

THE CANADIAN ARCTIC SHELF EXCHANGE STUDY (CASES)

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Synopsis

The extent and thickness of Arctic sea ice vary considerably from year to year and over decadal time scales. Recently, the multi-year ice pack that covers the central Arctic Ocean has thinned from 3.1 m in the 60's to 1.8 m in the 90's and its long-term areal extent has decreased by 14%. Although it may simply represent an extreme low in a natural cycle, this recent trend could also harbing the "meltdown" of the Arctic ice cover in response to anthropogenic climate warming. Whether man-made or natural, the observed fluctuations in sea ice extent dramatically affect the unique Arctic fauna and man's activities in the North. Assessing the effects of present variability in sea ice cover on Arctic marine ecosystems and regional climate (and *a fortiori* that of a potential net reduction of Arctic sea ice in response to climate change) requires a substantial improvement in our understanding of the links between freshwater and sea ice, sea ice and climate, and sea ice and biogeochemical fluxes. The need for data is particularly strong for the shallow coastal shelf regions (30% of the Arctic basin) where variability in the extent, thickness and duration of sea ice is most pronounced and where Arctic marine food webs are most vulnerable to change. Toward that goal, the central objective of the Canadian Arctic Shelf Exchange Study (CASES) is to understand and model the response of the Mackenzie Shelf ecosystem to atmospheric, oceanic and continental forcing of sea-ice cover variability.

The extensive Arctic shelves (25% of global shelf area) are strongly influenced by an immense riverine inflow of freshwater (2000 km³ year⁻¹, 10% of global discharge), discharged primarily from five large Siberian rivers and the Mackenzie River. This freshwater discharge plays a significant role in sea ice formation by stabilising the surface layer. The snow and ice covers, in turn, determine the air-sea exchange of heat and moisture over the Arctic Ocean and constrain the strongly pulsed annual cycle of biological productivity, therefore affecting the export of carbon to the pelagic and benthic food webs, and to the deep Arctic basins where it can be sequestered. The Mackenzie River, the only North American analogue of large Siberian rivers, discharges its enormous load of sediment and organic carbon onto the relatively narrow Mackenzie Shelf. We propose a major international effort under Canadian leadership to understand the biogeochemical and ecological consequences of sea ice variability and change on the Mackenzie Shelf. CASES will address (1) the role of hydrologic, oceanographic and meteorological processes in ice accretion, ablation and transport on the shelf and beyond; (2) the hydrodynamic (including ice and snow cover dynamics) control of Arctic shelf photosynthetic production and its exportation to the benthos and the pelagic food web; (3) the potential impact of increased UV radiation on biological productivity; (4) the role of microheterotrophs and mesozooplankton in transforming autochthonous and allochthonous particulate and dissolved matter on the shelf; (5) the fluxes of particulate matter and carbon across the shelf to the deep basins; (6) the distribution of riverine and air-borne contaminants in the trophic web; (7) the potential impact of a reduction in ice habitat on birds and marine mammals; and (8) decadal and millennial variations in ice cover and their impact on ecosystem productivity. Physical and biological measurements will be used to constrain and calibrate (9) regional models of climate and ice dynamics in the western Canadian Arctic and (10) biophysical models of the carbon flows on the Canadian Arctic shelf.

Previous experience demonstrates that a Research Network will supply the financial, logistic and scientific leverages needed to conduct a Canadian-led international effort in Arctic oceanography. The proposed Network brings together over 70 leading experts in polar science from 10 Canadian universities, 4 Federal Departments (Fisheries & Oceans, Environment, Natural Resources, Defence), and 9 foreign countries (USA, Japan, UK, Denmark, Russia, Poland, Norway, Belgium, Spain). The Canadian Coast Guard and the Polar Shelf Continental Project provide the *sine qua non* administrative, logistic and navigational expertise for an Arctic endeavour of this scope. The planned field program includes a preliminary 5-week expedition in August-September 2001 for the mooring of instruments at key locations, followed, from August 2002 to August 2003, by the over-wintering of an icebreaker on

the Mackenzie Shelf. This program will provide a 3-year interannual comparison of the ecosystem maturation in response to sea ice cover variability, and, for the first time ever, a year-round, highly-integrated, multidisciplinary study of an Arctic shelf ecosystem, including a segment of the circum-Arctic flaw polynya system.

Study area and field work. The Mackenzie Shelf is dominated by ice from October until May to early August, depending on year. The input of freshwater from the Mackenzie River on the Shelf continues throughout the year, but ca. 70% of the total, annual discharge is delivered between May and September. In late summer, the nearshore zone of the ice-free shelf is dominated by the river plume. Typically, ice starts forming in October in shallow areas and, by late fall, the freshwater plume extends immediately beneath the growing landfast ice cover. Farther offshore at the edge of the landfast ice, ice formation in the flaw polynya releases brine that triggers convection. Throughout winter, floe rafting at the edge of the landfast ice builds the “stamukhi”, a coast-parallel zone of thick ice ridges in waters between 15 and 50 m deep. In spring, the containment of the river plume by the stamukhi produces the so-called Lake Mackenzie. Beyond the stamukhi, the flaw polynya that stretches along the entire Arctic shelf, widens in summer to form the Cape Bathurst polynya in the Amundsen Gulf. Offshore of the polynya begins the central Arctic ice pack. Available evidence indicates large interannual variability in the timing and extent of widening of the flaw polynya, but relatively low variability in the timing of the river freshet in May. The proposed field work is designed to contrast the annual cycle of development of the ecosystem in three areas of the shelf: (1) Lake Mackenzie; (2) the Cape Bathurst polynya; and (3) the edge of the Arctic ice pack.

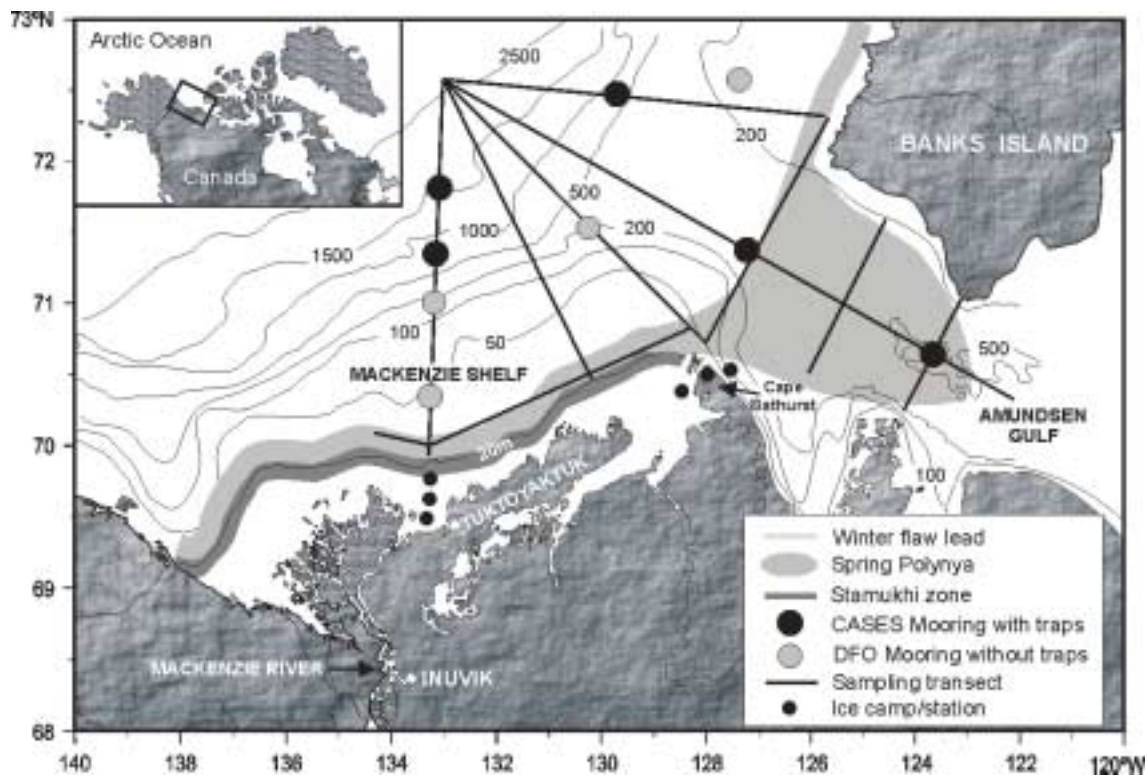


Figure 2. Schematic representation of CASES study area showing proposed sampling transects and mooring sites.

Because the area cannot be reached from southern ports until August when the ice retreats, the only possible way to achieve this is by over-wintering a research icebreaker in the area. In preparation for this over-wintering, we propose a preliminary, 5-week expedition in August-September 2001 for the mooring of instruments (current meters and sediment traps) at key locations. The main thrust of the program is the one-year over-wintering of a class-1200 CCG icebreaker in the study area, starting in August 2002. During this annual cycle, the ship and landfast ice camps will support the year-round sampling of the three oceanographic provinces of the Shelf ecosystem. As we will not be crossing the stamukhi with the icebreaker, work inshore of the ice ridges will be conducted at two locations on the first-year ice covered shallow shelf. The first sampling site will consist of an inshore-offshore transect of ice stations on the landfast ice extending from the mouth of the Mackenzie to the Stamukhi zone (Lake Mackenzie site). A second manned sampling site will be installed on Cape Bathurst with two on-ice sampling stations (each within snowmobile reach of the central camp) established in both the shallow waters of the shelf (west of the cape) and in the deeper waters of the Amundsen Gulf (East of the cape) to provide a contrast between an area typical of the Canadian Archipelago (200m ocean) with that typical of the shelf regions of the Canadian Basin (<50m ocean depth). At both sampling locations (Lake Mackenzie and Cape Bathurst), one of the sampling stations will be developed into a manned ice camp (or ice village) to be built and supplied with support from the ship (by helicopter and snowmobiles) in fall and winter, and with additional support from the Polar Continental Shelf Project base in Tuktoyaktuk (by helicopter and plane) from spring until the break-up of the land-fast ice. After the ice break-up, the ship will be able to enter both areas to pursue the study of the summer inshore ecosystem. Ship- and ice-based operations will be complemented by a strong program of drifting buoys (led by the Scott Polar Research Institute, UK). Moorings deployed in August 2001 will be retrieved and re-deployed in August 2002 and finally recovered in August 2003, at the end of the one-year expedition, producing a two-year record of hydrographic data and particle fluxes. This field program guarantees (1) a 3-year interannual comparison of the ecosystem maturity in August, in response to ice cover variability, and (2) a year-round, highly integrated, multidisciplinary study of an Arctic shelf ecosystem, including a segment of the circum-Arctic flaw polynya system.

As for NOW, satellite coverage (SSM/I, AMSR, ENVISAT, RADARSAT, and SeaWiFs) of the area will be extensive with real-time data received on the ship to assist field operations. Recent advances in thermodynamic modelling will be used to produce not only aerial extent but also ice type, concentration and a first order estimate of thickness. Synoptic images of the distribution of algal biomass in the open waters will be obtained through a DFO-operated SeaWiFS receiving station in Tuktoyaktuk (or Resolute) that will provide information on the spatio-temporal distribution of phytoplankton. High-resolution, cloud-independent RADARSAT images will be used for the *a posteriori* study of ice cover dynamics and as input in models of the regional circulation. Archived SMMR and SSM/I satellite data will be used to examine the spatial pattern of sea ice for the period 1978 to 2003 and after, to provide a historical context for CASES.

National and international partnerships

CASES builds on earlier studies of arctic and sub-arctic shelves, in the Canadian Beaufort Sea (NOGAP, PERD), southeastern Hudson Bay and the Canadian Archipelago (SARES). It is a natural complement to the on-going Mackenzie GEWEX Study (MAGS) that focuses on the watershed of the Mackenzie River under climate change. CASES will also be a unique occasion to compare the functioning of the Mackenzie Shelf and that of the Chukchi/Beaufort Shelf studied concurrently by the American-led Shelf Basin Interaction program (SBI). The differences between the two adjacent regions are the influence of the freshwater discharge of the Mackenzie and the presence of the large Cape Bathurst polynya. This conjunction of CASES, GEWEX and SBI, along with planned data exchange with the proposed Canadian Cryosphere Information Network (CCIN), represents a tremendous opportunity to further our understanding of Arctic land-shelf-ocean connections which play a key role in controlling ice cover dynamics and carbon fluxes.