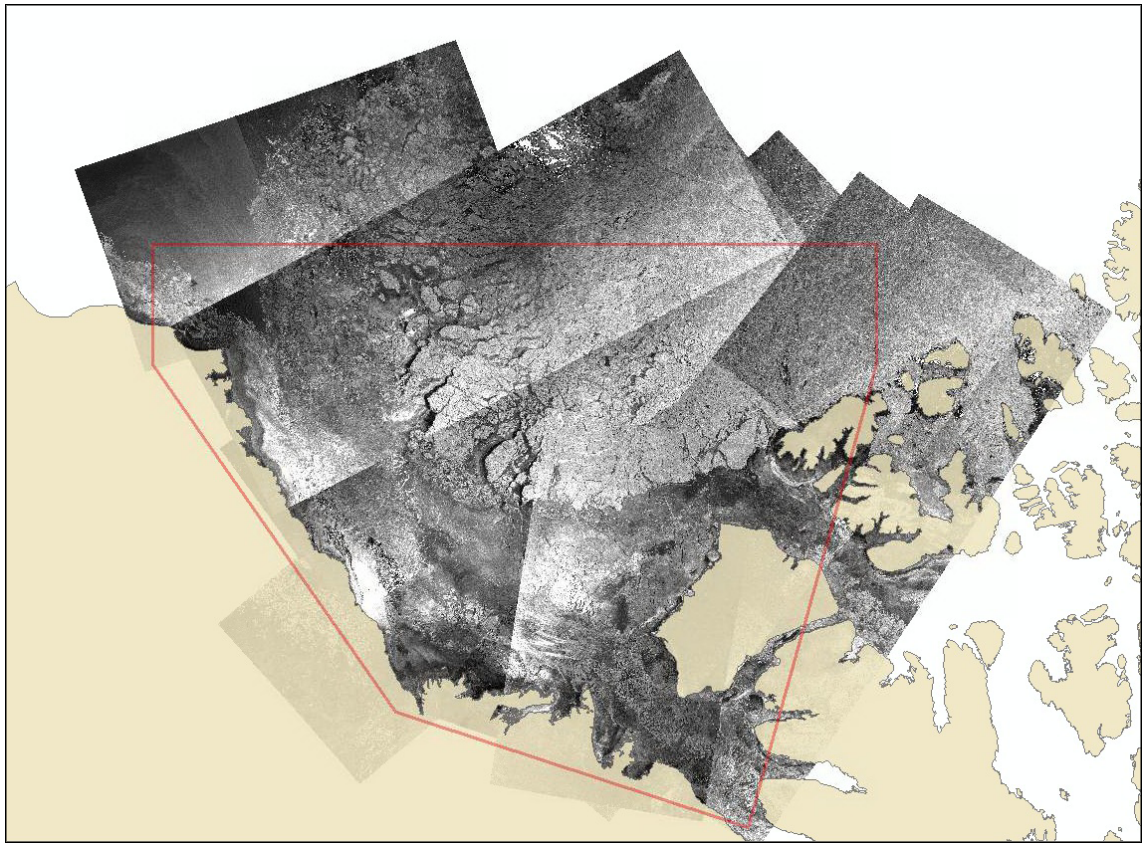


Future plans – Ice motion observation

- Derive sea ice motion products for the Beaufort Sea using the Canadian Ice Service operational archive of RADARSAT-1 and RADARSAT-2 imagery
- Same approach as for CAA

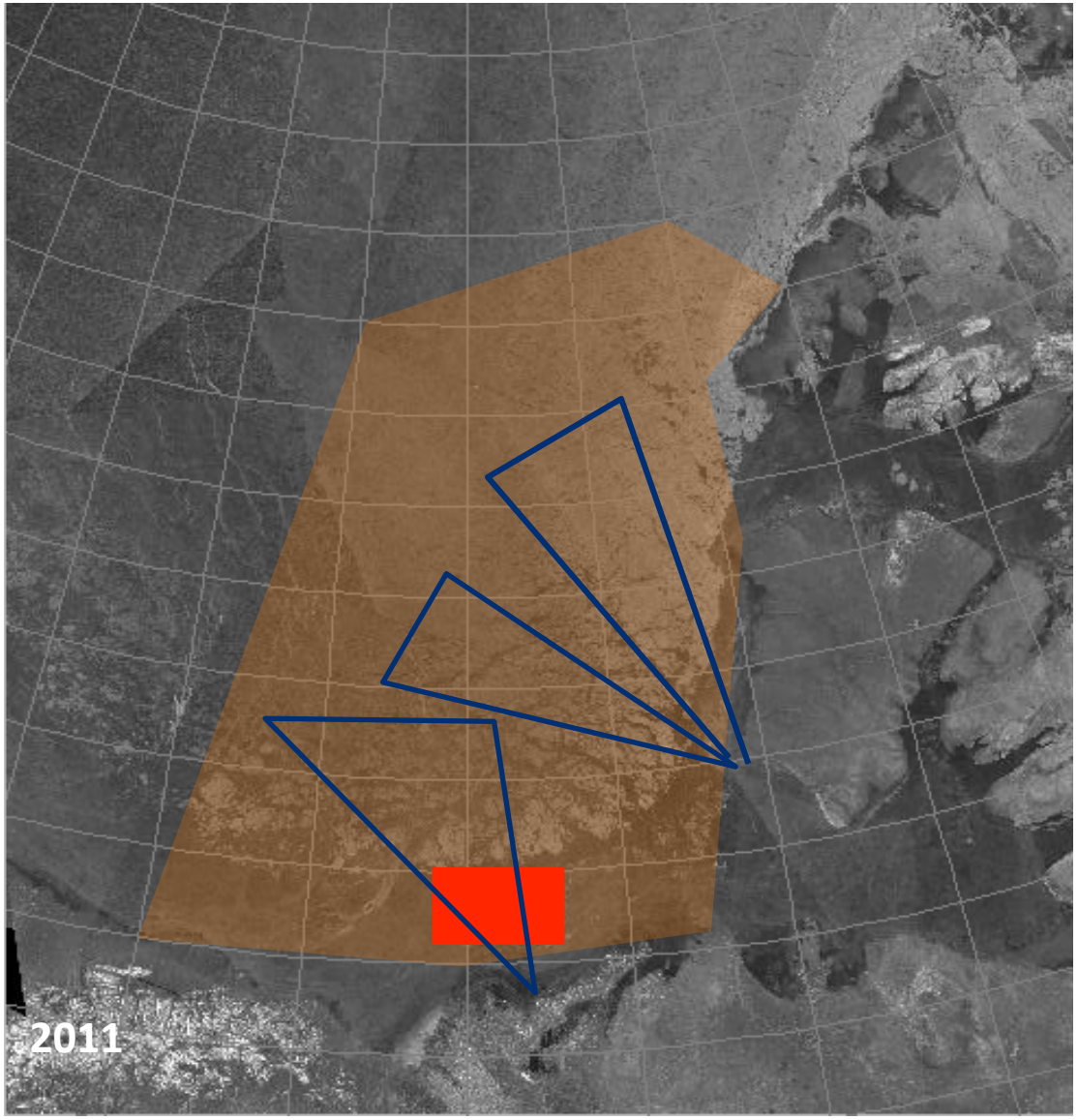
  Image volume: ~300 ScanSAR images per month = complete coverage every 3 to 4 days.

- Validation with GPS beacons



Future plans – Ice thickness surveys

- 3 flights planned from Inuvik and/or Sachs Harbor, aimed at multiyear ice and ice islands (April 10-17, 2013)
- GPS beacons will be air-dropped on same flights
- <u>Opportunity for wildlife observations and other community contributions/ participation</u>



Where from here?

- Results most useful for Regulators, Industry, and Academia?
- Regions/locations of particular interest?
- What parameters should additionally be observed?
- What is the traditional knowledge about multiyear ice thickness and drift in Beaufort Sea?

Thank you!