

Clayton H. Riddell  
Faculty of Environment, Earth, and Resources

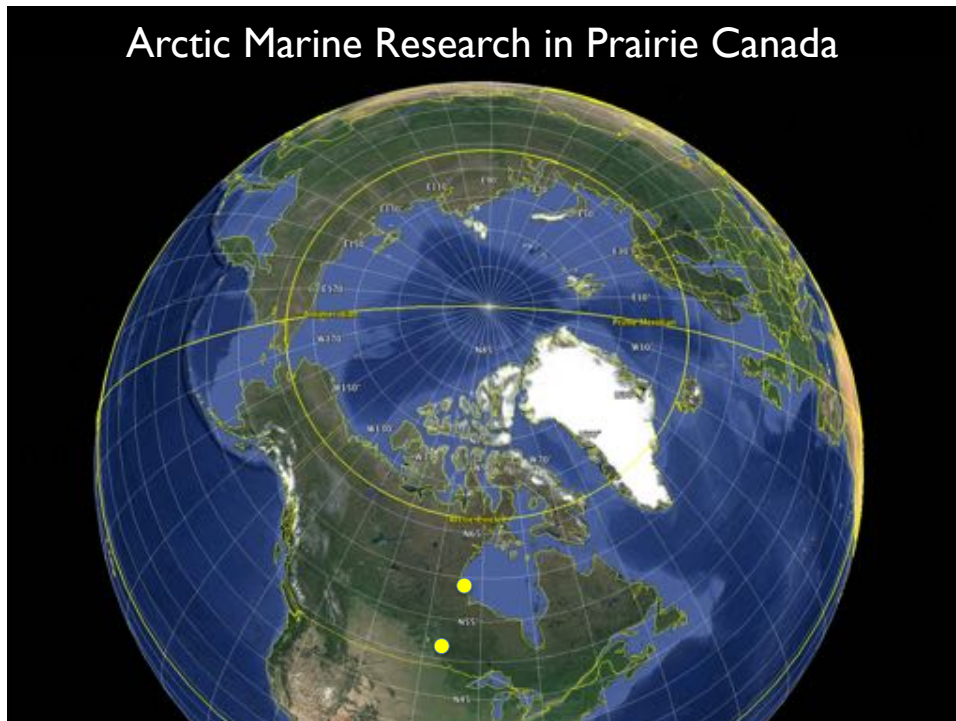
*The Centre for Earth Observation Science (CEOS)*

Oil and other transportation related contaminant spills in sea ice

*David G. Barber, DP, FRSC, OC*

204 474-7252  
umanitoba.ca/environment

UNIVERSITY OF MANITOBA  
One university. Many futures.





<p><b>Tenure Track Faculty (20)</b></p> <p>Barber, David (CRC)          Rysgaard, Soeren (CERC)          Wang, Feiyue (CRC)          Ali, Genevieve          Stern, Gary          Milne, Brooke          Oakes, J.          Puyan Mojabi          Mundy, C.J.          Kuzyk, Zou Zou          Ehn, Jens. E.          Hanesiak, John          Papakyriakou, Tim          Halden, Norman          Iacozza, John          Hansen, Mark          Isleifson, Dustin          * 1 CRC – T1          * 2 new faculty (Industry chairs) *</p>	<p><b>Research Faculty (8)</b></p> <p>Dmitrenko, Igor          Kirilov, Sergei          Galley, Ryan          Lui, George          Lukovich, Jennifer          McCullough, Greg          Ogi, Masayo          Pucko, Monika</p> <div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 10px auto;"> <p>28 Faculty              16 Adjunct/Affiliate              30 MSc, 17 PhD, 12 RA, 8              PDF, 16 staff              = 127</p> <p>*10 new technical staff*</p> </div> 	<p><b>Adjunct/Affiliate Faculty (16)</b></p> <p>Loseto, Lisa - DFO          Michel, Christine - DFO          Stadnyk, Tricia - UM - Eng          Lobb, David - UM Agriculture          Shafai, Lot - UM Eng          Sydor, Kevin - MB Hydro          Ng, Adolf - UM - Business          Tremblay, Jean-Eric - ULaval          Yackel, John - UCalgary          Deming, Jody - UWashington          Macdonald, Robbie - DFO          Fortier, Louis - ULaval          Ferguson, Steve - DFO          Hubert, Casey - UCalgary          Miller, Lisa - DFO          Gosselin, Michel - UQAR</p>
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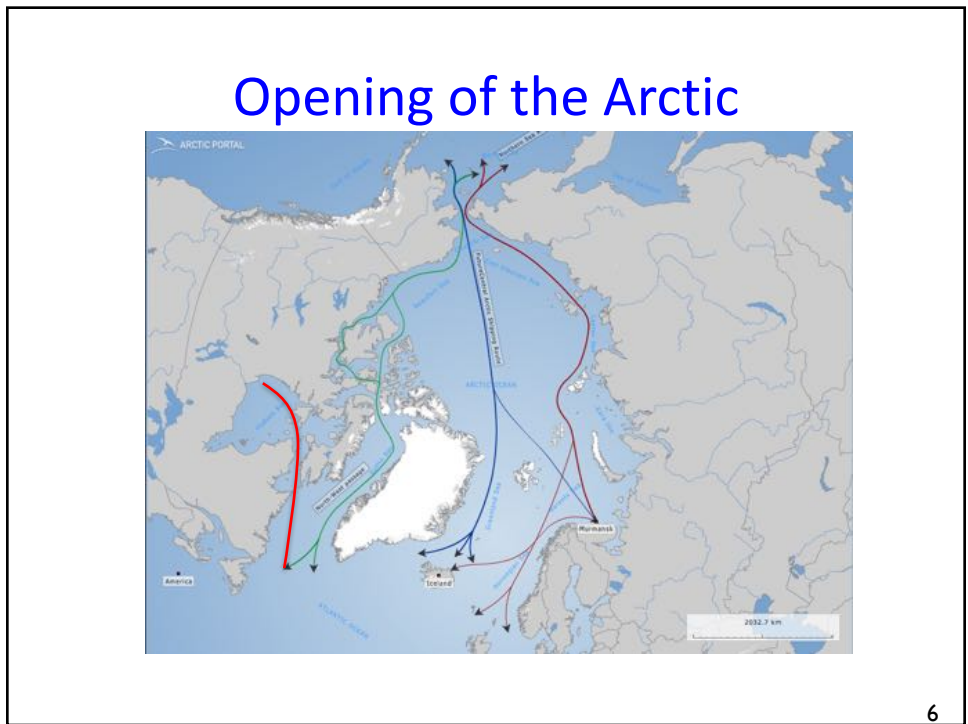
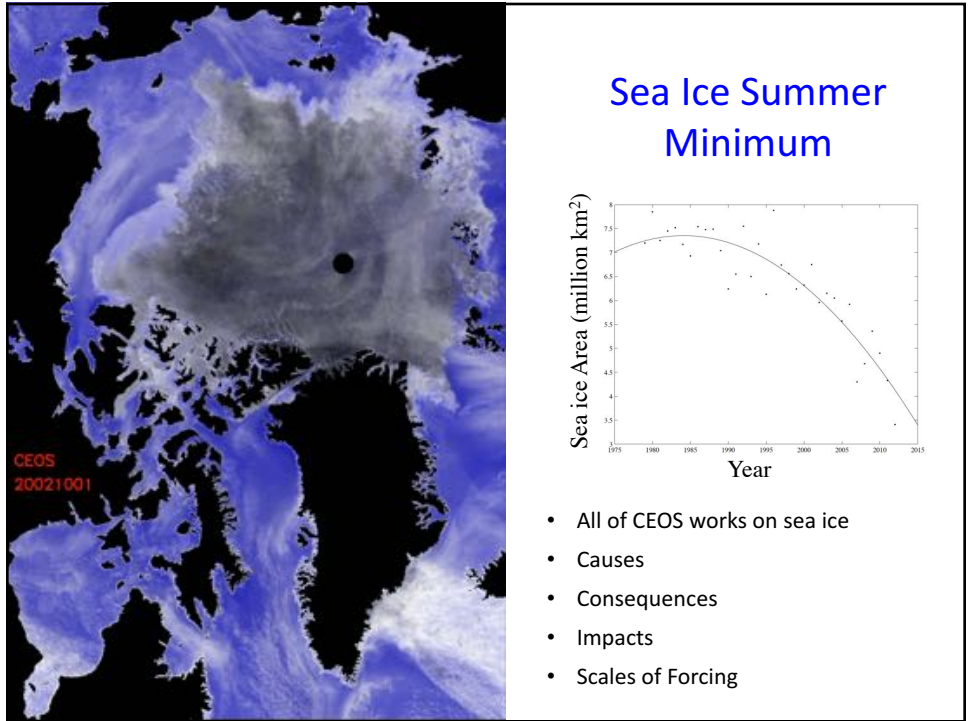
>350 investigators

- University of Aarhus, Denmark
- Greenland Institute for Natural Resources (GINR)
- University of Tromso, Norway
- AWI, Germany
- Others in discussion



>250 investigators

- Multisectoral NCE

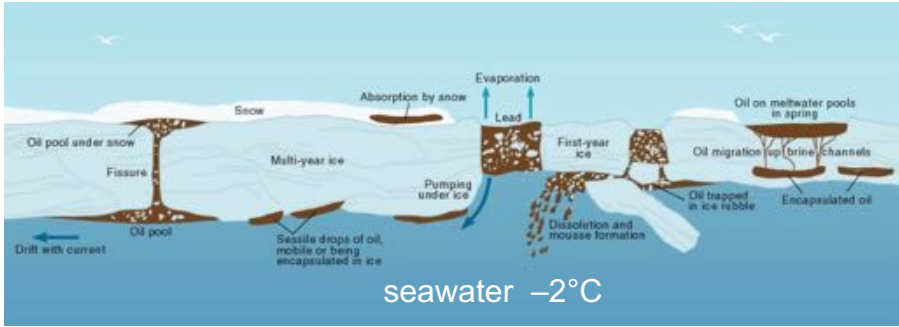




### The Integrated Arctic Corridors Framework

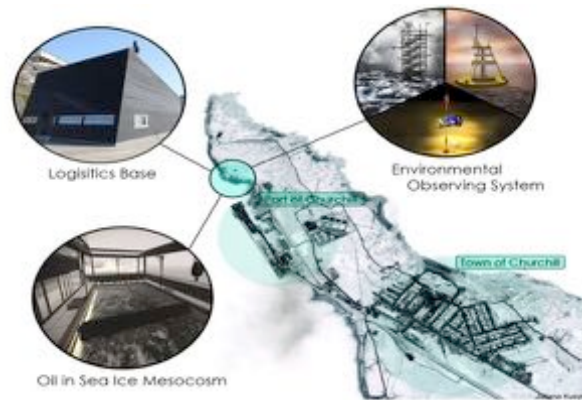


Coast Guard - Defense - Regulators - Indigenous - Industry



## The Churchill Marine Observatory (CMO)

*Science and Technology  
In support of Arctic Sustainable Development*



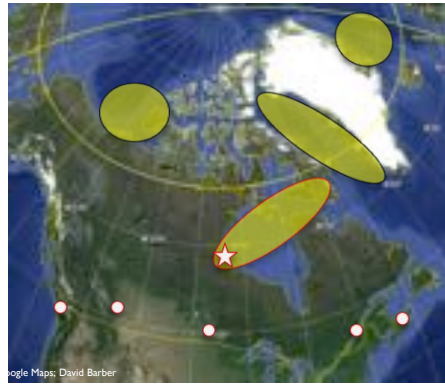
\$42.4M capital and \$18M operating

## The Churchill Marine Observatory (CMO)



## The Churchill Marine Observatory (CMO)

*Science and Technology in Support of Arctic Sustainable Development*



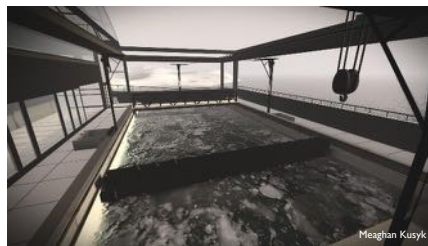
CMO will investigate 3 key scientific questions:

- 1) **Detection** of oil/contaminants in sea ice
- 2) **Fate and effects** of oil/contaminants spills on the marine ecosystem
- 3) **Mitigation** of oil/contaminant spills within the marine system

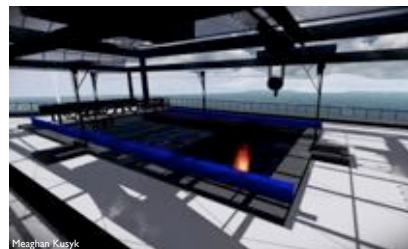
Results from CMO can be scaled from OSIM through the EO system to the circumpolar Arctic.



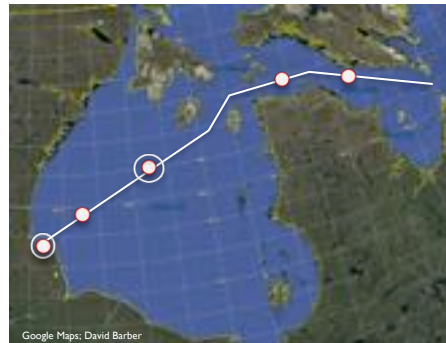
**OSIM:** The Oil in Sea Ice Mesocosm will consist of a swimming pool sized tank separated into two sections. One section can be used to spill oil or other contaminants in a controlled fashion and the other would be used as a control. Water from the bottom of the Churchill estuary would be pumped into the tanks



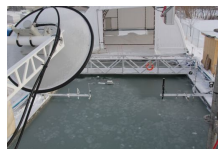
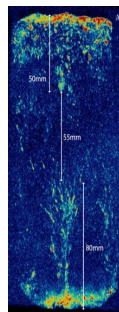
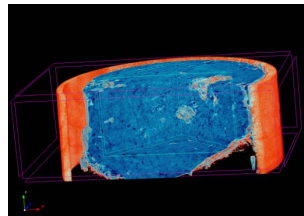
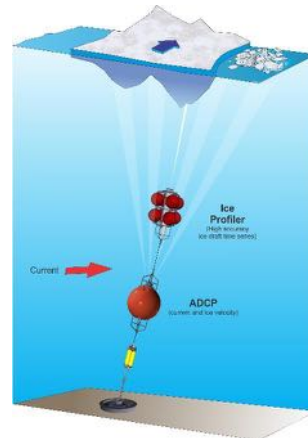
OSIM: Artist rendering



**EO system:** The Environmental Observatories will consist of 5 high-tech moorings (red circles) installed onto the ocean floor to monitor physical and biological variables. The Estuary observatory will be connected to CMO through a fiber optic cable and the shipping lane observatories will either transmit to satellite or be recovered annually to acquire their data.



Google Maps; David Barber



## Technology

- Detection
- Fate and Effects
- Mitigation



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~\$19M



### New Churchill Based Coastal Research Vessel

- Operations with ARF
- Overwintering
- Ice classed
- Can reach all of Hudson Bay
- \$2.5M in refit and science integration

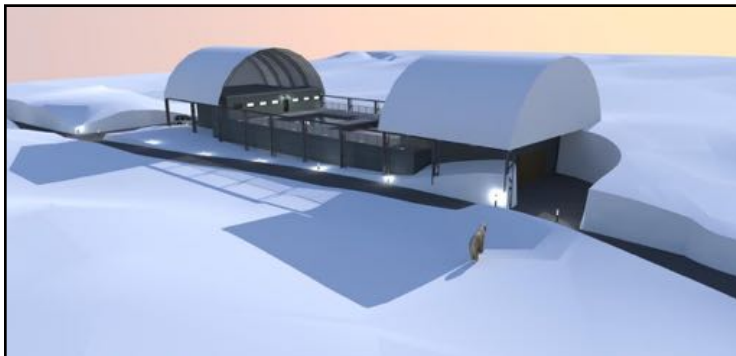


 Polar Knowledge Canada Savoir polaire Canada





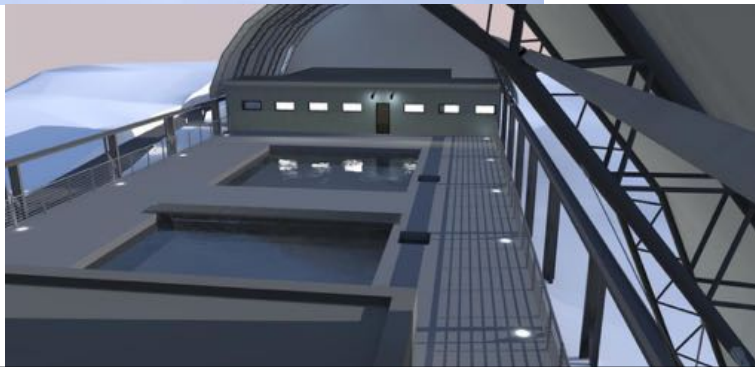
CMO will be located near the Churchill estuary, south of the Parks Canada Visitor Centre at Cape Merry Battery

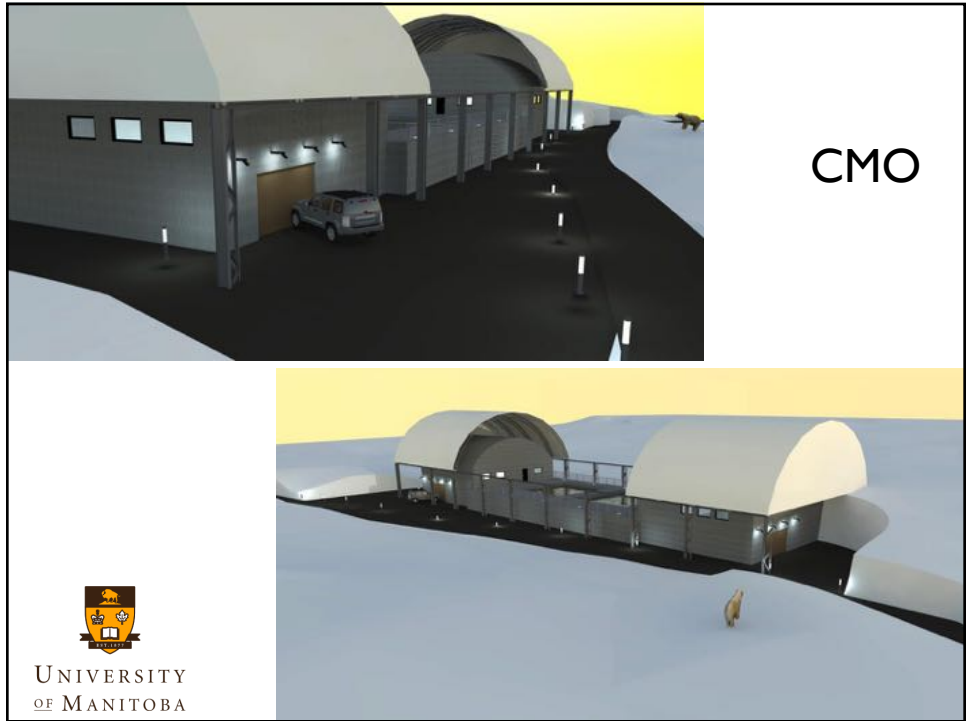


CMO

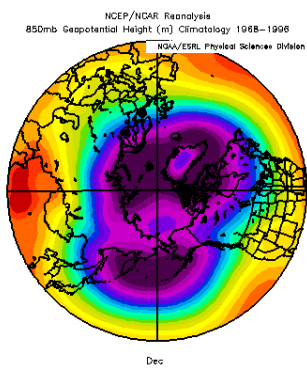


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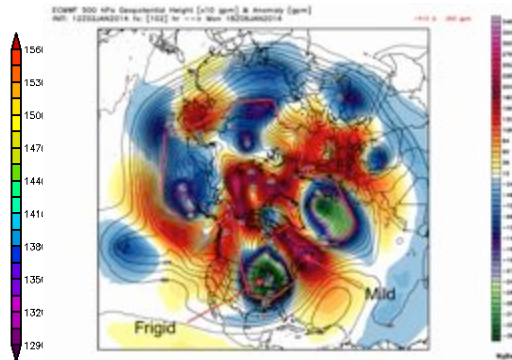




### Climate change and extreme weather:



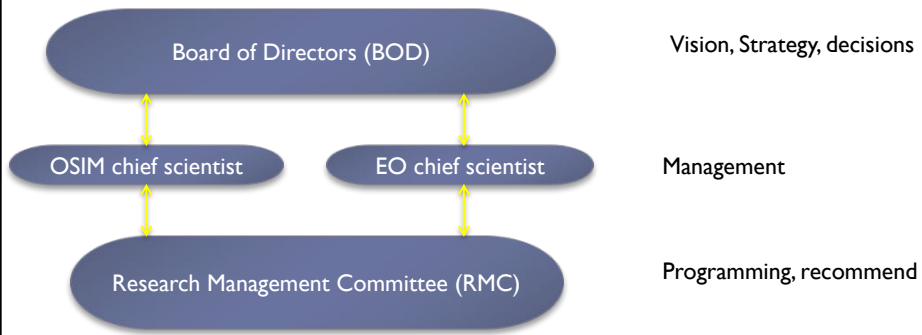
Polar Vortex  
Traps cold air in the Arctic



Polar Vortex breaks down  
Increases cold outflows and persistence in both temp and precipitation



## Management:



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**CNSC:** The Churchill Northern Studies Centre will provide logistical, technical and scientific support, including accommodations for researchers, laboratory space, access to workshops for maintenance and installation of observatories, and working space for two full-time technicians.



Churchill Northern Studies Centre

- Accommodations & Meals
- Laboratories
- Logistical support
- Technical support
- Facility management
- Office space
- Meeting rooms
- Staff

**Community of Churchill:** Businesses in Churchill will provide services to guests working in CMO, including accommodations for researchers, car rentals, meeting room rentals, and services to tourists visiting CMO.



- Accommodations & Meals
- Car rentals
- Logistical Support
- Meeting rooms
- Water and sewage services
- Maintenance services
- Employment opportunities
- \*Ecotourism opportunities



**Partners:**

- Town of Churchill
- Aboriginal Affairs & Northern Development
- Province of Manitoba
- Province of Alberta
- Province of British Columbia
- Government of Nunavut
- Churchill Northern Studies Centre
- Canadian High Arctic Research Station (CHARS)
- University of Calgary
- University of Victoria
- Université Laval
- University of Washington
- Université du Québec à Rimouski (UQAR)
- University of Alaska Fairbanks
- Dalhousie University and MEOPAR
- Fisheries and Oceans Canada
- Environment Canada, Canadian Ice Service
- Transport Canada
- Stantec
- Arctic Research Foundation
- KGS Group Consulting Engineers
- Greenland Institute of Natural Resources
- Aarhus University, Denmark
- European Space Agency (ESA)
- National Aeronautics and Space Administration (NASA)
- Multiple oil and gas companies
- ~170 investigators from 6 countries



## CMO Science Team Leads



**Dr. David Barber**  
Professor, Associate Dean (Research),  
Canada Research Chair, Arctic System  
Studies, Distinguished Professor

**CMO**  
Role: Scientific Director

**Contact:**  
576 Wallace Bldg  
204-474-6981  
David.Barber@umanitoba.ca



**Dr. Feiyue Wang**  
Professor  
Canada Research Chair Arctic Marine  
Chemistry

**CMO**  
Role: Chief Scientist - OSIM

**Contact:**  
588 Wallace Bldg  
204-474-6250  
Feiyue.Wang@umanitoba.ca



**Dr. CJ Mundy**  
Associate Professor

**CMO**  
Role: Chief Scientist - EO

**Contact:**  
582 Wallace Bldg  
204-272-1571  
Cj.Mundy@umanitoba.ca



## Implementation Schedule

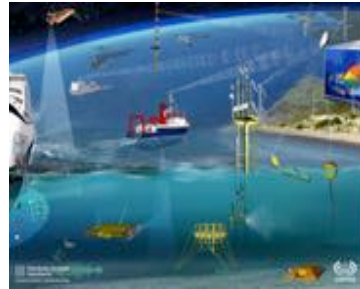
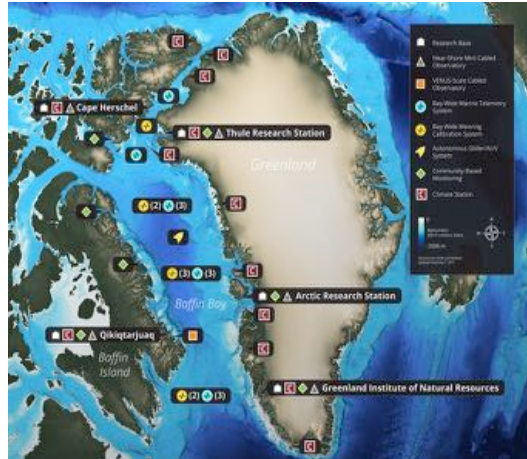
- Request to Build to Contractors – November, 2016
- Selection of Builder – March, 2017
- Build – May – November, 2017.
- First Science use – January, 2018.
- Ship Procurement and retrofit – Dec, 2016
- Ship Installation – August, 2017
- EO System installation – Sept, 2017.







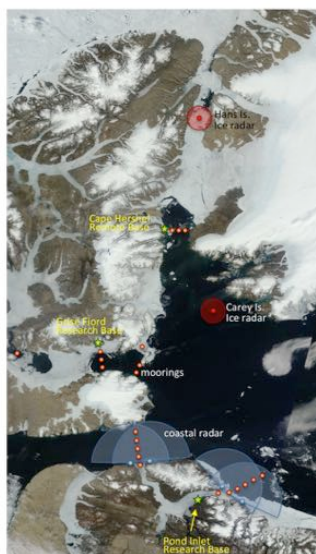
## Baffin Bay Observing System



- Technology Development
- Integrated data systems
- Inuit led CBM programs

5 year implementation period (\$150M)  
30 year observing period (\$5-\$10M per year)

## DRDC all domain situational awareness



- Share data (DRDC and environment)
- Technology test bed for BBOS
- Main station in Pond Inlet
- Remote Station test beds
- Engineering issues of design, implementation, and data processing
- Proposal currently under review– \$9.8M



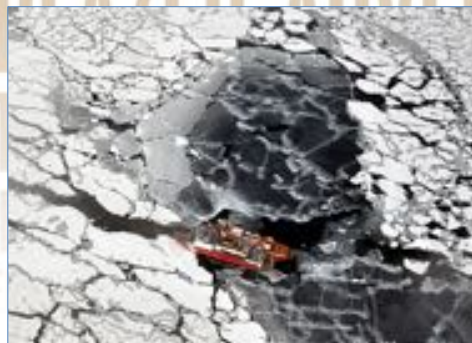


NSERC/KGS Chair in Impact & Mitigation  
Strategies of Oil in Sea Ice

by Dr. Monika Pućko



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NSERC/Stantec Industrial Research Chair in  
oils spills in sea ice

Candidate search currently underway



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CEOS led academic programs using CMO

**TRAILBLAZER ADVENTURER**  
**INNOVATOR DEFENDER CHALLENGER**  
**ADVENTURER TRAILBLAZER DEFENDER VISIONARY**

Detection Team:

<b>Faculty:</b>	<b>Students:</b>
Isleifson (Assistant Prof, ECE)	Firoozy (PDF)
Majobi (Associate Prof, ECE)	Landy (PDF)
Gillmore (CRC T2 (pending), ECE)	Gholami (PhD)
Stern (Professor)	Neusitzer (MSc)
Barber (Professor, CRC T1, CEOS)	Tiedet (MSc)
	Desmond (MSc)

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### Geophysical behavior of oil in ice

**Migration**

**Encapsulation**

**Under-ice pooling and spreading**

Multi-year ice, First-year ice, Absorption by snow, Snow, Ice, Oil migration up below channels, Oil trapped, Brash ice, Drifting, Water in oil emulsion, Spreading, Dispersion, Resuspension of larger oil droplets, Distribution of water-soluble components, Adsorption to particles, Uptake by biota, Sedimentation, Horizontal diffusion, Vertical diffusion, water-soluble, Oil trapped

Dickins et al. 2008

Izumiyama et al., 2004

NORCO, 1975

<http://www.nap.edu/catalog/18625/responding-to-oil-spills-in-the-us-arctic-marine-environment>

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Rationale & Objectives

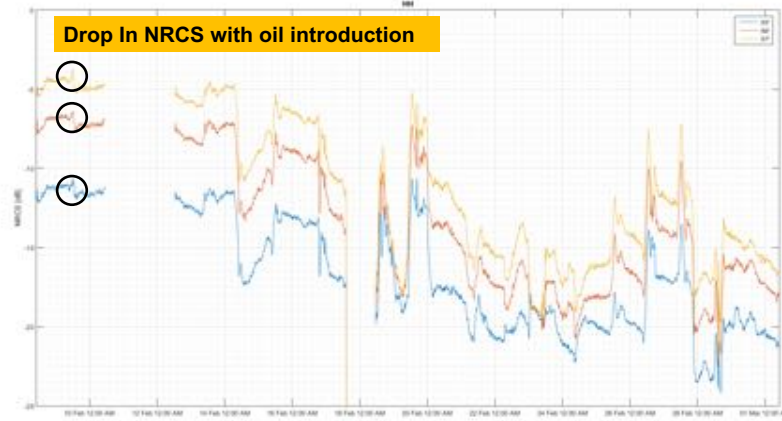
### Dielectric behavior of oil in ice

**Decrease in permittivity**

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Rationale & Objectives

## Microwave Scattering of oil in ice



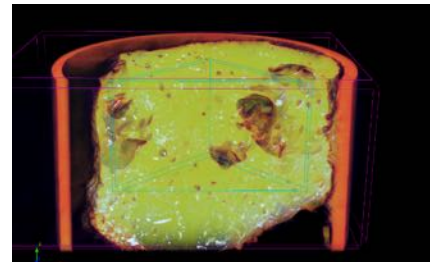
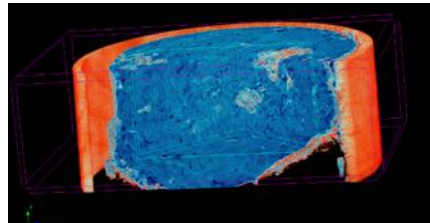
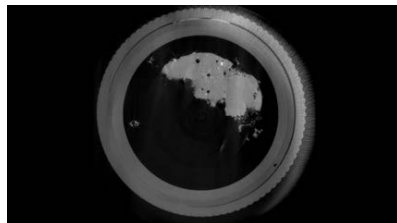
Rationale & Objectives



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## Microwave Scattering of oil in ice

- X-Ray scans of oil-contaminated samples
- Better understanding of the oil inclusion micro and macro structure




Rationale & Objectives



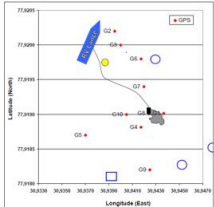
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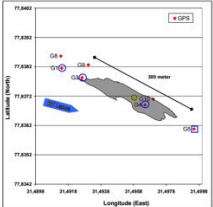
### Scaling Studies (geophysics)

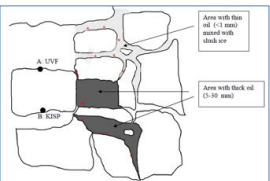
**Oil release** → **2 days later**



- Spreading, transport and weathering of oil in MIZ
- Environmental forcing (wind, current) + ice properties (concentration, floe geometry)








FEX 2009 experiment – SINTEFF 2010

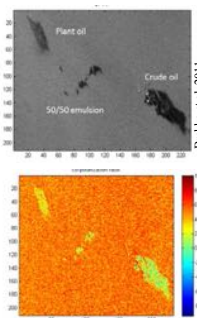
## Rationale & Objectives



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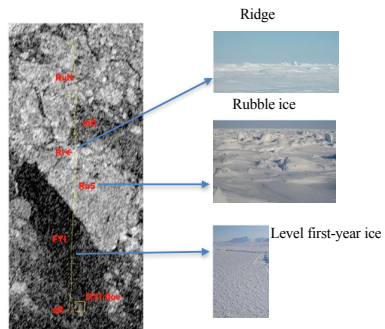
### Scaling Studies (Satellite detection)

**Spill detection from polarimetric SAR**




Brekke et al., 2011

- Direct detection of oil spill (polarimetric SAR)
- Ice management



Hwang, 2010

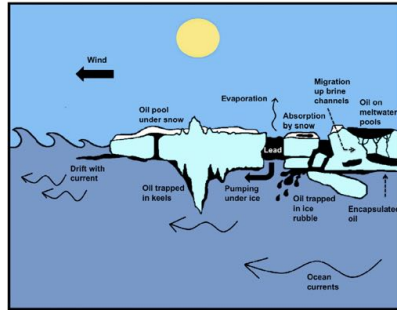
## Rationale & Objectives



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## Modeling of oil spill in ice

### Geophysical oil-ice interactions



- **Under-ice oil spreading/pooling**  
under-ice topography and current
- **Encapsulation and migration of oil**  
thermodynamics
- **Spreading/transport of oil in MIZ**  
ice concentration and floe properties

### Rationale & Objectives



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### Fate and Effects Team:

#### Faculty:

**Wang (Professor, CRC T1)**  
Stern (Professor)  
Pućko (Assistant Professor)  
Mundy (Associate Professor)  
Hanson (Associate Professor)  
Galley (Assistant Professor)  
Barber (Professor, CRC T1)

#### Students:

Geilfus (PDF)  
Desmond (M.Sc.)  
TBR



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## Fate and impacts of oil spills in sea ice

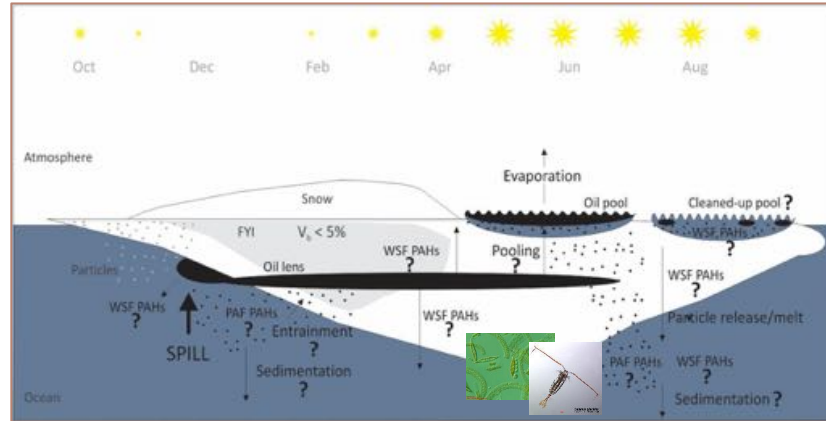


Diagram by Pućko in Wang *et al.*, in press / Ice algae photo credit: Rolf Gradinger / *Calanus glacialis* photo credit: Russ Hopcroft

### Rationale & Objectives



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## Cycling and fate of oil in sea ice



- how different ice types presence determine fate of oil in the environment
- what is the influence of emulsification of oil on entrapment, cycling and fate of oil in sea ice
- how sea ice physics/thermodynamics and timing of release affects entrapment, cycling and fate of oil in sea ice
- how different types of oil and its components behave differently in the sea ice environment

### Rationale & Objectives



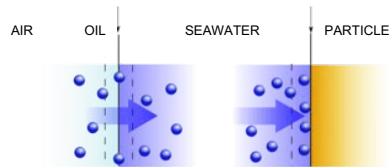
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## Fractionation of oil in cold water and sea ice



### Interphase partitioning



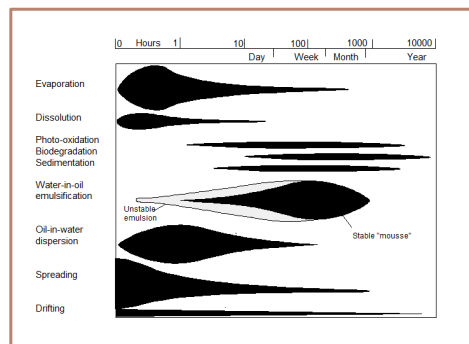
- a. what is the role of particulate matter for fractionation of oil in cold water and sea ice
- b. what is the role of oil emulsification for oil fractionation in cold water and sea ice
- c. how different oil components behave differently

### Rationale & Objectives



6

## Chemical weathering of oil in sea ice



- a. how oil chemical composition changes over time once it migrates to the surface of sea ice or if released in cold water conditions
- a. which weathering processes are critical in sea ice/cold water conditions
- a. how environmental forcing (wind speed, T, UV radiation, etc.) affect weathering of oil in cold water and on top of sea ice

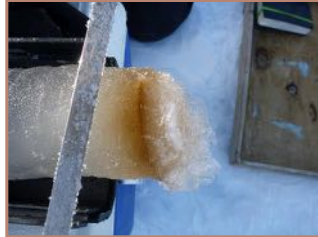
### Rationale & Objectives



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## Impacts of oil on ice algae



- a. how will presence of oil in sea ice affect growth of ice algae in the spring through e.g., light attenuation, nutrient depletion, or ice microstructural changes
- b. what is the potential for bioconcentration of Polycyclic Aromatic Hydrocarbons (PAHs) from brine or seawater during algal bloom after an oil spill

Rationale & Objectives



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## Impacts of oil on zooplankton



Credit: Allison Bailey/NPI

- a. what is the potential for PAHs bioaccumulation in *Calanus glacialis*, the major Calanoid grazing primarily on ice algae
- b. what is the potential for bioconcentration of PAHs from seawater for major species of Calanus (*C. glacialis*, *C. hyperboreus*, *C. finmarchicus*)

Rationale & Objectives



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**TRAILBLAZER ADVENTURER**  
**INNOVATOR DEFENDER CHALLENGER**  
**ADVENTURER TRAILBLAZER DEFENDER VISIONARY**

Mitigation Team:

<b>Faculty:</b>	<b>Students:</b>
<b>Stern (Research Professor)</b>	Zhang (PhD)
Pučko (Research Assistant Professor)	Chirkova (PDF)
Barber (Professor, CRC T1)	TBR
Wang (Professor, CRC T1)	

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**ADVENTURER TRAILBLAZER CHALLENGER DEFENDER VISIONARY INNOVATOR**  
**TRAILBLAZER CHALLENGER DEFENDER VISIONARY INNOVATOR EXPLORER TRAILBLAZER CHALLENGER DEFENDER VISIONARY INNOVATOR EXPLORER**


**GENICE will integrate genomics with oceanography, sea ice geophysics and petroleum geochemistry to deliver:**

- 1. baselines using microbial genomics**
- 2. bioremediation acceptance as a viable and attractive spill mitigation technology for Canada and Canadians**
- 3. maps of vulnerability created using genomics for regions of interest (e.g. Hudson Bay)**
- 4. a set of 'best practices' recommendations for end users**

**Ratusers & Objectives**

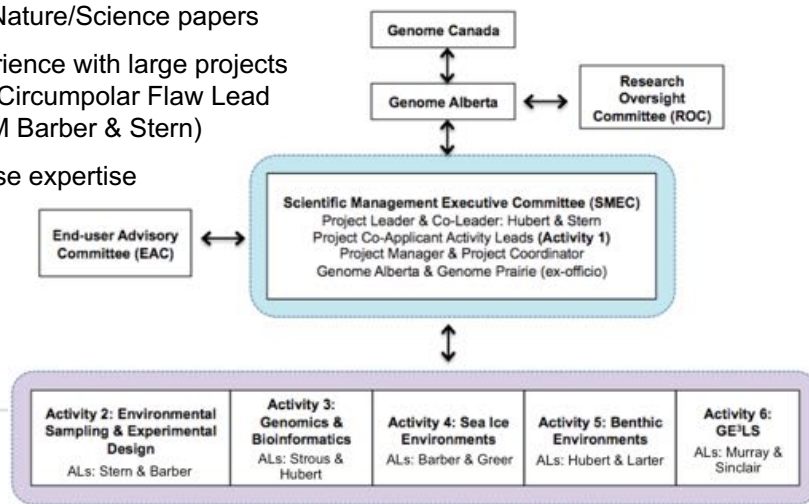
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## Tangible outcomes of GENICE (2020)

- **Canadian regulations for the use of dispersants**  
*e.g. Northern communities, National Energy Board, Oil Industry*
  - **New Baselines for shipping routes, marine protected areas**  
*e.g. Northern communities, Stantec, Parks Canada*
  - **Regionally tailored spill kits for vessels in Canadian waters** *e.g.*  
*Government of Canada, Shipping Industry*
  - **Revised insurance premiums (with or without a spill)**  
*e.g. Shipping Industry*
- 
- **Preparedness and Confidence in Northern Communities**   
*e.g. Northern Communities*

## GENICE Team and Project structure

- >120 years combined Arctic experience
- >20 Nature/Science papers
- experience with large projects (e.g. Circumpolar Flaw Lead \$42 M Barber & Stern)
- diverse expertise



ADVENTURER TRAILBLAZER CHALLENGER DEFENDER VISIONARY INNOVATOR  
 TRAILBLAZER CHALLENGER DEFENDER VISIONARY INNOVATOR EXPLORER TRAILBLAZER CHALLENGER DEFENDER VISIONARY INNOVATOR EXPLORER

## Petroleomics

- The name is a combination of petroleum and -omics (collective chemical characterization and quantification).
- Identification of the totality of the constituents of naturally-occurring petroleum and crude oil using high resolution mass spectrometry.
- In addition to mass determination, petroleomic analysis sorts the chemical compounds into heteroatom class (nitrogen, oxygen and sulfur), type (degree of unsaturation, and carbon number).

Crude Oil

Rationale & Objectives

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 TRAILBLAZER CHALLENGER DEFENDER VISIONARY INNOVATOR EXPLORER TRAILBLAZER CHALLENGER DEFENDER VISIONARY INNOVATOR EXPLORER

## Petroleum Environmental Research Laboratory (PETRL)

LECO Pegasus GC x GC-TOF-HRT  
 (2 dimensional gas chromatography high resolution time of flight mass spectrometer)

Mass range of 10 to 1500 m/z

Mass resolution of up to 60,000


Acquisition rates of up to 200 full range mass spectra per second at <1 ppm mass accuracy.

Diagram of GCxGC-TOFMS Instrument

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 TRAILBLAZER CHALLENGER DEFENDER VISIONARY INNOVATOR EXPLORER TRAILBLAZER CHALLENGER DEFENDER VISIONARY INNOVATOR EXPLORER


## Waters Synapt G2-Si (UPLC-TOF-HRMS)



- Ultra performance liquid chromatography (UPLC)
- Electrospray ionization (ESI)
- Atmospheric Chemical Ionization (APCI)
- Solid analysis probe
- Atmospheric Pressure Gas Chromatography
- Ion mobility
- Mass resolution of up to 60,000
- Mass accuracy < 1 ppm
- MS/MS
- Mass range
  - Quadrupole analyzer: 20 to 4000 m/z
  - TOF: 20-40,000 m/z

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**Rationale & Objectives**



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ADVENTURER TRAILBLAZER CHALLENGER DEFENDER VISIONARY INNOVATOR  
 TRAILBLAZER CHALLENGER DEFENDER VISIONARY INNOVATOR EXPLORER TRAILBLAZER CHALLENGER DEFENDER VISIONARY INNOVATOR EXPLORER

## Other Mitigation Strategies

- a. New chemical dispersants for oil spill mitigation in ice or cold water conditions
- b. In situ burning techniques

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**Rationale & Objectives**



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## The Churchill Marine Observatory (CMO)

*Science and Technology  
In support of Arctic Sustainable Development*



Dr. David Barber  
David.Barber@umanitoba.ca



Dr. Feiyue Wang  
Feiyue.Wang@umanitoba.ca



Dr. CJ Mundy  
CJ.Mundy@umanitoba.ca



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of MANITOBA