An Integrated Sea Ice Project For BREA:

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

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David Babb, Anna Crawford, Alexander Komarov,
Jennifer Lukovich, Matt Asplin

Community Based Monitoring

Charlie Haogak, Jim Wolki and J.D. Keogak

University of Manitoba

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Objectives

The project's overarching objective is to develop an understanding of the physical and engineering characteristics of sea ice features for shipping and future oil /gas exploration activities on the Beaufort sea shelf. The U of M portion of the project will involve:

- collecting new data and integrate existing field data on extreme sea ice features; ice thickness data/ice mass balance
- collect new data and integrate existing field data on how and why sea ice features move (oceanic and atmospheric forcing)
- develop approaches to identifying significant ice features using remote sensing
- pilot a community based monitoring program (CBM) whereby Sachs Harbour residents can monitor local ice thickness using a surface based EM induction (SEMI) system.

U of M portion fully 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

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

- Background
- Study Site
- Field Work:
  1) ice motion,
  2) ocean currents, in-situ winds
  3) ice temperature profiles (Ice Mass Balance),
  4) Surface EM induction surveys (Ice thickness)
- RADARSAT-2 Ice motion and Winds
- RADARSAT-2 detection/monitoring of extreme ice features (ice signatures)
- Community Based Monitoring (Sachs Harbour) – ice thickness, CTDs

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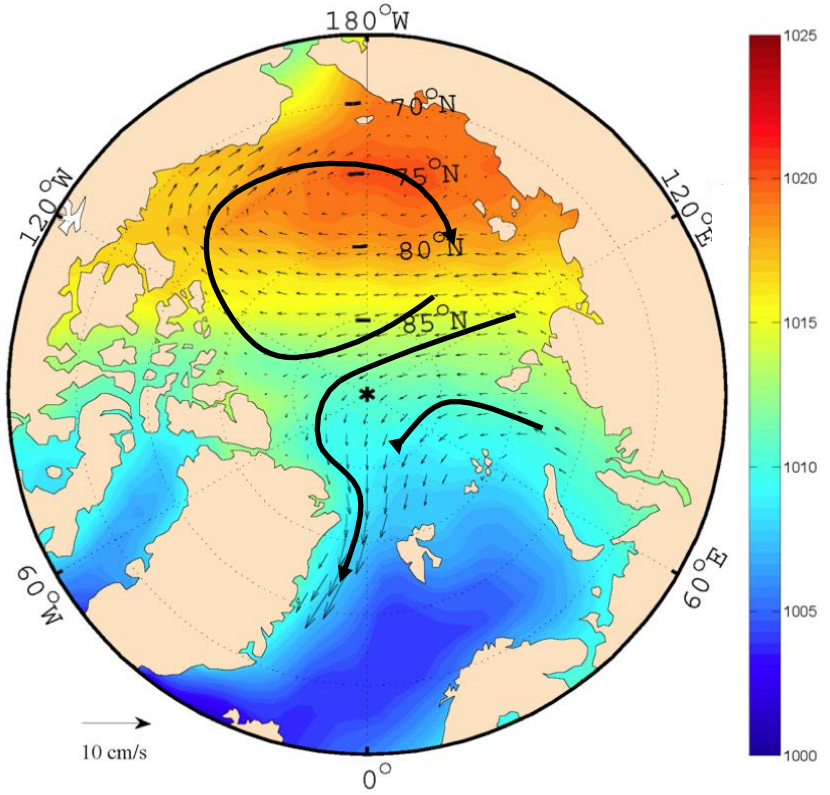
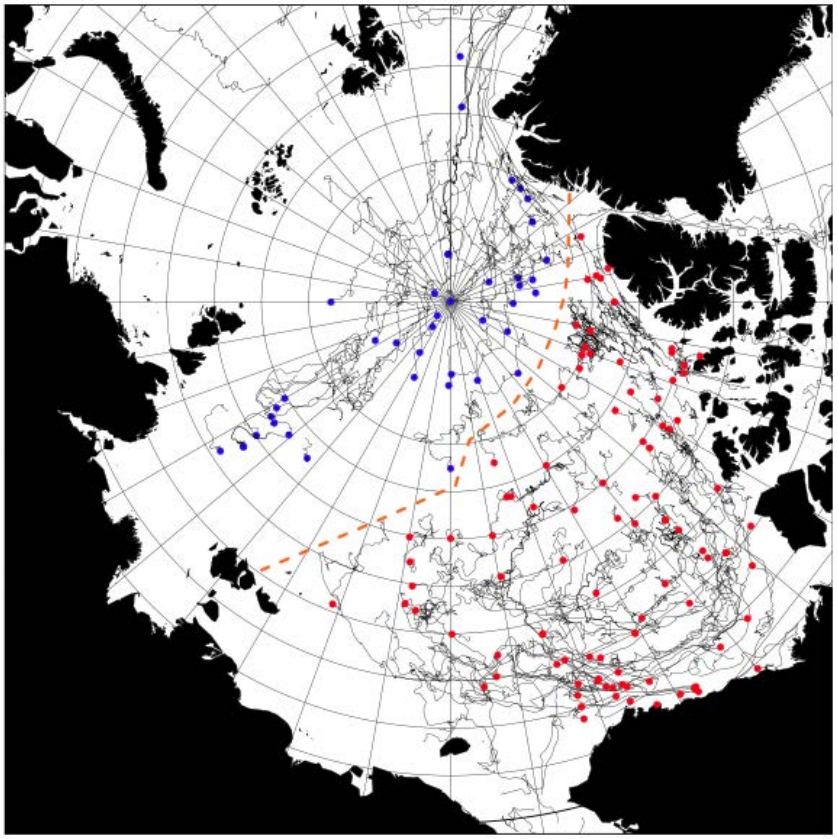
Ice Motion
The two sea ice gyres



Double Gyre Pattern



IABP ice motion

- Beaufort Gyre, generally clockwise rotation
- Transpolar Drift

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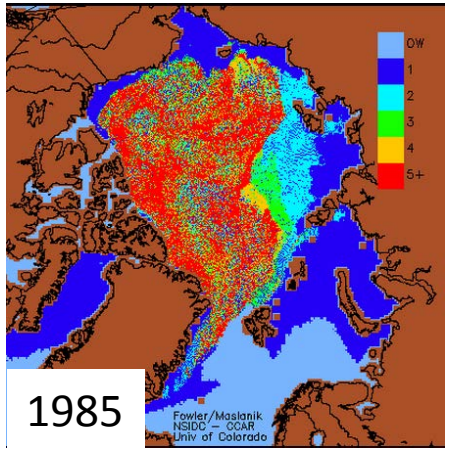
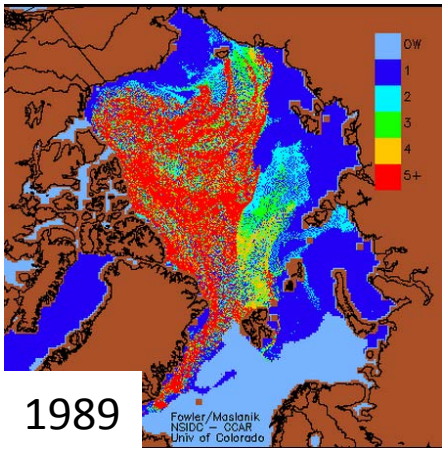
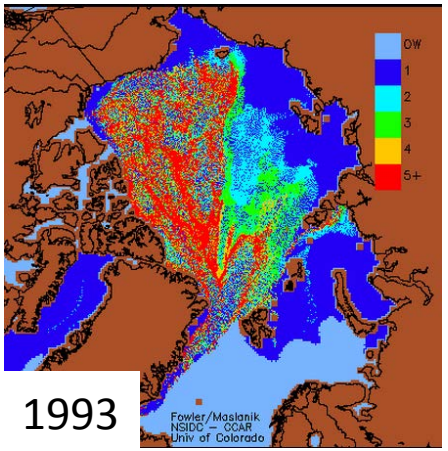
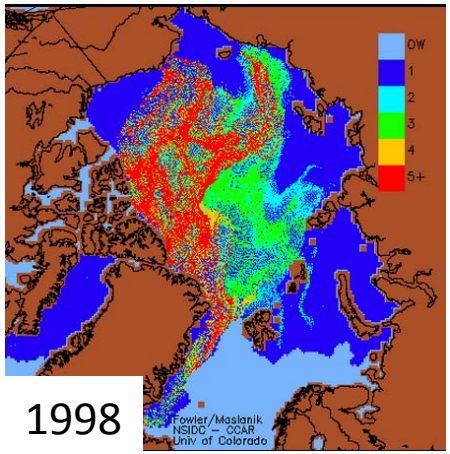
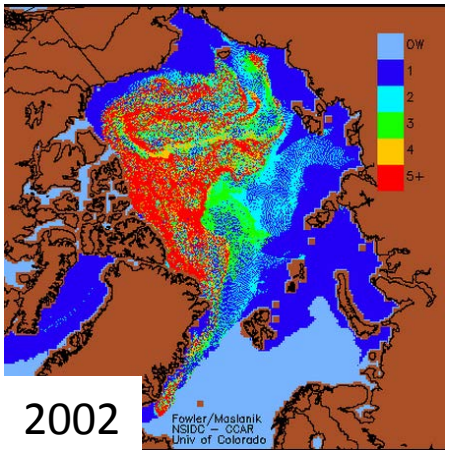
April

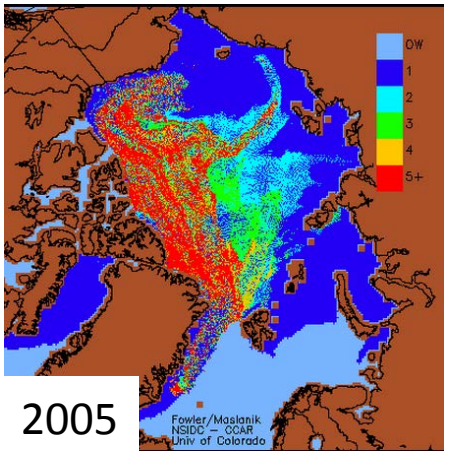


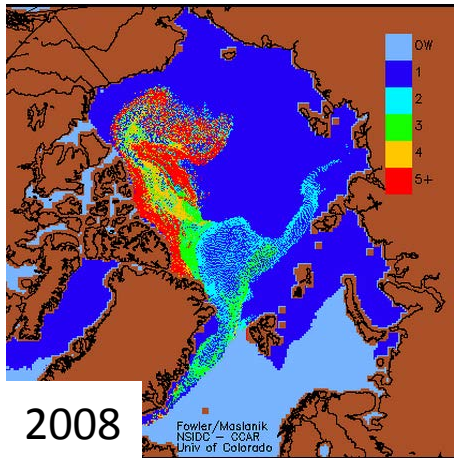


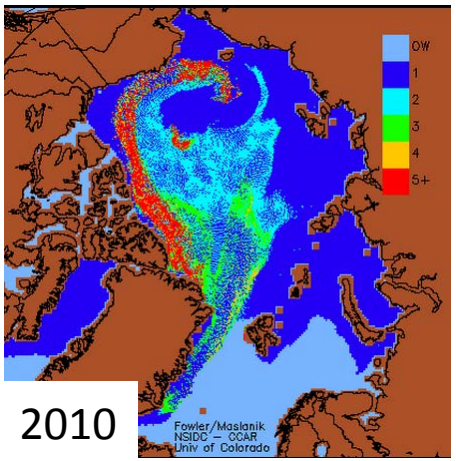




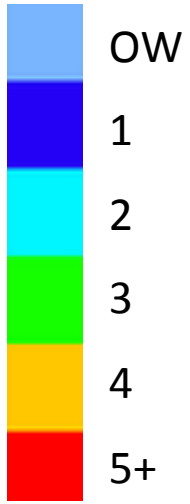








Ice Age



Less MYI; thinner thickest/oldest up against Canadian Archipelago, 2005-2009 net loss of 6,300 km^3 of MYI volume (>40% loss)

MYI persists along the Canadian coast

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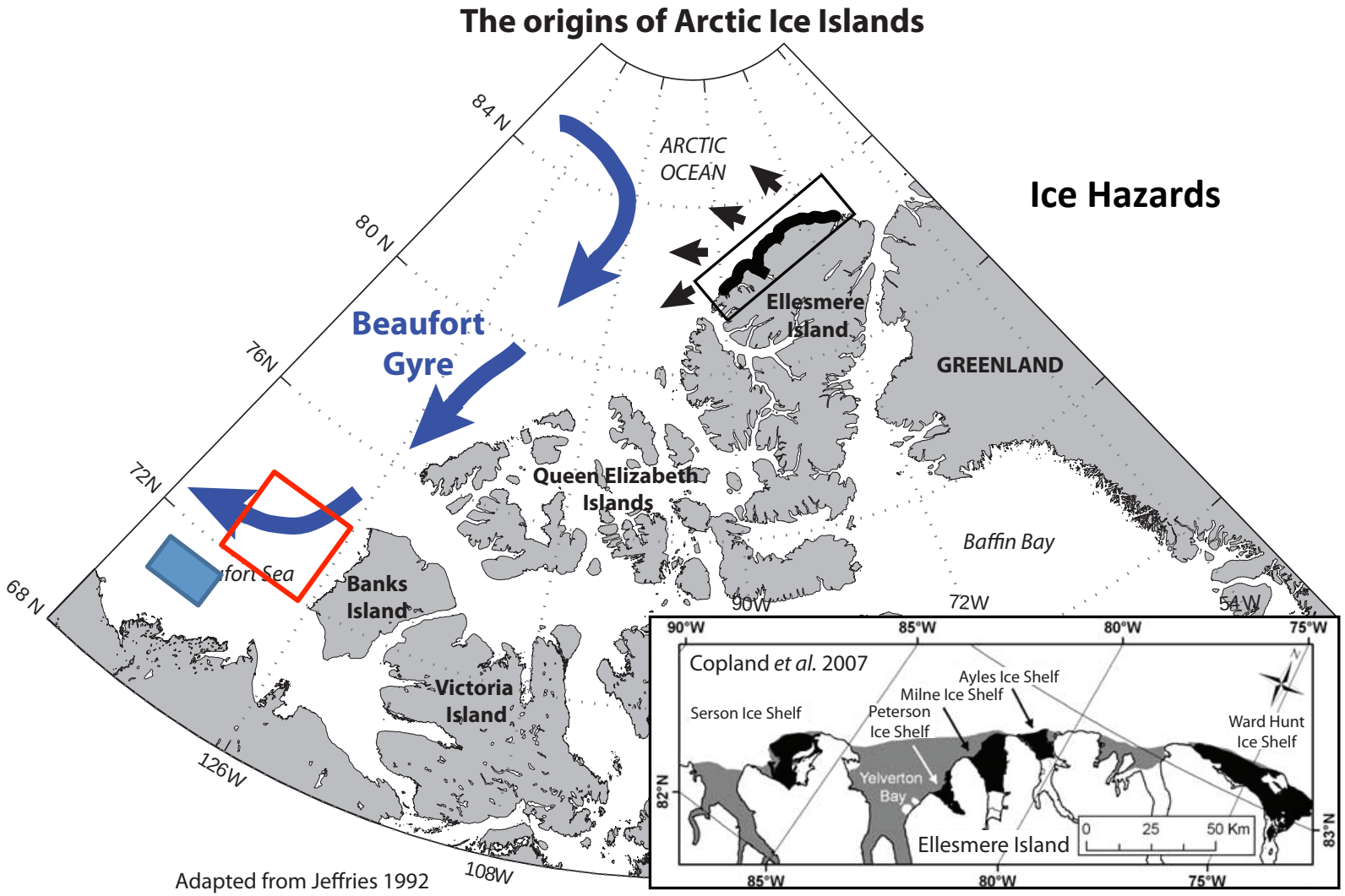
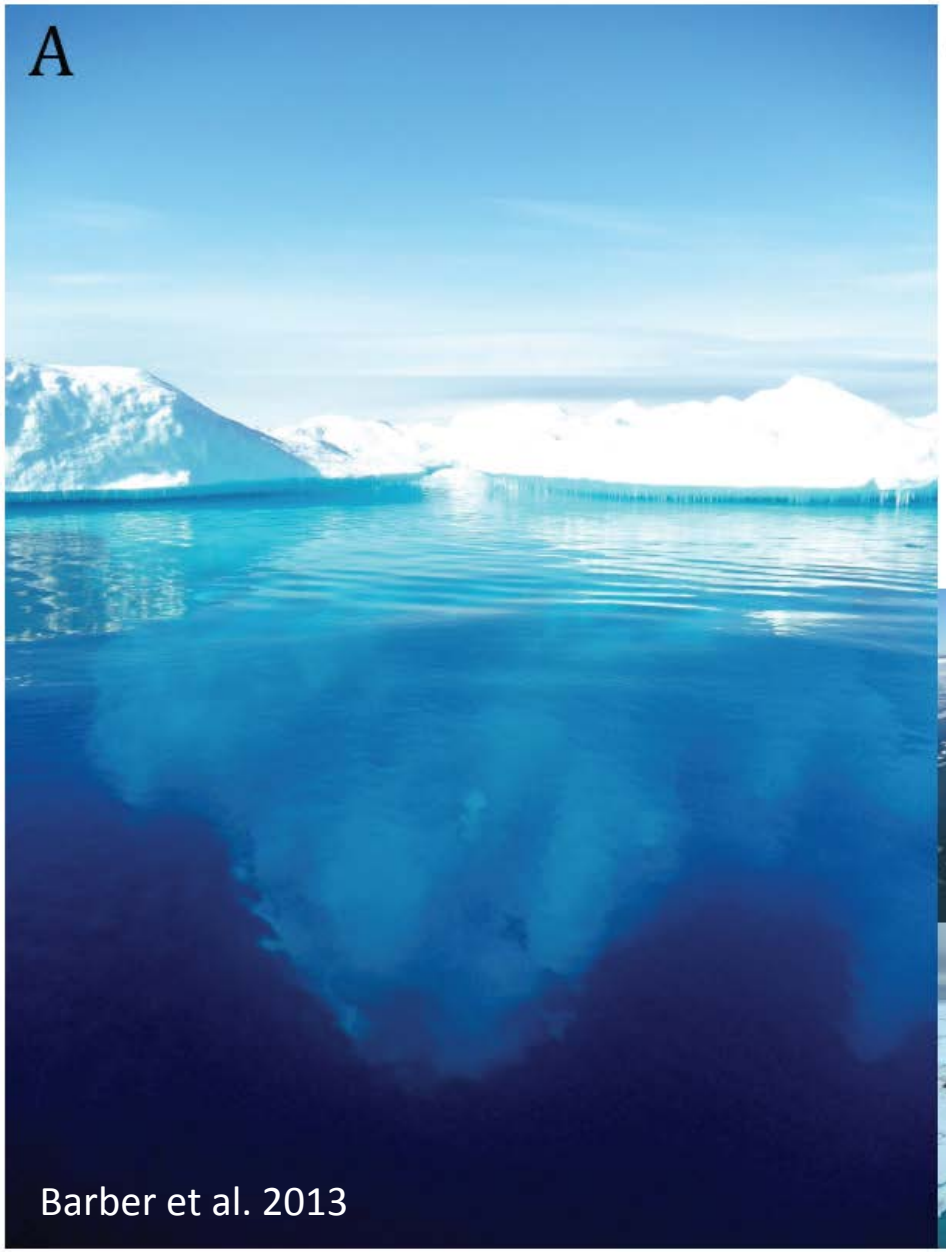
http://polarbear.colorado.edu/IceAge/

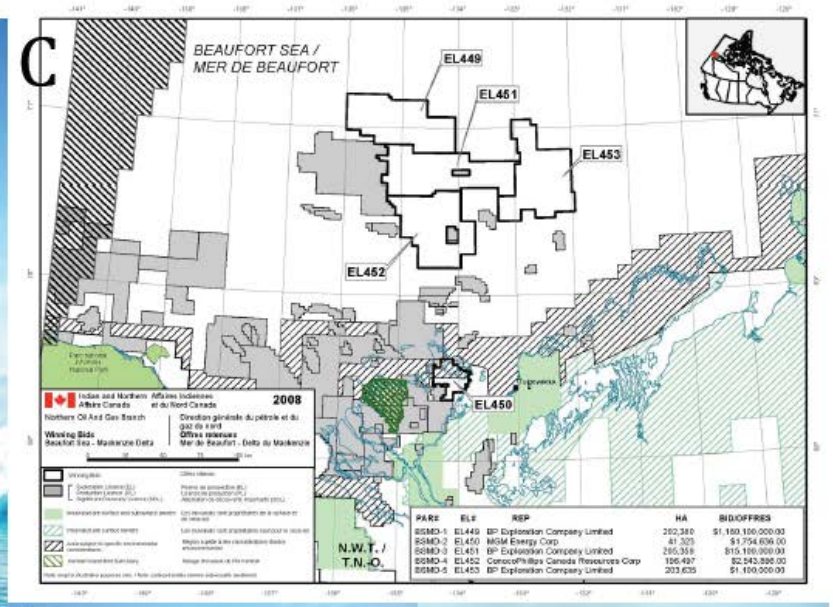


There has been a 90% reduction in the areal extent of ice shelves along the entire coast of N. Ellesmere Island [Vincent et al., 2001], most of the reductions where in the 50s/60s, leaving 6 major ones in 2004, no evidence of regrowth. In 2005, 66.4 km² calved, 214 km² in 2008, and sporadically since, ~220 km² (2010, 2011, 2012)

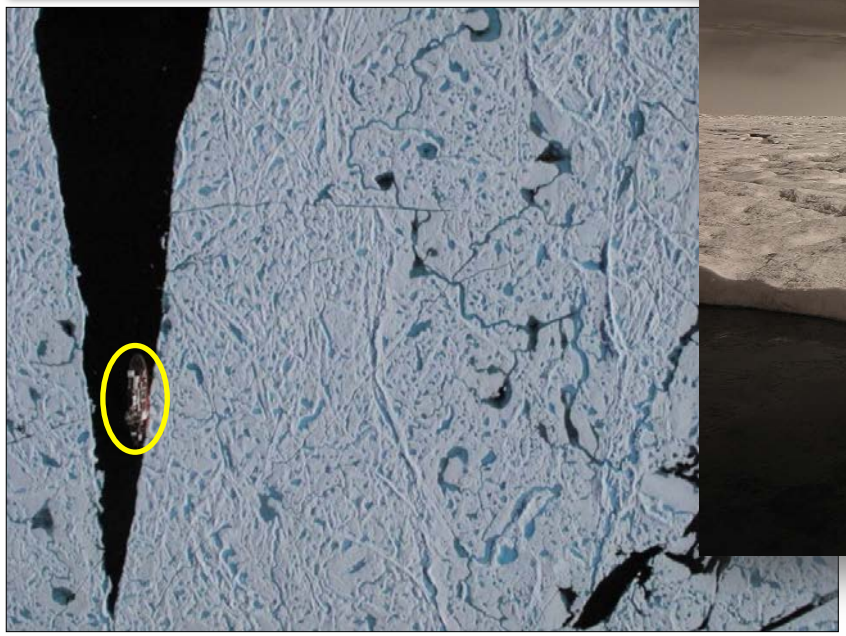
Extreme Ice Features: Multi-year ice and ice islands (glacial)



Barber et al. 2013



Multi-year(Summer 2011)



3-20m +

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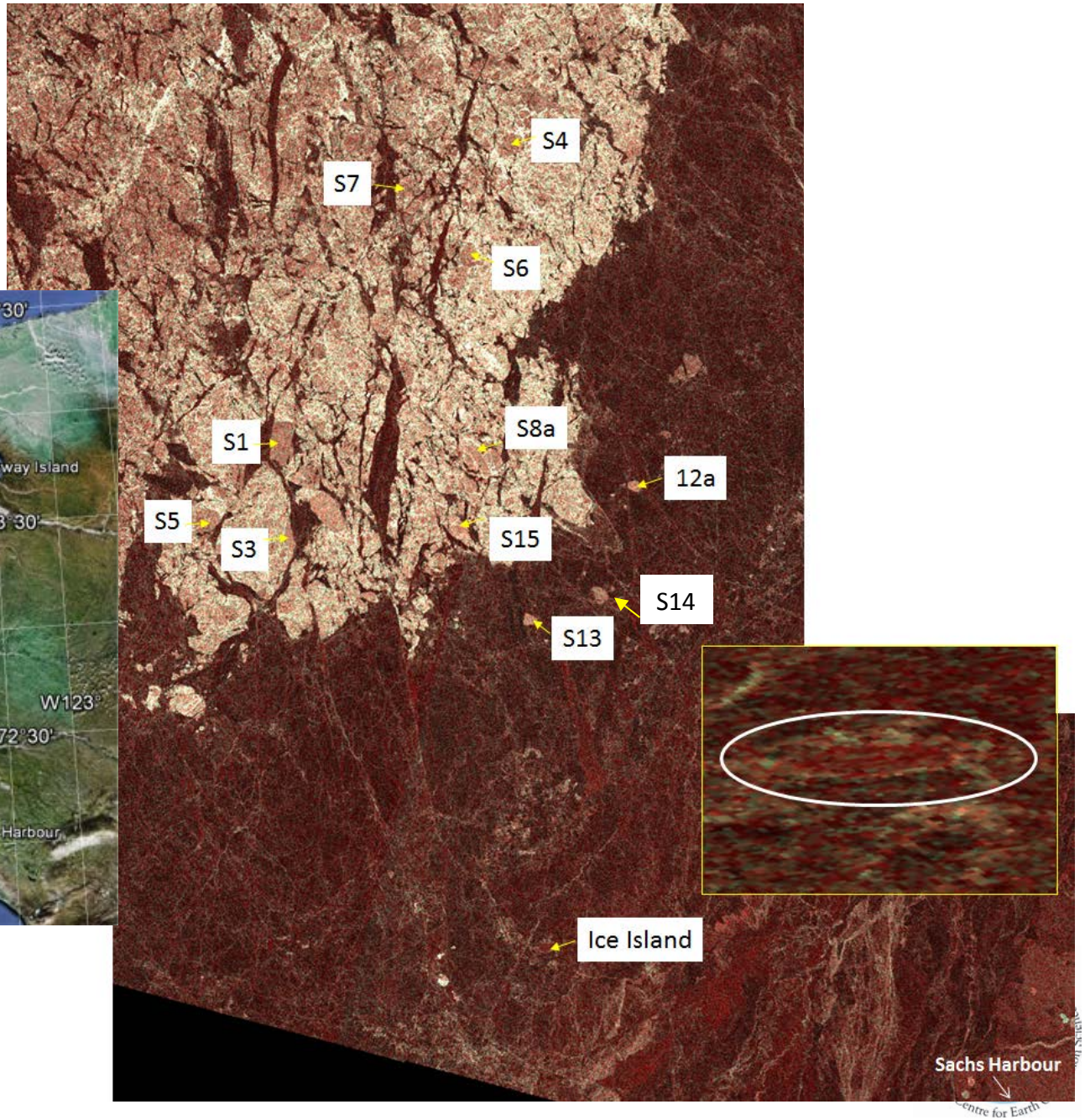
Study Site

West of Sachs Harbour



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Ice Dynamics Instrumentation: Position only Buoys

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Ice Drift Beacon Deployment:
10 on MYI, 2 on the Ice Island

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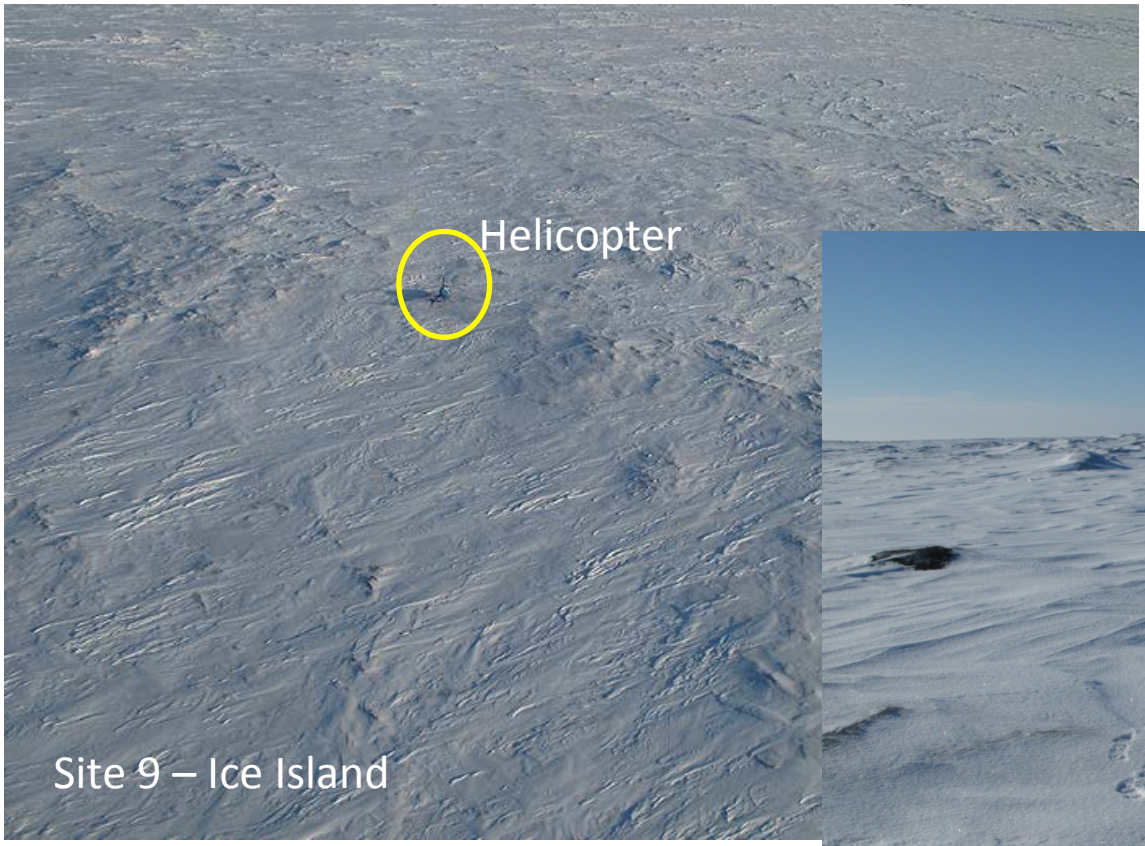
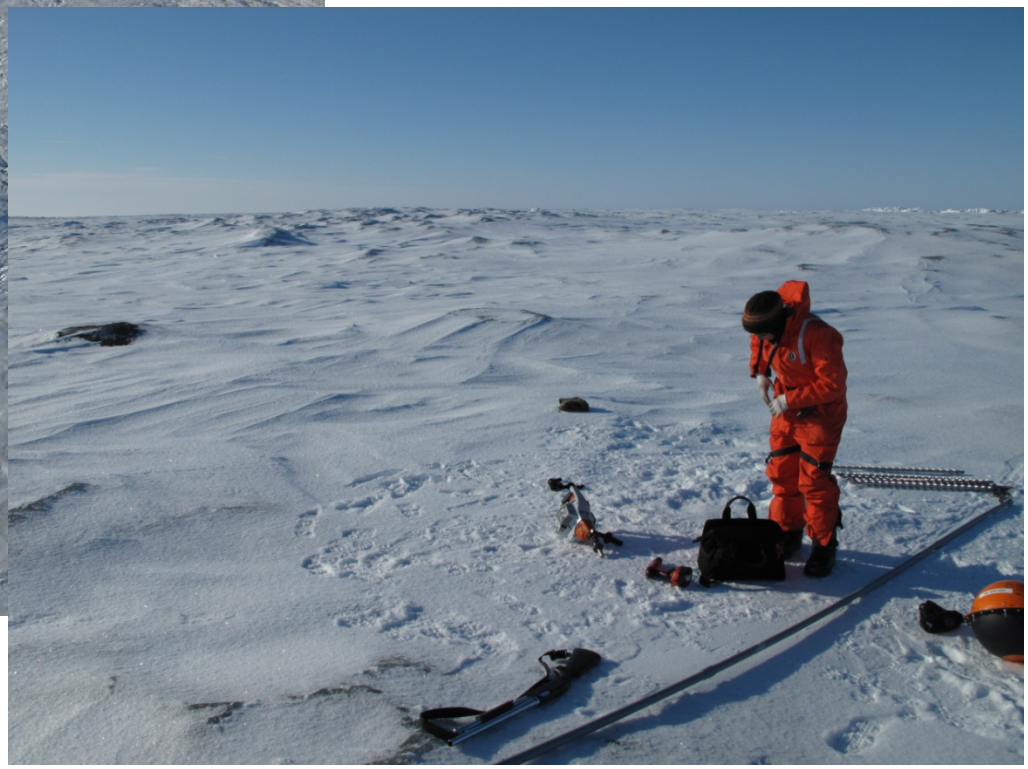
Ice Drift Beacon Deployment: Ice Island (2 beacons)





Installing 6m ablation stake

Markham Island: 2 x 1.0 km, >30m thick

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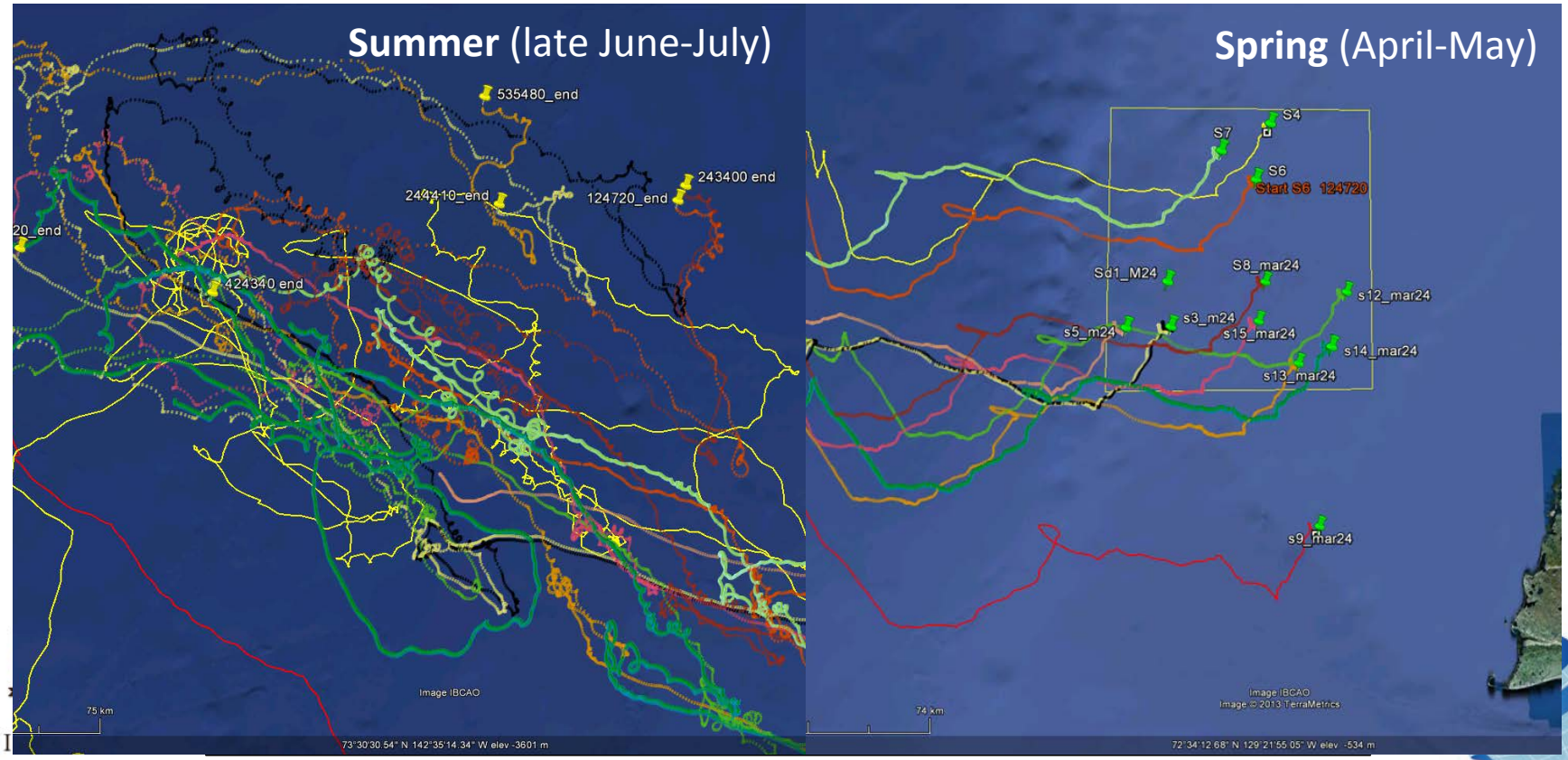
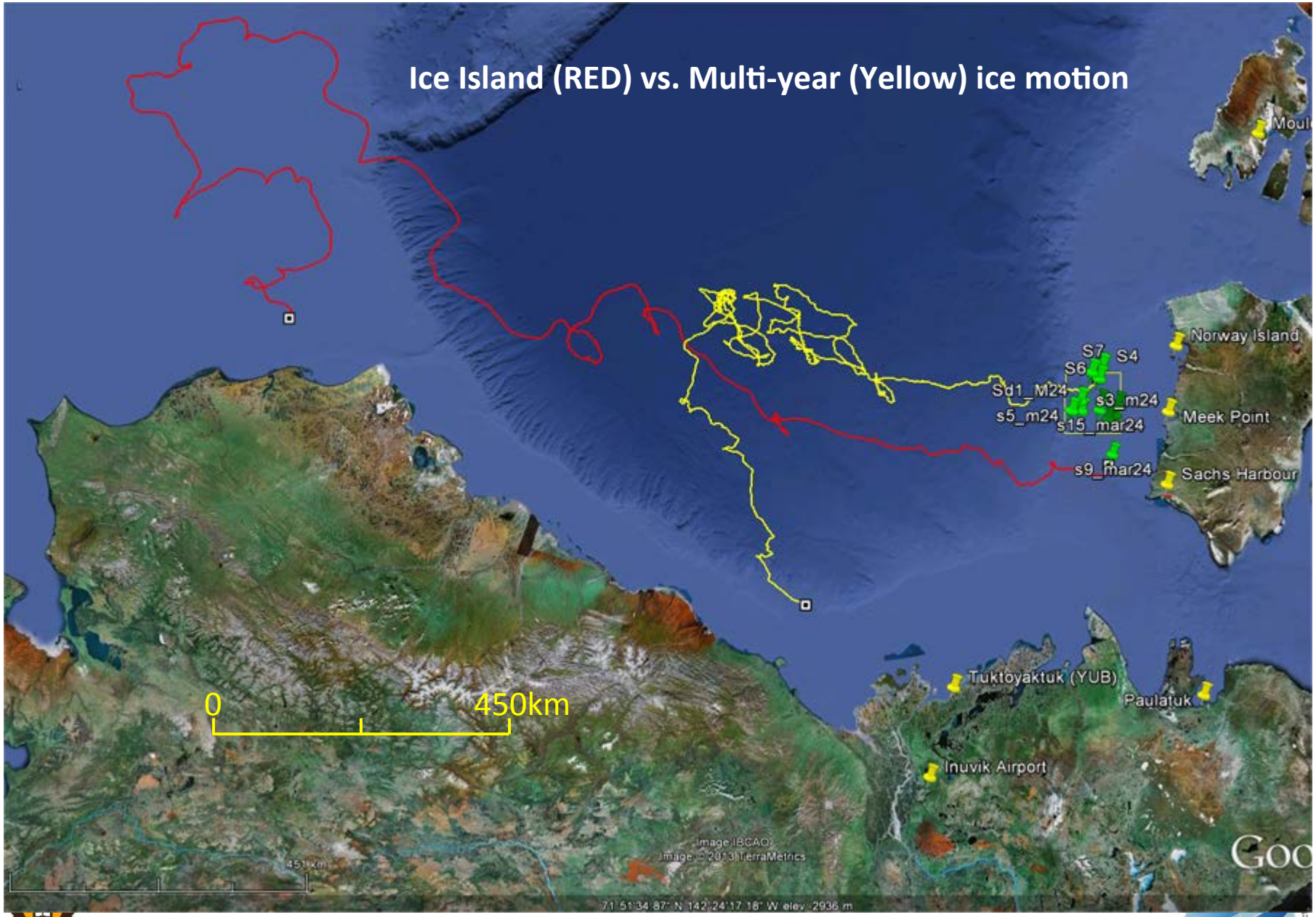
Ice motion

- **Spring:** ice moved as a pack
  - Less variable
  - More direct (Straight lines)
  - Lagged response to winds and currents (working hypothesis)
- **Summer:** Ice moved differentially
  - Highly variable
  - Inertial loops!
  - More responsive to winds and currents (working hypothesis)



Ice Movement – f(Local Winds, regional winds, ocean currents, sea ice concentration)


Ice Island (RED) vs. Multi-year (Yellow) ice motion
Norway Island
S7
S4
S6
Sd1_M24
s3_m24
s5_m24
s15_mar24
Meek Point
s9_mar24
Sachs Harbour
Tuktoyaktuk (YUB)
Paulatuk
Inuvik Airport
0
450km

Understanding Ice Dynamics: Instrumentation

Surface Winds

- 1 lasted from April 10th to July 31st.

Aquadopp Current Profiler

- lasted from April 10th to July 29th
- Measured ocean surface currents at 2m intervals down to 60m
- Data corrected relative to floe rotation, speed, etc.

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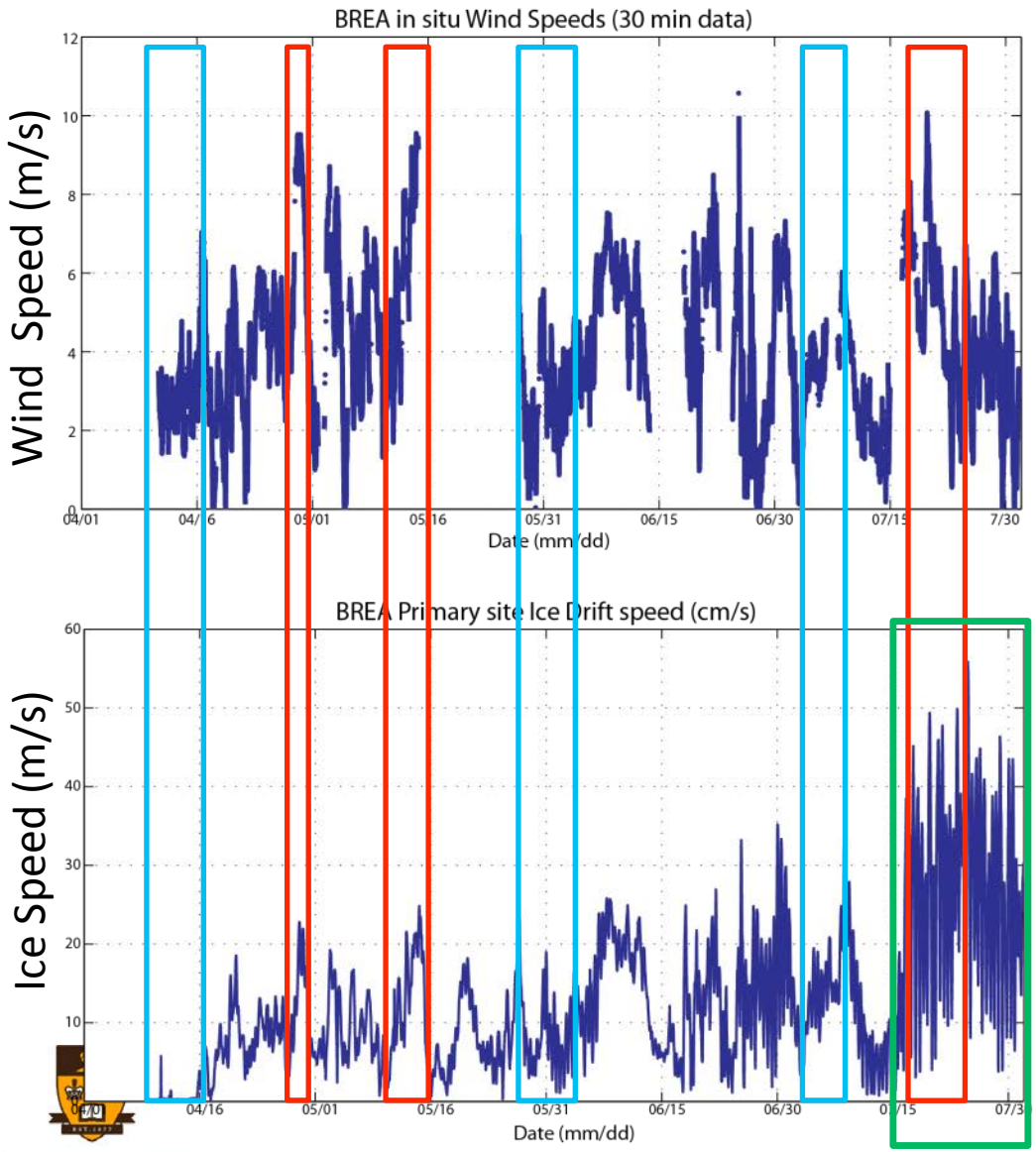
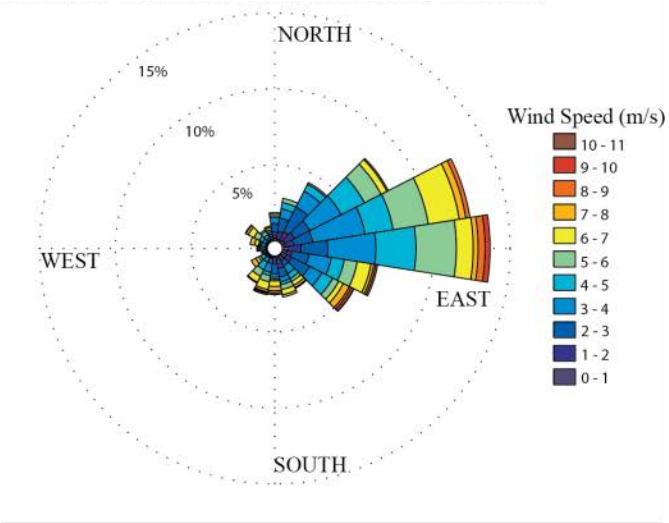
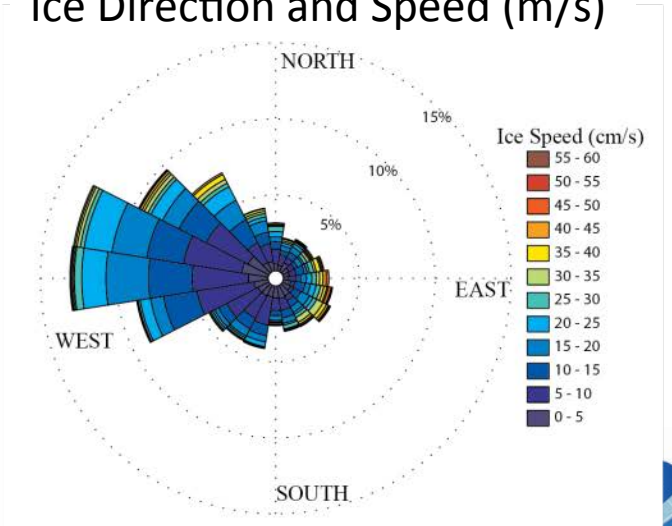


Wind Direction and Speed (m/s)



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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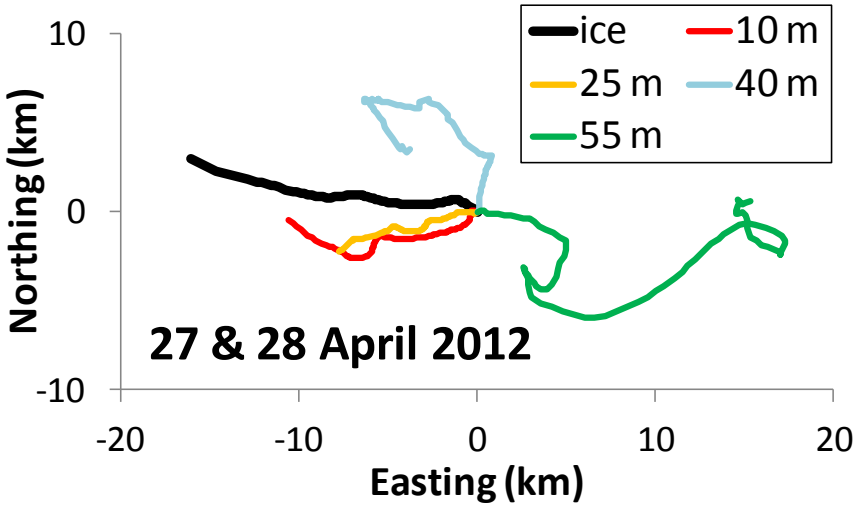

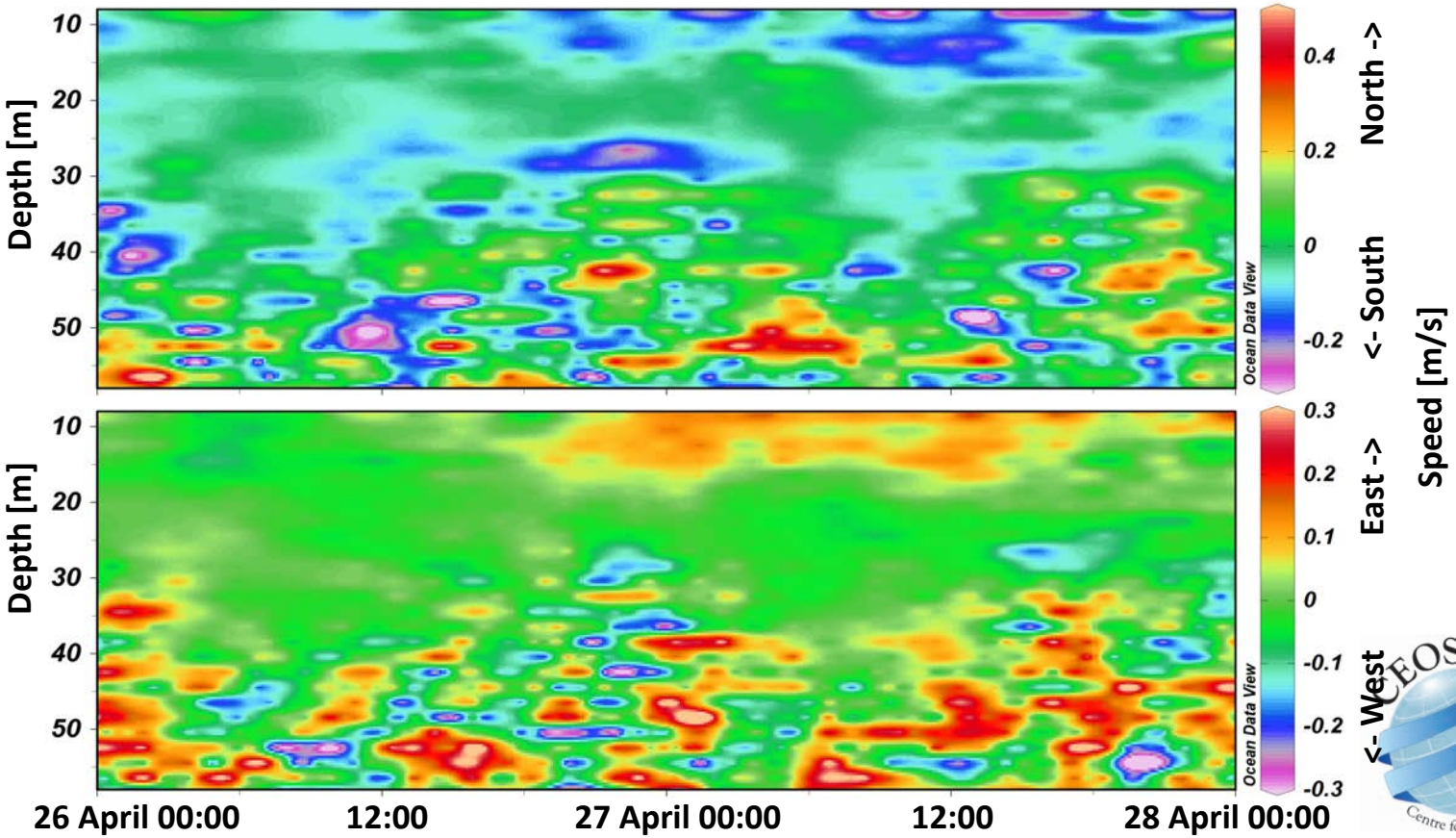

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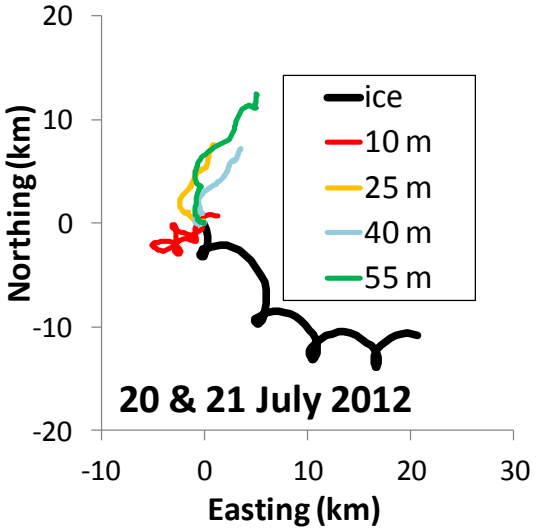
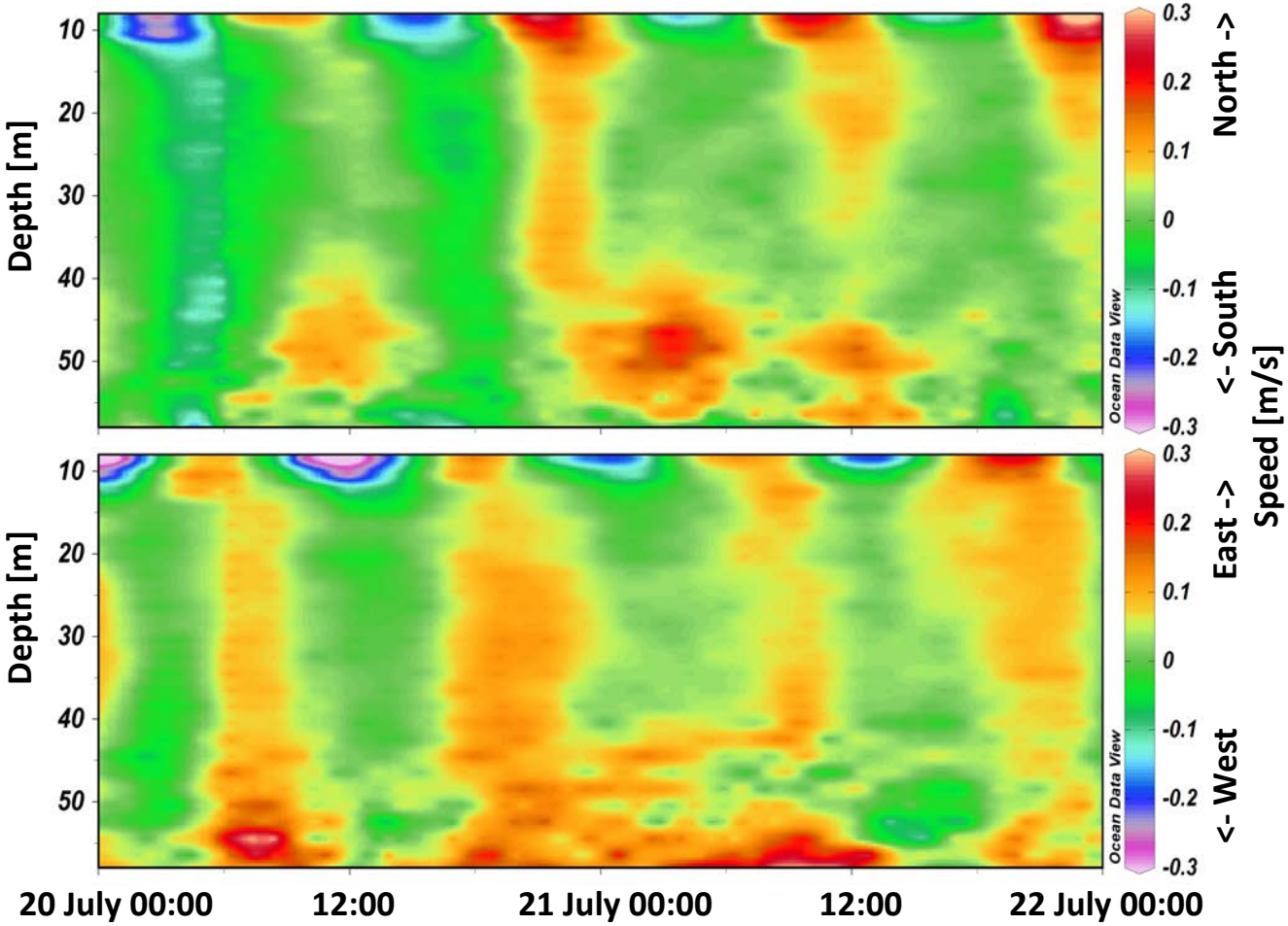
Late season

- Low ice concentration
- Unconstrained motion





- black line shows ice track
- average ice motion was to ESE; from 25-50 m depth, currents were NNE
- loops in ice track are due to semi-diurnal inertial oscillations of ice motion

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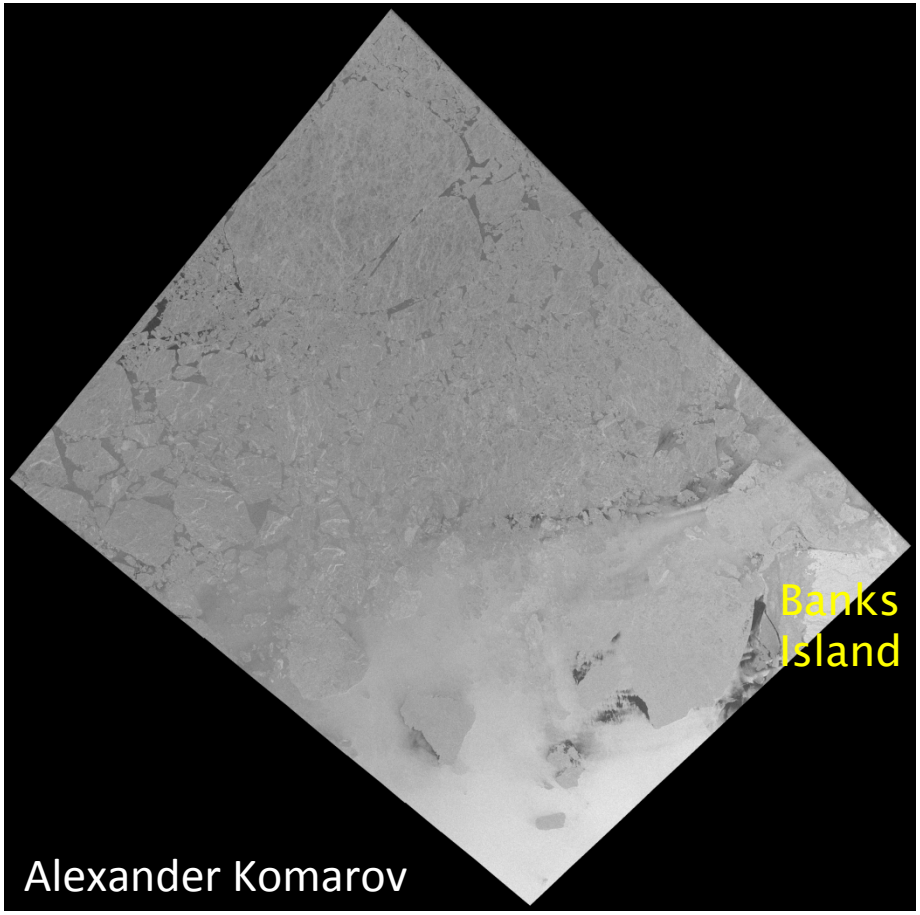
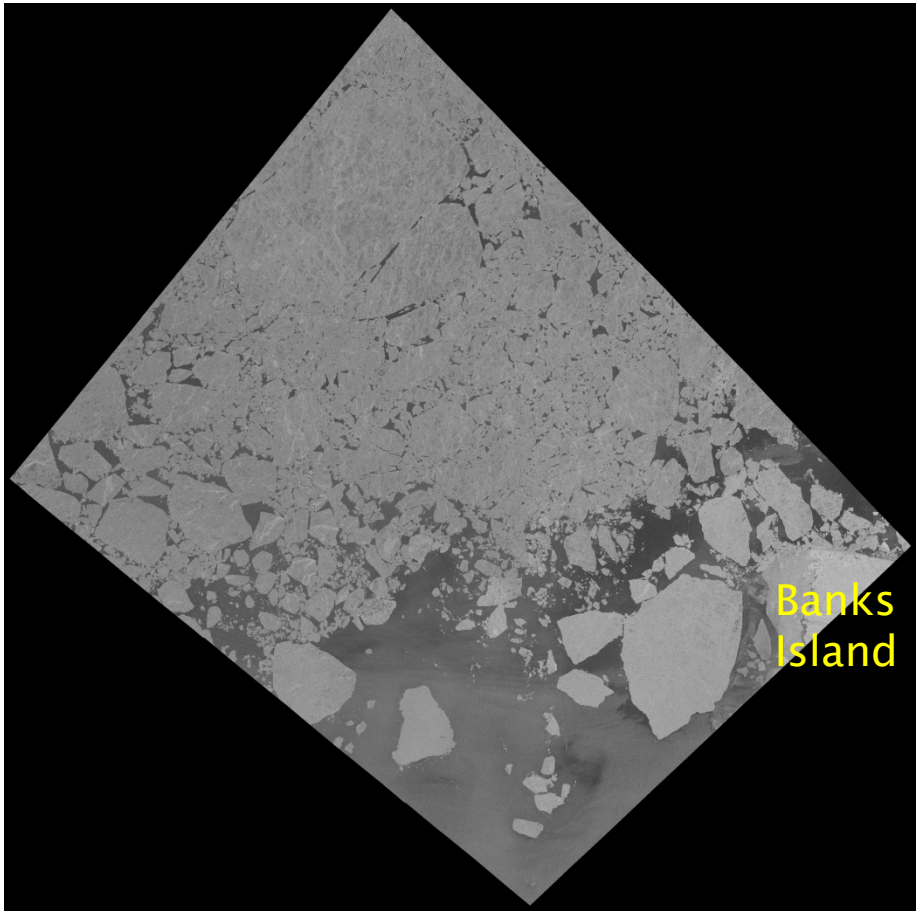
Regional Wind forcing – from SAR

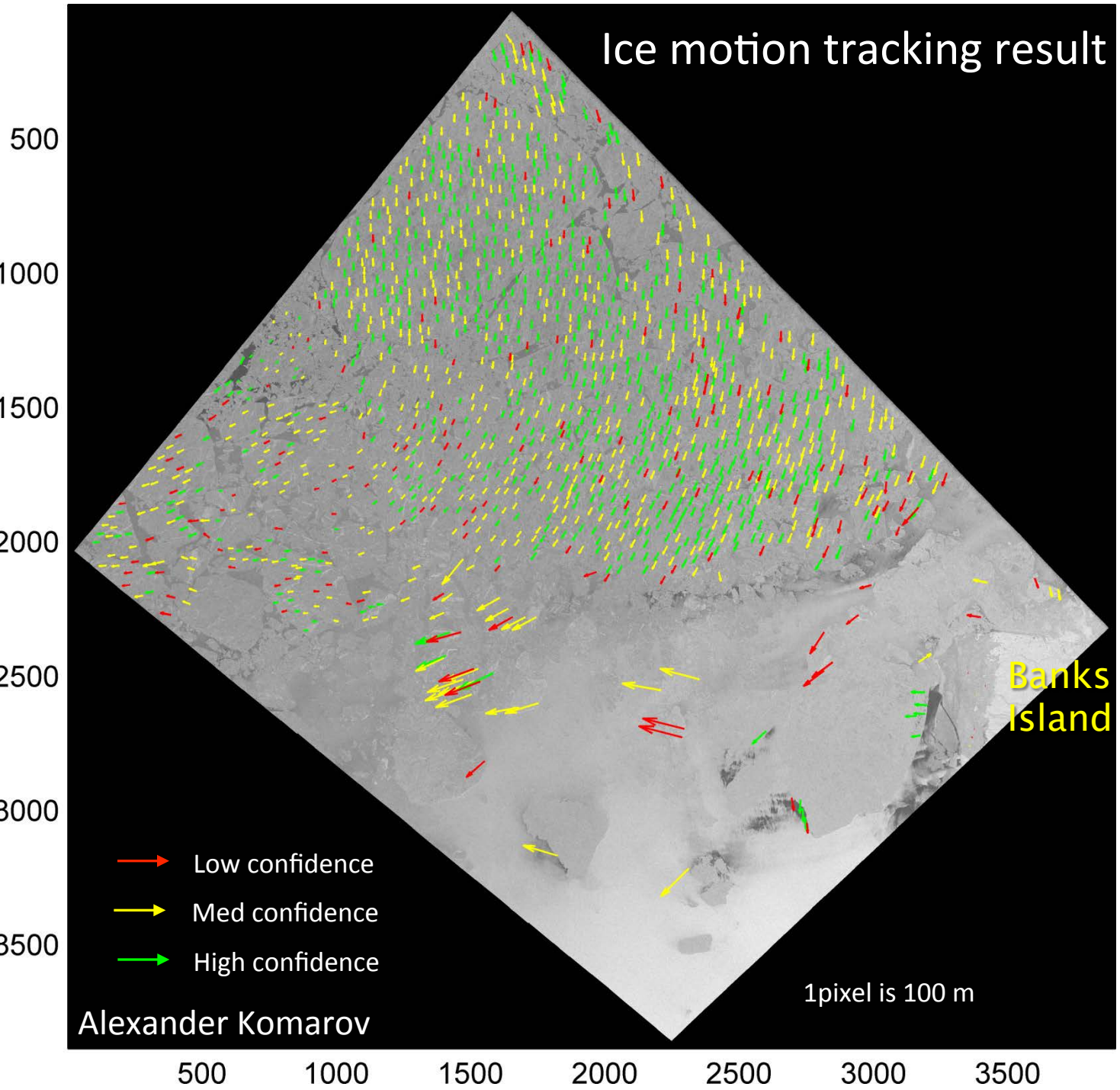
Two sequential images (HH) over the Beaufort Sea (week 10)

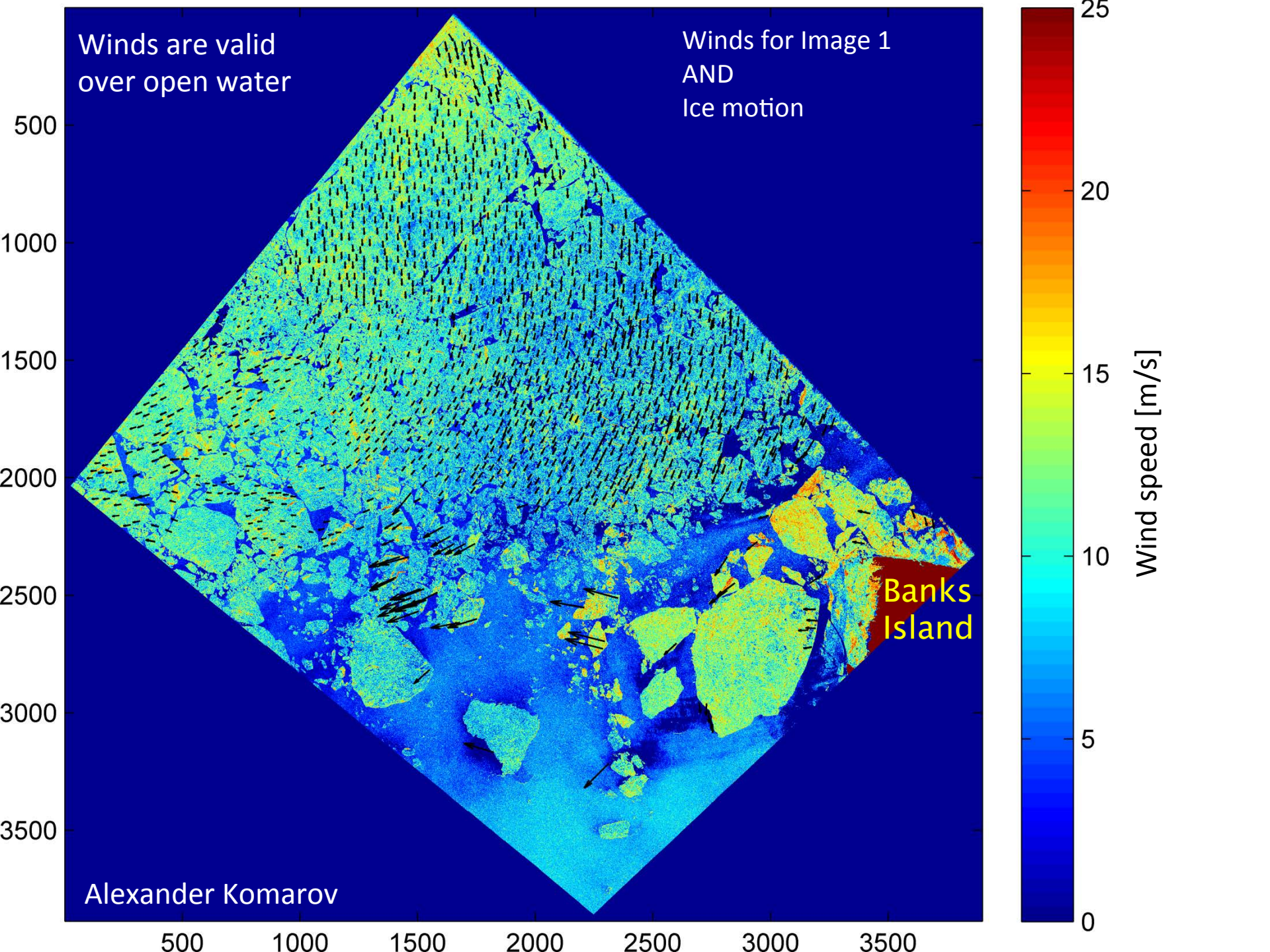


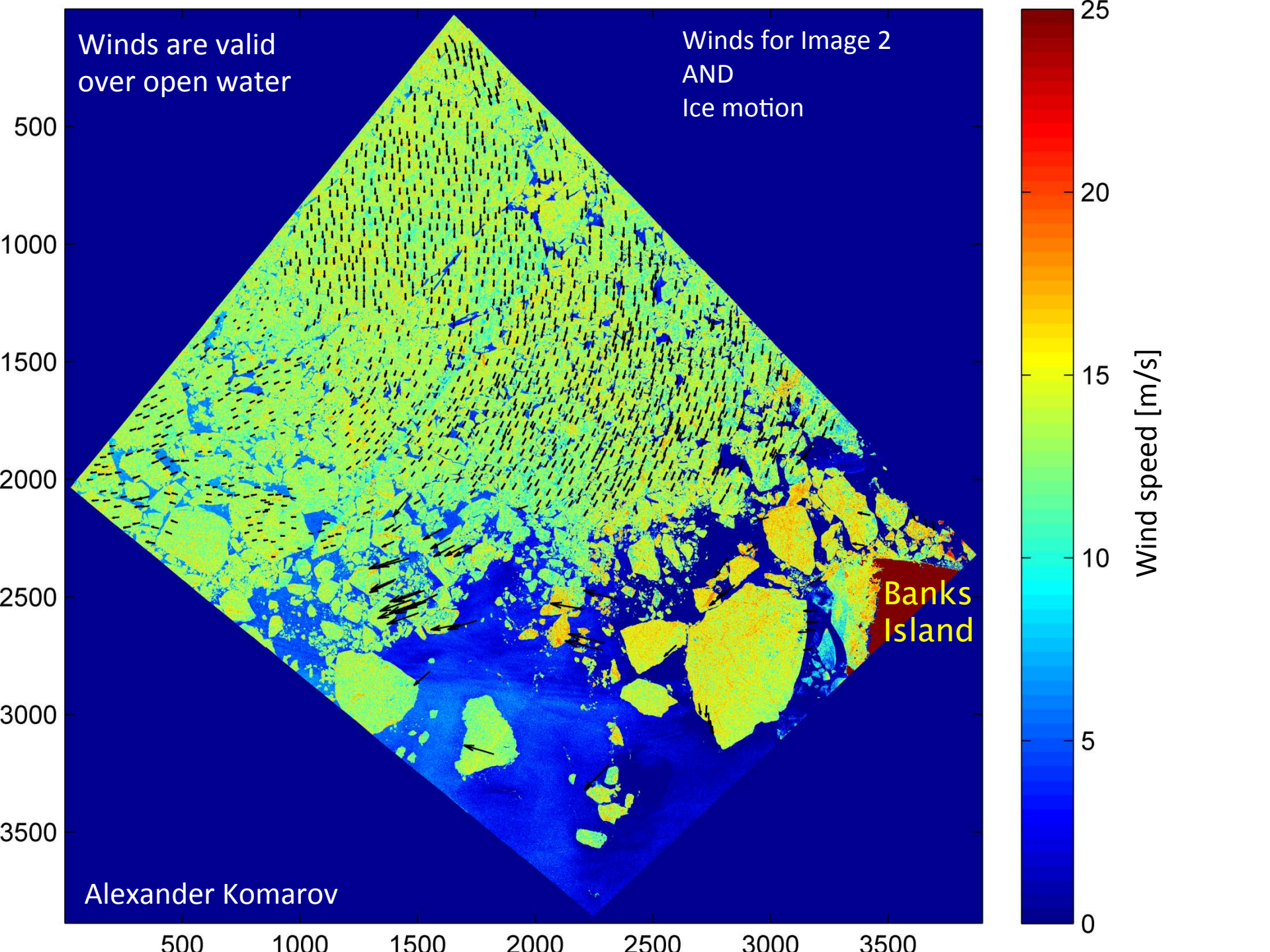
June 23, 2012



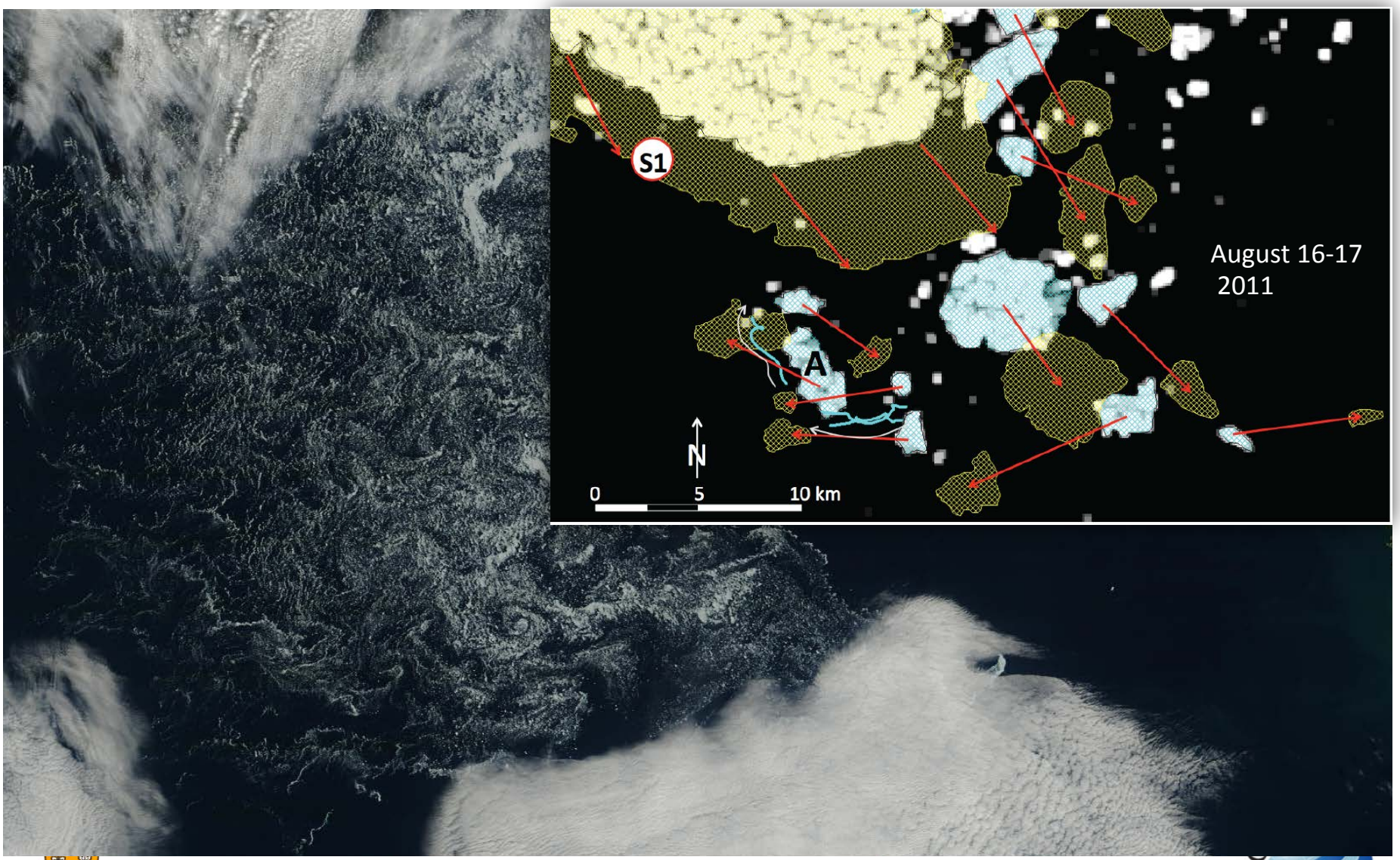
June 24, 2012


Ice motion tracking result
500
1000
1500
2000
2500
3000
3500
Banks Island
Low confidence
Med confidence
High confidence
1pixel is 100 m
Alexander Komarov
500
1000
1500
2000
2500
3000
3500


Winds are valid
over open water
Winds for Image 1
AND
Ice motion
Banks
Island
Alexander Komarov
500
1000
1500
2000
2500
3000
3500
Wind speed [m/s]
0
5
10
15
20
25


Winds are valid
over open water
Winds for Image 2
AND
Ice motion
Banks
Island
Alexander Komarov
500
1000
1500
2000
2500
3000
3500
Wind speed [m/s]
0
5
10
15
20
25

Eddies – complexity of surface ice motion



MODIS August 23, 2012 20:55 UTC

Ice Thermo-Dynamics: Instrumentation

2 Ice Mass Balance buoys

- 1 lasted from April 10th to July 31st.
- 1 died quickly, Temperature string died almost instantaneously.

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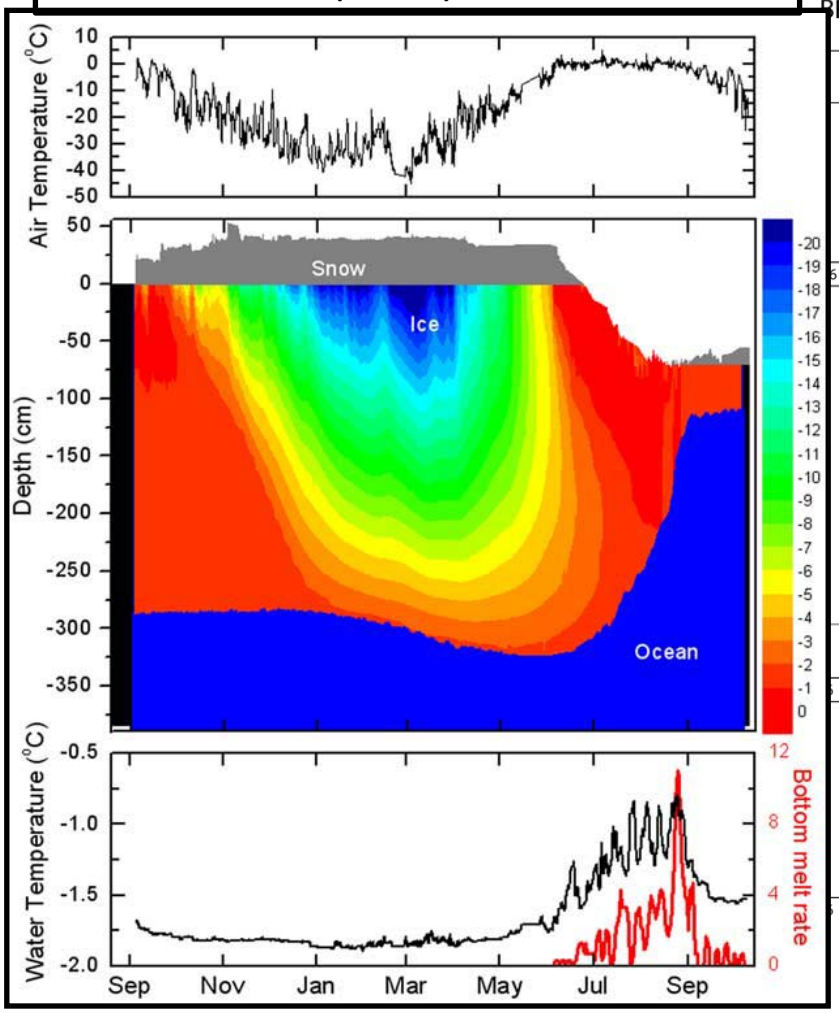
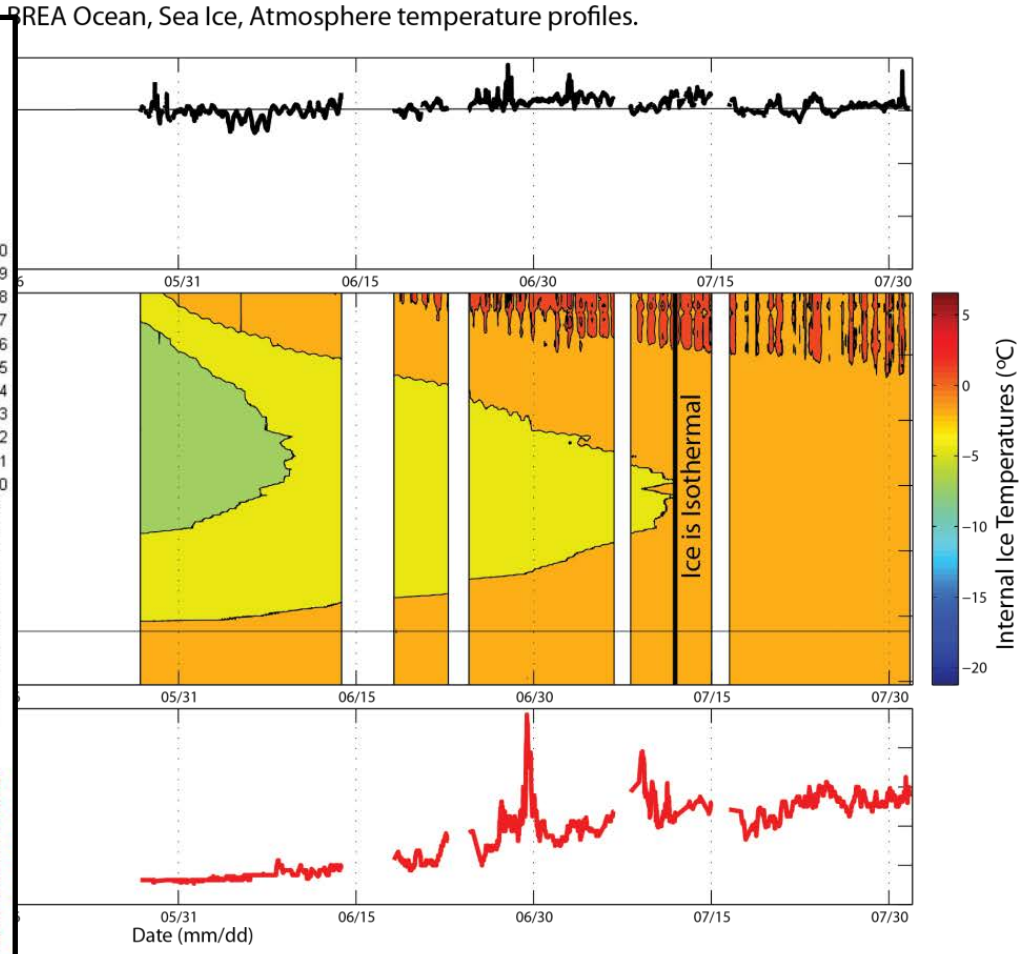
Perovich et al (2008) IMB in Beaufort





Ice temperature is related to ice strength. Plan to deploy 4 IMBs this coming April

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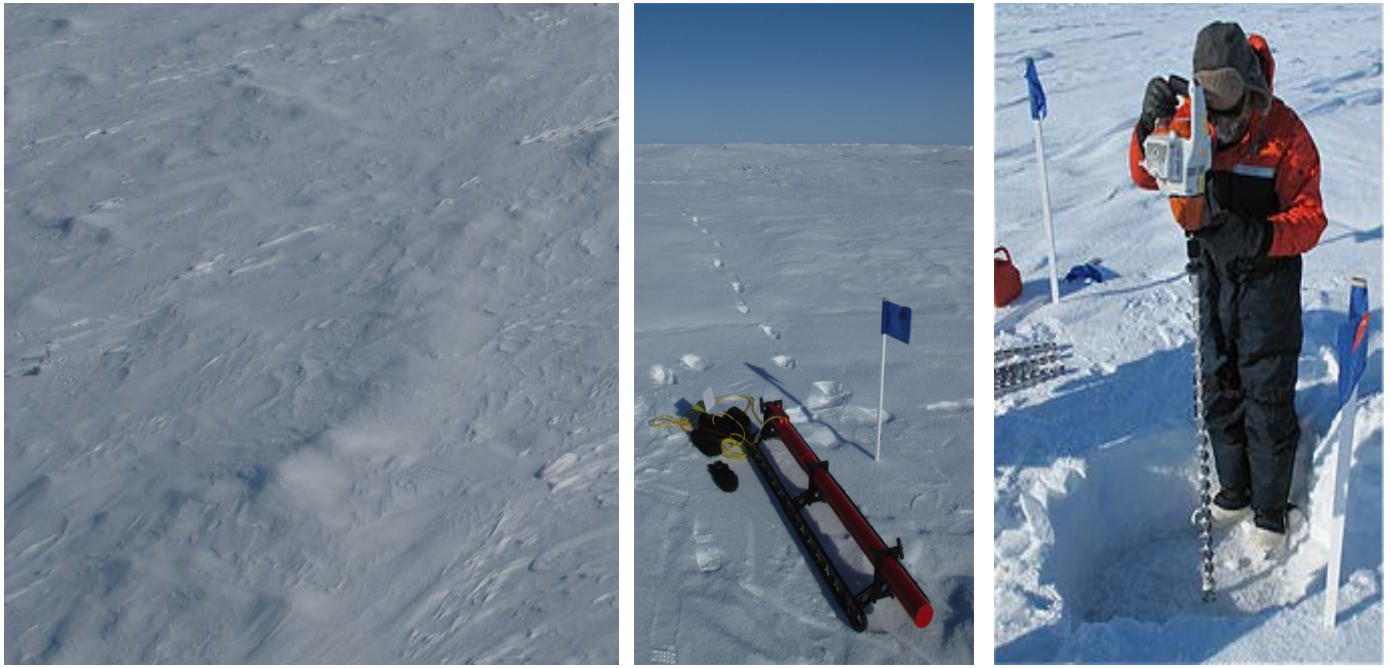
Surface EM Induction Surveys (MYI)



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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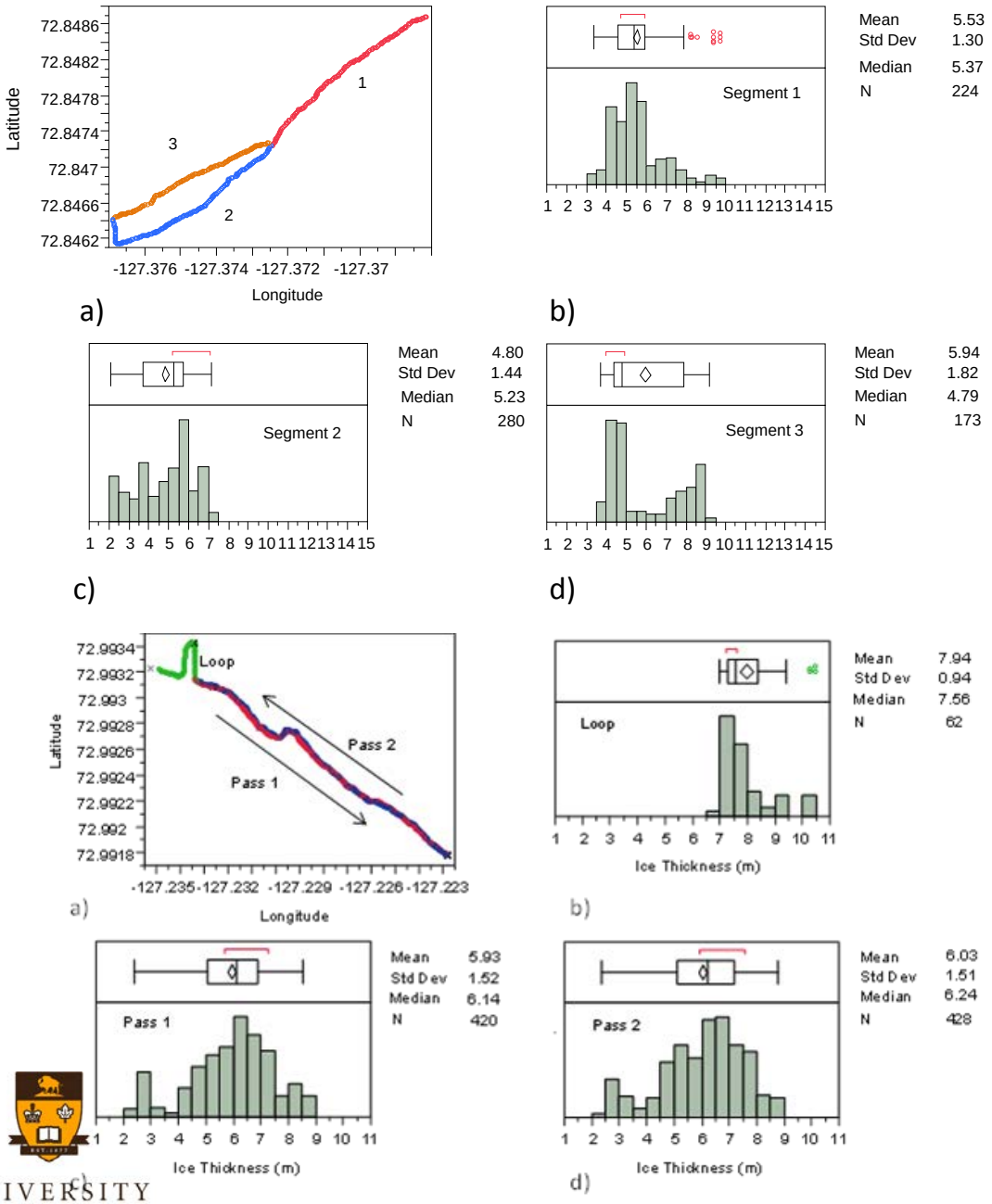

SEMI survey on S14, April 12, 2012 (file SIS00012). a) pass 1 with segments delineated, b) segment 1, **5.5m** avg.; c) segment 2, **4.8m** avg; d) segment 3, **5.9m** avg.

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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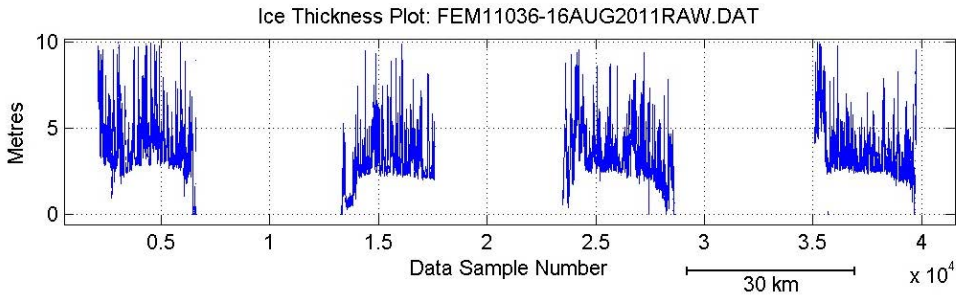
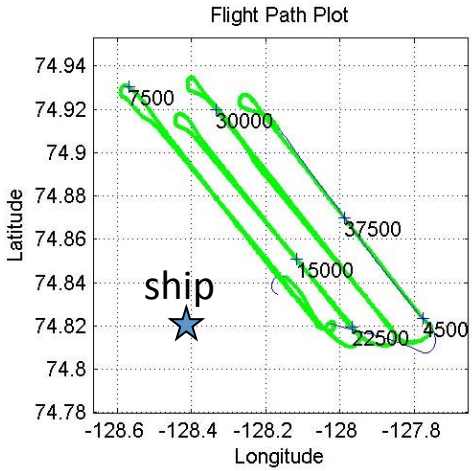
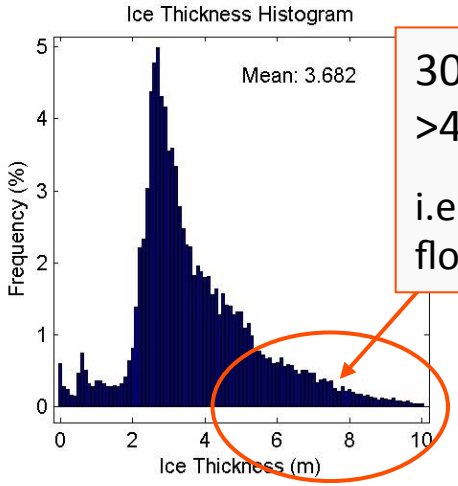
Integrating existing data…. 2009 - 11

Example: 16 Aug, 2011







30% of floe is >4.0m

i.e. similar to floes S1 and S2

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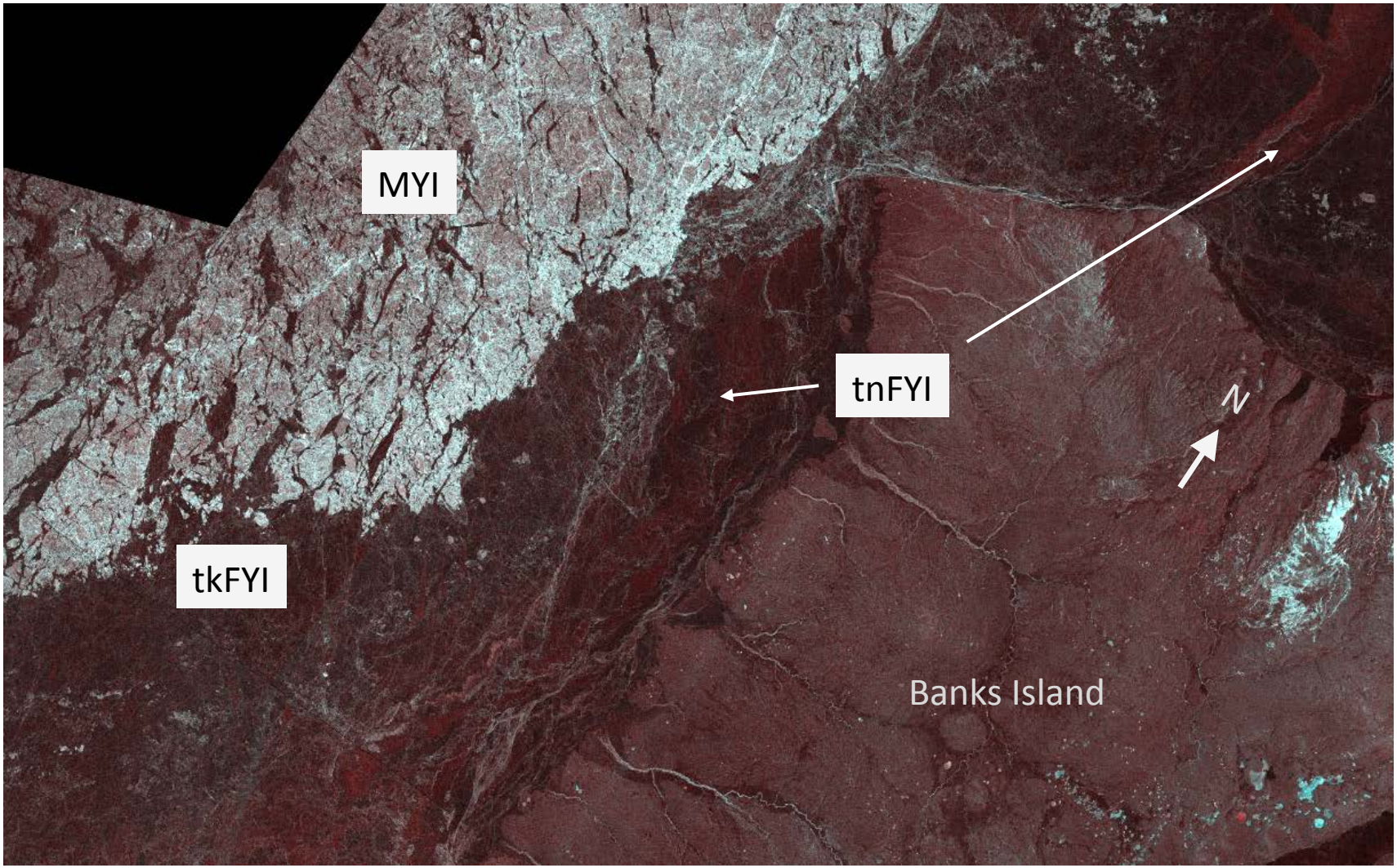
Detection of Extreme Ice Features: RADARSAT-2



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

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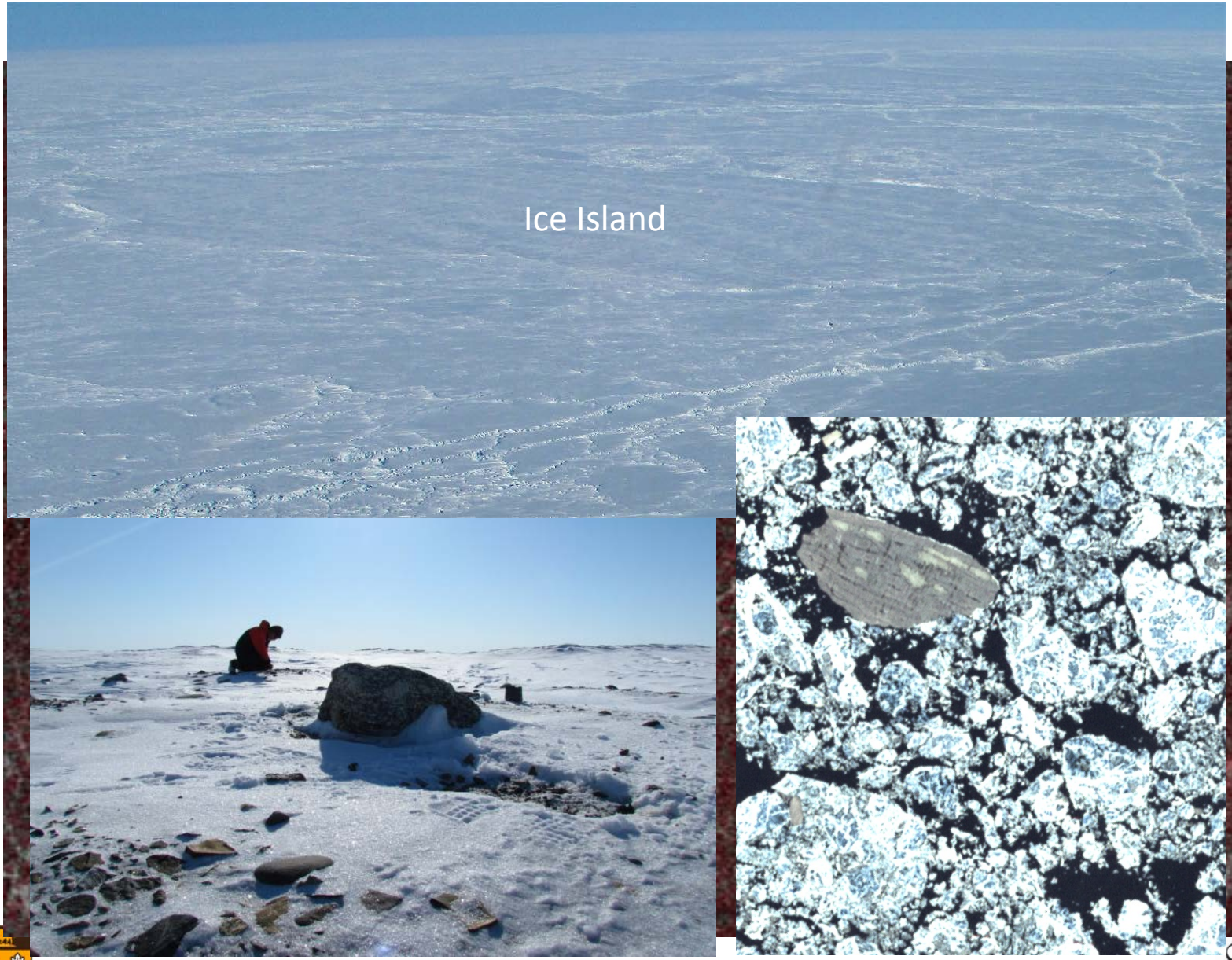

RADARSAT ScanSAR W, March 22, 2012 HH, HV

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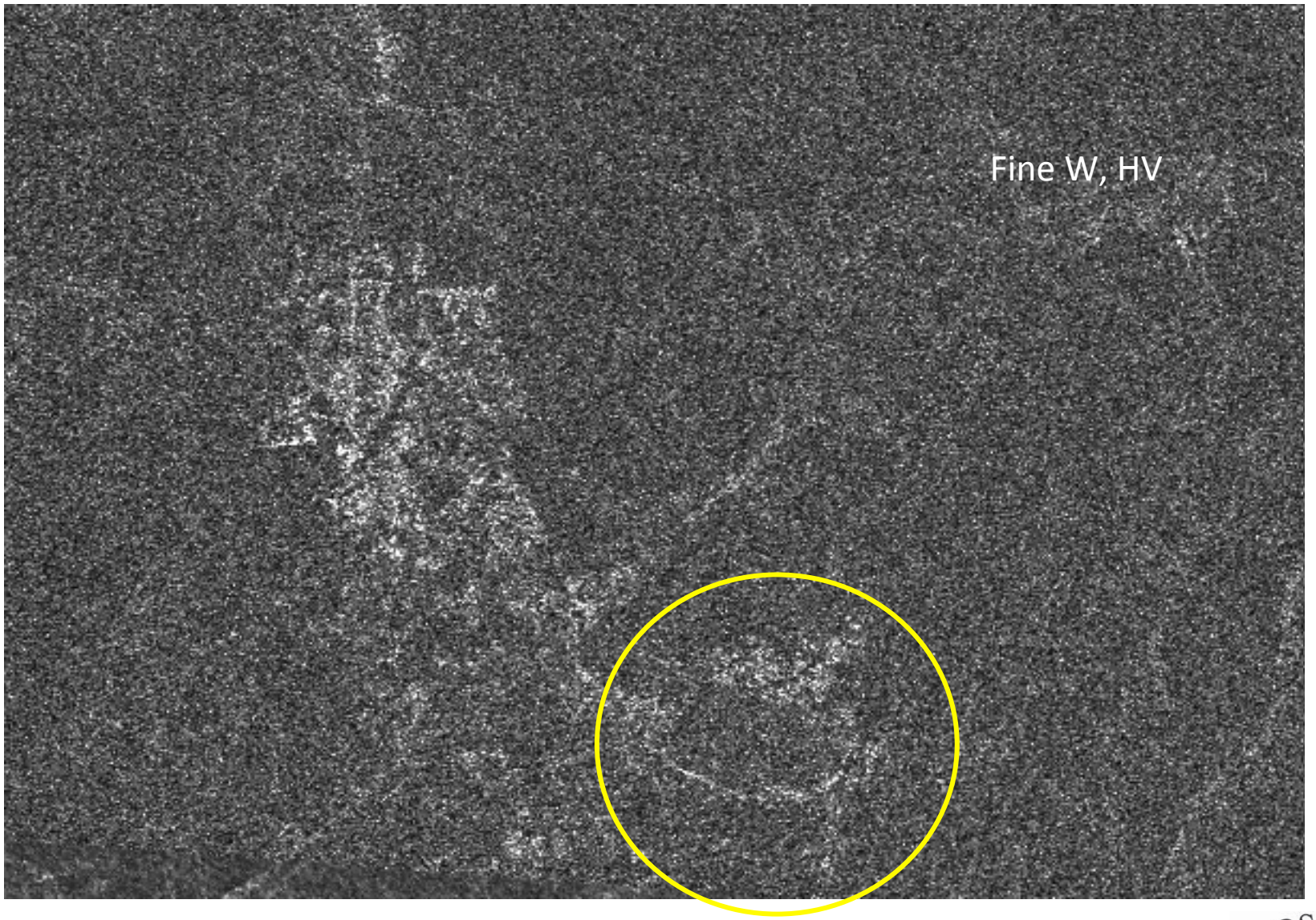

Ice Island vs. first year ice (winter)

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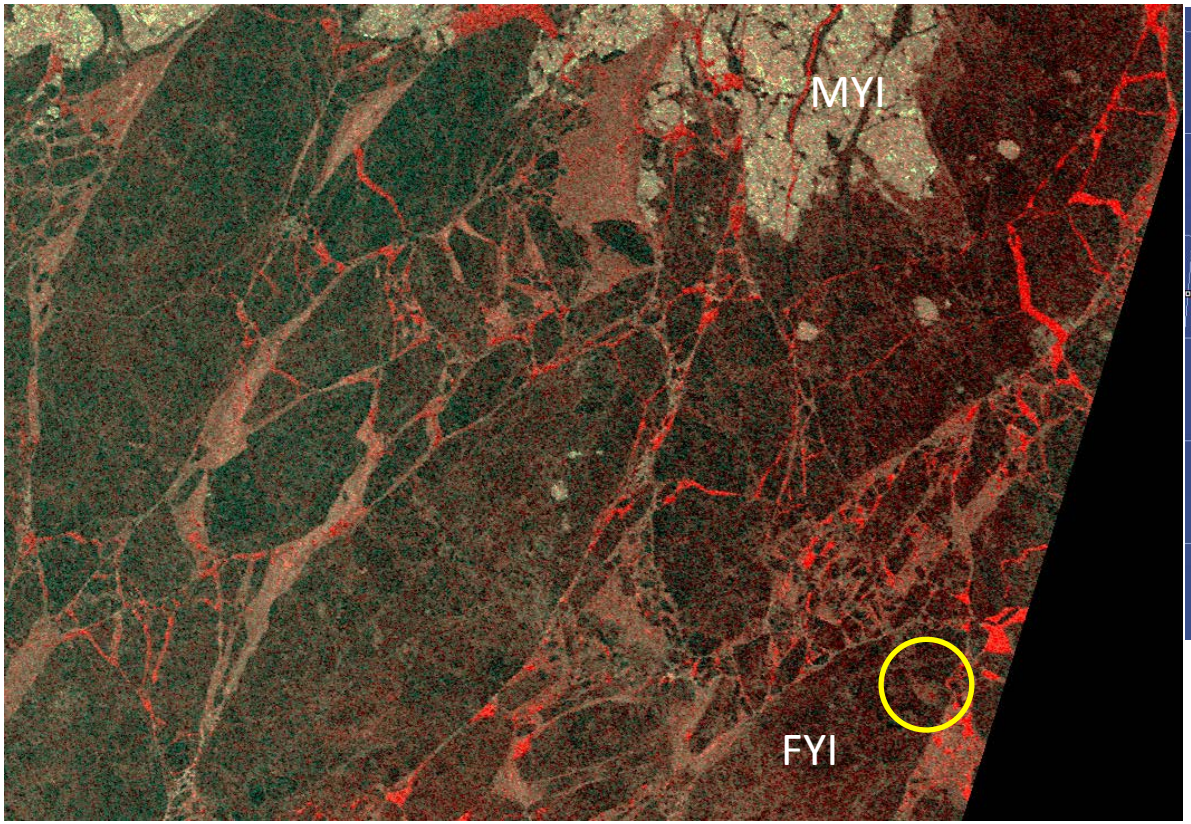
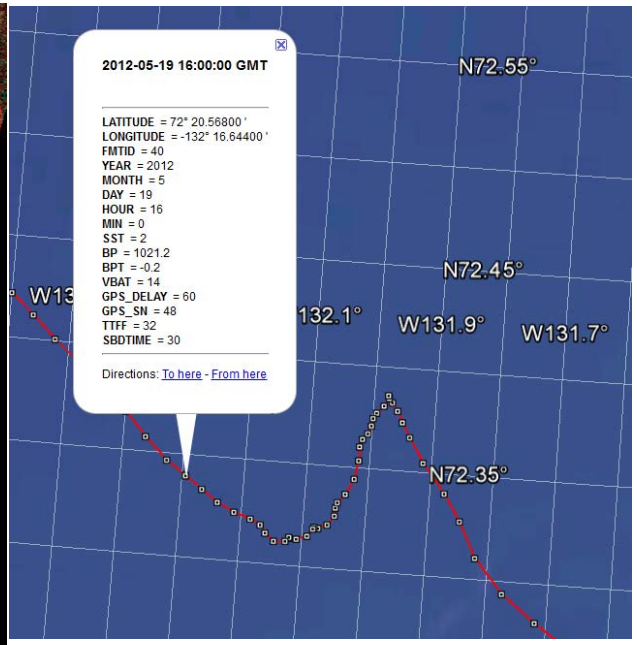
Where is the ice island?





May 19

Sensor: RADARSAT-2	Date: 19-May-2012 16:09:15 UTC	Beam Mode: SCWA	Frequency: C-band
Pass Direction: Descending	Number of Looks: 4 x 2	Polarization: HH HV	Incidence Angle (deg) : 19.8 (Near), 49.4 (Far)
Range and Azimuth	resolution (m): 160~70 x 100 (Nominal)		

Ice Island still similar to first year ice,
Multi-year ice still distinguishable from first year ice

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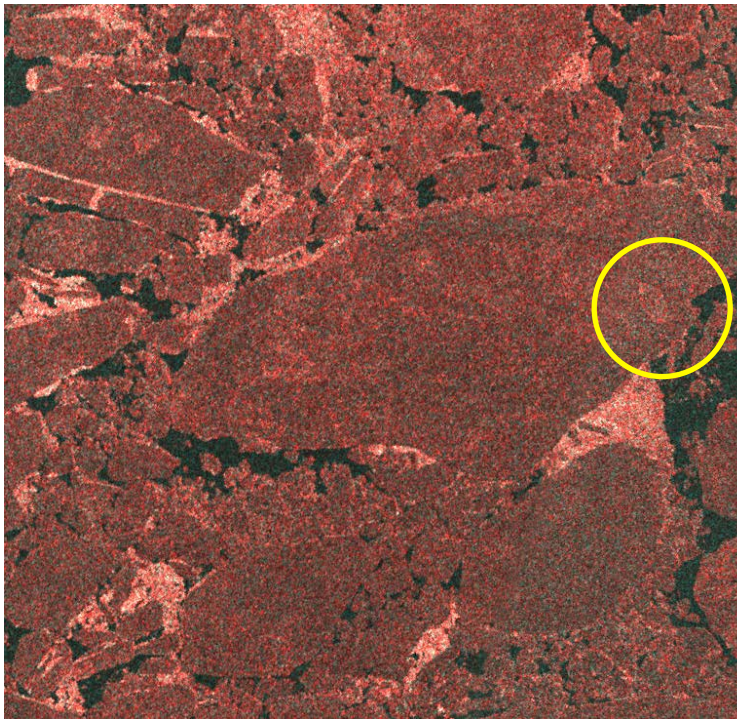
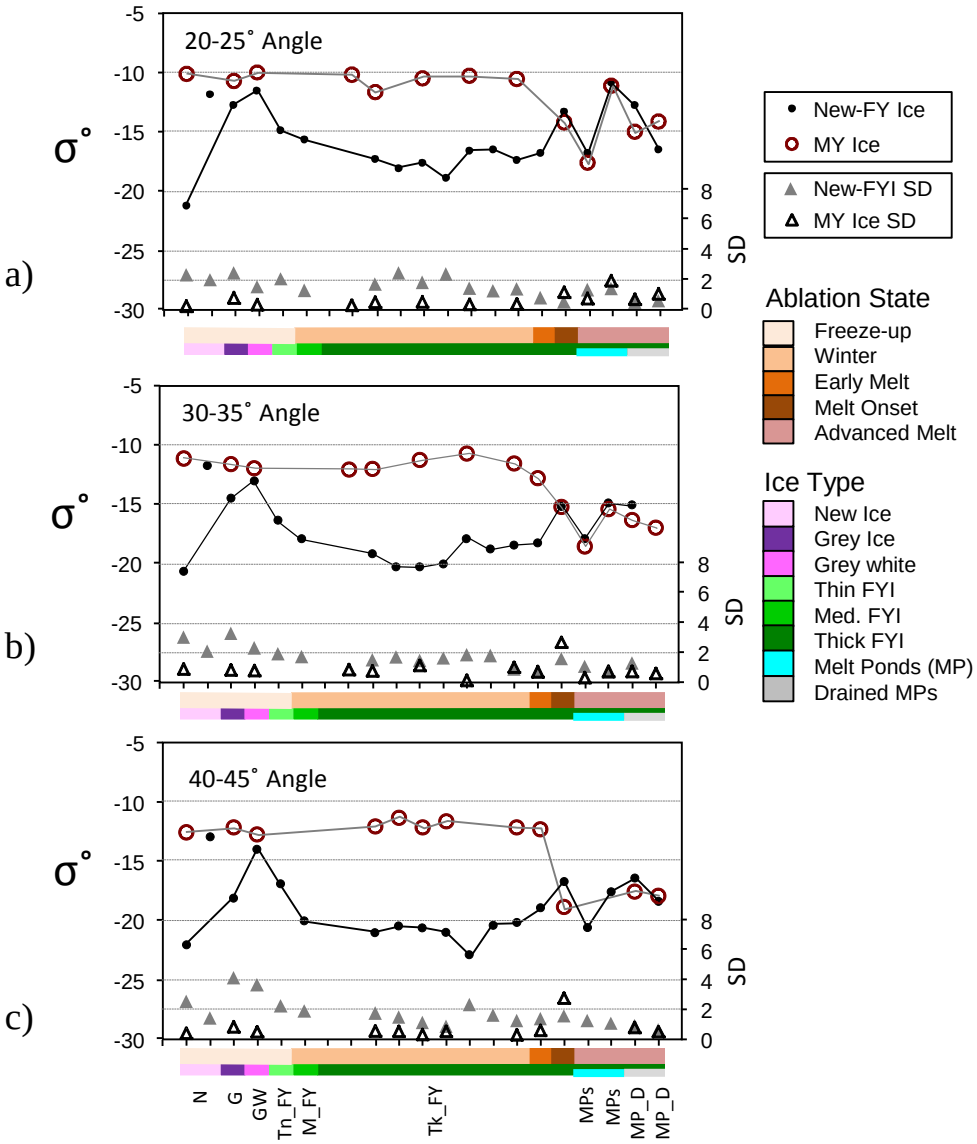
Where is the ice island?





Seasonal evolution of FYI, MYI, glacial ice

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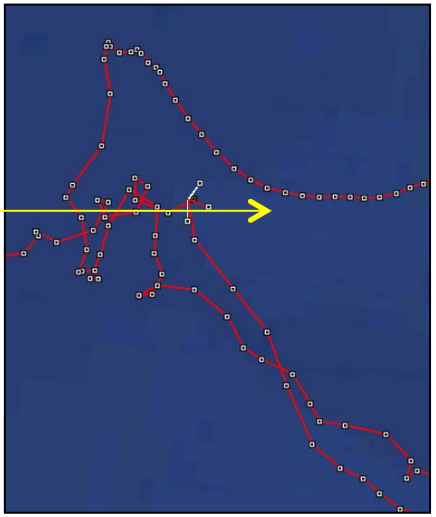
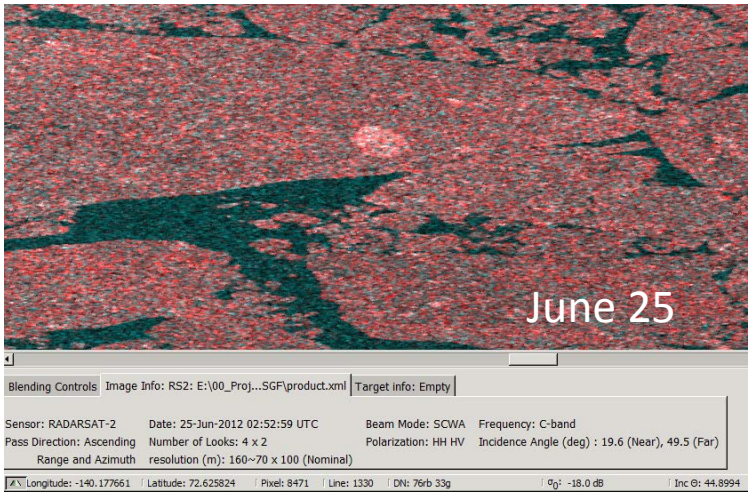
Signature reversal of ice island feature

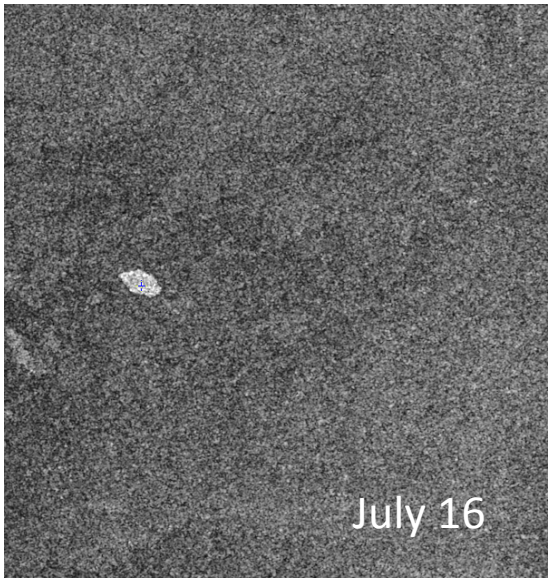
2012-06-25 16:00:00 GMT

LATITUDE = 72° 27.31200 '
LONGITUDE = -141° 4.69200 '
FMTID = 40
YEAR = 2012
MONTH = 6
DAY = 25
HOUR = 16
MIN = 0
SST = 11.1
BP = 995.1
BPT = 0.6
VBAT = 14
GPS_DELAY = 60
GPS_SN = 48
TTFF = 14
SBDTIME = 30

Directions: To here - From here







July 16, ice island clearly visible; MYI barely distinguishable from roughened water surface

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Community Based Monitoring: Sachs Harbour

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

University of Manitoba

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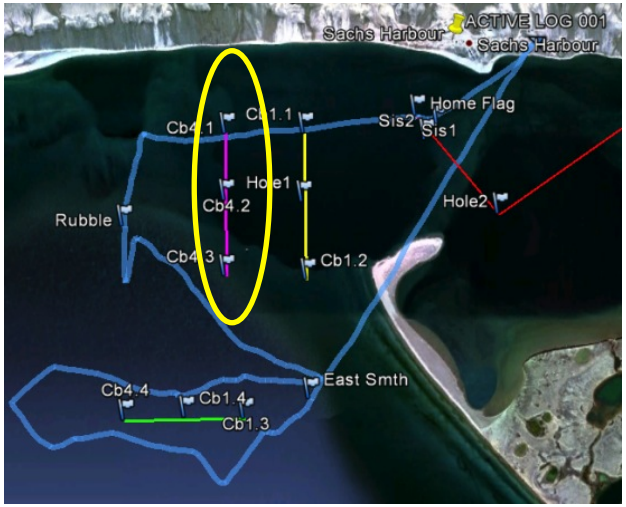
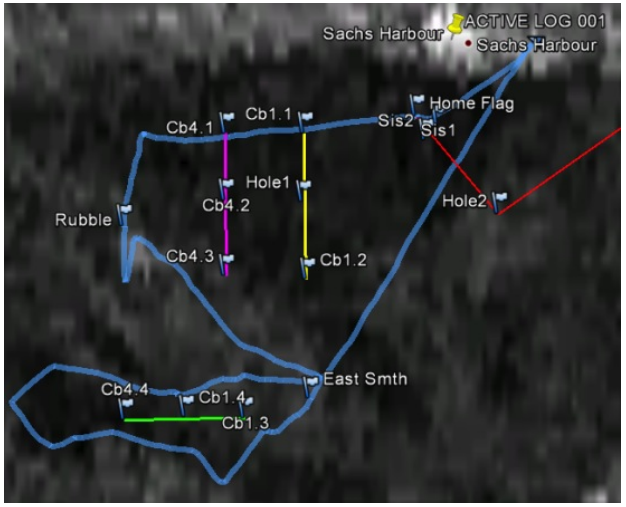
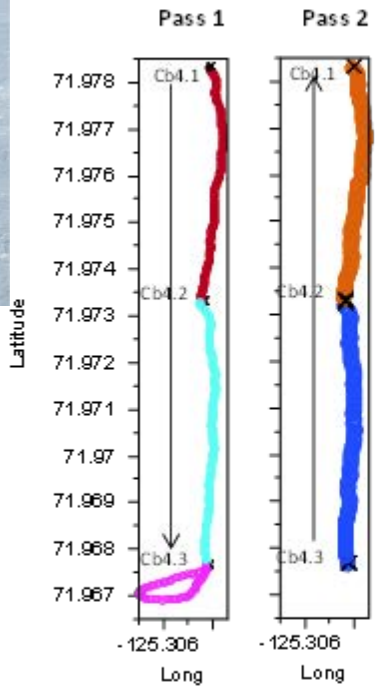
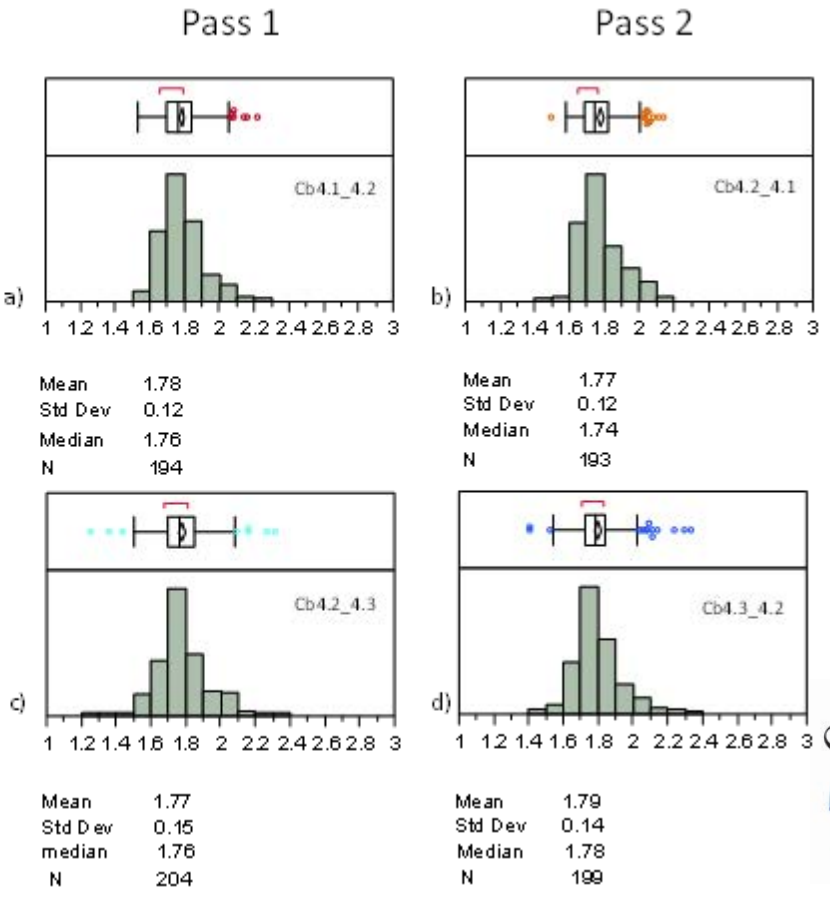
Local Ice Thickness Surveys





EM Induction surveys





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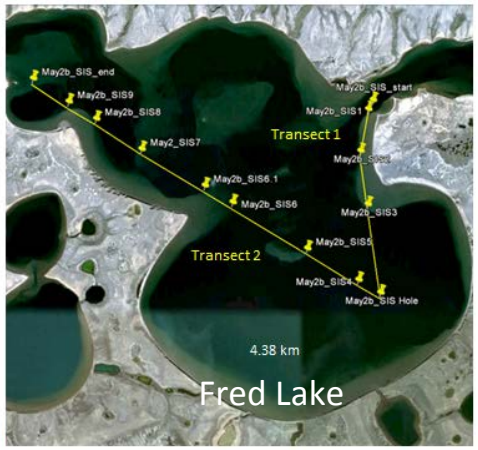
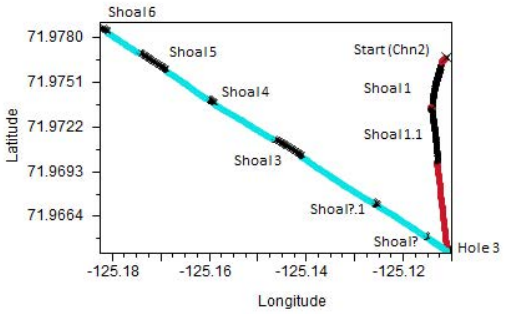
Fred Lake

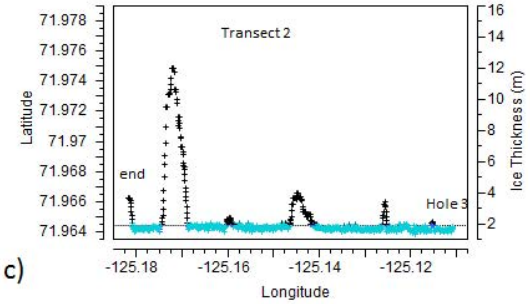
Ice Thickness/
Shoal detection



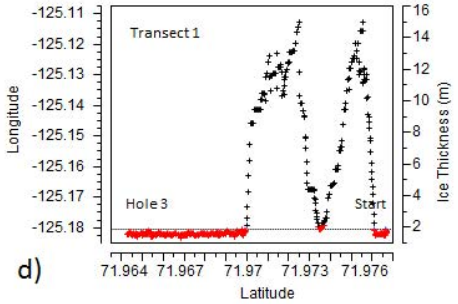
a)



b)



c)



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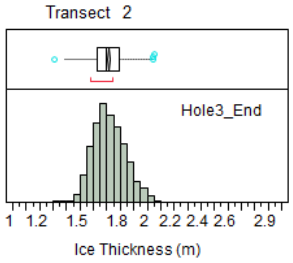
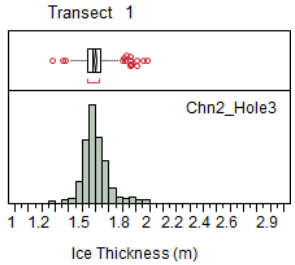


e)

Mean	1.713
Std Dev	0.118
Median	1.70
N	915



f)

Mean	1.596
Std Dev	0.093
N	292
Median	1.58

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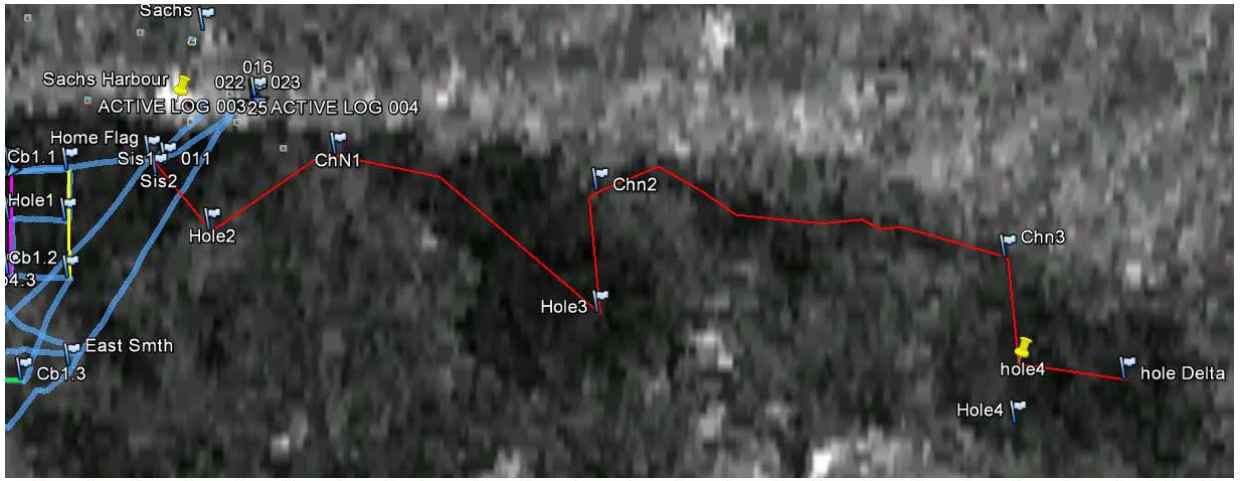
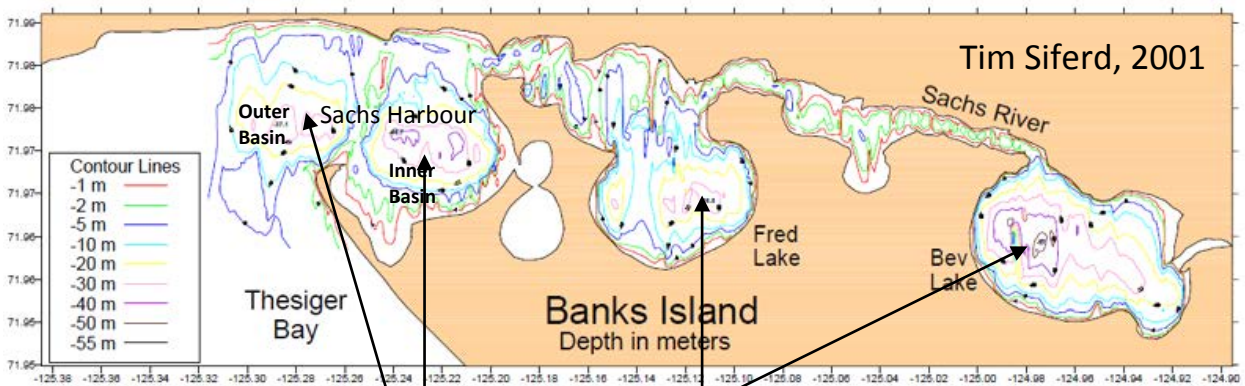
Sachs Harbour Estuary

CTD locations



EM Induction survey

Benthic Productivity
(clams, crabs, shrimp brittle stars, etc)



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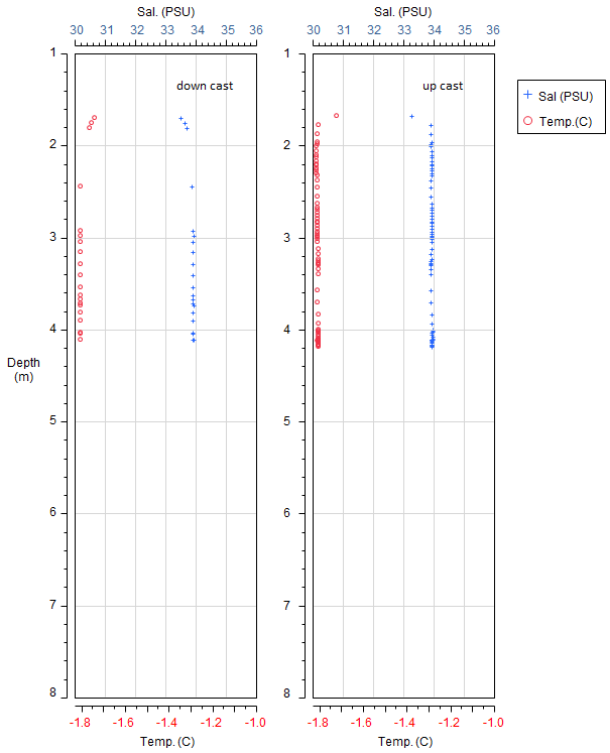
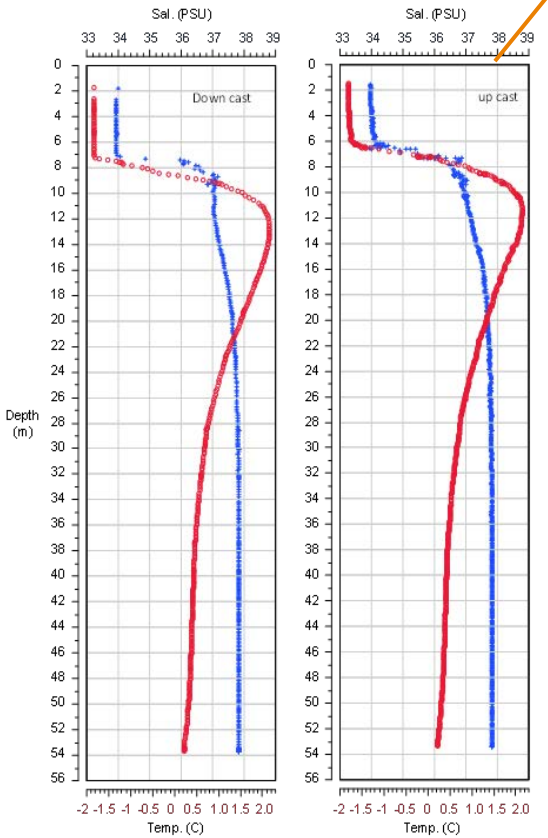
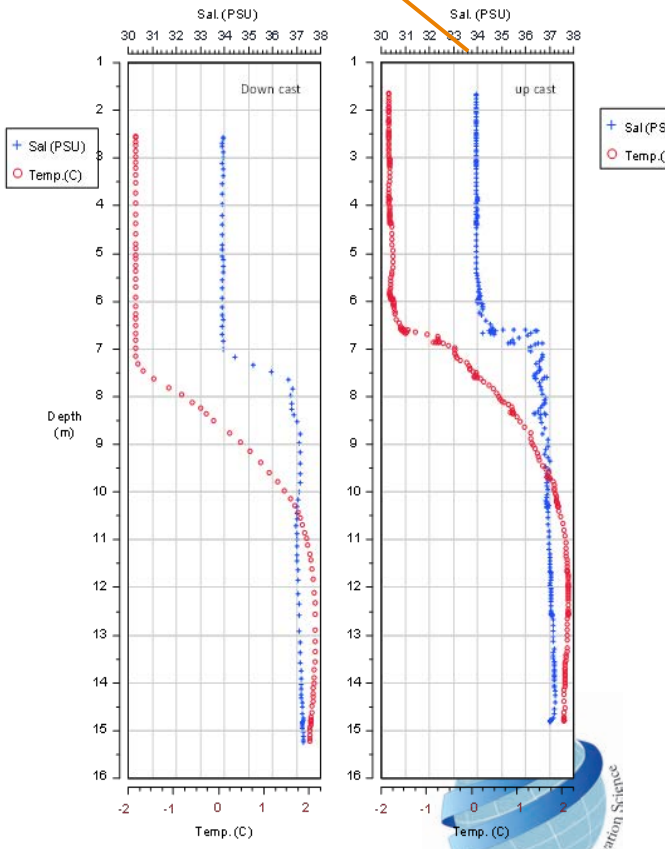
Conductivity
Temperature
Depth







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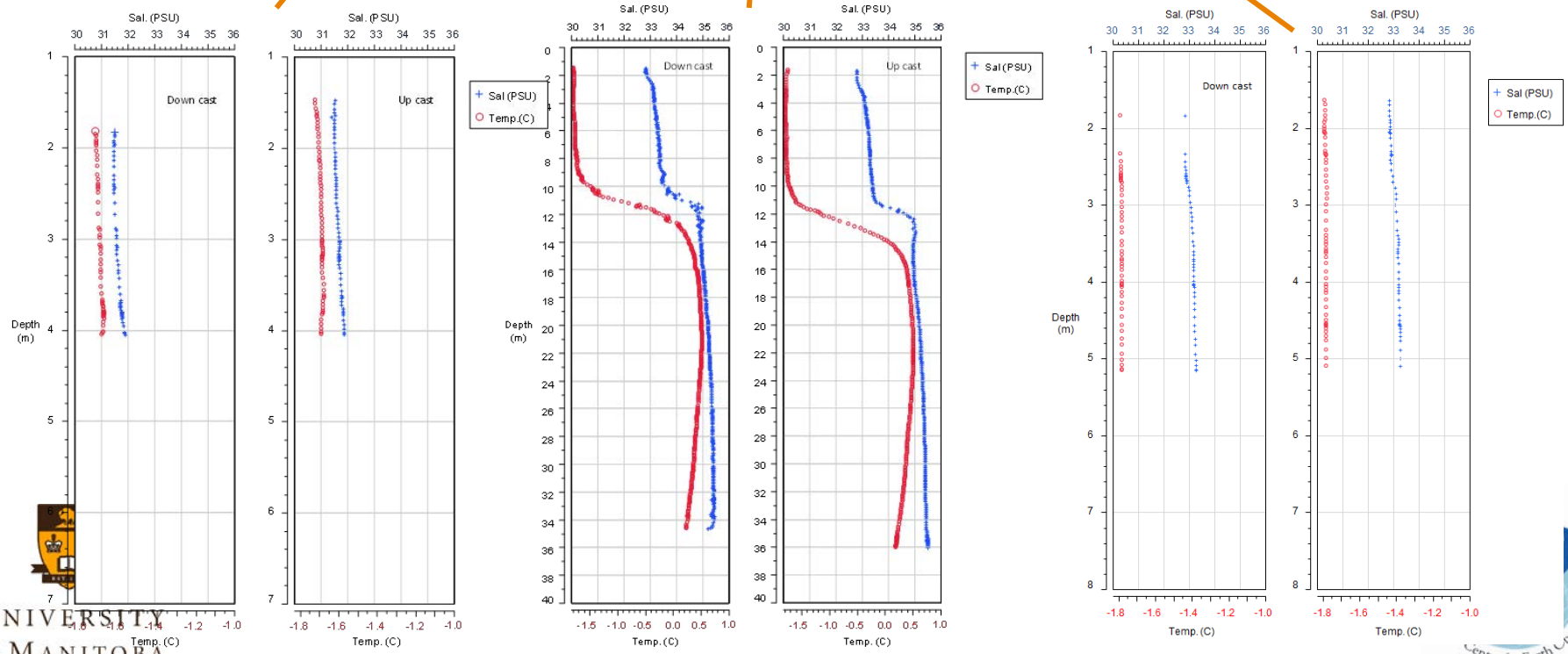
.May 16, 2012 CTD casts

Conductivity
Temperature
Depth



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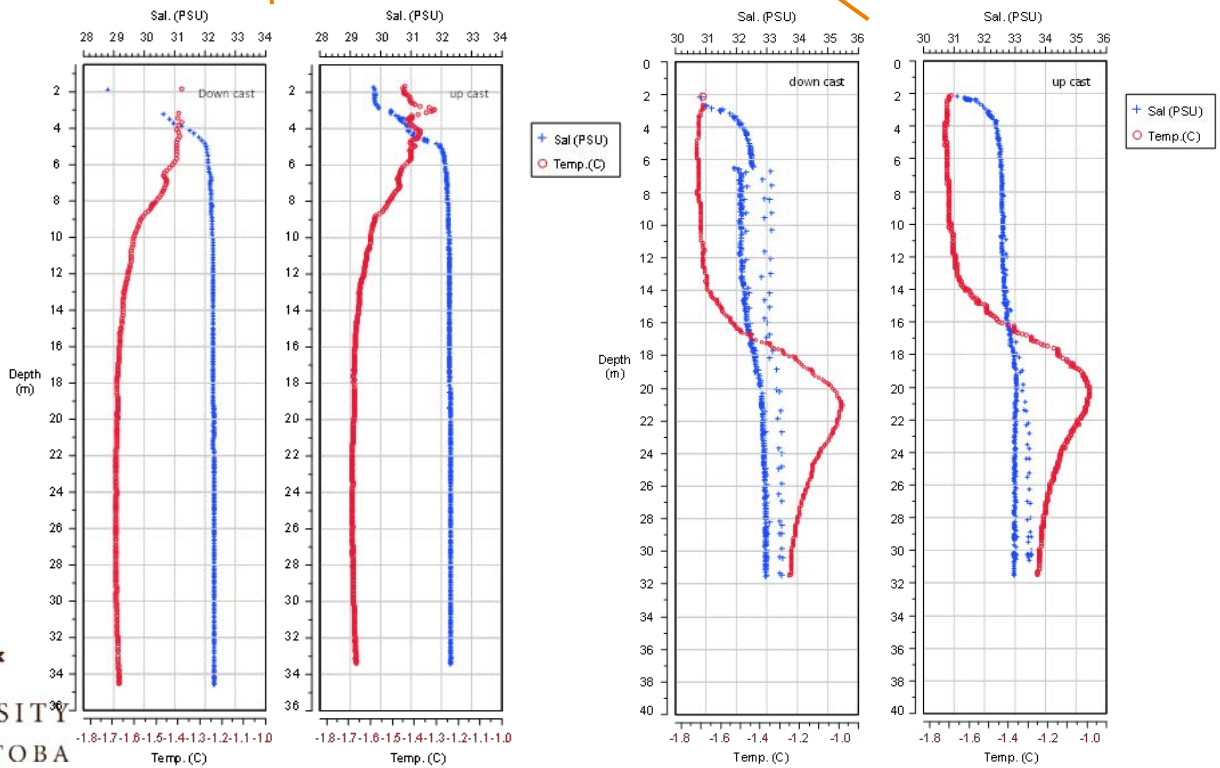
Conductivity
Temperature
Depth



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Expanding this work….Link project to DFO interests

- Links to community-based monitoring of water quality (and sea ice) and ecosystem indicators in the ISR (Inuvialuit Settlement Region), led by DFO scientist C. Michel (CIMP Cumulative Impact Monitoring Program) to contribute to the ISR-wide Community-Based Monitoring Program.

- Interest is to obtain baseline ecological information with indicators of water quality, sea ice and ecosystem conditions (e.g. salinity, temperature, nutrients, ice and snow thickness for sea ice, in ice bacteria/algae) and establish long-term monitoring.

Key Problems to address……

- Ice dynamics : the how's and why's ice motion relative to winds and currents, sea ice concentration etc. Prediction of movement is still problematic (scale dependent)
- Sea ice signatures,RADARSAT-2 feature identification, backscatter characteristics, scale
- Better handle on ice thermo-dynamics (related to ice strength, Michelle Johnson)

Next Field season….

- starting April 4, 2013: 18 POBS; 4 IMBs, SEMI surveys,
- Community Base Monitoring (integrate with DFO), sea ice thickness, ice productivity

Questions?

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Planned Publications

1) Seasonal Sea Ice Dynamics: Spring vs. Summer (Constrained vs. unconstrained ice motion)
   - Examine the nature of sea ice forcing seasonally (relative to atmosphere/ocean forcing, SIC).
   - Synoptic vs. local scales
   - integrate RADARSAT data (ice motion and winds, floes size, SIC, thermodynamics)
   - Separate paper in reference to scaling and dispersion laws? or integrate with above.
2) MYI vs. Ice Island Dynamics (event driven).
3) Seasonal signatures of MYI, FYI and Ice Islands (Glacial origin) and implications to ice hazard detection. Can integrate ESA work.
4) Mooring data 2011. Relative to multi-level ocean currents and surface winds. Good supplement to our surface (0-60m) current data (BREA). Long time series, ice keel data, floe size, supplement with CIS data and RADARSAT data.