

Canadian Arctic Shelf Exchange Study



The Canadian Arctic Shelf Exchange Study
2006/2007 General Meeting
Château Laurier
Québec City
30 April to 02 May 2007

Detailed Agenda

Sunday April 29

15:00 - 17:00 Registration at Château Laurier

17:00- 20:00 Cocktail at the Musée National des Beaux Arts du Québec located only a few blocks from the hotel (Ave Wolfe-Moncalm, off Grande Allée; see map). The reception will be held in the Atrium of the museum (old prison of the Plaines). For the occasion, the Hydro-Québec Gallery will be open so you can admire the Brousseau Inuit art collection which contains more than 2639 pieces; it is worth seeing!

Monday April 30 (Room Abraham-Martin)

8:00-9:00 Registration

9:00 -9:30 Welcome and Introduction by Louis Fortier

Sea ice and life

9:30-10:00 C. Pedrós-Alió Waking up from the arctic winter: identity and heterotrophic activity of the bacterioplankton

10:00-10:30 Coffee Break

10:30-10:50 D. Barber Ocean-sea ice-atmosphere processes during CASES; an overview.

10:50-11:10 M. Garneau Bacterial biomass and production in a coastal Arctic ecosystem: Seasonal dynamics and the importance of particles

11:10-11:30 M. Rózańska Protists entrapment in newly formed sea ice of the Canadian Beaufort Sea

11:30-11:50 P. Trela Fine-scale Vertical Distribution of Zooplankton and Arctic Cod at the CASES Overwintering Station Recorded with Underwater Video.

12:00-13:30 Lunch (on your own)

13:30-13:50 A. Riedel Role of exopolymeric substances (EPS) in Arctic sea-ice carbon cycling

Annual cycles

- 13:50-14:20 Y. Gratton Seasonal Evolution of the Physical Conditions in the Amundsen Gulf in 2003-2004.
- 14:20-14:40 D. Benoit Hydro-acoustic detection of large winter aggregations of Arctic cod (*Boreogadus saida*) at depth in ice-covered Franklin Bay (Beaufort Sea)
- 14:40-15:00 J. Payet Environmental effects on the spatial and seasonal dynamics of viruses and bacteria in the Amundsen Gulf and MacKenzie Shelf
- 15:00-17:00 Coffee Break (15:00h) and Poster session Sea ice and life/ Annual cycles (Room Wilfrid-Laurier)**
- 17:00- Dinner (on your own)**

Tuesday May 1(Room Abraham-Martin)

Carbon and climate

- 9:00-9:30 Jon Grant River to sea: particulate carbon coupling from Kugmallit Bay to the Beaufort Shelf
- 9:30-9:50 A. Forest Vertical fluxes of particulate organic carbon during the over-wintering year of the Canadian Arctic Shelf Exchange Study (CASES): where, when, and why?
- 9:50-10:10 S. Bélanger Quantification of inorganic carbon photoproduction in the Beaufort Sea using satellite ocean color data
- 10:10-10:40 Coffee break**
- 10:40-11:00 N. Morata Sedimentary pigments as biomarkers of spatial and seasonal variations in the Beaufort Sea benthic-pelagic coupling

Modelization and Other

- 11:00-11:30 A. Aitken Beaufort Shelf and Amundsen Gulf benthos: a wealth of biodiversity and hotspots for secondary production.
- 11:30-11:50 G. Lintern Results of sediment resuspension modelling in the shallow

Beaufort Sea

- 11:50-12:10 F. Dupont A ice-ocean-biology coupled model of the Pan-Arctic Ocean
- 12:10-12:30 L. Loseto Mercury levels in three Arctic Food webs in the summering range of Beaufort Sea Beluga
- 12:00-13:30 Lunch (on your own)**
- 13:30-15:30 Poster session CO2 and climate/model and other (Room Wilfrid-Laurier)**
- 19:00 Dinner- Banquet –Astral**

Wednesday May 02 (Room Abraham-Martin)

- 9:00- 9:20 Michaud/Vincent An ocean of data: The CASES legacy for IPY and beyond
- 9:20-9:30 F. Pokiak A few words from IGC
- 9:30-10:00 **Update on the special issues and the Synthesis document**

Abstracts titles by alphabetical order

Oral presentations are indicated by *

Authors	Title	Theme	Page
Aitken et al.*	Beaufort Shelf and Amundsen Gulf benthos: a wealth of biodiversity and hotspots for secondary production.	4	15
Alonzo et al.*	Waking up from the Arctic winter: identity and heterotrophic activity of the bacterioplankton	1	1
Barber et al.	Ocean-sea ice-atmosphere processes during CASES; an overview	1	1
Bélanger et al.	Quantification of inorganic carbon photoproduction in the Beaufort Sea using satellite ocean color data	3	10
Ben Mustapha et al.	Evaluation of ocean color algorithms in the Cape Bathurst polynya using MODIS and SeaWiFS spectral bands	4	15
Benoit et al.*	Hydro-acoustic detection of large winter aggregations of Arctic cod (<i>Boreogadus saida</i>) at depth in ice-covered Franklin Bay (Beaufort Sea)	2	5
Benoit et al.	Diel vertical migrations at depth in ice-covered Franklin Bay	2	5
Blasco et al.	Origin and Evolution of the Mackenzie Trough, Canadian Beaufort Shelf	3	15
Bouchard and Fortier	Hatching Season and Growth of Juvenile Arctic Cod (<i>Boreogadus saida</i>) in the Laptev Sea	4	16
Braithwaite et al.	An ocean of data: The CASES legacy for IPY and beyond	4	17
Brugel et al.	Dynamics of pico- and nanophytoplankton in the Amundsen Gulf during the vernal season.	1	1
Connelly and Deibel	Spatial Patterns of Particulate Organic Matter Composition in Near-bottom Waters of the Beaufort Sea Shelf, Arctic Ocean	3	10
Darnis and Fortier	Contrasting reproductive strategies among the dominant Arctic copepods: <i>Calanus glacialis</i> , <i>C. hyperboreus</i> and <i>Metridia longa</i> in the southeastern Beaufort Sea	1	1
Deibel et al.	Seasonal changes in fatty acid and lipid class content of suspended particulate organic matter (SPOM) and zooplankton in Franklin Bay	1	2
Dupont*	A ice-ocean-biology coupled model of the Pan-Arctic Ocean	4	17
Ehn et al.	Bio-optical and structural properties inferred from irradiance measurements within the bottommost layers in an Arctic landfast sea ice cover	2	6
Forest et al.	The annual cycle of particulate organic carbon export in Franklin Bay (Canadian Arctic): environmental control and food web implications	3	10

Authors	Title	Theme	Page
Forest et al.*	Vertical fluxes of particulate organic carbon during the over-wintering year of the Canadian Arctic Shelf Exchange Study (CASES): where, when, and why?	3	11
Galley et al.	Atmospheric and oceanic control of the sea ice mass balance in the southern Beaufort Sea and Amundsen Gulf during the CASES experiment	2	6
Garneau et al.*	Bacterial biomass and production in a coastal Arctic ecosystem: Seasonal dynamics and the importance of particles	1	3
Grant et al.*	River to sea: particulate carbon coupling from Kugmallit Bay to the Beaufort Shelf	3	11
Haaf et al.	Results of Mackenzie River water and sediment discharge modelling under present day and future scenarios	4	17
Hwang et al.	Spatial and temporal variability of ship-based passive microwave signatures during CASES fall field program	2	6
Jakes et al.	Results of sediment resuspension modelling in the shallow Beaufort Sea	4	18
Iacozza et al.	On the Relationship Between Snow Distribution and Sea Ice Surface Roughness in the Canadian Arctic	1	3
Juul-Pedersen et al.	Influence of a river plume on the fluxes and composition of particulate material exported on an Arctic shelf	3	12
Kamali-Nezhad et al.	Seasonal Evolution of the circulation in Franklin Bay, Amundsen Gulf	4	18
Lalande et al.	Export fluxes of biogenic matter in the presence and absence of seasonal sea ice cover in the Chukchi Sea	4	18
Lanos et al.	Evolution of the physical properties of the water column during winter in the Amundsen Gulf, Canadian Arctic	4	19
Leitch et al.	The Mackenzie River Basin as a source of mercury to the Beaufort Sea	2	7
Loseto et al.*	Mercury levels in three Arctic Food webs in the summering range of Beaufort Sea Beluga	4	19
Magen et al.	Origin and Fate of Particulate Organic Carbon in the Beaufort Sea shelf–Amundsen Gulf area, Canadian Arctic	3	12
Makabe et al.	Vertical migrating behaviors of arctic copepod <i>Calanus hyperboreus</i> (AF) in mid-winter	1	4
Miller et al.	Carbon dynamics in sea ice: A winter flux time series	3	13
Morata and Renaud*	Sedimentary pigments as biomarkers of spatial and seasonal variations in the Beaufort Sea benthic-pelagic coupling	3	13

Authors	Title	Theme	Page
Payet and Suttle*	Environmental effects on the spatial and seasonal dynamics of viruses and bacteria in the Amundsen Gulf and MacKenzie Shelf	2	7
Pomerleau et al.	Linkage between mercury and oceanographic processes in marine pelagic zooplankton in the Canadian High Arctic	2	8
Prokopowicz et al.	Seasonal and developmental variation in the lipid class composition of the hyperiid amphipod <i>Themisto libellula</i> (Mandt) in the Western Canadian Arctic	2	8
Rail et al.	Winter pulses in the Beaufort Sea undercurrent	4	19
Richerol and Rochon	Surface and pre-industrial dinoflagellate cyst assemblages: evolution of the paleo sea-surface conditions over the last 1000 years in the Mackenzie Trough, Beaufort Sea (Canada)	3	13
Riedel et al.*	Role of exopolymeric substances (EPS) in Arctic sea-ice carbon cycling	1	4
Rosenberg et al.	α -HCH air-water dynamics in the Southern Beaufort Sea, Northwest Passage and North Water Polynya (NOW)	4	19
Rózańska et al.*	Protists entrapment in newly formed sea ice of the Canadian Beaufort Sea	1	4
Schell et al.	Recent paleo-sea ice conditions of the Amundsen Gulf, Canadian Arctic Archipelago as indicated by the foraminiferal record of the last 200 years	3	14
Scott et al.	Foraminiferal assemblage changes over the last 15,000 years on the Mackenzie/ Beaufort sea slope and Amundsen Gulf, Canada: implications for past sea-ice conditions	3	14
Thanassekos et al.	An individual-based model for growth and survival of Arctic cod larvae	4	20
Terrado et al.	Microbes in the Beaufort Sea: Molecular insights from CASES and future directions	2	9
Trela and Deibel*	Fine-scale Vertical Distribution of Zooplankton and Arctic Cod at the CASES overwintering Station Recorded with Underwater Video	1	5
Walsh and B. Scott	Foraminifera associated with the Kopanoar mud volcano and other “pingo-like” features on the Beaufort Shelf, Arctic Ocean: possible paleo-indicators of methane seeps	2	9

THEME 1. SEA ICE AND LIFE

1.1 Waking up from the Arctic winter: identity and heterotrophic activity of the bacterioplankton

Laura Alonso, Olga Sánchez, M^a Montserrat Sala, Josep M. Gasol, C. Pedrós-Alió

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The microbial ecology of polar oceans is still little known. This is especially true of the winter period, when only a handful of studies have been carried out. The Canadian project CASES included a time series from the darkest (December 2003) to the most lit times of the year (June 2004) in Franklin Bay. We collected surface samples to determine the abundance and identity of the bacterioplankton using fluorescent in situ hybridization (FISH). FISH was combined with microautoradiography in order to count the fraction of active cells taking up three types of substrates: glucose, amino acids and ATP. Archaea made up 15% of the total cell count in the winter, but decreased to almost undetectable levels in summer. Bacteria, on the other hand, increased from 60 to 95% of the total count during the same period. Alfa-proteobacteria were the most abundant group followed by bacteroidetes and gamma-proteobacteria. The three groups increased from March on, although the bacteroidetes reached their maximal abundance earlier (July) than the proteobacteria (August). There was a significant increase in beta-proteobacteria towards the summer. Intriguingly, the latter were very active in the uptake of the three substrates. Bacteroidetes, on the contrary, showed a low percent of active cells. In comparison with temperate oceans, the percent of active cells was very high, even during the winter. The substitution of archaea (in winter) by beta-proteobacteria (in summer) was also a feature not seen in other systems. The data set is the first one to show the activities of different prokaryotic groups during the winter in a polar area.

1.2 Ocean-sea ice-atmosphere processes during CASES; an overview

Dave Barber¹ et al.

¹*Centre for Earth Observation Science, University of Manitoba, Winnipeg, Manitoba, Canada*

1.3 Dynamics of pico- and nanophytoplankton in the Amundsen Gulf during the vernal season

Sonia Brugel¹, Christian Nozais², Serge Demers¹

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We investigated the dynamics of phytoplankton communities in the upper water column (50m) of the Amundsen Gulf during June 2004. We measured the total and size fractionated (5 and 20 µm) chlorophyll *a* (Chl *a*) concentrations and we characterized by flow cytometry (FCM) the size-structure of small phytoplankton cells (picophytoplankton <2 µm, small nanophytoplankton 2-10 µm and large nanophytoplankton >10 µm). Our results allowed us to discriminate three distinct regions. The first region, the southern part of the Cape Bathurst polynya, showed low Chl *a* biomass associated with low cell concentration and an equal contribution of picophytoplankton and small nanophytoplankton cells (50% and 47% respectively of the total FCM cell counts). This region was characterized by an ice-edge system where the nutrients were still present in the surface layer. The second region, the centre of the polynya, exhibited even higher Chl *a* concentrations although nutrients were exhausted in the surface layer. The Chl *a* biomass was mainly due to cells smaller than 20 µm, and the picophytoplankton dominated the community with concentrations averaging 9711 cells.ml⁻¹. The third region, the West of the Amundsen Gulf on the eastern part of the Mackenzie shelf, showed Chl *a* standing stocks reaching levels ten times higher than in the two previously described regions (i.e., averaging 233 mg Chl *a*.m⁻²). All pico- and nanophytoplankton fractions had high concentrations; however, most of the Chl *a* biomass was attributed to cells larger than 20 µm. In this region, upwelling events could be responsible for the phytoplankton size-structure. In contrast, in the two other regions, ice dynamics could have led to a phytoplanktonic community in early stage of development close to the ice edge and to a community already in post-bloom conditions in the centre of the polynya, which already experienced ice retreat.

1.4 Contrasting reproductive strategies among the dominant Arctic copepods: *Calanus glacialis*, *C. hyperboreus* and *Metridia longa* in the southeastern Beaufort Sea

Gérald Darnis and Louis Fortier

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The primarily herbivorous copepods *Calanus glacialis*

and *C. hyperboreus* and the omnivorous *Metridia longa* make up the bulk of zooplankton biomass in Arctic pelagic ecosystems. They play a crucial role in the trophic flux of energy through the pelagic food web and in the vertical transport of carbon during their ontogenetic vertical migration. From studies conducted in the Greenland Sea and northern Norway, the two Calanidae are known to have evolved different reproductive strategies to deal with the strong seasonality of food availability. Despite its importance in Arctic zooplankton assemblages, the annual reproductive cycle of *M. longa* is hardly documented. The CASES program provided a rare opportunity to study the reproductive biology of these three dominant copepods over an annual cycle in the Canadian Arctic waters of the Beaufort Sea. The time series was conducted from 20 October 2003 to early August 2004. Samples for egg production experiments were collected in autumn and summer at different stations making the CASES sampling grid, and at one permanent station once the Amundsen settled in the landfast ice of Franklin Bay for the overwintering period. Females of all three species were present year round and reproduced successfully in the study region. Timing of spawning was markedly different for the two Calanidae. *C. hyperboreus* initiated reproduction in January-February that lasted until April in Franklin Bay, well before any significant chlorophyll concentrations could be measured in the water column or under the sea-ice. *C. glacialis* first spawning was measured in late May in Franklin Bay and its egg production rates peaked in June. Egg production by *Metridia longa* started in March and continued throughout spring and summer. The herbivorous *C. hyperboreus* used essentially its internal energy reserves to fuel its gonadal maturation and spawning processes at a time when no food resources were present. One possible explanation for the winter reproduction activity of the smaller omnivorous *Metridia longa* is that it was partly fuelled by exerting predation on eggs and nauplii of *C. hyperboreus*. This potential trophic link is interesting and needs further investigation. For *C. glacialis* females, gonadal maturation began prior to the spring bloom but maximum egg productions were reached in summer when phytoplankton biomass was higher.

1.5 Seasonal changes in fatty acid and lipid class content of suspended particulate organic matter (SPOM) and zooplankton in Franklin Bay

Don Deibel, Tara Businski, Tara Connelly, Piotr Trela,

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In this paper we report an investigation of the potential

food sources for several species of zooplankton at the Franklin Bay overwintering station from December 2004 to August 2005, as a test of whether the Parsons et al. (1989) food web model can be applied throughout the year. We used lipid class and fatty acid content of SPOM and zooplankton to determine the contribution of various terrestrial and marine source materials to their absorbed ration. Ice breakup began during the end of May, and phytoplankton and bacterial biomass increased linearly from mid-June to early August. Bacterial biomass was equal to or greater than phytoplankton biomass for most of the year, and bacterial fatty acids (FA's) were a high proportion of total FA's of SPOM throughout the year as well (i.e. 20-40%). The sum of bacterial and terrestrial FA's made up ca. 60% of total SPOM FA's throughout most of the year. The diatom marker 16:1(n-7)/16:0 was well below 0.5 in the SPOM for most of the year, indicating a relatively modest contribution of diatoms. However, the DHA/EPA ratio showed a sharp decline at the end of May and early June, indicating a rapid shift in the relative abundance of dinoflagellates and diatoms. Copepods had a higher diatom FA content than did SPOM, likely because they fed selectively on phytoplankton. Results from the present study did not confirm the separate food webs proposed by Parsons et al. (1989) as there were no clear differences in the relative contribution of terrestrial and marine-source materials to the diets of *Oikopleura* sp. vs. that of copepods. Terrestrial FA's in zooplankton increased in March/April before ice out, which suggests a spreading freshwater plume beneath the ice before breakup. *Oikopleura* had higher bacterial FA content than did the other zooplankton species but similar values to SPOM, in accordance with its ability to ingest bacteria, thus mediating a 'shunt' of the microbial loop. The lower diatom FA content and higher 18:1 ω 9/18:0 ratio (carnivory index) in *C. glacialis* in comparison with *C. hyperboreus* indicated that *C. glacialis* was the more omnivorous of the two species, even though CIV *C. hyperboreus* and mature *C. glacialis* have the same feeding mechanism and a similar size range. We conclude that food webs on the Mackenzie Shelf differ as much at one place over an annual cycle (this study) as they may over a cross-shelf transect at a single point in time (Parsons et al., 1989), that bacterial material moves into the food web via grazing by *Oikopleura* but not copepods, and that terrestrial source material moves into the food web via all species of suspension-feeding zooplankton.

1.6 Bacterial biomass and production in a coastal Arctic ecosystem: Seasonal dynamics and the importance of particles

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The overwintering deployment of our research platform in Franklin Bay allowed a multi-seasonal sampling and provided a unique record of bacterial abundance and production (BP) for the coastal Arctic Ocean. Microbial and environmental variables were collected from 8 depths at a 200-m deep site on thirty three occasions over a complete year. BP was estimated from leucine (³H-Leu) uptake rates with the objectives (1) to relate seasonal BP to physico-chemical characteristics in a coastal Arctic environment and (2) to quantify the annual bacterial carbon fluxes in terms of production and respiration (BR) as part of the CASES carbon budget for this region. BP occurred during all seasons and peak rates were measured in summer. During this period, a close statistical dependence of BP on chlorophyll *a* (Chl *a*) and temperature indicated a bottom-up control via the chemical and physical environment, rather than top-down control by biological processes. We estimated the bacterial carbon fluxes in Franklin Bay from fall 2003 to summer 2004 and compared them to carbon fluxes associated with primary production (PP). Annual BP and BR integrated over the water column were 6.0 and 20.7 g C m⁻² y⁻¹, respectively, whereas annual phytoplankton PP was 16.2 g C m⁻² y⁻¹. BP was a much higher fraction of PP relative to an analogous study in the coastal Antarctic environment. The coastal Arctic ecosystem is net heterotrophic, which implies an input of allochthonous organic carbon inputs to supplement BP. For the Franklin Bay area (ca. 8003 km²) the total bacterial CO₂ production would be 1.7 × 10¹¹ g C y⁻¹. This represents 13% of the terrestrial dissolved organic carbon fluxes by Mackenzie River to the Canadian Shelf of the Beaufort Sea. This shows that on an annual basis the microbial community is responsible for a major carbon flux in the region. The Mackenzie River brings large amounts of particulate organic and inorganic materials to the Beaufort Sea Shelf. Such loads may affect the spatial distribution, composition and productivity of bacterial communities. A further objective of our study was to assess the biological importance of bacteria that are attached to particles. Microbial and environmental variables were collected from surface waters (≤2 m) in the Mackenzie River plume from 30 June to 11 July 2004. We measured the

total amount and a small particle fraction (<3 μm) of suspended particulate matter (SPM), particulate organic matter (POM), particulate inorganic matter (PIM), Chl *a*, ³H-Leu uptake rates and BP. We hypothesized that there would be strong offshore gradients across the river plume in these environmental and associated microbiological properties. Preliminary results indicate that the relative contribution of BP from particle-associated bacteria to total BP was correlated with POM, PIM and Chl *a* concentrations. As a final objective, we addressed the question of whether particle-based bacteria differ from the free-living assemblage in terms of community structure. For this we applied a phylogenetic analysis based on denaturing gradient gel electrophoresis (DGGE). Our results show consistent difference in bacterial assemblage among stations across the river plume and between size fractions.

1.7 On the Relationship Between Snow Distribution and Sea Ice Surface Roughness in the Canadian Arctic.

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Our objective is to investigate the relationship between surface roughness and snow distribution over first-year sea ice at local to regional scales, using both in situ and helicopter-based (EM induction) sampling methods. This work is a preliminary step in understanding the dynamic processes responsible for the creation of snow distributions that would influence ecological, oceanographic and climatological aspects of the Arctic marine system. Results suggest that the snow depth and surface roughness parameters (average and standard deviation) vary between sites and are reasonably consistent at different scales. The average snow depth sampled at the local and regional scales range from approximately 5 cm to 35 cm, with a standard deviation between 2 cm and 35 cm. The average surface roughness vary from 7 cm to 55 cm. Sites at the two scales also exhibit similar correlation lengths with respect to surface roughness, with values less than 25 m for most sites. The standard deviation in snow depth is best estimated using the standard deviation in the surface roughness at the local level, accounting for approximately 70% of the variability in the snow depth. This relationship is non-linear and is best modeled using an S-curve. The best estimate for the mean snow depth is the mean surface roughness at the regional scale. This logarithmic relationship is able to account for approximately 80% of

the variability in the snow depth.

1.8 Vertical migrating behaviors of arctic copepod *Calanus hyperboreus* (AF) in mid-winter

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Time-series sediment traps were deployed at 200 m depth in the Beaufort Sea and the Amundsen Gulf to investigate overwintering behaviors of arctic copepods from October 2003 to August 2004 as part of the Canadian Arctic Shelf Exchange Study (CASES). Among trap-collected zooplankton (TCZ), *C. hyperboreus* AF (adult female) appeared through the year with two marked increases in October and late February-March. We compared the seasonal changes of *C. hyperboreus* AF in TCZ with those collected using plankton net and the UMP (Upward Migratory Trap, Hattori et al.). The former increase in October probably showed their downward movements of the seasonal vertical migration. The latter increase in February-March found at all stations are thought to reflect the upward and downward movements of *C. hyperboreus* AF in the depth range of 50-200 m within ca. 14 days.

1.9 Role of exopolymeric substances (EPS) in Arctic sea-ice carbon cycling

Andrea Riedel¹, Christine Michel², Michel Gosselin¹

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Sea ice on the Mackenzie shelf was sampled on 21 occasions during the overwintering period (February to June 2004) of the Canadian Arctic Shelf Exchange Study (CASES). First-year sea ice and surface waters were analyzed for chlorophyll *a* (chl *a*), exopolymeric substances (EPS) dissolved (DOC) and particulate (POC) organic carbon concentrations, and bacterial and protist abundances. EPS concentrations were measured with Alcian blue staining. Sea-ice EPS concentrations were one to three orders of magnitude higher than in

surface waters and EPS concentrations were significantly correlated with DOC and chl *a* concentrations. EPS contributed significantly to sea-ice POC (average 23%) especially during the ice melt period (72%). Our study indicates that EPS may be part of alternative microbial carbon transfer pathways in the Arctic.

1.10 Protists entrapment in newly formed sea ice of the Canadian Beaufort Sea

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Protist abundance and species composition were determined in four stages of newly formed sea ice (new ice, nilas, young ice and thin first-year ice) and in the underlying surface waters of the Canadian Beaufort Sea from 30 September to 19 November 2003. Pico- and nanoalgae were counted by flow cytometry whereas autotrophic and heterotrophic protists >4 µm were identified and counted by inverted microscopy. Protists were always present in sea ice and surface water samples throughout the study period. The most abundant algae in sea ice and surface waters were cells ≤4 µm. They were less abundant in sea ice (40-1700 x 10³ cells L⁻¹) than in surface waters (10-3030 x 10³ cells L⁻¹). In contrast, larger algae (4-20 µm) were more abundant in sea ice (59-821 x 10³ cells L⁻¹) than in surface waters (22-256 x 10³ cells L⁻¹). These results suggest a selective incorporation of larger algal cells in sea ice. Protists >4 µm assemblage was composed of a total number of 48 taxa and several unidentified algal groups at the genus and higher taxonomic rank, complex and size class. The species composition in early stages of ice formation (i.e. new ice and nilas) was very similar to the one observed in surface waters and composed of a mixed population of nanoflagellates (Prasinophyceae and Prymnesiophyceae), diatoms (mainly *Chaetoceros* species) and dinoflagellates. In older stages of sea ice (i.e. young ice and thin first-year ice), the species composition became markedly different from the one of the surface waters. These older ice samples contained relatively less Prasinophyceae and more unidentified nanoflagellates than the younger ice. Resting spores and dinoflagellate cysts were generally more abundant in sea ice than in surface waters. However, further studies are needed to determine the importance of this survival strategy in Arctic sea ice. This study clearly shows the selective incorporation of large cells (>4µm) in newly formed sea ice and the change in the species composition of protists between sea ice and surface waters as the fall season progresses.

1.11 Fine-scale Vertical Distribution of Zooplankton and Arctic Cod at the CASES Overwintering Station Recorded with Underwater Video.

Piotr Trela and Don Deibel

Ocean Sciences Centre, Memorial University, St. John's, NL, A1C 5S7 Canada

Distribution of zooplankton in the water column is not random. Changes in physical properties, patchy distribution of food and behavioural traits often result in zooplankton aggregating in fine, clearly defined layers, at scales often below the resolution of conventional instruments such as towed nets and pumps. The advent of underwater video instruments (UVI) enables us to observe zooplankton at scales of 10s of cms and meters, along with the physical properties of the water column at comparable scales. In addition, UVI may record fragile organisms that can be easily destroyed during net tows or subsequent sample preservation, transport and storage. We present vertical profiles of zooplankton from diurnal series recorded in Franklin Bay, Beaufort Sea. We observed pronounced vertical stratification among the dominant taxa. Some taxa, such as *Aglantha sp.*, other hydromedusae, and unidentified (meroplanktonic?) organisms, stayed in the surface half of the water column, while the copepods and the Arctic cod, stayed predominantly in the deep layer. The upper boundary of copepod layers moved upward during the dark period, despite the fact that the surface light signal was attenuated by almost 2 metres of ice.

THEME 2. ANNUAL AND INTERANNUAL CYCLES

2.1 Hydro-acoustic detection of large winter aggregations of Arctic cod (*Boreogadus saida*) at depth in ice-covered Franklin Bay (Beaufort Sea)

Delphine Benoit¹, Yvan Simard² and Louis Fortier¹

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In the Canadian Arctic, the large biomass of Arctic cod that must exist to explain consumption by predators has eluded detection. From December 2003 to May 2004, acoustic estimates of Arctic cod biomass at a 225-m deep station in central Franklin Bay (southeastern

Beaufort Sea) increased progressively by two orders of magnitude, reaching maximum values of 2.7 kg m⁻³ and 55 kg m⁻² in April. During accumulation in Franklin Bay, the fish occupied the lower part of the Pacific Halocline (140 m to bottom), where the temperature-salinity signature (-1.4 °C to 0.3 °C; 33 to 34.8 PSU) corresponded to slope waters. Currents at 200 m along the western slope of Amundsen Gulf headed SSW throughout winter, suggesting the passive advection of cod from southeastern Beaufort Sea into Franklin Bay. Retention in Franklin Bay against the general circulation resulted from the fish keeping at depth to reduce predation by diving seals and/or to benefit from relatively warm temperatures in the lower halocline. Based on an average standing biomass of 11.23 kg m⁻², we estimate the total biomass of Arctic cod in Franklin Bay in April at 30.3 Mt, a value that amply satisfies the requirements of predators. Dense accumulations of Arctic cod in embayments in winter likely play an important role in structuring the ecosystem of the Beaufort Sea. Understanding how climate change and the reduction of the sea ice cover will affect the stability of the oceanographic/behavioral accumulation process requires further research and modeling.

2.2 Diel vertical migrations at depth in ice-covered Franklin Bay

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The exceptional acoustic data set collected onboard the NGCC Amundsen through the CASES overwintering expedition (December 2003 to June 2004) allows to explore various aspects of the biological processes occurring in the ice-covered water column (station 230 m deep) in Franklin Bay. In previous study using echointegration on day time data, we showed that arctic cod is found as dense aggregations in the lower part (> 140 m) of the water column during winter. Here we present first results of diel vertical migrations of the scattering layer observed in the lower part of the water column. Net catches of arctic cod and zooplankton are used to determine which organisms compose the migrating scattering layer. Environmental variables (tide, light, temperature) and ecological stressors (predation) are explored to describe the processes stirring these migrations.

2.3 Bio-optical and structural properties inferred from irradiance measurements within the bottommost layers in an Arctic landfast sea ice cover

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Irradiance spectra were measured at increments within the bottommost layers of landfast sea ice with the aid of divers in Franklin Bay, Canada, in an effort to model *in situ* bio-optical properties of the bottom ice. The study took place between April 22 and May 9, 2004, during the over-wintering part of CASES (Canadian Arctic Shelf Exchange Study). The ice was about 1.8-m-thick with a snow cover of variable thickness (~ 0.04 to 0.4 m). Ice surface temperatures increased from about -12 to -6.4 °C during the sampling period, while ice temperatures within the bottommost layers of the ice cover ranged from -3.0 to -1.2 °C. A visible layer of bottom ice algae was observed with measured chlorophyll *a* (chl *a*) concentrations ranging from 0.1 to 10 mg chl *a* m⁻². This algal layer had a marked effect on the spectral distribution of transmitted irradiance beneath the ice. Particulate absorption spectra, $a_p(\lambda)$, measured on filters from melted ice samples showed evidence of pigment degradation and could not fully explain the shape of the *in situ* diffuse attenuation coefficient, $K_d(\lambda)$, for the algal layer. Interior ice layers with chl *a* signals did however show evidence of degradation. Additionally, $K_d(\lambda)$ was always larger than $a_p(\lambda)$ due to inclusions in the ice which increased the scattering. For the bottom 10 cm of the sea ice, the scattering coefficient, b (wavelength independent), was around 400 m⁻¹ while at the 10-20 cm layer from the ice bottom it decreased to 165 m⁻¹. Using $a_p(\lambda)$ combined with b tuned at 750 nm as inputs to DISORT seem to adequately explain the radiative transfer near the bottom of first-year sea ice.

2.4 Atmospheric and oceanic control of the sea ice mass balance in the southern Beaufort Sea and Amundsen Gulf during the CASES experiment

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The CASES study region, formed by the southern Beaufort Sea and Amundsen Gulf are of considerable interest from a climate variability and change

standpoint for several reasons. It is in this area that an all-important gradient of sea ice age and thickness occurs, an inter-connection of the Arctic multi-year pack with various thickness classes of mobile first year sea ice as well as landfast sea ice of the Canadian Arctic Archipelago. The interaction of these sea ice regimes creates a flaw lead system which has been a persistent feature of the region and has analogs on both sides of the pole. Canadian Ice Service digital ice charts for the western Arctic region were analyzed for the period 2003–2004 on a 4km² grid in order to characterize the sea ice mass balance in several areas within the CASES study region over an annual cycle. Within the CASES time frame, the spatial and temporal variability of ocean mixed layer depth and ocean heat content are explored in relation to their effects on sea ice mass balance. Atmospheric variables collected aboard the Amundsen during CASES are also explored.

2.5 Spatial and temporal variability of ship-based passive microwave signatures during CASES fall field program

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In this study, we describe variability of passive microwave signatures of a variety of ice types (new ice, nilas, grey ice, and first-year ice) and ice surface conditions (smooth, rafted and pancakes) observed during fall freeze-up. Ship-based observation was conducted from 18 October to 13 November 2003 in the study area of Canadian Arctic Shelf Exchange Study (CASES). Dual polarized (vertical and horizontal) microwave radiometers at 19, 37 and 85 GHz were mounted about 12 m above the sea level, onboard a research icebreaker *CCGS Amundsen*. A web camera attached to the radiometer shed used to take photographs of surface within the field-of-view of radiometers. During the observation, the microwave signatures were collected both at stations and along the transit between stations. At stations, the radiometers scan from 30-degree to 50-degree incident angle with 5-degree interval, and the scan was duplicated to ensure the stability of measurements. Along the transit, the radiometers were fixed at 50-degree incident angle and were programmed to sample the signatures every 5 seconds. In this study we mainly focus on the measurements along the transits. For the transit measurements, we rely on surface photographs and occasional notes taken during the measurements to infer ice type and surface condition. However, we collected geophysical properties (temperature, salinity and thickness) of snow and sea ice at stations, which can

be representative of nearby transit measurements. In addition, fine sampling interval (~ 5 seconds) of transit measurements provides good information of small-scale variability of passive microwave signatures. This small-scale variability (~ meters) are also compared with both airplane-scale (~kilometers) and satellite-scale (~tens of kilometers) measurements. The observed microwave T_{BS} along transit showed considerable spatial variability. For example, the microwave polarization ratio at 19 GHz (PR(19)) varied from 0.06 (i.e., snow-covered ice) to 0.24 (i.e., open water or very thin nilas) within 30 m apart. Here PRs is defined as $PR(v)=[TB(vV)-TB(vH)]/[TB(vV)-TB(vH)]$ where v is frequency (GHz) and V and H is vertical and horizontal polarizations. This type of small-scale variability is averaged out in satellite data. Another interesting feature is consolidated pancake ice. During our observation, we encountered large number of consolidated pancake ice, and they showed a unique microwave signature. Over consolidated pancake ice, the microwave polarization ratios (PRs) became ~0.05 for all frequencies (19, 37 and 85 GHz). As a result, the difference of PRs is distinctively smaller than those nearby locations. This is quite similar to what we observed at stationary measurements. We speculate surface scattering from rough surface of consolidated pancake ice play a role, but definite causes are still not clear. The observed T_{BS} are statistically compared with satellite-scale data (i.e., SSM/I) and discussions of these comparisons will be presented at the conference.

2.6 The Mackenzie River Basin as a source of mercury to the Beaufort Sea

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High levels of mercury (Hg) have been found in marine mammals in the Mackenzie Delta and Beaufort Sea area. Hg concentrations in beluga liver as high as 40.3 $\mu\text{g/g}$ (wet weight) were measured in 1996, which represented a 4-fold increase compared with measurements in 1981. We believe that the increase in Hg concentration in marine mammals in this area is at least partly a result of climate variation in the Mackenzie Basin. To investigate the role the

Mackenzie Basin plays on elevated concentrations of Hg in marine mammals, surface water samples for total Hg (THg) and methylmercury (MeHg) were taken from throughout the lower Mackenzie Basin (from Hay River to the Delta) in the summers of 2003, 2004 and 2005, and in the estuary area during the freshets of 2004 and 2005. Hg concentrations varied dramatically between years and between seasons. In the summers of 2003 and 2005, water levels in the Mackenzie River were high, while in 2004, they were extremely low. Hg concentrations seemed to follow this trend, with concentrations of THg, MeHg, suspended particulate Hg (SPM) being lowest in 2004, and higher in 2003 and 2005. During the spring freshet, water is noticeably much more turbid than in the summer. Values of THg and SPM were approximately 7x higher in the spring than in the summer, while MeHg values were very similar between spring and summer. Approximately 50% of the THg discharged annually occurs during the relatively short freshet. This is a time of the year when the ecosystem is especially vulnerable to the intrusion of bioaccumulative contaminants. Of the THg discharged, 75-88% was in the particulate form. MeHg showed the opposite trend whereby only 28% of the yearly discharge occurred in the spring. Calculations suggest that approx. 2.2 ± 0.9 tons of THg enter the Beaufort Sea via the Mackenzie River annually. This is comparable to estimates from other major arctic rivers such as Russia's Lena, Ob, and Yenisei Rivers with THg fluxes of 4.0, 1.3, and 0.7 tons/year respectively. The riverine flux for the Mackenzie River is approximately 13% of the total atmospheric deposition of Hg to the high Arctic Ocean (17 tons). Given that the temperature in the Mackenzie River Basin has been steadily increasing, we expect the Hg flux from the Mackenzie River will increase due to increased permafrost melt, increased erosion, increase frequency of forest fires, and an increased rate of mercury methylation.

2.7 Environmental effects on the spatial and seasonal dynamics of viruses and bacteria in the Amundsen Gulf and Mackenzie Shelf

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Viruses are the most abundant biological entities in the ocean, and are major players influencing the dynamics and structure of marine microbial communities as well as global biogeochemical cycles. Despite their likely significance, little is known about viruses and their roles in the shelf waters of the Arctic Ocean, a key area in the

sequestration and cycling of carbon. As a part of the Canadian Arctic Shelf Exchange Study (CASES), we investigated the spatial and seasonal variability in the distribution of viruses in relation to biotic (bacteria, chlorophyll *a*) and abiotic variables (temperature, salinity and depth). As well, we assessed viral production and lysogenic induction, with the goal of determining the role of viruses in bacterial mortality, and carbon and nutrient cycling in the Mackenzie Shelf and Amundsen Gulf. Viral and bacterial abundances estimated by epifluorescence microscopy and flow cytometry (FC) were significantly correlated ($r = 0.87$ and 0.89 , respectively). Viruses ranged from 0.13×10^6 to $23 \times 10^6 \text{ ml}^{-1}$ and were ~ 2 -fold higher in surface waters during the spring bloom in May and June and ~ 2 -fold higher during July and August, relative to winter. These increases were coincident with a ~ 6 -fold increase in chl *a* during spring and a ~ 4 -fold increase in bacteria during summer. Spatially, surface viral abundances near the Mackenzie River were ~ 2 -fold higher than in the Mackenzie Shelf and Amundsen Gulf regions during the peak summer discharge, concomitant with a ~ 5 -fold increase in chl *a* (up to $2.4 \mu\text{g l}^{-1}$) and a ~ 2 -fold increase in bacterial abundance (up to $22 \times 10^5 \text{ ml}^{-1}$). Using FC, two subgroups of viruses and heterotrophic bacteria were defined. A low SYBR-green fluorescence virus subgroup (V-II), representing ~ 72 % of the total viral abundance, was linked to the abundance of high nucleic acid fluorescence (HNA) bacteria (a proxy for bacterial activity), which represented 41 to 72 % of the bacteria in surface layers. A high SYBR-green fluorescence viral subgroup (V-I) was more related to high chl *a* concentrations that occurred in surface waters during spring and at stations near the Mackenzie River plume during the summer discharge. These results suggest that V-I infect phytoplankton, while most V-II are bacteriophages. Based on a viral reduction approach, viral production rates significantly increased from 0.09 to $15 \times 10^9 \text{ l}^{-1}\text{d}^{-1}$ from winter to summer, and measurements indicated that between 2 to 34 % of bacteria were lysed each day. The prevalence of lysogeny was assessed from May to August, by adding mitomycin C to induce temperate viruses. Between 4 and 26 % of the bacterioplankton could be induced (mean \pm SD: $9.9 \text{ \%} \pm 6.5 \text{ \%}$) and was greatest in spring compared to summer. Overall, this study highlights the importance of environmental variables, space and scale in viral community ecology and suggests that viruses play a key role in energy and element cycling on the Canadian Arctic Shelf.

2.8 Linkage between mercury and oceanographic processes in marine pelagic zooplankton in the Canadian High Arctic

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Mercury in the Arctic, especially in marine environments, represents a considerable risk due to its ability to undergo methylation and to biomagnify up through to top trophic level feeders. Recently, Stern et al. (2005) suggested that increases in the western arctic animals may link to changes in sea climate and ocean structure. This study aims to examine how climate variation is affecting mercury (Hg) biogeochemical cycle and trends in the coastal environment of the Canadian High Arctic. The main objective is to assess and explain the spatial and inter-specific variability of mercury measured in various marine and mostly pelagic zooplankton genera in three separate high Arctic regions (Baffin Bay, Arctic Archipelago and Western Arctic). We used stable-carbon isotope measurements to distinguish regional differences and general patterns of feeding preferences and stable-nitrogen isotope ratio to determine both trophic level and mercury transfer behaviour among the different taxonomic groups. We also examined water masses with salinity and $\delta^{18}\text{O}$ measurements. Here we present the results from samples collected during two field seasons onboard the Icebreaker CCGS Amundsen, from August 05 to September 15 2005 and August 18 to October 25, 2006 and during the CASES study. Significant relationships observed between salinity, $\delta^{18}\text{O}$, $\delta^{13}\text{C}$ and nutrients with Hg at selected water column depths suggest that differing water masses may be responsible for part of the assimilation of the mercury and carbon in lower trophic level species. The results of this research will lead to a better understanding of the speciation, cycling and transfer of mercury from their sources to the top predators.

2.9 Seasonal and developmental variation in the lipid class composition of the hyperiid amphipod *Themisto libellula* (Mandt) in the Western Canadian Arctic

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2.10 Microbes in the Beaufort Sea: Molecular insights from CASES and future directions

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One of the most outstanding achievements of the Canadian Arctic Shelf Exchange Study (CASES) was the deployment of the research vessel CCGS Amundsen in Franklin Bay, allowing a multi-seasonal sampling of the water column in the Beaufort Sea. Microbial and environmental variables were collected on a periodic basis, including samples for the analysis of DNA from the microbial community. Overall, some 350 DNA samples were collected in the Beaufort Sea, including several stations, different depths and fractions. This represents a valuable legacy for future work. The CASES DNA archives include samples from 50 sampling dates, most of them from the same 200-m deep station in Franklin Bay, giving a comprehensive view of microbial succession at this site. Depths sampled ranged from surface waters to bottom waters, providing a detailed record of microbial distribution through the water column. Samples were size fractionated to study the communities larger or smaller than three micrometers. Previous work showed a transition from a heterotrophic winter community to an autotrophic spring community that was mostly driven by light. As a continuation of this work the microbial community is being studied by means of a DNA fingerprinting technique: Denaturing Gradient Gel Electrophoresis (DGGE). This gives a view of how the community phylogenetic composition evolves through winter and spring, for both large and minute microbes. Correlation analysis of these microbial fingerprints with biotic and abiotic variables has the potential to show which variables drive the microbial community. Our first DGGE results show a significant change in the picoeukaryotic community fingerprint, with a characteristic clustering between winter and spring. The free bacterial community also shows a similar succession. The molecular fingerprint of the larger fractions will also be analyzed, which will give an insight in the seasonal succession of the larger eukaryotic microbes and the prokaryotes attached to particles. The objective of future analysis will be to relate the seasonal changes between the different communities, for example eukaryotes versus prokaryotes, with different chemical and physical variables by means of multivariate analyses. Further work will also include the construction of clone

libraries to identify the major components of the different microbial communities over the year. Also, quantitative molecular methods will be applied in order to quantify the succession of different microbial groups. The legacy of DNA samples from CASES will give us a precise view of how the microbial community assemblage responds to the environmental variables, which are the principal actors in these communities and how specific groups evolve through the year. This knowledge will help us understand how the microbial community participates in the fluxes of carbon in this polar environment and how they will respond to future environmental changes.

2.11 Foraminifera associated with the Kopanoar mud volcano and other “pingo-like” features on the Beaufort Shelf, Arctic Ocean: possible paleo-indicators of methane seeps.

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Results from three cores collected from a mud volcano and near “pingo-like” features (PFL) on the Beaufort Shelf are presented here to illustrate the relationship of benthic foraminifera with methane seeps. Methane was measured coming from the Kopanoar mud volcano shortly before sampling. Other cores were collected from a nearby area of suspected methane seepage and pingo-like features (PLF's). Low diversity foraminiferal fauna were found on the crest of the mud volcano, containing *Ammotium cassis* and *Elphidiella hannai* among other species. These two species are indicators of suspended matter and pollution, and were usually the “last standing” at these sites. The mud volcano samples were collected on the active surface as well as 30 cm subsurface, so it was known that the two species above were tolerating methane. In the distant core from the “pingo-like” area, these two species were only found at depth, suggesting we detected a methane event probably from relict permafrost in that area of the shelf. Although *A. cassis* had been reported from this shelf before, *E. hannai* had never been reported farther north than Vancouver Island. Although these results are from a limited data set, it is suggestive that we can detect both present and past methane seeps with foraminifera. This may be helpful in determining the safety of drilling sites on this or any Arctic shelf that has permafrost, by examining core histories using foraminiferal occurrences as a proxy of the presence and frequency of methane seeps at any one site.

THEME 3. CARBON AND CLIMATE

3.1 Quantification of inorganic carbon photoproduction in the Beaufort Sea using satellite ocean color data

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In DOM-rich Arctic waters, photochemical oxidation of dissolved organic carbon (DOC) plays a significant role in the marine carbon cycles. Depth-integrated photochemical production of dissolved inorganic carbon (DIC) and carbon monoxide (CO) in the Southeastern Beaufort Sea was assessed for the period from 1998 to 2004 using SeaWiFS-derived water inherent optical properties. More than 300 SeaWiFS images were processed using a turbid-water atmospheric correction algorithm that provides reliable water-leaving reflectance retrieval. After eliminating data contaminated by the adjacency effect due to sea ice, the ratio between chromophoric dissolved organic matter (CDOM) and the total absorption coefficients ($[a_{CDOM}/a_t]$) was calculated from the water-leaving reflectance spectrum using an empirical algorithm. The annual DIC/CO photoproduction estimated using SeaWiFS-derived $[a_{CDOM}/a_t]$ was slightly lower (~10%) than the estimation made using regionally constant $[a_{CDOM}/a_t]$ spectra determined from *in situ* measurements. In contrast, assuming a spectrally constant value for $[a_{CDOM}/a_t]$ of 0.9 as in previous published studies led to an overestimation of the annual DIC/CO photoproduction by ~60%. These results suggest that satellite ocean color data could be used to estimate $[a_{CDOM}/a_t]$ in the remote Arctic coastal waters where *in situ* measurements are still unavailable. In addition, the estimation of the absolute value in a_{CDOM} , as obtained from a_t calculated using a semi-analytical algorithm, was used to estimate empirically the variations in the apparent quantum yield for the DIC/CO photoproduction (ϕ). In the future, other ocean color products may also be used to account for the variability in ϕ but such data are currently lacking to develop a robust parameterization of ϕ .

3.2 Spatial Patterns of Particulate Organic Matter Composition in Near-bottom Waters of the Beaufort Sea Shelf, Arctic Ocean

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When assessing carbon cycling, research tends to focus on the quantity and quality of carbon resources in the upper-water column and sediments. Near-bottom water, often overlooked in carbon budgets, regulates the exchange and transport of organic matter between the water column and the sea floor, and therefore, influences the fate of organic matter on continental shelves. Near-bottom waters are also a reservoir for various consumer food resources resulting from sedimentation and resuspension. We evaluated the sources, quantity, and quality of organic matter in near bottom waters across the Beaufort Sea shelf by integrating chlorophyll, fatty acid, C, N, and P concentration and ratio, and C stable isotope data of particulate matter. These tools allow us to assess the importance of terrestrial inputs from the Mackenzie River and upper-water column and near-bottom water links as sources of organic matter in near-bottom waters. Our data show that the quantity and quality of organic matter is highly variable in this dynamic environment. With low C:N, C:P and highly polyunsaturated fatty acids at some stations, we conclude that near-bottom waters can be an important and generally neglected reservoir of labile organic matter that can fuel near-bottom food webs. However, conclusions about the source, quantity, and quality of organic matter reflects the tools used (i.e. chlorophyll, C:N, PUFA, etc.), highlighting the need for multiple and compound-specific tools to increase accuracy in ecosystem studies.

3.3 The annual cycle of particulate organic carbon export in Franklin Bay (Canadian Arctic): environmental control and food web implications

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As part of the Canadian Arctic Shelf Exchange Study (CASES), we assessed the importance of new production and resuspension in determining the nature and magnitude of the deep (200 m) particulate organic carbon (POC) flux from October 2003 to September 2004 in

central Franklin Bay. In spring and summer, phytoplankton production was nutrient limited in the stratified surface layer and the initial surface bloom evolved into a subsurface bloom at the nutricline. Large herbivorous calanoid copepods intercepted little of the initial surface bloom but grazed intensely on the subsurface bloom. The phytoplankton and fecal pellet fluxes culminated simultaneously in July-August (24 and 23 mg C m⁻² d⁻¹, respectively). The detrital POC flux peaked in September (52 mg C m⁻² d⁻¹), coincident with wind-induced resuspension of recently-settled POC. In the fall, detrital POC fluxes increased again to 22 mg C m⁻² d⁻¹, following the off-shelf transport of terrigenous POC carried by the Mackenzie River plume and POC resuspended by wind on the shelf. In winter, the relatively weak POC fluxes (2-7 mg C m⁻² d⁻¹, detrital at 90%) resulted from the settling down of resuspended sediments. We propose a conceptual model in which the ecosystem of Franklin Bay shifts from an algal to a detrital mode according to seasonal changes in the relative importance of fresh and old POC supplies. Based on this model, the ecosystem of southeastern Beaufort Sea could evolve towards a less productive equilibrium dominated by sediment resuspension in response to the on-going reduction of the ice cover.

3.4 Vertical fluxes of particulate organic carbon during the over-wintering year of the Canadian Arctic Shelf Exchange Study (CASES): where, when, and why?

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From October 2003 to August 2004, vertical fluxes of particulate organic carbon (POC) were recorded with an array of 15 sequential sediment traps moored at 100- and 200 m depth in the southeastern Beaufort Sea. The parallel over-wintering expedition of the CCGS *Amundsen* allowed us to investigate the mechanisms underlying the dynamics of the vertical POC fluxes. Magnitude of the annual POC fluxes demonstrated a relationship with the terrigenous POC fraction ($R^2 = 0.83$), indicating that allochthonous inputs are a major

determinant of particle fluxes in the CASES region. On average over the year, vertical POC fluxes at 100 m depth were higher at the tip of Cape Bathurst and in the Mackenzie Trough (respectively 12.8 and 6.9 g C m⁻² y⁻¹, in comparison to a mean of 5.2 g C m⁻² y⁻¹). The increased POC fluxes were related to greater terrestrial carbon fractions (50 and 35% each, compared to an average of 15%). To explain the terrigenous component, we suggest links with the expansion of the Mackenzie River plume, advection of shelf bottom particles, and/or coastal erosion of the Bathurst Peninsula. Seasonal variations in the daily POC fluxes at 200 m depth showed a complex sedimentation pattern characterized by discrete POC peaks. During fall, a first increase in POC centered on late November (up to 36 mg C m⁻² d⁻¹) corresponded to off-shelf particle transport by the river plume, thermohaline convection and windstorms. This coincided with the sinking of small and intact fecal pellets which reflected detritivorous feeding by small zooplankton. From January to April, vertical POC fluxes remained relatively low (1-7 mg C m⁻² d⁻¹) and corresponded again to the settling down of resuspended shelf sediments. In May and June, the magnitude of POC fluxes slightly increased relative to winter values (up to 16 mg C m⁻² d⁻¹), but the nature of the fluxes changed completely (e.g., more positive $\delta^{13}\text{C}$, higher C:N ratio, low terrigenous fraction). We associated the abrupt changes as the result of the direct sinking of ice algae and transparent exopolymeric substances flushed from melting sea-ice. From mid-July to early August, a last peak (up to 48 mg C m⁻² d⁻¹) was related to phytoplankton production from a subsurface bloom, and to the sinking of the intact fecal pellets of large herbivorous copepods and appendicularians.

3.5 River to sea: particulate carbon coupling from Kugmallit Bay to the Beaufort Shelf

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A variety of CASES studies have been directed toward understanding the coupling between the Mackenzie River and Beaufort Sea. The mechanics of sediment deposition and resuspension are central to the particle dynamics at the core of this linkage. We have conducted field studies through a range of river/shelf depths from 1-500m. This includes development of a novel method for quantifying sediment erosion threshold and rate. The turbidity plume of the river is affected by short-term wind-driven

resuspension, with a permanent nepheloid layer of unsculptable material. In summer, turbidity can be related directly to wind speed, with a consistent size-settling relationship. In the spring, a phytoplankton bloom from upriver appears under landfast delta ice. Under-ice sediment traps reflect enriched pigment content in spring. One-box model calculations suggest that the physical turnover time of POC in a defined shelf region (<20m isobath) is a matter of days, indicating the extent of river influence on nearshore carbon fluxes. Ongoing modelling studies with a 2D spatially-explicit model of the delta region, parameterized with empirical equations from field studies, will be used to further refine these estimates.

3.6 Influence of a river plume on the fluxes and composition of particulate material exported on an Arctic shelf

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The sinking fluxes of particulate organic material were assessed along two cross-sections of the Mackenzie River plume, Canadian Arctic, using free-drifting short-term particle interceptor traps. The arrays were deployed at 2-6 depths ranging from 25 to 150 m for ca. 24 h at 3 stations across the shelf during fall 2002 and at 3 stations along the shelf edge during summer 2004. Analyses on the collected material included particulate organic carbon (POC) and chlorophyll *a* (chl *a*). The river plume was extending northeastward along the shore during fall 2002 and northwestward during summer 2004. POC sinking fluxes at 25 m ranged from 12 to 98 mg C m⁻² d⁻¹ during fall 2002 and from 38 to 197 mg C m⁻² d⁻¹ during summer 2004. The highest sinking fluxes of POC and chl *a* were measured at stations under the influence of the river plume. During fall 2002, traps deployed at 25 m underneath the river plume contained the freshwater pennate diatom *Eunotia* sp. in addition to marine phytoplankton species. This indicates that freshwater phytoplankton from the river plume were also contributing to the sinking fluxes on the shelf. In the traps, the proportion of degraded algal material increased from 25 to 50 m and numerous fecal pellets were observed at 50 m. This indicates that the sinking particulate organic material underneath the river plume is grazed by mesozooplankton. This study shows that the river plume influences the fluxes and composition of the material exported on Mackenzie

Shelf and provides a food source for the marine heterotrophic community during summer and fall.

3.7 Origin and Fate of Particulate Organic Carbon in the Beaufort Sea shelf–Amundsen Gulf area, Canadian Arctic

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We examined the distribution and composition of organic matter in sediment cores from the Chukchi and Beaufort Seas and the Amundsen Gulf to establish the origin of the organic carbon. We determined the bulk C:N ratio and the stable isotopic composition ($\delta^{13}\text{C}$ and $\delta^{15}\text{N}$) of organic carbon and nitrogen of bottom sediment and sediment trap material. The oxygen penetration depth was also determined and used as an indicator of sediment reactivity. Organic carbon concentrations in surface sediments were similar on the Beaufort Sea shelf and slope and in the Amundsen Gulf. The C:N ratios did not vary significantly, except at one deep station in the Chukchi Sea. Oxygen penetrated deeper into the Amundsen Gulf sediments than elsewhere, indicating that organic matter is oxidized at or near the sediment surface, leaving little reactive organic carbon to be buried. The $\delta^{13}\text{C}$ values of sediment trap material were more negative than in underlying sediment, indicating preferential loss of light carbon during degradation of organic matter and the accumulation of heavier carbon in the sediment. The sediments from the Beaufort Shelf, the Amundsen Gulf and the Chukchi Sea revealed a linear relationship between $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$. The lightest isotopic signature found in the shelf sediments is unlikely to be caused by bacterial oxidation of settling particulate matter, indicating a large terrestrial carbon component. The sharp difference between the organic carbon isotopic composition between the Mackenzie Shelf ($\delta^{13}\text{C}$ -25.9; $\delta^{15}\text{N}$ 3.5) and the Amundsen Gulf ($\delta^{13}\text{C}$ -23.4; $\delta^{15}\text{N}$ 7.5) indicates a terrigenous origin for the organic matter on the Beaufort Shelf and a marine origin in the Amundsen Gulf, suggesting that the organic carbon carried by the Mackenzie River does not reach the Amundsen Gulf.

3.8 Carbon dynamics in sea ice: A winter flux time series

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A synthesis of inorganic carbon measurements from the atmospheric boundary layer, the water column, and the sea ice have confirmed that the ice is an active participant in the carbon dynamics of ice-covered seas. Even during the coldest periods, we observed significant downward carbon dioxide fluxes out of the atmosphere, although there were also some dramatic upward fluxes, particularly as temperatures increased. At the same time, extremely high pCO₂ values developed within the ice, while the inorganic carbon content at the very surface of the ice remained low. Variations within the water column were more subtle, with high concentrations of inorganic carbon accumulating both under the ice and at the bottom; the highest carbon concentrations at the bottom were seen after the melt period was well advanced. These observations indicate that the sea ice may act as a carbon capacitor, storing large quantities of carbon and releasing it to both the air and the water upon melting.

3.9 Sedimentary pigments as biomarkers of spatial and seasonal variations in the Beaufort Sea benthic-pelagic coupling

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The Arctic Ocean is characterized by broad continental shelves (51% of its surface area), which have high rates of primary productivity. In some areas, much of this production falls to the bottom, supplying rich and active communities of benthic organisms. Characterizing the major sources of production and understanding the fate of the organic matter to the

benthos is critical to understand the ecosystem functioning and changes due to global warming. Sedimentary pigments reflect primary production and its pathways in the water column and the sediment. Water column, ice and sedimentary pigments of the South Eastern Beaufort Sea were studied by HPLC analysis during the fall 2003 and summer 2004, in the framework of the CASES project. Phytoplankton species composition showed seasonal variations (more diatoms in the summer) as well as spatial variations (difference between the polynya and the continental shelf areas). These differences were reflected in the sedimentary pigment composition. Moreover, the sedimentary chlorophyll a/phaeopigment ratio, an indicator of the “freshness” of the organic matter reaching the sediment, suggested that the pelagic-benthic coupling is particularly tight in the continental shelf, where the ratios are the highest. In the polynya area, however, considerable recycling occurs in the water column, leading to inputs of more degraded material to the benthos.

3.10 Surface and pre-industrial dinoflagellate cyst assemblages: evolution of the paleo sea-surface conditions over the last 1000 years in the Mackenzie Trough, Beaufort Sea (Canada).

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Over the last three decades, a reduction of coverage and thickness of the multiyear sea ice cover was observed in several areas of the Arctic Ocean. Because the historical data needed to understand long-term climate cycles and predict future climate trends are very scarce for the Arctic, we need to look at the geological record to establish the link between historical and pre-historical sea surface parameters. Dinoflagellate cysts (dinocysts) constitute excellent proxy indicators of sea surface parameters (temperature, salinity, sea-ice cover, primary productivity) and may be used to reconstruct the evolution of sea surface conditions at decadal and millennial timescales. In this study we have analysed 34 new surface sediment samples collected in 2004 in the Beaufort Sea area (Mackenzie Shelf/Slope and Amundsen Gulf). These samples will be incorporated in the GEOTOP reference database (N=1171) and will serve as a base for the reconstruction of sea surface parameters during the Late Holocene time-period. In particular, we will focus on the pre-historical period in order to document the evolution of sea surface conditions prior to industrialisation. Here we present the surface distribution of recent dinocyst assemblages of the Beaufort Sea, in addition to dinocyst assemblages of three short cores along a North-South transect in the Mackenzie Trough, at the mouth of the Mackenzie River:

the core 2004-804-912A near the coast, the core 2004-804-909B in intermediate position and the core 2004-804-906B far from the coast. Dinocyst concentrations in surface sediments are relatively high outside the Mackenzie plume and increase gradually toward the Amundsen Gulf (East). The cyst of autotrophic dinoflagellates are dominant throughout the study area, while the maximum abundance of heterotrophic taxa is found within the Mackenzie plume. Hierarchical clustering analyses allowed defining two dinocyst assemblages. Assemblage I is located on the Mackenzie Slope and southern Amundsen Gulf, while assemblage II is located within the Cap Bathurst Polynya area in northern Amundsen Gulf. The three ~40 cm-long cores span the last ~1000 years for core 912A, from ~1550 A.D. until now for core 909B and the last ~200 years for core 906B, based on ²¹⁰Pb measurements. Each core focuses on a specific period, the last ~1000 years, the Little Ice Age (LIA, ~1550 to 1850 A.D.) and the Industrial Age (~1850 A.D. until now). Palynological analyses indicate an increase of dinocyst influx during LIA and a decrease at the onset of the Industrial Age. This is accompanied by a decrease in the proportions of heterotrophic taxa and increase proportions of autotrophic taxa. We observe a succession of two assemblages over the last ~1000 years. The shift occurs around the end of the LIA and the beginning of the Industrial Age (~1800-1850 AD). The fossil assemblage is mostly composed of dinocyst from heterotrophic taxa (55%) and the modern assemblage is essentially composed of dinocyst from autotrophic taxa (75%). Our reconstructions show that sea surface temperature throughout our study area started to increase substantially 1000 years ago (from ~2 to 5°C), and until ~1850 AD. Then, a shift in the temperature gradient occurs at the onset of industrialization, where temperature still increases, but at a slower rate (0.5 – 1.0°C over 150 years). Could it be that anthropogenic activities may be influencing a natural warming trend that started over 1000 years ago?

3.11 Recent paleo-sea ice conditions of the Amundsen Gulf, Canadian Arctic Archipelago as indicated by the foraminiferal record of the last 200 years.

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Four boxcores were collected as part of the Canadian Arctic Exchange Shelf Study (CASES) in the Amundsen Gulf at water depths of 59 m to 600 m. Data from these cores help to develop a record of changes in the oceanographic history of the area over the last 1000 yrs, with particular reference to the indication of paleo-sea ice formation – a key element of the Arctic ecosystem. The four sites have contrasting environments: low to high sedimentation rate areas, and from the shallow shelf to the deeper water upper slope environments. The benthic foraminifera of sites CA-06 (253 m water depth) and CA-18 (600 m water depth) show an increase in Arctic Surface Water associated agglutinated foraminifera over the last ~100 years (uppermost 8 to 16 cm) indicating a decrease in sea ice cover, a decrease in cold saline Arctic Bottom water influence and are similar to Canadian Arctic Archipelago postglacial faunas. This contrasts with abundant planktic foraminifera at the same stations, suggesting strong, oceanic Arctic surface influence (little freshwater) in the central Gulf. The foraminifera of sites 403B (59 m water depth) and 415B (56 m water depth) at the outermost regions of Amundsen Gulf indicate that the present day location of the winter flaw lead location has been in place for at least the last 100 years, with foraminiferal faunas similar to those of the Beaufort Shelf. Additionally, station 415 is on an earlier Holocene shoreline that is covered with cobbles.

3.12 Foraminiferal assemblage changes over the last 15,000 years on the Mackenzie/ Beaufort sea slope and Amundsen Gulf, Canada: implications for past sea-ice conditions.

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A core from the Beaufort Slope at 1000 m water depth covers the last ~14,000 cal BP. These data are compared with data from a core in the Amundsen Gulf. Site 750 is particularly sensitive to paleo-ice cover because at present it rests beneath the margin of the permanent Arctic ice pack. In the upper 120 cm there is mostly agglutinated foraminifera but at 120 cm there is a sudden appearance of a typical central Arctic interglacial fauna with the N. Atlantic bottom water indicator, *Oridorsalis*

umbonatus and abundant planktic forms, much like the central Arctic today; this unit is dated at ~11,500 cal BP and abundant ice rafted debris (IRD) first appears here. This fauna persists to 380 cm with a date of over ~13,500 cal BP; below this both the IRD and foraminifera disappear. There is abundant organic debris, possibly from eroding of pre-existing permafrost on the Beaufort Shelf resulting from landfast ice movement during a lowered sea level on the shelf. The core in the Amundsen Gulf also has IRD similar to that in 750 and the paleomagnetic data confirm that it has the same source as well as a date of ~12,000 cal BP. This location is very close to the former glacial margin in the Gulf. The commencement of ice rafting from icebergs, which could only occur if the ice pack started to move to allow glacial calving and iceberg movement, provides an accurate date of commencement of deglaciation for this Arctic shelf.

THEME 4. MODELIZATION AND OTHER

4.1 Beaufort Shelf and Amundsen Gulf benthos: a wealth of biodiversity and hotspots for secondary production.

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Regional variation in macrobenthic community structure was analyzed from more than 200 samples taken at 150 sites on the Beaufort Shelf and in Amundsen Gulf recovered over the periods 1971-1975 and 2002-2004. Generally, the macrobenthos were as abundant as in the Bering and Chukchi Seas to the west and in Baffin Bay to the east and an order of magnitude more abundant than in the Barents and Kara Seas. Community composition and secondary production in Amundsen Gulf were not significantly different from the Beaufort Shelf at similar depths, indicating a lack of a structuring footprint from the Cape Bathurst polynya. However, the community composition changed significantly and increased 10-fold in abundance in the shallows off Cape Bathurst, due to

large numbers of the suspension feeding amphipod *Ampelisca macrocephala* and the deposit feeding polychaete *Barantolla americana*. It is proposed that they may provide a food resource for bowhead whales and diving seabirds. The Beaufort Shelf macrofauna consist of numerous deposit feeding polychaetes and crustaceans, some of which are deep burrowing bioturbators. Inshore, the influence of the Mackenzie River favours dominance by the deposit feeding bivalve *Portlandia arctica* and the predaceous polychaete *Micronephthys minuta*. Climate warming in the Beaufort Sea would likely favour expansion of these stress-tolerant fauna over the shelf and immigration of other species with corresponding adaptations. With upwelling projected to increase also, the *Ampelisca-Barantolla* community may expand with it, which would benefit benthic-feeding birds, seals and whales.

4.2 Evaluation of ocean color algorithms in the Cape Bathurst polynya using MODIS and SeaWiFS spectral bands

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The Canadian portion of the Beaufort Sea, at least in its coastal domain, is dominated by the freshwater outflow from the Mackenzie River. The large Mackenzie plume behavior is known to be highly variable depending on runoff intensity and physical forcing by the coastal circulation and the wind field leading to a strong spatial variability showing frontal regions, filaments and other features that influence seawater optical properties. Previous studies conducted in arctic waters showed that operational algorithms were not performing well generally overestimating chlorophyll concentrations due to the presence of dissolved and suspended matter and because of significant pigment packaging in the arctic phytoplankton species. Wang and Cota (2003) developed the OC4L and OC4P algorithms using data measured in the western portion of the Beaufort Sea to take into account CDOM originating from the Mackenzie River. As part of the Canadian Arctic Shelf Exchanges Study (CASES) field program conducted in 2003 and 2004, we collected an extensive in situ optical and biological data set covering the entire Canadian Beaufort sea shelf and including the very productive Cape Bathurst polynya. This data set allowed us to validate various algorithms applied to SeaWiFS and MODIS spectral bands. The in situ data were also used to develop a locally tuned algorithm allowing a better estimation of the chlorophyll concentration for these complex Case II waters. The results indicated that neither the OC4v4 nor the OC3M algorithm currently used for processing SeaWiFS and AQUA-MODIS data are appropriate for the measurement

of chlorophyll-a concentration in the Cape Bathurst polynya. Algorithms developed specifically for the Arctic do not offer better performances. According to these results, it appears that the general description of phytoplankton biomass concentration and phytoplankton production available from the Arrigo and van Dijken (2004) study are probably seriously biased towards higher values. When divided by the MNB value (3.64), for the OC4L algorithm, developed by Arrigo and van Dijken (2004), the maximum daily phytoplankton production estimated using SeaWiFS data is now the lowest of all major Arctic polynyas such as NEW and NOW. As the Cape Bathurst polynya is located much closer to the Mackenzie river, there is a possibility that the OC4L algorithm introduced a bias in the results due to the presence not only of higher concentrations of CDOM but also of suspended matter that could affect the quality of the atmospheric correction. Despite that problem with the evaluation of the intensity of the phytoplankton bloom, we however believe that the spatial and temporal patterns described in that study are still valid. In the future, time series of images processed using this improved algorithm will be used to study the relationships between the phytoplankton distribution and the physical environment.

4.3 Origin and Evolution of the Mackenzie Trough, Canadian Beaufort Shelf

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The Mackenzie Trough is a northwest-southeast linearly trending bathymetric and paleobathymetric depression incised over 400m into the Canadian Beaufort Shelf. It is one of the largest cross-shelf troughs in the world, measuring approximately 150km long by 75km wide. Water depths within the Trough range from less than 2m to almost 500m. The Trough was likely excavated by continental glacial ice streams and was later modified by Mackenzie River outflow. Shelf stratigraphy indicates it was excavated in the early and mid to late Wisconsinan, and possibly earlier glaciations. Seismostratigraphic evidence of the Trough margins indicates formation by erosion by an ice

stream. This origin is suggested by the Trough's u-shape, lack of marginal faulting, deformed sediments at the margins, absence of slumping features, continuity of deeper reflectors such as the Sub-Iperk unconformity, and the smooth character of the Trough base. The Trough-wide basal unconformity is a well defined high-amplitude seismic reflector which incises the Sub-Iperk Unconformity in the central area. The Mackenzie Trough is infilled with in excess of 300m of Quaternary sediments of the Upper Iperk and Shallow Bay Sequences. The infill is thickest near the shelf edge and along the east side of the Trough. The thick infill has been subdivided into five seismostratigraphic units. Unit 5 forms a narrow, V-shaped valley in the west-central base of Trough and may represent a gravel or basal till. It reaches a maximum thickness of 70m and is recognized by its hummocky, acoustic character on seismic records. Unit 4, with a maximum thickness of 200m, rests on the base of Trough unconformity throughout most of the feature. Unit 3 forms a structureless axial ridge with approximately 30m relief along the west side of the Trough and is sometimes included as a subdivision of Unit 4. Unit 2, 55-90m thick, is separated from Unit 4 by an unconformity. It represents an acoustically transparent, trough-wide, silty-clay. Unit 1 is 40m to 120m thick and is composed of a lower deltaic sequence (1b) overlain by muds and marine clays up to 30m thick (1a). The base of Unit 1 is marked by a hummocky regional reflector representing a marine flooding surface overlying the acoustically transparent Unit 2. At the distal end of the Trough Unit 1a is draped over a series of small channels. The Trough was possibly excavated to its maximum depth during the early Wisconsinan, leaving behind the Unit 5 till. The thick sand, Unit 4, was deposited with the retreat of the ice stream. A second ice advance into the Trough during the late Wisconsinan partially eroded Unit 4. Unit 3 represents a deformation structure caused by the ice or possibly a moraine deposit. Unit 2, composed of silty-clays, is a subglacial drift that was also deposited by the ice. Unit 1b was formed by the deposition of prograding Mackenzie River deltaic sediments, followed by transgression and deposition of Unit 1a Holocene marine clays.

4.4 Hatching Season and Growth of Juvenile Arctic Cod (*Boreogadus saida*) in the Laptev Sea

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Young-of-year arctic cod were sampled in the Laptev Sea in September 2003 and 2005. Hatching season, growth and survival were studied and linked to ice conditions. Arctic cod larvae have been found to hatch as soon as

January, two months earlier than reported in previous studies. Some winter-hatched larvae survived although hatching occurred when mean ice concentration in the Laptev Sea was near 100 %, conditions associated with chance of survival almost null in another Arctic region. We suggest that lower ice concentrations caused by larger opening of polynyas during the winter in the Laptev Sea in 2005 compared to 2003 may have promoted a better survival of winter-hatched larvae in 2005. Length on age relationships and growth analysis based on otolith microstructure showed that growth rate during the first 4-5 months of life was superior the 2005 larvae. Different somatic and otolithic growths among hatch date suggest a possible selection for fast growth during the larval stage that should be stronger in years with heavier winter ice conditions.

4.5 An ocean of data: The CASES legacy for IPY and beyond

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The Canadian Arctic Shelf Exchange Study (CASES) Research Network deployed an ambitious field program studying the eastern Beaufort Sea ecosystem on an annual cycle. This initiative resulted in over 15 500 scientist-days in the Beaufort Sea with the participation of 225 scientists from 8 countries. CASES is now completing its final year and is at the crucial stage of dissemination of results as well as consolidation and archiving the resulting data. This enormously successful program will have a profound legacy, not only through its research insights, training and outreach achievements, but also through the unique multi-disciplinary data-sets it has generated. The CASES data will be particularly important as new initiatives such as ArcticNet, and International Polar Year (IPY) programs like the Circumpolar Flaw Lead Study, seek to build on the CASES success. It is essential that the data be appropriately archived and accessible to all CASES researchers and, ultimately, the broader science community and the public. A CASES data-set inventory will be created, identifying the type of data collected, by whom and its current location. Data-sets to be archived will be determined and appropriate archive locations will be identified. An over-arching Data Policy for CASES has been drafted and a data

distribution, long-term archiving strategy and a process for the capture of CASES metadata have been developed. The Canadian Cryospheric Information Network (CCIN), ArcticNet and Fisheries and Oceans Canada (DFO) are partnering to create a multi-user metadata database. This process has been developed to meet the needs of CASES, ArcticNet and ultimately IPY data producers. The metadata portal will be demonstrated.

4.6 A ice-ocean-biology coupled model of the Pan-Arctic Ocean

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A ice-ocean-biology coupled model of the Pan-Arctic Ocean will be presented. The model is an extension of the model of Holloway and Sou (2002). The present model includes now an improved vertical discretization and turbulence, an ice biology module and is forced by 6 hourly atmospheric ECMWF fields. This model will force in turn (one way coupling) an unstructured grid and regional model of the Canadian Arctic Archipelago.

4.7 Results of Mackenzie River water and sediment discharge modelling under present day and future scenarios

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Of all the World's northern rivers, the Mackenzie delivers the highest quantity of sediment to the Arctic Ocean. The immense size of the Mackenzie River system presents a challenge to modellers. Climate varies widely between relatively temperate Northern British Columbia and the high Arctic. Topography also varies greatly between the central plains and the Rocky Mountains. To add to the modelling difficulties, the river is nearly completely frozen for more than 6 months of the year, causing sediment laden water to be released abruptly during breaches in ice dams. Furthermore, the Mackenzie Delta comprises thousands of lakes, many of which act as sediment traps during the ice free seasons. Using a combination of software (Rivertools, Hydrotrend, Matlab, etc) some of these difficulties have been overcome to arrive at realistic discharges for the river under current day and future scenarios during ice-free months. Results vary widely under different climate

change scenarios. However, for an “average” scenario, river flow increases steadily by 10 to 20% over present day values to the year 2080, while the increase in sediment discharge remains below 10% over present day values. With the ice-free conditions adequately modelled, the work will continue to incorporate effects of ice-jamming, and under-ice flow.

4.8 Results of sediment resuspension modelling in the shallow Beaufort Sea

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Storm events during the open water months cause resuspension and transport of sediment in the shallow Beaufort Sea. Numerical modeling has been conducted using the Delft3D simulation package. Two main study periods were chosen due to the existence of shallow water data with which to compare the simulation results. A simulation of a storm from August 19th to 23rd 1982 was performed, which included the effects of both currents and waves on sediment transport. Results are compared between model and real-world for wave properties and currents at stations at mid depths, and the data are further interpreted to provide wave energy dissipation and mean sediment transport. A second model run simulated the period August 21st to September 9th 2006. Results are compared to shallow water current and wave data taken during this period. The most significant dissipation of wave energy occurred along the Tuktoyaktuk Peninsula. Strong wave dissipation during storms occurred on the north east tip of the peninsula. Noticeable wave dissipation was also present in Mackenzie Bay. Overall, the studies indicate that storm events can cause large resuspension of sediment along the Beaufort coast at the 5 m depth contour. This is most noticeable on the eastern side of Mackenzie Bay and western side of Liverpool Bay. Substantial sediment resuspension during storm events occurred in depths ranging from 1m to 15 m.

4.9 Seasonal Evolution of the circulation in Franklin Bay, Amundsen Gulf

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4.10 Export fluxes of biogenic matter in the presence and absence of seasonal sea ice cover in the Chukchi Sea

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Primary production on the Chukchi Sea continental shelf is constrained by the seasonal variation in ice cover. An earlier melting of sea ice due to climate warming is likely to enhance annual primary production on the Chukchi continental shelf and subsequently increase the annual export of biogenic matter. Drifting sediment trap were deployed in the Chukchi Sea as part of the Western Arctic Shelf-Basin Interactions (SBI) Project to investigate the variability in the vertical flux of biogenic matter in the presence and in the absence of sea ice cover. Chlorophyll-*a*, particulate organic carbon (POC), particulate organic nitrogen, phytoplankton, zooplankton fecal pellets, and the stable carbon isotope composition of the sinking material were measured along Barrow Canyon and East Hanna Shoal in spring and summer 2004. POC export fluxes were of similar magnitude in the presence and absence of ice cover at stations located in Barrow Canyon, while POC fluxes were significantly higher in the absence of ice cover at stations located in the East Hanna Shoal region. The biogenic matter exported to the basin and/or to the benthos was mostly freshly produced labile material, except in the East Hanna Shoal region under ice cover where export fluxes were mostly composed of advected refractory material. Barrow Canyon is clearly an important area of POC export in the Chukchi Sea, as has been shown in other independent studies. These results, along with ²³⁴Th-

derived POC fluxes obtained in 2002 that indicated a significant increase of POC export from ice-covered to ice-free conditions (Moran et al., 2005) suggest that there are large spatial, seasonal and interannual variations in export fluxes in the Chukchi Sea. A decrease in seasonal sea ice cover will undoubtedly affect the vertical flux of biogenic matter over the Chukchi Sea shelf and slope, however the effect is difficult to predict and will depend on productivity conditions in each region.

4.11 Evolution of the physical properties of the water column during winter in the Amundsen Gulf, Canadian Arctic

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4.12 Mercury levels in three Arctic Food webs in the summering range of Beaufort Sea Beluga

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Beaufort Sea beluga whales (*Delphinapterus leucas*) summer in the eastern Beaufort Sea and are an important food source to the local Inuvialuit communities. Mercury (Hg) levels in this population have been increasing since the 1990's; which raises health concerns. Ultimately it is the Hg content of prey that determines beluga Hg levels. However, the Beaufort Sea beluga diet is not understood, and little is

known about the food webs and Hg sources in beluga summering habitat. The Canadian Arctic Shelf Exchange Study (CASES) provided the opportunity to sample different food webs in the summering region of the Beaufort Sea beluga. We measured the methyl mercury (MeHg) and total mercury (THg) levels within three food webs; the estuarine-shelf, pelagic and epibenthic in the Western Canadian Arctic and assessed their contribution to Hg levels in beluga diet. While in eastern Beaufort Sea, beluga segregate into three social groups that may correspond with their feeding preferences. Thus, we paired the beluga social groups with food webs that may reflect the Hg content of their differing dietary sources. Beluga prey items from the estuarine habitat had the lowest MeHg levels in fish ranging from 0.1 to 0.2 ug/g dry weight (dw) in arctic cisco (*Coregonus autumnalis*) and saffron cod (*Eleginus gracilis*) respectively, which were lower than arctic cod (*Boreogadus saida*) MeHg levels (0.3 ug/g dw) in the pelagic food web. Highest MeHg levels occurred in forehorn sculpin (*Myoxocephalus quadricornis*) (0.5 ug/g dw) from the epibenthic food web. Pelagic and epibenthic food webs had the highest Hg levels and therefore likely provide significant dietary sources of Hg to Beaufort Sea beluga. The trophic level transfer of Hg was similar among the food webs, indicating the importance of the bottom-up effect of Hg concentrations at lower trophic levels. Differences in Hg concentrations among the beluga social groups support the likelihood of different feeding behaviours and diets. We propose future studies incorporate predator behaviour when evaluating contaminant levels in animals with complex social systems.

4.13 Winter pulses in the Beaufort Sea undercurrent

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4.14 α -HCH air-water dynamics in the Southern Beaufort Sea, Northwest Passage and North Water Polynya (NOW)

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Hexachlorohexane (HCH) exists as a technical mixture (α 60-70%, β 5-12 %, and γ 6-10%) or 100% γ , the active ingredient. Global use of the technical mixture was estimated at 10 million tons by 1997. HCHs are ubiquitous in water throughout the Northern Hemisphere with highest concentrations in surface waters lying beneath the permanent pack ice of the Arctic Ocean. With very low Henry's Law constant they partition very strongly from air into cold water. α -HCH is transported atmospherically and is the most significant HCH component in Arctic. α -HCH exists as racemic enantiomers unless it comes from a source, such as seawater, in which it is subjected to microbiological breakdown. The (+) α -HCH enantiomer is more rapidly depleted than the (-) α -HCH enantiomer. We studied the relationship between α -HCH degradation and depth and the effects of location (NOW through the Northwest Passage to the Beaufort Sea) on α -HCH enantiomer depletion. We evaluated the effects of changes in sea ice cover on α -HCH enantiomer ratios. We also studied the effects of ice free and ice covered conditions on air-water exchange of α -HCH. Samples analyzed in this study were collected in the Southern Beaufort Sea/Amundsen Gulf during the CASES 2003/04 expedition and the North Water Polyna and Northwest Passage during the 2005 and 2006 Arctic Net cruises.

4.15 An individual-based model for growth and survival of Arctic cod larvae

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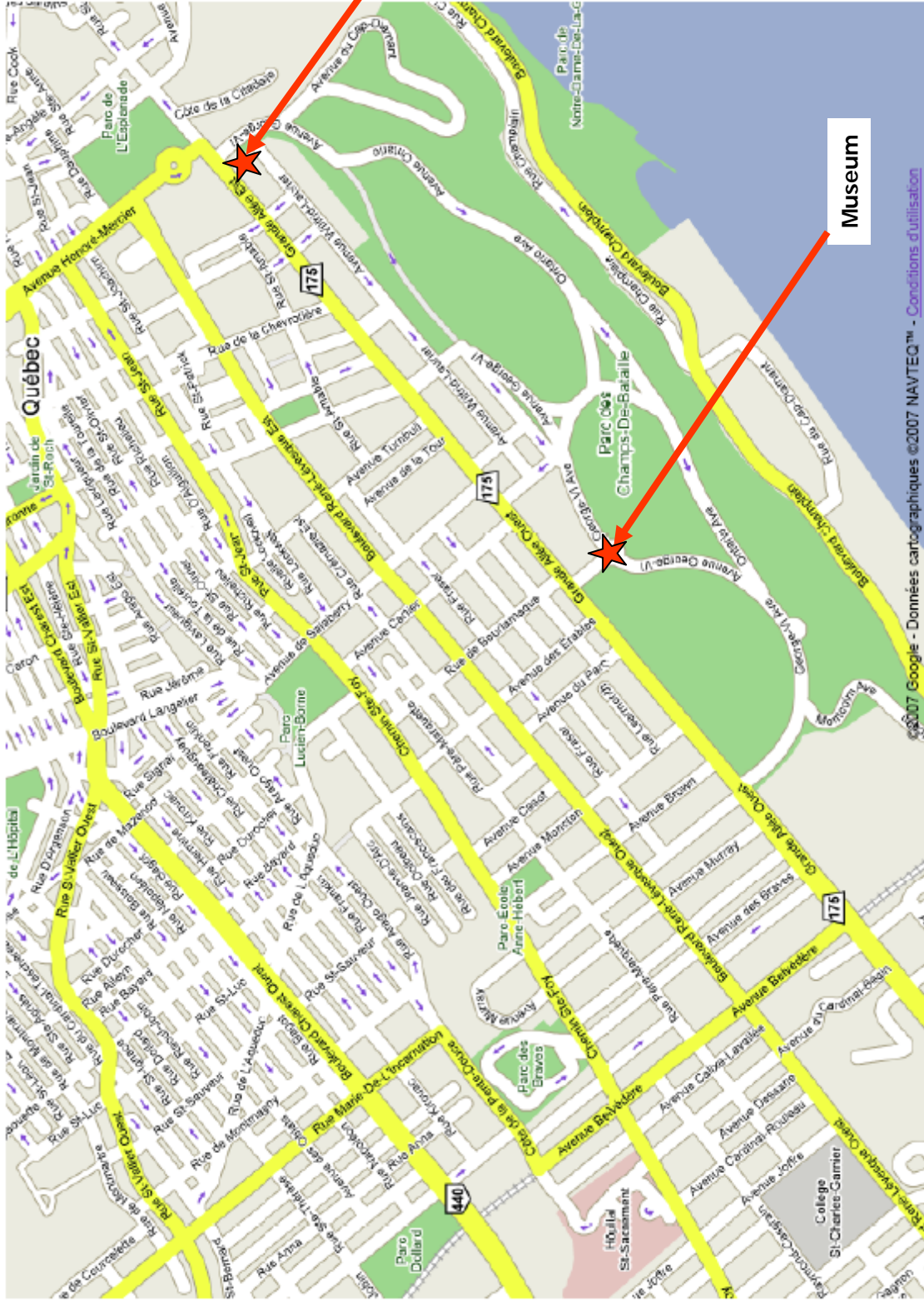
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