ARDEX : The Arctic River Delta Experiment

Workshop in Quebec City

March 3-4, 2005

Contents

Workshop Agenda

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10:30-11:00	Coffee
11:00-11:30	Craig Emmerton: Biogeochemical transitions of the Mackenzie Delta-Shelf system
11:30-12:00	Patricia Ramlal: A preliminary examination and comparison of daily CO_2 changes in surface waters in three regions of Canada.
12:00-13:30	Lunch
13:30-14:00	Catherine Vallières: The bacterial production in the Mackenzie River and Delta and in the Arctic Ocean
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Posters: Julie Breton & Isabelle Laurion: Thermokarst ponds
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	Friday March 4
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9:40-10:10	Marie-Eve Garneau: Prokaryotic community structure and heterotrophic production in a river-influenced, coastal Arctic ecosystem
10:10-10:20	Ramon Terrado: CASES microbes: eukaryotic flagellates as a major component of the Arctic Ocean food web
10:20-10:40	Sebastien Roy: Life in the dark : The winter microbial food web in Franklin Bay, Canadian High Arctic
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11:10-11:40	Marcel Babin: Inherent Optical Properties of Coastal Waters
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15:00-15:30	Coffee
15:30-16:30	Report from the groups including perspectives and priorities for publications, theses etc

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TALKS

In the order of presentation

THE ARCTIC RIVER DELTA EXPERIMENT: INTRODUCTION TO ARDEX AND CASES

WARWICK F. VINCENT & MILLA RAUTIO
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ARDEX was formulated as a satellite program of CASES (Canada Arctic Shelf Exchange Study) to extend offshore measurements from CCGS Amundsen into the Mackenzie River, freshwater-saltwater transition zone and delta. The overarching objectives of ARDEX were to evaluate the properties of dissolved organic matter (DOM) in the river and coastal waters, and the photochemical, geochemical and biological processes regulating DOM dynamics. Field sampling and experiments were undertaken to address the hypotheses that the combined effects of photobleaching and microbial degradation of DOM in the river and marine delta environment provide a major mechanism for ventilating Arctic soil carbon stocks into the atmosphere; that coloured DOM (CDOM) regulates primary production; that zooplankton release DOM with a distinct fluorescence signature; that parts of this river-delta system are net sources of CO_2 to the atmosphere; and that terrestrial carbon contributes to the food web productivity of the Mackenzie River and coastal zone. The program included an internship for an Inuvialuit school student, and a set of outreach activities including liaison with northern schools and website site development.

THE ARCTIC RIVER DELTA EXPERIMENT: 2004 SAMPLING

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The initial sampling phase of ARDEX was by helicopter (July 21-26, 2004), and the second phase was a research cruise on the CCGS Nahidik, from 26 July3 August 2004. In addition to river sampling the initial sampling included collection of climate change and trophic structure variables from thermokarst ponds on the Mackenzie delta. This presentation summarizes the research activities carried out during the cruise and presents the CTD data (temperature, salinity and chl-*a*) along the sampling transect from the freshwater stations (R1-R4) to the transition zone (R5a-e) and finally to marine stations (R7-R9). Short description of the pond sampling will also be given. The more detailed research results will be presented by individual researchers during the workshop. The map of the river cruise track is given in the Appendix 1 of this booklet. Environmental variables measured and experiments conducted during the ARDEX cruise are listed in Appendix 2. CTD data have been plotted up by Leira Retamal and are given in the Appendix 3.

ORGANIC GEOCHEMISTRY OF DISSOLVED ORGANIC MATTER IN THE MACKENZIE RIVER AND ESTUARY

CHRIS OSBURN
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Terrestrial DOM transported from rivers to the coastal ocean represents a major linkage between the land and ocean environments. In the Arctic, these effects are more pronounced given the large riverine inflow and large shelf areas relative to other oceans. I will present recent data on the geochemistry of DOM in samples collected from ARDEX and from CASES. Specifically, I will show dissolved organic carbon (DOC) concentrations and stable isotope values, as well as measurements of lignin-derived phenols. In tandem, these two measurements provide substantial information on the terrestrial nature of DOM in the coastal Beaufort Sea, as influenced by flow from the Mackenzie River. The goal is to understand the magnitude of terrestrial C flux to the Beaufort Sea and to understand how that magnitude might vary with climatic change.

BIOGEOCHEMICAL TRANSITIONS OF THE MACKENZIE DELTA-SHELF SYSTEM

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The Mackenzie Delta and adjacent estuary are important environments for biogeochemical change of incoming Mackenzie River water. Fluvial interactions within the delta's lake-rich floodplain and strongly stratified estuary drive changes in nutrient and organic chemistry and ultimately alter Beaufort fluxes. In order to assess the magnitude and spatial resolution of these changes through each environment, a nine-station sampling program was performed in mid-summer 2004 as part of the Arctic-Delta Experiment (ARDEX). Freshwater to marine stations (R1-R9) were sampled for organic matter, inorganic nutrients, particulates and other biologically-important components from July 26-August 2, 2004. Surface and bottom waters were sampled and supplemented by water taken at local chlorophyll maximum and chemocline layers. Most analyses showed significant changes between river and marine stations with change rates highest in the outer estuary stations and little change within river stations. Dissolved nitrogen and phosphorus show increasing trends through the outer estuary towards the marine stations while total and coloured DOM decreases steadily from the river toward the ocean. An additional sampling program was also performed from June-August 2004 in order to focus solely on changes within the delta floodplain and to lengthen the extent of riverine-floodplain interaction. Three delta-wide transect surveys covered incoming waters at the delta head, mid-reach and lower delta channels and were sampled for analyses simliar to ARDEX. Inorganic analyses show an apparent stripping of nitrate and leaching of ammonium downstream through the delta with relative stability of reactive phosphate and silica.

A PRELIMINARY EXAMINATION AND COMPARISON OF DAILY CO_2 CHANGES IN SURFACE WATERS IN THREE REGIONS OF CANADA.

PATRICIA S. RAMLAL & RAYMOND H. HESSLEIN
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With the ongoing concerns of global climate change there is a strong impetus to establish the importance of different types of water bodies as potential sources or sinks of carbon dioxide (CO_2). In order to be able to identify seasonal changes and long-term trends of the fluxes of CO_2 it was necessary to develop a method or device that could be used for frequent, simultaneous measurement and data storage of the partial pressure of CO_2 in conjunction with water and air temperatures. We have developed an in situ technique that is simple to assemble, robust, relatively inexpensive, low maintenance, portable and lends itself to application in remote locations as well as locations that are difficult access to measure those parameters. A brief overview of the method will be presented with preliminary data collected on the daily changes of CO_2 in the surface waters of (1) Lake 239 of the Experimental Lakes Area, Ontario; (2) the Nelson River of northern Manitoba; (3) the east channel of the Mackenzie River, N.W.T.; and (4) the Beaufort Sea.

BACTERIAL PRODUCTION IN THE MACKENZIE RIVER AND DELTA AND IN THE ARCTIC OCEAN

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Bacterial production was measured along the transect made during the ARDEX cruise by size-fractionated leucine uptake and shipboard incubations at ambient water temperatures. Rates varied from 70.39 to 404.51 nmol L^{-1} h-1 The percentage activity of free living versus total bacteria increased with decreasing turbidity, and was maximal in the oceanic sites. The fraction greater than 3µm accounted for 83 % (station R7, 0m) to 0.4 % (station R5a, 2.5m). A set of experiments was conducted to examine carbon limitation, and the effects of zooplankton exudation (collaboration with Dr Juanita Urban Rich). In addition, the effects of photobleaching on carbon availability (collaboration with Dr Chris Osburn) were examined. The results showed a significant increase in bacterial activity in river samples following the exposure to sunlight; conversely, bacterial activity in the oceanic samples decreased after light exposure. A long term (152 days) biodegradation experiment was undertaken to estimate the labile fraction of DOC at contrasting river and ocean sites. These results indicate a labile fraction of DOC that was rapidly consumed, with much slower consummation of a smaller fraction of the remaining DOC. Finally, samples were taken to investigate gradients in microbial community structure, specifically for picophytoplankton (picocyanobacteria and picoeukaryotes) and bacteria.

FROM THE RIVER TO THE SEA – DIFFERENTIAL INCORPORATION OF EXPORTED CARBON BY ZOOPLANKTON ACROSS THE WATERS OF THE MACKENZIE RIVER-DELTA-COASTAL ZONE

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Currently export carbon and other materials from the Arctic landscape through rivers into the coastal oceans is already large. In northern ecological zones this riverine transported organic matter (TOM) can be derived from either tundra and boreal vegetation or aquatic macrophytes and phytoplankton (i.e. allochthonous versus autochthonous continental sources). In either case this TOM is important in the trophic interactions of downstream riverine, estuarine and marine foodwebs. Atmospheric warming in the Arctic is predicted to the most globally profound, altering both the quantity and quality of TOM exported to the Arctic Ocean. Unfortunately because we lack knowledge of how exported carbon is incorporated into the regional foodweb, we are not able to offer predictions on the ecological significance of this change. Thus, as part of Arctic River-Delta Experiment, we sampled TOM and plankton along a transect from the freshwater portion of the Mackenzie River through the freshwater-saltwater transition zone and into the coastal marine environment. We hypothesized carbon assimilated by zooplankton should reflect either the signature of the locally dominant seston or one of the three principal types of carbon (marine, freshwater, terrestrial) that are preferentially assimilated. We use differential incorporation of stable isotopes of carbon and nitrogen to see if seston characteristics reflected either a gradually attenuated terrestrial-allochthonous signal or, alternatively, if terrestrial and marine carbon incorporation were sharply separated by the freshwater-saltwater transition zone. Animals analyzed for isotopic composition included larval stoneflies (Isoperlidae) and mayflies (Heptageniidae), calanoid copepods (*Calanus* and *Oithona*), shelled marine pterapods, *Mysis mixta*, pelagic marine amphipods (*Thermisto libellula* and *Hyperia galba*), larval cod (Gaddidae), and both larval and adult smelt (*Osmerus* spp.).

OPTICAL, PIGMENT AND PRIMARY PRODUCTION GRADIENTS IN THE MACKENZIE RIVER AND COASTAL SHELF, WESTERN CANADIAN ARCTIC

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The Arctic Ocean is strongly influenced by river inflows, and the largest of these in terms of total suspended matter input is the Mackenzie River. In this study (within the program ARDEX, Arctic River-Delta Experiment) we sampled from upstream freshwater sites to 50 km offshore in the coastal Beaufort Sea, during summer 2004. We measured UV and PAR attenuation, CDOM (colored dissolved organic matter) and spectral absorption by particles (ap, aph); pigment concentrations by size-fractionated HPLC analysis; and photosynthetic parameters by shipboard ^{14}C-incubations. The diffuse attenuation

coefficients for PAR reflected the high sediment content of the water and were 4 m^{-1} at the freshwater stations, rising to 5.6 m^{-1} at the transition zone, and dropping to 0.2-0.3 m-1 at the offshore sites. P_{max}, Ek and Beta were most closely correlated with CDOM absorption and temperature. The contribution to total phytoplankton (as Chlorophylls) by cells larger then 3um shifted from 1-10% in the freshwater sites to 20-75% offshore, and was correlated with the turbidity gradient. This Arctic river-delta ecosystem has distinctive properties that will be sensitive to future climate change.

APPARENT QUANTUM YIELDS OF PHOTOCHEMICAL CO/CO2 PRODUCTION AND BIOGEOCHEMICAL CYCLING OF CO IN THE MACKENZIE RIVER AND SURROUNDING SEAWATER

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Carbon dioxide (CO_2) and carbon monoxide (CO) are the most abundant carbon-containing photoproducts of dissolved organic matter (DOM) in marine waters. DOM photochemistry serves as the principal source of CO in seawater while microbial consumption and gas exchange are the loss processes of this compound. This presentation reports the biogeochemical cycling of CO in the Canadian Beaufort Sea and the apparent quantum yields (AQYs) of photochemical CO_2 and CO formation for water samples from the Mackenzie River and the neighboring shelf and open waters. The AQY of CO showed a negative correlation with salinity and a positive correlation with the absorption coefficients of DOM in the UV wavelengths, indicating that terrigenous DOM was more efficient in producing CO photochemically than marine DOM. The AQY of CO_2 increased from the freshwater zone to the freshwater-saltwater transitional zone, but decreased further seaward. The ratio of CO_2 to CO photoproduction implied from their AQYs ranged from three in the freshwater zone to 22 in the open ocean. Diurnal variations of [CO] were observed in fall 2003 but lacked in spring 2004. The mean surface-water [CO] in the spring (4.7 nM) was 13 times higher than that in the fall (0.36 nM) as a result of higher photoproduction and much slower microbial consumption in the spring. The first-year sea ice in the spring was highly enriched with CO compared to the nearby open water. In both seasons surface seawater was supersaturated with CO relative to the atmosphere, leading to a net sea-to-air flux of CO. Microbial CO consumption always followed the first-order kinetics in the fall while inhibition and saturation kinetics were observed in the spring.

REGIONAL ESTIMATION OF PHOTOCHEMICAL FLUXES OF CARBON USING SATELLITE REMOTE SENSING IMAGERY: POTENTIAL IMPACTS OF ENVIRONMENTAL CHANGES IN THE BEAUFORT SEA

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Photochemical degradation of colored dissolved organic matter (CDOM) by solar radiation can convert a significant amount of dissolved organic carbon (DOC) into inorganic species such as carbon dioxide (CO2). In the past this mechanism was not considered of importance for the Arctic Ocean which is largely shielded from sunlight by sea ice throughout the year. Recent observations and modeling show that sea ice conditions are changing, with complete loss of summer ice predicted for later this century. In the present study we examined the implications of these changes for photodegradation of CDOM. Combined with our recent measurements of the Apparent Quantum Yield for the photoproduction of dissolved inorganic carbon (DIC), the use satellite remote sensing data to characterize CDOM absorption over the continental shelf is explored to improve the regional estimation of DIC photoproduction. We present here a brief overview of the optical data collected during CASES. Our long term objective is to quantify the photoproduction of DIC under different sea ice, ozone, cloud cover and water optical conditions, as observed from satellite sensors.

PHOTOCHEMICAL REACTIVITY OF DISSOLVED ORGANIC MATTER IN THE MACKENZIE RIVER AND ESTUARY

CHRIS OSBURN
Marine Biogeochemistry Section, US Naval Research Laboratory, Washington

One potential removal mechanism for DOM in the coastal ocean is photochemical degradation, but to date, the possibility of this mechanism in the Arctic seems limited. Nevertheless, I have compiled data from the ARDEX and CASES cruises that suggests DOM transported from the Mackenzie River to the Beaufort Sea is very highly photochemically reactive. Given the opportunity for greater riverine flow and reduced ice cover in a warming Arctic, it is important to understand the potential C flux from the ocean to the atmosphere due to photochemical degradation of DOM. In this talk, I present findings that begin to understand the lability of Mackenzie River and Beaufort Sea DOM to photochemical degradation, and results of modeling efforts aimed at estimating the turnover time of DOM in the surface waters of the Beaufort Sea.

ZOOPLANKTON INPUTS TO FLUORESCENT DISSOLVED ORGANIC MATTER (FDOM) IN THE ARCTIC RIVER DELTA EXPERIMENT (ARDEX).

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Biological sources of dissolved organic material (DOM) in freshwater and seawater are poorly understood both in terms of rates of production and the types of material produced. While zooplankton have been considered a potentially important source of DOM little work has been done to examine their input to colored organic material or to DOM in coastal regions that are impacted by large rivers. Optical characteristics of marine environments can be strongly influenced by CDOM concentrations, composition and cycling. While much of the CDOM in the ocean is from terrestrial sources and is delivered to coastal environments from ground water runoff or river discharge, *in situ* biological production may be important on certain temporal and spatial scales. Seasonal cycles in CDOM concentrations along with non-conservative mixing in some coastal environments suggest that biological sources and removal of CDOM could be important.

Excretion experiments were conducted with zooplankton at three stations along the ARDEX transect (R2, R5 and R9) to determine the type of FDOM contributed by the zooplankton in the different water types. At all the stations fine scale (1-5 m) water samples were collected to examine the fluorescent composition of the water to determine where vertically the zooplankton were contributing to DOM pools. The results from the excretion experiments will be discussed with regards to changes in the zooplankton DOM composition from freshwater to seawater. Also the results from the fine-scale water sampling will be presented and discussed with regards to the contribution of zooplankton to DOM pools and carbon cycling.

PROKARYOTIC COMMUNITY STRUCTURE AND HETEROTROPHIC PRODUCTION IN A RIVER-INFLUENCED, COASTAL ARCTIC ECOSYSTEM

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The abundance, diversity and production of prokaryotes was studied over the Mackenzie Shelf, from the Mackenzie River to the arctic pack ice edge in the Beaufort Sea, within the framework of the CASES project (Canadian Arctic Shelf Exchange Study) during fall 2002 and throughout the year in 2003-2004. Since the area is characterized by large riverine loads of freshwater, dissolved materials, microbiota and particularly sediments brought by the Mackenzie River, size separation of material (filtration on 3 μm) was done to distinguish the prokaryotic community and the heterotrophic activity associated with cells attached to particles. The absolute and relative abundance of selected groups of Bacteria (alpha-, beta-, gamma-proteobacteria, and Cytophaga-Flavobacterium) and Archaea (Crenarchaeota and Euryarchaeota) in the river plume is determined with the Catalyzed Reporter Deposition for Fluorescence in situ Hybridization (CARD-FISH).

Bacterial production, estimated from incorporation rates of ^{3}H-leucine (protein synthesis) and ^{3}H-thymidine (DNA synthesis), will be assed for the entire area over the complete year of sampling. First results showed that Archaea were ubiquitous in the Mackenzie River plume, accounting for a large fraction of total bacteria (26%), much higher than typically reported elsewhere. Much of the bacterial production (more than 30% of leucine uptake) at the river-influenced sites was associated with particles larger than 3 μm, also a likely microhabitat for the large archaeal population.

CASES MICROBES: EUKARYOTIC FLAGELLATES AS A MAJOR COMPONENT OF THE ARCTIC OCEAN FOOD WEB

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Small flagellates are an abundant group in the Arctic and can play an important role in the dynamics of the marine ecosystem. During the CASES 2003-2004 cruise onboard the CGGS Amundsen, samples were taken throughout the overwintering period from the mooring station at Franklin Bay. Here we present the data for flagellates abundance and type from microscopy observation. Our results show that during this period heterotrophic picoeukaryotes (< 2-3 μm) are the most abundant groups, with surface values (under ice) ranging from 200 cells/ml in January to 1000 cells/ml in April. Photosynthetic flagellates started to increase in number beginning mid-March, with cells < 5 μm being the most abundant; prior to that time the autotrophic flagellate population during winter was at or below the limits of detection (< 20 cells/ml). We are planning further work using molecular tools in order to identify these organisms and to assess the dynamics of specific groups. As the first example of this approach we compared the 18s rDNA of the 2 μm diameter flagellate *Micromonas* sp. isolated from the North Water Polynya to clone libraries from the CASES study region and from other Arctic sites. The results show that there is a genetically distinct, panarctic *Micromonas* cluster. This clade of green algal picoeukaryotes appears to be one of the main photosynthetic phylotypes throughout the Arctic Ocean.

LIFE IN THE DARK : THE WINTER MICROBIAL FOOD WEB IN FRANKLIN BAY, CANADIAN HIGH ARCTIC

SÉBASTIEN ROY, CHRISTINE MARTINEAU, RAMON TERRADO, MILLA RAUTIO & WARWICK F. VINCENT
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Most sampling to date in the Arctic Ocean has been during summer, and winter has been considered a period of minimal activity. In fact, winter has been identified as a seriously undersampled period of the year in both polar regions, and a major gap exists in the ecological understanding of seasonal dynamics. Despite the persistent darkness, bacterial and other heterotrophic processes in the sea are likely to continue during this period. As

part of the CASES project sampling from the CGGS Amundsen, we measured the abundance of autotrophic and heterotrophic microbes and bacterial activity in the water column (220 meters) of Franklin Bay, during the dark period (November 19th 2003 to January 22nd 2004). Mean bacterial incorporation rate of thymidine was highest in the upper 10 m (0.061 pmol tdr L^{-1} h^{-1}), and was detectable throughout this period. In addition, an enrichment experiment was run with and without pre-filtration to evaluate the effect of heterotrophic flagellate grazers on the bacteria and to evaluate carbon, nitrogen and phosphorus limitation of winter bacterial production. Our preliminary analysis of these data show than an active microbial community persisted throughout winter darkness under the ice. Bacterial standing stocks were apparently limited by carbon supply, but also by nitrogen availability, while grazer control seemed to be less important as a microbial control at this time of year.

INHERENT OPTICAL PROPERTIES OF COASTAL WATERS

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The prediction of the light field in the upper ocean, or its inversion to retrieve the content of major dissolved and particulate constituents, necessitates the use of an optical forward model. Such a model essentially describes the inherent optical properties (IOPs) of the major constituents. Many such models now exist for open (so-called "Case 1") waters. For coastal (so-called "Case 2") waters, observations are just starting to be sufficient enough for generalizations to be made. In this presentation, we present our results from several studies on IOPs in Case 2 waters and propose some elements of an optical forward model.

DEVELOPMENT OF ACCESSIBLE ARCTIC EDUCATION FOR ELEMENTARY STUDENTS AND THE PUBLIC IN THE ARCTIC RIVER-DELTA EXPERIMENT (ARDEX)

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The Arctic is often viewed as a harsh, inhospitable place that is deserted and is remote enough not to affect our daily lives. When in reality, it is a highly dynamic area that supports a large amount of marine life. It is home to many indigenous people and the Arctic plays a critical role in global climate and ocean circulation. While scientists need to study this region in order to understand, model and predict the effects of global warming on this fragile and important ecosystem, future scientists (elementary students) and the public need to become more aware of this region and to learn about life and oceanic processes that occur there in order to protect and understand this ecosystem and understand its connection to the world.

To increase public awareness and knowledge of the Arctic three separate projects are being conducted. With regards to the ARDEX cruise, I developed a website that includes a daily dairy of the trip along with video interviews with each of the scientists. This portion of the public outreach was conducted in conjunction with a Canadian Joint Fisheries Research Council initiative to help local indigenous students learn and get involved with science. A second web-based exchange program has been developed between elementary students at schools in Aklavik, Paulatuk NT and Franklin MA. The dissemination of these sites, their current and future use in education will be discussed.

POSTERS

THERMOKARST PONDS: LIMNOLOGICAL CHARACTERIZATION AND CARBON CYCLING

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According with climatic models, vast extents of permafrost are susceptible of disappearance from polar and subpolar regions. Melting of permafrost mobilizes an old stock of carbon and generates the formation of thermokarst ponds. These ponds may act as carbon reactors. Carbon rejects from melting permafrost ground would contribute to increased greenhouse gases in the atmosphere. On the other hand, the rising export of organic matter to the aquatic network can have an impact on annual temperature and light budgets, which largely influence the microbial productivity. Dissolved organic matter (DOM) can also be a source of energy transferred through the food web via the bacteria, depending on its lability. The main objective of this study is thus to determine the role of thermokarst ponds on carbon transfer from the tundra to the atmosphere and to aquatic ecosystems. This project is part of ArcticNet theme 2.

The experimental approach includes a description of the different forms of carbon in the ponds, and the assessment of the stability and lability of DOM using bio- and photodegradation experiments. Stable isotopes are used to determine the source of the dissolved carbon pool (young carbon from drainage basin or older carbon stocked in peat and/or permafrost since many years). Aging of the ponds will be explored with aerial photography and satellite imagery, dendrochronology when possible and sediment profiles of radioactive isotopes. Basic limnological description of the ponds will complete the study; although omnipresent in the polar landscape, very few data are available on these systems.

A first survey was done in Nunavik during the summer of 2004 and following a latitudinal gradient. These sites cover 3 different ecosystems: the south limit of discontinuous permafrost (Whapmagoostui-Kuujjuarapik), the forest tundra (Umiujaq and Boniface River) and the tundra (Amundsen September 2004 cruise). Preliminaries results indicate that the ponds are biologically active (abundant bacteria and relatively high Chla) and that they present varying physicochemical conditions, concentrations of dissolved, gas and particulate carbon and DOM optical characteristics and long term biodegradation rates. The next sampling campaign will include in-site incubation of DOM, estimation of bacterial activity (leucine and CTC), further characterization of vertical structure of the ponds (including installation of thermistors for a 12 months period), and the use of floating chambers to measure water-atmosphere gas fluxes. We also plan to visit a site in the continuous permafrost zone north of Baffin Island (Bylot Island) where we can find ice-wedges thermokarst.
Julie Breton & Isabelle Laurion

SHALLOW FRESHWATER ECOSYSTEMS OF THE ARCTIC

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Numerous small lakes contribute significantly to arctic biodiversity by providing feeding, drinking and resting grounds to birds and other wildlife. Our aim is to define their ecological characteristics and to determine their sensitivity to climate. We have sampled 50 ponds and small lakes in northern Canada and Alaska. Their most distinctive characteristic is the importance of benthic processes to the functioning of the ecosystem. Most of the autotrophic biomass is confined to the bottom and is also important for life in the water column. The water columns are scarce in nutrients and phytoplankton resulting in low turbidity and low DOC water that is extremely clear. Solar radiation including ultraviolet wavelengths penetrates to the bottom of these water bodies. Exposed to continuous radiation during summer, some zooplankton allocate energy to photoprotective pigment production including melanin, MAAs and carotenoids. Scenarios of more intensive ozone depletion combined with temperature increases may affect the balance currently observed in high latitude freshwater ecosystems between benthic and water column processes.

NORTHERN RISCC AND THE ARCTICNET NETWORK OF TERRESTRIAL OBSERVATORIES IN THE EASTERN CANADIAN ARCTIC

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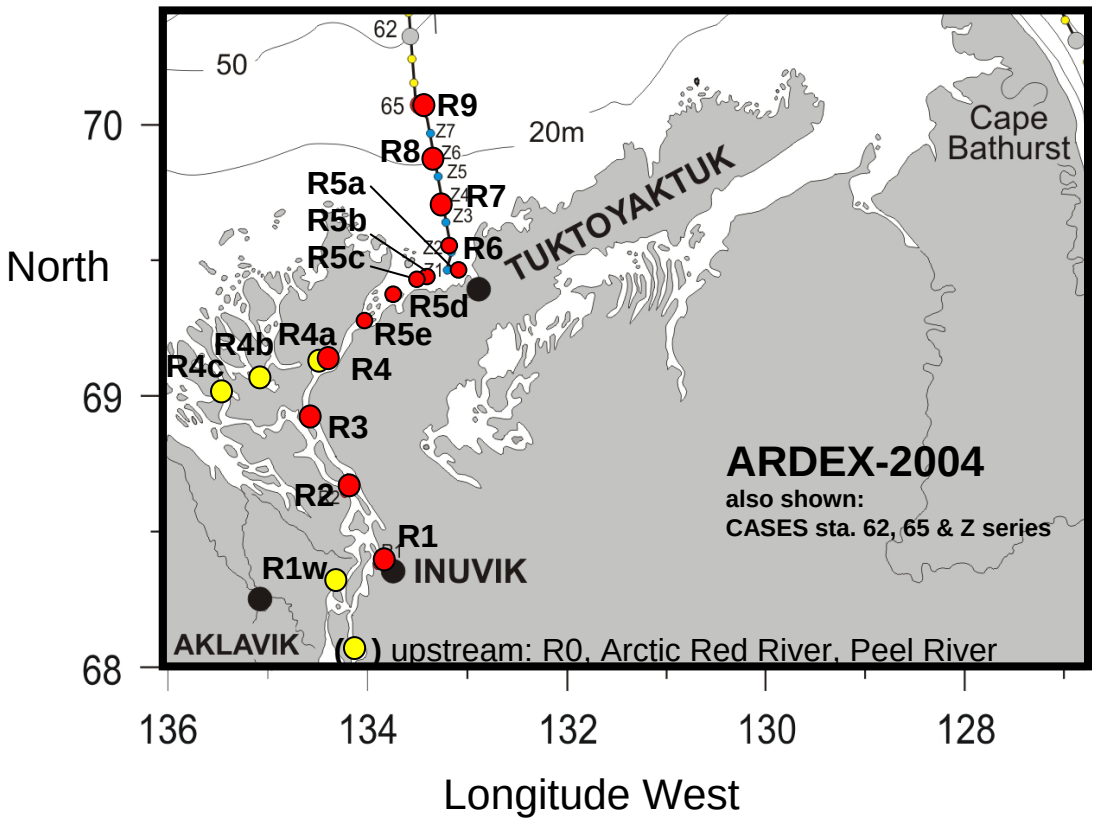
One of the primary aims of ArcticNet is to reinforce and extend environmental observations in the Canadian Arctic. The marine programs in Themes 1 and 3 include the establishment of a series of ocean observatory stations that will provide an important guide to present and future change in Canadian arctic seas. As a terrestrial counterpart to this marine work, Theme 2/Northern RiSCC is building on an existing set of observation sites on land with the aim of developing an integrated network of coastal observatories throughout the eastern Canadian Arctic. The geographic focus of these terrestrial observatories is on the coastal lands and freshwaters in a sector that crosses the boreal, subarctic and arctic ecoclimatic provinces, with vegetation zones ranging from forest to shrub tundra to high arctic polar desert. It spans over 30 degrees of latitude (53 to 83^{o}N) and a broad range of thermal regimes, from a mean annual temperature of –2^{o}C at the southern end (James Bay) to –20^{o}C at Ward Hunt Island, in Quttinirpaaq National Park, northern Ellesmere. Land-based observations are being coupled with measurements using the research icebreaker CCGS Amundsen as a moving field station to access coastal measurement sites.

APPENDICES

Appendix 1.

Station map of the ARDEX 2004 cruise. Yellow: Helicopter stations; Red: Nahidik stations



Helicopter

Station	Date	Latitude	Longitude
R4a (Middle Channel)	24 July	69.065	135.087
R4b (Reindeer Channel)	24 July	69.012	135.551
R4c(E Channel, Lousy Pt)	24 July	69.225	134.239
R1w (Middle Channel)	27 July	68.290	134.393
R0 (above Arctic Red R.)	27 July	Lance & Craig's	usual sites
Arctic Red River	27 July	"	"
Peel River	27 July	"	"

Nahidik

Station	Date	Latitude	Longitude
R1(E-Ch, Inuvik)	26 July	68.356	133.737
R4(LousyPt, Channel)	27 July	69.227	134.227
R9(Offshore)	28 July	70.05	133.417
R9b (night)	28 July	70.05	133.417
R9c(day2)	29 July	70.05	133.417
R8(offshore)	30 July	69.882	133.42
R7(offshore)	30 July	69.718	133.417
R6(inshore)	30 July	69.551	133.42
R5a(transition zone)	31 July	69.456	133.147
R5b(transition zone)	31 July	69.416	133.521
R5c(transition zone)	31 July	69.41	133.542
R5d(transition zone)	31 July	69.362	133.74
R5e(upstream)	31 July	69.281	133.97
R3(upstream, Middle)	1 August	68.842	134.63
R2(upstream, Middle)	1 August	68.626	134.188
R2a(upstream, Middle)	2 August	68.626	134.188
R2b(upstream, Middle)	2 August	68.626	134.188

Appendix 2.

A) List of environmental variables measured during the ARDEX cruise.

Optical variables	• Secchi • Turbidity • DOC • CDOM (absorbance and synchronous fluorescence) • PUV profiling • In vivo fluorescence of chl-*a*
Fluxes between river/sea and air	• CO_2 • O_2
Physical and chemical variables	• CTD casts • pH • DIC • Inorganic nutrients {PO_4 (SRP), NH_4, NO_3/NO_2, Si, plus major cations and anions (river water only)} • Organic nutrients - TDN (DON = TDN - NH_4 + NO_3), TDP (DOP = TDP - SRP) • Particulates - PC (Total C = PC + DOC), PN (Total N = PN + TDN), PP (Total P = PP + TDP), and TSS • Methyl Hg • Lipids
Terrestrial carbon transport to river/sea and to higher trophic levels	• Lignin • Aminoacids and carbohydrates • $\delta^{13}C$ DOC • $\delta^{13}C$ DIC • $\delta^{13}C$ and $\delta^{15}N$ of seston (total and <5µm) • $\delta^{13}C$ and $\delta^{15}N$ of DIN and DIP • $\delta^{13}C$ and $\delta^{15}N$ of individual zooplankton, insect larvae and fish species
Microbial community and protists	• Bacteria abundance (total and <3µm) and production • Picocyanobacteria and picoeukaryotes • Nanoflagellates and nanociliates • Protists and phytoplankton • Chl-a • Primary production (P vs E curves) • Pigments (HPLC)
Zooplankton	• Horizontal and vertical distribution of zooplankton

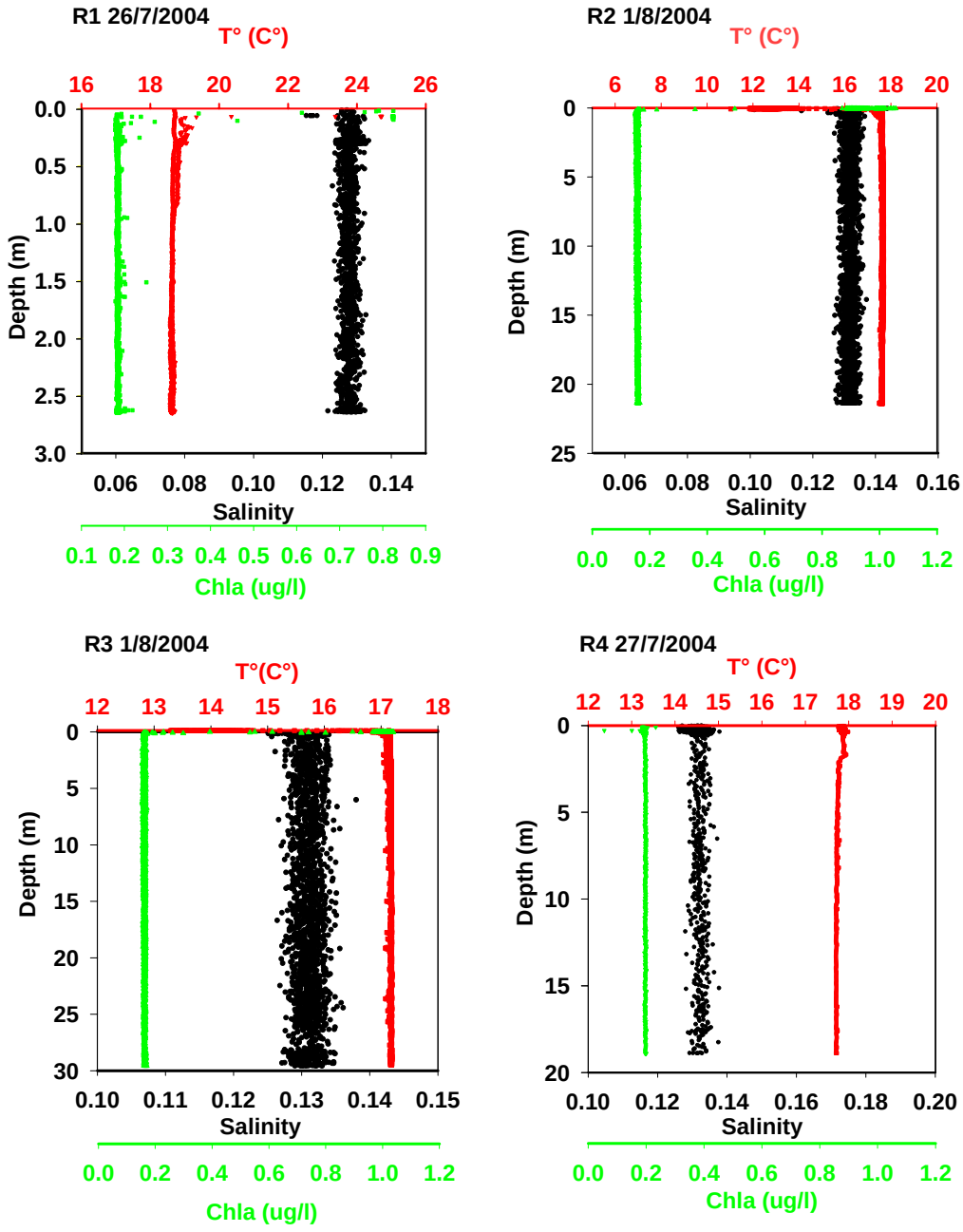
B) Experiments conducted

Photobleaching	• Bulk photobleaching of 0.2 μm filtered water from R9 and R4 • Photobleaching under optical cutoff filters (R7) • Photobleaching of R3 and R5d waters
Bacterial production	• Carbon limitation experiment: bacterial production in glucose enriched water (3 concentrations) • Bacterial growth rate • Photobleaching impact on the bio-availability of DOC for bacteria • Long-term biodegradation and carbon lability
The fate of zooplankton derived DOM and CDOM	• Bacterial utilization of zpl derived DOM/CDOM with and without photobleaching

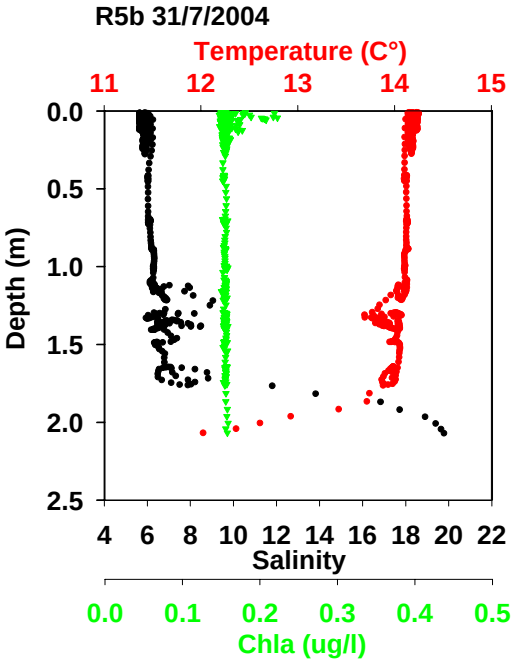
Appendix 3.

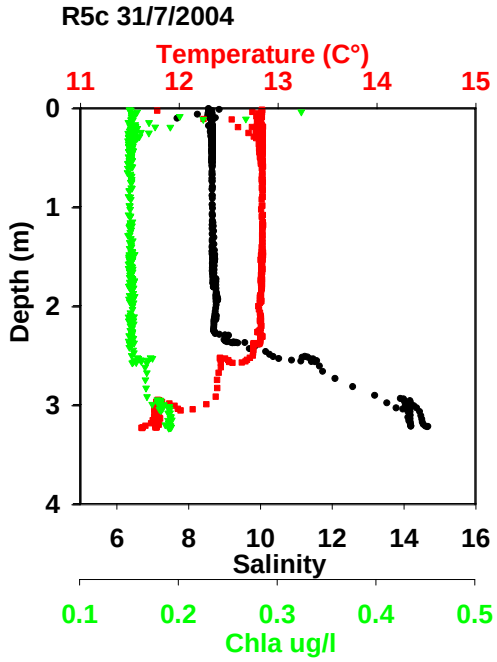
CTD data from the cruise stations R1 (Inuvik) to R9 (Beaufort Sea).

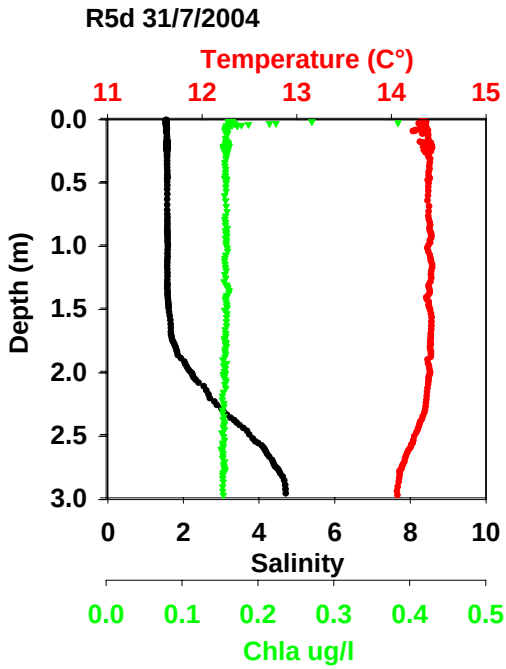
A) River stations R1-R4.

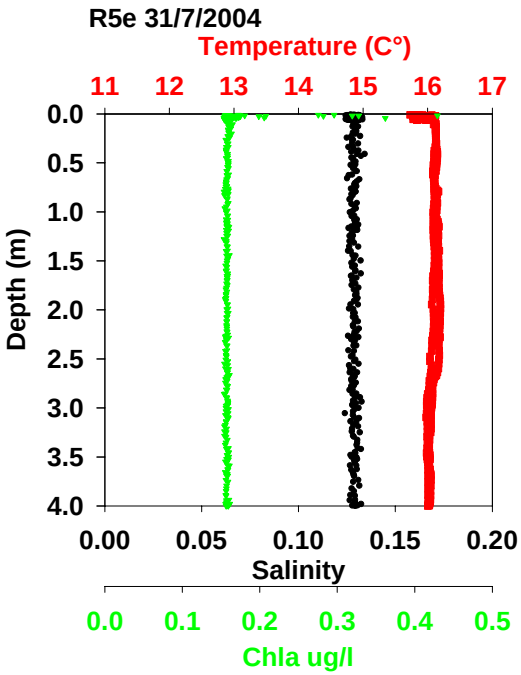


B) Transition Zone stations R5b-e.









C) Marine stations R7-R9.