

Centre for Earth Observation Science Annual Report

2015–2016

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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, 2015 to March 31, 2016. 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).

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 8 undergraduate students, 32 Master's students and 18 Ph.D. students, along with 22 Post-doctoral Fellows/Research Associates. An inventory of HQP is provided in the following sections. Eight graduate students completed their studies during the reporting period.

CEOS remains a productive research unit. In the reporting year, faculty had published 45 papers in top journals, and secured \$6.3M in research support. We actively form partnerships and these result in research opportunities for graduate students, post-doctoral fellows, and undergraduate student assistants. Networking is accomplished through our use of Adjunct Professor appointments, and numerous 'external' members to CEOS.

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 highly 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:

- 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);
- Develop research programs associated with new CRC Tier I in Arctic Environmental Chemistry (Wang);
- 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;
- 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);
- Continued operation of the Sea-ice Environmental Research Facility (SERF) for research into sea-ice.

In 2017, CEOS faculty will participate in BaySys field programs, in addition to ArcticNet and ASP field experiments. Core faculty will continue the development of the Churchill Marine Observatory. The group will take advantage of funding opportunities made available by funding agencies. Already we have secured a large grant through Genome Canada, and are developing proposals to continue a high level of activity, and maintain our position as a world-leading research centre. 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.

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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. Principal Tri-Council sources include programs within NSERC, NCE, CRC, CERC, and CFI. Grants support an additional 18 support staff, five nil-salary research professors, 16 research associates, and six post-doctoral fellows. Our graduate student cohort was 50 (combined Master's and Doctoral) 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, Associate 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, Senior Instructor, Department of Environment & Geography
- Zou Zou Kuzyk, Assistant Professor, Department of Geological Sciences
- Brooke Milne, Associate Professor, Department of Anthropology
- Christopher-John Mundy, Associate 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

- David Babb
- Lucette Barber
- Alexis Burt
- Lauren Candlish
- Ashley Gaden
- Nicolas-Xavier Geilfus
- Joel Heath
- Michelle Kamula
- Sergei Kirillov
- Marcos Lemes
- Zhuo (George) Liu
- Jennifer Lukovich
- Greg McCullough
- Nathalie Thériault
- Emmelia Wiley
- Cornelia Willing

2.3 Support Staff

- Debbie Armstrong, UCTEL Technician
- David Binne, SERF Technician
- Wayne Chan, Research Computer Analyst
- Michelle Clyde, Schools on Board Coordinator
- Linda Chow, Office Assistant
- Claire Hornby, BaySys Coordinator
- Ashley Elliott, Technician
- Justine Hudson, Student Technician
- Shiva Laskari, Technician
- Sebastian Luque, Technician
- Claire Reis, Lake Winnipeg Basin Portal Coordinator
- Jake Ritchie, Technician
- Aggie Roberecki, Administrative Assistant
- Cris Seaton, Technician
- Eva Slaicek, Technician
- Ashley Soloway, Technician
- Heather Stark, CMO Coordinator
- Denise Whynot, Office Assistant

2.4 Graduate Students

Fifty graduate students were supported (financially and/or logistically) over the reporting period. There were 18 doctoral students and 32 master's students.

2.4.1 Doctoral

- Atreya Basu (Environment & Geography; Advisors: Jens Ehn and Simon Bélanger (UQAR))
- Tonya Burgers (Environment & Geography; Advisor: Tim Papakyriakou)
- Wieter Boone (Environment & Geography; Advisors: Søren Rysgaard and Igor Dmitrenko)
- Karley Campbell (Environment & Geography; Advisors: Søren Rysgaard and C.J. Mundy)
- Emily Choy (Environment & Geography; Advisor: Lisa Loseto)
- Odile Crabeck (Geological Sciences; Advisor: Søren Rysgaard)
- Aurelie Delaforge (Environment & Geography; Advisor: C.J. Mundy)
- Nariman Firoozy (Electrical & Computer Engineering; Advisors: David Barber and Puyan Mojabi)
- Reza Gholami (Electrical & Computer Engineering; Advisors: David Barber and Vladimir Okhmatovski)
- Shabnam Jafarikhasragh (Environment & Geography; Advisor: David Barber)
- Satwant Kaur (Environment & Geography; Advisors: David Barber and Jens Ehn)
- David Landry (Anthropology; Advisor: Brooke Milne)
- Jack Landy (Environment & Geography; Advisor: David Barber)
- Lisa Matthes (Environment & Geography; Advisors: C.J. Mundy and Jens Ehn)
- Cory Matthews (Environment & Geography; Advisor: Steve Ferguson)
- Vlad Petrusevich (Environment & Geography; Advisors: Igor Dmitrenko and Jens Ehn)
- Kang Wang (Environment & Geography; Advisor: Feiyue Wang)
- Kristin Westdal (Environment & Geography; Advisor: Steve Ferguson)

2.4.2 Master's

- Jonathan Andrews (Environment & Geography; Advisor: David Barber)
- Wilhelmina Armah (Environment & Geography; Advisor: Zou Zou Kuzyk)
- Neal Bailey (Environment & Geography; Advisor: Feiyue Wang)
- Oksana Baniyas (Environment & Geography; Advisor: David Barber)
- Jasmine Brewster (Environment & Geography; Advisor: Lisa Loseto)
- Yanique Campbell (Environment & Geography; Advisor: David Barber)
- Laura Dalman (Environment & Geography; Advisors: C.J. Mundy and David Barber)
- Ellyn Davidson (Environment & Geography; Advisor: Steve Ferguson)
- Cassandra Debets (Environment & Geography; Advisor: Steve Ferguson)
- Durell Desmond (Environment & Geography; Advisors: Gary Stern and David Barber)
- Aura Diaz (Environment & Geography; Advisor: Jens Ehn and Tim Papakyriakou)
- Rosemary (Annie) Eastwood (Environment & Geography; Advisor: Zou Zou Kuzyk)
- Samantha Huyghe (Geological Sciences; Advisor: Zou Zou Kuzyk)
- Michelle Kamula (Environment & Geography; Advisor: Zou Zou Kuzyk)
- Zakhar Kazmiruk (Environment & Geography; Advisors: Zou Zou Kuzyk and Tim Papakyriakou)
- Scott Kehler (Environment & Geography; Advisor: John Hanesiak)
- Krista Kenyon (Environment & Geography; Advisors: David Barber and Steve Ferguson)
- David Kushner (Geological Sciences; Advisor: Feiyue Wang)
- Heather Kyle (Geological Sciences; Advisor: Søren Rysgaard)
- Kathleen MacMillan (Environment & Geography; Advisor: Lisa Loseto)
- Thomas Neusitzer (Electrical & Computer Engineering; Advisors: David Barber and Puyan Mojabi)

- Nicole Pogorzelec (Environment & Geography; Advisor: C.J. Mundy)
- Christine Quiring (Environment & Geography; Advisors: Jens Ehn and C.J. Mundy)
- Kevin Scharffenberg (Environment & Geography; Advisor: Lisa Loseto)
- James Singer (Environment & Geography; Advisor: Feiyue Wang)
- Tassia Stainton (Geological Sciences; Advisor: Zou Zou Kuzyk)
- Heather Stark (Environment & Geography; Advisor: David Barber)
- Randi Thomas (Environment & Geography; Advisor: Jill Oakes)
- Tyler Tiede (Electrical & Computer Engineering; Advisors: David Barber and Puyan Mojabi)
- Elizabeth Worden (Environment & Geography; Advisors: Lisa Loseto and Jill Oakes)
- Rui Zhang (Electrical & Computer Engineering; Advisors: Tim Papakyriakou and Gabriel Thomas)
- Kyle Ziokowski (Environment & Geography; Advisor: John Hanesiak)

2.5 Graduates

Eight CEOS students graduated during the 2015–16 reporting period:

- Dyck, Robin. (M.Sc.)(May 2015) *Boundary Layer Variations and Convective Regimes during UNSTABLE, 2008*. Advisor: John Hanesiak.
- Hornby, Claire. (M.Sc.)(February 2016) *Seasonal movement and habitat use of beluga whales in the Canadian Beaufort Sea*. Advisors: Lisa Loseto/David Barber.
- Inkster, Colton. (M.A.)(May 2015) *Skateboarding and the changing city: lessons from the public spaces of Reykjavik*. Advisor: Jill Oakes.
- Kamula, Michelle. (M.Sc.)(February 2016) *The sediment and particulate organic carbon cycle of Lake Melville, Labrador: a fjord estuary undergoing hydrologic and climatic change*. Advisors: Zou Zou Kuzyk/Gary Stern.
- McPhail, Katherine. (M.A.)(October 2015) *Power, knowledge, and Nanook; the relationships between colonialism and representation portrayed in Nanook of the North*. Advisor: Jill Oakes.
- Shields, Megan. (M.Sc.)(October 2015) *Polarimetric C-band microwave scattering from winter first-year sea ice ridges*. Advisor: David Barber.

- Stammers, Chris. (M.Sc.)(February 2016) *Observations of wintertime air-sea heat exchange within polynya and lead environments of Amundsen Gulf and the South-eastern Beaufort Sea*. Advisors: Tim Papakyriakou/David Barber
- Xu, Wen. (M.Sc.)(October 2015) *Distribution of chloride and bromide across the snow-sea ice-seawater interface in natural and mesocosm environments and its implication for halogen activation in polar regions*. Advisor: Feiyue Wang.

2.6 Post-doctoral Fellows

- Virginie Galindo
- Carie Hoover
- Yubin Hu
- Kathleen Munson
- Corinne Pomerleau
- Thomas Richerol

2.7 Adjuncts and 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 Prinsenber, 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

Eight summer students assisted various faculty members as research assistants or technicians in 2015–16 (see Table 1).

Name	Supervisor
Samantha Cortes	Ehn
Michael Frost	Galley
Larissa Gospodyn	Barber
Alessia Guzzi	Barber
Samantha Huyghe	Kuzyk
Ainsleigh Loria	Stern
Nicole Pogorzelec	Mundy
Nicholaus Zilinski	Galley

Table 1: CEOS summer students for 2015–16.

3 Activities and Research Projects

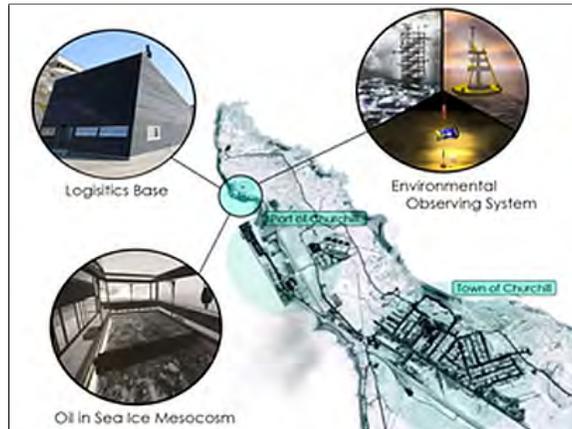
Selected ongoing research projects are highlighted here. A full list of CEOS projects can be found at: <http://umanitoba.ca/faculties/environment/departments/ceos/research/projects.html>.

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.

Additional information on CMO is available at: <http://umanitoba.ca/ceos/research/CMO.html>.

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 Hydroelectric 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, Calgary, Laval, and Trent, to conduct research on Hudson Bay. The overarching goal of the program 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-programs within BaySys will examine:

1. Historical variability and trends, and predicting 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 modelling 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.

Additional information on BaySys is available at <http://umanitoba.ca/faculties/environment/departments/ceos/research/1316.html>.

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: Lauren Candlish.
- 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. In 2016, the partnership was expanded to include the University of Tromsø in Norway. 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?

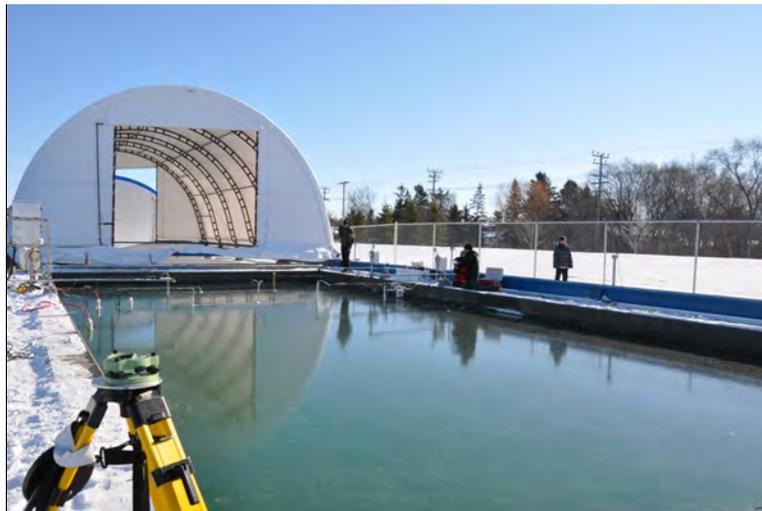
Søren Rysgaard is heading this large-scale, international research initiative, together with Dr. David Barber, University of Manitoba, and Drs. Josephine Nyman, Greenland Institute of Natural Resources; Malene Simon, Greenland Climate Research Centre; Ronnie Nøhr Glud, University of Southern Denmark; 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 2015 ASP Annual Meeting was held December 5–6 in Vancouver, BC. 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 carried out in 2015–16

The 2016 campaign at SERF began in early January, 2016. Experiments were conducted in the following areas:

Sea Ice Geophysics:

- February 10, 2016 to February 29, 2016: Measurement of sea ice physical properties using Multilevel Transmission Lines and Ground Penetrating Radar (GPR) (Elena Pettinelli/David Barber).
- February 14, 2016 to February 28, 2016: Measurement of bidirectional reflectance distribution function of sea ice using a Gonio-Radiometric Spectrometer System (GRASS) (Maxim Lamare/Martin King).

Sea Ice and Snow Geochemistry:

- January 11, 2016 to February 10, 2016: Carbonate system (DIC, TA, pH) and phosphate evolution during sea ice growth and decay (Yubin Hu/Fei Wang/Søren Rysgaard).
- February 10, 2016 to February 27, 2016: In situ, continuous measurement of CO₂ and pH in the near-surface water (Stan Beaubien/Tim Papakyriakou/Fei Wang).
- January 18, 2016 to February 29, 2016: Mercury transport in sea ice (Kathleen Munson/Fei Wang).

Oil-in-Sea-Ice Studies (carried out in a mesocosm pool separated from the SERF pool):

- December 10, 2015 to April 15, 2016: Chemical characteristics of oil migration in, under and through sea ice (Gary Stern/Monika Pućko/David Barber).
- January 13, 2016 to February 15, 2016: Characterisation of thermodynamic and dielectric properties of oil-contaminated sea ice through scatterometer and LiDAR measurements (David Barber/Puyan Mojabi).

3.6 Plains Elevated Convection at Night (PECAN)

The Plains Elevated Convection at Night (PECAN) project was designed to improve the understanding of thunderstorms at night over the continental United States. Fourteen universities and eight research laboratories participated in the campaign, which was conducted in Oklahoma, Kansas, and Nebraska from June 1 to July 15, 2015. It is jointly funded by NSF, NOAA, NASA, and DOE.

PECAN has four major objectives:

1. To advance the explanation of environmental characteristics and processes leading to nocturnal convection initiation and the early phases of large-scale storm clusters.
2. To increase our understanding of the internal structure and microphysics of large-scale nocturnal storm clusters.
3. To further knowledge of wave-like disturbances caused by convective storms.
4. To improve prediction of nocturnal convection, which will aid in improving operational forecasting and climate models.

Dr. John Hanesiak, along with two CEOS graduate students (Scott Kehler and Kyle Ziolkowski) participated in the six week field project. The students will be doing their master's projects using the field data collected.



Scott Kehler (left) and Kyle Ziolkowski (right) launching a weather balloon during PECAN.

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.

With three moorings collecting in situ data (chlorophyll A, phycocyanin, turbidity, temperature, and pressure) in combination with regularly scheduled water sampling, CEOS and the University of Manitoba are able to:

- Take a leadership role in monitoring the health of Manitoba's freshwater through nutrient and contaminant testing.
- Evaluate the anthropogenic impact on Manitoba's freshwater ecosystem.
- Develop an understanding of how nutrients and contaminants move throughout the freshwater ecosystem.

This information can be used by government, industry and other stakeholders to improve the health of Manitoba's freshwater, ensuring the stability of the clean water Manitoba's Great Lakes provide, and the economic and social infrastructure that have been built upon it.

- 2012: Moorings and research focused on Lakes Manitoba and Winnipegosis.
- 2013: Moorings and research focused on Lakes Manitoba and Waterhen.

- 2014: Moorings planned for Lakes Manitoba, Winnipegosis, and Waterhen, as well as the start of new research on Lake Winnipeg.
- 2016: Three moorings deployed — Lakes Manitoba, Winnipegosis and Waterhen. Graduate project by Claire Herbert with supervisor Dr. David Barber started. Began community-based monitoring initiative in conjunction with the Lake Winnipeg Foundation.

16 stations from Lake Manitoba, 10 from Lake Winnipegosis and 3 from Lake Waterhen were collected and analyzed for:

- Phosphorous - suspended and particulate
- Nitrogen - particulate and dissolved
- Carbon - inorganic and dissolved
- Chlorophyll and phaeophytin
- Total suspended solids (TSS)
- Suspended organic matter (LOI)
- Conductivity
- pH
- N fixation

Samples for algal and zooplankton identification and algal toxin analysis were also preserved.

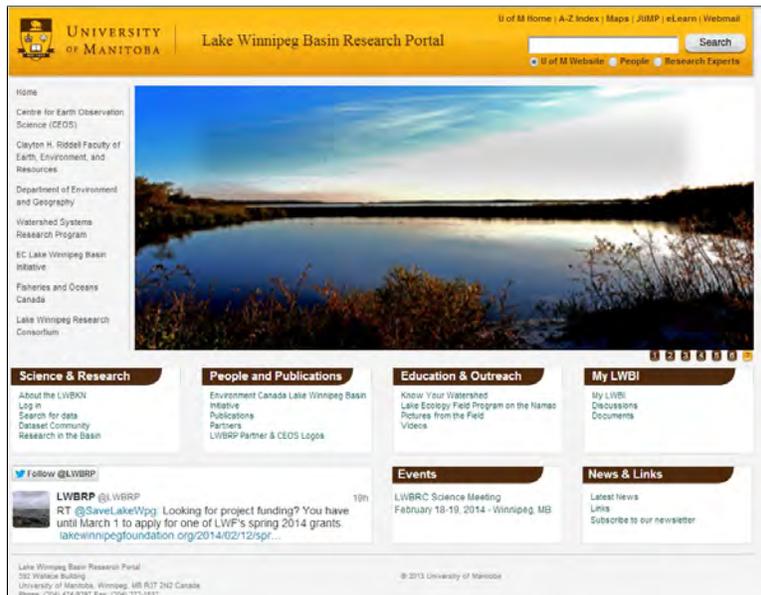
Reference: McCullough, G.K., S.J. Page, R.H. Hesslein, M.P. Stainton, H.J. Kling, A. Salki, and D.G. Barber. (2012) Hydrological forcing of a recent trophic surge in Lake Winnipeg. *J. of Great Lakes Research*, 38: 95–105.

3.8 Lake Winnipeg Basin Information Network

Coordinator: Claire Herbert

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 2015–2016, the LWBIN became the data storage portal for Arctic research at CEOS. The portal was rebranded as the Canadian Watershed Information Network and a new website was developed. The website will go live mid-February 2017. A developer was hired to increase the capacity of the data portal site, and the new site will be rolled out at the

same time in February. A GitLab instance and document version server were also installed within the CANWIN infrastructure to allow students and researchers to securely store their working data, code and documents.

3.9 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.

3.9.1 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).

3.9.2 2015–2016 Experiments

In July 2015, Dr. Brooke Milne, Dr. Rachel ten Bruggencate, David Landry, and Mulu Serzu (Geological Sciences, U of M) travelled to the LbDt-1 site on the banks of the Hone River on Southern Baffin Island and spent two days there conducting field research. Milne and ten Bruggencate focused on the collection of geological samples of raw chert toolstone and the mapping of the surrounding outcrops. A systematic foot survey was also conducted through the whole site area to search for surface artifacts that may give insight into the area’s occupational history. No artifacts were found, however.

Landry and Serzu focused on the geophysical and remote sensing aspects of the research and established three survey grids at the site. Two profile lines were also established to connect Grids 1 and 3. All grids were located in the site’s upper component in order to include the large surface scatters of chert debitage and debris found during the team’s first visit in 2013.

A 3D survey using a 400-MHz ground penetrating radar (GPR) system was done over each grid and along the profile lines connecting them.

To verify the geophysical data, Milne excavated three 25 x 25 cm test pits: one in Grid 2, one in Grid 3, and one at the intersection of the two profile lines. The thickness of the chert debris was noticeably greater compared to the two other test units, and surprisingly,

the sterile layer below each chert scatter consisted of fine grain soil instead of gravel or bedrock.

Several high-density LiDAR scans were conducted with a Leica ScanStation C10 system. Each scan provides a point cloud dataset, including a 360° digital image, intensity data, and RGB information. In addition, a vertical and horizontal survey was conducted on Grid 1 using an EM400 Profiler. Both vertical and horizontal modes mapped the in-phase magnetic response in the near-surface and the quadrature conductivity response at three different frequencies (1000-MHz, 4000-MHz, 16000-MHz).

The information collected during the two days in the field will enable the researchers to continue with their chert characterization work through continued testing of raw samples collected at LbDt-1. The mapping of the outcrops will help to determine if they belong to the Amadjuak or Boas formations, and the geophysical and LiDAR data are being used to develop a non-invasive research methodology to study large, complex quarry sites, such as LbDt-1. The success of this work will provide researchers with a means to map and quantify debris scatters to access site-use intensity spatially and temporally. The geophysical results were presented at the 2015 ArcticNet meeting in Vancouver, BC.

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. In addition, CEOS hosted a variety of workshops and school group visits during the reporting year.

4.1 Schools on Board

Coordinator: Michelle Clyde

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 ArcticNet's 2015 science expedition in the community of Resolute, NT and travelled to Pond Inlet, NU.

Schools represented in the 2015 field program include:

- Sir John Franklin High School - Yellowknife, NT
- Diamond Jenness Secondary School - Hay River, NT
- Nasivvik High School - Pond Inlet, NU
- Carihi High School - Campbell River, BC
- Collège Jeanne-Sauvé – Winnipeg, MB
- Gimli High School - Gimli, MB
- Canterbury High School - Ottawa, ON
- Delphi Secondary School - Toronto, ON
- Collège Jean de Brébeuf - Montreal, QC
- Collège Saint Charles Garnier - Quebec, QC

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



Students at Arctic Science Day 2016.

Arctic Science Day at FortWhyte Alive – March 2016. 144 middle years and senior years students attending the 2016 Arctic Science Day held at FortWhyte Alive on March 4, 2016. CEOS graduate students and scientists created a number of stations that

included hands-on activities and demonstrations. These stations included: snow pits and snow samples, ice cores, contaminants, Arctic ecosystem science, weather monitoring, and remote sensing.

4.2 ASP Field Course 2016, Nuuk, Greenland

From February 10–20, 2016, national and international graduate students, including students from the University of Manitoba, Aarhus University and other institutions converged on Nuuk to learn about various aspects of snow-covered sea ice. The multidisciplinary nature of the students not only enhanced the academic learning, but also led to interactions with students 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. The field course was organized by Dr. Nicolas-Xavier Geilfus (Aarhus University) and Karley Campbell (UM/CEOS), and the instructor was Dr. C.J. Mundy (UM/CEOS).

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 articles about CEOS research that occurred during the reporting period.

- “Driving discovery and insight: Ice and Oil”, *UM Today Magazine*, Fall 2015.
- “Prof leads Atlantic Ocean research expedition”, *UM Today News*, April 13, 2015.
- “CANDID: Q & A with grad student Krista Kenyon”, *UM Today News*, April 13, 2015.

- “Connecting with the North: Learning alongside top researchers in the Arctic”, *UM Today News*, April 21, 2015.
- “\$13 million in new funding supporting research projects vital to Manitoba”, *UM Today News*, May 7, 2015.
- “Genes, isotopes and oil spills top list for research funding boost”, *Globe and Mail*, May 29, 2015.
- “Arctic experience: Exploring the science behind climate change”, *UM Today News*, June 5, 2015.
- “From the field: Stories from the high Arctic”, *UM Today News*, June 22, 2015.
- “New research facility to open in Churchill”, *UM Today News*, July 6, 2015.
- “Northern Manitoba to get \$31-million marine observatory”, *Global News*, July 7, 2015.
- “Oceanographers Board a Fleet of Icebreakers to Study Mercury Pollution in the Arctic Ocean”, *Huffington Post*, August 3, 2015.
- “Live blog: Mercury in the Arctic Ocean”, *ResearchGate*, August 10, 2015.
- Bengsch, Danielle. “Update CCGS Amundsen: Bon voyage GEOTRACES!”, *ResearchGate*, August 20, 2015.
- Bengsch, Danielle. “Surprise visitors for the Canadian team”, *ResearchGate*, October 19, 2015.
- “ArcticNet publishes regional impact study for the Western and Central Canadian Arctic”, *UM Today News*, October 27, 2015.
- “In search of multi-year sea ice”, *UM Today News*, November 19, 2015.

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 (2015–2016)
Wang	301866-NSERC RGPIN 238408-2011 Wang	\$55,000.00
Barber	301912-CRC NSERC 950-206242 Sal Barber	\$47,000.00
Barber	301913-CRC NSERC 950-206242 Res Barber	\$157,300.00
Barber	302306-NSERC RGPIN 155265-09 BARBER	\$70,000.00
Barber	302826-ENV CDA/CDN ICE SERV/CICE	\$1,199.57
Hanesiak	308698-CFI-IOF 6901 (16-5) Hanesiak J.	\$14,743.13
Barber	310673-CFI - IOF 11393 Dr.Barber w Laval	\$29,733.02
Ferguson	310768-Indian Northern Affairs/IPY/Ferguson	\$3,265.00
Wang	311347-CFI-IOF 16549 Wang F	\$9,767.26
Rysgaard	312888-CERC NSERC Sal 214902 Rysgaard	\$265,000.00
Rysgaard	312890-CERC NSERC Res 214902 Rysgaard	\$1,135,000.00
Ferguson	313088-ANet Laval Ferguson Training C Watt	\$2,360.00
Barber	313785-INAC/1112-05-000199 /Barber	\$101,207.71
Barber	313874-NSERC PROSC 419490-2011/Barber	\$21,005.30
Hanesiak	314011-NSERC RGPIN 249561-12 Hanesiak	\$27,000.00
Papakyriakou	314038-NSERC RGPIN 227538-12 Papakyriakou	\$32,000.00
Papakyriakou	314052-NSERC RGPNS 331277-12 Papakyriakou	\$15,000.00
Hanesiak	314118-CFI IOF 26257 Hanesiak	\$56,039.88
Barber	314171-Anet Laval Barber IRIS3 Workshop	\$9,993.86
Barber	314872-Environment Canada 1205393/Barber	\$35,000.00
Wang	314947-UBC/RGPCC433848-12/Wang	\$49,100.53
Ehn	315105-NSERC RGPIN/435373-13 Ehn	\$28,000.00
Mundy	315116-NSERC RGPIN/418397-13 Mundy	\$27,000.00
Ehn	315131-NSERC RGPNS/444872-13 Ehn	\$17,500.00
Mundy	315132-NSERC RGPNS/424231-13 Mundy	\$15,000.00
Stern	315492-ANet Laval GS 2013 Shiptime Request	\$1,150.55
Michel	315710-NSERC RGPIN 327416-13/Michel	\$21,600.00
Stern	315948-AANDC/1112-05-000199/2013-14/Stern	\$44,712.00
Barber	316243-EC/MSC/Barber	\$1,532.29
Mundy	316268-CFI IOF Mundy	\$9,764.93
Barber	316287-Transport Canada/Barber	\$1,245.04
Rysgaard	316295-CFI IOF 30191 Rysgaard	\$65,941.76
Dmitrenko	316354-NSERC RGPIN 03606-14 Dmitrenko	\$37,000.00
Michel	316422-ANet CM Field Aircraft Support	\$18,317.00
Kuzyk	316430-NSERC EQPEQ 458531-14 Kuzyk	\$64,323.36
Stern	316564-NSERC RGPIN 06319-14 Stern	\$43,000.00
Barber	316802-Transport Canada/161108/Barber	\$235,750.00
Galley	317492-NSERC RGPIN 03842-15 Galley	\$20,000.00

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Papakyriakou	317524-ANet TP Marine Geochemistry 2018	\$78,000.00
Barber	317525-ANet DB Sea-Ice 2018	\$83,806.00
Rysgaard	317526-ANet SR Sea-Ice Exchanges 2018	\$35,000.00
Barber	317528-NSERC RGPIN 04950-15 Barber	\$41,000.00
Pučko	317538-NSERC RGPIN 05480-15 Pucko	\$24,000.00
Kuzyk	317540-ANet Kuzyk 3.6 Hudson Bay	\$87,071.00
Loseto	317544-ANet Loseto Knowledge Co-Production	\$70,728.00
Barber	317545-NSERC RGPNS 305426-15 Barber	\$20,000.00
Dmitrenko	317555-NSERC EQPEQ 472340-15 Dmitrenko	\$123,825.00
Barber	317559-CFI MSI 33108 Barber	\$302,593.00
Stern	317568-ANet Stern Marine Contaminants	\$92,403.00
Kuzyk	317569-MEOPAR Kuzyk OA-ZK-UM	\$58,000.00
Wang	317572-ANet Wang Marine Contaminants	\$36,750.00
Ferguson	317588-ANet SF Marine Mammals 2018	\$77,939.00
Stern	317598-ANet GS Training Fund Burt	\$1,854.00
Stern	317599-ANet GS IRIS-1 Coordinator	\$70,000.00
Barber	317602-ANet DB IRIS - 3 Coordinator	\$70,000.00
Barber	317663-ANet DB Training Fund Gunn etal	\$3,840.00
Kuzyk	317680-CFI IOF 32668 Kuzyk	\$24,000.00
Barber	317696-NSERC CRDPJ 470028-14 Barber	\$1,912,333.00
Ehn	317738-ANet Ehn 3.6 Hudson Bay	\$18,000.00
Pučko	317741-ANet Pucko Marine Contaminants	\$2,500.00
Dmitrenko	317800-NSER - GRF VPRIO 2015-16 Dmitrenko	\$6,175.00
Barber	317828-ANet DB Statoil 2015-2016	\$105,764.00
Mundy	317888-NSERC 470028-14 sub317696 Mundy	\$17,667.00
Kuzyk	317896-ANet Kuzyk 1.4 Oil Biodegradation	\$11,600.00
Papakyriakou	317897-ANet TP Training Fund Luque	\$1,440.00
Barber	317977-ANet DB Statoil Equipment 2015-2016	\$43,665.00
Loseto	318155-NSTP 2015-16/Loseto/Brewster	\$2,725.00
Papakyriakou	318156-NSTP 2015-16/Papakyriakou/Burgers	\$2,636.00
Mundy	318157-NSTP 2015-16/Mundy/Campbell	\$2,710.00
Ehn	318158-NSTP 2015-16/Ehn/Diaz	\$2,640.00
Kuzyk	318159-NSTP 2015-16/Kuzyk/Eastwood	\$2,590.00
Barber	318162-NSTP 2015-16/Barber/Kenyon	\$2,725.00
Rysgaard	318163-NSTP 2015-16/Rysgaard/Kyle	\$2,510.00
Oakes	318166-NSTP 2015-16/Oakes/Thomas	\$2,730.00
Mundy	318167-NSTP 2015-16/Mundy/Quiring	\$2,660.00
Barber	318182-ANet DB Training Fund Theriault	\$1,474.00
Barber	318183-ANet DB Beaufort Deployment 2015-16	\$56,720.00
Mundy	318228-MEOPAR Mundy ISI-CJ-MAN	\$12,000.00
Barber	318414-ANet DB Training Fund Dalman	\$2,925.00
Wang	318415-ANet Wang Training Fund Singer	\$2,700.00
Ferguson	318417-ANet SF Training Fund Davidson	\$2,045.00
Stern	318437-ANet GS Training Fund Desmond	\$3,300.00
Ferguson	318440-ANet SF Training Fund Debets	\$2,045.00
Ehn	318448-ANet Ehn Training Fund Fenton	\$2,925.00
Continued on next page		

Ehn	318449-ANet Ehn Training Fund Matthes	\$2,925.00
Kuzyk	318631-ANet Kuzyk Training Fund Kazmiruk	\$1,316.00
	Total:	\$6,322,806.19

Table 2: Research grants obtained or held during 2015–2016 reporting period.

6.2 Northern Scientific Training Program (NSTP)

Table 3 shows all CEOS students who received NSTP funding in 2015–2016.

Student	Supervisor	Amount
Tonya Burgers	Papakyriakou	\$2,636.00
Jasmine Brewster	Loseto	\$2,725.00
Karley Campbell	Mundy	\$2,710.00
Aura Diaz	Ehn	\$2,640.00
Annie Eastwood	Kuzyk	\$2,590.00
Krista Kenyon	Barber	\$2,725.00
Heather Kyle	Rysgaard	\$2,510.00
Christine Quiring	Mundy	\$2,660.00
Randi Thomas	Oakes	\$2,730.00
	Total:	\$23,926.00

Table 3: Students receiving NSTP funding for 2015–2016.

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.

Item	General Classification	YTD Total	%
1	Total Wages & Benefits	\$6,626.50	31.29
2	Travel	\$2,198.28	10.38
4	Materials, Supplies and Services	\$12,004.62	56.68
5	Professional and External Services	\$19.31	0.09
6	Repairs and Maintenance	\$329.76	1.56
	Total:	\$21,178.47	100.0

Table 4: Summary of annual operating budget.

7 Academic Contributions

CEOS researchers published 45 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 past annual reports.

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, 2015 – March 31, 2016. A full list of articles from the last five calendar years can be found on the CEOS website: www.umanitoba.ca/ceos.

- [1] Babb, D. G., Galley, R. J., Barber, D. G., & Rysgaard, S. (2015). Physical processes contributing to an ice free Beaufort Sea during September 2012. *Journal of Geophysical Research: Oceans*, 120. doi: 10.1002/2015JC010756.
- [2] Barber, D. G., Hop, H., Mundy, C. J., Else, B. G. T., Dmitrenko, I. A., Tremblay, J.-E., Ehn, J. K., Assmy, P., Candlish, L., & Rysgaard, S. (2015). Selected physical, biological and biogeochemical implications of a rapidly changing Arctic Marginal Ice Zone. *Progress in Oceanography*. doi: 10.1016/j.pocean.2015.09.003.
- [3] Bendtsen, J., Mortensen, J., & Rysgaard, S. (2015). Modelling subglacial discharge and its influence on ocean heat transport in arctic fjords. *Ocean Dynamics*. doi: 10.1007/s10236-015-0883-1.
- [4] Bendtsen, J. , Mortensen, K., Lennert, K., & Rysgaard, S. (2015). Heat sources for glacial ice melt in a west Greenland tidewater outlet glacier fjord: The role of subglacial freshwater discharge. *Geophysical Research Letters*, 42. doi: 10.1002/2015GL063846.
- [5] Brown, T. A., Belt, S. T., Gosselin, M., Levasseur, M., Poulin, M., & Mundy, C. J. (2016). Quantitative estimates of sinking sea ice particulate organic carbon based on the biomarker IP25. *Marine Ecology Progress Series*. doi: 10.3354/meps11668, Online publication date: March 21, 2016.
- [6] Crabeck, O., Galley, R. J., Delille, B., Else, B. G. T., Geilfus, N.-X., Lemes, M., Des Roches, M., Francus, P., Tison, J.-L., & Rysgaard, S. (2015). Imaging air volume fraction in sea ice using non-destructive X-ray tomography. *Cryosphere Discussions*, 9, 5203-5251.
- [7] Dmitrenko, I. A., Rudels, B., Kirillov, S. A., Aksenov, Y. O., Lien, V. S., Ivanov, V. V., Schauer, U., Polyakov, I. V., Coward, A. & Barber, D. G. (2015). Atlantic Water

flow into the Arctic Ocean through the St. Anna Trough in the northern Kara Sea. *Journal of Geophysical Research: Oceans*. doi: 10.1002/2015JC010804.

- [8] Elliott, A., Mundy, C. J., Gosselin, M., Poulin, M., Campbell, K., & Wang, F. (2015). Spring production of mycosporine-like amino acids and other UV-absorbing compounds in sea ice associated algae communities in the Canadian Arctic. *Marine Ecology Progress Series*, 541, 91–104. doi: 10.3354/meps11540.
- [9] Else, B. G. T., Rysgaard, S., Attard, K. M., Campbell, K., Crabeck, O., Galley, R. J., Geilfus, N.-X., Lemes, M., Lueck, R., Papakyriakou, T., & Wang, F. (2015). Under-ice eddy covariance flux measurements of heat, salt, momentum, and dissolved oxygen in an artificial sea ice pool. *Cold Regions Science and Technology*, 119, 158-169.
- [10] Firoozy, N., Komarov, A. S., Mojabi, P., Barber, D. G., Landy, J. C., & Scharien, R. K. (2015). Retrieval of young snow-covered sea-ice temperature and salinity evolution through radar cross-section inversion. *IEEE Journal of Oceanic Engineering*. doi: 10.1109/JOE.2015.2458212.
- [11] Galindo, V., Levasseur, M., Mundy, C. J., Gosselin, M., Scarratt, M. G., Papakyriakou, T. N., Stefels, J., Gale, M. A., Tremblay, J.-T., & Lizotte, M. (2016). Contrasted sensitivity of DMSP production to high light exposure in two Arctic under-ice blooms. *Journal of Experimental Marine Biology and Ecology*, 475, 38-48. doi: 10.1016/j.jembe.2015.11.009.
- [12] Galley, R. J., Babb, D. G., Ogi, M., Else, B. G. T., Geilfus, N.-X., Crabeck, O., Barber, D. G., & Rysgaard, S. (2016). Replacement of multiyear sea ice and changes in the open water season duration in the Beaufort Sea since 2004. *Journal of Geophysical Research: Oceans*. doi: 10.1002/2015JC011583, Online publication date: 19 March 2016.
- [13] Glud, R. N., Grossart, H.-P., Larsen, M., Tang, K. W., Arendt, K. E., Rysgaard, S., Thamdrup, B., & Nielsen, T. G. (2015). Copepod carcasses as microbial hot spots for pelagic denitrification. *Limnology and Oceanography*. doi: 10.1002/lno.10149.
- [14] Hanis, K. L., Amiro, B. D., Tenuta, M., Papakyriakou, T. N., & Swystun, K. A. (2015). Carbon exchange over four growing seasons for a subarctic sedge fen in northern Manitoba, Canada. *Arctic Science*. doi: 10.1139/AS-2015-0003.
- [15] Heikkila, M., Pospelova, V., Forest, A., Stern, G. A., Fortier, L., & Macdonald, R. W. (2016). Dinoflagellate cyst production over an annual cycle in seasonally ice-covered Hudson Bay. *Marine Micropaleontology*, 125, 1-24. doi: 10.1016/j.marmicro.2016.02.005, Online publication date: 2 March 2016.

- [16] Hornby, C. A., Hoover, C., Iacozza, J., Barber, D. G., & Loseto, L. L. (2016). Spring conditions and habitat use of beluga whales (*Delphinapterus leucas*) during arrival to the Mackenzie River Estuary. *Polar Biology*. doi: 10.1007/s00300-016-1899-9 Online publication date: 12 February 2016.
- [17] Jackson, J. M., Melling, H., Lukovich, J. V., Fissel, D., & Barber, D. G. (2015). Formation of winter water on the Canadian Beaufort shelf: New insight from observations during 2009–2011. *Journal of Geophysical Research: Oceans*, 120, 4090–4107. doi: 10.1002/2015JC010812.
- [18] Jantunen, L. M., Wong, F., Gawor, A., Kylin, H., Helm, P. A., Stern, G. A., Strachan, W. M. J., Burniston, D. A., & Bidleman, T. F. (2015). 20 Years of Air-Water Gas Exchange Observations for Pesticides in the Western Arctic Ocean. *Environmental Science & Technology*. doi: 10.1021/acs.est.5b01303.
- [19] Kang, S., Huang, J., Wang, F., Zhang, Q., Zhang, Y., Li, C., Wang, L., Chen, P., Sharma, C., Li, Q., Sillanpää, M., Hou, J., Xu, B., & Guo, J. (2016). Atmospheric mercury depositional chronology reconstructed from lake sediment and ice cores in the Himalayas and Tibetan Plateau. *Environmental Science & Technology*, 50, 2859–2869. doi: 10.1021/acs.est.5b04172, Online publication date: February 14, 2016.
- [20] Kehler, S., Hanesiak, J. M., Curry, M., Sills, D., & Taylor, N. (2016). High resolution deterministic prediction system (HRDPS) simulations of Manitoba lake breezes. *Atmosphere-Ocean*, 54(2), 93-107. doi: 10.1080/07055900.2015.1137857, Online publication date: 11 Feb 2016.
- [21] Kirillov, S. A., Dmitrenko, I. A., Babb, D. G., Rysgaard, S., & Barber, D. G. (2015). The effect of ocean heat flux on seasonal ice growth in Young Sound (NE Greenland). *Journal of Geophysical Research: Oceans*. doi: 10.1002/2015JC010720.
- [22] Komarov, A. S., Isleifson, D., Barber, D. G., & Shafai, L. (2015). Modeling and measurement of C-band radar backscatter from snow-covered first-year sea ice. *IEEE Transactions on Geoscience and Remote Sensing*, 53(7), 4063-4078.
- [23] Krawczyk, D. W., Witkowski, A., Juul-Pedersen, T., Arendt, K. E., Mortensen, J., & Rysgaard, S. (2015). Microplankton succession in a SW Greenland tidewater glacial fjord influenced by coastal inflows and runoff from the Greenland Ice Sheet. *Polar Biology*. doi: 10.1007/s00300-015-1715-y.
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- [25] Leu, E., Mundy, C. J., Assmy, P., Campbell, K., Gabrielsen, T. M., Gosselin, M., Juul-Pedersen, T., & Gradinger, R. (2015). Arctic spring awakening – Steering principles behind the phenology of vernal ice algal blooms. *Progress in Oceanography*, 139. doi: 10.1016/j.pocean.2015.07.012.
- [26] Loewen, T. N., Reist, J. D., Yang, P., Koleszar, A., Babaluk, J. A., Mochnacz, N., & Halden, N. M. (2015). Discrimination of northern form Dolly Varden Char (*Salvelinus malma malma*) stocks of the North Slope, Yukon and Northwest Territories, Canada via otolith trace elements and $^{87}\text{Sr}/^{86}\text{Sr}$ isotopes. *Fisheries Research*, 170, 116-124. doi: 10.1016/j.fishres.2015.05.02.
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- [29] Macdonald, R. W., Kuzyk, Z. Z. A., & Johannessen, S. C. (2015). Change in the Arctic Ocean – why we need a geochemical observing system. *CMOS Bulletin*, 43(3), 97-99.
- [30] Macdonald, R. W., Kuzyk, Z. Z. A., & Johannessen, S. C. (2015). It is not just about the ice: a geochemical perspective on the changing Arctic Ocean. *Journal of Environmental Studies and Sciences*, 5, 288-301.
- [31] Macdonald, R. W., Kuzyk, Z. Z. A., & Johannessen, S. C. (2015). The vulnerability of Arctic shelf sediments to climate change. *Environmental Reviews*, 23(4), 461-479. doi: 10.1139/er-2015-0040.
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- [33] Melbourne-Thomas, J., Meiners, K. M., Mundy, C. J., Schallenberg, C., Tattersall, K. L., & Dieckmann, G. S. (2015). Algorithms to estimate Antarctic sea ice algal biomass from under-ice irradiance spectra at regional scales. *Marine Ecology Progress Series*, 536, 107-121. doi: 10.3354/meps11396.

- [34] Ogi, M., Rysgaard, S., & Barber, D. G. (2016). Importance of combined winter and summer Arctic Oscillation (AO) on September sea ice extent. *Environmental Research Letters*, 11(034019). doi: 10.1088/1748-9326/11/3/034019, Online publication date: 10 March 2016.
- [35] Ogi, M., Taguchi, B., Honda, M., Barber, D. G., & Rysgaard, S. (2015). Summer-to-winter sea ice linkage between Arctic Ocean and the Okhotsk Sea through atmospheric circulation. *Journal of Climate*. doi: 10.1175/JCLI-D-14-00297.1.
- [36] Pomerleau, C., Sastri, A. R., & Beisner, B. (2015). Evaluation of functional trait diversity for marine zooplankton communities in the Northeast subarctic Pacific Ocean. *Journal of Plankton Research*, 37(4), 712–726.
- [37] Pomerleau, C., Stern, G. A., Pućko, M., Foster, K. L., Macdonald, R. W., & Fortier, L. (2016). Pan-Arctic concentrations of mercury and stable isotope ratios of carbon (d13C) and nitrogen (d15N) in marine zooplankton. *Science of the Total Environment*, 551-552, 92-100. doi: 10.1016/j.scitotenv.2016.01.172, Online publication date: Feb. 11, 2016.
- [38] Raddatz, R. L., Candlish, L. M., Asplin, M. G., & Barber, D. G. (2015). Static stability of the troposphere over the Southern Beaufort Sea – Amundsen Gulf region of the Western Maritime Arctic. *Atmosphere-Ocean*. doi: 10.1080/07055900.2015.1108181.
- [39] Raddatz, R. L., Papakyriakou, T. N., Else, B. G. T., Asplin, M. G., Candlish, L. M., Galley, R. J., & Barber, D. G. (2015). Downwelling longwave radiation and atmospheric winter states in the western maritime Arctic. *International Journal of Climatology*, 35, 2339-2351. doi: 10.1002/joc.4149.
- [40] Rodriguez-Gil, J. L., Lissemore, L., Solomon, K., & Hanson, M. L. (2016). Dissipation of a commercial mixture of polyoxyethylene amine surfactants in aquatic outdoor microcosms: Effect of water depth and sediment organic carbon. *Science of the Total Environment*, 550, 449-458. doi: 10.1016/j.scitotenv.2016.01.140, Online publication date: Feb. 2, 2016.
- [41] Shrestha, B. M., Raddatz, R. L., Desjardins, R. L., & Worth, D. E. (2016). Impact of Continuous Cropping on the Diurnal Range of Dew Point Temperature during the Foliar Expansion Period of Annual Crops on the Canadian Prairies. *Advances in Meteorology*, 2016, doi: 10.1155/2016/5731319.
- [42] Sievers, J., Sørensen, L. L., Papakyriakou, T. N., Else, B. G. T., Sejr, M. K., Søgaard, D. H., Barber, D. G., & Rysgaard, S. (2015). Winter observations of CO₂ exchange between sea ice and the atmosphere in a coastal fjord environment. *The Cryosphere*, 9, 1701-1713. doi: 10.5194/tc-9-1701-2015.

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- [44] Sørensen, H. L., Meire, L., Juul-Pedersen, T., de Stigter, H. C., Meysman, F. J. R., Rysgaard, S., Thamdrup, B., & Glud, R. N. (2015). Seasonal carbon cycling in a Greenlandic fjord: an integrated pelagic and benthic study. *Marine Ecology Progress Series*, 539, 1-17. doi: 10.3354/meps11503.
- [45] ten Bruggencate, R. E., Milne, S. B., Fayek, M., Park, R. W., & Stenton, D. R. (2015). Characterization of Chert Artifacts and Two Newly Identified Chert Quarries on Southern Baffin Island. *Lithic Technology*, 40(3), 189-198. doi: 10.1179/2051618515Y.0000000006.

7.2 Non-Refereed Contributions (E.2)

7.2.1 Reports

- Andrews, J., Babb, D., McKernan, M., Horton, B., and D.G. Barber (2016). *Climate Change in the Hudson Bay Complex: Opportunities and Vulnerabilities for the Port of Churchill's Marine Operations. A report prepared for Transport Canada Network of Expertise on Transportation in Arctic Waters (NEXTAW)*. Centre for Earth Observation Science, University of Manitoba. Winnipeg, MB. 130 pp., February 2016.

7.2.2 Poster Presentations

2015 American Geophysical Union Fall Meeting, December 14–18, San Francisco, CA.

- Burgers, T., Miller, L., Thomas, H., Else, B.G.T., Gosselin, M., Papakyriakou, T. (2015). *Implications of a changing Arctic on summertime surface seawater pCO_2 variations within the Eastern Canadian Arctic*.
- Hu, Y., Wang, F., Rysgaard, S., and Barber, D.G. (2015). *A new fast, reliable technique for the sampling of dissolved inorganic carbon in sea ice*.

ArcticNet Scientific Meeting 2015. The following is a selection of posters that were presented by CEOS students and researchers at the 2015 ArcticNet Scientific Meeting (December 7–11, Vancouver, BC).

- Andrews, J., Babb, D., and Barber, D.G. (2015). *Climate change in the Hudson Bay complex: implications for the port of Churchill's shipping operations*.

- Bailey, N., Hu, Y., Bartels, C., Papakyriakou, T., and Wang, F. (2015). *Frozen carbonates: determination of carbon dioxide solubility in cold brines.*
- Barber, L., Watts, M., and Barber, D.G. (2015). *Assessing short to long-term impacts of an experimental scientific outreach program on high school student and teachers.*
- Burgers, T., Miller, L., Thomas, H., Else, B.G.T., Gosselin, M., Papakyriakou, T. (2015). *Implications of a changing Arctic on summertime surface seawater pCO_2 variations within the Eastern Canadian Arctic.*
- Candlish, L., Barber, D.G. (2015). *A Comparison of in-situ, forecast and re-analysis winds over sea ice in the Beaufort Sea.*
- Crabeck, O., Galley, R., Delille, B., Boone, W., Geilfus, N.-X., Else, B.G.T., Tison, J.-L., and Rysgaard, S. (2015). *Imaging air volume fraction (V_a) in sea ice cover: implications for sea ice permeability and gas exchange at the ice-atmosphere interface.*
- Eastwood, R., Heath, J., Barber, D.G., Kuzyk, Z. (2015). *Temporal Evolution of the Winter Water column in Southeast Hudson Bay.*
- Loria, A., Burt, A.E., and Stern, G.A. (2015). *Preliminary comparisons of THg concentrations in decapods from the Beaufort Sea (2012-2014).*
- Wang, F., Barber, D.G., Rysgaard, S., and Papakyriakou, T. (2015). *Sea-ice Environmental Research Facility (SERF): Research highlights (2014-2015).*

7.2.3 Presentations (E.2)

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

- Kuzyk, Z.A., Ehn, J., Macdonald, R.W., (2015) *Winter Estuarine Processes in the Coastal Corridor, SE Hudson Bay and Effects of Environmental Change*, ArcticNet Annual Scientific Meeting 2015. 7–11 December 2015, Vancouver BC. (Invited)
- Landry, D.B., S.B. Milne, I.J. Ferguson, M. Serzu, R.W. Park, D.R. Stenton, and M. Fayek (2015) *Using Non-Invasive Remote Sensing Technologies to Document and Monitor Surface and Subsurface Changes to Frozen Arctic Archaeological Sites: A Case Study from Southern Baffin Island, NU*. Paper presented at the ArcticNet Annual Scientific Meeting in Vancouver, BC, December 7–11.
- ten Bruggencate, R.E., S.B. Milne, M. Fayek, R.W. Park, and D.R. Stenton (2015) *Palaeo-Eskimo Exploitation of Inland Chert Quarries on Southern Baffin Island, Nunavut, Canada*. Paper presented at the Society for American Archaeology Annual Meetings in San Francisco, CA, April 15–19.

- Ando, Y., M. Ogi, Y. Tachibana, K. Kodera and K. Yamazaki (2016) *Winter weather in Japan controlled by large-scale atmospheric and small-scale oceanic phenomena*. 2016 Ocean Sciences Meeting, New Orleans, February, 2016.
- Ogi, M., S. Rysgaard and D.G. Barber. (2015) *September Arctic sea ice and the association with atmospheric circulation*. ArcticNet Annual Scientific Meeting 2015, Vancouver, December 10, 2015.
- Ogi, M., B. Taguchi, M. Honda, D.G. Barber and S. Rysgaard (2015) *Summer-to-winter sea-ice linkage between the Arctic Ocean and the Okhotsk Sea through atmospheric circulation*. IUGG, Prague, June 26, 2015.
- Hanesiak, J. and R. Stewart. (2016) *Hydrometeorological Extremes and Severe Weather: Past Events and Potential Future Changes*. Manitoba Hydro, March 16, 2016.
- Hanesiak, J. (2015) *Update and Progress: Summer Storms and Convective Precipitation*, 3rd Annual CCRN General Meeting, Saskatoon, SK, Nov. 1–4, 2015.
- Wang, F. (2015) *Living with a Rapidly Changing Arctic Ocean*. Public lecture at St. John's Ravenscourt High School. April 22, 2015, Winnipeg, MB, Canada.
- Hu Y.-B., Wang F., Rysgaard S. and Barber D. (2015) *A new fast, reliable technique for the sampling of dissolved inorganic carbon in sea ice*. 2015 AGU Fall Meeting. December 14–18, 2015, San Francisco, CA, USA.
- Beattie, S.A., Munson, K.M., Armstrong, D., Chaulk, A., Galley, R.J., Geilfus, N.-X., Hare, A., and Wang, F. (2015) *A process-based investigation of mercury uptake and temporal evolution within experimental sea ice*. ArcticNet Annual Scientific Meeting. December 7–11, 2015. Vancouver, BC, Canada.
- Gaden, A., Wang, F., Kuzyk, Z.-Z., and Stern, G. (2015) *IRIS 3: Contaminant processes in Hudson Bay*. ArcticNet Annual Scientific Meeting. December 7–11, 2015. Vancouver, BC, Canada.
- Wang, K., Munson, K. and Wang, F. (2015) *Mercury in the Marine Water of the Canadian Arctic*. ArcticNet Annual Scientific Meeting. December 7–11, 2015. Vancouver, BC, Canada.
- Wang, F. (2015) *Freshwater and marine coupling in the Hudson Bay System under a changing climate: Recent development and new opportunities*. Invited talk. From Rivers to Oceans. Partners for the Saskatchewan River Basin. November 2–4, 2015. Winnipeg, Canada.
- Elliott, A.D., Mundy, C.J., Gosselin, M., Poulin, M., Campbell, K., and Wang, F. (2015) *Mycosporine-like amino acids in sea ice covered Arctic waters*. 98th Canadian Chemistry Conference and Exhibition. June 13–17, 2015. Ottawa, Canada

- Hu, Y.-B., Wang, F., Rysgaard, S., Barber, D., Nehrke, G., Dieckmann, G., and Wolf-Gladrow, D. (2015) *Interaction between phosphate and ikaite precipitation in sea ice*. 98th Canadian Chemistry Conference and Exhibition. June 13–17, 2015. Ottawa, Canada
- Wang, F. (2015) *Cryospheric chemistry: Chemical processes in frozen waters*. 98th Canadian Chemistry Conference and Exhibition. June 13–17, 2015. Ottawa, Canada.

7.3 Edited Books and Book Chapters (B)

- Fortier, L., Reist, J.D., Ferguson, S.H., Archambault, P., Matley, J., & Macdonald, R.W. (2015). Arctic Change: Impacts on marine ecosystems and contaminants. In G A Stern & A Gaden (Eds.), *From Science to Policy in the Western and Central Canadian Arctic: An Integrated Regional Impact Study (IRIS) of Climate Change and Modernization*. Quebec City: ArcticNet, pp. 201–251,.
- Kuzyk, Z.Z.A., Macdonald, R.W., & Johannessen, S.C. (2015). Calculating Rates and Dates and Interpreting Contaminant Profiles in Biomixed Sediments. In J M Blais, M R Rosen & J P Smol (Eds.), *Environmental contaminants: Using natural archives to track sources and long-term trends of pollution*. Dordrecht: Springer, pp. 547.
- Outridge, P M, & Wang, F. (2015). The stability of metal profiles in freshwater and marine sediments. In J M Blais, M R Rosen & J P Smol (Eds.), *Environmental Contaminants: Using Natural Archives to Track Sources and Long-term Trends of Pollution*. Springer, pp. 35–60.
- Stern, G.A., & Gaden, A. (Eds.). (2015). *From Science to Policy in the Western and Central Arctic: An integrated Regional Impact Study (IRIS) of Climate Change and Mobilization*. Quebec City: ArcticNet.

A Detailed Budget By Account Code

Description	Code	Title	YTD Total Activity
Academic Salaries	61410	FT Dept Head (excl. Dent) stipends	\$5,673.12
		Subtotal:	\$5,673.12
Support Salaries & Wages	65700	FT AESES Support Continuing	(\$2,540.36)
		Subtotal:	(\$2,540.36)
Student Wages	66202	FT Studnt Supp. Casual Bach. Foreign	\$0.01
		Subtotal:	\$0.01
Benefits	68000	Employment Insurance	\$397.79
	68001	Canada Pension Plan	\$692.92
	68010	Pension 1993	\$734.90
	68020	Dental	\$111.02
	68030	Spending Account	\$88.52
	68040	GWL Supp. Health	\$21.10
	68041	GWL Group Insurance	\$19.16
	68042	GWL Disability Insurance	\$98.91
	68050	Workers' Compensation	\$58.81
	68070	Campus Development Initiative	\$853.83
	68100	Basic AD&D	\$0.61
		Subtotal:	\$3,077.57
Health and Education Levy	68500	Health & Education Levy (operating)	\$416.16
		Subtotal:	\$416.16
		Total Wages & Benefits	\$6626.50
Travel & Conferences	706752	Meals for Staff Meetings	\$990.83
	706756	Meals/Business Meetings	\$983.52
	713001	Airfare - Domestic	\$554.21
	713300	Meals/Receipts - Hospitality	\$26.57
	713801	Taxis - Domestic (Excl Local)	\$197.36
		Subtotal:	\$2,198.28
Materials, Supplies and Services	704001	Printing	\$1,098.21
	706002	Toner & Ink	\$125.76
	706003	Office Consumables	\$1,171.58
	706005	Office Equipment - Under \$2500	\$21.13
	706007	Paper	\$1,166.29
	706105	Chemicals	\$87.10
	706107	Lab Equipment - Under \$2500	\$131.52
	706109	Shop Tools	\$341.38
	706710	Other Materials & Supplies	\$969.90
	706714	Barcode Labels	\$68.97
	706753	Water, Coffee, Drinks, etc.	\$1,391.87
	706901	Gasoline	\$2,672.91

Continued on next page

	706910	Cleaning Supplies	\$23.58
	706912	Caretaking Paper Products	\$36.42
	708502	Long Distance-IST Provided	\$155.30
	708503	Cell Phone Rental	\$720.62
	708515	Remove/Add Phones-IST Provided	\$120.00
	710105	Workshop/Seminar/Conference Registration	\$97.04
	710434	Freight - Inbound	\$68.27
	710447	Rush Cheque Fee	\$200.00
	710701	Recruitment Advertising	\$995.60
	710801	Licenses	\$222.66
	723001	Interest and Late Payment Fees	\$118.51
		Subtotal:	\$12,004.62
Professional and External Services	716004	Shredding Services	\$19.31
		Subtotal:	\$19.31
Repairs and Maintenance	740004	R & M - Computer Networks	\$140.00
	740105	R & M - Doors and Windows	\$189.76
		Subtotal:	\$329.76
		Total All Expenses:	\$21,178.47