Project title

Community-driven Sea Ice and Ocean Research in the Contrasting Coastal Domains of Hudson Bay

Objectives & Activities

The proposed project builds on a highly successful integration of community-driven and scientific research priorities to understand and predict environmental changes in the seasonally ice-covered coastal ecosystem of Hudson Bay. Community priorities for addressing cumulative impacts were established through Voices from the Bay (McDonald et al., 1997) and follow-up work by the Hudson Bay Consortium and ArcticNet IRIS initiatives. In eastern Hudson Bay, priorities include understanding changing surface water salinity, impacts on sea ice formation and melt, and implications for safe travel on the sea ice and security of wildlife resources in the face of changing sea ice habitats and ice entrapments of eiders and beluga. A community-driven research network was established by the Arctic Eider Society (AES) in partnership with CEOS, University of Manitoba, towards understanding these changes in the coastal corridor of eastern Hudson Bay. Successful community-based research programs are established in the communities of Sanikiluaq, Kuujuaraapik, Inukjuak, Chisasibi, and Umiujaq in eastern Hudson Bay. We began working with the communities of Chesterfield Inlet and Naujaat in 2016 on questions related to shipping impacts and wildlife resources. Some hunters in this community travel to the floe edge almost weekly during the winter, therefore understanding causes of changes in the ice ocean system and implications for the ice-associated food web are also a priority.

1. Continue the highly successful community-driven research in eastern Hudson Bay and expand it to northwest Hudson Bay (Chesterfield Inlet and Naujaat), with a goal towards

    i) establishing comparison sites in eastern and western Hudson Bay to support bay-wide monitoring objectives and

    ii) addressing hypotheses about contrasting oceanography in the coastal domain.

Activities will include community-based ice and ocean sampling focused on the winter period and winter/spring transition, with more modest sampling efforts in the summer/fall period.

2. Contribute to efforts to predictively model bay-wide environmental changes, which have been undertaken by the BAYSYS and NCE ArcticNet programs. The proposed project would contribute uniquely through provision of year-round coastal data collected by communities and by addressing key science gaps on the role of changing freshwater and ice dynamics in the Bay's coastal domain.The project's contributions will help ensure modelling products are relevant to coastal areas and thus community priorities such as ice safety and food security.

Scientific Background

The shallow Arctic Coastal Domain (ACD) is a critical gap in our understanding of Arctic ecosystems (Macdonald, 2000; Carmack et al., 2015). River runoff is near ubiquitous around the perimeters of the arctic and subarctic seas, but large variability reflects the distribution of various sources of river runoff along a coastline and large seasonal and inter-annual variability of the discharge. In some regions, there is little or no runoff during much of the year; in other regions, there are direct river inputs or flows from merged 'upstream' sources. Once reaching the ocean, the freshwater supplied by river runoff drives a contiguous coastal boundary current that is of key importance not only for physical and chemical processes that couple the terrestrial and marine environments, but also a controlling factor for wildlife and human use (Carmack et al., 2015). Through sensitive interactions and climate feedbacks, the ACD is a focal point for the environmental change we are witnessing today, and thus it is of key importance when considering sustainable northern development.

The sensitivity of the ACD to environmental change lies, first, in its combined estuarine-like terrestrial and marine influence, and second, in the influence of the seasonal sea ice growth-melt cycle. In addition, tidal dynamics mix things up by controlling the rate of exchange of heat, mass and properties between the terrestrial, marine and ice regimes. Through influences on stratification, freshwater inputs, and tidal mixing can alter the onset and rate of sea-ice formation. Where and when stratification is strong due to the presence of freshwater ("positive" estuary), the deep ocean remains largely isolated from terrestrial, surface ocean and atmospheric influences. In contrast, where freshwater is not present, it is possible for tidal mixing and/or brine released from sea-ice formation in winter to overcome stratification ("negative" estuary), and result in convection and possibly deep water formation that can, e.g., replenish dissolved O_2 levels, transfer CO_2 from the atmosphere, and also upwell nutrients to the surface layer. It is clear that these contrasting conditions have a strong influence on the biological productivity of the regions, however, they remain too poorly documented and understood in Hudson Bay to allow prediction.

Scientifically, Hudson Bay provides a very interesting study in contrasts: the southern portion of the system receives a tremendous amount of river runoff together with seasonal sea ice melt, while the northern (northwestern) portion receives Arctic Ocean outflow from the Archipelago and Foxe Basin and has no significant river runoff with the exception of Chesterfield Inlet. Thus, we encounter two oceanographically distinct regions within the Hudson Bay ACD, with marked differences to be expected in ice-ocean processes and nutrient dynamics. Specifically, we hypothesize that, in the absence of river runoff and the presence of a large, recurrent polynya (flaw lead), the northern coastal domain will be characterized by deep winter mixing and consequently strong replenishment of nutrients in surface waters. This will support strong new production (ice algae and phytoplankton) in the inshore waters in spring (with the return of sunlight). Formation of deep water (defined, in Hudson Bay, as the waters below ~100 m) may also occur in the northern ACD of Hudson Bay where wind-stress and tidal driven

divergence is strong. In contrast, in southeast Hudson Bay, where significant freshwater remains in the coastal region in winter (Eastwood et al., in prep.), we expect to find reduced depths of winter convective mixing, reduced nutrient replenishment in surface waters, and thus reduced inshore new production in spring. Only strong episodic weather events (storms) may overcome the stratification and cause a pulse of nutrients to the surface water layer. These differences in nutrient replenishment driven by contrasting stratification and mixing regimes may ultimately shape fundamental aspects of the ecosystem that cascade through the marine food web. The contrasting ACDs in Hudson Bay will also respond differently to ongoing and projected environmental change, particularly a shortened ice-covered season (Gagnon and Gough, 2005; Hochheim and Barber, 2014) and changes in the timing and volume of river runoff (Déry et al., 2011).

Changes in the ACD will have direct and observable impacts on both ecology and human food security. The people in the northern communities we have worked with have witnessed and reported notable changes in their environment. These changes relate the presence of freshwater and the timing of seasonal transitions in the sea ice cover to the presence of marine flora or animals. They look to the scientific community for answers why the coastal environment is changing and projections into the future. Of particular concern are climate change, altered river regimes from upstream hydroelectric projects, and industrial activities such as shipping. Improving understanding and predictive capacity, particularly for the coastal domain that is most used by Inuit, has been identified as a priority for research. This proposal is designed to address community priorities and gaps for predictive modeling of the Hudson Bay ACD.

Approach and methodology

This project will test hypotheses about contrasting ice-ocean processes and nutrient dynamics in the coastal domain of Hudson Bay by expanding upon existing community-based research programs in the communities of Sanikiluaq, Kuujuaraapik, Inukjuak, Chisasibi, and Umiujaq in eastern Hudson Bay and extending the program to northwest Hudson Bay (Chesterfield Inlet and Naujaat). Activities will include community-based ice and ocean sampling focused on the winter period and winter-spring transition, with potentially smaller sampling efforts in summer/fall. The sample sites will be selected with direct consultation with the communities.

We plan to continue and expand the scope of the existing and extremely successful community-based research programs in the communities of Sanikiluaq, Kuujuaraapik, Inukjuak, Chisasibi, and Umiujaq in eastern Hudson Bay (that will end with NCE ArcticNet). Run by the AES, this five-community network has a team of hunters in each community that have been trained and equipped to carry out oceanographic sampling. Local expertise on important ice processes (patterns of formation and melt), polynyas, and ecosystems, has helped shape the study. Coordinated efforts among these communities provide a broader geographical scope that spans the ACD, from inshore (Kuujjuaraapik) to offshore (Sanikiluaq), and from

upstream (Chisasibi) to downstream (Inukjuak). Now that capacity for supporting ocean research is established, we will expand the work to include endpoints related to nutrient dynamics and coastal productivity (e.g., particulate organic carbon, chlorophyll *a*). We also plan to extend the community-driven program initiative to northwest Hudson Bay (Chesterfield Inlet and Naujaat).

Proposed activities will include community-based ice and water sampling, deployments of relatively simple and robust ice-tethered moorings for time-series data collection, and hands-on training and instruction to build capacity in the community for oceanographic research support. We anticipate collecting *no more than 600 L of sea-water from the coastal environment of Chesterfield Inlet and Repulse Bay* will be collected over the period of 1 year. AES's IK-MAP and SIKU platforms will be incorporated for information exchange.

Results and Benefits

This project will generate data on the oceanographic and sea ice conditions, which will provide the first description of the ACD for Hudson Bay, and a direct comparison between the northwestern and eastern sides of the bay. The proposed project will train university students, other southern HQP, and Cree and Inuit in oceanographic sampling and observations. The data collected will result in scientific publications and presentations, as well as plain-language materials to be circulated in participating communities (translated into Inuktitut and Cree).

Additionally, results will be shared with communities through the Interactive Knowledge Mapping Platform (IK-MAP), an initiative of the AES designed to coordinate research efforts across the region and to engage community members and decision makers in sea ice research.

Outcomes from the project

Most past field programs in Hudson Bay have collected data only during the summer and fall periods, with an emphasis on surface layers and areas accessible by ship (i.e., excluding the shallow coastal domain). Due to the accumulation of sea ice from Foxe Basin in Repulse Bay, oceanographic data is significantly absent from this area. There is virtually no information on how the coastal domain in northwest Hudson Bay, which is upstream of the Bay's major river inputs, evolves through winter, nor whether this region's low freshwater regime contributes to greater coastal productivity, enhanced importance of ice algae at the base of the food web, and deep water formation and renewal. Measurements of winter conditions in flaw leads, such as the large and persistent one in northwest Hudson Bay may, for the first time, provide evidence of deep water formation in Hudson Bay. Thus, there is tremendous potential for generation of new knowledge from the proposed project.

The main end-users of the information are agencies involved in monitoring and setting priorities for monitoring, including communities, regional organizations and institutions of public government (management boards), and national and international bodies such as NCP and AMAP. At present, the coastal domain that stretches along thousands of

kilometers in northern Canada poses a real challenge for monitoring. The domain is extremely variable and the sources of variability are not well understood.
While the primary concern of most agencies may be ecosystem services (associated with wildlife harvests, for example), in the context of ongoing changes, it may be the oceanographic conditions that dictate whether ecosystems and their services are supported into the future. New knowledge generated in this project about winter processes in the coastal environment of Hudson Bay and drivers of variability and change will help provide a framework for selecting coastal monitoring sites and choosing elements of monitoring programs. The improved process-level understanding gained from Hudson Bay coastal sites is also transferable to the coastal domain of the Arctic Ocean, where many coastal areas are even more remote and inaccessible than those in Hudson Bay. Characterizing the ACD is an essential first step in understanding how cumulative effects may impact this important region in the future. This scientific understanding will provide the basis to consider and address many applied problems.

For coastal peoples whose way of life is inextricably linked to the health of the ecosystem, it can form the basis to model, for example, how climate change will affect ice conditions in the ACD, and if and how water management options by hydroelectric or mining companies could mitigate the warming effects of reservoir water, as well as altered freshwater flows. This scientific knowledge together with traditional knowledge of sea ice ecosystems will allow local and regional planners, managers and other stakeholders to have a broader and yet also more specific understanding of the system. Finally, improved understanding of sea ice dynamics and causes of variability in the ACD could improve ice safety for community members.

Training, outreach and capacity building
This project will provide opportunities to expand community-driven research approaches to Chesterfield Inlet and Naujaat, including development of skills for locals that will be useful for other research efforts. Opportunities for outreach include presentations of results to participating communities and circulation of plain-language versions of results in local language, as well as participation in scientific meetings to help raise the profile of arctic research. This project will improve capacity for research endeavors in each community.

Community and partner involvement
As described above, the proposed project represents a collaboration and partnership between U of M, AES and Northerners. Communities of Sanikiluaq, Kuujuaraapik, Inukjuak, Chisasibi, Umiujaq, Naujaat and Chesterfield Inlet have indicated their support and will help identify areas of local importance (polynya, flaw lead), and contribute to sampling efforts. Relationships are well established for the most part, with additional consultation planned for Chesterfield Inlet and Naujaat. The proposed project helps address key priorities identified by these communities as described above. Community members will benefit from training in sea ice / ocean research, improved access to scientific information, establishment of east-northwest comparison sites to support future Bay-wide monitoring.

Indigenous knowledge will inform the timing of the sampling efforts, with respect to safely navigating sea ice to sampling locations, as well as informing sampling sites based on local importance, and/or geographical/bathymetric interest. Project design and implementation will be done fully in partnership.

Team expertise and experience

Dr. Zou Zou Kuzyk is a coastal oceanographer/biogeochemist with experience working in various Arctic regions including Hudson Bay. She is interested in freshwater dynamics and biogeochemical cycles of carbon and other elements and impacts of environmental change. She leads the community-driven ArcticNet project on freshwater-marine coupling in Hudson Bay and is co-lead of the Hudson Bay IRIS. She is a co-investigator on the BAYSYS project and a MEOPAR project (COARnet). Dr. Jens Ehn is an Associate Professor and the academic lead for Team 1 (Climate and Marine System) of the NSERC CRD BAYSYS project, which is a collaborative effort with Manitoba Hydro to understand the contributions of climate change and hydro-electric regulation to the variability and change of freshwater marine coupling in the Hudson Bay System. He is a physical oceanographer with experience in measurements of oceanographic state variables, optical- and acoustical variables to study heat, salt, dissolved organic matter and particle transport and formation within sea ice and seawater, sea ice melting and heating rates. Dr. Robie Macdonald is an internationally respected geochemist and oceanographer, with tremendous expertise on the Arctic Ocean and climate change. Drs. CJ Mundy and Christine Michel are biological oceanographers with expertise in sea-ice associated food webs. Dr. Igor Dmitrenko and Sergei Kirillov are physical oceanographers specializing in arctic shelf seas and vertical mixing. Dr. David Barber is a Tier 1 Canada Research Chair in Arctic System Science specializing in remote sensing of sea ice environments. Dave Babb is an experienced researcher in ice mass balance and thickness distributions. Michelle Kamula is a biogeochemist with experience in community-driven research programs in Nunatsiavut and Nunavut and coordinated research in Chesterfield Inlet/Wager Bay for Government of Nunavut in 2016.

Dr. Joel Heath is the founder and Executive Director of the Arctic Eider Society and 2014-15 Fulbright Chair in Arctic Studies, sea ice ecologist, filmmaker (e.g. People of a Feather, Frozen Planet); he brings broad interdisciplinary experience in research, education, outreach, program management). Misha Warbanski is a marine ecologist and journalist who coordinates field activities and communications for the Arctic Eider Society. Lucassie Arragutainaq has led major initiatives in Hudson Bay for two decades and is actively engaged in ongoing work in eastern Hudson Bay. Barney Aggark is a former chairman of the Aqigiq HTO and an active proponent for community-driven research addressing priorities for Chesterfield Inlet.