Characteristics of two coastal regimes (Churchill River plume and adjoining marine waters) during the winter-spring transition

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Introduction

Freshwater plumes have significant effects on coastal marine ecosystems, altering nearshore stratification, circulation patterns, nutrient and particle dynamics, and the offshore transport and dispersal of materials. Ice further alters these patterns by preventing wind mixing and plumes sometimes become much larger under the ice than in open water conditions [1-5].

Extensive study has been conducted around rivers in southeastern Hudson Bay, especially the Great Whale River [5-8]. There, the dynamics of the under-ice freshwater plumes show strong inter- and intra-annual variability influenced by river discharge [3, 5] and the dynamics influence the vertical stability of the water column, nutrient distributions, phytoplankton production and export, and even the feeding success of higher trophic levels [5, 6, 8]. We currently know little about the nature and influence of river plumes in southwestern Hudson Bay, despite significant differences in the region's ice conditions (a comparatively narrow band of shorefast ice), oceanography (large tides), and hydrology (drainage from prairie watersheds).

To address this gap, we conducted a pilot study of the physical and biogeochemical features of the coastal environment in the vicinity of the Churchill River in western Hudson Bay, between March and May 2005. We focused on two contrasting regimes, one influenced by Churchill River waters, and the other outside the apparent river plume and characterized by high ambient salinities. This paper presents our observations of ice conditions and composition, water column structure and water mass characteristics over the winter-spring transition (from pre-melt to early melt to spring freshet).

Methods

Water column profiles were made with a Sea-Bird SBE 19plus CTD equipped with a transmissometer (providing beam attenuation coefficient (1/m) at 660 nm, Wetlabs C-Star, 25 cm path length) and coloured dissolved organic matter (CDOM) fluorescence sensor (WETStar). Water samples were obtained from the same hole using a submersible pump (Shurflo 9300 Series) and stainless steel hose (Swagelok Company) or (occasionally) a Kemmerer-type sampler. Particulate was collected onto baked Whatman GF/F. Ice cores were collected with a MARK II corer (Kovacs Enterprises). Salinity was measured at IOS, $\delta^{18}O$ at the University of Helsinki, Finland, and University of Ottawa, nutrients and dissolved organic carbon (DOC) at FWI, and C, N, $\delta^{13}C$ and $\delta^{15}N$ at the University of British Columbia using standard methods.

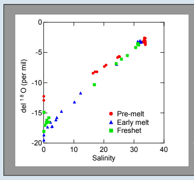

Figure 4 (left). Salinity-$\delta^{18}O$ relationships in water samples during the pre-melt, early melt and spring freshet periods.

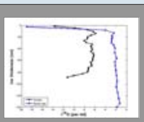

Figure 5 (left). $\delta^{18}O$ profiles in ice cores.

Results and Discussion

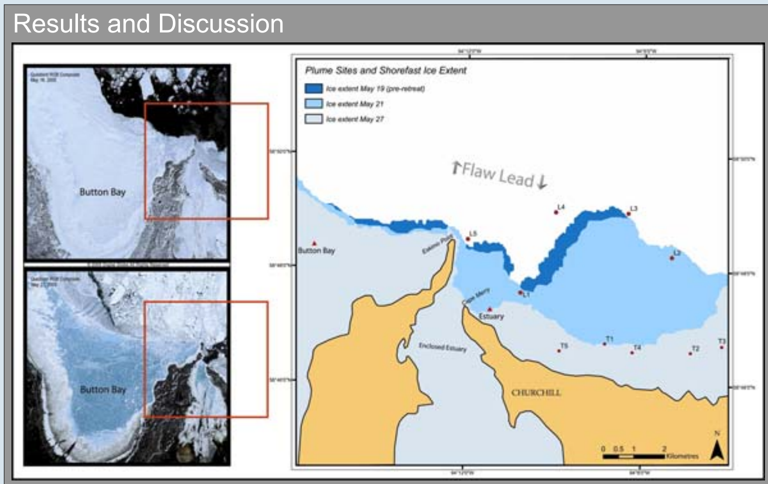

Figure 1. Sampling locations in the Churchill River estuary/plume and adjoining marine waters (Button Bay) and seasonal changes in ice cover. Red boxes on images (left) denote the area of the map (right).

1. Ice Conditions and Hydrology

From winter through May 12, shorefast ice covered Button Bay and the estuary (Figure 1). The seaward edge was defined by ice ridges and rubble up to 7 meters thick (R. Galley, unpub.), some of it apparently grounded. Beyond that, a lead opened and closed as mobile pack ice was moved about by the wind. River discharges were very low (<100 m^3/s, Figure 2) and the Churchill River plume appeared to be contained inside the rubble at the estuary. On May 12, warm temperatures, persistent insolation and a SW wind coincided with parts of the rubble field in the estuary breaking off, which allowed river waters to flow out into the open lead. Freezing conditions returned briefly, then from May 17 to 26, the shorefast ice in the estuary began to rot in place. From May 19 onward, the ice extent changed quickly. River flows increased to their maximum spring levels. By May 28, the ice in the mouth of the estuary had completely ablated and river water was flowing unimpeded into the Bay.

2. Water Mass Characteristics

Based on the evolution of the ice conditions and the pattern of river discharge, our observations are divided into three periods: pre-melt (mid-March to mid-April), early melt (late April to early May) and spring freshet (late May) (Figure 3).

- Pre-melt: well mixed water column in Button Bay; brackish surface plume in the estuary
- Early melt: little change in Button Bay; freshening of the plume in the estuary and strong halocline at 5-6 m; shift in $\delta^{18}O$ in river water and plume water (Figure 4) indicates altered composition, presumably increased meltwater; shift in $\delta^{18}O$ in bottom of ice core (Figure 5) indicates plume water incorporated into still-growing ice
- Freshet: slight freshening in Button Bay, apparently river influence; very fresh surface layer in the estuary, about 3-4 m thick

Photo 1. Shorefast ice and rubble in Button Bay.

Photo 2. River water influence in estuary.

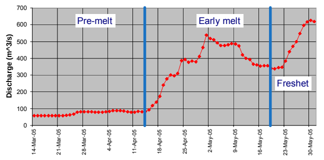

Figure 2. Churchill River discharge, March-May 2005.

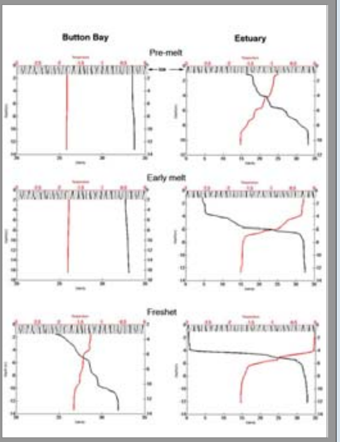

Figure 3. Salinity and temperature in Button Bay and the Churchill River estuary during winter-spring 2005.

3. Nutrients, Particulate Matter and Organic Carbon

The freshwater plume was associated with much higher CDOM and turbidity (Figure 6) and high concentrations of DOC (Figure 7). Salinity was positively correlated with phosphate but negatively correlated with silicate and, at times, nitrate (Figure 8). Because of nutrients or perhaps stratification, and in spite of turbidity, the estuary had higher phytoplankton biomass (as indicated by chlorophyll *a* levels; Figure 9) than either Button Bay or the river. The composition of the particulate material was distinct in each environment (Table 1) reflecting the input of terrestrial and possibly freshwater (biogenic) organic matter from the river.

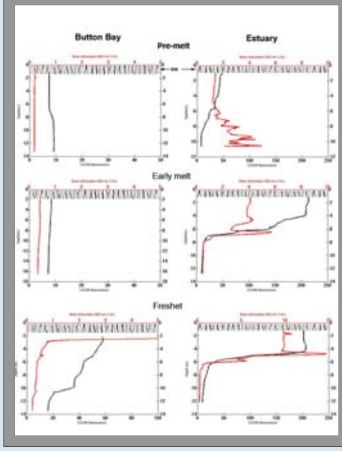

Figure 6 (left). Turbidity and CDOM in Button Bay and the Churchill River estuary.

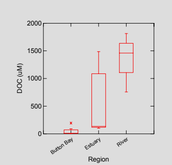

Figure 7. Box plot showing spatial differences in DOC.

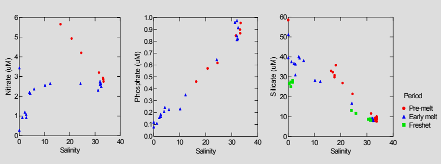

Figure 8. Salinity versus nitrate (+nitrite), phosphate and silicate across the pre-melt, early melt and spring freshet periods.

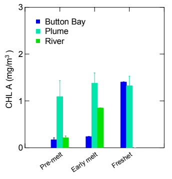

Figure 9. Seasonal change in chlorophyll *a* (mean ± SEM).

	SPM (mg/L)	$\delta^{15}N$ [air] (‰)	$\delta^{13}C_{org}$ [PDB] (‰)	C to N Ratio
Pre-melt				
Button Bay	4.0 ± 1.8 (4)	6.2 - 6.5	-25.4 - -24.3	7.8 - 9.5
Estuary	8.8 ± 6.3 (6*)	4.5	-28.4	5.4 - 6.0
River	2.7	4.8	-29.4	5.4
Early melt				
Button Bay	5.6	7.2	-24.8	10.7
Estuary	13.9 - 17.4	3.2	-27.4	6.3
River	N/A	2.6	N/A	5.8
Spring freshet				
Button Bay	7.5	4.4	-28.2	3.9
Estuary	39.3 ± 22.3 (7)	3.3 ± 0.5 (5)	-27.6 ± 0.8 (5)	4.6 - 6.8

Table 1. Quantity and composition of particulate matter (mean ± SD (n) or range) across the pre-melt, early melt and spring freshet periods.

Conclusions and Future Directions

Figure 10 summarizes our preliminary impressions of the seasonal dynamics of the Churchill River plume and the adjacent coastal waters. Despite large tides (>4.5 m), strong currents (>40 cm/s), and low river discharge, we saw a distinct plume develop and evolve inside the ice rubble boundary. The plume influenced water turbidity, nutrients, phytoplankton biomass, and particle/carbon composition. Spring freshet and a breach in the rubble allowed the plume to spread and influence surface waters more than 7 km away. Future study should consider the influence of large rivers entering western Hudson Bay (e.g., the Nelson River) and also build on the present work to develop a more thorough biogeochemical understanding of the Churchill River and estuary system.

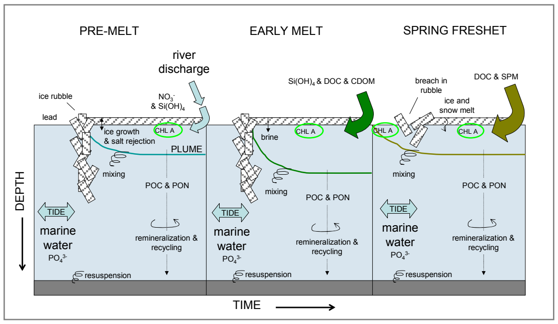

Figure 10. Schematic diagram of the changes in the Churchill River plume and the adjacent marine waters during winter-spring transition.

References

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Acknowledgements

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