Centre for Earth Observation Science Annual Report

2014–2015

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Centre for Earth Observation Science

Executive Summary

This is the Annual Report for the Centre for Earth Observation Science (CEOS) for the period April 1, 2014 to March 31, 2015. CEOS is a water-centric research centre with a particular interest in how climate forces variability and change in the hydrosphere. The overarching objective of CEOS is to:

> *Understand how climate and climate change force various water-related processes operating within the Earth System.*

CEOS works with academic units within CHRFEER and in the Faculties of Engineering and Agriculture. CEOS core membership (18 members) is drawn from the Department of Environment and Geography (12 members), Geological Sciences (5 members) and Anthropology (1 member). Membership will grow in 2016 associated with a competition for tenure-stream appointment in applied electromagnetics of sea ice (joint with ECE) and two NSERC Industrial Research Chairs associated with the Churchill Marine Observatory.

CEOS hosts the University of Manitoba's CERC program in Geomicrobiology and Tier-1 CRC program in Arctic System Science. Major collaborative international research partnerships are associated with these programs. Foremost of these programs include the ArcticNet Network of Centres of Excellence (2001-2011, extended until 2018) and the Arctic Science Partnership (ASP). These are described in subsequent sections.

In the reporting year we mentored 14 undergraduate students, 29 Master's students and 16 Ph.D. students, along with 27 Post-doctoral Fellows/Research Associates. An inventory of HQP is provided in the following sections. Nine graduate students graduated over the reporting period.

CEOS remains a productive research unit. In the reporting year, faculty had published 60 papers in top journals, and secured $4.3M in research support. This year the Centre secured funding for large initiatives, including the NSERC CRD BaySys ($16M) and through CFI, the Churchill Marine Observatory ($32M).

BaySYS was developed in collaboration with Manitoba Hydro with the overarching objective to examine the downstream effects of river discharge variability associated with climate and hydro regulation on physical, biological and biogeochemical processes within Hudson Bay. The estimated cost of the project will be $16M, with $4.5M from the NSERC CRD program.

The Churchill Marine Observatory will be an innovative multidisciplinary facility to facilitate research into the detection, impacts and mitigation of oil spills in sea ice. The $12.4M contribution from CFI ($32M infrastructure proposal) will provide CEOS, the University, Manitoba and Canada the technical capacity to better safeguard the Arctic from mishaps associated with the extraction and transport of fossil fuels in Arctic waters.

CEOS researchers are active in the community, annually providing public lectures, radio, television, newspaper and web-based stories in the fields of climate change, weather, drought assessment, flooding, water quality, and freshwater eutrophication. As well, CEOS works closely with northern and stakeholder communities with the objective of making the science that we conduct relevant to those with a stake in understanding variability and change. The Centre also runs the very successful Schools

on Board program which brings high school students and teachers to the Arctic aboard the *Amundsen* icebreaker for an exhaustive immersion into the field of polar marine science.

CEOS researchers have been profiled on numerous national and international broadcasts and documentaries on climate change. The Centre has an international reputation as a 'Centre of Excellence' in Arctic marine systems and climate change. It is widely known to have played a key role in detecting changes in sea ice dynamic and thermodynamic processes driven by global-scale climate change and in the determination of changes in the marine ecosystem driven by these physical changes.

As a Centre we continue to realize our five-year goals. These are:

- To maximize benefit associated with the 2012 Memorandum of Understanding (MOU) signed between the University of Manitoba, the Greenland Climate Research Centre (GCRC), and Aarhus University (Denmark) on 'Enhancing Education and Science Cooperation in the Arctic' through the development of an Arctic Science Partnership (ASP), thereby partnering and coordinating Arctic research among CEOS (and the University of Manitoba), the Greenland Climate Research Centre (GCRC), and the Arctic Research Centre (ARC) of the University of Aarhus;
- Broaden ASP collaboration to include Norway through the University of Tromsø.
- Continued development of the Canada Excellence Research Chairs (CERC) Program, and use of the CERC program as a catalyst for deeper collaboration with GCRC, ARC, and other Arctic research centres in Norway, Germany and the United Kingdom.
- Develop research programs associated with anticipated CRC Tier 1 in Arctic Environmental Chemistry (Wang);
- Working to better develop research programs on Manitoba Lakes and ramp up the process for the creation of a Water Resource Centre;
- Continued strengthening of the partnerships developed through the ArcticNet Network of Centres of Excellence, and research icebreaker *Amundsen*-based programs;
- Leading the ArcticNet development of an 'Integrated Regional Impact Study' (IRIS) for Hudson Bay and the Western Arctic, and contributing in a substantive manner to other IRISes across the Canadian Arctic;
- Play a central role in the development of a pan-Canadian network to replace ArcticNet (2018 sunset);
- Develop an outreach program to extend or replace our highly successful Schools on Board program which will end with ArcticNet;
- Continued operation of the Sea-ice Environmental Research Facility (SERF) for research into sea-ice;
- Successfully open and operate the Churchill Marine Observatory;
- Successfully implement and complete the NSERC CRD BaySys;
- Successfully develop a CERC proposal for the 2018 competition corresponding with the end of our existing CERC (Rysgaard);

- Prepare a major proposal to CFI for a Baffin Bay Observing System;
- Host the 2016 ArcticNet Annual Science Meeting in Winnipeg; and
- Host the 2017 International Glaciological Society Meeting in Winnipeg.

Highlights for this reporting period include:

- Successful grants: NSERC CRD BaySys and the Churchill Marine Observatory through CFI;
- Successful integration of recent faculty hires into collaborative programs and engagement with proposal development;
- Collaborative field research programs in the Canadian and Greenlandic Arctic in support of the CEOS/CERC polar marine program and the NCE ArcticNet;
- Implementation of Arctic Science Partnership working committees on program leadership, collaborative operations and logistics, administration, education, and outreach and communication, with equal membership from CEOS, ARC, GCRC, and now Tromsø;
- Implementation of the 4^{th} annual sea ice experiment at our CFI-funded Sea-ice Environmental Research Facility (SERF);
- Addition of new research associates and research staff.

In 2016 CEOS will host the ArcticNet Annual Science Meeting in Winnipeg. The ASM ranks amongst the largest conferences devoted to Arctic science, and the largest in Canada. Core faculty will initiate the development of the Churchill Marine Observatory. The faculty will participate in the fall and winter BaySys field programs, in addition to ArcticNet and ASP field experiments. Future research activities will continue to build on the research strengths of CEOS members and partners. We see the need to broaden the scope of our research to better integrate processes that dictate the delivery of freshwater from the terrestrial watershed to the marine system. In doing so we foresee strengthened collaboration with colleagues from Soil Science, Civil Engineering and the DFO's Freshwater Institute.

Contents

1 Mission

> *The Centre for Earth Observation Science (CEOS) will research, preserve and communicate knowledge of earth system processes using the technologies of Earth Observation Science. These endeavours will contribute to the economic, cultural, and physical well-being of the people of Manitoba, Canada and the world.*

CEOS was established as a Type I Research Centre within the Department of Geography in the Faculty of Arts in 1994. In 2002, the Centre became part of the Clayton H. Riddell Faculty of Environment, Earth and Resources as a stand-alone unit along with the Departments of Environment and Geography, Geological Sciences and the Natural Resources Institute. In 2005, the Centre was relocated to the Wallace Building on the Fort Garry Campus. CEOS has been able to establish a strong national and international research reputation. In doing so, it has been able to form broad partnerships and leverage significant funding. This support has not only enhanced the research activities of the Centre, but it has also enabled the University to attract and retain new faculty and graduate students.

The basis of CEOS is research partnerships, leveraging resources, and providing a research umbrella under which members conduct multi-disciplinary collaborative research projects. Areas of existing research activity are divided among six key themes:

- **Ocean, sea ice and climate**, including the study of geophysical, biogeochemical and biological processes and properties of sea ice and the ocean; their linkages and feedbacks across the ocean, ice and atmosphere at cascading temporal and spatial scales.
- **Contaminants** such as mercury in the Arctic food web. We study the pathways that contaminants follow in the ecosystem, and how they might be affected by climate change.
- **Mammals**, how they interact with different ice types, and how they could be affected by the changing environment.
- **Meteorology**, improving our understanding of the planetary boundary layer, with a focus on atmospheric phenomena such as precipitation and cloud formations to better predict storms and extreme weather.
- **Aquatic Systems**, freshwater availability, water quality and ecology within watersheds and lakes over a geographic domain that extends from the prairies to Canada's Arctic.
- **Traditional and local knowledge** from Northern people contributes to our understanding of the environment.

CEOS is involved in major collaborative national and international research partnerships. The Centre is a founding member and an active participant in the Lake Winnipeg Research Consortium (LWRC). These partnerships have provided funded research opportunities for Master's and Ph.D. students.

The Centre is supported by the University of Manitoba through an operating grant and transfer of research-leveraged funds through the Clayton H. Riddell Faculty of Environment, Earth and Resources. Additionally, the Centre received a transfer of research-leveraged funds through the Clayton H. Riddell Faculty of Environment, Earth and Resources. Researchers operating under the CEOS umbrella manage annually ˜$4 million in research funds. NSERC, the NCE, CRC, and CERC are major funding sources. This translates into an external:internal funding ratio of over 40:1. This is the largest in the Faculty, and likely in the University. Annually, research funds cover an additional 10 support staff, five nil-salary professors, 21 research associates and six post-doctoral fellows. Our graduate student cohort was 45 (combined M.Sc. and Ph.D.) during the reporting year. Operational support from baseline assists with a range of services, including phones, office consumables, printing/copying, physical plant renovations, etc. This year, as in previous years, baseline operational support is supplemented by research funds.

2 CEOS Membership

2.1 Faculty

- Genevieve Ali, Assistant Professor, Department of Geological Sciences
- David Barber, Professor, Department of Environment & Geography
- Igor Dmitrenko, Professor (nil-salary), Department of Environment & Geography
- Jens Ehn, Assistant Professor, Department of Environment & Geography
- Ryan Galley, Assistant Professor (nil-salary), Department of Geological Sciences
- Norman Halden, Professor, Department of Geological Sciences
- John Hanesiak, Professor, Department of Environment & Geography
- John Iacozza, Instructor, Department of Environment & Geography
- Zou Zou Kuzyk, Assistant Professor, Department of Geological Sciences
- Brooke Milne, Associate Professor, Department of Anthropology
- Christopher-John Mundy, Assistant Professor, Department of Environment & Geography

- Jill Oakes, Professor, Department of Environment & Geography
- Masayo Ogi, Associate Professor (nil-salary), Department of Environment & Geography
- Tim Papakyriakou, Professor, Department of Environment & Geography
- Monika Pućko, Assistant Professor (nil-salary), Department of Environment & Geography
- Søren Rysgaard, Professor, Department of Geological Sciences
- Gary Stern, Professor (nil-salary), Department of Environment & Geography
- Feiyue Wang, Professor, Department of Environment & Geography

2.2 Research Associates

- Natalie Asselin
- David Babb
- Lucette Barber
- Jonathan Belanger
- Alexis Burt
- Lauren Candlish
- Jessie Carrie
- Ashley Gaden
- Geoffrey Gunn
- Brian Horton
- Sergei Kirillov
- Sergey Komarov
- Marcos Lemes
- Zhuo (George) Liu
- Jennifer Lukovich
- Greg McCullough

- Richard Raddatz
- Kerri Warner
- Emmelia Wiley
- Cornelia Willing
- Brent Young

2.3 Support Staff

- Debbie Armstrong, UCTEL Technician
- Sarah Beattie, Technician
- David Binne, SERF Technician
- Wayne Chan, Research Computer Analyst
- Linda Chow, Office Assistant
- Sebastian Luque, Technician
- Chantalle Pitre, Office Assistant
- Michelle Watts, Schools on Board Coordinator
- Denise Whynot, Office Assistant
- Irene Zhao, Office Assistant

2.4 Graduate Students

Forty-five graduate students were supported (financially and/or logistically) over the reporting period. There were 16 doctoral students and 29 master's students.

2.4.1 Doctoral

- Wieter Boone
- Karley Campbell
- Gauthier Carnat
- Emily Choy
- Odile Crabeck

- Aurelie Delaforge
- Shannon Fargey
- Nariman Firoozy
- Mukesh Gupta
- Satwant Kaur
- Alex Komarov
- Jack Landy
- Cory Matthews
- Vlad Petrusevich
- Kang Wang
- Cortney Watt

2.4.2 Master's

- David Babb
- Jasmine Brewster
- Tonya Burgers
- Michele Curry
- Robyn Dyck
- Rosemary (Annie) Eastwood
- Ashley Elliott
- Matthew Gale
- Pamela Godin
- Geoffrey Gunn
- Michelle Kamula
- Scott Kehler
- Krista Kenyon

- Heather Kyle
- Amber Penner
- Halya Petzold
- Meredith Pind
- Christine Quiring
- Breanne Reinfort
- Oksana Schimnowski
- Megan Shields
- Christopher Stammers
- Heather Stark
- Jeffrey Stup
- Randy Thomas
- Tyler Tiede
- Wen Xu
- Rui Zhang
- Dan Zhu

2.5 Graduates

Nine CEOS students graduated during the past academic year:

- David Babb (M.Sc.), Thesis title: *Sea ice motion within the Beaufort Sea.*
- Sarah Beattie (M.Sc.), Thesis title: *Mercury dynamics within natural and experimental sea ice.*
- Gauthier Carnat (Ph.D.), Dissertation title: *Towards an understanding of the physical and biological controls on the cycling of dimethylsulfide (DMS) in Arctic and Antarctic sea ice.*
- Shannon Fargey (Ph.D.), Dissertation title: *Characterization of orograhic cloud and precipitation features over Southern Baffin Island and surrounding area.*

- Pamela Godin (Ph.D.), Dissertation title: *Using lignin biomarkers and 14C, of both river DOC and POC, and permafrost soils, to characterize the impacts of climate warming and permafrost degradation on the organic carbon budget of the Hudson Bay, Canada.*
- Geoffrey Gunn, (M.Sc.), Thesis title: *Polynya formation in Hudson Bay during the winter period.*
- Mukesh Gupta (Ph.D.), Dissertation title: *On the estimation of physical roughness of a marginal sea ice zone using remote sensing.*
- Breanne Reinfort (M.Sc.), Thesis title: *Inuvialuit perceptions of contaminants and communication processes in Sachs Harbour, Northwest Territories.*
- Cortney Watt (Ph.D.), Dissertation title: *Narwhal (Monodon monoceros) diet and dive behaviour as an assessment of foraging adaptability with changing climate.*

2.6 Post-doctoral Fellows

- Brent Else
- Karen Foster
- Virginie Galindo
- Yubin Hu
- Thomas Richerol
- Randy Scharien

2.7 Affiliates

- Jody Deming, Professor of Oceanography, University of Washington
- Steve Ferguson, Research Scientist, Department of Fisheries and Oceans, Winnipeg
- Michel Gosselin, Professor, Biology, University of Quebec, Rimouski
- Casey Hubert, Assistant Professor, Microbiology, University of Calgary
- Lisa Loseto, Research Scientist, Department of Fisheries and Oceans, Winnipeg
- Robie Macdonald, University of British Columbia
- Christine Michel, Research Scientist, Department of Fisheries and Oceans, Winnipeg

- Lisa Miller, Research Scientist, Department of Fisheries and Oceans, Sydney
- Puyan Mojabi, Assistant Professor, Electrical and Computer Engineering, U of M
- Peter Outridge, Natural Resources Canada (Geological Survey of Canada)
- Simon Prinsenberg, Department of Fisheries and Oceans
- Jim Reist, Research Scientist, Department of Fisheries and Oceans, Winnipeg
- Lot Shafai, Professor, Electrical and Computer Engineering, U of M

2.8 Summer Students

Fourteen summer students assisted various faculty members as research assistants or technicians in 2014–15 (see Table 1).

Name	Supervisor
Jonathan Andrews	Papakyriakou
Wieter Boone	Rysgaard
Tonya Burgers	Papakyriakou
Aura Diaz	Papakyriakou/Ehn
Rosemary Eastwood	Kuzyk/Barber
Ashley Elliott	Mundy/Wang
Matthew Friesen	Barber
Scott Kehler	Hanesiak
Michelle Kamula	Kuzyk
Christine Quiring	Mundy
Jake Ritchie	Stern
Heather Stark	Barber
Jason Taylor	Rysgaard
Kyle Ziolkowski	Hanesiak

Table 1: CEOS summer students for 2014–15.

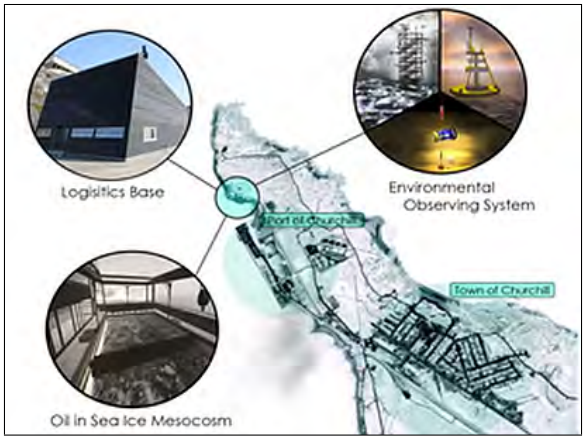
3 Activities and Research Projects

Selected ongoing research projects are highlighted here. A full list of CEOS projects can be found at: `http://umanitoba.ca/faculties/environment/departments/ceos/research/projects.html`.

3.1 Churchill Marine Observatory (CMO)

The Churchill Marine Observatory (CMO) will be a globally unique, highly innovative, multidisciplinary research facility located in Churchill, Manitoba, adjacent to Canada's only Arctic deep-water port. The CMO will directly address technological, scientific, and economic issues pertaining to Arctic marine transportation and oil and gas exploration and development throughout the Arctic.

CMO will include an Oil in Sea Ice Mesocosm (OSIM), an Environmental Observing (EO) system, and a logistics base. OSIM will consist of two saltwater sub-pools designed to simultaneously accommodate contaminated and control experiments on various scenarios of oil spills in sea ice. The EO system will be located in the Churchill estuary and along the main shipping channel across Hudson Bay and Strait. The EO system will provide a state-of-the-art monitoring system and will be used to scale process studies conducted in OSIM to Hudson Bay and the larger Arctic environment. The logistics base will underpin all CMO research.



CMO will position Canada as a global leader of research into the detection, impacts, and mitigation of oil spills in sea ice and the effect of climate change and water regulation on freshwater-marine coupling in the Arctic. Knowledge gained through CMO will strengthen Canada's technological capacity to protect the Arctic environment. Partnerships with indigenous organizations will ensure knowledge exchange; the private sector will provide market-driven uptake of technology; and various levels of government will transfer knowledge into policy and regulation.

3.1.1 Anticipated Outcomes

CMO is specifically designed to investigate a variety of contaminants under both landfast first-year sea ice and mobile ice types. Three mutually supporting core research and technology elements are proposed: 1) the Oil in Sea Ice Mesocosm (OSIM); 2) a fully integrated

Environmental Observing (EO) system; and 3) a Logistics Base. Anticipated outcomes for CMO include the following:

- A newly developed suite of remote sensing and modeling tools for detecting contaminants across a range of space and time scales.
- Procedures to mitigate environmental impacts from a spill using conventional techniques such as dispersants and in situ burning, in addition to novel techniques such as cold temperature-adapted bioremediation.
- Advanced capacity to monitor for and quantify potential impacts from shipping and development activities in the Arctic while also providing advanced information required by operators for safe shipping, exploration and development.

The true strength of the proposed program is the full integration of OSIM research and technology development with the state-of-the-art EO system. The EO system directly supports OSIM by supplying in situ data on the natural range and variability of the key environmental factors that define ocean/sea ice/atmosphere (OSA) climate states (e.g., ocean salinity, temperature, ice thickness, roughness, and biological productivity). By deploying identical instruments in both OSIM and the EO system, equivalent observations will be made in the upper ocean, ocean-ice interface, through the ice volume, and the ice-atmosphere interface. This level of coordinated cross-disciplinary environmental monitoring is unprecedented in Canada's Arctic.

OSIM will address research of how crude oils, distillates, fuel oils, herding agents, dispersants and residues from in situ burning, liquefied natural gas, and other transportation-related contaminants affect processes across the OSA interface. The OSIM science objectives are organized under three broad categories to develop an understanding of what effects various contaminants have on Arctic ecosystems, and on the thermodynamic and dynamic evolution of snow-covered sea ice:

- Detection (remote sensing from under, within above and from space)

- Impacts (physical, biological and chemical impacts across the full ocean-sea ice-atmosphere system)
- Mitigation (scientific and technological solutions required to mitigate effects)

3.2 BaySys: Contributions of Climate Change and Hydro-electric Regulation to Freshwater-Marine Coupling Processes in the Hudson Bay System

BaySys is a 4-year collaboration among Manitoba Hydro and the Universities of Manitoba, Northern British Columbia, Québec à Rimouski, Alberta and Calgary, and Laval and Trent Universities to conduct research on Hudson Bay. The overarching goal of the project is to understand the role of freshwater in Hudson Bay marine and coastal systems. In particular, we seek a scientific basis to distinguish climate change effects from those of hydroelectric regulation of freshwater on physical, biological and biogeochemical conditions in Hudson Bay. We will use a combination of data mining, new data collection and process modelling to achieve these goals. Three field expeditions are planned: Autumn 2016 installation of moorings in western Hudson Bay, winter 2017 field studies in the estuaries of the Churchill and Nelson Rivers, and a spring 2017 mission aboard the CCGS *Amundsen*. The latter will support bay-wide and estuary-scale field programs during the spring melt season—a time of high productivity, yet a season for which there is a scarcity of in situ data in Hudson Bay. These field components will be supported by remote-sensing data and ocean and atmospheric observatories, and scaled up by coupled modelling studies.

Sub-projects within BaySys will examine:

1. Historical variability and trends, and predicted change in freshwater sources and pathways and their effects on freshwater-marine coupling;
2. Mass and energy exchange between freshwater, marine, sea ice and atmosphere systems in the context of current and anticipated future conditions, and the impact on vertical mixing and horizontal circulation in the Bay;
3. Sources, transport and cycling of organic matter and nutrients, and how these influence primary production and higher trophic levels;
4. How seasonal variations and trends in freshwater fluxes may impact the Bay as a net source or sink of carbon dioxide;
5. How mercury transport and transformation in the Hudson Bay ecosystem responds to hydroelectric regulation and a changing climate.

Three modelling teams will examine processes related to climate change and hydroelectric regulation, including hydrological modeling of freshwater supply from the watershed under changing climate or regulation scenarios, sea ice-ocean modelling of mixing and circulation

in Hudson Bay under changing climate and freshwater supply from the watershed, and biological modelling of productivity responses to physical-chemical changes in the Bay.

3.3 ArcticNet: A Network of Centres of Excellence

(2004 – 2011; Extended until 2018)

ArcticNet is a Network of Centres of Excellence (NCE) that brings together scientists and managers in the natural, human health and social sciences with their partners in Inuit organizations, northern communities, government and industry to help Canadians face the impacts and opportunities of climate change and globalization in the Arctic. The central objective of ArcticNet is to generate the knowledge and assessments needed to formulate the adaptation strategies and policies that will help northern societies and industries prepare for the full impacts of the transformation of the Arctic. In the reporting year, six ArcticNet projects were led by CEOS research staff. Dr. David Barber led two projects, and Drs. Steven Ferguson, Tim Papakyriakou, Søren Rysgaard, and Gary Stern each led one project.

Geographically, ArcticNet has primarily focused on the coastal regions of the Canadian Arctic environment for several reasons. First, the largest fraction of Arctic and sub-arctic Canada is primarily a maritime territory. Second, Canadian Inuit are a coastal maritime people. Third, while continental regions of Arctic Canada (e.g., Mackenzie Basin, Northern Quebec) are relatively well studied, the coastal Canadian Arctic encompasses some of the least studied regions identified in the Northern Climate Exchange-GAP Assessment (2001). Fourth, the logistic support provided by the research icebreaker CCGS *Amundsen*, the central infrastructure of the Network, is limited to coastal marine and terrestrial regions. Temporally, ArcticNet will address the present state of the coastal Canadian Arctic, and

try to anticipate the nature and magnitude of the impacts of climate warming on this region at the horizons of 2025, 2050 and 2100. Paleoclimatic studies and Regional Climate Models will reconstruct conditions in the coastal Canadian Arctic over the last several millennia to help cast present observations in a long-term perspective. However, ArcticNet will focus on the short-term evolution of the coastal Canadian Arctic environment and the strategies needed for communities and industries to adapt to the impacts of incoming warming and modernization. Culturally, ArcticNet focuses on the impacts of environmental and societal changes on Inuit-dominated regions and communities that fall within the boundaries of ArcticNet's geographical domain of research activity.

The scientific program of ArcticNet has been specifically tailored to address the central recommendation of the Northern Climate Exchange Gap Assessment (NCE-GAP) to conduct Integrated Regional Impact Studies (IRISes) in which community level studies are embedded. ArcticNet has developed four highly integrated, multidisciplinary, cross-sector studies of climate change impacts in key regions of the coastal Canadian Arctic. Originally in the form of 'themes' during Phase I (2004-2007) of ArcticNet, these four campaigns changed into IRISes for Phase II (2008-2011).

A summary of the geographical focus of the four IRISes is outlined below:

- IRIS 1 focuses on research conducted in the Canadian Western and Central Arctic including the Northwest Territories Inuvialuit region, as well as the Nunavut's Kitikmeot region. Lead: Dr. G. Stern, Coordinator: Ashley Gaden.
- IRIS 2 focuses on research in the Eastern Arctic. This region is entirely within Nunavut and ranges from Hudson Strait to Alert, including Baffin Island and Ellesmere Island. Coastal Communities of the Kivalliq region of Nunavut and Sanikiluaq are part of IRIS 2.
- IRIS 3 is focused on the Hudson Bay region and includes the coastal regions of Nunavut, Manitoba, and Ontario. The northern reaches of this IRIS include Hudson Strait and Foxe Basin. Lead: Dr. D.G. Barber, Coordinator: Brian Horton.
- IRIS 4 is focused on the Eastern Subarctic region. This includes the Nunavik region of Quebec and the Nunatsiavut region of Labrador.

For further details on ArcticNet please go to: `http://www.arcticnet.ulaval.ca`.

3.4 Arctic Science Partnership (ASP)

The Arctic Science Partnership is a formal partnership among institutions: the University of Manitoba, Aarhus University (Aarhus, Denmark), and the Greenland Climate Research Centre (Nuuk, Greenland) and associated researchers whose overarching objective is to better understand impacts of climate change and variability on Arctic regions, particularly those under the jurisdiction of Canada, Greenland and Denmark. The partnership is a

direct consequence of the University of Manitoba's CERC program. Vision, mission and strategies appear below.

> **Vision**: The Arctic Science Partnership will be a leading consortium on climate, cryosphere, ecosystems, and human interactions through research, monitoring and education.
>
> **Mission**: To facilitate and integrate active scientific cooperation between the ASP and its members.
>
> **Strategies**:
>
> - Joint projects, field campaigns, and workshops
> - Sharing facilities (labs, instruments, field stations, logistics, ships)
> - Joint positions (staff, technicians, students, visiting scientists)
> - Joint observatories and data sharing
> - Joint publications and acknowledgements
> - Education, outreach and capacity building in the Arctic
> - Collaborative work on industry-relevant assessments
> - Development of new environmental Arctic technologies
> - Information dissemination

Seven questions guiding ASP research:

1. What controls change in i) snow, sea ice area extent and thickness? ii) the glacier-sea ice ocean interactions? iii) the permafrost thaw and the associated atmosphere-land interactions?
2. What controls the marine and atmospheric transport of pollutants to the Arctic?
3. How can proxies of palaeoclimate/ecology inform us of changes in ocean current, wind systems, precipitation, future Arctic climates and their ecological consequences?
4. What are the consequences of these changes (1–2) for i) ecosystem ecology, structure and function? and ii) chemical contaminants affecting ecosystems and human exposure?
5. What are the impacts of the transition and environmental changes on the Arctic population's lifestyle and changes in disease patterns?
6. What will be the combined effects of natural and anthropogenic forcing on ecosystems and their services?

7. What are the feedbacks between the Arctic and Earth climate system?

Søren Rysgaard is heading this large-scale, international research initiative, together with Dr. David Barber, University of Manitoba, and Drs. Josephine Nymand, Greenland Institute of Natural Resources; Malene Simon, Greenland Climate Research Centre; Ronnie Nøhr Glud, University of Southern Denmark; Tage Dalsgaard, Arctic Research Centre (Aarhus, Denmark); Tim Papakyriakou, University of Manitoba; and Torben Røjle Christensen, Lund University. The network includes several hundred research specialists within multiple research areas.

Formation of the Arctic Science Partnership has leveraged significant resources (people, equipment, and funds) that did not exist prior to the CERC program. The ASP brings together over 350 scientists and integrates them into a single collaborative research team. The inaugural meeting was held in Gimli, Manitoba in November, 2012 and the first field programs were conducted in April, 2012, and between March and October, 2013, and April to June in 2014.

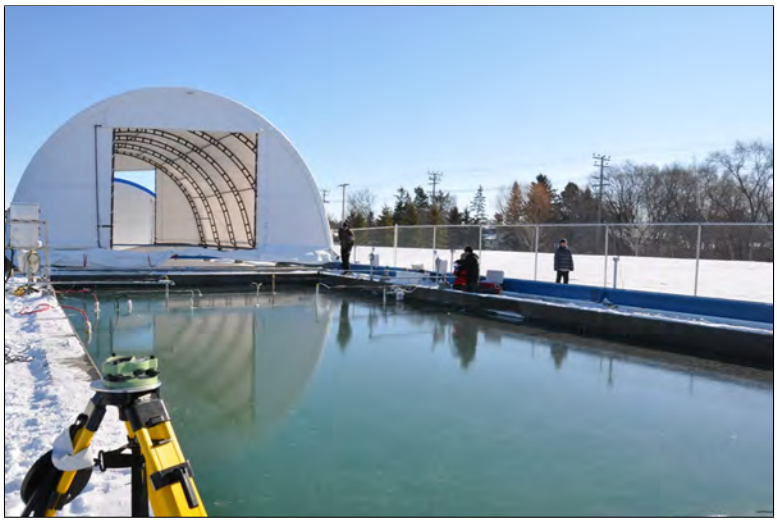
The 2014 ASP Annual Meeting was held November 4–5 in Rønde, Denmark. CEOS sent a team of delegates representing the major areas of responsibility of the Arctic Science Partnership: leadership, administration, operations, communications, and education. The objective of the meeting was to enhance and strengthen the collaboration and working relationship of the partnership, and to collectively plan upcoming field campaigns.

3.5 Sea Ice Environmental Research Facility (SERF)

The Sea-ice Environmental Research Facility (SERF) is the first experimental sea-ice facility in Canada. Located on the campus of the University of Manitoba, the main feature of the SERF facility is an outdoor seawater pool (60 feet long, 30 feet wide and 8 feet deep). It is equipped with a movable roof to control snow cover and ice growth, and various sensors and instruments to allow real-time monitoring. The SERF facility also includes a trailer laboratory and a storage building.

By fabricating and growing sea ice under various controlled conditions, mesocosm-scale studies will be carried out at SERF to enhance our fundamental understanding of how sea ice forms and melts on polar oceans, and to gain insight into the processes that regulate the exchange of energy and matter between the ocean and atmosphere. Along with the concurrent field studies on board the Canadian Research Icebreaker *Amundsen* in the Arctic Ocean, experimental studies at SERF will improve our ability to predict the impact of the rapid sea-ice loss on the marine ecosystem, on Arctic and global climates, on transport and biogeochemical cycles of greenhouse gases and contaminants, and on the human use of sea ice.

SERF is funded by the Canada Foundation for Innovation, the Manitoba Research and Innovation Fund, and the University of Manitoba. The project is led by Drs. Fei Wang, Tim Papakyriakou, David Barber, and Søren Rysgaard.



3.5.1 Research Conducted in 2015.

Preparation for the 2015 research at SERF started in November 2014, following the hiring of David Binne as the SERF technician. The experiment started on January 28, 2015. The ice reached a thickness of 42 cm on March 05. The heater was then turned on to study the melting process. The experiment ended on March 16. The roof was kept on throughout the experiment to study sea ice properties and processes in the absence of snow.

Three major research projects were carried out during the 2015 experiment:

1. Microwave remote sensing of artificial sea ice (January 28 – March 16, 2015). The objective was to investigate the possibility of retrieval of physical properties of bare sea ice from in-situ microwave remote sensing measurements. The team included David Barber (PI), Alexander Komarov (Project Lead), Nariman Firoozy (CEOS), Tyler Tiedet, Jack Landy, Puyan Mojabi, and Lotfollah Shafai.

2. Phosphate removal by ikaite precipitation (January 28 – March 5, 2015). The objective was to determine at which degree the precipitation of ikaite will affect phosphate abundance in sea ice and whether this coprecipitation of phosphate with ikaite results in phosphate being a limiting nutrient for biological activity in sea ice. The team included Feiyue Wang (PI), Yubin Hu (Project Lead), and Wieter Boone.

3. Quantification of ikaite (January 28 – February 28, 2015). The objective was to compare two methods in quantifying ikaite concentrations in sea ice, one based on image analysis and the other based on the measurement of dissolved inorganic carbon concentration. The team included Søren Rysgaard (PI) and Heather Kyle (Project Lead).

Research at SERF contributed, in full or in part, to the following papers published during the reporting period:

Firoozy, N., Komarov, A.S., Landy, J., Barber, D.G., Mojabi, P., Scharien, R.K. (2015). "Inversion-based sensitivity analysis of snow-covered sea ice electromagnetic profiles". *IEEE J. Sel. Topics Appl. Earth Observ. in Remote Sens.* 8:3643-3655, doi: 10.1109/JSTARS.2015.2399651.

Galley, R.J., Else, B.G.T., Geilfus, N.-X., Hare, A., Isleifson, D., Ryner, L., Barber, D.G., Rysgaard, S. (2015) "Imaged brine inclusions in young sea ice – Shape, distribution and formation timing". *Cold Regions Science and Technology.* 111: 39–48.

Galley, R.J., N.-X. Geilfus, B.G.T. Else, T. Papakyriakou, A.A. Hare, D. Babb, D.G. Barber and S. Rysgaard (2015) "Micrometeorological and thermal control of frost flower growth on young sea ice", *Arctic*, 68(1), doi: 10.14430/arctic4457.

Landy, J.C., Isleifson, D., Komarov, A.S., Barber, D.G., (2015) "Parameterization of Centimeter-Scale Sea Ice Surface Roughness Using Terrestrial LiDAR", *IEEE Transactions on Geoscience and Remote Sensing*, 53(3): 1271-1286, March 2015, doi: 10.1109/TGRS.2014.2336833. Published online 28 July 2014.

3.6 Effects of Lake Breeze on Weather – Manitoba (ELBOW-MB)

Although most research on lake and sea breezes has taken place outside of Canada, lake breeze fronts (LBF) are known to be important factors for initiation of convective storms and can be associated with tornadic events in Canada. An LBF existed in close proximity to the Elie, Manitoba F5 tornadic storm with unknown effects, if any. Lake breeze circulations primarily result from differential heating between water bodies and the land surface that can result in onshore flow at the surface that generates the LBF. The extent to which the LBF penetrates inland depends on various factors, including the temperature gradient between the land and water, the background (synoptic-scale) boundary layer flow, the shape of the coastline, and characteristics of the land surface. LBFs have been known to penetrate quite far inland, from a few kilometres to as far as hundreds of kilometres.

There have been no detailed studies of lake breezes in Manitoba even though it is well known that LBFs appear on weather radar and can impact cloud and storm initiation in the region. A pilot field project called ELBOW-MB (Effects of Lake Breezes On Weather – Manitoba) was conducted between July 5–26, 2013. The main objectives of ELBOW-MB were to:

- Add to the climatological database of Manitoba lake breezes by determining variations in lake breeze front (LBF) penetration distances, frequency of occurrence and speeds,
- Characterize LBF and lake breeze airmass thermal and dynamic attributes,
- Examine the LBF impacts on convective cloud development in the region in relation to the background synoptic setting, and,
- Examine how well the operational Canadian models simulate Manitoba lake breezes and associated convection.

ELBOW-MB contributed to the broader knowledge of lake breezes globally as well as provided insights into local-scale processes of lake breezes. The study also provided weather forecasters with new knowledge on these mesoscale phenomena and associated weather.

One master's thesis (Michelle Curry) was dedicated to this project. Three journal articles have also resulted from this research: two from Curry's master's degree work and one from an undergraduate honours thesis (Scott Kehler).

3.7 Manitoba Great Lakes Project

CEOS is a founding member of the Lake Winnipeg Research Consortium (LWRC). With funding from a Canadian Space Agency GRIP (Government Related Initiatives Program) Grant, in partnership with the Canadian Department of Fisheries and Oceans, we continued a study of the potential use of satellite remote sensing data to improve algorithms for chlorophyll measurement and to discriminate cyanobacteria from other phytoplankton in Lake Winnipeg.

The overarching goal of the Manitoba Great Lakes Project (MGLP) is to investigate watershed forcing on nutrient chemistry and biology of the three largest lakes in Manitoba: Lakes Winnipeg, Manitoba, and Winnipegosis, and to develop a better understanding of how major nutrients and contaminants move through the freshwater ecosystem associated with these great lakes. In the past, this work led to a significant publication (McCullough et al., 2012) which demonstrated that increased frequency and extent of flooding in the Red River basin had greater effect on phosphorus loading to Lake Winnipeg than had the previous 25 years (at least) of increased anthropogenic loading by fertilization, animal husbandry and lack of adequate sewage treatment in the watershed.

In autumn 2012, CEOS began a study of sediment loading to Lake Winnipeg by long term erosion of glaciolacustrine sediments forming the north shore. This study combines in situ water quality (suspended solids, nutrients, chlorophyll) and bottom sediment sampling (nutrient chemistry, mineralogy and particle size) along shore-perpendicular transects with remote sensing to quantify shore erosion rates and sediment transport in the littoral plume. The principal investigator is Greg McCullough.

Since 2012, CEOS has collected water samples and maintained moorings throughout the open-water seasons in the northern basin of Lake Manitoba and the southern basin of Lake Winnipegosis. In 2014, we installed a third mooring in Waterhen Lake. Unfortunately, the Lake Winnipegosis mooring was lost in a storm in the fall of the same year. Moorings are instrumented for lake water conductivity, temperature and turbidity, and fluorescence for biomass estimation of both total algae and the contributing concentration of cyanobacteria. Water samples collected at roughly monthly intervals from May through October have been analyzed for concentrations of nitrogen, phosphorus, chlorophyll and total suspended solids.

Historical tributary discharge and precipitation data accessed from Environment Canada, and historical records of nutrient concentrations accessed from Manitoba Water Conservation and Stewardship are being analyzed to develop annual water and nutrient budgets for Lakes Manitoba and Winnipegosis, and for the upstream Dauphin Lake. Fluxes from these tributaries will be studied as functions of watershed physiography, geology, vegetation cover and land use (data accessed from AgriFood Canada, Manitoba Agriculture and other sources) to improve understanding of natural and anthropogenic forcing of nutrient loading to these lakes. The program's principal investigators include: Drs. D.G. Barber, G. McCullough and T. Papakyriakou.

Reference: McCullough, G.K., S.J. Page, R.H. Hesslein, M.P. Stainton, H.J. Kling, A. Salki, D.G. Barber. 2012. Hydrological forcing of a recent trophic surge in Lake Winnipeg. *J. of Great Lakes Research.* 38:95–105

3.8 Southern Baffin Island Chert Provenance Project

Archaeologists refer to the original inhabitants of the Arctic as Palaeo-Eskimos, and chert is the most common type of stone used for their technological needs. However, few lithic sourcing studies have been done in the Arctic, meaning little is known about how, from where, and when Palaeo-Eskimo peoples acquired this essential toolstone.

In 2007, we began a pilot provenance study to identify from where local Palaeo-Eskimo populations were acquiring chert. We focused our efforts on the interior of southern Baffin

Island for three reasons: local oral histories attesting to the availability of the stone near Amadjuak Lake and a place known as "chert island"; recent geological mapping indicating the presence of chert-bearing formations in the interior; and, our own first hand observations of widespread surface scatters of the stone in close proximity to previously identified Palaeo-Eskimo sites.

Our pilot study successfully developed a chert sourcing protocol, which we applied to raw chert samples collected from several locations in the island's interior in addition to archaeologically-derived chert from local Palaeo-Eskimo sites. The data generated indicate at least one local source of chert that was used by Palaeo-Eskimo toolmakers as well as three other types of chert of unknown provenance.

Our current four-year research project, funded by a SSHRC Insight Grant, will build on these preliminary results by applying our sourcing methodology to achieve the following objectives: (1) identify other potential sources of chert used by the Palaeo-Eskimos in the interior of southern Baffin Island; (2) determine if the Palaeo-Eskimos who used the neighbouring coastal regions also used chert from these same inland sources; (3) combine our inland and coastal findings in order to reconstruct Palaeo-Eskimo mobility patterns and settlement using chert as a proxy; and, (4) develop a database of chert distribution, both from archaeological sites and from "raw" sources, and make it available as a resource for other researchers and local stakeholders.

To meet our objectives, we carried out two seasons of archaeological and geological survey in 2012 and 2013 to collect additional raw chert samples to expand our existing comparative database, and to locate and test new Palaeo-Eskimo sites in the region. Ideally, we had hoped to identify quarry locations in the interior where Palaeo-Eskimo toolmakers mined the chert stone they used to make their tools. Fortunately, in 2013 we found two such quarry locations. One is located on the banks of the Hone River while the other appears to be the infamous "chert island" along the shores of Amadjuak Lake. We also successfully identified extensive limestone exposures containing abundant nodules of *in situ* chert adjacent to these quarry sites, which confirms Palaeo-Eskimo toolmakers came to these places to get chert.

The fieldwork portion of the project has been immensely successful and our analyses of the newly acquired raw and archaeological chert samples acquired are now beginning. We will spend the next two years of the project acquiring geochemical signatures for the chert found in the interior and comparing these data to those that will be similarly acquired from Palaeo-Eskimo sites located in neighbouring coastal areas. These comparisons will provide us with the unprecedented opportunity to reconstruct seasonal land use patterns and technological organization for Palaeo-Eskimo populations in this region of the eastern Arctic using lithic provenance data.

3.8.1 Participants

- Principal Investigators: Brooke Milne, Mostafa Fayek (Geological Sciences), Robert Park (Anthropology, University of Waterloo), Douglas Stenton (Director, Culture and Heritage, Government of Nunavut).

- U of M Participants: Rachel ten Bruggencate, Post-Doctoral Fellow; David Landry, Ph.D. candidate (Anthropology).

3.8.2 2014-2015 Experiments

In 2014, Drs. Brooke Milne (CEOS, University of Manitoba), Ian Ferguson (Geological Sciences, University of Manitoba) and Robert Park (Anthropology, University of Waterloo) executed a short field season at the LdFa-1 site near Mingo Lake, Southern Baffin Island. Due to unforeseen logistical complications associated with accessing the original site planned for investigation – LbDt-1 on the Hone River – Milne's permit was amended to shift the project's focus to LdFa-1. Much to the team's disappointment, LdFa-1 also could not be reliably or repeatedly accessed via Twin Otter. Therefore, research efforts for 2014 were restricted to a single day (i.e., 8 hours on the ground).

On July 15, 2014, the research team flew to LdFa-1 and, after many attempts, finally landed near the site. Milne and Park knew there were no outcrops similar to the one identified at LbDt-1 given the results of the 2013 survey in this area. Therefore, efforts were focused instead on recovering archaeological samples of chert toolstone for analysis. Two 50 x 50 cm test pits were excavated in Area 1 of the site – a confirmed inland Late Dorset deposit. Chert debitage and abundant faunal remains were recovered as well as several formal tools including a harpoon head, several barbed implements presumably for fishing, and an implement handle. A burin-like tool was also identified.

The results of these limited test excavations will make a notable contribution to our provenance research and provide further insights into toolstone exploitation and use strategies at the LdFa-1 site. Analysis of the materials collected in 2014 is presently underway, as are plans to geochemically characterize the new chert samples.

Ferguson and Landry conducted a magnetometer/gradiometer survey of Area 5 at LdFa-1. A 20 x 20 m grid with a horizontal line spacing (x-axis) of 0.5 m was set up in this vicinity of the site. This area was chosen specifically to include two test units previously excavated by Park in 2008. The goal was to test the feasibility of the geophysics instrumentation in this Arctic environment and to see if any measurable differences in magnetic levels associated with the disturbances created by the subsurface testing could be detected. Measurements of the magnetic susceptibility were taken every 20 cm along the vertical axis (y-axis) so as to provide greater Y-axis resolution. A local base-station set-up was used to correct for diurnal fluctuations in the Earth's magnetic field along with a vertical gradient to correct for any isolated changes. The corrected results of the survey illustrate gradual/natural changes in soil and bedrock susceptibility from the northwest corner of the

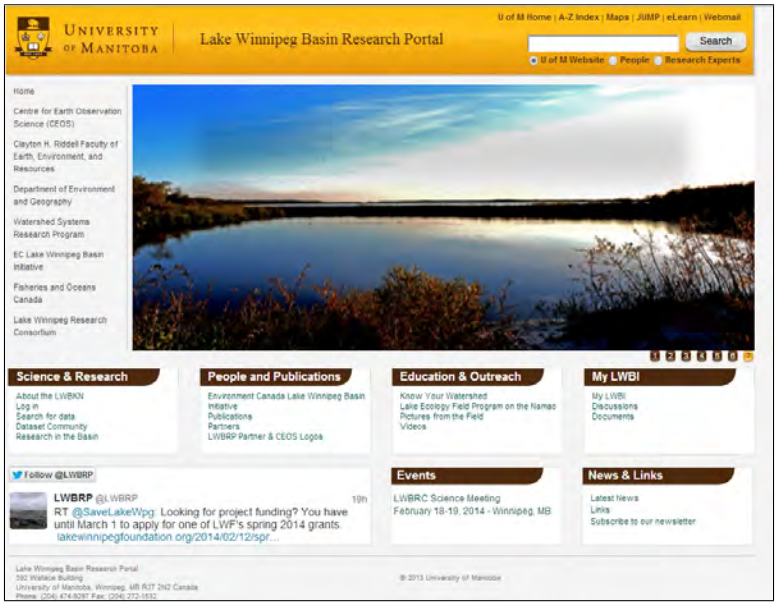
grid down to the southeast corner, which is lowest point of elevation in the survey area.

What is of particular interest is the higher levels of magnetic variation observed around the test pits. The magnetic levels in this area may be attributable to two factors. One possibility is that activities relating to burning or cooking may be creating these levels of remnant magnetism (i.e., the original site occupants had a fire of some kind in this location). It is also possible the 2008 test excavations had an effect on the soil in this area since such disruptions can increase or decrease the magnetism at the surface. In all likelihood, both scenarios are correct since excavated faunal remains from the tests yielded evidence of subsistence activities and the test excavations did indeed cause disturbances to the soil.

The results of this small survey are promising for future applications. This survey also determined that the bedrock is amenable to radar survey applications (i.e., ground penetrating radar), which had been planned for the 2014 site investigations but as noted, could not be carried out. Still, this is valuable information for future geophysical surveys at this site and others like it in the interior region of southern Baffin Island

3.9 Lake Winnipeg Basin Information Network

Coordinator: Claire Reis



The Lake Winnipeg Basin Information Network (LWBIN) is a web-based data and information network created by Environment Canada as part of the Lake Winnipeg Basin Initiative under Canada's Action Plan on clean water. It was created in order to help

address key water quality issues within the lake and its contributing watersheds. In 2012, management of the network transferred to the University of Manitoba under CEOS, where it supports the CEOS key theme of aquatic ecosystems.

The LWBIN facilitates research, education and decision-making through three key goals:

1. To facilitate networking and collaboration between researchers, decision makers, government agencies, organizations and the public by acting as a hub for open-source data, metadata and information.

2. Act as a central hub to ensure decision makers and managers have access to relevant scientific information to guide and evaluate water and land management objectives.

3. Facilitate citizen science and public education and outreach throughout the basin.

For several years, water quality in Lake Winnipeg has been deteriorating. Nutrient loading has led to advanced anthropogenic eutrophication of the lake, causing increased blue-green algal blooms, affecting in turn the local commercial fishing industry as well as recreational and agricultural activities throughout the basin.

Understanding the dynamics of nutrient loading, the associated algal blooms and resulting changes in fish populations, beach closures, and ecosystem imbalance requires access to various sources of data, information, knowledge, expertise and tools. Such critical components are delivered through the Lake Winnipeg Basin Information Network, which integrates multiple geospatial and non-geospatial datasets and information pertaining to the basin. With data coming from many disparate sources, the Canadian Geospatial Data Infrastructure standards (FGDC) are applied to ensure international interoperability.

In 2015 the LWBIN underwent a new name change to CanWIN (Canadian Watershed Information Network). The name change reflects the fact that the CanWIN will now be storing and sharing data from the entire Nelson River Watershed and into the Arctic, including CEOS data from projects such as BaySys and the Churchill Marine Observatory.

3.10 BREA–Extreme Ice Features in the Southern Beaufort Sea

The CEOS project "Detection, Motion and Radarsat Mapping of Extreme Ice Features in the Southern Beaufort Sea" is one of three studies comprising Beaufort Regional Environmental Assessment (BREA) Integrated Sea Ice Project, which ran from April 2012 through March 2015. CEOS provided the overall lead for the larger project. The main goal of this project was to develop knowledge required to better monitor, model and predict the motion and physical characteristics of extreme ice features (EIFs) in areas of the southern Beaufort Sea where oil and gas exploration and development may occur. In particular, it focused on: 1) collecting new and integrating existing data to determine the thickness and thermo-dynamics of EIFs, and the influence of key ocean and atmospheric factors (currents and winds) on EIF motion; 2) developing approaches for identifying and tracking EIFs

using satellite imagery; and, 3) piloting a community-based monitoring program (CBM) focused on the measurement of ice thickness near Sachs Harbour. The CEOS study and its Integrated Sea Ice Project counterparts contributed to a number of specific BREA goals and objectives. New information on and methods for assessing the motion and physical characteristics of EIFs will: better prepare stakeholders for future oil and gas exploration and development in the Beaufort Sea; support informed regulatory decisions related to oil and gas activity; and provide guidance for project-level environmental assessment.

Over the course of the study, CEOS researchers measured and reported on thickness of remaining multi-year ice, physical processes contributing to multi-year ice decay, and the influence of atmospheric and ocean forces (winds and currents) on the movement of extreme ice features (EIFs) in the southern Beaufort Sea. They also tested satellite-based radar techniques for estimating wind speed in the marginal ice zone, identifying and tracking EIFs, and initiated a community-based monitoring program for measuring ice thickness near Sachs Harbour. While multi-year ice, ice islands, and compacted first-year ice can all constitute EIFs, this project focused specifically on multi-year ice and ice islands, the features of greatest concern to industrial and regulatory agencies in the region. Ice thickness and under-ice salinity and temperature profiles were also recorded on landfast ice in a community monitoring study based in Sachs Harbour. Field data was collected in the summer of 2011 (ship-based) and April-to-July 2012 (helicopter-based survey, drifting instrument packages and community monitoring) and winter 2013 (community monitoring only). CEOS activities in 2014–15 were limited to analysis of field data and reporting.

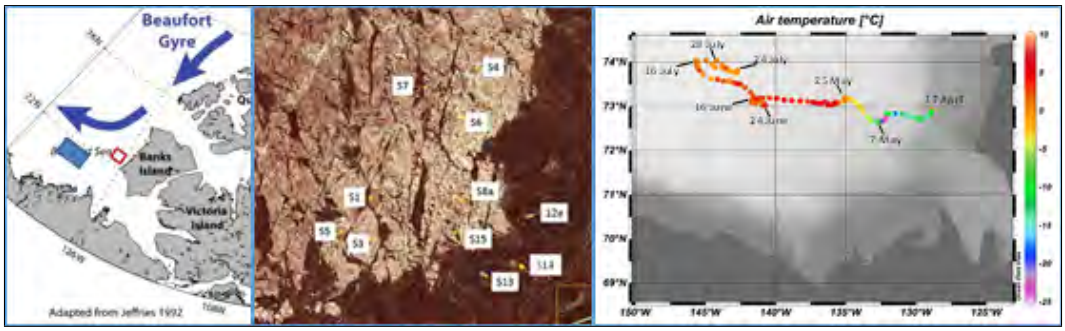


Figure 1: Left: the field study region in the context of the Beaufort Gyre and oil and gas leases off the Mackenzie Shelf. Middle: deployment locations of a primary site (S1, with winds-currents-ice mass balance instruments) and ice beacons (other numbered locations) relative to the MYI pack (light tones on background RADARSAT image; dark indicates first year ice). Right: track of the primary site with air temperature indicated by coloured location symbols.

This work culminated in a science-to-management bridging publication that demonstrates that the hazard to shipping and potential oil extraction infrastructure of extreme ice features drifting into the southern Beaufort Sea may be expected to continue for at least

several decades, in spite of Arctic warming and reduction of the summer ice pack (Barber et al. 2014). Implications of climate-forced changes in the Arctic marginal ice zone are described in articles currently in review (Barber et al. 2105; Babb et al. 2015).

Over the course of the project, CEOS researchers used synthetic aperture radar (SAR) images from Canada's RADARSAT-2 satellite to develop and test satellite-based techniques for identifying EIFs and measuring local wind fields and ice motion in the Beaufort. The ice motion technique involved developed of a new computational method combining the strengths of two existing (cross- and cross-phase correlation) methods for measuring spatial displacement of EIFs between sequential SAR images. Results were validated against ice motion information derived using ice beacon transmissions for the same time period, location and EIFs (Komarov and Barber 2014). Meanwhile, development of wind-field information was carried out for the first time using RADARSAT-2 "C-band" imagery in horizontal polarization HH-HV Scan-SAR mode, the "beam mode" in most common use by the Canadian Ice Service (Komarov et al. 2014). Experimentation with RADARSAT-2 imagery for the purpose of differentiating between first-year, multi-year ice, and ice islands (i.e., identifying EIFs) compared the effectiveness of different polarization modes across seasons and EIF types.

References

Barber, D.G., G. McCullough, D. Babb, A.S. Komarov, L.M. Candlish, J.V. Lukovich, M. Asplin, S. Prinsenberg, I. Dmitrenko and S. Rysgaard (2014). Climate change and ice hazards in the Beaufort Sea. *Elementa-Oceans. Elem. Sci. Anth.* 2: 000025 doi: 10.12952/journal.elementa.000025.

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. (2015). Selected physical, biological and biogeochemical implications of a rapidly changing Arctic marginal ice zone. *Progress in Oceanography.* In review.

Komarov, A. and D. G. Barber (2014). Sea Ice motion tracking from Sequential Dual-polarized Radarsat-2 images. *IEEE Geosci. Remote Sensing.* vol. 52, no. 1, pp. 121–136.

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

4 Education, Outreach & Communications

The Centre for Earth Observation Science is involved in numerous educational outreach activities. Schools on Board, a national outreach program of ArcticNet, is based out of CEOS. Its goal is to provide high school students with authentic and simulated experiences in conducting Arctic science research.

4.1 Schools on Board

Coordinator: Michelle Watts

4.1.1 Field Programs

The Centre for Earth Observation Science runs the very successful Schools on Board program, which brings high school students and teachers to the Arctic aboard the CCGS *Amundsen* icebreaker to provide an immersive experience in the field of polar marine science. Based on the success of this program, a terrestrial-based outreach program called Schools on Tundra was also developed.

Schools on Board – Arctic Field Program. Each year, a team of high school students and teachers are selected from across Canada to participate in an ArcticNet research program on board the CCGS *Amundsen*. Schools are given the unique opportunity to send students and teachers to the Arctic to participate in an educational experience completely integrated into the research activities of the ArcticNet science team.

Participants in the 2015 field program joined the final leg of ArcticNet's 2015 science expedition in Resolute, NU and travelled across Lancaster Sound, between Ellesmere Island and Greenland before sailing south to Pond Inlet where students had the opportunity to interact with northern youth and elders. In addition to the ship-based portion of the journey, students had the opportunity to interact with local high school students in Kugluktuk and venture to Bloody Falls.

Schools represented in the 2015 field program include:

- Carihi Secondary School – Campbell River, BC

- Sir John Franklin High School – Yellowknife, NWT
- Diamond Jennes Secondary School – Hay River, NWT
- Nasivvik High School – Pond Inlet, NU
- Canterbury High School – Ottawa, ON
- Delphi Secondary Alternative School - Toronto, OT
- Collège Saint-Charles-Garnier – Quebec City, QC
- Collège Jean-De-Brébeuf – Montreal, QC
- Gimli High School – Gimli, MB
- Collège Jeanne-Sauvé - Winnipeg, MB

4.1.2 Arctic Science Days

Arctic Science Day focuses on bringing Arctic scientists and high schools students together in an outdoor learning environment. Scientists demonstrate and involve students in sampling techniques while communicating the importance of conducting research in the Arctic. Students are introduced to different aspects of Arctic research and may include the following themes:

- Snow and ice sampling
- Contaminants in snow, water, and biota
- Atmospheric sciences
- Surface energy budget and albedo
- Remote sensing
- Arctic people and their environment

Arctic Science Day at FortWhyte Alive – March 6, 2015. 150 middle and high school students attended the 2015 Arctic Science Day held at FortWhyte Alive on March 6. CEOS graduate students and scientists created a number of different stations, which included: pop-up fishing shelters for water sampling and microbiology, a meteorological station, a snow pit and ice coring activity, and sampling for contaminants in snow and ice. Students also learned about remote sensing and examined Arctic marine mammal artifacts, such as narwhal tusks and seal skins.

4.1.3 ICE-Camp Day - Cambridge Bay – May 2014

During the Ice Covered Ecosystem - CAMbridge bay Processes Studies (ICE-CAMPS) field campaign, Schools on Board worked with scientists and teachers from Kiilinik High School to create a unique learning opportunity for 40 high school students and five teachers that we called ICE-Camp Day. ICE-Camp Day was based on the successful model of our Arctic Science Day where 200 high school students attend. The intent of ICE-Camp Day was to inform local high students about what scientists are studying in their community and why, to provide an opportunity to learn and experience first hand how to sample (ice coring, zooplankton tows, snow sampling, etc.), to create interest in science and research, and to initiate a meaningful relationship between scientists, the school and community. ICE-Camp Day was successful, bringing positive responses from students, teachers and members of the community.

4.1.4 Arctic Climate Change Youth Forum 2014

The Arctic Climate Change Youth Forum (ACCYF) is a youth-oriented, day-long conference devoted to raising awareness of climate change and ongoing research in Canada's Arctic. In addition to science, the day also includes the northern perspective on climate change and the complexities of a changing Arctic. The conference is held in conjunction with a scientific meeting and features keynote speakers and presentations from scientists in the forefront of Arctic research. An ACCYF is co-hosted with a high school and aims to bridge Arctic science with science education. The event took place on December 8, 2014.

4.2 ASP Field School 2015

In 2015, the Arctic Science Partnership began a series of six field schools in Nuuk, Greenland as part of a new education initiative. This initiative was led by the three education leads – Drs. Lise Lotte Sørensen (Aarhus University), Dorte Søgaard (Greenland Institute of Natural Resources) and John Iacozza (University of Manitoba). The goal is to offer these field schools every year in the Greenland, allowing students to learn about the Arctic in the Arctic.

During Reading Week (February 13-20, 2015), 21 national and international graduate students, including students from the University of Manitoba, Aarhus University and other institutions converged onto Nuuk to learn about various aspects of snow-covered sea ice. These students were from various disciplines, including glaciology, biology, physics and modelling. The multidisciplinary nature of the students not only enhanced the academic

learning, but also led to interactions with student that might not be available through traditional conferences or workshops. The goal of this course was two-fold: the first and most obvious one was to provide students with a multi-disciplinary scientific understanding of snow covered sea ice, with the second to provide an opportunity to physically explore the Arctic marine system. Dr. John Iacozza and Dr. Lars-Chresten Lund-Hansen (Aarhus University) led the lectures, which focused on the geophysics of snow and sea ice, optical properties of sea ice and the biological habitat relationships. Ms. Ann Eileen Lennert (a PhD student in Greenland) gave a lecture that provided students some insight into the social aspects of this feature on the past and present societies in Greenland. A critical component of the field school was hand-on experiential learning, with students actually going onto the sea ice around Nuuk and sampling both snow and sea ice. This part of the course was led by Dr. Nicolas-Xavier Geilfus (Aarhus University) and Dr. Dorte Søgaard.

5 Service

CEOS researchers have been profiled on numerous national and international broadcasts and documentaries on climate change. The Centre has an international reputation as a 'Centre of Excellence' in Arctic marine systems and climate change, and is widely known to have played a key role in detecting changes in sea ice dynamic and thermodynamic processes driven by global scale climate change and in the determination of changes in the marine ecosystem driven by these physical change.

CEOS researchers are active in the community, annually providing public lectures, radio, television, newspaper and web-based stories in the fields of climate change, weather, drought assessment, flooding, water quality, and freshwater eutrophication. As well, CEOS works closely with northern and stakeholder communities with the objective of making the science that we conduct relevant to those with a stake in understanding variability and change.

5.1 Media

The following is a selection of media interviews and public lectures that occurred during the reporting period.

- Dr. David Barber – Invited lecture at TEDx UManitoba 2014, "Seven surprising results from the reduction of Arctic sea ice cover", 4 November 2014. `https://www.youtube.com/watch?v=ofaoiHYKtlc&feature=youtu.b`
- *Canadian Geographic*, "Captain's Log, Victoria Strait Expedition 2014 — Surveying the Arctic: New tools create maps of archaeological sites". Discusses use of CFI-funded research infrastructure provided by Brooke Milne to colleagues Robert Park and Douglas Stenton during the season's terrestrial archaeological research project. Published 20 August 2014.

- *CBC News*, "Poles apart? Antarctic sea ice hits record high while the Arctic's keeps melting", Interview with David Barber about the difference in sea ice conditions between the Arctic and Antarctic, 21 October 2014.
- *CBC Radio*, Interview with John Hanesiak about winter weather, December, 2014.
- *CBC Radio Regina*, Interview with John Hanesiak about Bethune radar outages, June, 2014.
- *CityTV*, Interview with John Hanesiak about balloon program, June, 2014.
- *CTV News Winnipeg*, Interview with John Hanesiak about balloon program, June, 2014.
- *CTV News Winnipeg*, Interview with Brooke Milne about the use of LiDAR in the recent discovery of Sir John Franklin's ship, HMS *Erabus* near King William Island, NU. Airdate: 10 September 2014.
- *Toronto Star*, Article discussing use of CFI-funded research infrastructure used by Brooke Milne's colleagues Robert Park and Douglas Stenton in the discovery of Sir John Franklin's ship, HMS *Erabus*. Published 9 September 2014.
- *TV avisen (DR1, Denmark)* – Indvielse af Villum Forskningsstation ved Station Nord, 10 July 2015. (National Television).
- *UM Today*, "1,000 km north of the Polar Circle: U of M's Arctic field research at the Zackenberg station in Daneborg," 13 June 2014.
- *UM Today* "Journey to Churchill opens this week," , 2 July 2014.
- *UM Today* "Arctic Partners: Dynamic trio brings together world's leading arctic climate scientists", 2 February 2015.
- Basse, E.M., Rysgaard, S. "Sådan undgår vi miljøkatastrofer i Arktis (How do we avoid environmental disasters in the Arctic?)", Debat i *Politiken*, 13 November 2015. (Largest Danish Newspaper).
- *UM Today*, "Lost Ship Found: Solving a Mystery in the Arctic," , 6 January 2015. Summary story profiling the contributions of members from the University of Manitoba's Centre for Earth Observation Science made to the discovery of the HMS *Erabus* in September 2014. CEOS faculty member Brooke Milne and graduate student Emily Choy are featured.
- *Winnipeg Free Press*, "A place to study oil spills", 22 April 2014. Interview with David Barber about the new Churchill Marine Observatory (CMO).

6 Financial Information

6.1 Grant Funding

Table 2 shows all research grants (dollars and/or value in kind) that were obtained or held during the reporting period.

Principal Investigator	Research Project	Amount (2014-2015)
Barber	120081-Schools on Board	$59,000.00
Barber	301912-CRC NSERC Sal	$29,473.32
Barber	301913-CRC NSERC Res	$171,000.00
Barber	302304-NSERC RGPNS	$15,000.00
Barber	302306-NSERC RGPIN	$70,000.00
Barber	303044-MCEF ArcticNet	$94,984.00
Barber	310673-CFI - IOF Laval	$118,901.00
Barber	312216-CFI - IOF	$33,349.07
Barber	313065-ArcticNet Laval Hudson Bay IRIS 3.2	$169,095.00
Barber	313066-ArcticNet Laval Role Sea Ice IRIS 3.6	$112,410.00
Barber	313079-MRIF/CDA Excellence Research	$500,000.00
Barber	313785-INAC	$230,360.00
Barber	313874-NSERC PROSC	$25,800.00
Barber	314872-Environment Canada	$40,000.00
Barber	315322-European Space Agency	$48,551.62
Barber	316008-Transport Canada	$25,000.00
Barber	316243-Environment Canada	$7,715.00
Barber	316253-WWF Canada	$52,200.00
Dmitrenko	315868-ArcticNet Laval Marine Observatory	$4,000.00
Ehn	315105-NSERC RGPIN	$28,000.00
Ehn	315131-NSERC RGPNS	$17,500.00
Ferguson	302299-NSERC RGPIN	$22,000.00
Ferguson	313072-ArcticNet Laval Marine Mammals 3.3	$60,650.00
Hanesiak	314011-NSERC RGPIN	$27,000.00
Kuzyk	315313-ArcticNet Laval Nunatsiavut 4.6	$20,000.00
Mundy	315116-NSERC RGPIN	$27,000.00
Mundy	315132-NSERC RGPNS	$15,000.00
Mundy	316172-MRIF	$319,992.00
Papakyriakou	313068-ArcticNet Laval Carbon Dynamics 3.1	$70,610.00
Papakyriakou	314038-NSERC RGPIN	$32,000.00
Papakyriakou	316390-ArcticNet Laval TP Fieldwork Safety	$3,225.00
Rysgaard	312888-CERC NSERC Sal	$269,000.00
Rysgaard	312890-CERC NSERC Res	$1,131,000.00
Rysgaard	313075-ArcticNet Laval Geomicrobio 2.8	$35,000
Rysgaard	316875-ArcticNet SR Training Fund Campbell	$2,540.00
Stern	122555-Soil/Water Testing	$25,228.00
Stern	308594-Analytical Costs& Expenses	$2,973.39
Stern	313069-ArcticNet Laval Contaminants 1.2	$95,355.00

Continued on next page

Stern	313076-ArcticNet Laval IRIS Coord. Contaminants	$70,000.00
Stern	316564 - NSERC RGPIN	$43,000.00
SStern	317316-AANDC	$32,465.00
Stern	317317-AANDC	$28,438.00
Stern	317318-AANDC	$18,916.00
Wang	311347-CFI IOF	$12,436.00
Wang	313064-ArcticNet Laval Contaminants 1.2	$42,000.00
Wang	314947-UBC/RGPCC	$41,206.00
	Total:	$4,299,373.40

Table 2: Research grants obtained or held during 2013–2014 reporting period.

6.2 Northern Scientific Training Program (NSTP)

Table 3 shows all Environment and Geography/CEOS students who received NSTP funding in 2014–2015.

Student	Supervisor	Amount
Tonya Burgers	Papakyriakou	$2,437.48
Karley Campbell	Mundy	$2,677.27
Ashley Elliott	Mundy	$2,294.40
Claire Hornby	Loseto	$2,685.46
Alex Komarov	Barber	$2,669.16
Megan Shields	Barber	$2,836.44
Heather Stark	Barber	$1,674.27
	Total:	$17,274.48

Table 3: Students receiving NSTP funding for 2014–2015.

6.3 Summarized Annual Operating Budget

A summary of the annual operating budget is shown in Table 4. Details can be found in Appendix A.

7 Academic Contributions

CEOS researchers published 60 peer-reviewed journal articles and several book chapters and edited volumes during the reporting year. CEOS members also presented a number of posters at various workshops and conferences.

Only contributions for the reporting period are listed. Previous years' contributions can be found in previous annual reports.

Item	General Classification	YTD Total	%
1	Total Wages & Benefits	$15,986.32	35.47
2	Travel	$1,796.14	3.99
4	Materials, Supplies and Services	$20,615.29	45.74
5	Utilities, Taxes and Insurance	$50.00	0.11
6	Professional and External Services	$1,717.36	3.81
7	Capital Asset	$3,824.55	8.49
8	Repairs and Maintenance	$1,081.37	2.40
	Total:	$45,071.03	100.0

Table 4: Summary of annual operating budget.

7.1 Primary Publications (C.1)

The following is a list of peer-reviewed research articles published by CEOS that fall within the reporting period of April 1, 2014 – March 31, 2015. A full list of articles from the last two calendar years can be found on the CEOS website: `www.umanitoba.ca/ceos`.

[1] Ando, Y., Ogi, M., and Tachibana, Y. (2015) "Abnormal Winter Weather in Japan during 2012 Controlled by Large-Scale Atmospheric and Small-Scale Oceanic Phenomena", *Monthly Weather Review*, 143: 54–63. doi: 10.1175/MWR-D-14-00032.1.

[2] Asplin, M. G., R. Scharien, B. Else, S. Howell, D. G. Barber, T. Papakyriakou, and S. Prinsenberg (2014). "Implications of fractured Arctic perennial ice cover on thermodynamic and dynamic sea ice processes", *J. Geophys. Res. Oceans*, 119, doi:10.1002/2013JC009557.

[3] Attard, K.M., Glud, R.N., McGinnis, D.F., and S. Rysgaard (2014). "Seasonal rates of benthic primary production in a Greenlandic fjord measured by aquatic eddy-correlation", *Limnology & Oceanography*, 59(5): 1555–1569. doi:10.4319/lo.2014.59.5.1555.

[4] Barber, D.G., Ehn, J.K., Pućko, M., Deming, J., Rysgaard, S., Papakyriakou, T., Galley, R., Søgaard, D. (2014) "Frost flowers on young sea ice: The climatic, chemical and microbial significance of an emerging ice type", *Journal of Geophysical Research (Atmospheres)*,119(20), 11593–11612, doi: 10.1002/2014JD021736.

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[10] Brimelow, J.C., Stewart, R.E., Hanesiak, J.M., Kochtubajda, B., Szeto, K., and Bonsal, B. (2014) "Characterization and assessment of the devastating natural hazards across the Canadian Prairie Provinces from 2009 to 2011", *Natural Hazards*, 73(2), 761-785, doi: 10.1007/s11069-014-1107-6.

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7.2 Non-Refereed Contributions (E.2)

7.2.1 Reports

- Milne, S.B. (2014a) *Chert Sourcing and Palaeo-Eskimo Lithic Technology: An Archaeometric Approach to Understanding Technological Organization. Non-Technical Summary Report for Nunavut Archaeology Permit 2014-24A*. Manuscript on File with the Department of Culture and Heritage, Government of Nunavut, Igloolik, NU. (3 pages).
- Milne, S.B. (2014b) *Climate Change and the Arctic Archaeological Record: An Archaeo-Geophysical Approach to Assess Site Stability and Predict Future Impact. Non-Technical Summary Report for Nunavut Archaeology Permit 2014-22A*. Manuscript

on File with the Department of Culture and Heritage, Government of Nunavut, Igloolik, NU. (3 pages)

- Wallace, D.W.R., de Young, B., Iverson, S., LaRoche, J., Whoriskey, F., Lewis, M., Archambault, P., Davidson, F., Gilbert, D., Greenan, B., Pepin, P., Johnson, C., Hebert, D., Gall N., Hanlon, J., Rysgaard, S., Carter, B., Gillespie, R., House, D., Snelgrove, P., Myers, P., Babin, M., Holthus, P., Rae, A. (2015), *A Canadian contribution to an integrated Atlantic ocean observing system (IAOOS)*. Oceans 2014, St. John's, Newfoundland, 14-19 Sept. 2014, White paper, 10 pp.

7.2.2 Poster Presentations

The following is a selection of posters that were presented by CEOS students and researchers during the 2014–15 reporting period.

ESA Earth Observations for Ocean-Atmosphere Interactions Science 2014, 28–31 October 2014, Frascati, Italy.

- Firoozy, N. and Barber, D.G. *Reconstruction of snow-covered sea ice dielectric profiles through normalized radar cross-section data inversion.*

- Komarov, A.S., Isleifson, D., Barber, D.G., and Shafai, L. *Modeling and measurements of C-band radar backscatter from snow-covered sea ice.*

27th Conference on Severe Local Storms, 3–7 November 2014, Madison, Wisconsin.

- Dyck, R., J. Hanesiak, N. Taylor, D. Sills *Tornadic Events During UNSTABLE: use of supplemental soundings.*

2014 ArcticNet Scientific Meeting, 8–12 December 2014, Ottawa, Ontario.

- Burt, A. and Stern, G.A. *Temporal trend studies of trace metals and organic contaminants in Mackenzie River burbot, Fort Good Hope, NT (1985–2014).*

- Burgers, T., Thomas, H., Gosselin, M., Else, B., and Papakyriakou, T. *Local influences on the rate of air-sea CO_2 exchange within Northern Baffin Bay and Nares Strait.*

- Delaforge, A., Campbell, K., Belzile, C., Gosselin, M., Ehn, J.K., Rysgaard, S., Barber, D., and Mundy, C.J. *Seasonal succession of under-ice phytoplankton in Cambridge Bay, Nunavut.*

- Diaz, A., Ehn, J., Papakyriakou, T., Campbell, K., Delaforge, A., Else, B., Landy, J., and Luque, S. *Interruption of spring-summer transition of landfast sea ice in Dease Strait, Nunavut, by late season snow storms.*

- Eastwood, R., Kuzyk, Z., Heath, J., Petrusevich, V., Ehn, J., Dmitrenko, I., Gueguen, C., and Barber, D. *Oceanographic conditions under the landfast sea ice in Southeast Hudson Bay.*

- Elliot, A., Mundy, C.J., Gosselin, M., Poulin, M., Campbell, K., and Wang, F. *Arctic sunscreens: production of mycosporine-like amino acids in sea ice covered Arctic waters.*

- Geilfus, N.-X., Galley, R., Crabeck, O., Papakyriakou, T., Landy, J., Tison, J.-L., and Rysgaard, S. *Inorganic carbon dynamics of melt pond covered first-year sea ice in the Canadian Arctic.*

- Hoshi, K., Ukita, J., Honda, M., Iwamoto, K., Ogi, M., and Nakamura, T. *Influence of Northern Hemisphere sea-ice extent on atmospheric circulation.*

- Kamula, M., Kuzyk, Z., Lobb, D. *Towards a sediment budget of Lake Melville, Labrador.*

- Pućko, M., Stern, G., Barber, D., Macdonald, R., Rysgaard, S., Jantunen, L., Bidleman, T., and Wong, F. *The delivery of organic contaminants to the Arctic food web: why sea ice matters.*

- Ritchie, J., Carrie, J., Burt, A., Foster, K., and Stern, G. *Analysis of polycyclic aromatic hydrocarbons in benthic invertebrates from Baffin Bay.*

- Stark, H., Iacozza, J., and Barber, D. *Identifying changes in the formation and dissolution of the North Water Polynya ice arch, 1979–2012: an index classification approach.*

- Wang, F., Barber, D., Rysgaard, S., and Papakyriakou, T. *Sea-ice Environmental Research Facility (SERF): Research Highlights (2012-2014).*

- Warner, K., Isleifson, D., and Barber, D.G. *Variability of C-band backscatter signatures of summer sea ice.*

- Xu, W. and Wang, F. *Distributions of chloride and bromide in snow, sea ice and seawater in the Arctic.*

- Zhang, R., Thomas, G., Mork, E.T., Luque, S.P., and Papakyriakour, T.N. *Spectral analysis of ship-based eddy covariance data.*

2014 American Geophysical Union (AGU) Fall Meeting, 15–19 December 2014, San Fransisco, California.

- Babb, D., Lukovich, J.V., Scharien, R., Galley, R.J., McCullough, G., Hochheim, K., and Barber, D.G. *Seasonal evolution of sea ice motion and atmospheric forcing in the Beaufort Sea.*

- Kuzyk, Z.Z.A., Gobeil, C., Goñi, M.A., and Macdonald, R.W. *Early diagenesis and trace element accumulation in North American Arctic margin sediments.*

7.2.3 Presentations

Below is a selection of oral presentations given by CEOS researchers during the reporting year:

- Attard, K.M., Glud, R.N., Hancke, K., McGinnis, D.F., Rovelli, L., Rysgaard, S. *Benthic primary production in temperate and arctic coastal marine ecosystems quantified using eddy correlation technique.* ASLO meeting, 22–27 February 2015, Granada, Spain.

- Barber, D.G. *Seven surprising results from the reduction of Arctic sea ice cover*, TEDx UManitoba, 21 January 2015.

- Bendtsen, J., Falkenberg, M., Mortensen, J., Pedersen, J.-O. P., Rysgaard, S. *Optimizing current fields, sea level and chlorophyll from regional modelling and remote sensing.* 18th Danish Marine Science meeting. 28–30 January 2015, GEUS, Copenhagen, Denmark.

- Curry, M. and J. Hanesiak, *Radar observations of lake breezes in southern Manitoba, Canada*, 16th Conference on Mountain Meteorology, 18-22 August 2014.

- Fargey, S., J. Hanesiak and R. Goodson, *An evaluation of vertical profiles using a limited area numerical weather prediction model over Baffin Island, Nunavut and surrounding area during autumn 2007*,16th Conference on Mountain Meteorology, 18–22 August 2014.

- Grimm, R., Notz, D., Rysgaard, S., Glud, R.N. *The role of the sea-ice carbon pump for the marine carbon budget.* Gordon Research Conferences, Polar Marine Science. 15–20 March 2015, Lucca, Italy.

- Hanesiak, J., *Year 2 of CCRN: Progress and Plans*, CCRN Annual General Meeting, Waterloo, ON, Oct. 19–22, 2014.

- Landry, David B., S. Brooke Milne, Robert W. Park, Douglas R. Stenton, and Mostafa Fayek. *3D LiDAR Scanning Technology and its Application in Arctic Archaeological Research: A Test Case from Inland Southern Baffin Island, NU.* Paper presented at the Canadian Archaeological Association Annual Meetings in London, ON. May 14–18, 2014.

- McAvoy, Deanna G., S. Brooke Milne, Robert W. Park, and Douglas R. Stenton. *The Missing Terrestrial Component: An Examination of Pre-Dorset Caribou Hunters from the Interior of Baffin Island, Nunavut.* Paper presented at the Annual Archaeological Society of Alberta Conference, Bodo, AB. May 9–11, 2014.

- McAvoy, Deanna G., S. Brooke Milne, Robert W. Park, and Douglas R. Stenton. *The Missing Terrestrial Component: An Examination of Pre-Dorset Caribou Hunters from the Interior of Baffin Island, Nunavut.* Paper presented at the Canadian Archaeological Association Annual Meetings in London, ON. May 14–18, 2014.

- Milne, S. Brooke, Robert, W. Park, Douglas R. Stenton, and Mostafa Fayek, and Rachel E. ten Bruggencate *Novice Flint Knapping, Seasonal Mobility, and Palaeo-Eskimo Lithic Raw Material Acquisition in the Interior of Southern Baffin Island, NU.* Paper presented at the Society for American Archaeology Annual Meetings in Austin, Texas. April 23–27, 2014.

- Oakes, J. *Winter Survival and Igloo Building Weekend Workshops* (Public lecture).

- Oakes, J. *Mittens, Mukluks and Annorak Weekend Workshops* (Public lecture).

- Park, R. W., S. Brooke Milne, Mostafa Fayek, Robert W. Park, Douglas R. Stenton, Rachel ten Bruggencate, and David B. Landry. *Chert Toolstone Availability in the Interior of Southern Baffin Island: New Insights from Two Recently Identified Source Locations.* Paper presented at the Canadian Archaeological Association Annual Meeting in London, ON. May 14–18, 2014.

- Rysgaard, S., *Arctic observing systems, data and observing infrastructure.* Trilateral EU–US–CANADA workshop on increased science collaboration in the Arctic. UiT The Arctic University, 21 January 2015, Tromsø, Norway. Invited.

- Rysgaard, S. *The Greenland Ice Sheet: Is it melting? What are the consequences?* Riddell faculty seminar series. 29 January 2015, University of Manitoba, Canada. Invited.

- ten Bruggencate, Rachel E., S. Brooke Milne, Mostafa Fayek, Robert W. Park, and Douglas R. Stenton *Characterizing Chert from Southern Baffin Island: Bulk vs. Microbeam Mass Spectrometry.* Paper presented at the Canadian Archaeological Association Annual Meeting in London, ON. May 14–18.

7.3 Edited Books and Book Chapters (B)

- Hanesiak, J., 2014. contributed a 700-word article about severe weather as related to agriculture for the Alberta Institute of Agrologists called "Moving toward Prairie Agriculture 2050" - Green paper presented at the Annual Conference of the Alberta Institute of Agrologists, Banff, AB, April 2, 2014, edited by B. Amiro, C. Rawluk and Karin Wittenberg. The article focused on historic and future changes in severe weather and surface contributions to severe weather pertaining to agriculture.

- Kuzyk, Z.A., Macdonald, R.W., Johannessen, S.C. (2015) "Calculating Rates and Dates and Interpreting Contaminant Profiles in Biomixed Sediments", in: Blais, J.M., Rosen, M.R., Smol, J.P. (Eds.), *Environmental contaminants: Using natural archives to track sources and long-term trends of pollution*. Springer, Dordrecht, p. 547.

- Outridge P.M. and Wang F. (2015) "The stability of metal profiles in freshwater and marine sediments". In: *Environmental Contaminants: Using Natural Archives to Track Sources and Long-term Trends of Pollution* (J.M. Blais, M.R. Rosen, and J.P. Smol, Eds). Springer. pp. 35-60.

A Detailed Budget By Account Code

Description	Code	Title	YTD Total Activity
Academic Salaries	61410	FT Dept Head	4,171.50
	63210	Research Associate	2,186.61
	63230	Other Academic	5,000.04
Support Salary	65706	AESES Support Casual	710.85
Student Wages	66200	FT Student Support	$1,671.90
Benefits	68000	Employment Insurance	$151.27
	68001	Canada Pension Plan	$232.01
	68010	Pension 1993	$855.42
	68020	Dental	$89.98
	68030	Spending Account	$86.36
	68040	GWL Supp. Health	$39.43
	68041	GWL Group Insurance	$22.47
	68042	Workers' Compensation	$42.92
	68050	GWL Disability Insurance	$153.40
	68070	Campus Development Initiative	$285.88
	68100	Basic AD&D	$0.22
Health and Education Levy	68500	Health & Education Levy	$286.06
		Subtotal:	**$15,986.32**
Travel	700702	Parking	$193.40
	706752	Meals for Staff Meetings	$476.77
	706756	Meals/Business Meetings	$161.19
	713001	Airfare - Domestic	$554.21
	713300	Meals/Receipts - Local	$410.57
		Subtotal:	**$1,796.14**
Materials, Supplies and Services	704001	Printing	$1,975.46
	706002	Toner & Ink	$114.33
	706003	Office Consumables	$1,438.45
	706007	Paper	$191.78
	706401	Safety Supplies	$130.07
	706704	Signs/Meters	$88.49
	706710	Other Materials & Supplies	$1,283.81
	706714	Barcode Labels	$25.82
	706753	Water, Coffee, Drinks, etc.	$1,331.65
	706901	Gasoline	$3,288.40
	708501	Telephone Line Rental	$7,868.33
	708502	Long Distance - IST Provided	$228.25
	708503	Cell Phone Rental	$736.88
	708508	Voice Mail	$1,407.40
	708515	Remove/Add Phones-IST Provided	$40.00
	708550	Postage	$66.63

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	710105	Workshop/Seminar/Conference Registration	$117.23
	710403	Other Services	$243.08
	710433	Freight - Outbound	$6.34
	710434	Freight - Inbound	$32.89
		Subtotal:	**$20,615.29**
Other Operational Expenses	710403	Other Services	$712.02
	710409	Computer Services	$915.56
	710431	Customs	$(20.74)
	710433	Freight - Outbound	$66.53
	710434	Freight - Inbound	$110.62
	710439	Audio Visual Rentals/Services	$12.50
	710446	Delivery Charges - Physical Plant	$130.84
	710506	Automobile	$15.00
		Subtotal:	**$1,942.33**
Utilities, Taxes and Insurance	710506	Automobile	$50.00
		Subtotal:	**$50.00**
Professional and Ext. Services	716003	Externally Contracted Services	$1,678.74
	716004	Shredding Services	38.62
		Subtotal:	**$1,717.36**
Capital Asset	730051	Construction Cost - Bldgs & Major Reno.	$3,604.84
	730052	Professional Fees - Bldgs & Major Reno.	$219.71
		Subtotal:	**$3,824.55**
Repairs and Maintenance	740002	R & M - Vehicles	$981.37
	740101	R & M - Buildings	$100.00
		Subtotal:	**$1,081.37**
		Total Salary Revenue Less Expenditures:	**($15,986.14)**
		Total Non-Salary Revenue Less Expenditures:	**($29,084.71)**
Total Non-Salary Revenue			$44,881.00
		Total Revenues Less Expense:	**($-189.85)**