

Centre for Earth Observation Science Annual Report

2013–2014

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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, 2013 to March 31, 2014. 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 (16 members) is drawn from the Department of Environment and Geography (11 members), Geological Sciences (4 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.

With the spinning up of CERC activity, the number of research personnel has almost doubled. In the reporting year we mentored 18 undergraduate students, 24 Master's students and 20 Ph.D. students, along with 26 Post-doctoral Fellows/Research Associates. An inventory of HQP is provided in the following sections. Five graduate students graduated over the reporting period.

CEOS remains a productive research unit. In the reporting year, faculty had published 42 papers in top journals, and secured \$5.1M 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. Examples from 2013–14 included our hosting of a scoping meeting for Canada–Germany research collaboration in the Arctic, with researchers and administrators from the Alfred Wegener Institute (AWI). Additionally we hosted the SOAR (Science and Operational Applications Research) for RADARSAT-2 workshop.

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:

- 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;
- 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 towards the development 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; and
- Continued operation of the Sea-ice Environmental Research Facility (SERF) for research into sea-ice.

Highlights for this reporting period include:

- Grand opening of the 60,000 ft² Nellie Cournoyea Arctic Research Facility on the fifth floor of the Wallace Building in support of CEOS/CERC polar marine research;
- Successful integration of recent faculty hires into collaborative programs and engagement with proposal development;
- Successful CFI and NSERC (DG and RTI) grant applications by recent hires and nil-salary appointments;
- 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 and GCRC;
- Implementation of the 3rd annual sea ice experiment at our CFI-funded Sea-ice Environmental Research Facility (SERF);
- Addition of new research associates and research staff.

In 2015, CEOS faculty will participate in 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. Associated with this theme, CEOS personnel have, in the reporting year, developed and submitted major grant applications to NSERC (CRD Program – BaySYS) and CFI (Churchill Marine Observatory (CMO)).

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 \$14.9M, 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. If successful, the \$12.4M contribution from CFI (\$31M infrastructure proposal) will provide CEOS, the University, Manitoba, and Canada with the technical capacity to better safeguard the Arctic from mishaps associated with the extraction and transport of fossil fuels in Arctic waters.

Sadly, in 2013 three friends and colleagues were lost in a tragic helicopter accident in the High Arctic. Amongst the lost included Klaus Hochheim, a longtime CEOS researcher and friend. In memory of Klaus and his accomplishments, we renamed our theatre the *Klaus Hochheim Memorial Theatre* on February 21, 2013.

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In Memoriam: Dr. Klaus P. Hochheim (1958-2013)



On the evening of September 9, 2013, while doing routine ice operations from the Canadian Research Icebreaker *Amundsen*, a tragic helicopter crash occurred over the Arctic Ocean. The accident claimed the lives of University of Manitoba researcher Dr. Klaus Hochheim and two Canadian Coast Guard officers: Captain Marc Thibault and Pilot Daniel Dubé. Klaus had worked with the Centre for Earth Observation Science (CEOS) since 2005. During both Arctic and Antarctica expeditions, Klaus, 55, contributed to our collective understanding of sea ice climatology and microwave and optical remote sensing of ocean–sea-ice–atmosphere coupled processes.

Intellectually, Klaus had a well-developed sense of what it means to be a scientist. He retained the curiosity of his childhood and this drove his scientific passion. Simply stated, he wanted to know how things worked. He was adept at using various environmental technologies, which allowed him to look at sea ice through a cascade of scales from micro to hemispheric. He took as much interest in precisely characterizing the microstructure of the brine pockets in sea ice as he did in understanding how sea ice growth, decay, and motion responded to changing global teleconnections.

Within our academic family, Klaus was both a friend and mentor. As we gathered to remember him in the days following the crash, we all recalled his laugh, his willingness to help, and his ability to problem-solve. Almost without exception, our pictures of Klaus in the field show him working alongside graduate students and other research associates — helping members of *his* academic family to achieve *their* goals.

Klaus was also very committed to aspects of social justice and he felt that science was an absolute requirement to make honest and equitable policy decisions affecting people. He was concerned that climate change disproportionately affects the poor of our planet and he died trying to provide the world with scientific data needed to make choices about our collective future. Some of his final work (including the papers in this compendium) will supply policy makers with scientific information as to how the Arctic is changing, what the relative impacts various industries (e.g., hydroelectric development, oil and gas exploration, marine transportation, etc.) and climate change have on the Arctic system.

We have lost a dear and highly respected member of our academic family. We join with his biological family in shared sorrow and grief. We honour Klaus by continuing our drive to understand our Arctic and the connection between the Arctic and our Earth’s climate system for the betterment of our human habitat.

Dr. David Barber
Canada Research Chair, Arctic System Science

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. Baseline support totalled \$113K (OA and operating envelope). Additionally, the Centre received a transfer of research-leveraged funds through the Clayton H. Riddell Faculty of Environment, Earth and Resources. In total we received approximately \$132K through ICR. 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 11 support staff, three nil-salary professors, 22 research associates and four post-doctoral fellows. Our graduate student cohort was 44 (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
- 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
- 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
- Lucette Barber
- Alexis Burt
- Lauren Candlish
- Jessie Carrie
- Ashley Gaden
- Ryan Galley
- Alex Hare
- Klaus Hochheim (deceased)
- Brian Horton
- Dustin Isleifson
- Sergei Kirillov
- Marcos Lemes
- Zhuo (George) Liu
- Jennifer Lukovich
- Marianne Marcoux
- Greg McCullough
- Monika Pućko

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

2.3 Support Staff

- Debbie Armstrong, Technician
- Wayne Chan, Research Computer Analyst
- Amanda Chaulk, Technician
- Linda Chow, Office Assistant
- Geoffrey Gunn, Operations Support
- Sebastian Luque, Technician
- David Mossdrop, Operations Manager
- Ryan Smith, Technician
- Michelle Watts, Schools on Board Coordinator
- Denise Whynot, Office Manager
- Irene Zhao, Office Assistant

2.4 Graduate Students

Forty-four graduate students were supported (financially and/or logistically) over the reporting period. There were 20 doctoral students and 24 master's students.

2.4.1 Doctoral

- Matthew Asplin
- Wieter Boone
- Karley Campbell
- Gauthier Carnat
- Emily Choy

- Odile Crabeck
- Aurelie Delaforge
- Shannon Fargey
- Nariman Firoozy
- Mukesh Gupta
- Satwant Kaur
- Trish Kelley
- Alex Komarov
- Jack Landy
- Tracy Loewen
- Cory Matthews
- Vlad Petrusевич
- Maliheh Rabie
- Kang Wang
- Cortney Watt

2.4.2 Master's

- David Babb
- Sarah Beattie
- Tonya Burgers
- Michael Chiasson
- Michele Curry
- Robyn Dyck
- Matthew Gale
- Pamela Godin
- Geoffrey Gunn

- Michelle Kamula
- Amber Penner
- Halya Petzold
- Meredith Pind
- Breanne Reinfort
- Oksana Schimnowski
- Megan Shields
- Christopher Stammers
- Heather Stark
- Qiying Sun
- Marci Trana
- Wen Xu
- Brent Young
- Rui Zhang
- Dan Zhu

2.5 Graduates

Five CEOS students graduated during the past academic year:

- Matthew Asplin (Ph.D.), Dissertation title: *Cyclone forcing of coupled dynamic and thermodynamic processes in Arctic sea ice, and across the ocean-sea ice-atmosphere interface.*
- Sarah Beattie (M.Sc.), Thesis title: *Mercury dynamics within natural and experimental sea ice.*
- Trish Kelley (Ph.D.), Dissertation title: *Linking feeding and reproductive ecology in beluga (*Delphinapterus leucas*) and narwhal (*Monodon monoceros*).*
- Meredith Pind (M.Sc.), Thesis title: *An examination of the spatial and temporal variability of seawater pCO_2 within the Canadian Arctic Archipelago and Baffin Bay during the summer and fall seasons.*

- Brent Young (M.Sc.), Thesis title: *Seasonal, inter-annual, and spatial variation in ringed seal feeding ecology in Hudson Bay assessed through stable isotope and fatty acid biomarkers.*

2.6 Post-doctoral Fellows

- Brent Else
- Karen Foster
- Nicolas-Xavier Geilfus
- 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 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

Eighteen summer students assisted various faculty members as research assistants or technicians in 2013–14 (see Table 1).

Name	Position	Supervisor
Jeremy Barber	Student Research Assistant	Papakyriakou
Julien Barber	Student Research Assistant	Papakyriakou
Jeremy Krogh	Student Research Assistant	Barber
Tonya Burgers	Student Research Assistant	Papakyriakou
Ashley Elliott	Student Research Assistant	Mundy/Wang
Juliana Kusyk	Student Research Assistant	Stern/Barber/Halden/ Rysgaard/Wang
Ryan Smith	Summer Technician	Papakyriakou
Michele Curry	Student Research Assistant	Hanesiak
Scott Kehler	Student Research Assistant	Hanesiak
Kyle Ziolkowski	Student Research Assistant	Hanesiak
Rosanne Sengenberger	Student Research Assistant	Hanesiak
Michelle Kamula	Student Technician	Kuzyk
Heather Stark	Student Technician	Barber
Marc Cadieux	Student Technician	Stern
Jason Taylor	Student Technician	Rysgaard
Erin Untereiner	Student Research Assistant	Ali
Cody Ross	Student Research Assistant	Ali
Lauren Timlick	Student Research Assistant	Ali

Table 1: CEOS summer students for 2013–14.

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 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>.

3.2 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.

gies 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.

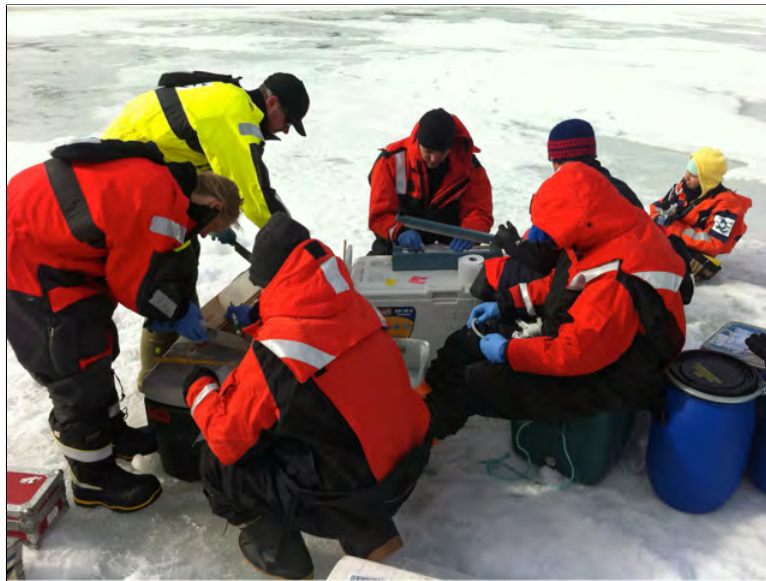
Formation of the Arctic Science Partnership has leveraged significant resources (people, equipment, and funds) that did not exist prior to the CERC program. The ASP brings together over 350 scientists and integrates them into a single collaborative research team.

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 2013 ASP Annual Meeting was held November 13–20 in Nuuk, Greenland. CEOS sent a team of 10 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.

3.2.1 ASP – 2013 Nuuk Campaign

The ASP 2013 Nuuk–Davis Strait campaign examined a sub-Arctic system under change. The rationale behind this study is to increase year-round knowledge on sub-arctic ecosystems.



Approximately one hundred scientists collaborated on this comprehensive project across water, land and atmosphere to investigate:

1. Ongoing changes in ice-ocean interactions, snow and ice extent, permafrost thaw and their combined consequences for Arctic ecosystems and the benefits we receive from the systems.
2. Proxies for predicting future changes in ocean currents, weather systems and ecosystems.

3. Impact of climate change on the Arctic societies, population's lifestyle and disease patterns.
4. Pollutant transport to the Arctic and exposure consequences on ecosystems and humans.
5. Feedbacks between the Arctic and Earth climate systems.

Sub projects led by CEOS:

- Greenhouse gases ($\text{CO}_2 - \text{CH}_4 - \text{N}_2\text{O}$) dynamics within fjord sea ice. Lead: Nicolas-Xavier Geilfus
- Underwater eddy correlation measurements of ice-ocean heat and mass exchange. Lead: Brent Else
- Evolution and distribution of pH in natural first-year sea ice. Lead: Alex Hare
- Assessment of sea ice algae production in Kanajorusuit Fjord. Lead: Karley Campbell
- Mercury transport and transformation across the sea ice environment. Lead: Fei Wang
- Circulation and exchange processes at the entrance to Godthåbsfjord. Lead: Søren Rysgaard

3.3 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.

3.3.1 2013–2014 Experiments

The winter 2013–2014 season is year 3 of SERF. Data collection focused on regularly scheduled measurements linking the geophysical and electromagnetic (EM) properties of sea ice as it progresses through distinct growth and ablation phases. Measurements of sea ice biogeochemical properties were also acquired. Three experiments were conducted:

- Experiment 3.1 (ice ridge) - Dec. 3–31, 2013: Growth of thick ice and simulated ice ridge radar remote sensing sub-project.
- Experiment 3.2 (geophysics and biogeochemistry) - Jan. 10–31: Time series geophysical and biogeochemical data collection.
- Experiment 3.3: (geophysics) - Feb. 01 to end: Replication of Experiment 3.2, geophysical data collection under different seasonal forcing conditions.

Geophysical and EM data were used for understanding the key processes which affect the visible, near-infrared, and microwave signals recorded by satellite remote sensing systems. The information will be used to improve the accuracy of satellite-based measurements of sea ice properties, and contribute to new retrieval methods for parameters such as snow water equivalent (SWE). Biogeochemical information will address ongoing SERF goals of understanding the role of sea ice in polar marine biogeochemical cycling.

Participants

- Principal Investigators (CEOS): Drs. David Barber and Feiyue Wang
- Program Lead: Dr. Randall Scharien
- U of M Participants: Dr. David Barber, Dr. Feiyue Wang, Dr. Randall Scharien, David Mosscrop (Operations Manager), Alex Komarov (Ph.D. Student), Nariman Firoozy (Ph.D. Student), Jack Landy (Ph.D. Student), Megan Shields (M.Sc. Student), Wen Xu (M.Sc. Student)
- University of Calgary: Dr. John Yackel, Mallik Mahmud

3.4 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.

3.5 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.

For Lake Winnipeg data, the MGLP relies on monitoring by federal and provincial agencies supported by our mutual partner in Lake Winnipeg research, the Lake Winnipeg Research Consortium (of which the University of Manitoba is a member). In preliminary work on Lake Winnipeg and its watershed, the Centre for Earth Observations Sciences (CEOS) collaborated with the Canadian Department of Fisheries and Oceans and others to investigate the proximate causes of the surge in the frequency, extent and sever-

ity of surface blooms of cyanobacteria that occurred in the mid-1990s. This work led to a significant publication (McCullough et al., 2011) 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.

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. 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.

3.6 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.

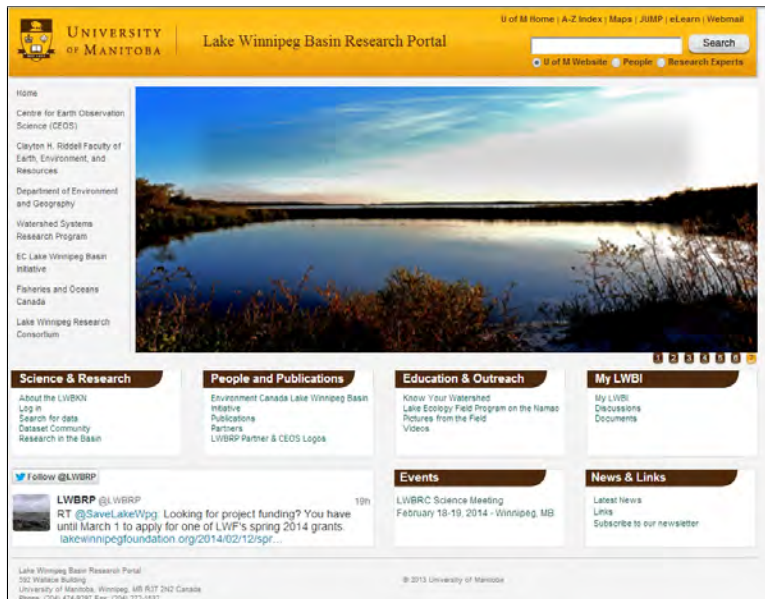
3.6.1 Participants

- 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).

3.7 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.

The Lake Winnipeg Basin Information Portal underwent a front-end and back-end re-design in 2014. The name was also changed to the Lake Winnipeg Basin Information

Network (LWBIN) to reflect the diverse capabilities of the portal. The data architecture back-end was restructured to fit within the IST framework. ESRI ArcGIS (Geographical Information System), for which the University holds a license, was utilized to develop a second server to add mapping capability to the Portal. Several students within the Watershed Systems Program utilized the free mobile application associated with the mapping software to log their field sample sites and add associated pictures. The use of this mapping software allows the LWBIN to provide data in an easy-to-view visual manner to users who may not have access to expensive mapping software. It can facilitate student and researcher research by allowing users to access and update site location on the fly.

The LWBIN also partnered with the University of Manitoba Libraries MSpace program to develop an LWBIN collection to host open-access documents. The collection includes documents, reports or any type of publication related to the Lake Winnipeg Basin. The collection currently includes Canadian federal and provincial government reports and documents, pre-print journal publications, and student posters.

The LWBIN also partnered with the University of Manitoba libraries to provide all datasets with permanent Digital Object Identifiers (DOI), which allows research data to become citeable by providing a permanent ID and link.

To improve data warehousing and delivery, a third server was added. This server currently hosts open source data portal software which the LWBIN is using to provide data to users.

The LWBIN is also working at partnering with the Government of Manitoba to facilitate sharing and open access to water quality and biotic data for research conducted within the Lake Winnipeg Basin.

3.8 Orcas of the Canadian Arctic

Killer whales (*Orcinus orca*) are seasonal visitors to the Eastern Canadian Arctic (ECA), where they have been observed to prey on marine mammals. Their occurrence and residence time in regions of the ECA (e.g., Hudson Bay) may be increasing as a result of decreases in sea ice. Recent sightings of killer whales in Cambridge Bay, Nunavut constitute the furthest westward report. As apex predators, it is predicted that killer whales influence their marine mammal prey populations and the entire



ECA marine ecosystem; however, with the limited knowledge currently held about these predators, it is difficult to determine their impact. Currently, only a minimum population estimate exists. Whether there are specific groups, the group sizes and compositions, the seasonal distribution within and outside of the ECA, and the relatedness of ECA killer

whales to other killer whales all remain unknown.

The overall project objective is to learn more about the ecology and biology of ECA killer whales to improve our understanding of how marine mammal prey populations and the entire ECA ecosystem may be affected by their predation. With the use of photos for individual identification, satellite telemetry, an ongoing sightings database, and tissue biopsies for chemical and genetic analyses, we hope to elucidate:

- An ECA killer whale population estimate.
- Specific groups of killer whales, their numbers and compositions.
- Killer whale distribution within and outside of the ECA.
- Extent of temporal and spatial overlap between ECA killer whales and other North Atlantic groups.
- Extent of prey specialization towards (1) marine mammals or fish, and (2) specific marine mammal species.
- Prey behaviour in response to killer whales.
- Amount of prey necessary to meet ECA killer whale energetic requirements.
- ECA killer whale relatedness to other killer whale populations.

A final objective is to build the capacity of Inuit community-based-monitoring of ECA killer whales. Enabling Inuit to gather data (e.g., tissue biopsies, photographs) carries dual benefits of community empowerment and potential for increased data collection. This initiative will be important for continued killer whale research in the ECA.

3.9 Beaufort Regional Environmental Assessment (BREA)

The Beaufort Regional Environmental Assessment (BREA) was coordinated by the Department of Aboriginal Affairs and Northern Development Canada, and had the objective of collecting an extensive set of baseline observations across the physical, chemical and biological fields of the Beaufort Sea. BREA was proposed in response to growing interest in offshore resources and transportation corridors through the Beaufort Sea that are becoming increasingly viable as the Arctic ice pack retreats. The Centre for Earth Observation Science led a project entitled “Detection, Motion and Radarsat Mapping of Extreme Ice Features in the Southern Beaufort Sea” that was comprised of two intensive field campaigns and a community monitoring program in the town of Sachs Harbour, NWT. The project began in 2012, with proposed field campaigns during 2012 and 2013, and is to be completed during 2015. The project focused on detecting extreme sea ice features in the Beaufort Sea and then visiting them during helicopter surveys and deploying a suite of autonomous

equipment that would drift with the features and allow us to track them while analyzing the forcing mechanisms that acted upon them. Extreme ice features are defined as features that pose a serious threat to industry activity and may prove hazardous or unmanageable. Generally extreme ice features are defined as either deformed multi-year ice fields with deep keels, or ice islands, both of which can be difficult to detect with current remote sensing platforms and therefore difficult to track and manage for industrial applications. Ice islands are large tabular pieces of glacial ice that have broken off the ice shelves of northern Ellesmere Island and entered the drifting ice pack. Ice islands can span multiple kilometres in diameter and can be up to 50m thick, making them a serious threat to any activity in the Beaufort Sea.

During 2012, a successful helicopter-based survey of the multi-year ice pack was carried out from Sachs Harbour, NWT, with an extensive suite of autonomous ice beacons, ice mass balance buoys, and ocean current profilers deployed on ice floes with mean thicknesses of 4–7m. Unfortunately, the 2013 survey was cancelled at the last minute due to poor ice conditions, which made for poor flying conditions around Sachs Harbour. The equipment deployed during 2012 provided a spatially and temporally coincident dataset of ice drift, surface winds, ice thickness, air temperature, water temperature, and ocean currents that was used to describe the dynamic and thermodynamic coupling across the ocean–sea–ice–atmosphere system. The equipment was deployed during early April and left to drift with the mobile ice pack until it broke up and satellite transmissions of data ended throughout August, 2012. The observations highlight the evolution of the ice pack from a consolidated, strong ice pack during late winter to a diffuse, weak ice pack in late summer during which ice floes entered free-drift conditions. *In situ* observations were supplemented by remotely-sensed observations of the ice surrounding the equipment, and ice features identified during April were tracked through subsequent satellite images using the ice beacon dataset. Overall, the goal was to use ice drift data to identify these hazardous features in satellite images throughout the melt season and then work back towards identifying these features based on their radiometric signatures which could be used subsequently to identify these features without the *in situ* observations. The 2012 BREA dataset has led to two submitted publications that are presently going through peer-review, with work still being conducted on the datasets and contributing to future publications.

Beyond the field campaign, a community-based monitoring program was established in the town of Sachs Harbour during spring 2012 and 2013. The program focused on measuring ice thickness of the landfast ice around the town and to conduct oceanographic surveys of the water around the town. Community members were trained on electromagnetic instruments that measure ice thickness and CTD profiling equipment. They then utilized this equipment to conduct surveys of the landfast ice from late winter to late spring when the ice pack became unsafe to continue working on. The goal of this project was to gain an understanding of the processes that influence the landfast ice around Sachs Harbour, which the locals rely on for hunting and travel, and which also protects the shores from coastal erosion and ice scouring. As a result of climate change in the Arctic, the landfast

ice along the Canadian coast is declining and becoming less stable and therefore less safe to travel or hunt on. This greatly affects the ability of local Inuit to maintain a traditional way of life and increases the risk of spending time on the ice.

Overall, a very extensive dataset of *in situ* observations from the multi-year ice pack was collected during 2012 and is contributing to our improved understanding of extreme ice features in the Beaufort Sea. Another unique dataset of observations around the landfast ice pack surrounding Sachs Harbour was collected during 2012 and 2013 and contributing towards further knowledge surrounding the stability of this integral ice feature around the town.

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 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 2014 field program joined the final leg of ArcticNet’s 2014 science expedition in the community of Kugluktuk, NU and travelled through the famed Northwest Passage to Iqaluit, NU. 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 2014 field program include:



- Elmwood High School – Winnipeg, MB
- Dauphin Regional Comprehensive Secondary School – Dauphin, MB
- Lower Canada College – Montreal, QC
- Dawson Creek High School – Dawson Creek, BC
- East Three High School – Inuvik, NWT
- Kiilinik High School – Cambridge Bay, NU
- Jonah Amitnaaq Secondary School – Baker Lake, NU
- Ecole Emilie-Tremblay/Academie Tremblay – Whitehorse, YK
- Gulf Islands Secondary School – Saltspring Island, BC
- Penticton Secondary School – Penticton, BC

Schools on Tundra. Building on the success of the ship-based field program, Schools on Board partnered with the Churchill Northern Studies Centre (CNSC) and Parks Canada to pilot this subarctic terrestrial-based outreach program in the winter of 2013. Similar to the ship-based program, Schools on Tundra takes a small team of high school students and teacher from across Canada to Churchill, MB to participate in the science being conducted at the centre. The next Schools on Tundra is tentatively scheduled for August, 2015.



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 – February 2014. Over 200 middle years and senior years students attending the 2014 Arctic Science Day held at FortWhyte Alive in February. This event was also part of the University of Manitoba’s SET (Science, Engineering and Technology) Day. CEOS graduate students and scientists created six different stations that included hands-on activities and demonstrations.



4.1.3 Arctic Climate Change Youth Forum

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. Planning for the December 8, 2014 event took place during the reporting period.

4.2 Workshops Hosted by CEOS

CEOS hosted several workshops during the 2013–2014 reporting year:

- **WWF Rapid Assessment of Circum-Arctic Ecosystem Resilience to Climate Change (RACER) Workshop – November 3, 2013**

Conveners: Martin Sommerkom, WWF-Global Arctic Program, and Vicki Sahanian, WWF-Canada Arctic Programs. Twenty participants from: WWF, Department of Fisheries and Oceans, U of M, Geoanalytics/Canatec, Acadia University, University of North Carolina, Arctic Biological Consultants, and Dalhousie University.

- **Alfred Wegener Institute (AWI) Delegation – May 31, 2013**

The objective of the workshop was to share information regarding current and planned research activities, to identify opportunities for cooperation between AWI and CEOS, and to showcase U of M collaborative research facilities. Facilitated by: Jennifer Decker, Embassy of Canada.



Delegates:

- Dr. Karin Lochte, director of the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (Germany)
- Dr. Nicole Biebow, head of the International Cooperation and Research Funding Unit
- Dr. Ruediger Stien, senior research scientist, AWI
- Dr. Hugues Lantuit, group leader, Helmholtz Young Investigators Group, AWI
- Dr. Bernhard Diekmann, senior researcher, AWI, associate professor, University of Potsdam
- Dr. Ilka Peeken, senior scientist, University of Bremen, MARUM – Centre for Marine Environmental Sciences in cooperation with AWI

- Dr. Boris Koch, AWI cooperation professorship with University of Applied Sciences, Bremerhaven
- Dr. Catherine Lalande, research scientist, AWI Polar and Marine Research, Bremerhaven
- Dr. Catalina Gebhardt, research scientist, AWI

Approximately 40 members of CEOS attended the workshop.

- **Science and Operational Applications Research for RADARSAT-2 (SOAR) Mini Workshop - May 16, 2013**

Objectives were to share information regarding RADARSAT missions and the SOAR education initiative program, to identify areas of interest and potential use by CEOS, and to showcase CEOS research facilities and remote sensing capabilities. Twenty participants from CEOS attended the workshop.

4.3 Other Activities

4.3.1 2013–2014 CNC-SCOR Western Lecture Tour

As part of the Canadian National Committee for Scientific Committee on Oceanic Research (CNC-SCOR) Western Lecture Tour, CEOS hosted Dr. Philippe Archambault from the Université du Québec à Rimouski, who gave a talk entitled, “Marine biodiversity and its influence on ecosystem functioning”. The event was held on March 21, 2014 with approximately 40 people in attendance.

4.3.2 China/Canada Student Day – July 23, 2013

The Faculty of Environment, Earth, and Resources hosted approximately 60 Chinese schoolchildren (mostly from Shenzhen, China) aged 1-12 years old, here on an exchange with Ecole St. Avila. CEOS graduate students engaged the exchange in a variety of hands-on activities that demonstrated Arctic sea ice research, contaminant sampling procedures, and a tour of the facilities at CEOS.

4.3.3 Climate Change Connection High School Youth Conferences

Climate Change Connection is a non-profit organization that informs the public on the science of climate change as well as providing information on actions that can be taken to mitigate or reduce our carbon footprint.

CEOS graduate students have presented workshops at several youth conferences that focus on the nature of Arctic science research, the importance of the Arctic in the global climate system, and provided a hands-on activity.

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.

- *Winnipeg Free Press*, “Yes, it’s cold enough for them”. Interview with Dr. Feiyue Wang about Sea-ice Environmental Research Facility (SERF), Jan. 22, 2013.
- *Global TV*, “Winnipeg students help predict severe weather”. Segment about balloon launch program at U of M, June 20, 2013.
- *Global TV*, “Chasing storms with Prof. John Hanesiak”. Coverage of U of M storm chasing trip, June 25, 2013.
- *Winnipeg Free Press*, “Receding ice shipping boon for Churchill”. Interview with Dr. David Barber, July 11, 2013.
- *Canadian Press*, “Stronger Arctic cyclones rapidly chewing up weak sea ice”. Interview with graduate student Matthew Asplin and Dr. David Barber, July 25, 2013.
- *Winnipeg Free Press*, “Manitoba storm-chasers take a trip down Tornado Alley”. Interview with Dr. John Hanesiak about storm chasing trip, Aug. 17, 2013.
- *CBC TV*, “Arctic Shipping and Climate Change”. Interview with Dr. David Barber.
- *Associated Press*, “What is happening with the sea ice minimum”. Interview with Dr. David Barber.
- *Discovery Channel*, “Sea ice and polar bear habitat”. Interview with Dr. David Barber.

- *Globe and Mail*, “Sea ice and climate change”. Interview with Dr. David Barber.
- Dr. David Barber – Public Lecture, Winnipeg Zoo, “Sea ice and polynyas”.
- Dr. David Barber – Public Lecture, Canadian Shield Club, “The Arctic and Climate Change”.
- Dr. David Barber – Public Lecture, The Arctic Circle Club (Ottawa), “Seven surprises about sea ice”.
- *Winnipeg Free Press*, “An icy glare: U of M team simulates Arctic conditions to better understand impact on satellites”. Interview with graduate student Megan Shields and Dr. David Barber about Sea ice Environmental Research Facility (SERF), Feb. 15, 2014.

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 (2013-2014)
CEOS/ASP	127183-Gather-Learn Field School	\$6,069
Barber	120081-Schools on Board	\$59,000
Barber	301912-CRC NSERC Sal	\$29,000
Barber	301913-CRC NSERC Res	\$171,000
Barber	302304-NSERC RGPNS	\$15,000
Barber	302306-NSERC RGPIN	\$70,000
Barber	303044-MCEF ArcticNet	\$94,984
Barber	310673-CFI - IOF Laval	\$118,901
Barber	313065-ArcticNet Laval Hudson’s Bay IRIS 3.2	\$169,095
Barber	313066-ArcticNet Laval Role Sea Ice IRIS 3.6	\$112,410
Barber	313079-MRIF/CDA Excellence Research	\$500,000
Barber	313785-INAC	\$230,360
Barber	313874-NSERC PROSC	\$25,800
Barber	314872-Environment Canada	\$40,000
Barber	315322-EuropeanSpaceAgency	\$48,552
Barber	316008-Transport Cda	\$25,000
Barber	316187-Churchill Gateway Dev Corp	\$50,000
Barber	316243-Environment Canada	\$7,715
Barber	316287-Transport Canada	\$49,985
Barber	316253-WWF Canada	\$52,200
Dmitrenko	315868-ArcticNet Laval Marine Observatory	\$4,000
Ehn	316072-Start-up Funds	\$14,898
Continued on next page		

Ehn	315105-NSERC RGPIN	\$28,000
Ehn	315131-NSERC RGPNS	\$17,500
Ferguson	302299-NSERC RGPIN	\$22,000
Ferguson	313072-ArcticNet Laval Marine Mammals 3.3	\$60,650
Ferguson	315237-ArcticNet Laval Field Aircraft Supp	\$11,250
Ferguson	315238-ArcticNet Laval Train Westdal CRRU	\$3,410
Ferguson	315239-ArcticNet Laval Train Matthews ISF	\$1,825
Ferguson	315240-ArcticNet Laval Training Watt CRRU	\$2,770
Hanesiak	314011-NSERC RGPIN	\$27,000
Kuzyk	315313-ArcticNet Laval Nunatsiavut 4.6	\$20,000
Loseto	314698-INAC	\$18,000
Michel	315710 NSERC RGPIN	\$21,600
Mundy	315116-NSERC RGPIN	\$27,000
Mundy	315132-NSERC RGPNS	\$15,000
Mundy	315491-ArcticNet Laval 2013 Shiptime	\$21,000
Mundy/Ehn	316170-CFI LOF	\$319,992
Mundy/Ehn	316172-MRIF	\$319,992
Papakyriakou	313068-ArcticNet Laval Carbon Dynamics 3.1	\$70,610
Papakyriakou	314038-NSERC RGPIN	\$32,000
Papakyriakou	314052-NSERC RGPNS	\$15,000
Rysgaard	312888-CERC NSERC Sal	\$250,000
Rysgaard	312890-CERC NSERC	\$1,150,000
Rysgaard	313075-ArcticNet Laval Geomicrobio 2.8	\$35,000
Rysgaard	316173-ArcticNet Rysgaard Ilinnia Field School	\$20,000
Stern	122555-Soil/Water Testing Lab	\$15,238
Stern	313069-ArcticNet Laval Contaminants 1.2	\$95,355
Stern	313076-ArcticNet Laval IRIS Coord Contaminants	\$70,000
Stern	313943-INAC	\$9,198
Stern	315011-AANDC	\$35,000
Stern	315053-CFI Match Aarhus University	\$100,000
Stern	315404-DeBeers Canada Inc.	\$90,000
Stern	315492-ArcticNet Laval Shiptime Request	\$35,000
Stern	315948-AANDC	\$58,775
Stern	316061-AANDC	\$33,810
Stern	316062-AANDC	\$27,945
Stern	316063-AANDC	\$29,095
Stern	316067-AANDC	\$31,400
Wang	301866-NSERC RGPIN	\$55,000
Wang	313064-ArcticNet Laval Contaminants 1.2	\$42,000
Wang	314947-UBC/RGPCC	\$25,917
Wang	316065-AANDC	\$14,300
	Total:	\$5,196,593

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 2013–2014.

Student	Supervisor	Amount
Ryan Anderson	Ferguson	\$2,732.00
Sarah Beattie	Wang	\$2,500.00
Karley Campbell	Mundy	\$2,976.00
Matthew Gale	Mundy	\$2,902.00
Alex Komarov	Barber	\$2,697.00
Meredith Pind	Papakyriakou	\$2,837.00
Megan Shields	Barber	\$2,896.00
Heather Stark	Barber	\$2,797.00
Cortney Watt	Ferguson	\$2,656.00
Total:		\$24,993.00

Table 3: Students receiving NSTP funding for 2013–2014.

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	\$85,411.16	78
2	Travel	\$369.23	0.34
3	Printing and Duplicating	\$1,913.88	1.75
4	Materials and Supplies	\$8,810.72	8.05
5	Telecommunications	\$10,388.00	9.49
6	Other Operational Expenses	\$1,942.33	1.78
7	Interest And Bank Charges	\$61.81	0.06
8	Repairs and Maintenance	\$183.13	0.17
9	Land & Bldg Acquisitions & Improve	\$345.68	0.32
Total:		\$109,425.94	100.0

Table 4: Summary of annual operating budget.

7 Academic Contributions

CEOS researchers published 42 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.

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, 2013 – March 31, 2014. A full list of articles from the last two calendar years can be found on the CEOS website: www.umanitoba.ca/ceos.

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- [2] Babb, D.G., R.J. Galley, M.G. Asplin, J.V. Lukovich, D.G. Barber. 2013. "Multi-year sea ice export through the Bering Strait during winter 2011-2012", *Journal of Geophysical Research: Oceans*, 118, doi:10.1002/jgrc.20383.
- [3] Bailey, Joscelyn N.-L., Robie W. Macdonald, Hamed Sanei, Peter M. Outridge, Sophia C. Johannessen, Klaus Hochheim, David Barber, and Gary A. Stern. 2013. "Change at the Margin of the North Water Polynya, Baffin Bay, Inferred from Organic Matter Records in Dated Sediment Cores". *Marine Geology*, 341 (July): 1–13. doi:10.1016/j.margeo.2013.04.017.
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- Arctic Ocean.” *Environmental Science & Technology*, 47 (11) (June 4): 5553–5561. doi:10.1021/es304398j.
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- [8] Birkel, C., C. Soulsby, G. Ali, and D. Tetzlaff. 2013. “Assessing the Cumulative Impacts of Hydropower Regulation on the Flow Characteristics of a Large Atlantic Salmon River System”. *River Research and Applications*, 30(4): 456–475. doi:10.1002/rra.2656.
- [9] Bracken, L.J., J. Wainwright, G.A. Ali, D. Tetzlaff, M.W. Smith, S.M. Reaney, and A.G. Roy. 2013. “Concepts of Hydrological Connectivity: Research Approaches, Pathways and Future Agendas”. *Earth-Science Reviews*, 119 (April): 17–34. doi:10.1016/j.earscirev.2013.02.001.
- [10] Candlish, Lauren M., Richard L. Raddatz, Geoffrey G. Gunn, Matthew G. Asplin, and David G. Barber. 2013. “A Validation of CloudSat and CALIPSO’s Temperature, Humidity, Cloud Detection, and Cloud Base Height over the Arctic Marine Cryosphere.” *Atmosphere-Ocean*, 51 (3): 249–264. doi:10.1080/07055900.2013.798582.
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- [13] Else, B. G. T., T. N. Papakyriakou, M. G. Asplin, D. G. Barber, R. J. Galley, L. A. Miller, and A. Mucci. 2013. “Annual Cycle of Air-sea CO₂ Exchange in an Arctic Polynya Region.” *Global Biogeochemical Cycles*, 27(2): 388–398. doi:10.1002/gbc.20016.
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- [20] Isleifson, Dustin, Ryan James Galley, David G. Barber, Jack C. Landy, Alexander S. Komarov, and Lotfollah Shafai. 2013. “A Study on the C-Band Polarimetric Scattering and Physical Characteristics of Frost Flowers on Experimental Sea Ice.” *IEEE Transactions on Geoscience and Remote Sensing*: 1–1. doi:10.1109/TGRS.2013.2255060.
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- [32] Raddatz, R.L., Galley, R.J., Else, B.G., Papakyriakou, T.N., Asplin, M.G., Candlish, L.M., and D.G. Barber. 2014. “Western Arctic Cyclones and Equilibrium between the Atmospheric Boundary Layer and the Sea Surface”, *Atmosphere-Ocean*, 52(2): 125–141, doi:10.1080/07055900.2014.890921.
- [33] Raddatz, R.L., T. Papakyriakou, R.J. Galley, M.G. Asplin, L.M. Candlish, B. Else and D.G. Barber. 2013. “All-sky surface radiation & clear-sky surface energy budgets: summer to freeze-up in the western maritime Arctic.” *Atmosphere-Ocean*, 51(5), 489–504.
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- [37] ten Bruggencate, R., Fayek, M., Milne, S.B., and K. Brownlee. 2014. “Characterizing Quartz Artifacts: A Case Study from Manitoba’s Northern Boreal Forest”. *Archaeometry*, 56(6): 913–926. doi:10.1111/arc.12092.
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7.2 Non-Refereed Contributions (E.2)

7.2.1 Poster Presentations

ArcticNet Scientific Meeting 2013. The following is a selection of posters that were presented by CEOS students and researchers at the 2013 ArcticNet Scientific Meeting (December 9–13, Halifax, Nova Scotia).

- Barber, L., Rysgaard, S., and Barber, D.G. *Arctic Science Partnership (ASP): a new international network to examine and understand a changing Arctic.*
- Beattie, S.A. and Wang, F. *A Mesocosm-Based Investigation of Mercury Dynamics within Sea Ice.*
- Beattie, S.A., Watts, M., Barber, L., and Barber, D.G. *Arctic Science Day: an effective outreach concept for communicating Arctic system science to high school students.*
- Burgers, T. and Papakyriakou, T. *The Influence of Glacial Meltwater on the Air-Sea Exchange of CO_2 with Nares Strait.*
- Candlish, L. and Barber, D.G. *Microclimates of large ice islands in the Eastern Canadian Arctic.*
- Crabeck, O., Delille, B., Rysgaard, S., Thomas, D.N., Geilfus, N.-X., Else, B.G.T., Tison, J.-L. *First 'in situ' determination of gas transport coefficients (D_{O_2} , D_{Ar} and D_{N_2}), implication for sea ice permeability.*
- Else, B.G.T., Papakyriakou, T., Raddatz, R., Galley, R.J., Mundy, C.J., Barber, D.G., and Rysgaard, S. *Surface energy budget of landfast sea ice during the winter-to-spring transition.*
- Else, B.G.T., Attard, K., Barber, D.G. Campbell, K., Crabeck, O., Galley, R.J., Geilfus, N.-X., Glud, R.N., Hare, A.A., Lemes, M., Papakyriakou, T.N., Wang, F. and Rysgaard, S. *Under-ice eddy covariance flux measurements of heat, salt, momentum, and dissolved oxygen in an artificial sea ice pool.*
- Fishback, F., Watts, M., Barber, L., and Barber, D.G. *Schools on Tundra: Terrestrial-Based Science Outreach Program.*
- Gaden, A. and Stern, G.A. *What's the story? A look into the ArcticNet IRIS 1 Regional Impact Assessment.*
- Horton, B. and Barber, D.G. *The Hudson Bay Integrated Regional Impact Study: Community, Government and industry priorities intersecting with ArcticNet knowledge.*

- Kamula, C.M. and Kuzyk, Z.Z. *Establishing sedimentation rates using ^{210}Pb and ^{137}Cs for Lake Melville, a subarctic estuary in Labrador Canada.*
- Stark, H., Babb, D., and Barber, D.G. *Atmospheric forcing and ice drift dynamics that influence the formation of the North Water Polynya.*
- Watts, M., Barber, L., and Barber, D.G. *Schools on Board: ArcticNet's platform for Arctic system science outreach, targeting high schools across Canada.*
- Winegardner, A.K., Fishback, L., and Macrae, M. *Characterization of tundra pond wetlands and nutrient sources from spring to autumn in the Subarctic.*

Promotion of Arctic Science Partnership. Below are poster presentations during the reporting period that promoted the Arctic Science Partnership to the international community:

- Barber, L., Rysgaard, S., and D.Barber. *Arctic Science Partnership (ASP): a new international network to examine and understand a changing Arctic*, ESA Living Planet Symposium, Edinburgh, UK, September 2013.
- Barber, L., Rysgaard, S., and D. Barber. *Arctic Science Partnership (ASP): a new international network to examine to examine the effects of Arctic climate change*, ArcticNet Annual Science Meeting, Halifax, NS, December, 2013.
- Barber, L., Stern, G., Horton, B., Wang, F., Papakyriakou, T., Rysgaard, S., and D. Barber. *Sea ice research and outreach at the Centre for Earth Observation Science (CEOS), University of Manitoba*. International Symposium on Sea Ice in a Changing Environment, International Glaciological Society, Hobart, Tasmania, March 9–14, 2014.

7.2.2 Workshop Presentations (E.2)

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

- Hanesiak, J. *et. al.*, “Effects of Lake Breezes On Weather (ELBOW) – Manitoba: Background and Field Project Plans for 2013”, 2013 Northern Plains Convective Storm Symposium, Grand Forks, ND, May 13–14, 2013.
- Dyck, R. *et. al.*, “Understanding Severe Thunderstorms and the Alberta Boundary Layers Experiment (UNSTABLE): Characterizing the convective boundary layer to understand convective initiation and development”, 2013 Northern Plains Convective Storm Symposium, Grand Forks, ND, May 13–14, 2013.

- Brimelow, J. *et al.*, “On the devastating natural hazards across the Canadian Prairies between 2009 and 2011”, Joint CMOS, CGU and CWRA Scientific Congress 2013, 26–30 May 2013, Saskatoon, SK.
- Ware, R. *et al.*, “Convective Storm and Lightning Alerts Based on Continuously Updated Stability Indices”, Joint CMOS, CGU and CWRA Scientific Congress 2013, 26–30 May 2013, Saskatoon, SK.
- Oakes, J. and R. Riewe, “Inuit Lifestyles Workshop”, Winnipeg, MB, January–February 2014.
- Gary Stern, C.J. Mundy, Brent Else, and Emily Choy (panellists), “Canada and Arctic: Opportunities and Challenges”, Political Science Students Annual Conference. Feb., 2014.

7.3 Edited Books and Book Chapters (B)

- Barber, L. 2014. Bridging scientific research and science education in high schools through authentic and simulated science experiences. In V.C.H. Tong (ed.) *Geoscience Research and Outreach: Schools and Public Engagement. Innovations in Science Education and Technology*, Vol. 21, Springer, pp. 251–71. Doi: 10.1007/978-94-007-6943-4_15.
- Hanesiak, J., 2013. Contributed a 1000-word article on new technologies to study storms for an undergraduate textbook titled *Weather and Climate* by Sheila Loudon Ross, published by Oxford University Press. ISBN: 9780195445879.
- Milne, S.B., R. W. Park, and D. R. Stenton. 2013. “For Caribou, Chert, and Company: Assessing Mobility as Evidence of Cultural Continuity Among the Palaeo-Eskimos of Southern Baffin Island, Arctic Canada.” in *Mobility, Transition and Change in Prehistory and Antiquity. Proceedings of the Graduate Archaeology Organisation Conference. Hertford College, Oxford, UK*, eds. P. R. Preston and K. Schorle, pp. 49-61. British Archaeological Reports, International Series. Archaeopress.
- Oakes, J. (Ed.) 2014. *Written in Mitten*. Aboriginal Issues Press. University of Manitoba.

A Detailed Budget By Account Code

Description	Code	Title	YTD Total Activity
Total Wages & Benefits	63239	Academic Other	\$20,000.16
	65700	FT AESES Support	\$65,411.00
		Subtotal:	\$85,411.16
Travel	713101	Accom - Domestic (Excl Local)	\$183.55
	713201	Meals/PDiem - Domestic (Excl Local)	\$48.72
	713301	Meals/receipts - Domestic (Excl Lcl)	\$14.21
	713500	Parking - Local (Winnipeg)	\$33.12
	713800	Taxis - Local (Winnipeg)	\$64.30
	713801	Taxis - Domestic (Excl Local)	\$25.33
		Subtotal:	\$369.23
Printing and Duplicating	704001	Printing	\$1,586.28
	704101	Copying	\$327.60
		Subtotal:	\$1,913.88
Materials and Supplies	706003	Office Consumables	\$1,634.06
	706004	Office Furnishings - Under \$2500	\$322.50
	706007	Paper	\$168.17
	706702	General Equipment - Under \$2500	\$35.24
	706704	Signs/Meters	\$159.65
	706710	Other Materials & Supplies	\$2,391.27
	706714	Barcode Labels	\$13.53
	706716	Food	\$426.41
	706752	Meals for Staff Meetings	\$129.42
	706753	Water Coffee Drinks etc.	\$1,977.68
	706756	Meals/Business Meetings	\$1,385.28
	706901	Gasoline	\$167.51
	Subtotal:	\$8,810.72	
Telecommunications	708011	IST -Internet/Internet devices	\$162.78
	708501	Telephone Line Rental	\$7,386.76
	708502	Long Distance-IST Provided	\$166.28
	708503	Cell Phone rental	\$1,231.84
	708508	Voice Mail	\$1,312.53
	708515	Remove/Add Phones-IST Provided	\$120.00
	708555	Parcels	\$7.81
		Subtotal:	\$10,388.00
Other Operational Expenses			

Continued on next page

	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
Interest And Bank Charges	723001	Interest and Late Payment Fees	\$61.81
		Subtotal:	\$61.81
Repairs and Maintenance	740101	R & M - Buildings	\$25.00
	740105	R & M - Doors and Windows	\$158.13
		Subtotal:	\$183.13
Land & Bldg Acquisitions & Improve	730056	PP Construct Costs-Bldg & Maj Reno	\$345.68
		Subtotal:	\$345.68
Total Academic Pool Revenue			\$10,000.16
Total Salary/Benefits Revenue			\$65,411.00
Total Salary/Benefits Expenditures			\$(88,276.54)
		Total Salary Revenue Less Expenditures	\$(12,865.38)
Total Non-Salary Revenue			\$37,635.00
Total Non-Salary Expenditures			\$(24,014.78)
		Total Non-Salary Revenue Less Expenditures	\$13,620.22
		Total Revenues Less Expenses	\$754.84