Freshwater-Marine Coupling in the Hudson Bay IRIS

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Abstract

Climate models predict warming in the Hudson Bay watershed that may alter the amount and timing of runoff and hence, of the load of suspended solids, dissolved organic matter and other major nutrients, and heat delivered to the Bay. In the Churchill and Nelson estuaries, such changes will be superimposed on earlier changes in the hydrological regime; diversion of Churchill River flows into the Nelson River and a shift of a third of total discharge from summer to winter. Our study of transfer pathways through river estuaries into Hudson Bay will improve our understanding of the effects of these changes. The overarching objective of this project is to describe the impact of freshwater quality and quantity on marine processes within Hudson Bay. In particular we are interested in understanding the principal processes which couple the freshwater and marine systems in Hudson Bay and to examine the cumulative impacts of climate change and hydroelectric development on Hudson Bay. Our key industry partner (Manitoba Hydro) will use this information to examine aspects of environmental impacts due to development of dams along the Nelson River, including the planned development of Conawapa Generating Station.

More specifically our team will determine the fluxes, pathways and fate of suspended solids and dissolved organic matter transferred through the Churchill and Nelson estuaries during the open water season when mixing in the estuary is determined by wind-driven waves, tides and fluvial and marine currents, and under ice, when mixing is determined by tides and fluvial and marine currents alone. We will also investigate the relative significance of fluvial loading and littoral resuspension to concentrations of suspended solids in the estuaries and Hudson Bay and to study the effect of suspended solids and dissolved organic matter on radiative transfer in the estuary and nearby Hudson Bay. This team will also investigate historical effects of climate on Hudson Bay by interpretation of data stored in bottom sediments within our three supersites - the estuaries of the Nelson and Churchill Rivers, and of the Grande Rivière de la Baleine - and also in sediments deposited at the Bay-wide scale.

Key Messages

1. Between 1980-2010, the open water season has, on average, increased by 3.1 (±0.6) weeks in Hudson Bay, 4.9 (±0.8) in Hudson Strait and 3.5 (±0.9) weeks in Foxe Basin. For every 1˚C increase in SAT, SIE decreases by 14% (% of basin area) with in the Hudson Bay System; a 1˚C increase delays freeze-up by 0.7 to 0.9 weeks on average. Spring SIEs and breakup dates are highly correlated with fall (lag1) and spring SATs, and U and V component winds. Proportionately spring and fall SATs combined, play a dominant role (70-80%) in SIE, the remaining leverage is attributed to dynamic forcing (winds). The relative leverage of fall (lag1) SATs and surface winds are shown to be significant and vary by basin (Hochheim and Barber 2014).

2. Two separate papers have recently been completed that examine surface sediment samples from the Hudson Bay system (Hare et al. 2014; Heikkilä et al. 2014). The role of light and nutrients as affected by fresh water stratification and sea-ice cover in regulating marine primary production in Hudson Bay was investigated using sedimentary dinoflagellate cysts and geochemical tracers as proxies (Heikkilä et al. 2014). There are large regional differences in species composition and flux. In Hudson Bay, nitrate availability and vertical stratification are key drivers. By contrast, in Hudson Strait, availability of diatoms is the main control. Seasonal sea-ice cover is not important for cyst production in the system.

3. Hare et al. (2014) use Rock-Eval pyrolysis and isotopic analyses to characterize organic matter contributions from marine and terrigenous sources. Organic matter contributions from both marine and terrigenous sources are distinguishable based on hydrogen index, oxygen index and residual carbon, as well as carbon isotopes. The authors find that these analyses fully describe marine vs. terrigenous and fresh vs. degraded organic matter patterns.

4. Differences between 137Cs and 210Pb sediment accumulation rates suggest an offshore shift in the locus of fine sediment deposition during the past ~150 yr (Hülse and Bentley Sr. 2012). In the pan-arctic context, 210Pb and 137Cs inventories in sediment cores together allowed Kuzyk et al. (2013) to differentiate sites influenced by horizontal particle transport (focusing) vs. scavenging driven by vertical particle flux. Large inventories of 210Pb in sediments along the North Bering-Chukchi shelf result primarily from focusing, while those along the north Chukchi slope (Barrow Canyon) and in Baffin Bay/Davis Strait reflect strong boundary scavenging, likely supported by lateral exchanges with deep/interior Atlantic-origin waters. Spatial variability within Hudson Bay will be further investigated using existing cores to learn whether similar spatial and temporal are replicated there.

5. Colored dissolved organic matter (CDOM) in Hudson Bay is controlled by terrestrial inputs making it possible to detect river plumes through remote sensed methods more reliably than using suspended sediment plumes alone. CDOM absorption was reduced significantly within the Bay, likely due to photobleaching. However, there was no or negligible indication of absorption removal during initial estuarine mixing. Spectral slope parameters at shorter wavelengths were the best indicators for absorption removal by photobleaching (Granskog 2012).

6. Watershed and seasonal ice each supply roughly half of freshwater inventory, equivalent to ~3 m depth spread over the upper mixed layer, in Hudson Bay. The spatial distribution differs: Sea ice meltwater contribution grades from <2 m freshwater in northwest to >3 m in southeast; influence of fluvial water is greater near the southern and eastern shores, lowest in northern and central Hudson Bay (<0.25 m) and highest near the mouth of James Bay (>2 m) (Granskog et al. 2007).

7. Exchange between the previously-described coastal fresh water conduit, which carries relatively nutrient-rich, river-derived fresh water anticlockwise around the littoral zone of the Bay (Granskog et al. 2009), and central Hudson Bay was described (St. Laurent et al. 2011); model results suggest this process effectively increases the residence time of fluvial water in Hudson Bay to an average of 3 years. Isotopic data, that distinguish river-derived fresh water from sea-ice melt (Granskog et al., 2011) imply a somewhat longer (~5 year) flushing time for the interior portion of Hudson Bay.

8. Simulations of the halocline, the baroclinic boundary current, spatial variability of freshwater content, and the fall maximum in freshwater export in Hudson Bay and James Bay clarified the important differences in the freshwater balance of the western and eastern sides of Hudson Bay (St-Laurent et al. 2012), but do not discuss residence time specifically. This is the subject of planned further study by Heath et al. and Barber et al. using a combination of in situ, remotely sensed and model approaches.

9. Hata et al. (in review) have document the first observations of anisotropic thermal stresses in sea ice. Using models, this is attributed to preferred c-axis alignment in the ice crystal with the surface ocean currents.

Objectives

We are in the process of addressing a number of interrelated objectives that are designed to gain insights into the processes which control freshwater-marine coupling in Hudson Bay, the southern Beaufort Sea (SBS) and Baffin Bay (BB). The following objectives highlight our ongoing program:

- To advance knowledge of spatial and temporal variability in the dynamic and thermodynamic forcing of sea ice by freshwater, both within

Hudson Bay, and relative to other regions of the Arctic.

- to determine sources, fluxes and sinks of suspended sediments, particulate and dissolved organic matter (DOM) over the seasonal cycle in Hudson Bay and in particular for the three Hudson Bay IRIS supersites; relative to those in the SBS.
- to determine how freshwater fluxes affect the marine ecosystem, biogeochemical processes and contaminant transport (through collaboration with other teams in our IRIS).
- to determine how sea ice affects freshwater-marine coupling and associated marine ecosystem function particularly in terms of the dynamics freshwater plumes under sea ice.
- to understand the significant role played by the boundary current in the freshwater budget of the system, and its sensitivity to wind-forcing.
- to retrieve/redeploy all ArcticNet Long Term Observatory and Manitoba Hydro (MH) funded moorings.
- to analyse data and publish a Hayes - Nelson estuary sediment budget and sediment transport study (publication in collaboration with Manitoba Hydro).
- to analyse data and publish Hudson Bay carbon flux papers (see collaborator list).
- to model salient processes and to use these models to illuminate particular processes required in the development of the Hudson Bay IRIS, and
- through these studies to determine the relative roles of climate change versus hydroelectric development on freshwater-marine coupling in Hudson Bay by linking contemporary climate process studies to paleo-oceanographic analysis.

Introduction

Freshwater loading has a major influence on coastal arctic marine waters. Freshwater fluxes into Hudson Bay are dominated by the large-scale hydrological cycle of the Hudson Bay watershed. Recent evidence (Déry et al. 2005) has shown that freshwater input to Hudson Bay has decreased over the past decades due to climate variability and increased water use. There has also been a notable shift in the seasonality of Hudson Bay discharge related in part to storage of water in reservoirs and later release for the generation of hydroelectricity (Déry et al. 2011). The annual cycle of sea ice growth and melt over Hudson Bay also plays an important role in the freshwater budget of the Bay and the associated exchange of freshwater between the estuaries, coastal current, and sea ice features. These dynamics have both biological and biogeochemical impacts (see summary in Macdonald and Kuzyk 2011).

Imported heat and nutrients make estuaries highly productive regions and preferred habitats in Hudson Bay (Stewart and Lockhart 2005; Kuzyk et al. 2008). Beyond the estuaries, freshwater runoff affects primary productivity negatively by increasing vertical stability of the water column, and positively through nutrient additions. Suspended solids are associated with nutrient loading that supports primary production, but may also reduce light penetration needed for production (e.g., Herdendorf et al., 1977) and they carry most of the organic and heavy metal pollutant load transported in this system (e.g., Hare et al. 2008; Kuzyk et al. 2010; Kuzyk et al. 2013).

Our team focuses on three ArcticNet Hudson Bay IRIS supersites. The first two, the estuaries of the Churchill and Nelson Rivers, are appropriate regions to focus much of our study of fluvial loading to Hudson Bay. The Nelson delivers 13% of total annual runoff into the Hudson-James Bay system, and fully one-third in winter (Déry et al. 2005) and with it an equal or greater proportion of terrigenous suspended solids and dissolved organic matter (DOM). The Nelson is a highly productive estuary (Baker, 1989) and is summer home to the largest concentration of beluga in the world (Stewart and Lockhart 2005). Together the two western ArcticNet supersite estuaries are affected by hydro-electric development resulting in more than 75% reduction in the flow of the Churchill River and a 30% increase in the Nelson. The third supersite, the estuary of the Grande Rivière de la Baleine, is unaltered by hydro-electric development and presents a further contrast in draining a watershed confined to the Precambrian Shield, whereas the Nelson River drains predominantly Plains geography. Due to funding constraints, this supersite is no longer active. Climate models predict warming in the Hudson Bay watershed that may alter the amount and timing of runoff and hence, of the loads of suspended solids, DOM and other major nutrients, and heat delivered to the Bay. These delivery mechanisms affect physical-biological, and freshwater marine coupling within the Bay. We contrast processes in Hudson Bay with Freshwater-marine coupling in the Soutuern Beaufort Sea (Mackenzie River influence) and we are preparing to scale up our work on Freshwater-marine coupling in Baffin Bay as part of our CERC collaborations and new initiatives between Greenland, Canada and Denmark.

Activities

A total of 21 stations in the Nelson/Hayes estuarine system were sampled from a Zodiac on August 31, 2013 (Nelson River) and September 1, 2013 (Hayes River) by the participants (Figure 1). At each station a photograph was captured for sky condition and water colour and a CTD cast was made using a cage with two RBR CTDs and an Idronaut CTD operating in triplicate to ensure redundancy and provide cross-calibration information. Casts were made to 55 m or until solid bottom was contacted.

We collected water samples following identical protocols to previous BaySys cruises: surface samples were collected approximately 0.3 m below the surface within the Nelson/Hayes estuarine system and subsampled onboard the Pierre Radisson for total suspended sediments, CDOM, chlorophyll, particulate organic carbon (POC), particulate organic nitrogen (PON), phosphorus, dissolved delta-O18, and salinity.

In October 2013, CEOS (Drs. Kuzyk, Ehn, Dmitrenko and Barber and PhD student Vlad Petrusevich)

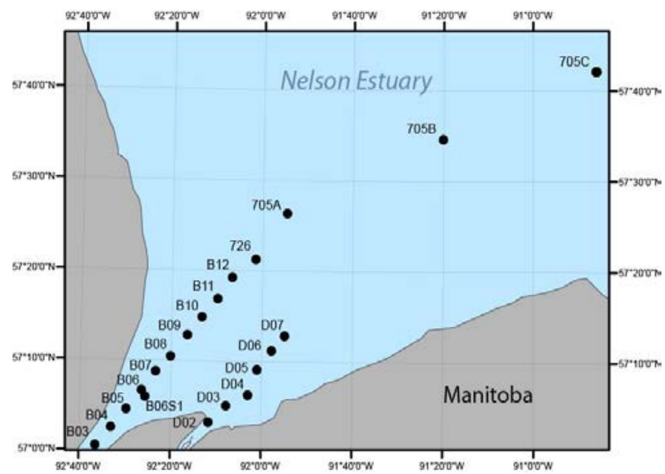

Figure 1. Nelson Estuary Water Quality Stations.

began working with a group that includes the Arctic Eider Society, the Sanikiluaq Hunters and Trappers Association (HTA), Fisheries and Oceans, and Environment Canada, seeking to assess the cumulative impacts of environmental change on southeast Hudson Bay. This project will expand to include another PhD or Masters student under the supervision of David Barber. The plan is for at least three years of study, with a focus on community-based research and monitoring of the ocean and sea ice in the region. Specifically, our aim is to determine the wintertime distribution of freshwater in southeast Hudson Bay, its sources, and its interactions with and impacts on sea ice and polynyas. Field work began in January 2014, with Dr. Kuzyk and PhD student Vlad Petrusevich joining other team members for about 10 days of sampling and data collection in the Sanikiluaq area. Instruments were installed to monitor salinity, temperature and current velocities in the area for a two-month period. Local team members will also be continuing to collect monitoring data throughout the winter. Parallel projects will link the oceanographic information to changes in sea ice habitats including entrapment events for marine mammals and birds.

Beginning in December 2013, we initiated a project that is receiving funding from Transport Canada's Northern Transportation Adaptation Initiative.
This project, entitled "From Science to Policy: Sea

ice changes and their impacts on transportation infrastructure and operation in Hudson Bay, with particular emphasis on the Churchill Gateway System" will be a contribution to a group called the Network of Expertise on Transportation in Arctic Waters (NEXTAW). The initial phase of our work with this group focusses on reviewing literature in order to identify and elaborate on climate-related vulnerabilities and opportunities for the infrastructure and operations of Port of Churchill. Later phases of applied science work will focus on adding to the research body required to address vulnerabilities and take advantage of opportunities. This will include a combination of in-depth review of historical data, in situ data from ArcticNet work in Hudson Bay, and modelling output from NEMO. Finally, the project is expected to have an education and outreach component that will engage high school students (through the Schools on Board program), university students, and transportation professionals.

Also in December 2013, we made a large advance in our efforts to launch a collaborative project in Hudson Bay with Manitoba Hydro. Manitoba Hydro has now officially committed to the project and will provide substantial funding towards it. We plan to hold a planning workshop for the project in early April, 2014 and will finalize the proposal to NSERC in early May.

This year, we also initiated an Arctic Watersheds Systems Group. This group gathers expertise from across the University of Manitoba including Drs. Lobb (Soil Science), Ali (Geological Science), and Stadnyk (Civil Engineering). This collaboration connects U of M freshwater and marine expertise, focusing it around regulated and permafrost-dominated watersheds. This group is currently collaborating on the above noted NSERC-CRD proposal with Manitoba Hydro.

In an effort to relate our knowledge of freshwater marine coupling in Hudson Bay to coupling processes elsewhere in the Arctic, we have continued our collaboration with Bruno Tremblay. This year, his team re-deployed an internal Ice Stress Buoy (ISB) was deployed near the center of a multiyear floe in the Viscount Melville Sound in the Canadian Arctic Archipelago (CAA). The buoy collected hourly internal sea-ice stresses, Global Positioning System (GPS) coordinates, air temperature and orientation of principal stresses for nearly ten months between October 10, 2010 and August 17, 2011, with some data degradation after the ice temperature at the depth of the stress sensor reached the freezing point on June 28, 2011. The position record indicates that the landfast season was nearly five-month long from January 18 to June 22, 2011.

Each year since 2007, Tremblay's team has deployed ice buoys in the Viscount Melville Sound or Queen Elizabeth Islands. This year an UpTempo buoy that measures the vertical profile of ocean temperature at several depths (manufactured by MetOcean) was deployed – in addition to the Ice Mass Balance buoy and Spherical Drifters. The buoy data will be analyzed this coming year after we have collected a full seasonal cycle.

Finally, as reported in the Sea Ice annual report, our collaborative implementation of the NEMO numeric ice-ocean model (between Bedford Institute of Oceanography and Centre of Earth Observation Science) has continued. In the last year, we have completed a series experiments on spin up: the NEMO was driven by a CORE2 normal year forcing and run 20 years. Then the results were used as initial conditions to run NEMO driven by CORE2 inter-annual year forcing from 1948 to 2009 (hindcasting). The results of spin-up run were also used to do the projection, use it as initial condition, run NEMO driven by MIROC5 model output from 2006 to 2050. This effort will continue by validating model simulation for specific years with available DFO and ArcticNet observations, and by upgrading the present ice-ocean model for shallow and narrow strait ice and ocean processes that occur within the Hudson Bay, Baffin Bay, and the Beaufort Sea.

Results

Hochheim and Barber (2014) completed an updated climatology of the Hudson Bay Ice system extending from 1980-2010. Statistically significant changes in sea ice extent and freeze-up and break-up dates are found through-out the Hudson Bay system (including Hudson Bay, Hudson Strait and Foxe Basin) (Figure 2). These changes are not evenly distributed, but reflect both dynamic and thermodynamic forcing, as well as freshwater cycling towards the SE corner of the Bay.

This paper also examined the thermodynamic and dynamic forcing of sea ice within the Hudson Bay System including: Hudson Bay, Hudson Strait, and Foxe Basin and found that in fall freeze-up dates (Figure 3) and spring breakup dates (Figure 4) highly correlate to seasonal surface air temperatures (SATs) and winds, as are changes in freeze-up dates and breakup dates. Similarly strong correlations are found for sea ice extent (SIE). Lagged correlations are also found between spring SIE / breakup and the temperature from the preceding fall.

Two separate papers have recently been completed that examine surface sediment samples from the Hudson Bay system were analysed in order to examine the role of key regulators of arctic marine productivity (Heikkilä et al. 2014) and organic matter contributions from marine and terrigenous sources (Hare et al. 2014). These analyses are based on 13 box core sample that were collected from the CCGS Amundsen in 2005, as well as one from Foxe Basin collected in 2006 (Figure 5).

Heikkilä et al. (2014) investigate how light and nutrients as affected by freshwater stratification and sea-ice cover affect the spatial distribution and production of dinoflagellate cysts. The highest cyst fluxes are found in eastern Hudson Bay. Dinoflagellate cyst assemblages show distinct spatial patterns revealing three compositional domains: eastern Hudson Bay, western-central Hudson Bay and Hudson Strait. There are also distinct spatial variations in heterotophic and autotrophic cysts. The authors also use lignin and its biomarkers as proxies for freshwater

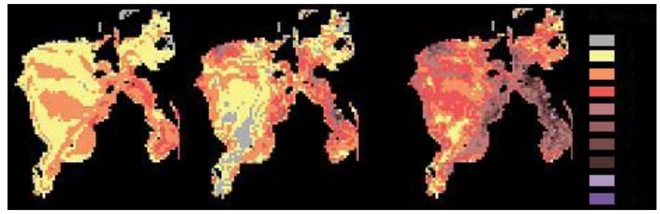

Figure 2. The spatial distribution of changes in, a) median freeze-up date (1980-1995 vs. 1996-2010), weeks later; b) median breakup date (1980-1995 vs. 1996-2010), weeks earlier; c) cumulative change in weeks indicating a longer open water season.

inputs and nitrate availability (nitrogen isotopes), and sea-ice concentrations derived from passive microwave data as a proxy for light availability. The authors note the following highlights, as summarised conceptually in Figure 6:

- In Hudson Bay, nitrate availability and vertical stratification are key drivers.
- In Hudson Strait, availability of diatoms is the main control.
- Seasonal sea-ice cover is not important for cyst production in the system.

Hare et al. (2014) use Rock-Eval pyrolysis and isotopic analyses to characterize the sources and distribution of organic matter in the box cores indicated in Figure 5. Organic matter contributions from both marine and terrigenous sources are disguishable based on hydrogen index, oxygen index and residual carbon, as well as carbon isotopes. The authors find that these analyses fully describe marine vs. terrigenous and fresh vs. degraded organic matter patterns (Figure 7).

In a pan-arctic study, Kuzyk et al. (2013) evaluate 210Pb and 137Cs in 25 sediment cores collected during the International Polar Year from a transect spanning the North American Arctic margin, from the North Bering Sea to Baffin Bay/Davis Strait. Profiles and inventories of the radioisotopes were used to determine sediment mixing and accumulation at each site and to assess the intensity of scavenging

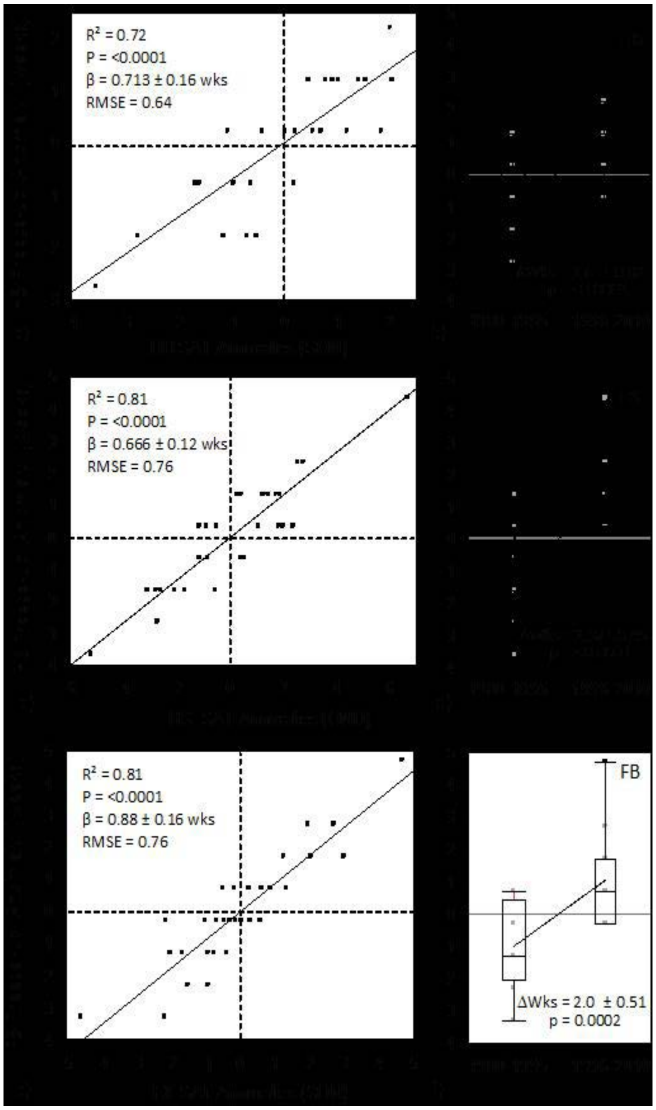

Figure 3. Observed vs. predicted freeze-up dates based on fall SATs for a) Hudson Bay, c) Hudson Strait and e) Foxe Basin. (b,d,f) The distribtion of freeze-up dates during the cooler (1980-1995) and warmer (1996-2010) climate regime and the resulting mean change in freeze-up date (weeks). Sigificance of differences based on t Test assumming unequal variances.

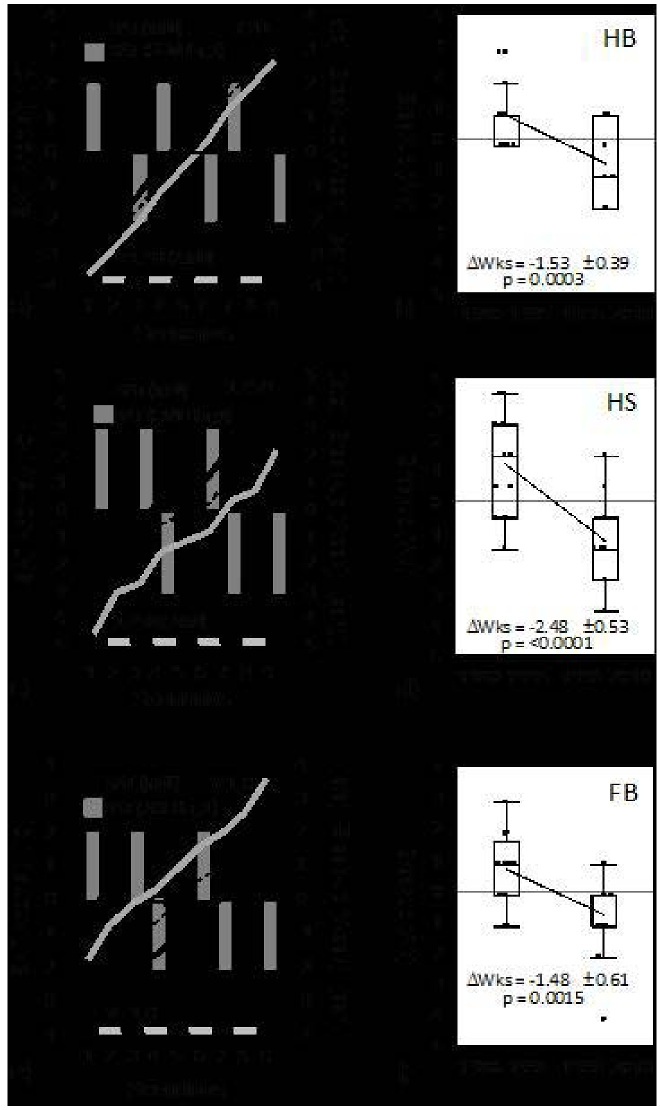

Figure 4. Predicted breakup dates based on spring and fall (lag1) SATs stratified by the wind component (± UorV winds), for a) Hudson Bay, c) Hudson Strait and e) Foxe Basin. (b,d,f) The distribution of observed breakup dates during the cooler (1980-1995) and warmer (1996-2010) climate regime and the resulting mean change in breakup date (weeks). Sigificance of difference based on t Test assumming unequal variances.

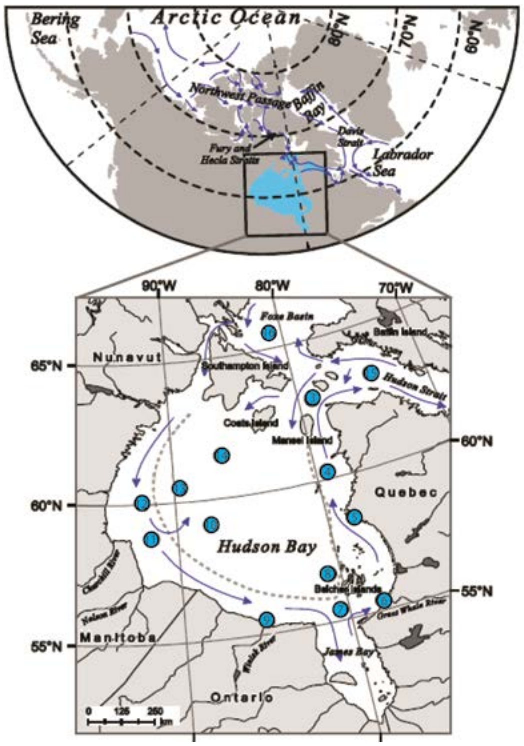

Figure 5. Locations of box core samples taken in 2005, 2006 (modified from Heikkilä et al. 2014).

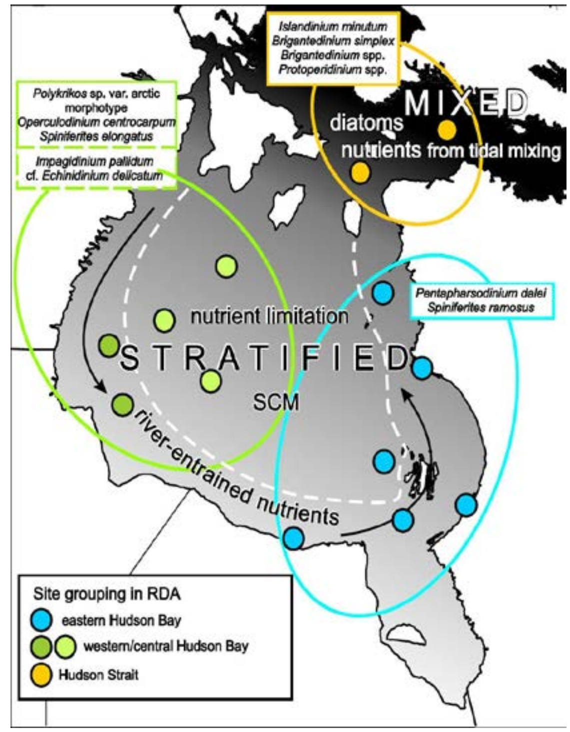

Figure 6. Conceptual summary of the spatial organisation of dinoflagellate cyst assemblages in the Hudson Bay System (from Heikkilä et al. 2014).

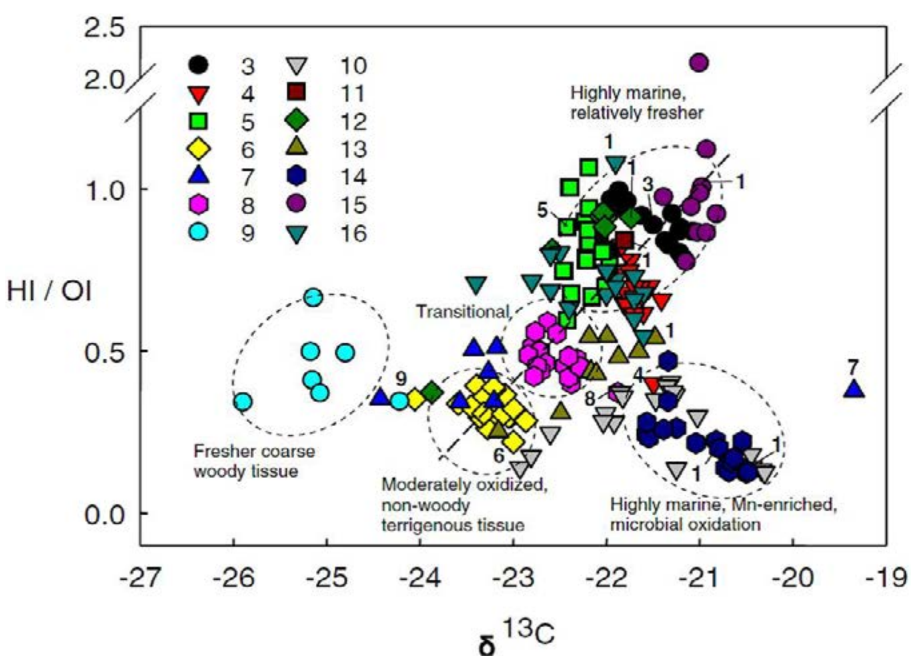

Figure 7. HI/OI vs. δ13C in HB sediment. Text in the figure indicates general characteristics of the sediment within groupings enclosed by short-dashed lines. Numbers identify the surface layer of each core (from Hare et al. 2014).

and burial. They report elevated 137Cs in recently deposited sediments which are attributed to delayed inputs of particle-associated 137Cs to the sediments, likely transported from the watersheds surrounding the Arctic Ocean to the coast and subsequently redistributed to shelf/slope sediments through biomixing and primary productivity. 210Pbex inventories in sediments are up to 21-fold greater than the in situ supply at some sites. Large inventories of 210Pbex in sediments along the North Bering-Chukchi shelf result primarily from focusing, while those along the north Chukchi slope (Barrow Canyon) and in Baffin Bay/Davis Strait reflect strong boundary scavenging, likely supported by lateral exchanges with deep/interior Atlantic-origin waters. By using 210Pb and 137Cs inventories in sediment cores together the authors were able to differentiate sites influenced by horizontal particle transport vs. scavenging driven by vertical particle flux, an approach that could have strong relevance in cores from Hudson Bay.

Because Hudson Bay is relatively shallow, the contrast in dissolved components in the water column available to be scavenged out will be much less. The inventory of dissolved components in the shorter water column will be much lower than in the deeper waters of the Arctic Ocean. However, the inshore/offshore contrast, in terms of primary productivity and vertical particle flux high, is the same as it is in the Arctic Ocean. In Hudson Bay the absence of vertical mixing and thus depleted surface nutrients that make the offshore region low in primary productivity. As a result, despite relatively shallow waters, boundary scavenging is expected to be a significant process. This will be investigated further in the next year using the cores collected during earlier ArcticNet cruises.

Results from Bruno Tremblay's work are another avenue for us to compare freshwater marine coupling and ice processes observed in Hudson Bay to those observed elsewhere. In a paper currently in review, Hata et al. find for the first time isotropic internal ice stresses before the landfast ice onset, and anisotropic stresses during the landfast season. The authors test the hypothesis that this is the result of preferred c-axis alignment in the ice crystal with the surface ocean currents, which result in different along and across c-axis material properties. Hata et al. are also able to estimate ice strength from the GPS record and wind data throughout the fast-ice season. Firstyear cold salty ice strength is estimated to be around 44 kN/m at the onset of the landfast ice season and 20 kN/m at the end of the landfast season in summer.

Other modelling efforts by Tremblay et al. advance the modelling of energy dissipation in viscous plastic sea ice models. The group has derived a complete kinetic energy (KE) balance for sea ice, including plastic and viscous energy sinks to study energy dissipation. The main KE balance is between the energy input by the wind and the dissipation by the water drag and the internal stresses (dissipating respectively 87% and 13% of the energy input on an annual average). The internal stress term is mostly important in winter when ice-ice interactions are dominant. The energy input that is not dissipated locally is redistributed laterally by the internal stresses in regions of dissipation by small scale deformations (LKFs). Of the 13% dissipated annually by the internal stress term, 93% is dissipated in friction along LKFs (14% in ridging, 79% in shearing) and 7% is stored as potential energy in ridges. For all time and spatial scales tested, the frictional viscous dissipation is negligible in the KE balance. This conclusion remains valid when the spatial resolution and the numerical convergence of the simulations are increased. Overall, the results confirm the validity, from an energetical point of view, of the VP approximation. These results have strong relevance in the FYI dominated environment of Hudson Bay, and can be investigated at the broader scale as the NEMO model implementation continues. This work will contribute to a better model representation of the role sea ice plays in controlling momentum exchange with the ocean surface mixed layer in areas such as Hudson Bay and the SBS.

Another study with implications for the provision of scientific knowledge towards extension of the shipping season in Hudson Bay comes from recent

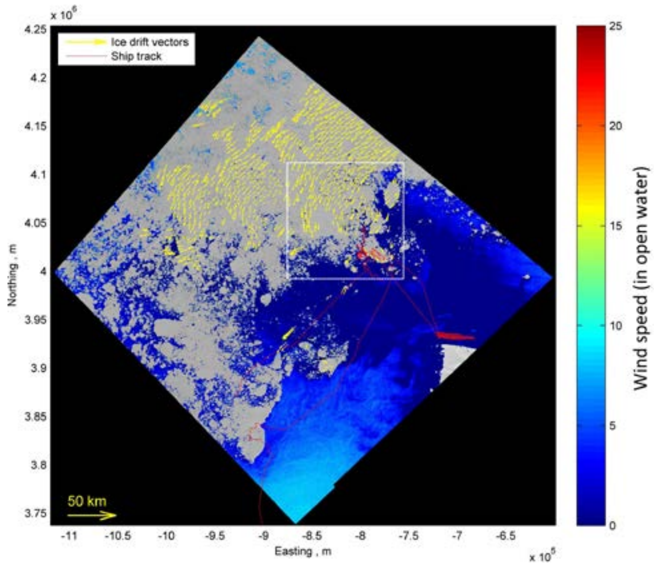

Figure 8. Ice drift and surface wind speed estimated from a model relating RADARSAT-2 backscatter to surface winds. RADARSAT-2 HH-HV Image acquired on Aug 16, 15:46, 2011 (Komarov et al. 2013; Barber et al. 2014).

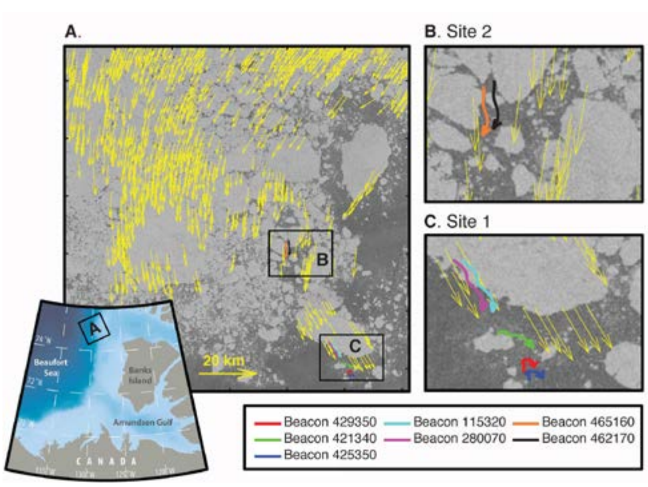

Figure 9. Radarsat derived ice motion between images acquired on Aug. 17, 15:17 and Aug. 18, 15:35, 2011 illustrating the average ice motion (yellow vectors). Beacon data are shown in other colours and in general show good agreement between the general ice motion and the motion of floes. This is particularly valid for first year ice floes (Komarov and Barber 2013; Barber et al. 2014).

work by Komarov and Barber (2013) and Komarov et al. (2013) (Figure 8, 9). They demonstrate that RADARSAT-2 could become a very valuable tool in the estimation of both windspeed as well as sea-ice motion in regions such as Hudson Bay where there is little or no direct observational data. This is particularly relevant during spring, when wind-driven ice continues to circulate into the Churchill region well into June, preventing passage of cargo ships.

To date, the experiments conducted by Komarov et al. have not been replicated in Hudson Bay. However, a planned winter camp that will be part of our NSERC CRD collaboration with Manitoba Hydro will provide an opportunity to test this approach in the dynamic first year ice climate of Hudson Bay. Improved estimation of wind speed in the open water season would also advance our understanding of the boundary current, and in turn, on the fresh water export from the basin.

Discussion

The open water season across Hudson Bay has increased significantly between 1980 and 2010. Spring and Fall sea ice extent has decreased significantly over the same period. Both are significantly related to surface temperature and surface zonal winds from spring and the preceding fall (Hochheim and Barber 2014). The use of the NEMO model at CEOS will provide an opportunity to incorporate Ouranos climate scenario output and drive projections of both marine and terrestrial freshwater and sea ice circulation in Hudson Bay.

Hare et al. (2014) and Heikkilä et al. (2014) have maximized the use of past data collection efforts by ArcticNet by applying contrasting analytical techniques to box cores collected in 2005 and 2006. Each paper contributes new insight into key drivers of arctic marine productivity, and the ability to describe marine vs. terrigenous and fresh vs. degraded organic matter patterns. These results will significantly improve our ability to identify areas impacted by terrestrial freshwater, and to evaluate implications for lower trophic levels in the Bay. Evaluation of these box cores is ongoing, with Kuzyk and collaborators planning to study 137Cs and 210Pb variability among the same set of cores in the coming year. This planned study will allow comparison of freshwater marine coupling in Hudson Bay to other Arctic shelf regions (Kuzyk et al. 2013).

Newly developed analytical approaches by Tremblay and collaborators, and use of new tools such as RADARSAT-2 by Komarov, Barber and collaborators show great promise in enhancing our ability to model and monitor ice motion through full annual cycles. This is a key goal for network members such as the Manitoba Government, Omnitrax, and others with an interest in extending viability of marine transportation in Hudson Bay.

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