An Integrated Sea Ice Project For BREA:

Detection, Motion and RADARSAT Mapping of Extreme Ice Features in the Southern Beaufort Sea

David G. Barber, Klaus Hochheim, Greg McCullough, David Babb, Anna Crawford, Alexander Komarov, Jennifer Lukovich, Matt Asplin

Community Based Monitoring

Charlie Haogak, Jim Wollki and J.D. Keogak

Inuvik, February 2015

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Objectives

The project's overarching objective is to develop an understanding of physical and engineering characteristics of sea ice features as they relate to shipping and future oil /gas exploration activities in the Beaufort Sea.

The University of Manitoba work included

- collecting new data and integrating existing field data on
  - extreme sea ice features (ice thickness/ice mass balance)
  - sea ice motion (oceanic and atmospheric forcing)
- developing approaches to identifying significant ice features using remote sensing
- piloting a community based monitoring program in which Sachs Harbour residents monitored local ice thickness using an electro-magnetic induction system.

The U of M portion is integrated with components lead by Michelle Johnson (NRC, Ice thickness and strength) and Christian Haas (U of York, regional ice thickness distribution).

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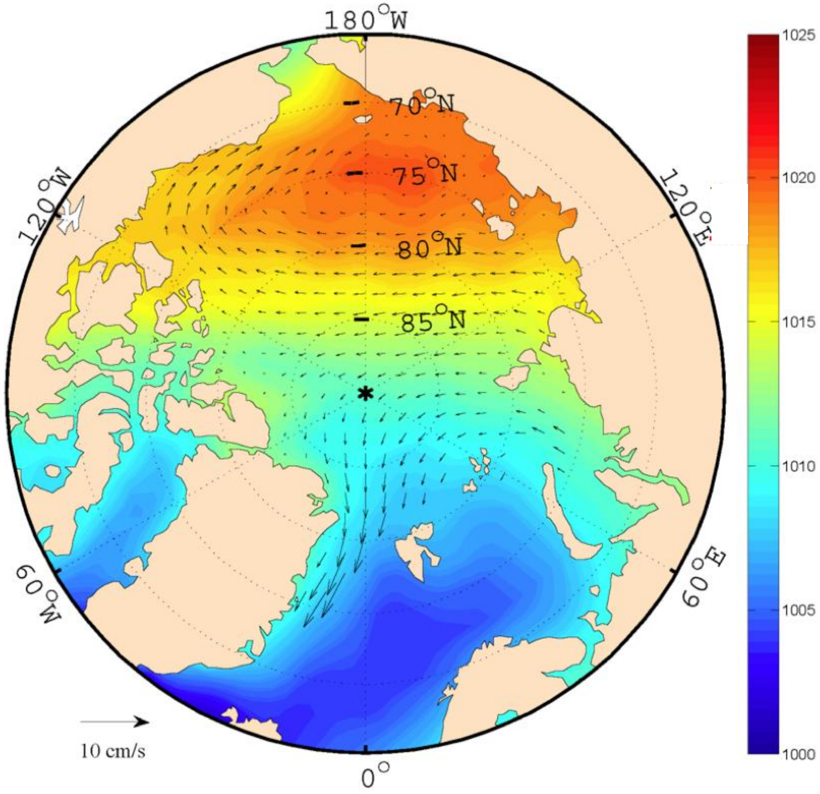
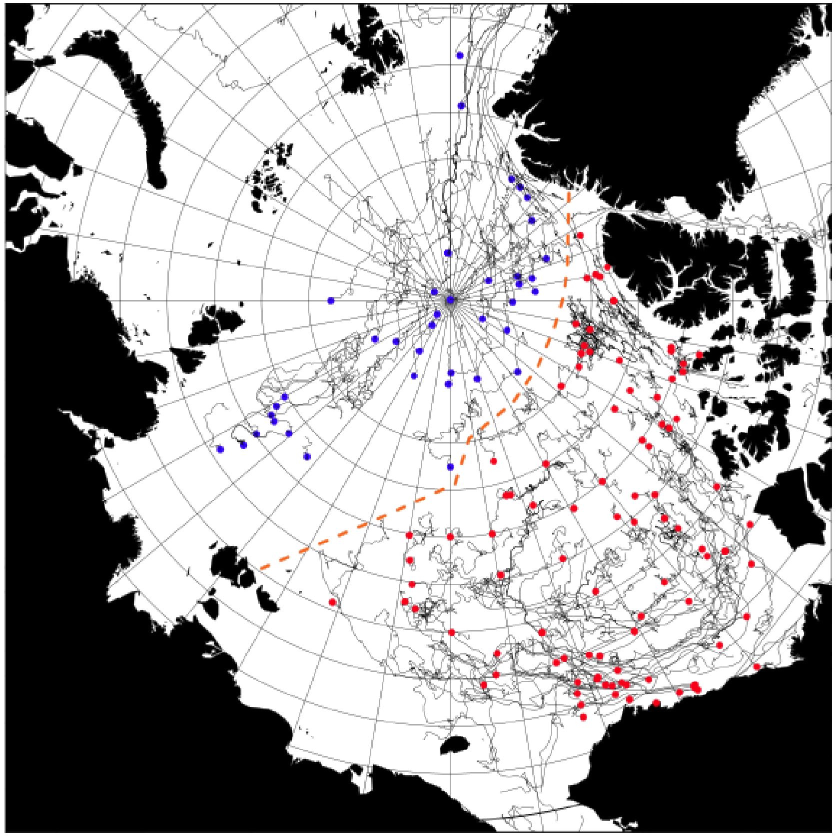
Presentation Outline

- Background
- Study Site
- Field Work:
  - multiyear ice motion by drifting ice beacons
  - in-situ winds and under-ice ocean currents by weather station and drifting current profiler
  - ice floe decay by ice mass balance measurements
  - ice thickness by surface electromagnetic induction surveys
  - ice drift and surface winds by satellite (synthetic aperture RADAR)
- RADARSAT-2 detection/monitoring of extreme ice features (ice signatures)
- Community Based Monitoring (Sachs Harbour) – ice thickness, CTDs

Ice Motion
The two sea ice gyres



Double Gyre Pattern



IABP ice motion

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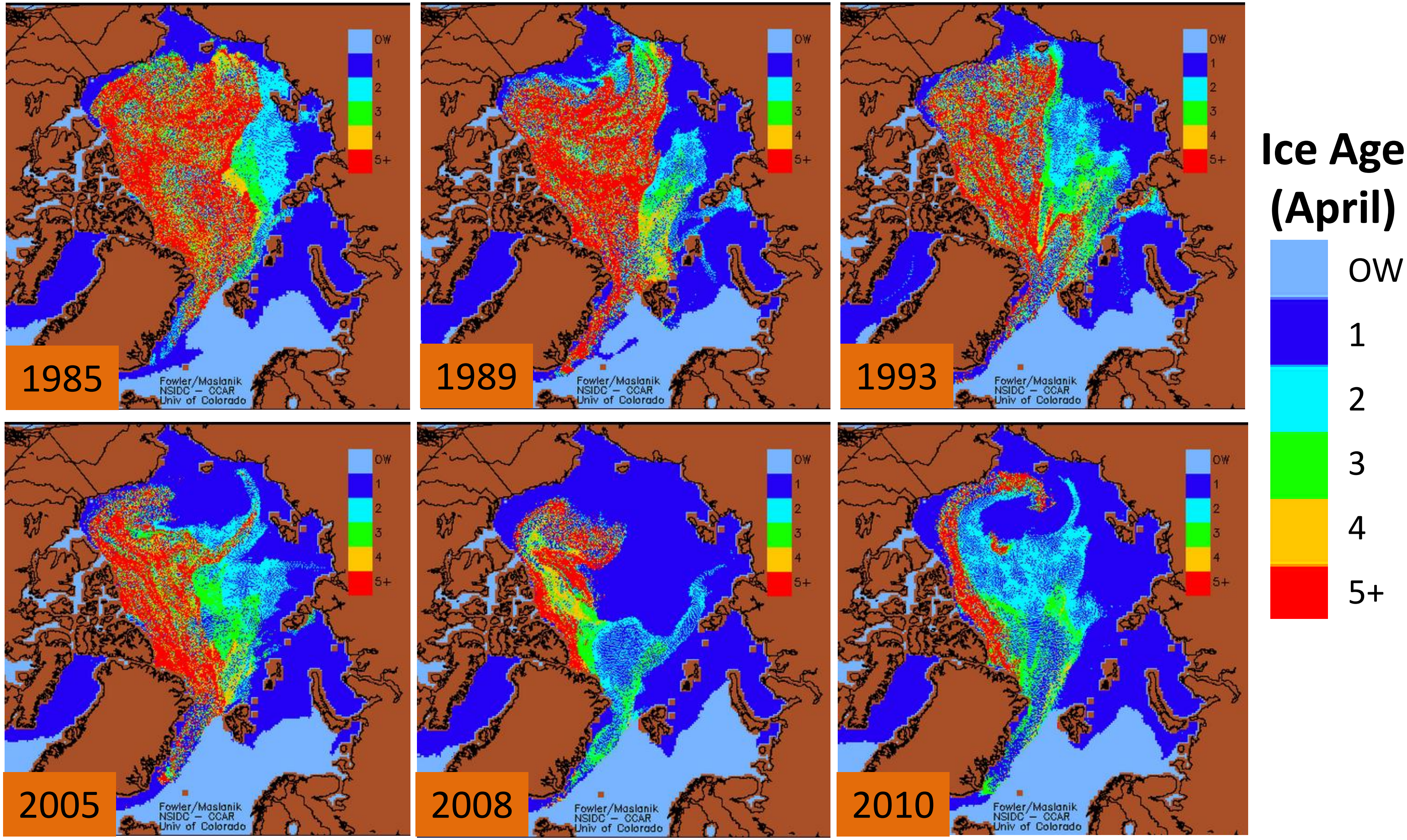

Multiyear ice extent decreasing since 1980s
with thickest/oldest remaining
along the Canadian Arctic Archipelago

http://polarbear.colorado.edu/IceAge/Age_Apr.html

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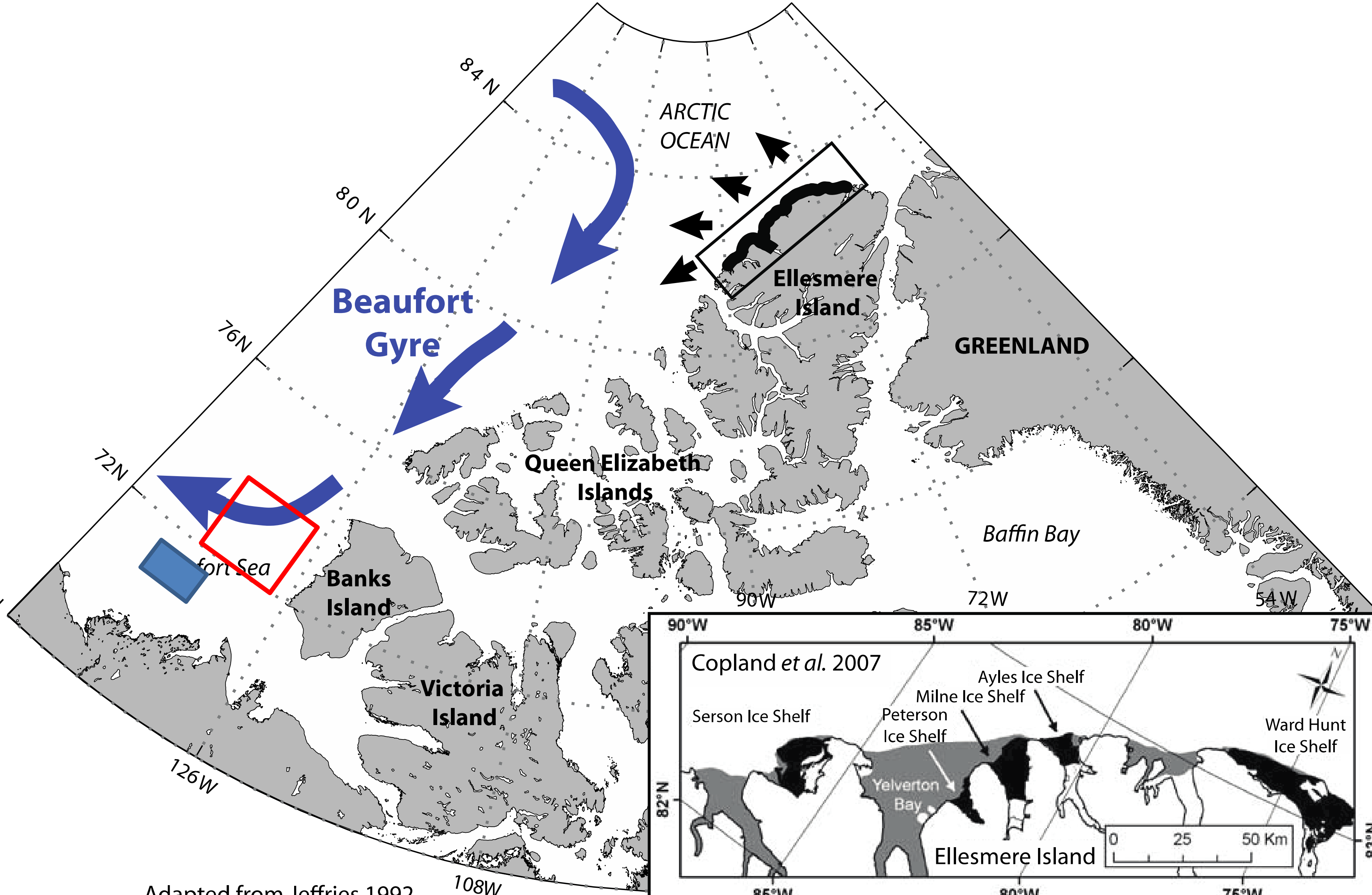
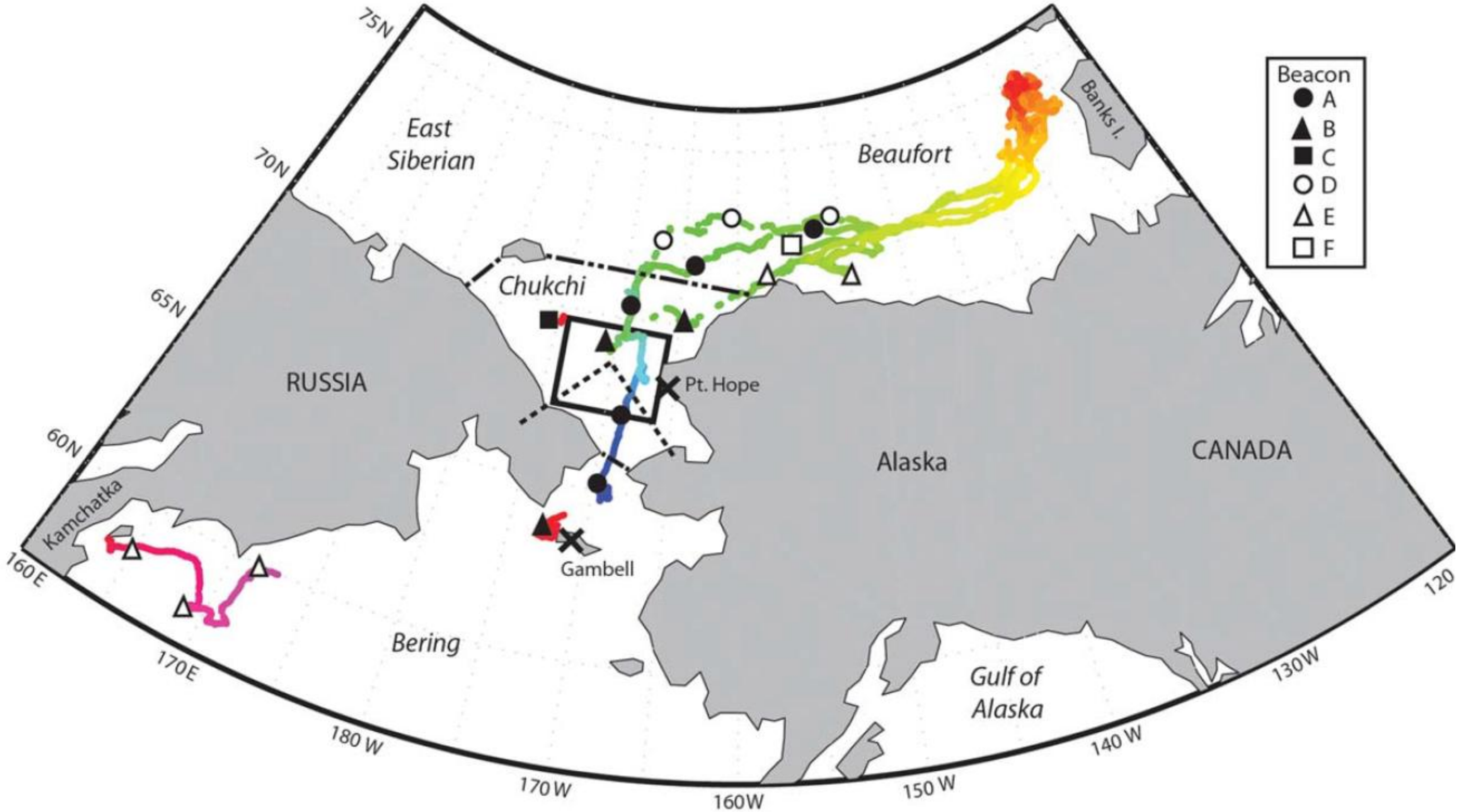
The origins of Arctic Ice Islands



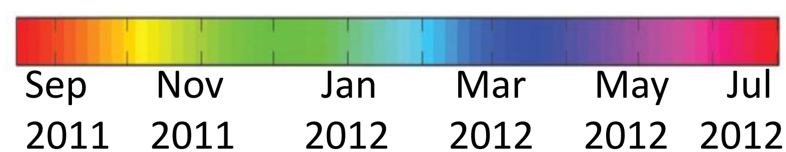
Adapted from Jeffries 1992

Multiyear ice drift

D.G. Babb, R.J. Galley, M.G. Asplin, J.V. Lukovich and D.G. Barber. 2013. Multiyear ice export through the Bering Strait during winter 2011. JGR Oceans 118:5489–5503.



Ice beacon tracks from deployment in the eastern Beaufort Sea (August 2011) to the Chukchi Sea (C, D) and the Bering Sea (A, B, E) (Babb et al. 2013)



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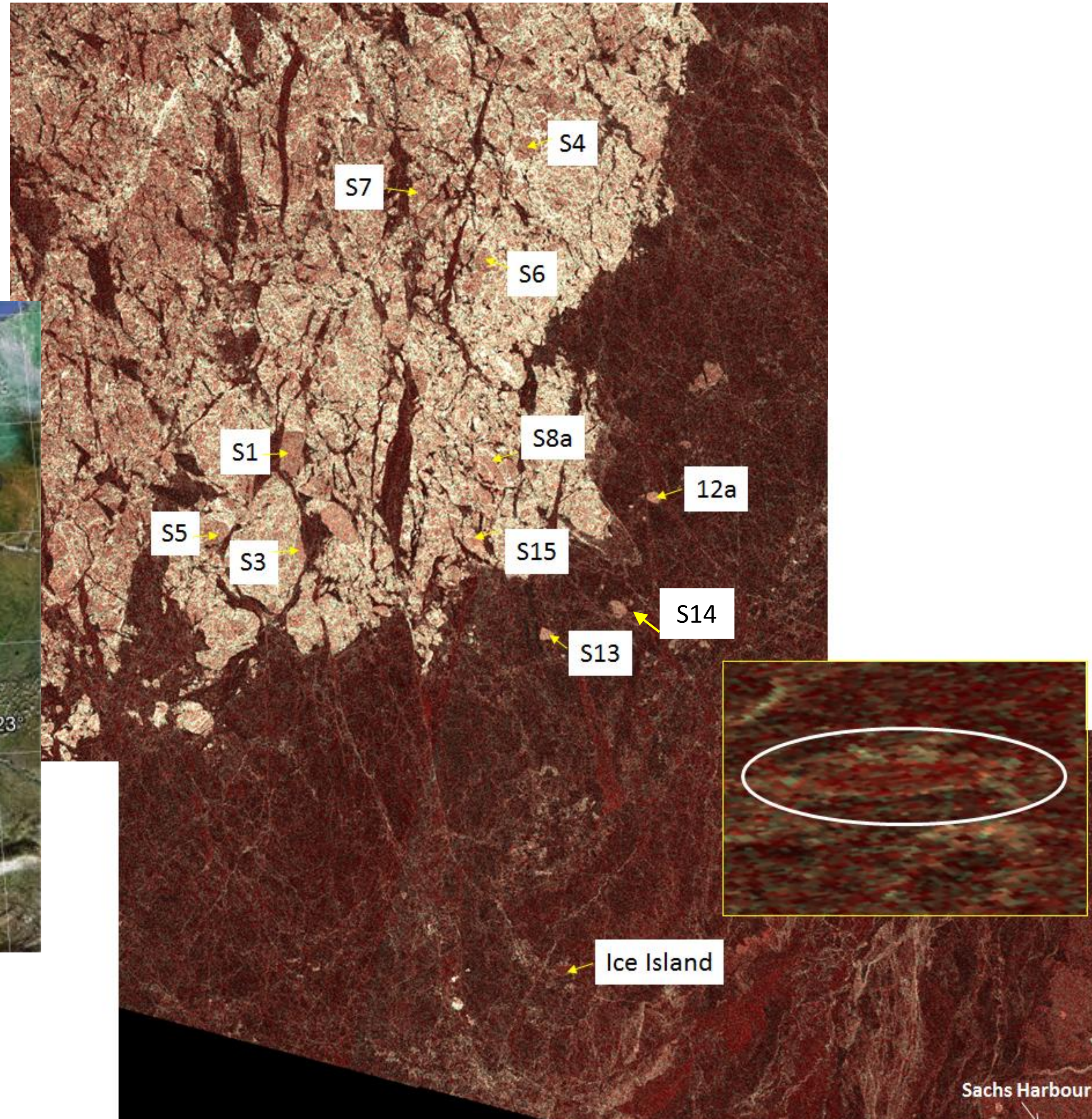
2012
Study Site
West of Banks Island



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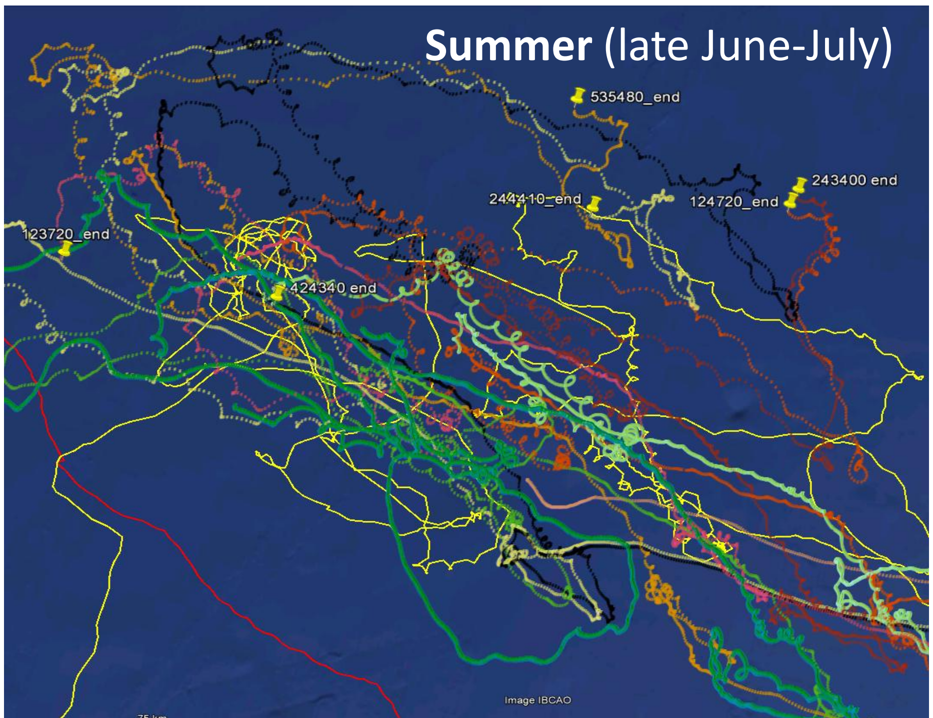
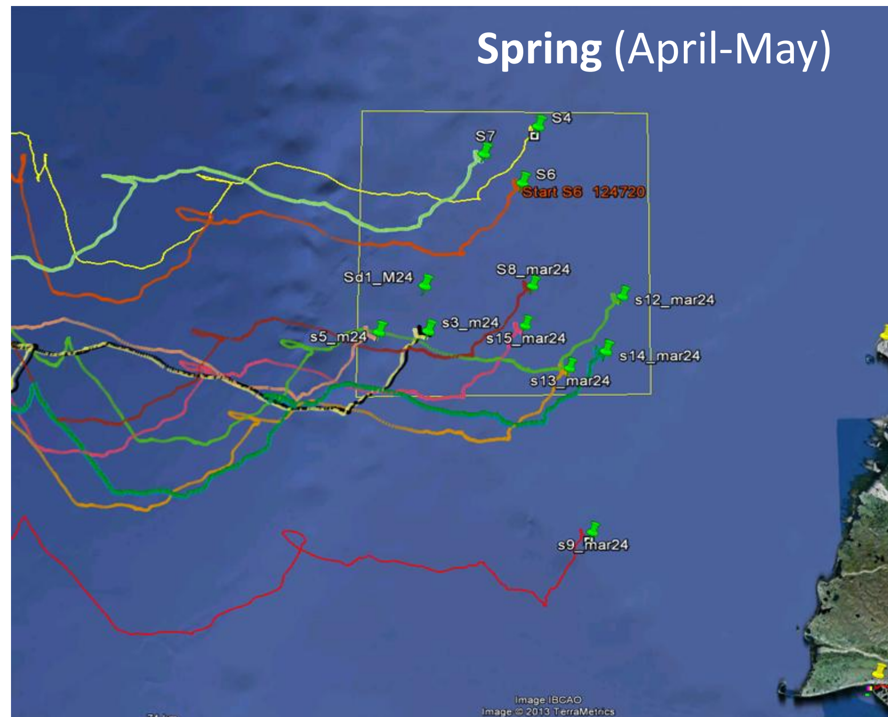
- **Summer:** less coherent motion
  - Highly variable
  - Tidal/inertial loops
  - More responsive to local winds and currents
- **Spring:** strongly coherent drift
  - Less variable
  - Weaker inertial motions
  - Lagged response to winds and currents





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In-situ winds and under-ice ocean currents

D.G. Babb, R.J. Galley, D.G. Barber and S. Rysgaard. 2015. Physical processes contributing to an ice-free Beaufort Sea during September 2012. Submitted to JGR-Oceans.

G.K. McCullough, D.G. Babb, J. Ehn, D.G. Barber and D. Fissel. In Prep. Shallow current structure under drifting multiyear ice in the Beaufort Sea

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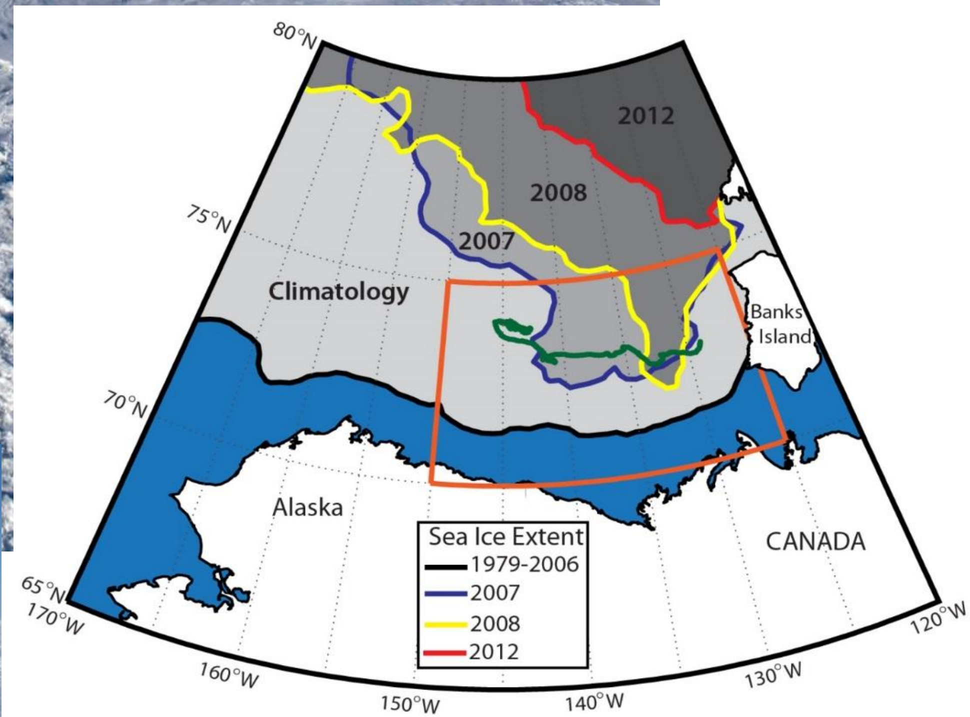

Minimum September sea ice extent in the Beaufort Sea (ice edge = 15% sea ice concentration)

Babb et al. Submitted.; McCullough et al. In prep.

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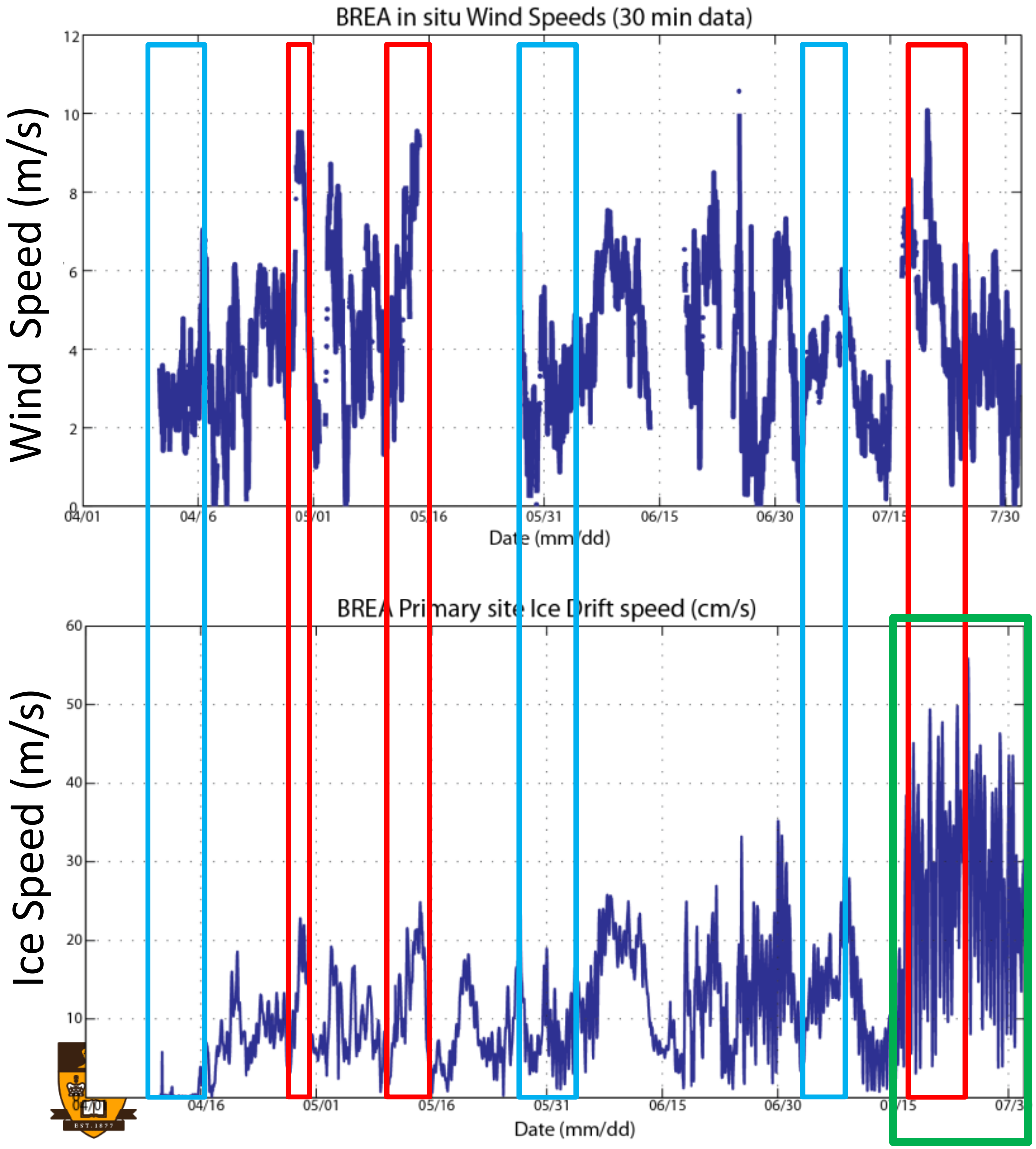
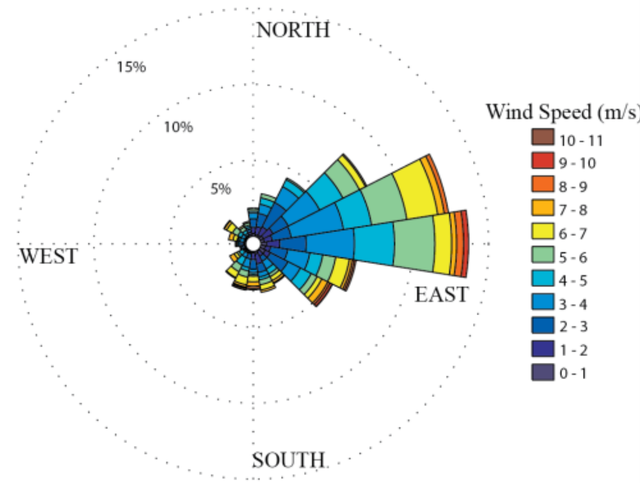
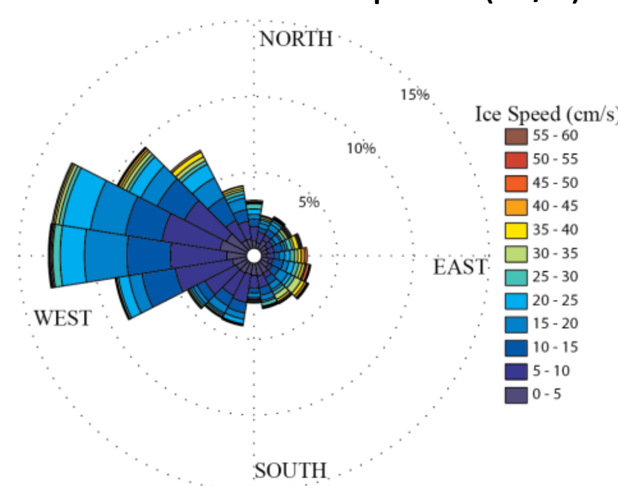


Wind Direction and Speed (m/s)



Ice Direction and Speed (m/s)



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Ice is more responsive to northerly winds into areas of open water (Lower internal stress).
Southerly winds compress ice against itself and increase internal stress, similar to onshore and offshore winds

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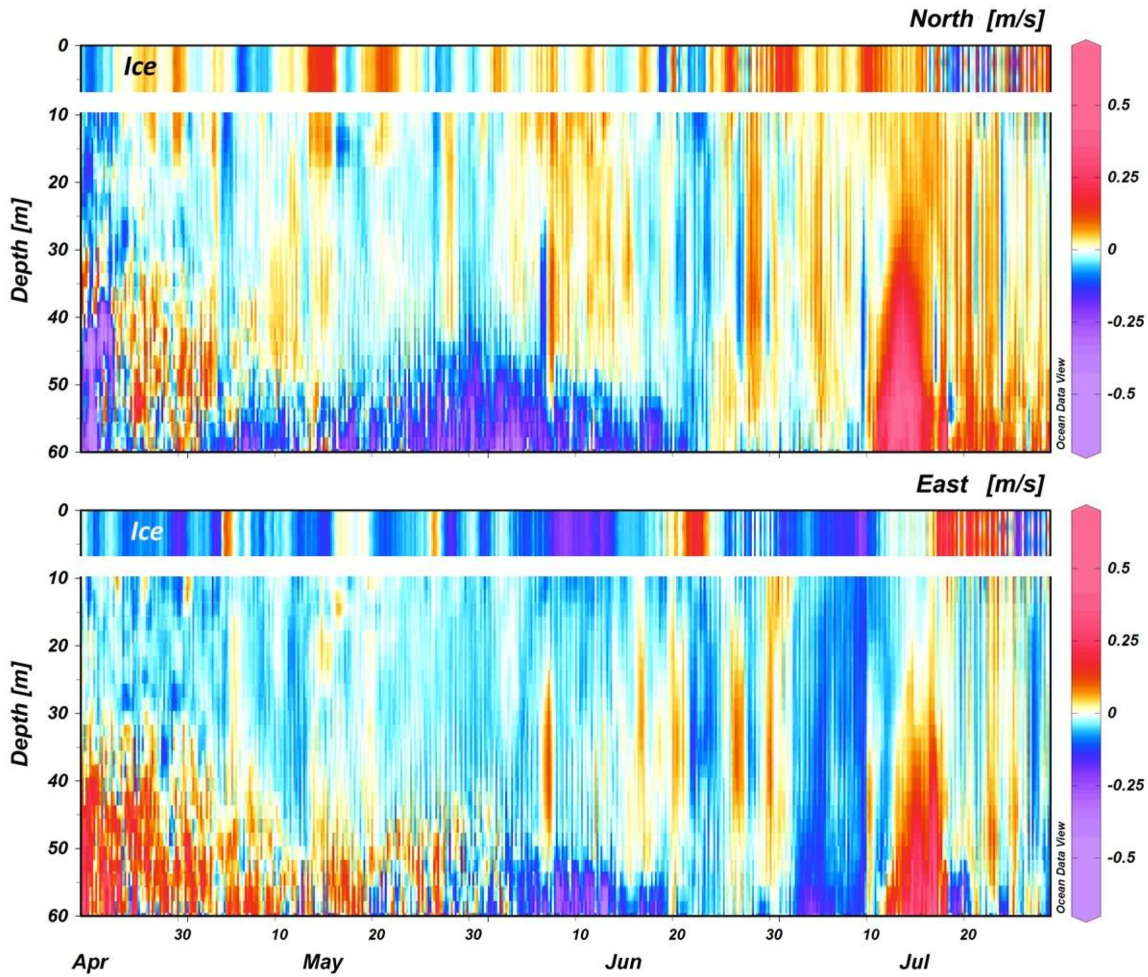
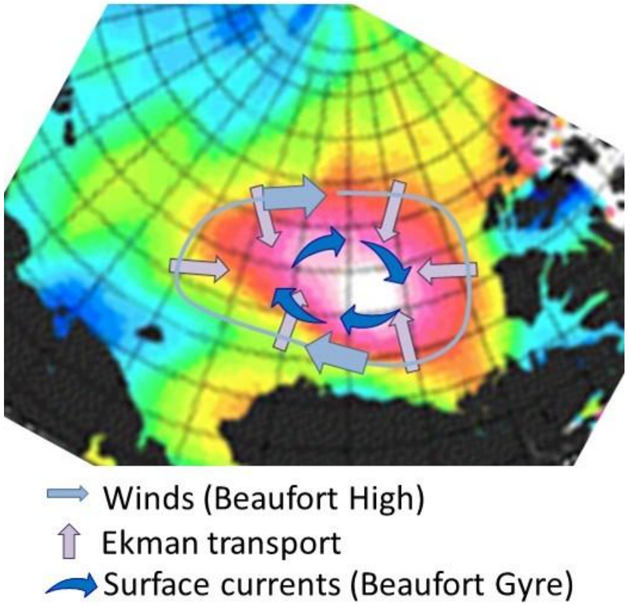
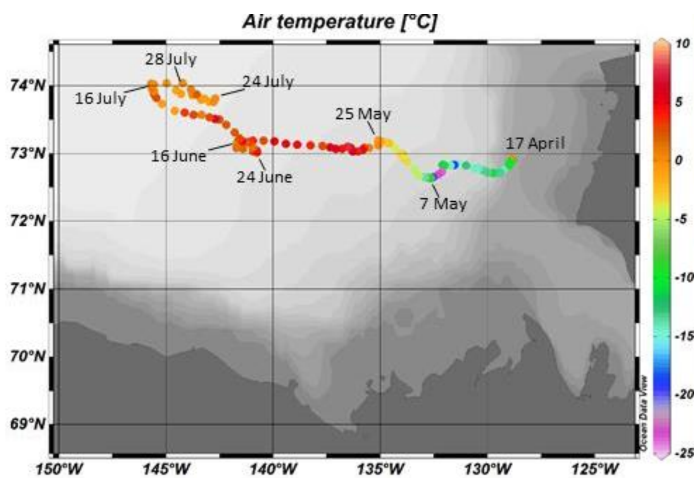
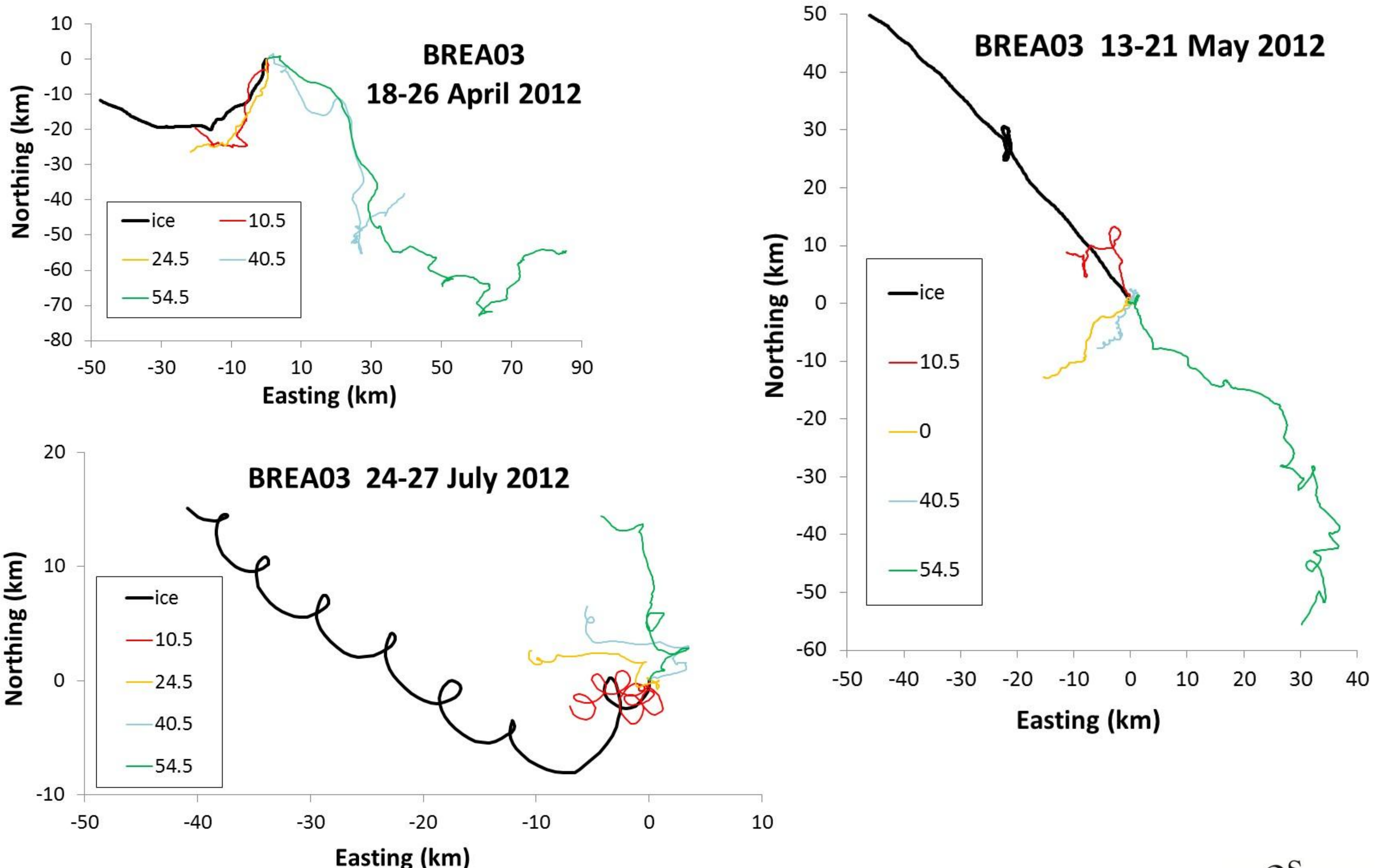


Current structure in the mixed (freshening) layer under the ice. McCullough et al. In prep.

Sea level anomaly (colour scale)
(Proshinsky et al. 2011)







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Selected ice tracks and under-ice summed velocity vectors.
McCullough et al. In prep.

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Multiyear ice decay

D.G. Babb, R.J. Galley, D.G. Barber and S. Rysgaard. Submitted. Physical processes contributing to an ice-free Beaufort Sea during September 2012.

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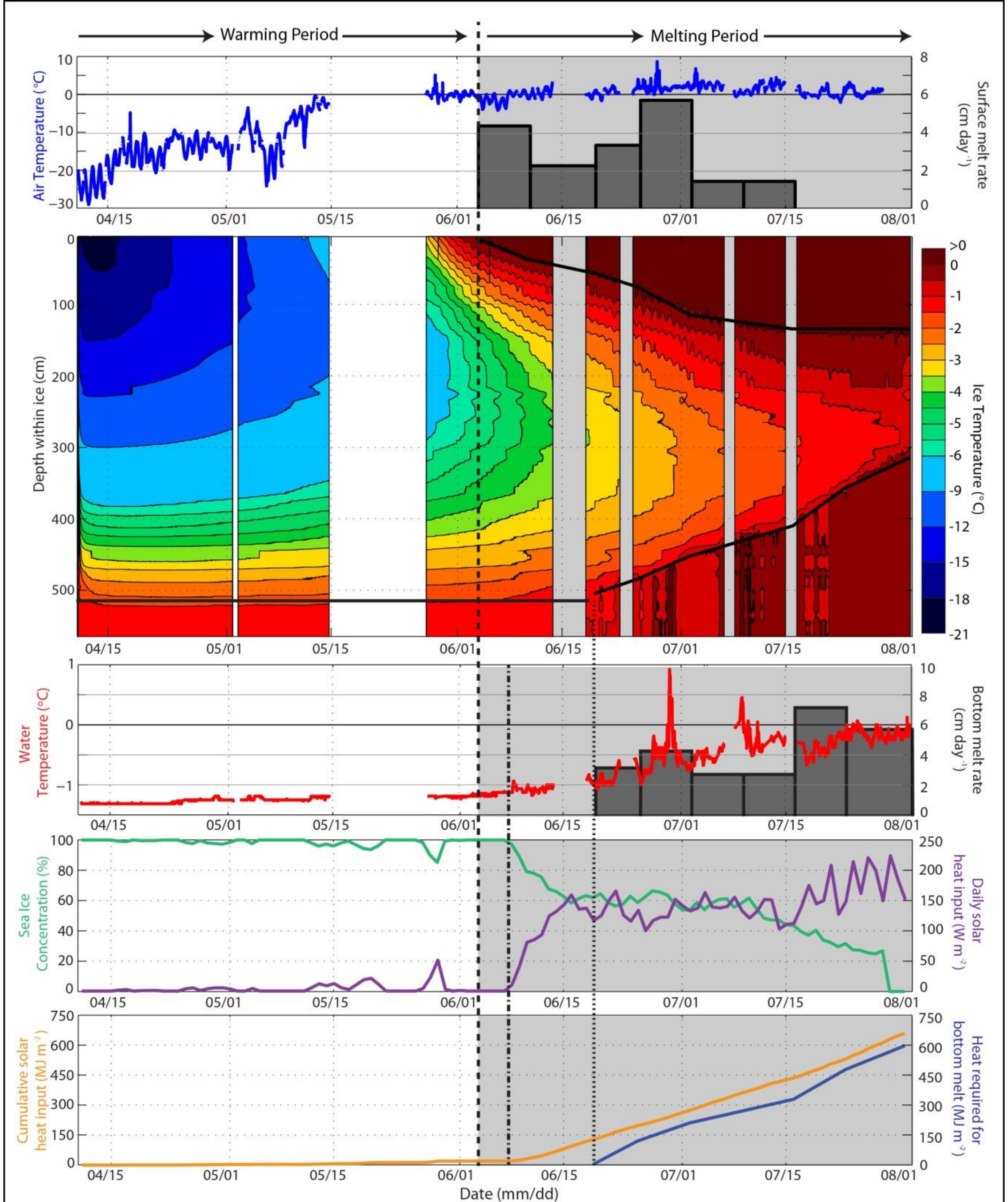

July 31 last observations
185 cm thick
Isothermal (>-1°C)

Initial ice thickness 523cm

$$F_{ow} = F_i (1-\alpha) A_{ow}$$

F_{ow} Daily solar heat input
F_i = Solar energy
A_{ow} = area of open water

Babb et al. Submitted.

Ice thickness

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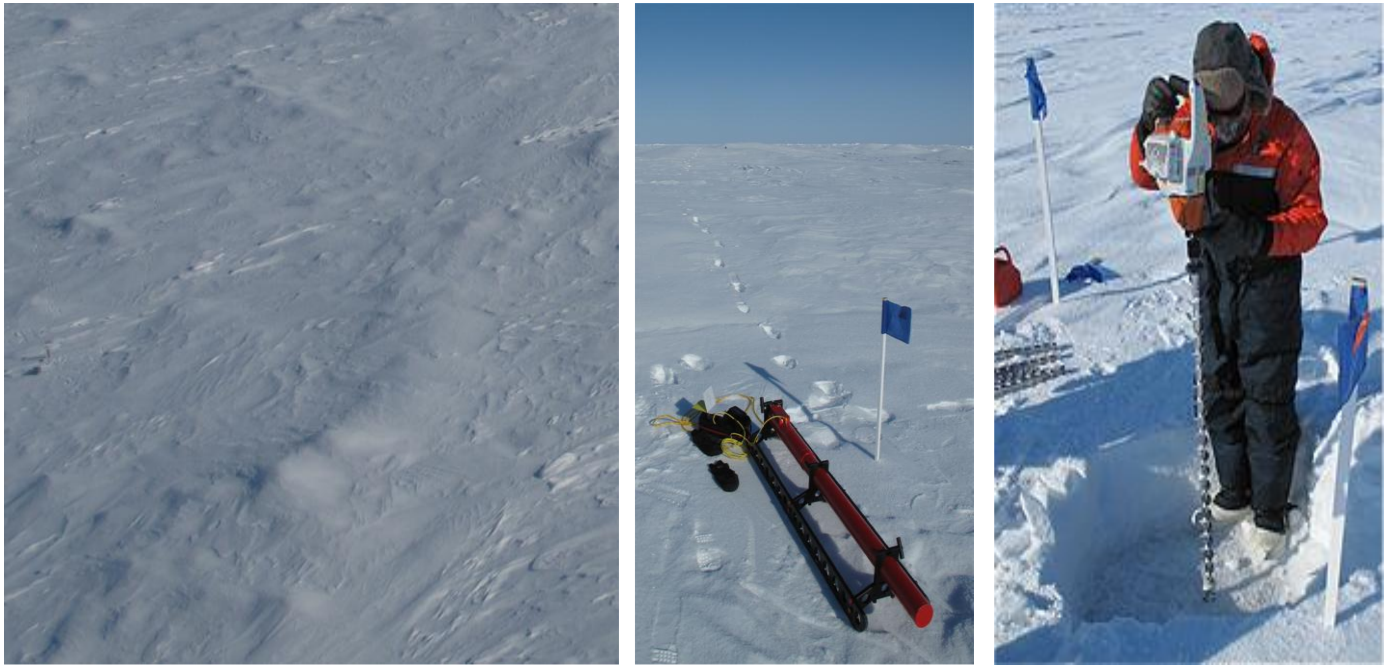
Surface EM Induction Surveys (MYI)



April 11 Site S5 a) typical multi-year floe as seen from the helicopter, b) hand towed SEMI instrument, c) obtaining ground confirmation data for SEMI.

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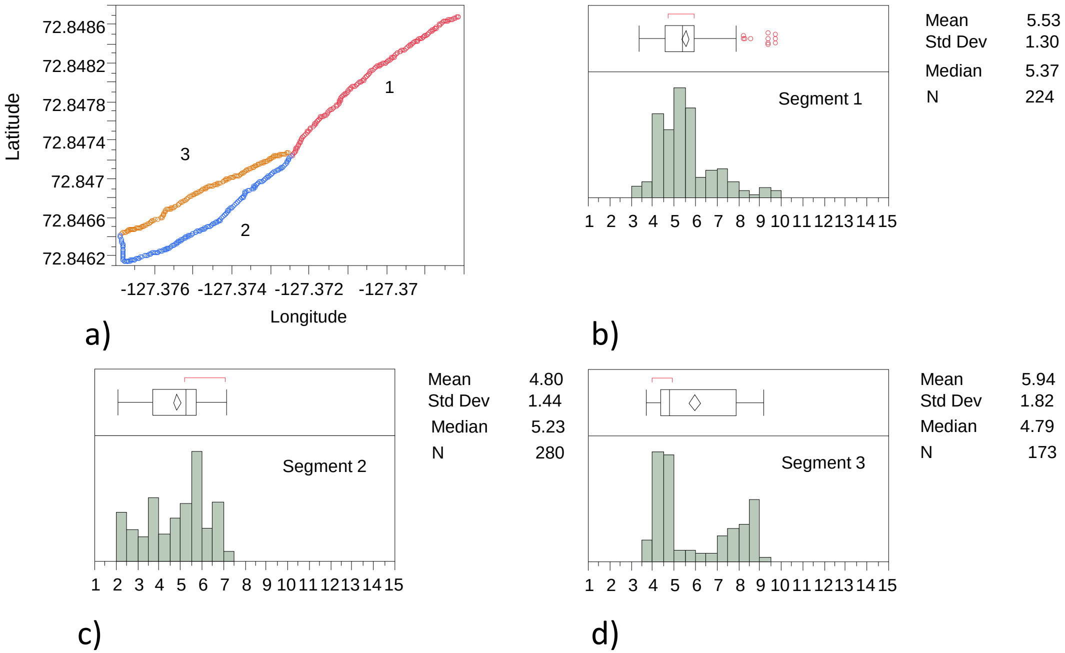
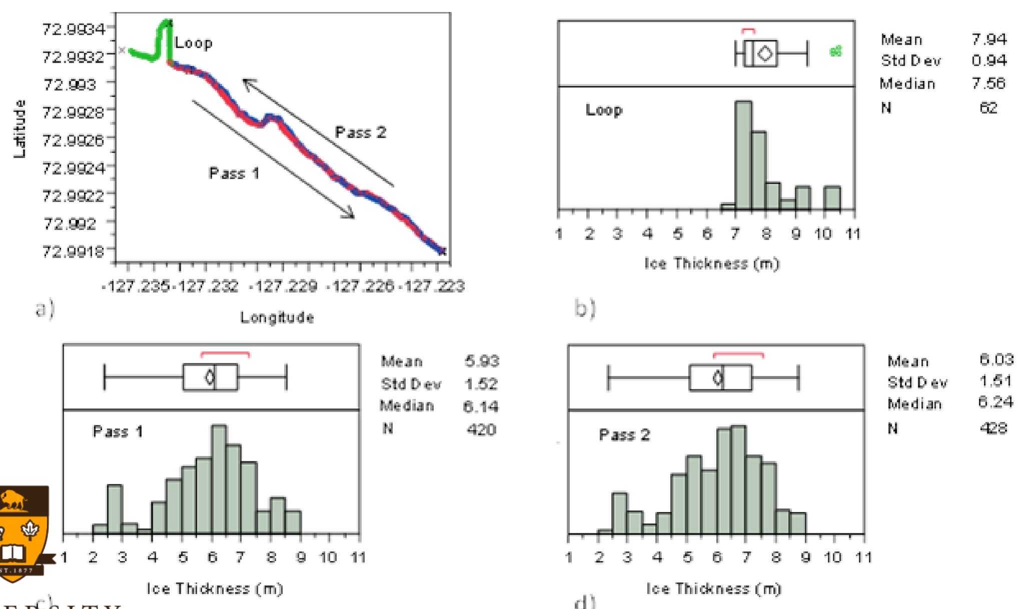


SEMI survey on S14, April 12, 2012 (file SIS00012). a) pass 1 with segments delineated, b) segment 1, **5.5m** avg.; c) segment 2, **4.8m** avg; d) segment 3, **5.9m** avg



SEMI survey on S12, April 12, 2012 (file SIS00014). a) transects with survey segments delineated, b) large multi-year hummock, **7.94m avg**; c) Pass-1, **5.93m**, d) Pass 2, **6.03m**.

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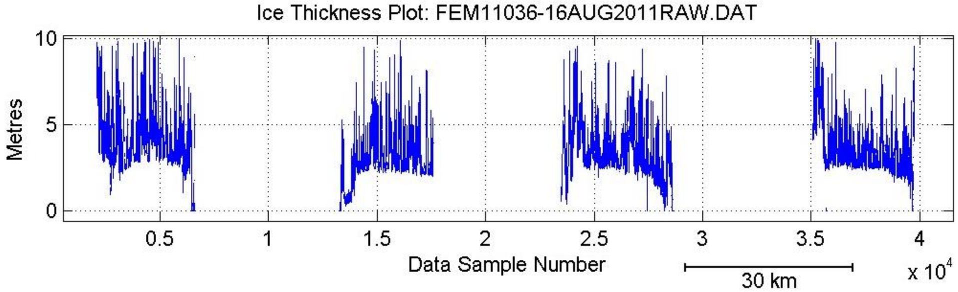
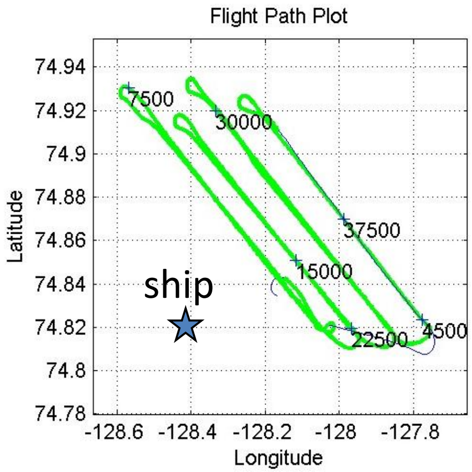
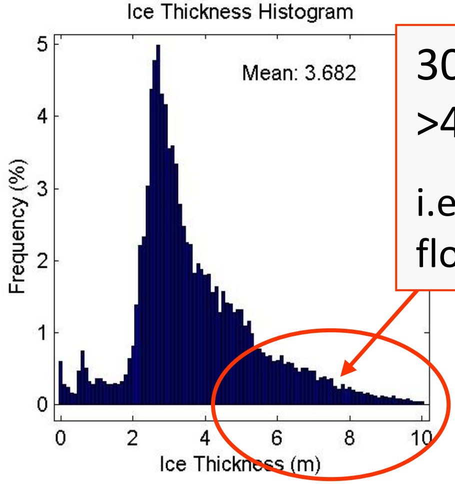
Integrating existing data…. 2009 - 11

Example: 16 Aug, 2011







30% of floe is >4.0m

i.e. similar to floes S1 and S2

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Ice drift and surface winds by satellite

A.S. Komarov and D.G. Barber. 2014. Sea ice motion trackng from sequential dual-polarization RADARsat-2 images. IEEE Trans. Geosci. and Rem. Sens. 52(1):121–136.

A.S. Komarov, V. Zabeline and D.G. Barber. 2014. Ocean surface wind speed retrieval from C-band SAR images without wind direction input. IEEE Trans. Geosci. and Rem. Sens. 52(2):980–990.

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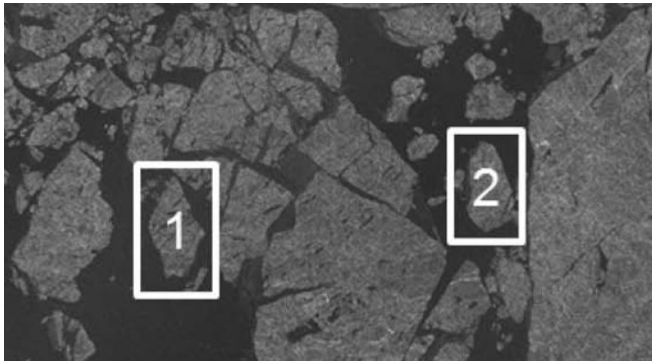
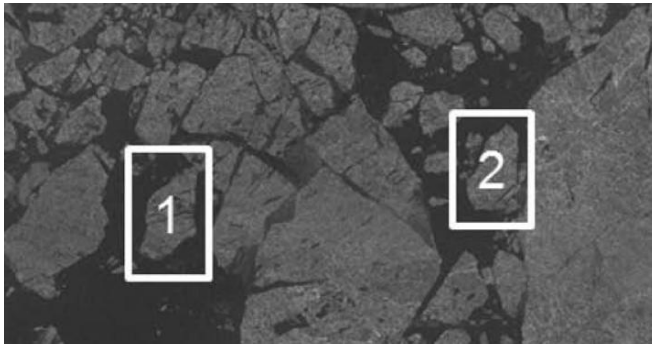
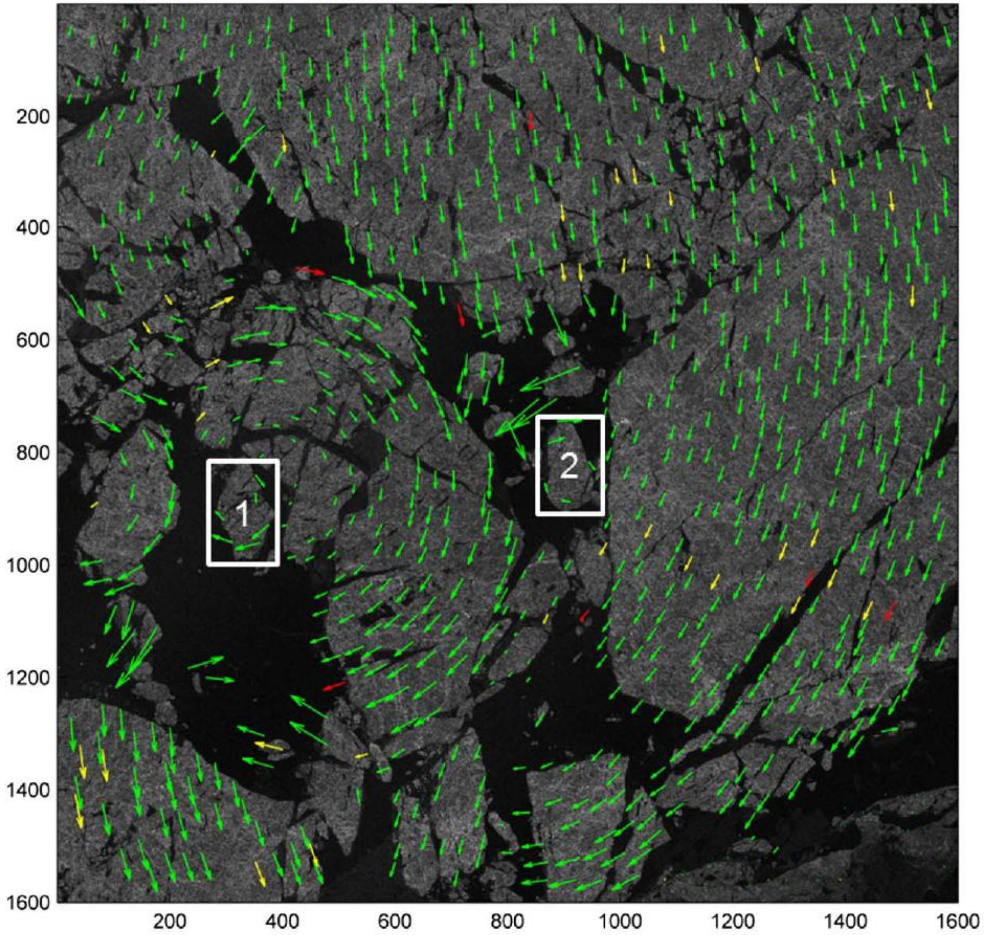


15:32 24 May 2008



15:03 25 May 2008



Rotating floes west of Ellesmere Island, with ice drift vectors from sequential RADARsat-2 image (HV polarization). Komarov and Barber 2014.

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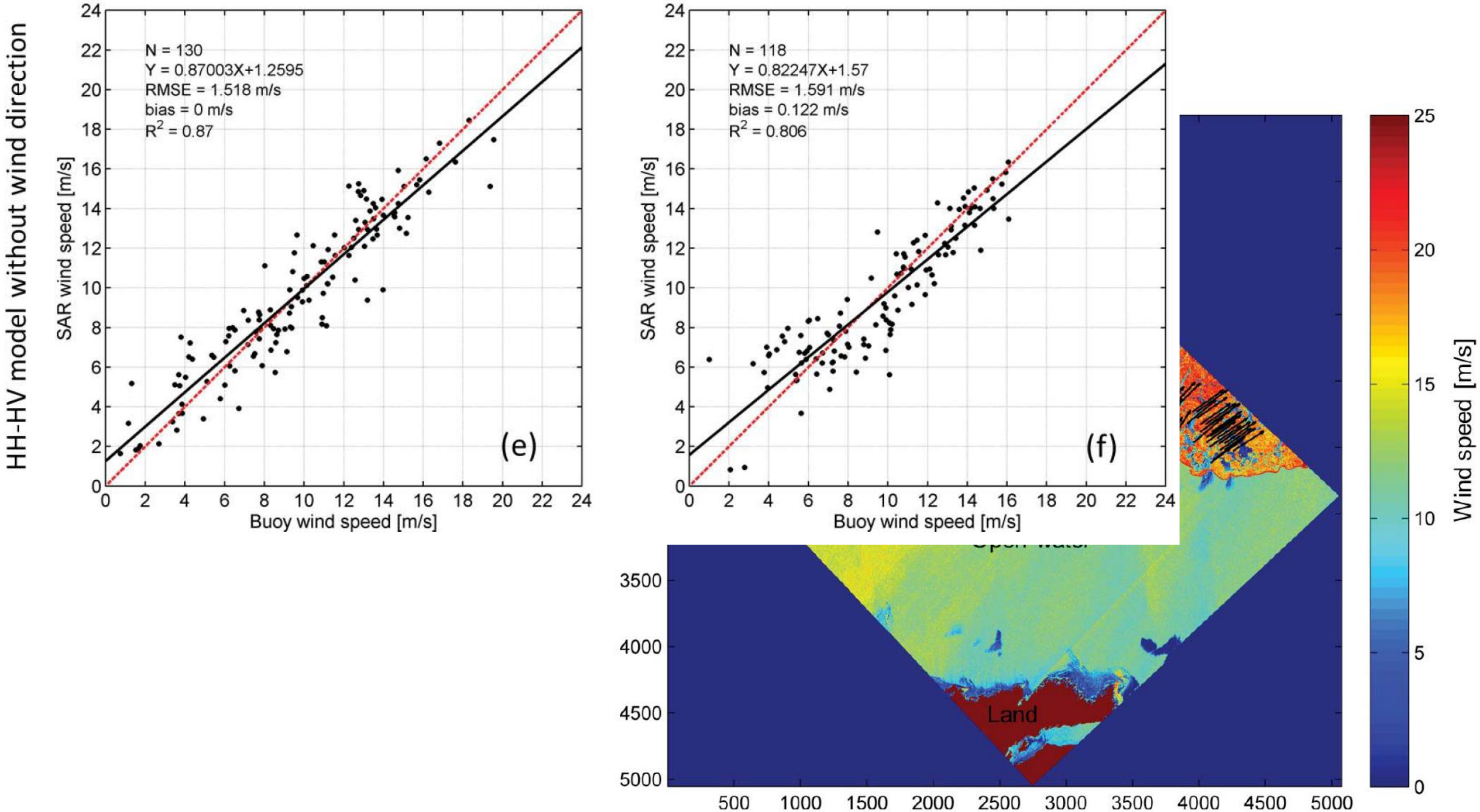

Komarov et al. 2014.

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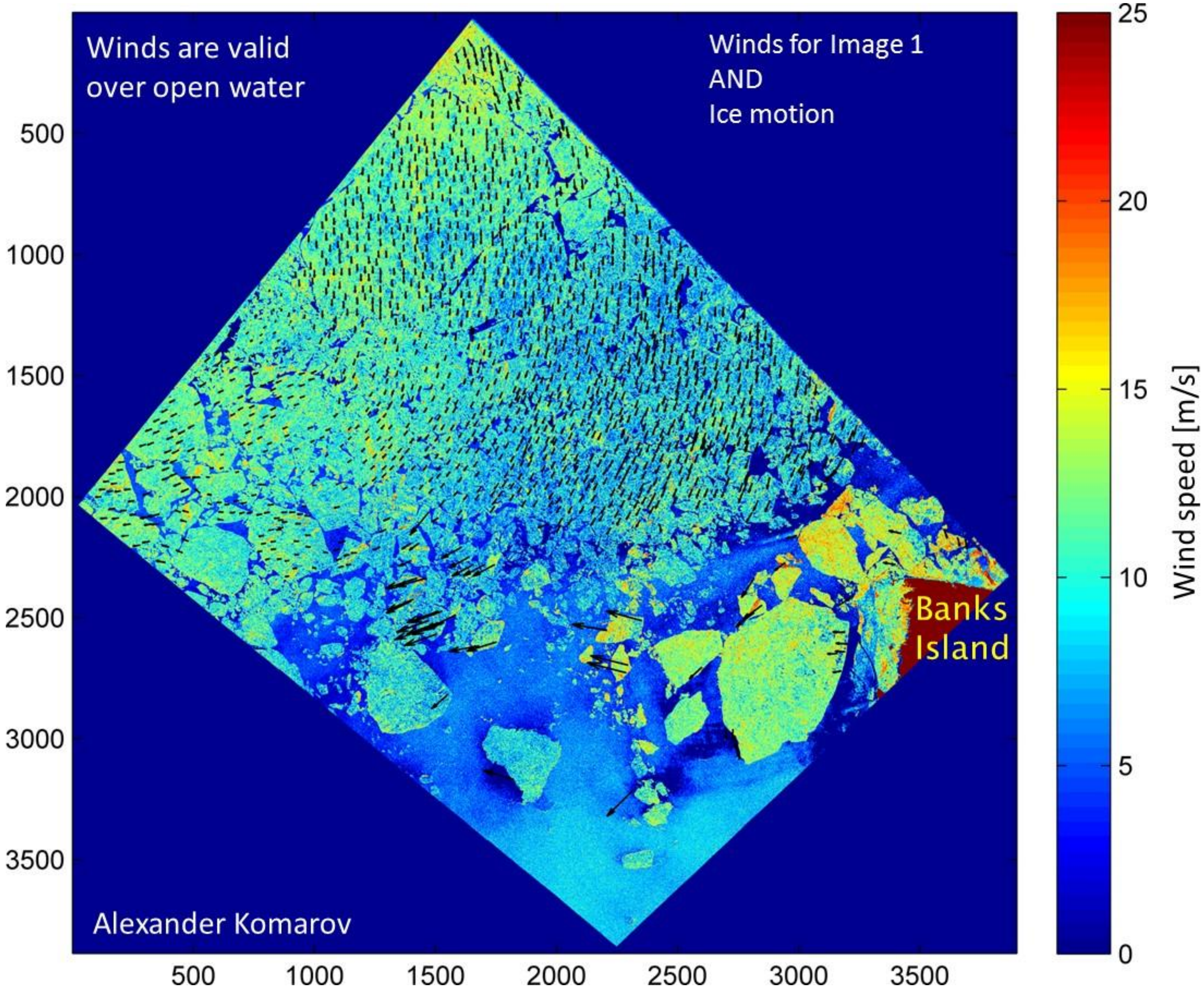

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RADARSAT-2 detection/monitoring of extreme ice features

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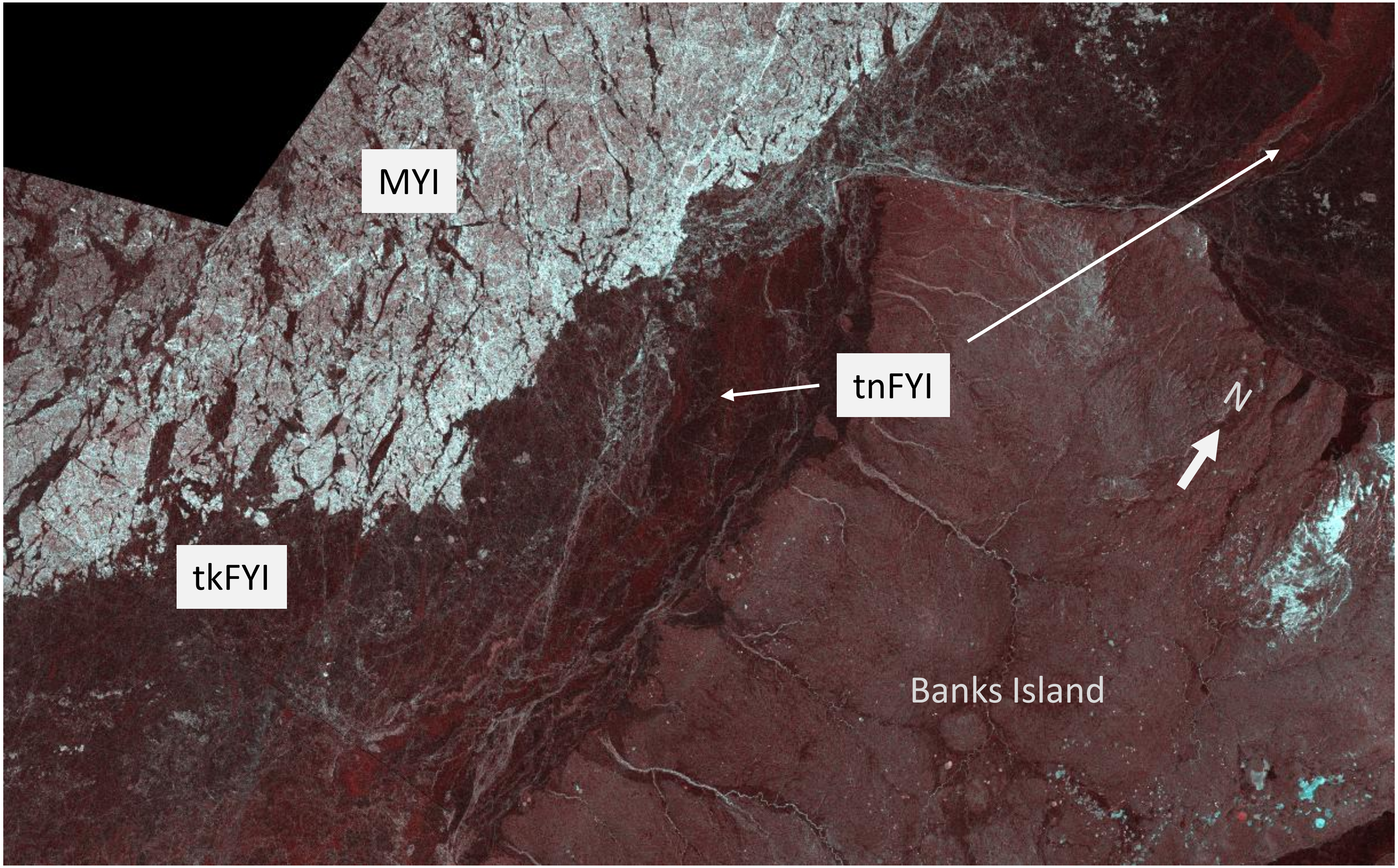
Detection of Extreme Ice Features: RADARSAT-2



Multi-year ice clearly distinguishable from first year ice in winter

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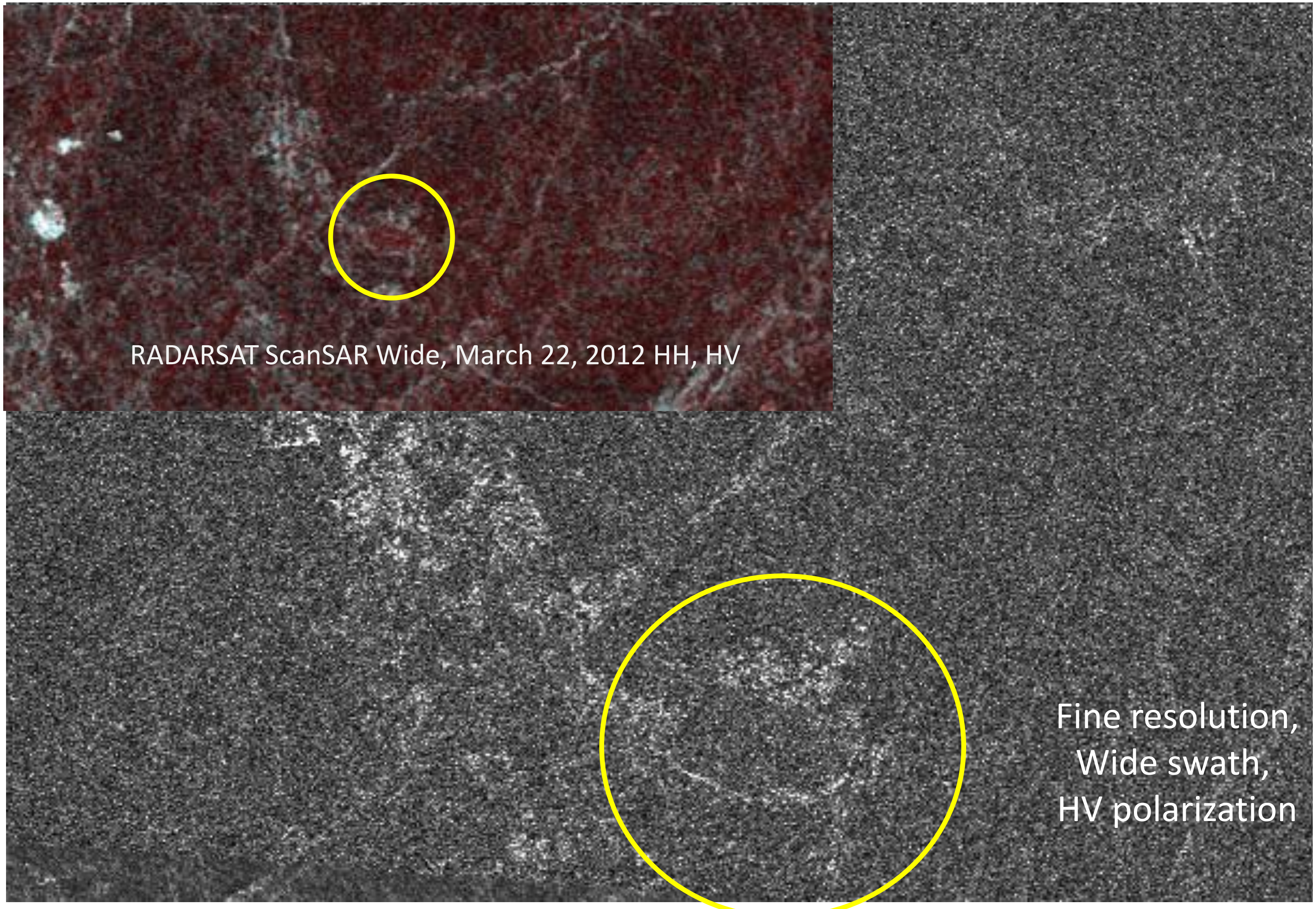

Ice Island vs. first year ice (winter)

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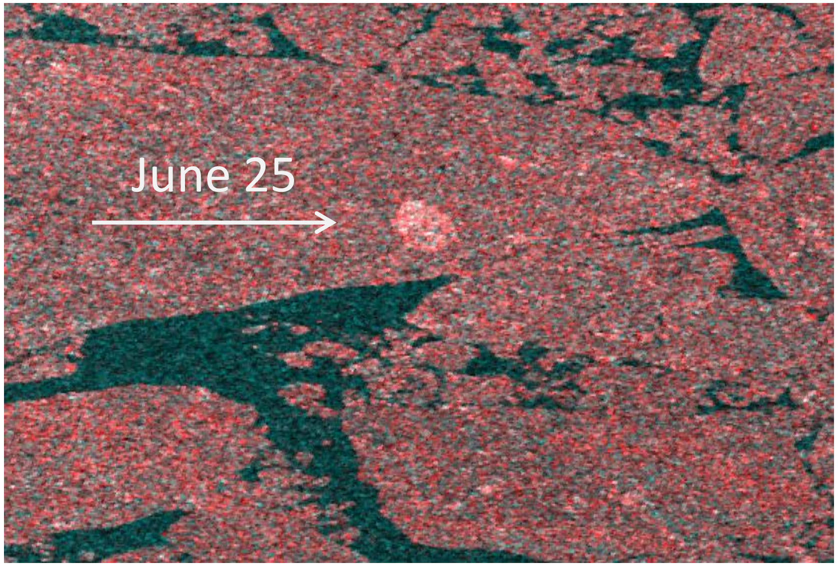

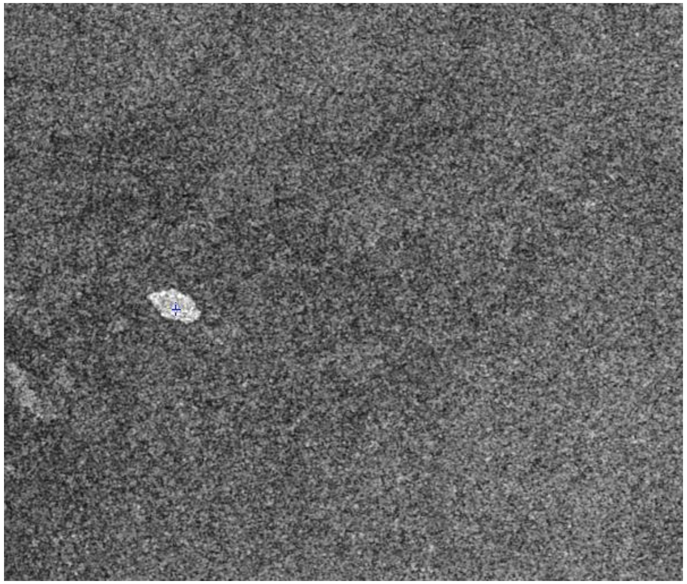

July 16, ice island clearly visible; multi-year ice barely distinguishable from roughened water surface

Ice Island albedo (spring and summer)

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Hazardous ice features

D.G. Barber, G.K. McCullough, D.G. Babb, A. Komarov, L.M. Candlish, J.V. Lukovich, M. Asplin, S. Prinsenberg, I. Dimitrenko and S. Rysgaard. 2014. Climate change and ice hazards in the Beaufort Sea. Elementa: Science of the Anthropocene. DOI 10.12952/journal.elementa.000025

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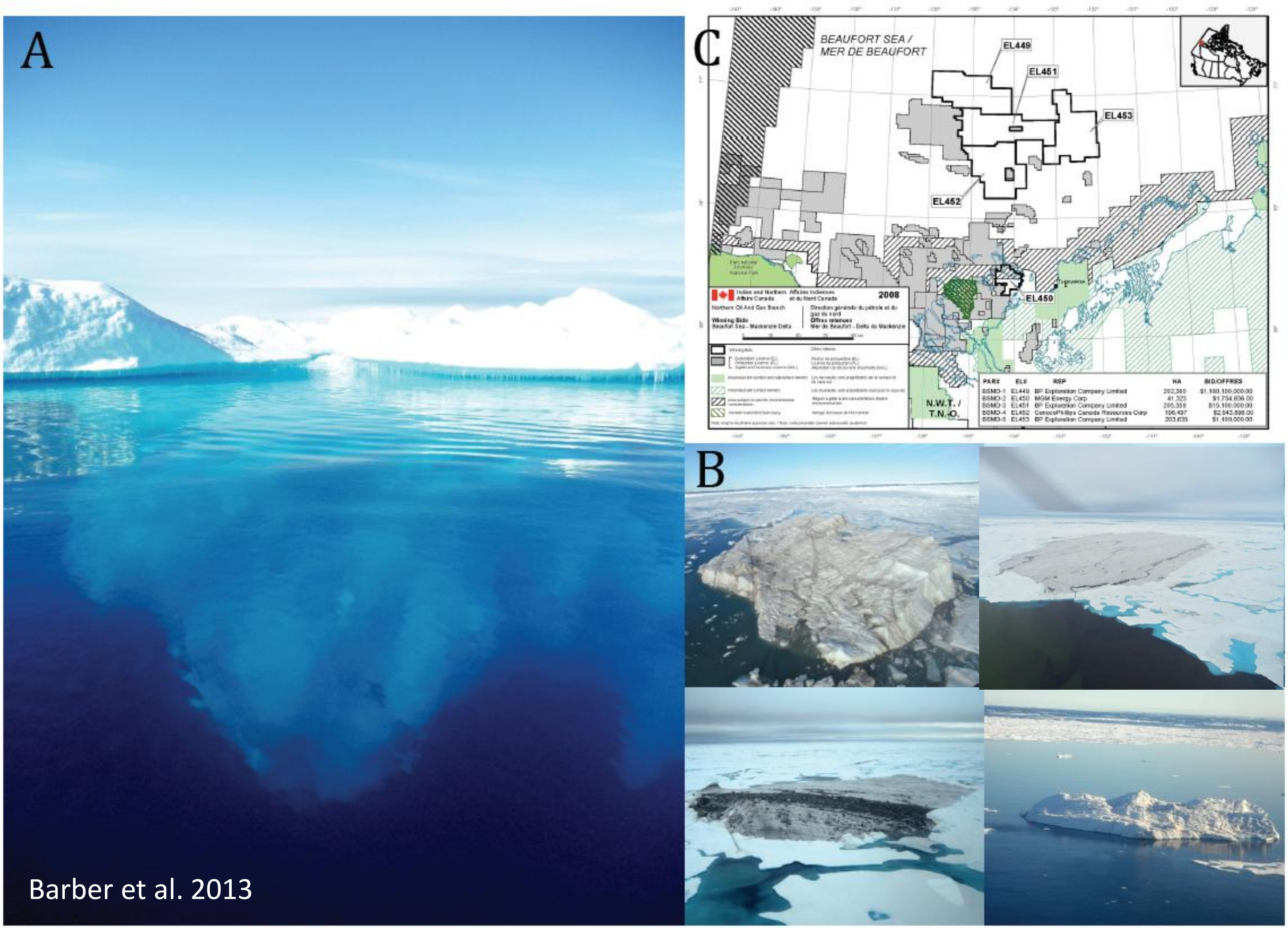
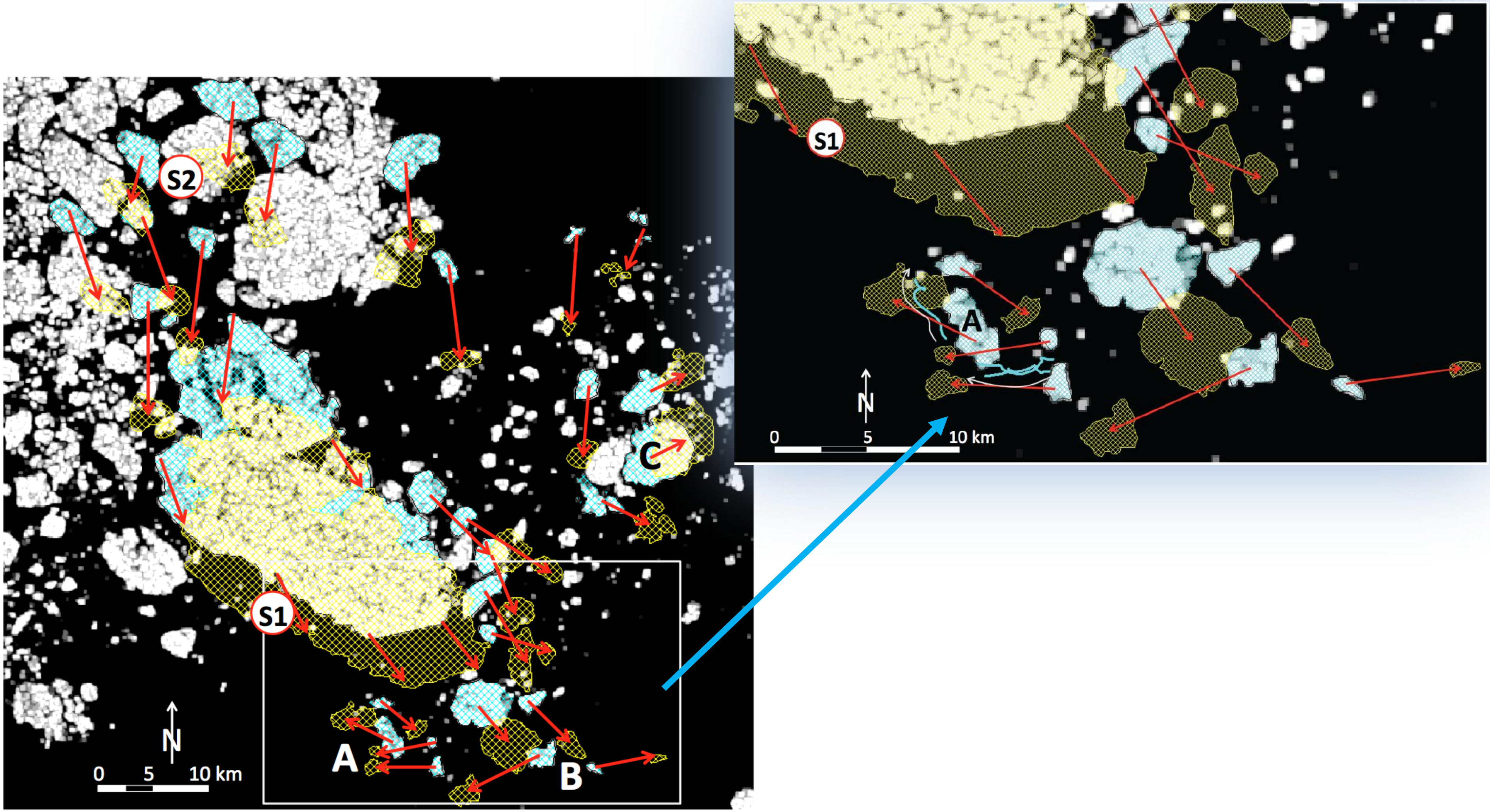
Extreme Ice Features: Multi-year ice and ice islands (glacial)



Barber et al. 2013

Management of ice hazards



Barber et al. 2013

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D.G. Barber et al. 2014.

Climate change and ice hazards in the Beaufort Sea

Conclusions

- At present rate, calving of Ellesmere I. ice shelves will continue to produce ice islands for at least two decades
- Multiyear ice will continue to be produced at the edge of the Canadian Arctic Archipelago

Challenges

- improved remote sensing detection methods are needed to distinguish hazardous ice features entrained in 1^{st} year ice
- better local surface wind forecasting is needed to forecast short term average drift of the pack
- high resolution near-surface wind and current data would be required for useful forecasting of near-field motion of individual hazardous ice features

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Community Based Monitoring

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Community Based Monitoring: Sachs Harbour

Charlie Haogak, Jim Wollki and J.D. Keogak (Alternate)

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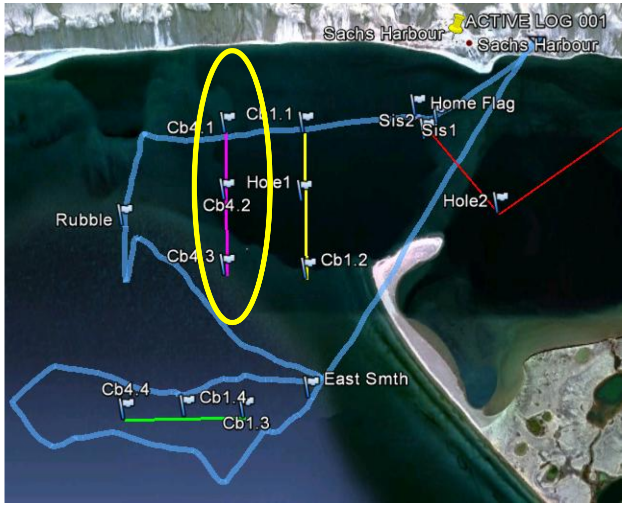
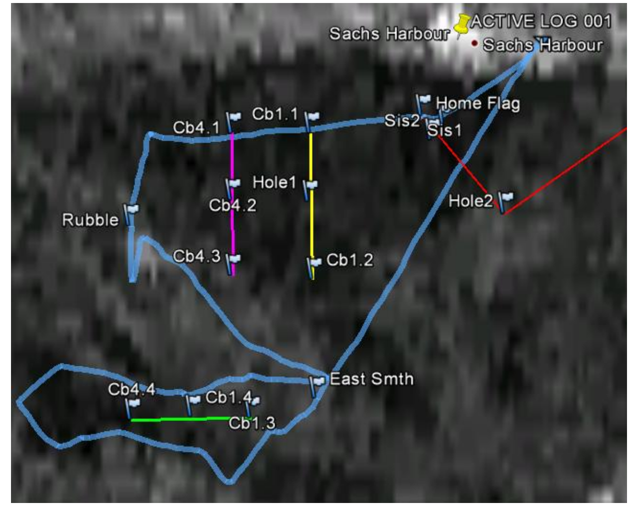
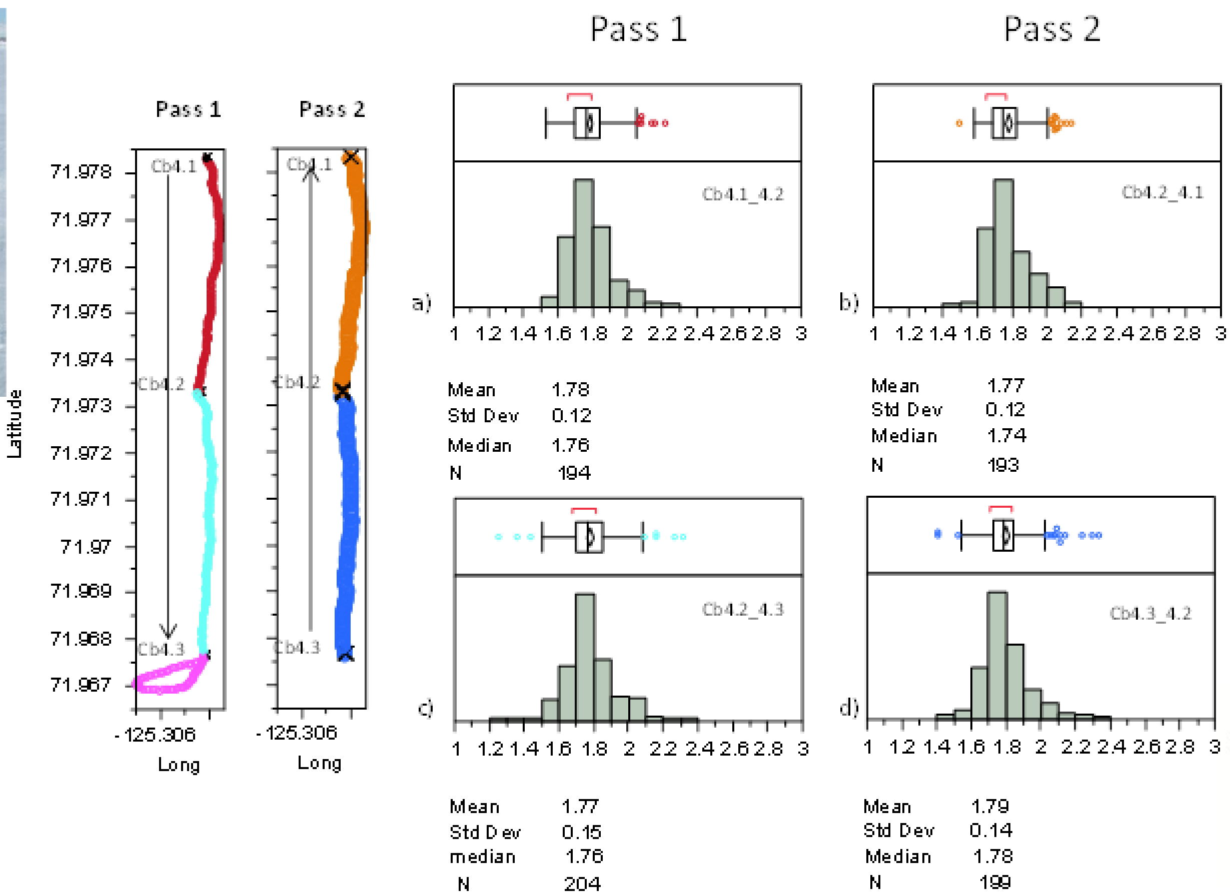
Local ice thickness surveys





EM Induction surveys



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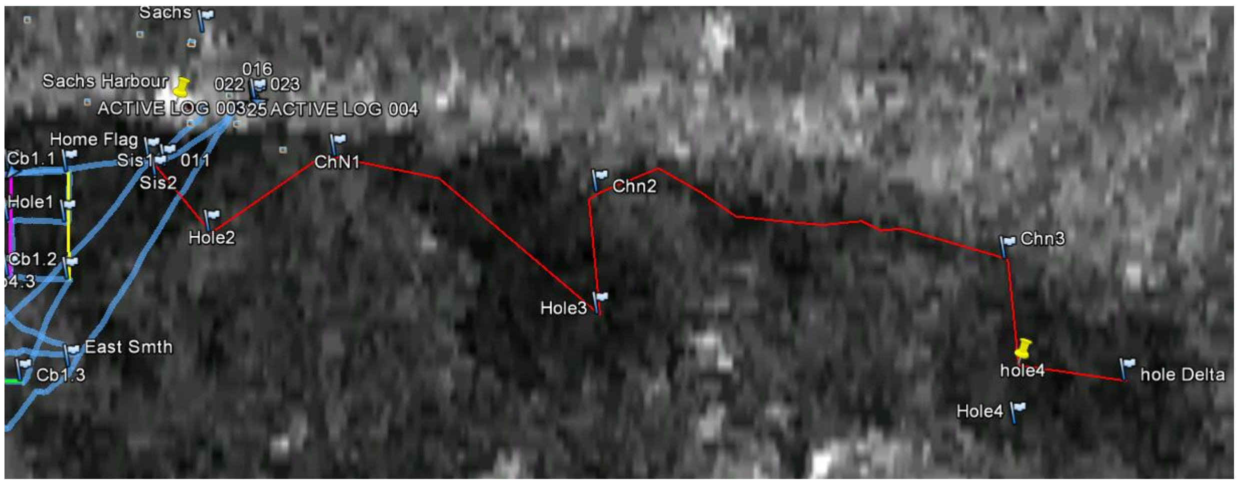
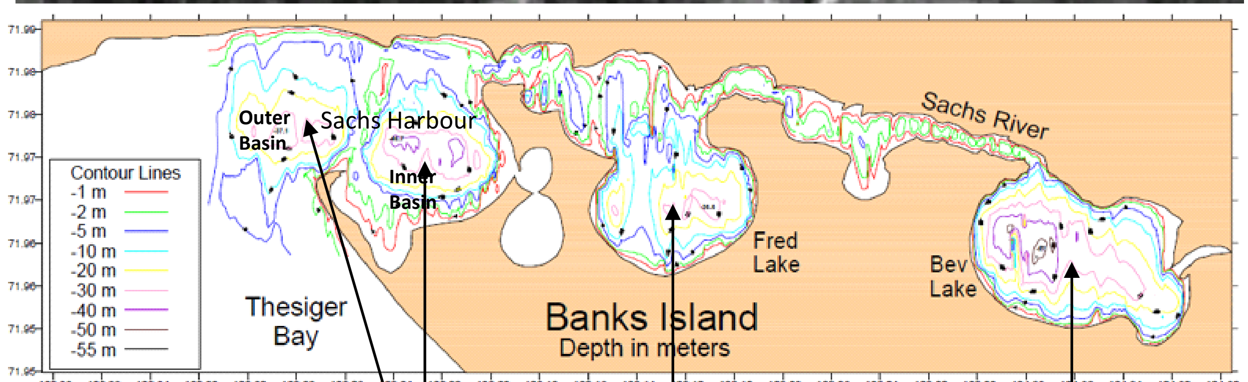
Sachs Harbour Estuary

Benthic Productivity

CTD locations



EM Induction survey



High Productivity low productivity no productivity

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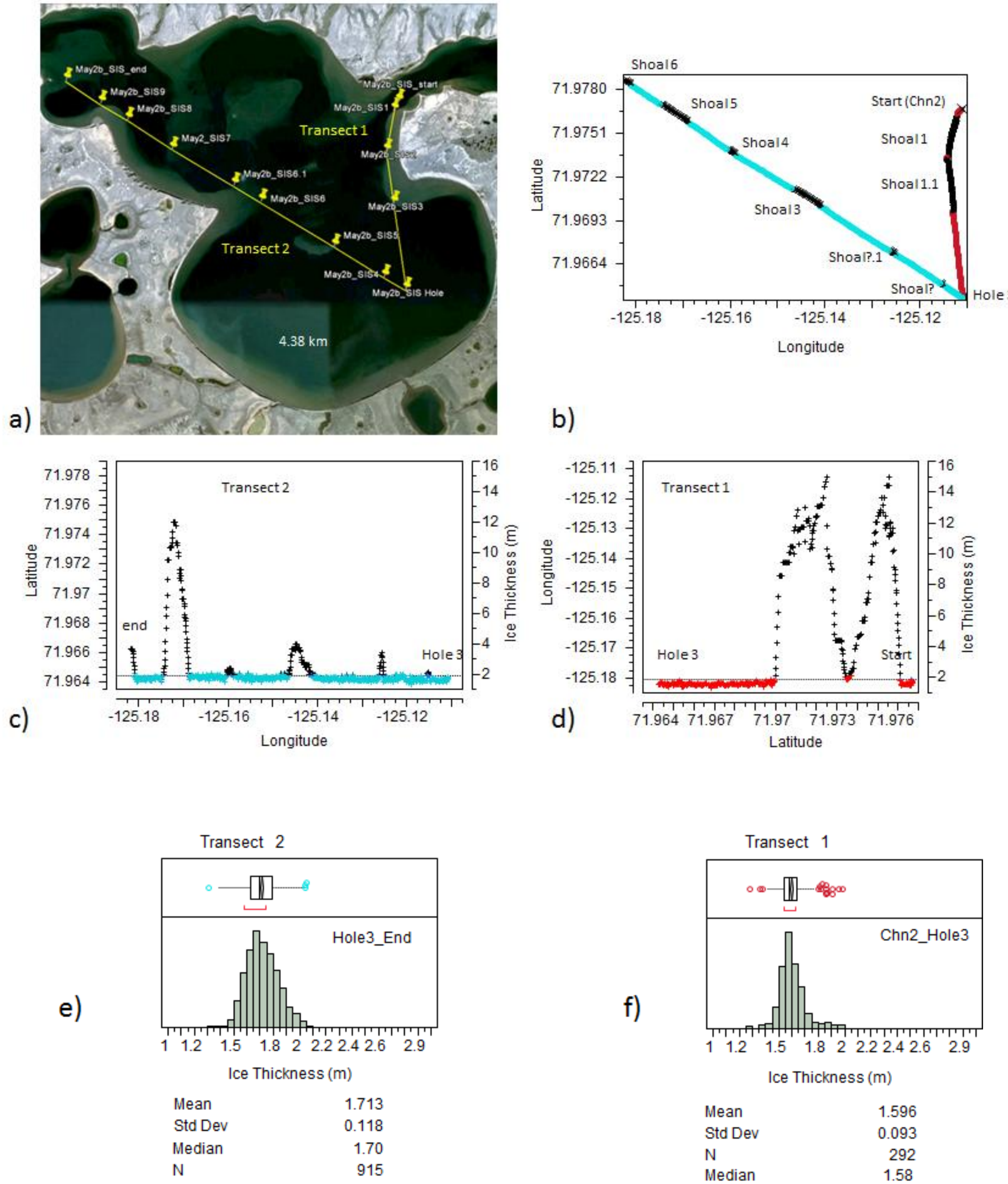
Fred Lake

Ice Thickness/
Shoal detection



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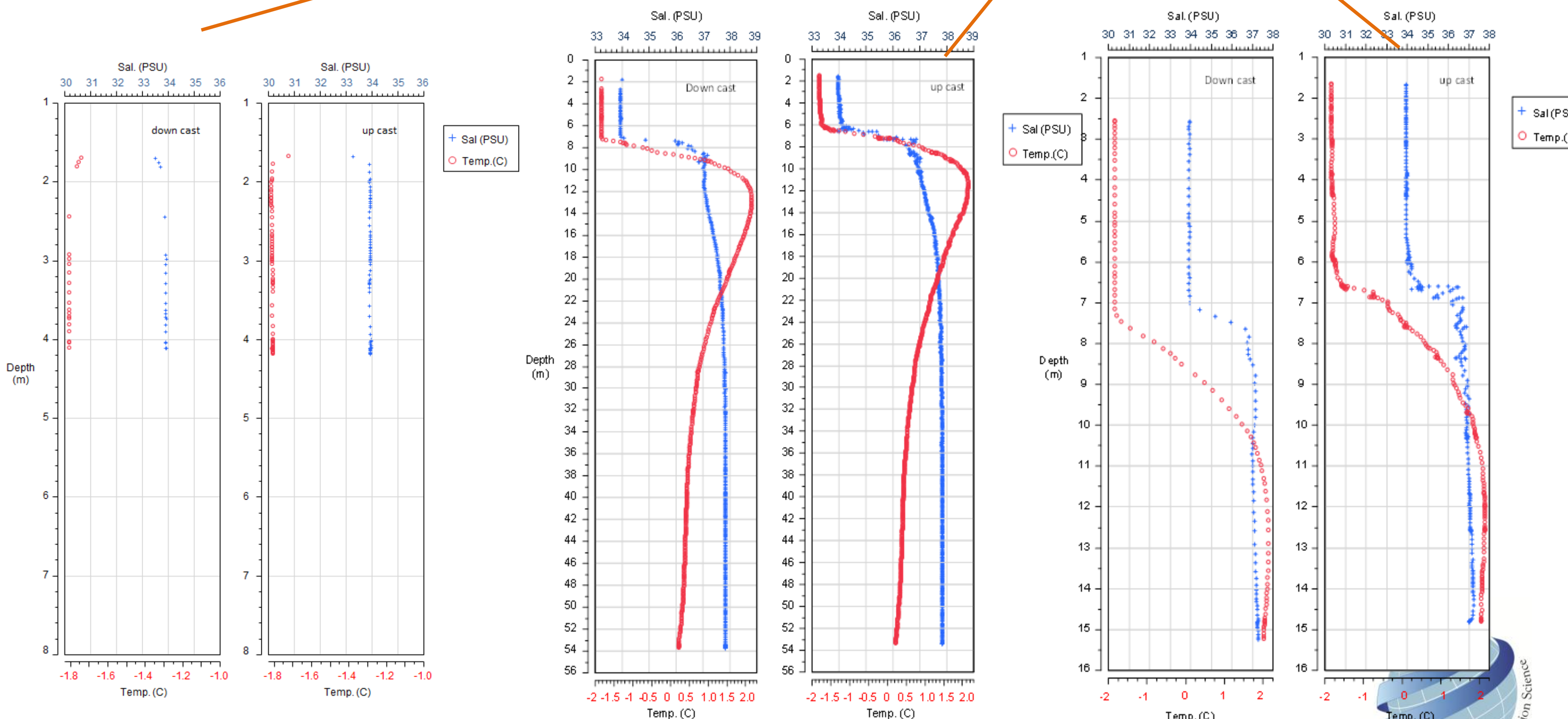
Conductivity
Temperature
Depth



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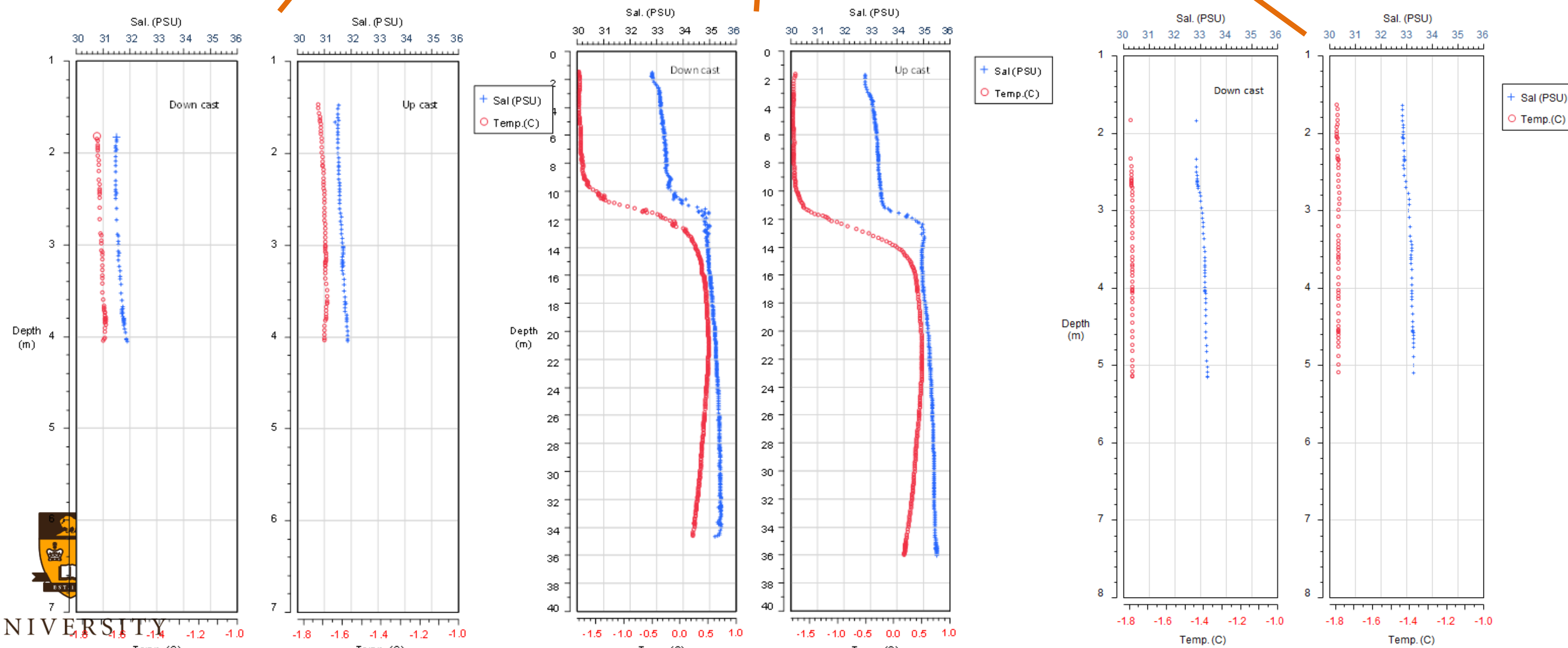
.May 16, 2012 CTD casts

Conductivity
Temperature
Depth



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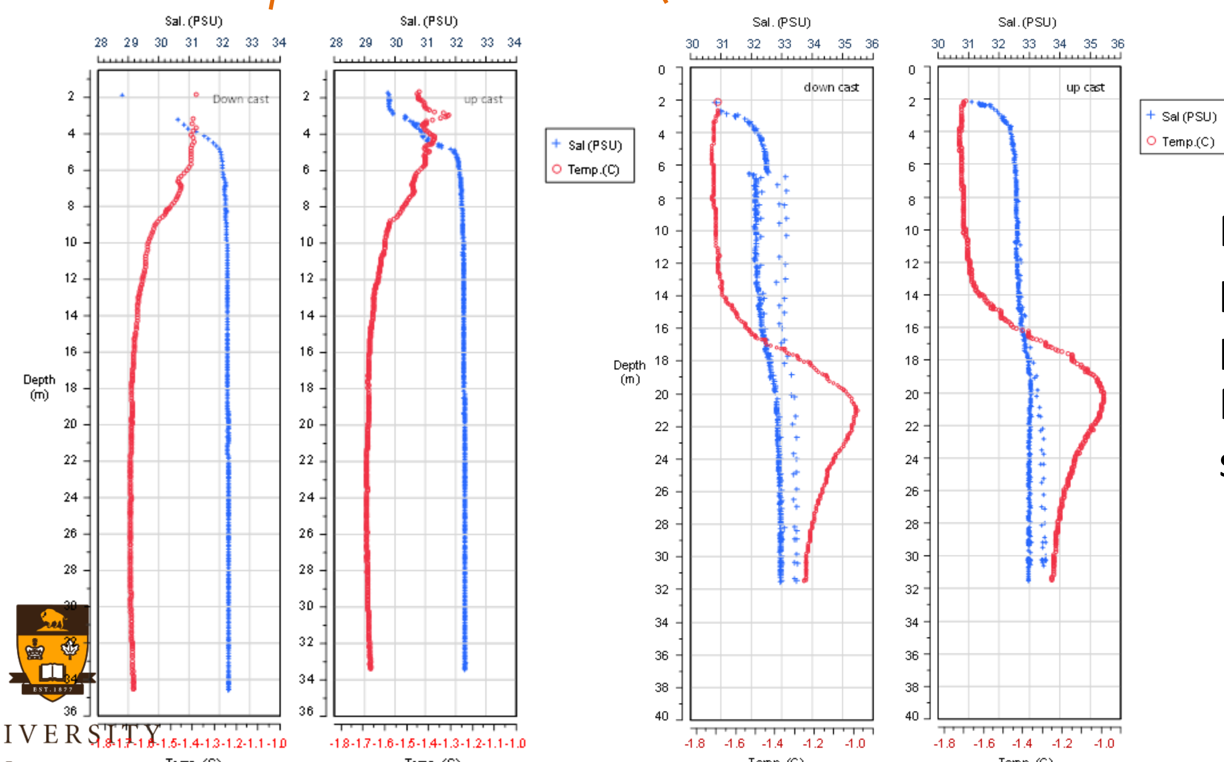
Conductivity
Temperature
Depth



Possible link with DFO project looking at productivity (Christine Michel), extension into summer late fall.

Publications in prep/press

Barber, D.G., H. Hop. C. J. Mundy, B. Else, I.A. Dmitrenko, J.E Tremblay, J. Ehn, P. Assmy. M. Saase, L.M. Candlish. and S. Rysgaard. (2014). Selected physical, biological and biogeochemical implications of a rapidly changing Arctic marginal ice zone. Progress in Oceanography. In review.

Candlish, L.M., J. Iacozza, J.V. Lukovich, B. Horton, and D. G Barber. (2014). Sea Ice Climatology in the Canadian Western Artic: Thermodynamic versus Dynamic Controls. Int. J. Climatology. In second review.

Firoozy, N. P. Mojabi, and D. G. Barber. (2014). Nonlinear inversion of Arctic snow covered sea ice dielectric profiles using microwave scattering data. IEEE Trans. Geosci. and Remote Sensing. In review.

Gupta, M., R. Scharien and D. G. Barber (2014). Passive and active microwave scattering from ocean surface waves in the southern Beaufort Sea. Int. J. Oceanography. In Press.

Komarov, A., D. G. Barber, D. Isleifson and L. Shafi. (2014). Modelling and Measurement of C-band Radar Backscatter from Snow-Covered First-Year sea ice. IEEE Trans. Geosci. Remote Sensing. In review.

Lukovich, J.V., C. Bélanger, D.G. Barber and Y. Gratton (2014). On the relative contributions of oceanic and atmospheric forcing of the Beaufort Sea Ice Gyre. J. Geophys. Res. (Oceans). In review.