Physical Oceanography in Canada, 2003-2007: A Review for the International Union of Geodesy and Geophysics

William Crawford[(1)] and Blair J.W. Greenan[(2)]

[(1)]Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, British Columbia, Canada

[(2)]Bedford Institute of Oceanography, Fisheries and Oceans Canada, Dartmouth, Nova Scotia, Canada

This report presents a brief summary of papers describing physical oceanographic research undertaken in Canada in the period 2003 to early 2007. This report is part of the Canadian contribution to the International Association for the Physical Sciences of the Ocean (IAPSO) on the occasion of the meeting of the Interannual Association of Geodesy and Geophysics (IUGG) in Perugia, Italy in July 2007. Previous reports have been prepared at four-year intervals to coincide with quadrennial IUGG meetings.

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Global Ocean

International Argo Project

Canadians have contributed to the International Argo Project, a global operational oceanography and research effort to provide real-time data from ocean profilers launched into all oceans (Gould et al, 2004; Freeland and Cummins, 2005). Each profiler drifts at 2000 metres depth in the ocean, rising to the surface every ten days, measuring temperature and salinity during this rise. Upon reaching the surface each profiler transmits these data to satellite. All observations from all Argo profilers are placed in public Internet directories for simultaneous access by all interested public as well as the research community. Fisheries and Oceans Canada has provided considerable funding for purchase and launch of these drifters. In May 2007, there were 96 active Canadian floats and 105 inactive. At present there are approximately 2850 active floats globally, which is close to the program objective of 3000. Canadian floats report through the Service ARGOS satellite communication system to the Marine Environmental Data Service (MEDS) in Ottawa. Data are received every six hours, processed automatically and subjected to duplicate checks and data quality control. They are then transmitted to the Global Telecommunication System (GTS) and Argo Servers within 24 hours. The data are also made available to principal investigators (PI) and posted on a MEDS website within 24 hours. The delayed mode data from PI's is also sent to MEDS for duplicate checks, data quality control and storing in the MEDS database. Information on the present status is available at the following Internet sites.

http://www.argo.ucsd.edu/

http://www.pac.dfo-mpo.gc.ca/sci/osap/projects/argo/default_e.htm

http://www.meds-sdmm.dfo-mpo.gc.ca/meds/Prog_Int/Argo/Canadian_Info/A_Can_e.asp

http://www.meds-sdmm.dfo-mpo.gc.ca/meds/Prog_Int/Argo/Canadian_Info/A_Can_f.asp

Park et al (2004) have developed an analysis method to determine the amplitude of inertial motion from surface trajectory data of ARGO profiling floats. This method gives an estimate of inertial current speed and phase from satellite fixes transmitted while a float drifts at the surface, over a time which is typically about one local inertial period. Globally distributed ARGO floats could provide useful information on the co-variability of wind-forced inertial currents and mixed layer depths in the ocean.

Argo floats deployed in the Arabian Sea provided an opportunity to look at the temporal variability of the core-depth of Arabian Sea High Salinity Water mass (ASHSW) at three locations in the north, central and southern Arabian Sea (Joseph and Freeland, 2005). These three locations show distinctly different variability patterns. At the northern location a prominent semi-annual cycle was observed, whereas at the central location an annual cycle dominates. Comparison with TOPEX/JASON sea level data shows that this difference can be attributed to the influence of Rossby waves at the central location. In the southern Arabian Sea the variability in core depth is also dominated by an annual-mode, but there are 2 high frequency components near the Madden-Julian Oscillation frequencies. Thus the salinity distribution in the Arabian Sea apparently is influenced by both remote forcing and ocean atmospheric coupling.

Global Scale Modeling

Improvements to global scale modeling continue to be made both in the physical processes and their impact on biology. Hannah and Peters (2006) provide an overview of the field of physical–biological interactions, which is growing rapidly and is central to predicting harmful algal blooms, fish recruitment, and the response of the marine ecosystem to human activities and the influences of climate change. Physical–biological interactions are a core element of international programs such as GLOBEC (www.globec.org), GEOHAB (www.jhu.edu/scor/GEOHABfront.htm) and IMBER (www.imber.info).

In the area of physical oceanography, Thompson and Demirov (2006) calculate the skewness of sea level variability for the world's oceans using gridded altimeter data for the period 1993–2001. It was shown, through an idealized example and results from a quasi-geostrophic model, that sea level skewness can be used to identify the mean path of unstable ocean jets and also regions dominated by eddies with a preferred sense of rotation. It was argued that sea level skewness, like variance, is a potentially powerful diagnostic for testing the realism of high-resolution ocean circulation models. Thompson et al (2006) also provide a simple method for reducing seasonal bias and drift in eddy resolving ocean models. Stacey et al (2006) investigated the ability of spectral nudging to improve the eddy statistics determined from model simulations. Spectral nudging differs from standard nudging in that only specified frequency and wave number bands of the simulated potential temperature and salinity fields are nudged toward the observed climatology. Therefore the simulated eddy field can develop and evolve with time while the model is prevented from drifting far from the observed climatology.

Lu and Stammer (2004) analyzed the vorticity budget of the vertically integrated circulation from two global ocean simulations. The two simulations differ in their initial hydrographic conditions and surface wind and buoyancy forcing. The analysis points to needs for further improvement of models and controlling the influence of data errors in ocean state estimation.

Dupont et al. (2003) investigated the influence of a step-like coastline on the basin scale vorticity budget using mid-latitude gyre models. Dupont and Lin (2004) discussed the adaptive spectral element method as applied to ocean models. For a nonlinear wind-driven application, the spectral element model proved to be more expensive to run at reasonable accuracy than a second-order-accurate finite-difference model. Nonetheless the spectral element model appears to be a large improvement compared to finite-element models of low order.

deYoung et al. (2004a) discuss the difficulties associated with modeling decadal variability in ocean basin ecosystems. deYoung et al. (2004b) also discuss data considerations in detecting regime shifts in the ocean.

Climate Dynamics
Professor Mysak, director of the Earth System Modelling Group (ESMG) at McGill University, develops and applies reduced complexity models of the Earth system to better understand decadal and longer term climate variability and change. Analysis of climate data and data-model intercomparison studies are also important activities of the ESMG. Currently, the ESMG is working with two Earth system models, namely, the UVic Earth System Climate model version 2.6 and a simplified global model with the ocean carbon cycle. Some ESMG publications with direct application to physical oceanography include Rahmstorf et al (2005), Petoukhov et al (2005), Mysak et al (2005) and Armstrong et al. (2004)

Rahmstorf et al. (2006) presented results from an intercomparison of 11 different climate models of intermediate complexity, in which the North Atlantic Ocean was subjected to slowly varying changes in freshwater input. All models show a characteristic hysteresis response of the thermohaline circulation to the freshwater forcing; which can be explained by Stommel's salt advection feedback. Major differences are found in the location of present-day climate on the hysteresis diagram.

Petoukhov et al. (2005) carried out an intercomparison of eight EMICs (Earth system Models of Intermediate Complexity) to investigate the variation and scatter in the results of simulating (1) the climate characteristics at the prescribed 280 ppm atmosphere CO_2

concentration, and (2) the equilibrium and transient responses to CO_2 doubling in the atmosphere. The results of the first part of this intercomparison suggest that EMICs are in reasonable agreement with the present-day observational data. Each of the EMICs participating in the intercomparison exhibited a reduction of the strength of the thermohaline circulation in the North Atlantic under CO_2 doubling, with the maximum decrease occurring between 100 and 300years after the beginning of the transient experiment. After this transient reduction, whose minimum notably varies from model to model, the strength of the thermohaline circulation increases again in each model, slowly rising back to a new equilibrium.

Armstrong et al. (2004) validated the dynamic-thermodynamic granular rheology sea-ice model of Tremblay and Mysak against 40 years of observed sea-ice concentration (SIC) data. Over the entire Arctic domain, surface air temperature anomalies are negatively correlated with sea-ice anomalies. The observed downward trend in total sea-ice cover in the last two decades as well as record minima in the East Siberian Sea are well reproduced in the simulation.

Dr. Andy Bush at the University of Alberta has also published research on climate dynamics. Bush et al. investigated the spatio-temporal variability in Eurasian Late Quaternary loess-paleosol sequences using a coupled atmosphere-ocean general circulation model. Bush (2004) provided a synthesis of modeling of the late Quaternary climate over Asia and studies the CO_2/H_2O and orbitally-driven climate variability over central Asia through the Holocene (Bush, 2005).

Abyssal Flows

Dr. G. Swaters at the University of Alberta has published extensively on abyssal flows. Choboter and Swaters (2003) studied the role of baroclinicity in the dynamics of abyssal equator-crossing flows using two-layer models of the flow valid in the equatorial region. Observations show that the near-sill dynamics of dense abyssal overflows is variable and is governed, to a significant extent, by a balance between rotation, bottom friction and downslope acceleration due to gravity. Numerical simulations indicate that the near-sill downslope velocities are comparable to the phase/group velocities of long internal gravity waves. This suggests the possibility that overflows can become supercritical and destabilized by bottom friction. Swaters (2003) presented a theory for the frictional destabilization of rotating abyssal overflows and the accompanying baroclinic coupling with the overlying ocean.

Choboter and Swaters (2004) applied shallow-water modeling of Antarctica Bottom Water crossing the Equator. Ha and Swaters (2006) describe the weakly nonlinear baroclinic instability characteristics of time-varying grounded abyssal flow on sloping topography with dissipation. The equatorward flow of source-driven grounded deep western boundary currents within a stratified basin with variable topography was examined by Swaters (2006a,b). The model used in this study is the two-layer quasigeostrophic (QG) equations, describing the overlying ocean, coupled to the finite-amplitude planetary geostrophic (PG) equations, describing the abyssal layer, on a midlatitude β plane. Swaters (2006c) examined the frictional destabilization of abyssal overflows dynamically coupled to internal gravity waves.

El Nino-Southern Oscillation (ENSO)

Dr. W. Hsieh's research group at the University of British Columbia has published articles in the review period which focus on the ENSO and AO. Newbigging et al. (2003) demonstrated two improvements to the Non-linear Principal Component Analysis (NLPCA) method using sea surface temperature anomaly data from the tropical Pacific, where the ENSO phenomenon is manifested. NLPCA, via a neural network (NN) approach, was applied to an ensemble of six 47-yr simulations conducted by the Canadian Centre for Climate Modelling and Analysis (CCCma) second-generation atmospheric general circulation model (Wu et al., 2003). Each simulation was forced with the observed sea surface temperature from January 1948 to November 1994. The NLPCA modes reveal nonlinear structures in both the winter 500-mb geopotential height (Z500) anomalies and surface air temperature (SAT) anomalies over North America, with asymmetric spatial anomaly patterns during the opposite phases of an NLPCA mode. Only during its negative phase is the first NLPCA mode related to the El Niño–Southern Oscillation (ENSO); the positive phase is related to a weakened jet stream.

Nonlinear interdecadal changes in the ENSO phenomenon were investigated using several tools: a nonlinear canonical correlation analysis (NLCCA) method based on neural networks, a hybrid coupled model, and the delayed oscillator theory (Wu and Hsieh, 2004). The leading NLCCA mode between the tropical Pacific wind stress (WS) and sea surface temperature (SST) reveals notable interdecadal changes of ENSO behaviour before and after the mid 1970s climate regime shift, with greater nonlinearity found during 1981–99 than during 1961–75. Wu et al (2005) performed nonlinear projections of the tropical Pacific sea surface temperature anomalies (SSTAs) onto North American winter (November–March) surface air temperature (SAT) and precipitation anomalies were performed using neural networks. During El Niño, the linear SAT response has positive anomalies centered over Alaska and western Canada opposing weaker negative anomalies centered over the southeastern United States. In contrast, the nonlinear SAT response, which is excited during both strong El Niño and strong La Niña, has negative anomalies centered over Alaska and northwestern Canada and positive anomalies over much of the United States and southern Canada.

Other ENSO related papers include An et al. (2006), Wu et al. (2006a,b), Li et al. (2005), Rattan et al. (2005), Hsieh (2004), Ye and Hsieh (2006), An et al. (2005) and Tang and Hsieh (2003).

IPCC 4th Assessment Report

The Intergovernmental Panel on Climate Change (IPCC) has been established by WMO and UNEP to assess scientific, technical and socio- economic information relevant for the understanding of climate change, its potential impacts and options for adaptation and mitigation. It is open to all members of the UN and of WMO. Working Group I (WGI) of this panel examined the physical basis of climate change. In February 2007, WGI released the Fourth Assessment Report Summary for Policymakers, and over the next several months the full reports of this and other working groups are to be released. The final report of WGI is available at the following Internet site: http://ipcc-wg1.ucar.edu/ .

These reports present the results of many simulations of global climate change on the world's largest computers, as well as the most recent interpretation of past climate change. The WGI report was produced by around 600 authors from 40 countries, and reviewed by over 620 experts and governments. Before being accepted, the summary was reviewed line-by-line by representatives from 113 governments. The Canadian Centre for Climate modelling and analysis (CCCma) in Victoria, British Columbia, took the Canadian lead in this program. In addition, many Canadian scientists at other academic and government institutions contributed.

On the issue of global warming and its causes, the Summary for Policy Makers states that: "**Warming of the climate system is unequivocal**.", and "**Most of the observed increase in globally averaged temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic greenhouse gas concentrations**." Readers are encouraged to read more of these reports on IPCC Internet sites.

Other Global Studies

Thomson and Fine (2003) presented a method for estimating mixed layer depth from oceanic profile data. Kang et al. (2005) studied sea level rise in the East Japan Sea. The Mediterranean Ocean Forecasting system and it applications are described by Pinardi et al. (2003), Sparnocchia et al. (2003) and Demirov et al. (2003).

Arctic Ocean

Climate Variability

A number of broadly based papers examine aspects of Arctic Ocean and climate variability. McBean et al. (2006) in the paper "Arctic Climate: Past and Present"provide historical context for present changes in Arctic climate. Overpeck et al. (2005) note how the Arctic climate is changing to a new state. Macdonald et al. (2004) present another overview, with focus on the carbon cycle.

Arctic Throughflow

Many studies have focused on fresh water flow through the Arctic Ocean. The Bering Strait provides massive inputs of fresher water to the Arctic Ocean, but continuous current meter measurements of this flux have only recently become available. Cherniawsky et al. (2006) developed a technique to take advantage of satellite altimetry to determine surface flow through this strait in ice-free months, publishing a record of 14 years of flow. The TOPEX/Poseidon and Jason-1 satellites pass over Bering Strait at their most northern arc of orbit, with about 8 passes in 10 days across the strait. These east-west passes enable measurements of sea-surface slope from which geostrophic surface flow can be computed. The full impact of changes in this throughflow on ice cover are described by Shimada et al. (2006).

McLaughlin et al. (2004) note the relative impacts of Atlantic and Pacific water flowing into the Arctic. Physical and geochemical data were collected during the year-long 2800-km drift of the *CCGS des Groseilliers*. The halocline was thinner over the Mendeleyev Abyssal Plain and northern Chukchi Plateau. Pacific-origin upper- and middle-halocline waters occupied the upper 80m of the water column. Underlying Atlantic-origin lower halocline waters were fresher, colder and much more ventilated than observed in the past. These new observations of a sub-surface oxygen maximum suggest that outflow from the East Siberian Sea now supplies the Canada Basin lower halocline.

Shimada et al. (2004 2005) note how the warm Atlantic water of the 1990s penetrated into the Arctic Ocean and discuss the halocline structure of the Canada Basin. Steiner et al. (2004) analyse the heat and freshwater content of the Arctic Ocean. Timmermans et al. (2007) examine measurements by a thermistor chain in the deep region of Canada Basin, and observe more variability then expected from internal tides and advecting water masses. McLaughlin et al. (2005) note the hydrology of the southern Canada Basin in the summer of 2002. Macdonald and Yu (2005) present features of the Mackenzie River estuary.

Yamamoto-Kawai et al. (2006) examine the nitrogen balance in Arctic Throughflow. They note that Atlantic ocean waters tend to be enriched in nitrate relative to phosphate, whereas Arctic Ocean waters entering the Atlantic through Fram Strait and the Canadian Archepelago have excess phosphate relative the nitrate. They show that phosphate in this flow accounts for 16% or more of nitrogen fixation in the north Atlantic Ocean.

Flow through the Canadian archipelago and adjacent straits comprises a significant contribution to North Atlantic climate processes. A major Canadian program to examine this flow is described by Prinsenberg (2003). Munchow et al. (2006) estimate the volume of flow and freshwater flux through Nares Strait. Melling (2004) summarizes flow through the northern Canadian Archipelago, and Prinsenberg and Hamilton (2003, 2004, 2005) examine the volume, freshwater and heat fluxes passing through Lancaster Sound. Dunlap and Tang (2006) model the circulation of Baffin Bay. Polyakov et al. (2003) propose a long term circulation and water mass monitoring program for the Arctic Ocean. Lobb et al. (2003) discuss features of a mixing front in Baffin Bay. Van der Baaren et al. (2003) describe low-frequency variability in Lancaster Sound. A correction for beam spread in acoustic Doppler current profiler measurements is developed by Marsden and Ingram (2004).

Sea Ice

Understanding sea-ice motion is critical to predicting gains or (more likely) losses of Arctic sea ice. Samelson et al. (2006) examine atmospheric factors controlling ice flow through Nares Strait. Holloway et al. (2007a) compare many numerical simulations of Arctic ice cover from 1970 to 1999. They find differences in averaged temperature and salinity fields arising from models' differences in parameterizations and numerical methods and from different domain sizes, with anomalies that develop at lower latitudes carried into the Arctic. They note that models would benefit from introduction of topostrophy, defined as the vertical component of $V\times\nabla D$ where V is monthly mean velocity and ∇D is the gradient of total depth, characterizing the tendency to follow topographic slopes. Positive topostrophy expresses a tendency for cyclonic ``rim currents''. Holloway and Proshutinsky (2007) examine how several numerical models simulate the impact of tides on Arctic ice, as part of the Arctic Ocean Model Intercomparison Project (AOMIP). Among results from AOMIP is a tendency for models to accumulate excessive Arctic Ocean heat throughout the intercomparison period 1950 to 2000, which is contrary to observations. Tidally induced ventilation of ocean heat reduces this discrepancy. Steiner et al. (2003) estimate Arctic windspeeds and stresses and their impacts on ocean-ice snow modeling. Dumas et al. (2005) note the climate change impacts on the Beaufort Shelf landfast ice. Melling et al. (2005) measure trends in draft and extent of seasonal pack ice in the Canadian Beaufort Sea. Carmack and Chapman (2003) discuss the joint roles of ice cover and bathymetry on wind-driven shelf/basin exchange on an Arctic shelf: Williams et al. (2006) determine joint effects of wind and ice motion in forcing upwelling in Mackenzie Trough in the Beaufort Sea.

Marsden et al. (2005) pose the question "Are polynyas self-sustaining?", perhaps a follow-on study to Yao and Tang (2004), who examine formation and maintenance of the North Water Polynya. Mei et al. (2003) summarize phytoplankton production in this same polynya.

The structure and distribution of ice itself is critical to navigation in the Arctic and in the Northwest Passage. Falkingham et al. (2003) investigate possible climate change scenarios and their impact on shipping in the Canadian Arctic. Amundrud et al. (2004, 2006) investigate geometrical constraints on evolution of ridged sea ice, and the impact of porosity on melting ice in ridge keels. Prinsenberg and Peterson (2003) compare ice chart parameters against ice observations. Peterson et al. (2003) discuss a technique to measure sea-ice thickness using helicopter-borne EM-Induction sensors. Jackett et al. (2006) provide updated algorithms for density, potential temperature, conservative temperature and freezing temperature of seawater. Dumas et al. (2007) observe ice thickness in the Canadian Archipelago.

Contaminants Transport

A series of papers examine transport of contaminants through the Arctic. Li and Macdonald (2005) examine sources and pathways of selected organochlorine pesticides to the Arctic. Brooks et al. (2005) look at transport pathways and processes leading to environmental exposure. A series of papers by Macdonald and coauthors (2003a, 2003b, 2003c, 2005a, 2005b, 2005c, 2005d) note the changing nature of contaminant transport and accumulation in the Arctic due to climate change. Stein and Macdonald (2005) examine mercury in the Beaufort and Chukchi Seas. Li et al. (2003) note the transport and fate of hexachlorocyclohexanes in the North American Arctic Ocean.

Carbon Cycle and Ecosystems

The carbon cycle in the ocean is another important climate change process. Carmack et al. (2005) summarize the role of climate variability on the carbon budget of Arctic continental shelves. Belicka et al. (2004) note the role of sediment depositional regimes on carbon transport and preservation in Arctic Ocean. The carbon cycle in the Beaufort

Sea is described in a thorough overview by Macdonald et al. (2004). Stein and Macdonald (2004a, 2004b) and Stein et al. (2004) describe the Arctic Ocean organic carbon accumulation, including accumulation in sediments, and its global significance. Anderson et al. (2003, 2004) describe carbon export to sediments in the central Arctic Ocean, and the uptake of atmospheric CO_2 when seawater freezes.

The role of sediments is examined in two papers. O'Brien et al. (2005) examine particle fluxes, sediment transport and deposition on the Canadian Beaufort Shelf. Eiken et al. (2005) suggest that changing ice conditions will increase the importance of sediment transport by sea ice in the Chukchi and Beaufort Seas. They note that sea ice transports about 5 to 8 x 10^6 tonnes of sediment over the Chukchi and Beaufort shelves. Most of the sediment is transported into waters too deep for re-suspension and entrainment, and is a major component of the sediment budget. Changes in ice regimes of the past decade likely have increased the amount of sediment attached to sea-ice

Finally, a series of papers discuss ecological processes in the Arctic Ocean as impacted by physical oceanographic conditions and changes. Michel et al (2006) provide a summary of variability in oceanographic and ecological processes in the Canadian Arctic Archipelago. They examine historical observations of water masses, circulation patterns, sea ice conditions, and nutrients, primary and secondary production, and sedimentation. These observations reveal high variability in nutrients, ice algae, phytoplankton blooms, the timing of ice algae sedimentation in the spring, and the composition of the zooplankton community. An estimate of total primary production in the Canadian Archipelago is also presented, along with published production estimates for other Arctic shelves, showing that the Archipelago may support up to 32% of the total primary production of Arctic shelves. They discuss expected resiliency of this ecosystem to future expected climate change.

Lavioe et al. (2005) model ice algae growth and decline in a seasonally ice-covered region of the Arctic. Carmack et al. (2004) examine phytoplankton productivity on the Canadian Shelf of the Beaufort Sea. Lu et al. (2003) present the cross-shore separation of adult and juvenile euphausids in a shelf-break alongshore current. Mundy et al. (2007) Link ice structure and microscale variability of algal biomass in Arctic first-year sea ice.

Pacific Ocean

Northeast Pacific Ocean

A major breakthrough of the 1990s was the discovery of the Pacific Decadal Oscillation (PDO) in measurements of sea surface temperatures from 1950 to mid-1990s, and its impact on decadal variability of marine species (Mantua et al. 1997). Bond et al. (2003) discovered that the second mode of this pattern of sea surface temperature variability dominated in the 1990s to early 2000s. A PICES report edited by King (2005) provides region-by-region impacts of the 1997/98 regime shift in marine species that accompanied major shifts in both modes of the PDO. It was a change in sign of the second mode of the PDO that is associated with most of the oceanographic changes in 1997/98, whereas a change in the PDO first mode was associated with the 1976/77 change. Schwing et al.

(2005) describe physical oceanographic processes of the northeast Pacific Ocean accompanying this shift. For example, ocean temperatures decrease along much of the North American west coast after 1998, but increased in the central Pacific Ocean near 30°N.

Batten and Welch (2004) examine changes in zooplankton due to the 1997/98 regime shift, based on measurements by the Continuous Plankton recorder between Alaska and California. Boreal calanoid copepod species showed lower abundances prior to 1998 while subtropical species showed higher abundances and a more northerly distribution on the northern part of the transect. Batchelder et al. (2005), and Zamon and Welch (2005) summarize other impacts of this regime shift on biological species. Batten et al. (2003) determine latitudinal differences in the duration of development of Neocalanus plumchrus copepodites.

The years of 2003 to 2007 saw the near-completion of the international array of Argo floats measuring temperature and salinity from 2000 metres depth to the ocean surface every ten days. Freeland and Cummins (2005) present an overview of new products developed from these real-time observations. Jackson et al. (2006) investigate advection of heat in the northeast Pacific Ocean by comparing the observed heat content estimated from Argo data to the expected heat content based on surface heat fluxes. The difference between these was defined as advection. Results show that although advection is minimal in the Alaska Gyre, there are periods in which use of 1-D models for studies of short (monthly) scale processes is questionable.

Cherniawsky et al. (2004) present images and analyses of the very high to very low sea level transition in 1998 along the west coast of California to Alaska, based on satellite altimetry observations. This transition was surprisingly quick in late winter 1998. Cummins et al. (2005) develop an alternative climate index, similar to the PDO, but based only on satellite measurements of sea surface height anomaly (SSHA) available after the launch of TOPEX/Poseidon satellite in 1993. This index reduces high-frequency variability because sea surface height is a better integrator of ocean temperature variability than is sea surface temperature. Cummins and Lagerloef (2004) examine ocean temperature and thermocline depth variability, and note that a simple ocean model forced by wind stress curl reproduces winter mixed layer depth well at Ocean Station P (50°N, 145°W) in the northeast Pacific Ocean.

Thomson and Fine (2003) develop robust algorithms to determine mixed layer depth from profile data. Li et al. (2005) examine historical mixed layer depths along Line P in the Gulf of Alaska. Freeland (2006) examines variability in the portion of the North Pacific Current that forms the Alaska Current. Laine et al. (2006) and Crawford et al. (accepted) examine atmospheric forcing and its impact on temperature and salinity along Line P, taking advantage of a half-century of detailed observations along this section. Both studies note that temperatures along Line P are more responsive to changes in westerly winds than to southerly winds. Crawford et al. (accepted) plot Hovmuller diagrams of Line P temperature and salinity anomalies in the upper mixed layer (10 to 50 m depth) and just below the mixed layer (100 to 150 m depth) over the period 1956 to

2006. These diagram reveal that both temperature and salinity experienced extremes in the upper layer over the past 10 years, attributed the large changes in westerly winds.

Foreman et al. (2006) determine the tidal energy in the Bering Sea from a numerical model. Interestingly, they note basin-wide variations of approximately 19% in the net incoming tidal energy flux due to the 18.6-year nodal modulation. The impact of this nodal modulation is examined over a wide region of the northeast Pacific Ocean and adjacent land by McKinnell and Crawford (2007). They observe significant fluctuations in air and sea temperatures at this period over the past 100 years of measurement, and even in longer records from tree rings. Their analyses indicate the northeast Pacific is presently in a cool era, whereas the very warm years of 1996 to early 1998 were during the warm phase of the lunar nodal cycle. Most studies of temperature changes accompanying this 18.6-year cycle attribute its ocean effect to changes in tidal mixing. Although McKinnel and Crawford (2007) find convincing evidence of this cycle in the northeast Pacific temperatures, they do not find sufficient modulations in local tidal mixing in this region except in the Aleutian Islands. They speculate that modulations in tidal mixing in the outflow of the Sea of Okhotsk might be the trigger in Pacific-wide impacts, as noted earlier by Yasuda et al. (2006).

Impacts of climate-related variability of winds on northeast ocean ecosystems are modelled by Monahan and Denman (2004). Harrison et al. (2004, 2005) and Whitney et al. (2005a, 2005b) examine physical processes and nutrient inputs to the northeast and northwest gyres of the Pacific Ocean, as well as processes influencing coastal ecosystems. An even larger geographic domain is examined by McKinnell et al. (2006) in their review of Pacific climate variability and marine ecosystem impacts from the tropics to the Arctic. Finally, Thomson et al. (2003, 2005) develop a numerical simulation of hydrothermal vent-induced circulation at Endeavour Ridge, and determine that circulation at Endeavour ridge facilitates colonization by vent larvae.

Subarctic Ecosystem Response to Iron Experimental Release (SERIES 2002)

Most of the publications resulting from this experiment at Ocean Station P in July 2002 were published in 2003 to 2007. This experiment proved conclusively that the high-nitrate, low-chlorophyll (HNLC) surface waters of the Gulf of Alaska are iron-limited. The experiment began with an injection of iron in solution into surface waters at Ocean Station Papa that set up a plankton bloom visible in SeaWiFS observations of ocean colour. Boyd et al. (2005) presented an overview of aspects of the phytoplankton bloom stimulated by the iron injection, and the changes in nutrients accompanying this bloom. Timothy et al. (2005), Le Clainche et al. (2006), Denman et al. (2006) and Steiner et al. (2006) model aspects of phytoplankton growth and nutrient drawdown. Wong et al. (2004) discuss the temporal and spatial distribution of dimethylsulfide. Law et al. (2006) document the evolution of the iron-enriched patch of surface water. Pena (2003a, 2003b) model the response of the planktonic food web to iron fertilization, and determine size classes, functional groups and ecosystem dynamics. Crawford et al. (2003) determine the influence of zinc and iron enrichments on phytoplankton growth in the Northeastern subarctic Pacific. Stenman et al. (2004) develop a vertical model of particle size distributions and fluxes in the mid-water column that includes biological and physical processes.

Mesoscale Eddies

Canadian scientists led a major field program to examine physical and biochemical interactions of mesoscale eddies of the northeast Pacific Ocean. These anticyclonic eddies form in winter along the northern Canadian and southeast Alaskan continental margins, and propagate westward into deep-sea regions, or along the Alaskan Stream. A special issue of *Deep-Sea Research II* presents early results of this study (Miller et al. 2005). A detailed modelling study by Di Lorenzo et al. (2005) establishes how Haida Eddies form in winter at the southern cape of the Queen Charlotte Islands. Stacey et al. (2006a, 2006b) develop numerical models to represent these eddies in the northeast Pacific Ocean. The offshore transport of heat and salt in ocean surface layers is described by Crawford (2005). Yelland and Crawford (2005) investigate rotational currents in eddies as measured by drifters, ship-based sensors and as inferred from satellite-based measurements of sea surface height. Johnson et al. (2005) describe observations of iron transport by these eddies from coastal to deep-sea regions and Peterson et al. (2005) explain the macronutrient cycles. Chierici et al. (2005) determine the carbon dioxide cycle in a Haida Eddy. Batten and Crawford (2005) and Crawford et al. (2005a, 2007) note the impacts of these eddies on phytoplankton and zooplankton distributions of the Gulf of Alaska. Mackas et al. (2005) show how zooplankton species composition evolves as eddies age, shifting from mainly coastal to mainly deep-sea species, while Tsurumi et al. (2005) describe the possible role of eddies in an unusual enrichment of pteropods in the northeast Pacific Ocean.

Continental Slope and Shelf-Slope Exchanges

Several papers emerged from a study of currents at the shelf-break of the outer continental shelf off the west coast of Vancouver Island and Washington State. Allen (2004) provides an overview of these processes. Mirshak and Allen (2005) examine upwelling in Astoria Canyon. Allen et al. (2003) compare numerical models and laboratory models of submarine canyons. Crawford et al. (2005b) examine Argo profile observations to discover the deep-sea source of extremely cold bottom water in 2002 on the Canadian, Washington, and Oregon continental shelves. Mackas and Coyle (2005) study shelf-offshore exchange processes, and their effects on mesozooplankton biomass and community composition patterns in the Northeast Pacific.

Continental Shelf Studies

Ianson et al. (2003) present an overview of the inorganic carbon system in the coastal upwelling region west of Vancouver Island. Mackas et al. (2006) compile the interdisciplinary oceanography of continental margin from Vancouver Island to Baja California. Many studies focus on smaller regions.

MacFayden et al. (2005) observe and model the transport of surface waters from the Juan de Fuca eddy region to the Washington coast. This paper is an early publication of the ECOHAB project to examine phytoplankton productivity and species in the Juan de Fuca Eddy west of southern Vancouver Island and Washington State. Coastal regions of

Washington State to the east of this eddy are frequently hit by harmful algal blooms (HABs) in summer originating in waters of the Juan de Fuca Eddy. ECOHAB science focuses on specific aspects of this eddy that might favour production of HABs, and the physical processes that transport the toxins to shore.

Gower (2004) and Gower et al. (2004) undertake a compilation of SeaWiFS and MODIS images of ocean colour to show significant features of Canadian waters. Robinson et al. (2004) provide twenty years of satellite observations describing phytoplankton blooms in seas adjacent to Gwaii Haanas National Park Reserve in the southern Queen Charlotte Islands. Sathyendranath et al. (2004) undertake a multispectral remote sensing study of coastal waters off Vancouver Island. Physical processes impacting rare sponge reefs in Hecate Strait are presented by Conway et al. (2005) and Whitney et al. (2005c). Robinson et al. (2005) investigate the oceanographic connectivity among marine protected areas on the north coast of British Columbia. Sinclair et al. (2005) determine associations between bathymetric, geologic, and oceanographic features and the distribution of the British Columbia bottom trawl fishery, based on a recent compilation of trawling effort. Sinclair and Crawford (2005) develop a reliable predictor of recruitment of Pacific cod in Hecate Strait, based only on pressure-adjusted sea level in winter at Prince Rupert.

Inshore Waters

Tidal regimes and possible extraction of tidal energy were considered in several papers. Sutherland et al. (2005) modelled tidal resonance in Juan de Fuca Strait and the Strait of Georgia. Sutherland et al. (2006) undertake a tidal current energy assessment for Johnstone Strait. Foreman et al. (2004) develop an inverse modelling approach to examine M2 tidal dissipation around Vancouver Island. Stacey (2005) reviews the partition of tidal energy in five Canadian fjords. Stacey and Pond (2005a) examine the sensitivity of deepwater renewals in Indian Arm, British Columbia, to the production of turbulent kinetic energy caused by horizontal variations in the flow field. Stacey and Pond (2005b) determine the energy fluxes due to the surface and internal tides in Knight Inlet. Garrett and Cummins (2004, 2005) examined theoretical limitations of extracting power from tidal currents. Foreman et al. (2006) modelled estuarine and tidal currents in the Broughton Archipelago. Masson (2005) and Masson and Cummins (2004, 2006) apply observations and models to examine seasonal variability in the Strait of Georgia and Juan de Fuca Strait. Johannessen et al. (2005a) examine historical trends in mercury sedimentation and mixing in Strait of Georgia. Johannessen et al. (2005b 2006) note the distribution and cycling of suspended particles in the Strait of Georgia, Haro Strait and Juan de Fuca Strait. Stucchi et al. (2005a, 2005b) model the transport and dispersion of IHN pathogens in the Broughton Archipelago and the near-field deposition of finfish aquaculture waste. Johannessen et al. (2003) compile a sediment and organic carbon budget for the Georgia Basin.

Atlantic Ocean

The Labrador Sea

The Labrador Sea is a key area of field studies for the Canadian oceanographic research community. This is a region of deepwater formation and, therefore, is an important element of the meridional overturning circulation. The transport of freshwater is analyzed in an eddy-permitting regional model of the sub-polar North Atlantic, focusing on the export of freshwater (in liquid form) through Davis Strait (Myers, 2005). The results show that in the model simulations there is a limited exchange of freshwater between the Labrador shelf and the interior of the Labrador Sea. Very little of the freshwater exported from the Canadian Arctic gets taken up into the model Labrador Sea water. Enhancing the freshwater export through Davis Strait by 2/3 has little effect on the freshwater content in the Labrador Sea interior, as well as on Labrador Sea Water formation. Myers and Deacu (2004) utilize a numerical model to further investigate the Labrador Sea freshwater content. The distribution and ventilation of water masses in the Labrador Sea were studied by Azetsu-Scott et al. (2005) using tracers such as CFCs and carbon tetrachloride. Following this, Zhao et al. (2006) used an adiabatically-corrected ocean circulation model to simulate CFC transport in the North Atlantic.

Karcher et al. (2005) use a numerical model and observations to trace a strong freshwater release to subpolar waters in the mid-1990s. In contrast to the ice export driven 1970's 'Great Salinity Anomaly', its source was a large additional liquid freshwater release from the Arctic Ocean. In fact it was a consequence of a change of the Arctic Ocean's thermohaline structure in response to the very intense North Atlantic Oscillation in the early 1990s. These results show a strong link of large-scale Arctic Ocean changes with the freshwater flux to subpolar waters.

Lilly et al. (2003) used current meter moorings and satellite altimetry to study small-scale, coherent eddies in the Labrador Sea. This study concluded that there is a lack of a clear relationship between eddy energy and the intensity of wintertime cooling. These observations also suggest an active role for boundary current dynamics in shaping the energetics and water mass properties of the interior region. An eddy-admitting model of the North Atlantic was applied to study the seasonal variations of temperature at 1000 m in the Labrador Sea (Lu et al., 2006). The model successfully reproduced the seasonal cycle of the near-bottom temperature observed from a long-term mooring deployed on the 1000 m isobath on the upper continental slope off Labrador. It also provided an estimate of the spatial distribution of the seasonal temperature variation in the whole Labrador Sea that can be interpreted in terms of the roles played by surface cooling, deep convection, lateral mixing and advection. The model results suggest that mixing along the steeply sloped isopycnal surfaces plays an important role in communicating the cold water formed by surface cooling to deep layers over the Labrador Slope in later winter. Upstream conditions are also communicated to the mooring site along the Slope through advection by the prevailing cyclonic circulation. In particular, the advection of warm water off Greenland contributes to the gradual warming from spring to winter at the mooring site.

Application of Satellite Altimetry

Satellite altimetry has also been used to estimate the low-frequency variability of sea level and currents off Newfoundland (Han, 2006). TOPEX/Poseidon (T/P) sea level data for the period from 1992 to 2002 are analysed to investigate sea level and current variability over the Newfoundland Slope. Sea level anomalies relative to local means for this period are derived and surface current anomalies normal to ground tracks are then calculated under the geostrophic approximation. Climatological mean surface currents normal to the ground tracks are also obtained from the solution of a regional circulation model. The sum of the model means and altimetric current anomalies is used to nominally represent absolute currents. Statistical analyses are carried out based on topographic regimes for along-slope and cross-slope current variability. The altimetric sea level and current variability increases offshore, toward the Gulf Stream or its extension the North Atlantic Current. The sea level was higher in summer and lower in winter, with an increased range offshore. The shelf-edge current (water depth of 200 3000 m) was stronger in fall and weaker in spring. Interannual sea level and current variations were also substantial.

Sea level observations from the tandem T/P and Jason-1 altimetry missions (2002–2003) are used to study characteristics of sea level and surface currents over the Scotian Shelf and Slope off Nova Scotia (Han, 2004). The consistency and error characteristics of T/P and Jason-1 measurements are examined not only in terms of sea level and cross-track current anomalies but also with respect to current anomalies at crossovers, kinematic properties associated with Gulf Stream warm core rings (WCRs), and the shelf-edge current transport. The current anomalies derived from altimetry and moored measurements are significantly correlated and comparable in the rms magnitude. Han (2004) also used T/P altimetry, in conjunction with concurrent frontal analysis data from infrared imagery, to study temporal and spatial variability of sea-surface currents over the Scotian Slope. The altimetric results reveal prominent spatial variability of cross-track currents with an overall intensification toward the west and south, typically 20–30 cm/s over the upper and lower slope, 20–50 cm over the continental rise, and up to 70–75 cm/s near the Gulf Stream northern wall. A rapid westward intensification on the western slope contrasts with nearly uniform distribution on the eastern slope. The intensification seems to be associated with the high occurrence of Gulf Stream warm core rings (WCR) and with the close proximity to the Gulf Stream. When combined with CTD data, T/P observations can produce the vertical profile of the total geostrophic current that is in approximate agreement with ADCP measurements.

Basin-Scale Processes

Dr. Greatbatch's research group at Dalhousie University has contributed significantly to understanding of large-scale processes in the Northwest Atlantic Ocean. Greatbatch et al. (2004) provided an overview of the semi-prognostic method, a new and novel technique that can be used for adjusting models to correct for systematic error. Applications of the method to a regional model of the northwest Atlantic Ocean, and to an eddy-permitting model of the entire North Atlantic, show improvement in the handling of the Gulf Stream/North Atlantic Current systems, especially in the "northwest corner" region southeast of Newfoundland where prognostic models show systematic errors of as much as 10°C in the temperature field. Use of the semi-prognostic method also leads to improvement in the modelled flow over the eastern Canadian shelf. Zhai et al (2004a) present a variation of the semi-prognostic method for use with ocean models. The new version has the advantage that model drift is effectively prevented, while at the same time the meso-scale eddy field is free to evolve. They used the method to probe the importance of the eddy-driven circulation in the northwest Atlantic Ocean. It was shown that the eddies strongly reinforce the eastward Gulf Stream jet and the northern recirculation in the slope region, with over 50% of the total transport of this recirculation being directly eddy-driven. The eddies also play a role in setting the temperature and salinity properties of the "northwest corner" southeast of Newfoundland. Sheng et al. (2005) presented a new two-way nesting technique for a multiple nested-grid ocean modeling system. The new technique used the smoothed semi-prognostic (SSP) method to exchange information between the different subcomponents of the nested-grid system. Nesting using the semi-prognostic method is shown to effectively prevent unrealistic drift of the inner model, while use of the SSP method avoids unnecessary damping of small scales on the inner model grid. Comparison of the annual-mean flow field with the near-surface currents determined from observed trajectories of near-surface drifters demonstrates the overall superiority of the nesting technique based on the SSP method.

Zhang et al. (2004) presented a coupled ice-ocean modeling system developed for the northwest Atlantic Ocean based on the second version of the Los Alamos sea ice model and a regional ocean circulation model. The coupled ice-ocean system differs from other coupled systems for the same region mainly in two ways. First, the semi-prognostic method was used in the ocean component. Second, the sea ice component uses an elastic-viscous-plastic ice rheology and three-layer thermodynamics. The coupled system reproduces reasonably well the phase and magnitude of the annual cycle of sea ice. The effect of the ice heat capacity, previously unaccounted for in earlier model results of this region, is a delay in the springtime sea-ice melt on the Labrador and Newfoundland Shelves.

Zhai et al (2004b) discussed the spreading of inertial oscillations induced by the passage of Hurricane Juan in 2003 across the Gulf Stream and the Scotian Shelf. It was found that surface-intensified inertial oscillations develop at locations remote from the storm track after a period of 5–10 days. A diagnostic technique reveals the importance of advection by the background geostrophic flow for explaining this effect. The results suggest that advection by mean circulation can play a role in redistributing near-inertial energy in the ocean. Zhai et al. (2005) studied the interaction between inertial oscillations generated by a storm and a mesoscale eddy field, using a Southern Ocean channel model. It was shown that the leakage of near-inertial energy out of the surface layer is strongly enhanced by the presence of eddies, with the anticyclonic eddies acting as a conduit to the deep ocean. Given the ubiquity of the atmospheric storm tracks and regions of strong ocean mesoscale variability, they argued that this effect could be important for understanding pathways by which near-inertial energy enters the ocean and is ultimately available for mixing. Sheng et al. (2006) used a nested-grid ocean circulation modelling system to assess the upper ocean response of the Scotian Shelf and adjacent slope to Hurricane Juan in September 2003. The model-calculated upper ocean response to

Hurricane Juan was characterized by large divergent surface currents forced by the local wind forcing under the storm, and intense near-inertial currents in the wake of the storm. The sea surface temperature (SST) cooling produced by the model is biased to the right of the storm track and agrees well with a satellite-derived analysis. Over the deep water, off the Scotian Shelf, some of the near-inertial energy input by the storm is advected eastward by the Gulf Stream away from the storm track. The hurricane also generates shelf waves that propagate equatorward with the coastline on their right.

Zhai and Greatbatch (2006a) estimated the eddy-induced diffusivity for heat at the surface of the western North Atlantic Ocean using satellite altimetry and sea surface temperature data. The resulting eddy-induced diffusivity shows considerable spatial variability with a value near 10^4 m^2 s^{-1} just to the south of the Gulf Stream and values in the range 1-2 × 10^3 m^2 s^{-1} within the Gulf Stream itself. Zhai and Greatbatch (2006b) demonstrated that eddies influence the surface heat budget both by modifying the surface heat flux and by the lateral transfer of heat within the surface mixed layer. It was shown that the presence of eddies modifies the surface heat flux in a model of the northwest Atlantic Ocean by more than 100 W m^{-2} over the Gulf Stream system. They estimated the surface eddy diffusivity associated with surface thermal damping and showed that it takes large values (more than 10^3 m^2 s^{-1}) south of the Gulf Stream and smaller values elsewhere.

Zhai and Greatbatch (2007) examined the work done by the wind over the northwest Atlantic Ocean using a realistic high-resolution ocean model driven by synoptic wind forcing. Two model runs were conducted with the difference only in the way the wind stress was calculated. Their results show that the effect of including ocean surface currents in the wind stress formulation is to reduce the total wind work integrated over the model domain by about 17%. The reduction is caused by a sink term in the wind work calculation associated with the presence of ocean currents. In addition, the modelled eddy kinetic energy decreases by about 10%, in response to direct mechanical damping by the surface stress. A simple scaling argument shows that the latter can be expected to be more important than bottom friction in the energy budget.

Greatbatch et al (2007) discussed the role of the ocean heat budget of eddy-induced missing due to air-sea interaction. The traditional point of view is that in the ocean, the meridional transport of heat is achieved by the wind-driven and meridional overturning circulations. Greatbatch et al (2007) argued that mixing associated with eddies, especially in the surface mixed layer, can play an important role in closing the ocean heat budget. Their results argue that the lateral mixing applied at the surface of ocean/climate models should be playing an important role in the heat balance of these models, indicating the need for physically-based parameterizations to represent this mixing.

Wright et al. (2006) provided a new technique for assimilating long-term hydrographic information into eddy-permitting ocean model of the North Atlantic. The basic idea of the new technique is to add correction terms to the model equations that directly influence the model solution only in prescribed frequency and wave number bands, leaving the variations outside of these bands free to evolve prognostically. For this reason the technique is referred to as spectral nudging.

Other papers contributed in this area of research include Yang et al (2006), Deacu and Myers (2005a), Myers et al. (2005), Sinha and Topliss (2006), Dupont et al. (2006) and Stramma et al. (2004).

Atmosphere-Ocean Interactions and Surface Waves

Ocean wave modeling research is carried out by W. Perrie's group at the Bedford Institute of Oceanography. Perrie et al. (2003) considered the impact of waves on surface currents. It was shown that the wave effect on currents is largest in rapidly developing intense storms, when wave-modified currents can exceed the usual Ekman currents by as much as 40%. A large part of this increase in velocity can be attributed to the Stokes drift. Reductions in momentum transfer to the ocean due to wind input to waves and enhancements due to wave dissipation are each of the order 20%–30%. Model results were compared with measurements from the Labrador Sea Deep Convection Experiment of 1997.

Perrie et al. (2004a, 2005) investigated the coupling of atmosphere and ocean by including sea-spray in their numerical model. Simulations of extratropical Hurricane Gustav (2002) were performed using the MC2 (Mesoscale Compressible Community) atmospheric model, coupled to the Princeton Ocean Model (POM), and a sea spray parameterization. The impact of coupling POM to MC2 generates sea surface temperature (SST) cooling, which reduced the sea surface heat fluxes. Reduced heat fluxes lead to reduced storm intensity. Simulation of the heat and mass flux contributions of sea spray enhances sea surface heat fluxes and slightly increases maximum storm intensity compared to coupled MC2-POM simulations without spray. Perrie et al. (2004b, 2004c, 2006) also investigated the impact of mid-latitude storms on air-sea CO_2 exchange. Ren et al. (2004) also investigated the atmosphere–ocean dynamics of midlatitude North Atlantic storms by using the MC2 atmospheric model coupled to the POM. Case studies include midlatitude extratropical storm Earl (1998) and an intense winter storm from January 2000, denoted Superbomb. Late-summer storms such as Earl encounter a thin mixed layer and produce a cold wake by inducing strong currents. Sea surface temperatures (SSTs) can be depressed as much as 5°C or more. Winter storms such as Superbomb occur when the mixed layer is quite deep. Although impacts on SSTs and the upper-ocean temperature profile tend to be weak, about 1°C or so, storm-induced ocean currents can be large.

Zhang et al. (2006a) demonstrated that sea spray tends to intensify storms, whereas wave-related drag tends to weaken storms. When wind speeds are high and sea surface temperatures warm, spray can significantly increase the surface heat fluxes. By comparison, momentum fluxes related to wave drag are important over regions of the storm where young, newly generated waves are prevalent, for example during the rapid development phase of the storm. These momentum fluxes decrease in areas where the storm waves reach maturity. The collective influence of spray and waves on storm intensity depends on their occurrence in the early stages of a storm's rapid intensification phase, and their spatial distribution with respect to the storm center. Zhang et al. (2006b) shows that increasing gas transfer rates during winter storms are coincident with increasing winds and deepening bubble penetration.

Shen et al (2006) provided a new hurricane wind retrieval algorithm using synthetic aperture radar (SAR) images. Jiang et al (2005) investigated the energy flux from the wind to ocean inertial motions and estimated the sensitivity to wind fields.

Biophysical Processes

Greenan et al. (2004) demonstrated that short-term physical events can play an important role in controlling phytoplankton growth during the fall bloom period. In October 2000, a wind-driven upwelling event lasted about one week and was a primary factor in initiating the fall bloom on the inner Scotian Shelf. These results were based on a three-week mooring deployment measuring currents, temperature, salinity and fluorescence, combined with biweekly sampling of temperature, salinity, nutrients and chlorophyll.

Zakardjian et al. (2003) used a coupled, three-dimensional ocean model to study the effects of circulation and temperature on the population dynamics of *Calanus finmarchicus* in the Gulf of St. Lawrence and Scotian Shelf. The GSL-SS region was divided into eight sub-areas to compare the net fluxes of *C. finmarchicus* across lateral boundaries to the net production in each sub-area. They found that the annual cross-boundary exchange rates constitute from <1% to 39% of the local net production, indicating that the horizontal transport of *C. finmarchicus* by the ocean currents can play a very important role in the dynamics of local *C. finmarchicus* populations.

Brickman (2003) used a combination of biophysical modelling and data analysis to infer some important aspects of the southwest Nova Scotia (Canada)-Bay of Fundy (BoF) ecosystem with respect to the first year of life of Browns Bank (BB) haddock. One of the main observations in this ecosystem is that adult fish found in the BoF region consistently exhibit a larger length-at-age than fish found in the BB region. This is generally thought to be due to drift and retention processes acting during the early life stages, with the larger fish assumed to be the result of settlement in a more favourable temperature and food environment downstream in the BoF. Also, while BB is considered to be an important juvenile nursery ground and the source for the smaller southwest Nova (SWN) fish, the existence of the larger BoF fish suggests a downstream nursery ground. The combination of biophysical modelling and analysis of fisheries data provides evidence of the metapopulation structure of haddock stocks on the Scotian Shelf/Gulf of Maine.

Losa et al. (2006) developed a simple ecosystem model is coupled to a 3-dimensional general circulation model for the North Atlantic. The physical model is based on the Los Alamos Parallel Ocean Program (POP) and forced by climatological monthly mean data. Four biological components (phytoplankton, zooplankton, nutrients and detritus) were incorporated into POP as additional tracers with biological sources and sinks. The model solutions, obtained with different physical and biological parameterizations were compared against monthly mean SeaWiFS colour data averaged over the period 1997-2003 and with climatological nitrate data.

Coastal and Nearshore Processes

Oceanography on the continental shelves and nearshore regions are also areas of important research as impacts of human activity can be intensified in these regions. Loder et al. (2003) used archived data and geostrophic computations to examine variability in hydrographic properties and along-shelf transport on the Scotian Shelf, with focus on the Halifax section and a decadal-scale hydrographic anomaly during the late 1950s and early/mid 1960s. The long-term annual cycle shows strong seasonal variations in baroclinic transport on the inner shelf and at the shelf edge, and an associated steric change in adjusted sea level (ASL) at Halifax. Regional wind-forcing and barotropic currents make smaller contributions to the annual cycle in ASL.

Panteleev et al. (2004) also modeled the circulation of the Scotian Shelf through the application of a variational algorithm and a non-linear diagnostic model. Han and Loder (2003) used a three-dimensional nonlinear finite element model with an advanced turbulence scheme is used in conjunction with historical current, temperature, and salinity observations to describe seasonal-mean circulation and hydrography on the eastern Scotian Shelf (ESS). The circulation is dominated by surface-intensified baroclinic nearshore and shelf-break currents, both directed southwestward with prominent seasonal and alongshelf changes. These currents are primarily associated with the equatorward inflow of relatively fresh water from the Gulf of St. Lawrence and Newfoundland Shelf/Slope. Pronounced and persistent influences of outer-shelf banks, inner-shelf basins, and cross-shelf channels are evident in the circulation fields. Han (2005) uses a similar model to investigate barotropic wind-driven circulation over the Newfoundland and Labrador Shelf. The model solutions show a shelf-edge current and an inshore current, both of which directed equatorward. The cross-shelf flows and anticyclonic circulation over shallow banks are evident as a consequence of topographic steering. There are prominent seasonal variations in the two branches of the Labrador Current, strongest in December and weakest in July. Results indicate that the wind forcing contributes significantly to the inshore branch of the Labrador Current and less to the shelf-edge branch. Han and Wang (2006) have computed the monthly mean circulation in the Flemish Cap region as well.

Xu and Loder (2004) used in situ currents and elevation data and a direct inverse data assimilation model in conjunction with global inverse tidal solutions to obtain high-resolution regional assimilative model solutions for the barotropic K1 and O1 tides on the southern Labrador and Newfoundland Shelves. A striking feature of the regional model solutions is a series of small-scale (radius of approximately 100 km) eddy-like features along the shelf edge. The assimilative elevation fields reveals the existence of topographically trapped waves at the shelf edge. There are amplified diurnal currents over the outer shelf and slope associated with the topographic waves, pointing to the potential for topographic amplification of other subinertial currents in the region. Wright and Xu (2004) demonstrated that double Kelvin waves do exist over the Newfoundland shelf break.

Operational oceanography for the purposes of Search and Rescue and impacts of storm surge has been researched in the Atlantic coastal zones. Thompson et al. (2006) developed a storm surge forecast system using a depth-averaged, non-linear, barotropic ocean model driven by forecast winds and air pressures produced by the Canadian Meteorological Centre's regional atmospheric model. This system is now being utilized by the Meteorological Service of Canada to forecast storm surges along the Atlantic coasts and public warnings are being routinely issued. Bernier and Thompson (2006) performed a 40 year hindcast of storm surges in the northwest Atlantic and adjacent shelf seas. This hindcast was used to generate spatial maps of the return level of storm surges and also to estimate the return period of extreme total sea levels. Thompson et al. (2003) assessed the predictive skill of a simple model of surface flow on the Scotian Shelf using oceanographic data collected in February 1996. The model is forced by wind stress, water density, and sea level along the open boundaries of the model domain. The skill of the model with respect to drifter position is quantified by the search radius, centered on the predicted drifter position, that ensures a 50% chance of locating the drifter. Skill varies significantly with time but is generally highest when the drifter motion is strongest.

The fate and environmental effects of offshore drilling mud discharges from hydrocarbon production platforms has been studied by Hannah et al. (2005) and Hannah and Drozdowski (2005). Wang et al. (2003) developed a theoretical, two-layer, reduced-gravity model for descending dense water flow on continental shelves and slopes.

A high resolution model of the upper Bay of Fundy was developed to simulate the tides and sea level (Dupont et al., 2005). The model includes the wetting and drying (inundation) of the extensive tidal flats in Minas Basin. Overall the system is capable of a sea level simulation with a relative error of ~10%. Comparison of observed and simulated coastlines showed that a high quality representation of the local topography/bathymetry is as important as the sea level simulation in the calculation of the coastline. Greenberg et al. (2005) modeled embayments with drying intertidal areas in the Bay of Fundy.

Gulf of St. Lawrence

The Gulf of Saint Lawrence is the world's largest estuary and is the outlet of North America's Great Lakes via the Saint Lawrence River into the Atlantic Ocean. Considerable research continues to be conducted in the St. Lawrence. The region is of great importance not only because of the fisheries but also because it is part of a very important shipping route stretching into the heart of North America, to the Great Lakes. Operational oceanography is therefore an important part of the research and forecasts are provided of the currents and ice conditions on a routine basis

Since 2000, Fisheries and Oceans Canada operates a Gulf of St. Lawrence ice-ocean model for daily short-term forecasting of the surface currents, water levels, and sea ice for the shipping industry, the national Search and Rescue program, civil protection agencies, and environmental protection agencies for oil spill trajectory modeling. The Gulf of St. Lawrence ice-ocean model of Saucier et al. (2003) was coupled to the Canadian weather forecast model (Pellerin et al., 2004). It was shown that the coupled atmosphere-ocean model improves the weather and sea ice predictions over eastern Canada.

Faucher et al. (2004) tested the sensitivity of the Canadian Regional Climate Model (CRCM) and the Gulf of St. Lawrence Ocean Model (GOM) with an ensemble of simulations over eastern Canada from 1 November 1989 to 31 March 1990. The goal of this study was to investigate the interaction of the CRCM and GOM with respect to each other's forcing fields. The results indicated that on a monthly or longer timescale, the CRCM is not very sensitive to the details of the oceanic fields from GOM, except locally over the Gulf of St. Lawrence (GSL). However, GOM is quite sensitive to the differences in atmospheric fields from the CRCM.

Gilbert et al. (2005) have examined a seventy-two year time series from the St. Lawrence estuary and demonstrated the connection between the northwest Atlantic and the diminishing deep-water oxygen in the Gulf. A 1.6°C warming of the bottom water from the 1930s to the 1980s suggested that changes in the relative proportions of cold, fresh, oxygen-rich Labrador Current Water (LCW) and warm, salty, oxygen-poor North Atlantic Central Water (NACW) in the water mass entering the Laurentian Channel probably played a role in the observed oxygen depletion. They estimated that about one half to two thirds of the oxygen loss in the bottom waters of the Lower St. Lawrence Estuary can be attributed to a decreased proportion of LCW. This leaves between one third and one half of the oxygen decrease to be explained by causes other than changes in water mass composition.

Drinkwater and Gilbert (2004) studied the hydrographic variability of the waters of the Gulf of St. Lawrence, Scotian Shelf and Eastern Gulf of Maine. Han (2004) used satellite altimetry to study sea level and surface current variability in the GSL. Plourde and Therriault (2004) examined the link between climate variability and vertical advection of nitrates in the GSL.

Turbulence and Mixing

Coastal Mixing Induced by Internal Waves.

After a remote-sensing study in the upper St. Lawrence estuary revealed the existence of high-frequency internal waves that may be important to mixing in the region (Bourgault and Kelley, 2003), a program dubbed SLEIWEX (St. Lawrence Internal Wave EXperiment) was set up by a team of researches from Memorial University of Newfoundland, Dalhousie University, and the Maurice Lemontagne Institute. Continuing field work, set into context with numerical simulations with a nonhydrostatic laterally-averaged code (Bourgault and Kelley, 2004), has focussed in increasing detail on the mechanism of wave collision with sloping topography. Using time series observations, Bourgault et al. (2005) showed that a central finding of laboratory tests seems to hold in the ocean also, namely the transformation of internal waves into smaller boluses that travel up the slope as isolated features, transporting deep water both inshore and closer to the surface. Further insight into the transformation mechanism was provided by a follow-up study with echosounder transects made by rapidly sampling back and forth across shoaling waves made visible by surface slicks (Bourgault et al., 2007). Field work continues in this region, with the present aims being to identify the sources of the internal waves, to trace their propagation, and to compare boundary-induced mixing during wave-boundary collison to shear-induced mixing during wave propagation. In the meantime, broader issues are being addressed. Bourgault and Kelley (2007) have used numerical simulations to study the reflectance of general (planar) bottom slopes for normally incident interfacial solitary waves. In their simulations of laboratory experiments, they found suggestions that the latter were biased by sidewall effects. This sounds a note of caution for extrapolation of idealized laboratory tests to the field. Another issue that needs attention is the angle of incidence of waves, since most studies have dealt only with normal incidence. A first step has been taken by Mirshak and Kelley (2007), who have developed a technique for inferring wave propagation direction from moorings.

Island-Wake Mixing.

A study of an island within the Great Barrier Reef lagoon (Suthers et al., 2004) yielded insights into particle suspension in island wakes. Two mechanisms for suspension were considered: centrifugal upwelling in lee eddies and entrainment driven by turbulence generated in swift island-edge flows. By setting the results of extensive interdisciplinary sampling into a simple theoretical context, the authors showed that in this case turbulent entrainment is more important than eddy upwelling, and also raised the possibility that island-wake effects may affect larval recruitment.

Turbulence in the Nearshore Zone

Smyth and Hay (2003) used remote acoustic measurements of turbulence intensity profiles to investigate the relationship of the intensity to wave energy and bedstate. Outside the wave boundary layer, velocity power spectral densities were found to increase with increasing wave energy for all bedstates at frequencies across the wave and turbulence bands up to the Nyquist frequency of the measurements, 8 to 10 Hz. The power spectra of the horizontal and vertical velocity exhibit the −5/3 slope characteristic of inertial subrange turbulence. As the seafloor is approached, the slopes of the vertical velocity spectra in this subrange become progressively less steep, reaching values between −1.2 and −0.6 within the wave boundary layer where the spectral densities are independent of bed state and incident wave energy. Estimated wave friction factors are highest for low-energy rippled beds and smallest for flat bed conditions, and within the uncertainty of the measurements, are generally consistent with predictions.

Zou and Hay (2003) and Zou et al. (2003) compared theoretical solutions for the wave bottom boundary layer (WBL) over a sloping bed with field measurements in the nearshore zone. The field measurements were obtained with a coherent Doppler profiler over a 2° bed slope. Results were presented for both flat and rippled bed conditions, the latter being characterized by low steepness, linear transition ripples. Close to the bed, the observed velocity profiles change rapidly in amplitude and phase relative to potential flow theory, indicating the presence of a wave boundary layer with a thickness of 3–6 cm. The observed velocity and shear stress profiles were in good agreement with the theory.

Dr. Hay's research group continues to study turbulence in the nearshore zone with other recent papers including Ngusaru and Hay (2004), Hay and Mudge (2004) and Newgard and Hay (2007).

Turbulence and Waves in the Laboratory

Dr. B. Sutherland's research group in the Applied Mathematics Department at the University of Alberta has contributed significantly to understanding of internal waves, mixing and turbulence in the ocean. This has been primarily through laboratory based fluid dynamics experiments.

Dohan and Sutherland (2005) performed numerical simulations of internal waves that are generated from eddies within a mixed region and were directly compared to laboratory observations. The mixed region was created in the laboratory by an oscillating grid at the top of a uniformly salt-stratified region. A tank with a length-to-width ratio of 5:1 was used in order to visualize the internal waves and, as such, large-scale waves were produced from a mean circulation which develops in the mixed region. In addition, smaller-scale waves were generated from the turbulent eddies. Fully non-linear numerical simulations in two dimensions of a mixed region overlying a uniformly stratified region were performed to investigate separately the large-scale and small-scale generation of waves from a mixed region, and the qualitative results compare well with the experimental results. This suggested that the first order dynamics of the laboratory experiments may be captured by the simulations of the two-dimensional model.

Aguilar and Sutherland (2006) used laboratory experiments to examine internal wave generation above and in the lee of finite-amplitude periodic topography having various degrees of roughness. They showed that internal waves are generated not only by flow over the hills but also by flow over "boundary-trapped" lee waves and by vigorous turbulence created in the lee of sharp-crested hills. For low values of the excitation frequency, linear theory well predicts the internal wave frequencies but significantly overestimates the wave amplitudes because it neglects processes associated with boundary layer separation. When the excitation frequency exceeds the buoyancy frequency, turbulence results in the excitation of internal waves with frequencies approximately 0.72 ± 0.05 of the buoyancy frequency, and vertical displacement amplitudes ranging between 1.5% and 2% of the horizontal wavelength.
Sutherland et al. (2004) examined the collapse of a uniform density fluid into a surrounding ambient fluid with complex stratification by way of laboratory experiments and fully nonlinear numerical simulations. The analysis focused upon the consequent generation of internal gravity waves and their influence upon the evolution of the collapsing mixed region. In experiments and simulations for which the ambient fluid had uniform density over the vertical extent of the mixed region and is stratified below, they found the mixed region collapses to form an intrusive gravity current and internal waves were excited in the underlying stratified fluid. In simulations for which the ambient fluid was stratified everywhere, including over the vertical extent of the mixed region, Sutherland et al. (2004) found that internal waves were excited with such large amplitude that the collapsing mixed region was distorted through strong interactions with the waves.

Other papers of interest to physical oceanography from Dr. Sutherland's group include: Sutherland (2006a), Sutherland (2006b), Alexander et al. (2006), Aguilar et al. (2006), Flynn and Sutherland (2004), Sutherland et al. (2004), Sutherland and Yewchuk (2004), Sutherland et al. (2004), Flynn et al. (2003) and Dohan and Sutherland (2003).

Intrusions and Double Diffusion

Kelley et al. (2003) provided the first extensive review of the "diffusive" variety double-diffusion. This mode occurs when relatively warm and salty water lies under relatively cold and fresh water, and is thus the reverse of the more frequently studied salt-finger case. The authors pointed out that the diffusive case needs more study, given its possible importance in high-latitude waters (a key issue in climate-change research) and to interleaving fronts at arbitrary latitudes. The authors outlined some outstanding questions that relate to both mechanisms and parameterizations, and noted the need for field tests to test the validity of extrapolating laboratory studies to the very different ocean scales.

Ruddick and Kerr (2003) provide a review of theories governing growth and evolution of thermohaline intrusive motions. They concluded that more work needs to be done in at least two areas. Firstly, tests of linear theory against observations should continue, particularly to discover the extent to which linear theories actually explain the genesis of intrusions. Secondly, theoretical studies are needed on the nonlinear effects that control the evolution and finite amplitude state of intrusions, since these determine the lateral fluxes of salt, heat, and momentum.

Ruddick and Richards (2003) reviewed observations of intrusions and the results of comparisons of properties such as scale, slopes, microstructure activity, and fluxes with theoretical models. A summary of estimates of lateral heat fluxes indicated a wide range of lateral diffusivities. They concluded by noting that present knowledge is insufficient to predict the structure, length-scales and lateral fluxes of thermohaline intrusions with confidence, and list a number of unresolved questions. Suggestions were made for compilation of existing data into a database for exploratory analysis and testing of theoretical hypotheses. Ruddick (2003b) also compiled a summary of laboratory studies of interleaving.

Ruddick (2003a) provided an introduction to the use of seismic sound sources to study ocean fine structure. Ruddick and Gargett (2003) produced an introduction the oceanic double diffusion. Holloway (2006) examined statistically stationary differential diffusion in a large-scale internal waves-vortical modes environment. Gargett et al. (2003) did direct numerical simulation of differential scalar diffusion in three-dimensional stratified turbulence.

Mixing on the Continental Shelf

Sundermeyer et al (2005) provided evidence that lateral dispersion on scales of 1–10 km in the stratified waters of the continental shelf may be significantly enhanced by stirring by small-scale geostrophic motions caused by patches of mixed fluid adjusting in the aftermath of diapycnal mixing events. Dye-release experiments conducted during the recent Coastal Mixing and Optics (CMO) experiment provide estimates of diapycnal and lateral dispersion. Microstructure observations made during these experiments showed patchy turbulence on vertical scales of 1–10 m and horizontal scales of a few hundred meters to a few kilometers. For parameter values relevant to CMO, lower-bound estimates of the effective lateral diffusivity by this mechanism ranged from 0.1 to 1 m^2 s^{-1}. Revised estimates after accounting for the possibility of long-lived motions were an order of magnitude larger and ranged from 1 to 10 m^2 s^{-1}. The predicted dispersion is large enough to explain the observed lateral dispersion in all four CMO dye-release experiments examined.

Oakey and Greenan (2004) presented results from the CMO experiment in which they were able to make a comparison of the diffusivity from both dye and microstructure measurements. Although the mixing rates were quite small (vertical diffusivity of heat, $K_T < 10^{-5}$ m^2 s^{-1}), the two techniques yielded consistent results.
Moum et al. (2003) provided detailed observations of the structure within internal solitary waves propagating shoreward over Oregon's continental shelf reveal the evolving nature of interfaces as they become unstable and break, creating turbulent flow. A persistent feature was high acoustic backscatter beginning in the vicinity of the wave trough and continuing through its trailing edge and wake. This was demonstrated to be due to enhanced density microstructure. Increased small-scale strain ahead of the wave trough compresses select density interfaces, thereby locally increasing stratification. Moum et al. (2003) argued that this is the generation mechanism for the observed turbulence and hence the persistent structure of high acoustic backscatter in these internal solitary waves.

Acoustics, Bubbles and Turbulence
Ross and Lueck (2005) estimate turbulent dissipation rates through an inversion of 307 kHz acoustic scattering data collected in the lee of a sill in Knight Inlet, British Columbia. These data have been shown previously to be strongly correlated with temperature and shear microstructure measurements. Ross and Lueck (2005) show that inversion methods can be used to get turbulent dissipation rates from acoustic backscatter, provided that independent measurements of temperature and salinity stratification are available. The temperature salinity characteristics of the environment, however, can place limitations on the inversion technique. The strong negative salinity gradient in Knight Inlet decreases the slope of the functional relationship between dissipation rate and scattering cross-section for high dissipation rates and increases the uncertainty of the inversion. This limitation on the inversion technique is not an issue throughout most of the world's oceans (where $dT/dS>0$) and, in places where it could be a problem, the limitation can be overcome by using multi-frequency techniques. Ross et al. (2004) describe the turbulent co-spectrum of two scalars and its effect on acoustic scattering from oceanic turbulence. Ross and Lueck (2003) examine sound scattering from oceanic turbulence.

Vagle et al. (2005) performed measurements of high-frequency (100 kHz) acoustical backscatter in the surf zone and have identified the presence of a wall formed by dense assemblages of bubbles generated by breaking gravity waves and persisting for periods up to 30 min. These bubbles are advected by alongshore and cross-shore rip currents and are controlled by the local wave field, turbulence, dissolution, and buoyancy. Gemmrich and Farmer (2004) produced a study of near-surface turbulence in the presence of breaking waves. Thorpe et al. (2003) used observations and models to study bubble clouds in Langmuir circulation.

Tsunami Research

A general review of tsunami risks in Canada (Clague et al. 2003) outlines the state of knowledge prior to the 2004 Asian tsunami. Tsunamis became a major news story along the Pacific Coast of Canada following the Asian tsunami of December 26, 2004, because the Cascadia Subduction Zone, just 100 km west of the Canadian coast, has generated tsunamis as big as the Asian tsunami. In late December 2004 and early 2005 Pacific oceanographers and geophysicists devoted many hours to news interviews explaining the specific hazards to which Canadians are at risk.

The Fisheries & Oceans Canada Internet site was the most useful, as it displayed results of a very recent numerical simulation of a Cascadian tsunami propagating through West Coast Canadian waters. This project is described by Cherniawsky et al. (2007). The following link presents this material and more recent information
http://www-sci.pac.dfo-mpo.gc.ca/osap/projects/tsunami/default_e.htm

The first wave of a Cascadia tsunami could arrive at the West Coast of Vancouver Island within 20 minutes of the earthquake, which is too soon for local authorities to evacuate communities. Therefore, scientists pointed out the need for persons at sea level to move to higher ground immediately following a severe earthquake.

Over the next months and years many studies examined evidence of the deep-ocean propagation of the Asian tsunami. Gower (2005) noted clear evidence in satellite altimeter tracks. Gower and Gonzales (2006) detected this signal in the American network of deep-sea, tsunami buoys in the Pacific Ocean. Rabinovich and Thomson (2006) and Rabinovich et al. (2006) followed its progress in records of traditional tide gauges. Fine et al. (2005b) and Titov (2006) developed numerical simulations of its generation and progress.

Local landslide-generated tsunamis are also a risk to British Columbians who live along steep-sided fjords. These landslides can be set off by earthquakes, or even by minor tremors. An example of a landslide-generated tsunami in British Columbia is presented by Bornhold et al. (2007). This tsunami wiped out a local village. Rabinovich et al. (2003) present an assessment of tsunami risks in the event of underwater landslides in the Strait of Georgia, BC.

Underwater landslides also pose a risk in many regions. Canada's most destructive tsunami hit Newfoundland and Nova Scotia in 1929 following an underwater landslide, killing 29 persons. Fine et al. (2005a) published an analysis and numerical simulation of this wave.

References

Aguilar, D. A., and B. R. Sutherland, 2006. Internal Wave Generation over Rough Topography, *Phys. Fluids* 18 Art. No. 066603.

Aguilar, D. A., B. R. Sutherland and D. J. Muraki, 2006. Laboratory Generation of Internal Waves from Sinusoidal Topography, *Deep-Sea Res. II* 53, 96-115.

Alexander, M. J., J. H. Richter and B. R. Sutherland, 2006. Generation and Trapping of Gravity Waves from Convection with Comparison to Parameterization, *J. Atmos. Sci.* 63, 2963-2977.

Allen, S.E., 2004. Restrictions on deep flow across the shelf-break. *Surveys in Geophysics* 25, 221-247.

Allen, S.E., M.S. Dinniman, J.M. Klinck, D.D. Gorby, A.J. Hewett, and B.M. Hickey, 2003. On vertical truncation errors in terrain following numerical models: Comparison to a laboratory model for upwelling over submarine canyons. *Journal of Geophysical Research, Oceans* 108, art. no. 3003.

Amundrud, T.L., H. Melling and R.G. Ingram, 2004. Geometrical constraints on the evolution of ridged sea ice. J*ournal of Geophysical Research* 109(C06005). doi:10.1029/2003JC002251.

Amundrud, T.L., H. Melling, R.G. Ingram and S.E. Allen, 2006. The effect of structure porosity on the melting of ridge keels in pack ice. *Journal of Geophysical Research* 111(C06004). doi: 10.1029/2005JC002895.

An, S.-I., Z. Ye and W.W. Hsieh, 2006. Changes in the leading ENSO modes associated with the late 1970s climate shift: Role of surface zonal current. *Geophys. Res. Lett*. 33, L14609, doi:10.1029/2006GL026604.

An, S.-I., W.W. Hsieh and F.-F. Jin, 2005. A nonlinear analysis of the ENSO cycle and its interdecadal changes. *J. Climate* 18(16): 3229-3239.

Anderson, L.G., E.P. Jones and J.H. Swift, 2003. Export production in the central Arctic Ocean evaluated from phosphate deficits. *Journal of Geophysical Research* 108, No. C6, 3119, doi:10.1029/2001JC001057, 2003.

Anderson, L.G., E. Falck, E.P. Jones, S. Jutterström, and J. Swift, 2004. Enhanced uptake of atmospheric CO2 during freezing of seawater: A field study in Storfjorden, Svalbard. *J. Geophys. Res.* 109, C06004, doi:10.1029/2003JC002120.

Armstrong, A.E., L.-B. Tremblay and L.A. Mysak, 2004. A data-model intercomparison study of Arctic sea-ice variability. *Climate Dynamics* 20, 465-476.

Azetsu-Scott, K., R.M. Gershey and E.P. Jones, 2005. Distribution and Ventilation of Water Masses in the Labrador Sea inferred from CFCs and Carbon Tetrachloride. *Marine Chemistry* 94, 55-66.

Batchelder, H.P., W.R. Crawford, A. Hallowed, J. King, G. McFarlane, F. Mueter, I.R. Perry and J. Schweigert, 2005. Recent ecosystem changes in the Gulf of Alaska. In: King, J. [Eds.].. Report of the study group on fisheries and ecosystem responses to recent regime shifts, *PICES Scientific Report 28.*

Batten, S.D. and W.R. Crawford, 2005. The influence of coastal origin eddies on oceanic plankton distributions in the eastern Gulf of Alaska. *Deep-Sea Research II* 52, 991-1009, doi:10.1016/j.dsr2.2005.02.011.

Batten, S.D. and D.W. Welch, 2004. Changes in oceanic zooplankton populations in the north-east Pacific associated with the possible climatic regime shift of 1998/1999. *Deep-Sea Research II* 51, 863-873.

Batten, S.D., D.W. Welch and T. Jonas, 2003. Latitudinal differences in the duration of development of Neocalanus plumchrus copepodites. *Fisheries Oceanography* 12(3), 201-208.

Belicka, L.L., R.W. Macdonald, M.B. Yunker and H.R. Harvey, 2004. The role of depositional regime on carbon transport and preservation in Arctic Ocean sediments. *Marine Chemistry* 86, 65-88.

Bernier, N. B., and K. R. Thompson, 2006. Predicting the frequency of storm surges and extreme sea levels in the northwest Atlantic, *J. Geophys. Res.* 111, C10009, doi:10.1029/2005JC003168.

Bobanovic, J., K.R. Thompson, S. Desjardins and H. Ritchie, 2006. Forecasting Storm Surges along the East Coast of Canada and Northeastern US: The Storm of 21 January, 2000. - *Atmosphere-Ocean* 44(2), 151-161.

Bond, N.A., Overland, J.E., Spillane, M., Stabeno, P., 2003. Recent shifts in the state of the North Pacific. *Geophysical Research Letters* 30(23), doi:10.1029/2003GL018597.

Bornhold, B.D., J.R. Harper, D. McLaren and R.E. Thomson, 2007. Destruction of the Pre-contact First Nations Village of Kwalate by a Rock Avalanche-generated tsunami. *Atmosphere-Ocean* (in press, June 2007).

Bourgault, D. and D. Kelley, 2004. A laterally-averaged nonhydrostatic ocean model. *J. Atm. Oceanic. Tech*. 21, 1910–1924.

Bourgault, D. and D.E. Kelley, 2003. Wave-induced boundary mixing in a partially mixed estuary. *J. Mar. Res*. 61(5), 283–296.

Bourgault, D. and D.E. Kelley, 2007. On the reflectance of uniform slopes for normally incident interfacial solitary waves. *J. Physical Oceanogr*. 37(5), 1156–1162.

Bourgault, D., D.E. Kelley, and P.S. Galbraith, 2005. Interfacial solitary wave run-up in the st. Lawrence estuary. *J. Mar. Res*. 53, 1001–1015.

Bourgault, D., M. D. Blokhina, R. Mirshak, and D. E. Kelley, 2007. Evolution of a shoaling internal solitary wavetrain. *Geophys. Res. Letters*. 34(L03601, doi:10.1029/2006GL028462).

Boyd P.W., Law C, Nojiri Y, Wong C.S., Tsuda A., Levasseur M., Takeda S., Jackson G., Needoba J., Strzepek R., Gower J.R., McKay M., Arychuk M., Barwell-Clarke J., Crawford W., Crawford D., Hale M., Harrison P.J., 2004. The decline and fate of an iron-induced subarctic phytoplankton bloom. *Nature* 428, 549-553, doi:10.1038/nature02437.

Brickman, D., 2003. Controls on the distribution of Browns Bank juvenile haddock. *Mar. Ecol. Prog. Ser.* 263: 235-246.

Brooks, S., J. Christensen, V. Gordeev, A. Susev, S. Lindberg, R.W. Macdonald, S. Marcy, K. Puckett and O. Travnikov, 2005. Transport pathways and processes leading to environmental exposure. In: Marcy, S. [Ed.]. AMAP assessment 2002:

Heavy metals in the Arctic, Arctic Monitoring and Assessment Programme (AMAP). 11-41. Oslo, Norway, AMAP.

Bush, A.B.G., 2005. CO2/H2O and orbitally-driven climate variability over central Asia through the Holocene. *Quaternary International* 136, 15-23.

Bush, A.B.G., 2004. Modelling of late Quaternary climate over Asia: a synthesis. *Boreas* 33, 155-163.

Bush, A.B.G., E.C. Little, D. Rokosh, D. White, and N.W. Rutter, 2004. Investigation of the spatio-temporal variability in Eurasian Late Quaternary loess-paleosol sequences using a coupled atmosphere-ocean general circulation model. *Quaternary Science Reviews* 23, 481-498.

Carmack, E.C. and D. C. Chapman, 2003. Wind-driven shelf/basin exchange on an Arctic shelf: The joint roles of ice cover extent and shelf-break bathymetry. *Geophys. Res. Lett.* 30(14), 1778 doi:10.1029/2003GL017526.

Carmack, E., R.W. Macdonald and S.Jasper, 2004. Phytoplankton productivity on the Canadian Shelf of the Beaufort Sea. *Marine Ecology Progress Series.* 277, 37-50.

Carmack, E., D.G. Barber, J.R. Christensen, R.W. Macdonald, B. Rudels and E. Sakshaug, 2005. Climate variability and physical forcing of the food webs and the carbon budget on panarctic shelves. *Progress in Oceanography* 71, 145-181.

Cherniawsky, J.Y., M. Foreman, W.R. Crawford and B. Beckley, 2004. Altimeter observations of sea-level variability off the west coast of North America. *International Journal of Remote Sensing.* 25(7-8), 1303-1306.

Cherniawsky, J.Y., W.R. Crawford, O. Nikitin and E. Carmack, 2005. Bering Strait transports from satellite altimetry. *Journal of Marine Research* 63(5), 887-900.

Cherniawsky, J.Y., Titov, V.V., Wang, K. and J.-Y. Li, 2007. Numerical simulations of tsunami waves and currents for southern Vancouver Island from a Cascadia megathrust earthquake. *Pure and Applied Geophysics* 164(2-3), 465-492.

Chierici, M., L.A. Miller, F.A. Whitney, K. Johnson and C.S. Wong, 2005. Biogeochemical evolution of the carbon dioxide system in the waters of long-lived mesoscale eddies in the Northeast Pacific Ocean. *Deep-Sea Research II* 52(7-8), 955-974.

Choboter, P. F., & G. E. Swaters, 2003. Two-layer models of abyssal Equator-crossing flow. *J. Phys. Oceanogr.* 33, 1401-1415.

Choboter, P. F., & G. E. Swaters, 2004. Shallow-water modelling of Antarctic Bottom Water crossing the Equator. *J. Geophys. Res.* 109, C03038, doi: 10.1029/2003JC002048.

Clague, J.J., A Munro, T Murty, 2003. Tsunami hazard and risk in Canada. *Natural Hazards* 28(22), 433-461.

Conway, K., M. Krautter, V. Barrie, F.A. Whitney, R.E. Thomson, H.M. Reiswig, H. Lehnert, G. Mungov and M. Bertrum, 2005. Sponge reefs in Queen Charlotte Basin, Canada: controls on distribution, growth and development. In: Friewald, A. and Roberts, J. M. [Eds.]. *Coldwater corals and ecosystems* 605-621. Berlin Heidelberg, Springer-Verlag.

Crawford D.W., M.S. Lipsen, D.A Purdie, M.C. Lohan, P.J. Statham, F.A. Whitney, J.N. Putland, W.K. Johnson, N. Sutherland, T.D. Peterson, P.J. Harrison, C.S. Wong, 2003. Influence of zinc and iron enrichments on phytoplankton growth in the Northeastern subarctic Pacific. *Limnol. Oceanogr.* 48(4), 1583-1600.

Crawford, W.R., 2005. Heat and fresh water transport by eddies into the Gulf of Alaska. *Deep-Sea Research II* 52(7-8), 893-908, doi:10.1016/j.dsr2.2005.02.003.

Crawford, W.R., P.J. Brickley, T.D. Peterson and A. Thomas, 2005a. Impact of Haida Eddies on chlorophyll distribution in the Eastern Gulf of Alaska. *Deep-Sea Research II* 52(7-8), 975-990, doi:10.1016/j.dsr2.2005.02.011

Crawford, W.R., P. Sutherland and P. van Hardenberg, 2005b. Cold water intrusion in the Eastern Gulf of Alaska in 2002. *Atmosphere-Ocean* 43(2), 119-128.

Crawford, W.R., Brickley, P.J., Thomas, A.C., (accepted 2007) Mesoscale eddies determine phytoplankton distribution in northern Gulf of Alaska, *Progress in Oceanography*.

Crawford, W.R., Galbraith, J., Bolingbroke, N., (accepted 2007) Line P ocean temperature and salinity, 1956-2005, *Progress in Oceanography*.

Cummins, P.F. and G.S.E. Lagerloef, 2004. Wind-driven interannual variability over the Northeast Pacific Ocean. *Deep-Sea Research I* 51, 2105-2121.

Cummins, P.F., G.S.E. Lagerloef and G. Mitchum, 2005. A regional index of northeast Pacific variability based on satellite altimeter data. *Geophysical Research Letters.* 32(L17607), 1-4, doi: 10.1029/2005GL023642.

Deacu, D. and P.G. Myers, 2005a. Analysis of an 80-year integration of a 1/3-degree model of the Sub-Polar North Atlantic *Journal of Oceanography* 61 , 549-555.

Deacu, D. and P.G. Myers, 2005b. Effect of a Variable Eddy Transfer Coefficient in an Eddy-Permitting Model of the Sub-Polar North Atlantic *Journal of Physical Oceanography* 35 289-307.

Demirov E., N. Pinardi, P. DeMey, M. Tonani, C. Fratianni, 2003. Assimilation scheme of Mediterranean Forecasting System: Operational implementation, Annales *Geophysicae* 21, 189-204.

Denman, K.L., C. Voelker, A. Peña and R. Rivkin, 2006. Modelling the ecosystem response to iron fertilization in the subarctic NE Pacific: The influence of grazing, and Si and N cycling on CO2 drawdown. *Deep-Sea Research II* 53, 2327-2352, doi: 10.1016/j.dsr2.2006.05.026.

deYoung, B., M. Heath, F. Werner, F. Chai, B. Megrey and P. Monfray, 2004a. Challenges of modelling decadal variability in ocean basin ecosystems. *Science* 304, 1463-1466.

deYoung, B., R. Harris, J. Alheit, G. Beaugrand, N. Mantua and L. Shannon, 2004b. Detecting regime shifts in the ocean: data considerations. *Progress in Oceanography* 60, 143-164.

Di Lorenzo, E., M. Foreman and W.R. Crawford, 2005. Modeling the generation of Haida Eddies. Topical Studies in Oceanography: Haida Eddies: mesoscale transport in the Northeast Pacific. *Deep-Sea Research II* 52(7-8), 853-874, doi:10.1016/j.dsr2.2005.02.007.

Dohan, K., and B. R. Sutherland, 2005. Numerical and Laboratory Generation of Internal Waves from Turbulence, *Dyn. Atmos. Oceans* 40, 43-56.

Dohan, K., and B. R. Sutherland, 2003. Internal Waves Generated from a Turbulent Mixed Region, *Phys. Fluids* 15, 488-498.

Drinkwater, K.F., D. Gilbert, 2004. Hydrographic Variability in the Waters of the Gulf of St. Lawrence, the Scotian Shelf and the Eastern Gulf of Maine (NAFO Subarea 4) During 1991-2000. *J. Northwest Atl. Fish. Sci*. 34: 85-101 .

Dumas, J., E. Carmack and H. Melling, 2005. Climate change impacts on the Beaufort Shelf landfast ice. *Cold Reg. Sci. Tech*. 42, 41-51.

Dumas, J.A., H. Melling, G. Flato, 2007. Late-summer pack ice in the Canadian archipelago: Thickness observations from a ship in transit. *Atmosphere-Ocean* 45(1), 57-70.

Dunlap, E. and C.L. Tang, 2006, 2006. Modeling the mean circulation of Baffin Bay. *Atmosphere-Ocean* 44, 99-110.

Dupont, F., C.G. Hannah and D.G. Wright, 2006. Model investigation of the SlopeWater, North of the Gulf Stream. *Geophysical Research Letters* 33, L05604, oi:10.1029/2005GL025321.

Dupont, F., C.G. Hannah and D. Greenberg. 2005. Modelling the sea level in the upper Bay of Fundy. *Atmosphere-Ocean* 43, 33-47.

Dupont, F. and C.A. Lin, 2004. The adaptive spectral element method and comparisons with more traditional formulations for ocean modeling. *J. Atmos. Oceanic Tech*. 21, 135-147.

Dupont, F., D. Straub and C.A. Lin, 2003. Influence of a step-like coastline on the basin scale vorticity budget of mid-latitude gyre models. *Tellus* 55A, 255-272.

Eicken, H., R. Gradinger, A. Graves, A. Mahoney, I. Rigor and H. Melling, 2005. Sediment transport by sea ice in the Chukchi and Beaufort Seas: Increasing importance due to changing ice conditions? *Deep-Sea Research II* 52, 3281-3302.

Falkingham, J., H. Melling and K.Wilson, 2003. Shipping in the Canadian Arctic: Possible climate change scenarios. *Canadian Meteorological and Oceanographic Society Bulletin* 31(3), 68-69.

Faucher, M., D. Caya, F.J. Saucier, R. Laprise, 2004. Sensitivity of the CRCM atmospheric and the Gulf of St. Lawrence ocean-ice models to each other. *Atmos.-Ocean* 42: 85-100.

Fine, I.V., A.B. Rabinovich, B.D. Bornhold, R.E. Thomson and E.A. Kulikov, 2005. The Grand Banks landslide-generated tsunami of November 18, 1929: Preliminary analysis and numerical modeling. *Marine Geology* 215, 45-57.

Fine, I.V., A.B. Rabinovich and R.E. Thomson, 2005. The dual source region for the 2004 Sumatra tsunami. *Geophysical Research Letters* 32(L16602). doi: 10.1029/2005GL023521.

Flynn M. R., and B. R. Sutherland, 2004. Intrusive Gravity Currents and Internal Gravity Wave Generation in Stratified Fluid, *J. Fluid Mech.* 514, 355-383.

Flynn, M. R., K. Onu and B. R. Sutherland, 2003. Internal Wave Excitation by a Vertically Oscillating Sphere, *J. Fluid Mech.*, 494, 65-93.

Foreman, M., G. Sutherland and P.F. Cummins, 2004. M2 tidal dissipation around Vancouver Island: An inverse approach. *Continental Shelf Research* 24, 2167-2185.

Foreman, M.G.G, P.F. Cummins, J.Y. Cherniawsky and P. Stabeno, 2006. Tidal energy in the Bering Sea. *J. Mar. Res*. 64, 797-818.

Foreman, M., D. Stucchi, Y. Zhang and A.M. Baptista. 2006. Estuarine and tidal currents in the Broughton Archipelago. *Atmosphere-Ocean* 44(1), 47-63.

Freeland, H.J. and P.F.Cummins, 2005. Argo: A new tool for environmental monitoring and assessment of the world's ocean, an example from the NE Pacific. *Progress in Oceanography* 64(1), 31-44.

Freeland, H.J., 2006. How much water from the North Pacific Current finds its way into the Gulf of Alaska? *Atmosphere-Ocean* 44(4), 321-330.

Fukasawa, M., H.J. Freeland, R. Perkin, T. Watanabe, H. Uchida and A.Nishina, 2004. Bottom water warming in the North Pacific Ocean. *Nature* 427, 825-827.

Gargett, A.E., W.J. Merryfield and G. Holloway. 2003. Direct numerical simulation of differential scalar diffusion in three-dimensional stratified turbulence. *Journal of Physical Oceanography* 33,1758-1782

Garrett, C. and P.F. Cummins, 2004. Generating power from tidal currents. *Journal of Waterway, Port, Coastal and Ocean Engineering.* (May/June).

Garrett, C. and P.F. Cummins, 2005. The power potential of tidal currents in channels. *Proc.R.Soc.Lond. A* 461, 2563-2571.doi: 10.1098/rspa.2005.1494.

Gemmrich, J.R. and D.M. Farmer. 2004. Near-surface turbulence in the presence of breaking waves. *Journal of Physical Oceanography* 34, 1067-1086.

Gilbert, D., B. Sundby, C. Gobeil, A. Mucci, G.-H. Tremblay, 2005. A seventy-two-year record of diminishing deep-water oxygen in the St. Lawrence estuary: The northwest Atlantic connection. *Limnol. Oceanogr*. 50(5), 1654-1666.

Gould, J., D. Roemmich, S.Wijffels, H.J. Freeland, M. Ignaszewsky, X. Jianping, S. Pouliquen, Y. Desaubies, U. Send, K. Radhakrishnan, K. Takeuchi, K. Kim, M. Danchenkov, P. Sutton, B. King, B. Owens and S. Riser., 2004. Argo profiling floats bring new era of in situ ocean observations. *EOS Transactions*. *American Geophysical Union* 85(19).

Gower, J., 2004. SeaWiFS global composite images show significant features of Canadian waters for 1997-2001. *Canadian Journal of Remote Sensing* 30(1), 26-35.

Gower, J., L. Brown and G. Borstad, 2004. Observation of chlorophyll fluorescence in west coast waters of Canada using the MODIS satellite sensor. *Canadian Journal of Remote Sensing* 30(1), 17-25.

Gower, J. F., 2005. Jason 1 detects December 26, 2004 tsunami. *Eos Trans AGU* 86(4), 37-38.

Gower, J. and F. González, 2006. U.S. Warning System Detected the Sumatra Tsunami. *Eos Trans. AGU* 87(10), 105:108.

Greatbatch, R.J., J. Sheng, C. Eden, L. Tang, X. Zhai and J. Zhao, 2004. The semi-prognostic method. - *Continental Shelf Research* 24/18, 2149-2165.

Greatbatch, R. J., X. Zhai, C. Eden, and D. Olbers, 2007. The possible role in the ocean heat budget of eddy-induced mixing due to air-sea interaction, *Geophys. Res. Lett.*, 34*,* L07604, doi:10.1029/2007GL029533.

Greenan, B. J. W., B. D. Petrie, W. G. Harrison and N. S. Oakey, 2004. Are the spring and fall blooms on the Scotian Shelf related to short-term physical events? *Continental Shelf Research* 24, 603-625. doi:10.1016/j.csr.2003.11.006.

Greenberg, D.A., J.A. Shore, F.H. Page and M. Dowd, 2005. Modelling Embayments with Drying Intertidal Areas for Application to the Quoddy Region of the Bay of Fundy., *Ocean Modelling* 10(1-2), 211-231.

Ha, Seung-Ji, & G. E. Swaters, 2006. Finite-amplitude baroclinic instability of time-varying abyssal currents. *J. Phys. Oceanogr.* 36, 122-139.

Han G., 2006. Low-frequency variability of sea level and currents off Newfoundland, *Advances in Space Research* 38, 2141-2161.

Han G., and Z. Wang, 2006. Monthly-mean circulation in the Flemish Cap region: a modeling study, *Estuarine and Coastal Modeling*, ASCE, 138-154.

Han G., 2005. Wind-driven barotropic circulation off Newfoundland and Labrador, *Continental Shelf Research* 25, 2084-2106.

Han G., 2004. TOPEX/Poseidon-Jason comparison and combination off Nova Scotia, *Marine Geodesy* 27, 577-595.

Han G., 2004. Scotian Slope circulation and eddy variability from TOPEX/Poseidon and frontal analysis data, *J. Geophys. Res.* 109, C03028, doi:10.1029/2003JC002046.

Han G., 2004. Sea level and surface current variability in the Gulf of St. Lawrence from satellite altimetry. *Int. J. Remote Sensing* 25, 5069-5088.

Han G. and J.W. Loder, 2003. Three-dimensional seasonal-mean circulation and hydrography over the eastern Scotian Shelf, *J. Geophys. Res.*, 108(C5), 3136, doi:10.1029/2002JC001463.

Hannah, C.G., and F. Peters, 2006. Future Directions in Modelling Physical-Biological Interactions: Preface to the Special Issue of the Journal of Marine Systems. Peters, F., and C.G. Hannah (editors). *J. Marine Systems* 61, 115-117. doi:10.1016/j.jmarsys.2006.01.003.

Hannah, C.G., and A. Drozdowski., 2005. Characterizing the Near-bottom Dispersion of Drilling Mud on Three Offshore Banks. *Marine Pollution Bulletin* 50, 1433-1443. 10.1016/j.marpolbul.2005.09.002

Hannah, C.G., A. Drozdowski, J.W. Loder, K. Muschenheim and T. Milligan, 2006. An Assessment Model for the Fate and Environmental Effects of Offshore Drilling Mud Discharges. *Estuarine, Coastal and Shelf Science (Special Issue devoted to IMEMS 2004)* 70:577-588. doi:10.1016/j.ecss.2006.06.008.

Harrison, P.J., F.A. Whitney, A. Tsuda, H. Saito and K. Tadokoro, 2004. Nutrient and plankton dynamics in the NE and NW gyres of the Subarctic Pacific Ocean. J*ournal of Oceanography* 60, 93-117.

Harrison, P.J., F.A. Whitney, D.L. Mackas, R.J. Beamish, M. Trudel and I.R. Perry, 2005. Changes in coastal ecosystems in the NE Pacific Ocean. *Proceedings of the*

International Symposium on Long-Term Variations in the Coastal Environments and Ecosystems, 27-28 September, 2005. Matsuyama, Japan. 17-35.

Hay, A.E. and Mudge, T., 2004. Principal bed states during SandyDuck97: Occurrrence, spectral anisotropy, and the bedstate storm cycle. - *J. Geophys. Res. - Oceans 110 (C03013),* doi:10.1029/2004JC002451.

Holloway, G., 2006. Statistically stationary differential diffusion in a large-scale internal waves-vortical modes environment. *Deep-Sea Research II* 53, 116-127. doi: 10.1016/j.dsr2.2005.09.012.

Holloway, G., Proshutinsky, A., 2007. Role of tides in Arctic ocean/ice climate, *Journal of Geophysical Research* 112, C04S06, doi:10.1029/2006JC003643, 2007

Holloway, G.; Dupont, F.; Golubeva, E.; Häkkinen, S.; Hunke, E.; Jin, M.; Karcher, M.; Kauker, F.; Maltrud, M.; Morales Maqueda, M. A.; Maslowski, W.; Platov, G.; Stark, D.; Steele, M.; Suzuki, T.; Wang, J.; Zhang, J., 2007. Water properties and circulation in Arctic Ocean models, *Journal of Geophysical Research* 112(C4) DOI: 10.1029/2006JC003642.

Hsieh, W.W., 2004. Nonlinear multivariate and time series analysis by neural network methods. Reviews of Geophysics, 42, RG1003, doi:10.1029/2002RG000112.

Ianson, D.C., S. Harris, S.E. Allen, K. Orians, D.E. Varela and C.S. Wong, 2003. The inorganic carbon system in the coastal upwelling region west of Vancouver Island, Canada. *Deep-Sea Research I* 50, 1023-1042 (2003).

Jackett, D.R., T.J. McDougall, R. Feistel, D.G. Wright and M. Griffies, 2006. Updated algorithms for density, potential temperature, conservative temperature and freezing temperature of seawater. *Journal of Atmospheric and Oceanic Technology* 23(12), 1709-1728.

Jackson, J.M., P.G. Myers and D. Ianson, 2006. An examination of advection in the Northeast Pacific Ocean, 2001-05. *Geophysical Research Letters* 33(L15601). doi: 10.1029/2006GL026278.

Jiang, J., Y. Lu, and W. Perrie, 2005. Estimating the energy flux from the wind to ocean inertial motions: The sensitivity to wind fields. *Geophys. Res. Letters* 32, L15610,doi:10.1029/2005GL023289.

Johannessen, S.C., R.W. Macdonald and D. Paton, 2003. A sediment and organic carbon budget for the greater Strait of Georgia. *Estuarine, Coastal and Shelf Science* 56, 845-860.

Johannessen, S.C., R.W. Macdonald and M.K. Eek. 2005a. Historical trends in mercury sedimentation and mixing in Strait of Georgia, Canada. *Environmental Science & Technology* 39(12), 4361-4368.

Johannessen, S.C., M.C. O'Brien, K.L. Denman and R.W. Macdonald, 2005b. Seasonal and spatial variations in the source and transport of sinking particles in the Strait of Georgia, British Columbia, Canada. *Marine Geology* 216, 59-77.

Johannessen, S.C., D. Masson and R.W. Macdonald, 2006. Distribution and cycling of suspended particles inferred from transmissivity in the Strait of Georgia, Haro Strait and Juan de Fuca Strait. *Atmosphere-Ocean* 44(1), 17-27.

Johnson, K., L.A. Miller, N.E. Sutherland and C.S. Wong, 2005. Iron transport by mesoscale Haida eddies in the Gulf of Alaska. Topical Studies in Oceanography: Haida Eddies: mesoscale transport in the Northeast Pacific. *Deep-Sea Research II* 52(7-8), 933-954.

Joseph, S. and H.J. Freeland. 2005. Salinity variability in the Arabian Sea. *Geophysical Research Letters* 32(9), 1-4. doi: 10.1029/2005GL022972.

Kang, S.K., J.Y. Cherniawsky, M. Foreman, H.S. Min, C.-H. Kim and H.-W. Kang. 2005. Inhomogeneous sea level rise in the East/Japan Sea. *Journal of Geophysical Research* 110(C07002). doi:10.1029/2004JC002565.

Karcher, M., R. Gerdes, F. Kauker, C. Köberle, and I. Yashayaev, 2005. Arctic Ocean change heralds North Atlantic freshening, *Geophys. Res. Lett.* 32, L21606, doi:10.1029/2005GL023861.

Kelley, D. E., H. J. S. Fernando, A. E. Gargett, J. Tanny, and E. Ozsoy, 2003. The diffusive regime of double-diffusive convection. Progr. Oceanogr. 56, 461–481.

King, J. [Ed.], 2005. Report of the study group on fisheries and ecosystem responses to recent regime shifts. *PICES Scientific Report 28.*

Laine, A., Hsieh, W.W., Freeland, H.J., 2006. Forcing mechanisms controlling surface and subsurface temperature anomalies along Line-P, North-east Pacific Ocean. *Atmosphere-Ocean* 44, 163-176.

Lavoie, D., K.L. Denman and C. Michel, 2005. Modelling ice algae growth and decline in a seasonally ice-covered region of the Arctic (Resolute Passage, Canadian Archipelago). *Journal of Geophysical Research* 110(C11009), oi:10.1029/2005JC002922.

Law, C.S., Crawford, W.R., Smith, M., Boyd, P.W., Wong, C.S., Nojiri, Y., Robert, M., Abraham, E.R., Johnson, W.K., Forsland, V., Arychuk, M., 2006. Patch evolution and the biogeochemical impact of entrainment during an iron fertilisation experiment in the sub-Arctic Pacific, *Deep-Sea Research II* 53, 2012-2033, doi10.1016/j.dsr2.2006.05.28.

Le Clainche, Y., Levasseur, M., Vézina, A., Merzouk, A., Michaud, S., Scarratt, M., Wong, C.S., Bouillon, R.C., Rivkin, R.B., Boyd, P.W., Anderson, P.J., Miller, W.L., Saucier, F.J., 2006. Modeling analysis of the effect of iron enrichment on DMS dynamics in the N.E. Pacific (SERIES experiment). *J Geophys Res*. 111, C01011, doi: 10.1029/2005/JC002947.

Li, M., P.G. Myers and H.J. Freeland, 2005. An examination of historical mixed layer depths along Line P in the Gulf of Alaska. *Geophysical Research Letters* 32(5), doi:10.1029/2004GL021911.

Li, S., W.W. Hsieh and A. Wu, 2005. Hybrid coupled modeling of the tropical Pacific using neural networks. *J. Geophys. Res*. 110, C09024, 10.1029/2004JC002595.

Li Y-F, R.W. Macdonald, L. Jantunen, T. Harner, T. Bidleman and W. Strachan, 2003. Transport and fate of hexachlorocyclohexanes in the North American Arctic Ocean. In: T.F. Bidleman, R.W. Macdonald and J. Stow. (Eds.). *Canadian Arctic Contaminants Assessment Report II, Sources, occurrence, trends and pathways in the physical environment*. INAC. Ottawa. pp. 202-213.

Li,Y.F. and R.W. Macdonald, 2005. Sources and pathways of selected organochlorine pesticides to the Arctic and the effect of pathway divergence on HCH trends in biota: A review. *Science of the Total Environment, Special Issue* 342, 87-106.

Lilly, J., P. Rhines, F. Schott, K. Lavender, J. Lazier, U. Send and E. D'Asaro, 2003. Observations of the Labrador Sea eddy field. *Progress in Oceanography* 59 (1), 75-176.

Lobb, J., A.J. Weaver and E. Carmack, 2003. Structure and mixing across an Arctic/Atlantic front in northern Baffin Bay. *Geophysical Research Letters* 30(16), 1833. doi:10.1029/2003GL017755.

Loder, J.W., C.G. Hannah, B.D. Petrie and E.A. Gonzalez, 2003. Hydrographic and transport variability on the Halifax section. *J. Geophys. Res*. 108 (C11), 8003, 1-18.

Losa., S., A. Vezina, D. Wright, Y. Lu, K. Thompson and M. Dowd, 2006. 3D coupled physical-biological modelling the North Atlantic: relative impacts of physical and biological parameterizations on biogeochemical simulation. *Journal of Marine Systems* 61(3/4), 30-245. DOI:10.1016/j.jmarsys.2005.09.011.

Lu, B., D.L. Mackas and D.F. Moore, 2003. Cross-shore separation of adult and juvenile euphausids in a shelf-break alongshore current. *Progress in Oceanography* 57, 381-404.

Lu, Y., D.G. Wright and R.A. Clarke. 2006. Modelling deep seasonal temperature changes in the Labrador Sea. *Geophys. Res. Lett*. 33, L23601, doi:10.1029/2006GL027692.

Lu, Y., and D. Stammer, 2004. Vorticity balance in coarse-resolution global ocean simulations. *J. Phys. Oceanogr*. 34, 605-622.

Macdonald, R.W., D. Mackay, Y.F. Li and B. Hickie, 2003a. How will global climate change affect risks from long-range transport of persistent organic pollutants? *Human and Ecological Risk Assessment.* 9(3), 643-660.

Macdonald, R.W., B. Morton and S.C. Johannessen, 2003b. A review of marine environmental contaminant issues in the North Pacific: the dangers and how to identify them. *Environ. Rev*. 11, 103-139. doi:10.1139/A03-017.

Macdonald R.W., T. Harner, J. Fyfe, H. Loeng and T. Weingartner, 2003c. The influence of global change on contaminant pathways to, within and from the Arctic. *Arctic Monitoring and Assessment Programme.* Oslo, Norway. 65 p.

Macdonald, R.W., A.S. Naidu, M.B. Yunker and C. Gobeil, 2004. The Beaufort Sea: distribution, sources, variability and burial of carbon. In: Stein, R. and Macdonald, R. W. [Eds.]. *The Arctic Ocean organic carbon cycle present and past.* (7.2), 177-193. Berlin - New York, Springer Publishing Company.

Macdonald, R.W., E. Sakshaug and R. Stein, 2004. The Arctic Ocean: modern status and recent climate change. In: Stein, R. and Macdonald, R. W. [Eds.]. *The Arctic Ocean organic carbon cycle present and past* (1.2), 6-21. Berlin - New York, Springer Publishing Company.

Macdonald, R.W., 2005. Beaufort Sea. In: Nuttall, M. [Ed.]. *Encyclopedia of the Arctic* 1, 219-221. New York, Taylor & Francis.

Macdonald, R.W., 2005a. Climate change, risks and contaminants: a perspective from studying the Arctic. *Human and Ecological Risk Assessment* 11(6), 1099-1104. doi:10.1080/10807030500346482.

Macdonald, R.W. and Y. Yu, 2005. The Mackenzie estuary of the Arctic Ocean. In: Wangersky, P. J. [Eds.]. *Water Pollution: Estuaries* 5, 91-120. doi: 10.1007/027. Heidelberg, Springer-Verlag.

Macdonald, R.W., 2005b. Contaminants, global change and cold regimes. Orabaek, J. B. *Arctic-alpine ecosystems and people in a changing environment*. Berlin, Spinger-Verlag. in press.

Macdonald, R.W., 2005c. Sources, occurrence, trends and pathways of contaminants in the Arctic. In: Bidleman, T. F., Macdonald, R. W. and Stow, J. P. [Eds]. *Science of the Total Environment, Special Issue* 342(1-3), 1-313.

Macdonald, R.W., T. Harner and J. Fyfe, 2005d. Recent climate change in the Arctic and its impact on contaminant pathways and interpretation of temporal trend data. *Science of the Total Environment*, *Special Issue* 342:5-86. doi: 10.1016/j.scitotenv.2004.12.059.

MacFadyen, A., B.M. Hickey and M. Foreman, 2005. Transport of surface waters from the Juan de Fuca eddy region to the Washington coast. *Continental Shelf Research*. 25, 2008-2021, doi:10.1016/j.csr.2005.05.005.

Mackas, D.L. and K.O. Coyle, 2005. Shelf-offshore exchange processes, and their effects on mesozooplankton biomass and community composition patterns in the Northeast Pacific. *Deep-Sea Research II* 52, 707-725.

Mackas, D., M. Tsurumi, M. Galbraith and D. Yelland, 2005. Zooplankton distribution and dynamics in a North Pacific Eddy of coastal origin: II. Mechanisms of eddy colonization by and retention of offshore species. Topical Studies in Oceanography: Haida Eddies: mesoscale transport in the Northeast Pacific. *Deep-Sea Research II* 52(7-8), 1011-1036.

Mackas, D.L., 2006. Interdisciplinary oceanography of the western North American continental margin: Vancouver Island to the tip of Baja California. In: Robinson, A. R. and Brink, K. H. [Eds.]. *The Sea XIV: The Global Coastal Ocean, Interdisciplinary Regional Studies and Syntheses* (12), 441-501.

Mantua, N.J., Hare, S.R., Zhang, Y., Wallace, J.M., Francis, R.C., 1997. A Pacific interdecadal climate oscillation with impacts on salmon production. *Bulletin of the American Meteorological Society* 78, 1069-1079.

Marsden, R. and R.G. Ingram, 2004. Correcting for beam spread in acoustic Doppler current profiler measurements. *J. Atmospheric and Oceanic Technology* 21, 1491-1498.

Marsden, R.F., J. Serdula, E. Key and P.J. Minnett, 2005. Are polynyas self-sustaining? *Atmosphere-Ocean* 42, 251-265.

Masson, D. 2006. Seasonal water mass analysis for the Straits of Juan de Fuca and Georgia. *Atmosphere-Ocean* 44(1), 1-15.

Masson, D. and P.F. Cummins, 2004. Observations and modeling of seasonal variability in the Straits of Georgia and Juan de Fuca. *Journal of Marine Research* 62, 491-516.

Masson, D. and P.F. Cummins, 2006. Temperature trends and interannual variability in the Strait of Georgia, British Columbia. *Continental Shelf Research,* doi: 10.1016/j.csr.2006.10.009.

McBean, G.A., G. Alekseev, D. Chen, E. Forland, J. Fyfe, P.Y. Groisman, R. King, H. Melling, R. Vose and P.H. Whitfield, 2005. 2. Arctic Climate: Past and Present. In: *Arctic Climate Impact Assessment* 21-60. doi: 10.1029/2005GL024483. -1042. Cambridge University Press.

McKinnell, S. M., Brodeur, R. D., Hanawa, K., Hollowed, A. B. and Polovina, J. J., 2005. Pacific climate variability and marine ecosystem impacts from the tropics to the arctic. In: Angel, M. V. and Smith, R. L. [Eds.]. *Progress in Oceanography* 49, (1-4).

McKinnell, S. and W. Crawford, 2007. The 18.6-year lunar nodal cycle and surface temperature variability in the northeast Pacific, *Journal of Geophysical Research - Oceans* 112, C02002 doi:10.1029/2006JC003671.

McLaughlin, F.A., E.C. Carmack, R.W. MacDonald, H. Melling, J.H. Swift, P.A. Wheeler, B.F. and E.B. Sherr, 2004. The joint roles of Pacific and Atlantic-origin waters in the Canada Basin, 1997-1998. *Deep Sea Research I* 51(1), 107-128.

McLaughlin, F., K. Shimada, E. Carmack, M. Itoh and S. Nishino, 2005. The hydrography of the southern Canada Basin, 2002. *Polar Biology* 28(3), 182-189. doi: 10.1007/s00300-004-0701-6.

Mei, Z.-P., L. Legendre, Y. Gratton, J.-E. Tremblay, B. Leblanc, B. Klein & M. Gosselin, 2003. "Phytoplankton production in the North Water Polynya: size fractions and carbon fluxes, April to July 1998", *Marine Ecology Progress Series* 256, 13-27,

Melling, H., 2004. Fluxes through the Northern Canadian Arctic Archipelago. *ASOF Newsletter* 2, 3-13.

Melling, H., D.A. Riedel and Z. Gedalof, 2005. Trends in draft and extent of seasonal pack ice, Canadian Beaufort Sea. *Geophysical Research Letters* 32(L24501). doi: 10.1029/2005GL024483.

Michel, C., R.G. Ingram and L.R. Harris, 2006. Variability in oceanographic and ecological processes in the Canadian Arctic Archipelago. *Progress in Oceanography* 71, 379-401.

Miller, L.A., M. Robert and W.R. Crawford, 2005. The large, westward-propagating Haida Eddies of the Pacific eastern boundary. Topical Studies in Oceanography: Haida Eddies: mesoscale transport in the Northeast Pacific. *Deep-Sea Research II* 52(7-8), 845-852.

Mirshak, R. and S.E. Allen, 2005. Spin-up and the effects of a submarine canyon: applications to upwelling in Astoria Canyon. *Journal of Geophysical Research - Oceans* 110, art. no. C02013.

Mirshak, R. and D. E. Kelley, (submitted April 2007). Inferring propagation direction of nonlinear internal waves in a vertically sheared background flow. *J. Atm. and Oceanic Tech*.

Monahan, A.H. and K.L. Denman, 2004. Impacts of atmospheric variability on a coupled upper-ocean/ecosystem model of the subarctic northeast Pacific. *Pacific Global Biogeochemical Cycles* 18(GB2010), doi: 10.1029/2003GB002100.

Moum, J., D. M. Farmer, W.D. Smyth, L. Armi and S. Vagle. 2003. Structure and generation of turbulence at interfaces strained by internal solitary waves propagating shoreward over the continental shelf. *Journal of Physical Oceanography* 33, 2093-2112.

Münchow, A., H. Melling and K.K. Falkner, 2006. An observational estimate of volume and freshwater flux leaving the Arctic Ocean through Nares Strait. *Journal of Physical Oceanography* 36, 2025-2041.

Mundy, C.J., C.G. Barber, C.M. Michel and R.F. Marsden, 2007. Linking ice structure and microscale variability of algal biomass in Arctic first-year sea ice using an in situ photographic technique", *Polar Biology* (accepted subject to revisions).

Myers, P.G., 2005. Impact of Freshwater From the Canadian Arctic Archipelago on Labrador Sea Water Formation *Geophysical Research Letters* 32, L06605, doi:10.1029/2004GL022082

Myers, P.G., S. Grey and K. Haines, 2005. A Diagnostic Study of Interpentadal Variability in the North Atlantic Ocean Using a Finite Element Model, *Ocean Modelling* 10, 69-81

Myers, P.G. and D. Deacu, 2004. Labrador Sea Freshwater Content in a Model with a Partial Cell Topographic Representation. *Ocean Modelling* 6, 359-377.

Newbigging, S.C., L.A. Mysak and W.W. Hsieh, 2003. Improvements to the Nonlinear Principal Component Analysis method, with applications to ENSO and QBO. *Atmos.-Ocean* 41(4), 291-299.

Newgard, J. and A. E. Hay, 2007. Turbulence intensity and friction in the wave bottom boundary layer under (mainly) flat bed conditions, *JGR Oceans*, 2006JC003881 (in press).

Ngusaru, A.S., and Hay, A.E., 2004. Cross-shore migration of lunate megaripples during Duck94. - *J. Geophys. Res. 109,* C02006, 16pp.

Oakey, N. S. and B. J. W. Greenan. 2004. Mixing in a coastal environment: 2. A view from microstructure measurements. *Journal of Geophysical Research - Oceans* 109, C10014, doi:10.1029/2003JC002193.

O'Brien, M.C., R.W. Macdonald, H. Melling and K. Iseki, 2005. Particle fluxes and geochemistry on the Canadian Beaufort Shelf: implications for sediment transport and deposition. *Continental Shelf Research* 26, 41-81. doi: 10.1019/j.csr.2005.09.007.

Overpeck, J.T., M. Sturm, J.A. Francis, D.K. Perovich, M.C. Serreze, R. Benner, E. Carmack, F.S. Chapin III, S.C. Gerlach, L.C. Hamilton, L.D. Hinzman, M. Holland, H.P. Huntington, J.R. Key, A.H. Lloyd, G.M. MacDonald, J. McFadden, D. Noone, T.D. Prowse, P. Schlosser and C. Vorosmarty, 2005. Arctic system on trajectory to new state. *EOS, Transactions, American Geophysical Union* 86(34), 309-316.

Panteleev, G.G., B. deYoung, M. Luneva, E.V. Semenov and C.S. Reiss, 2004. Modelling the circulation on the Scotian Shelf through sequential application of a variational algorithm and a non-linear-diagnostic model. *Journal of Geophysical Research* 109, 1-15.

Park, J. J., K. Kim, and W. R. Crawford, 2004, Inertial currents estimated from surface trajectories of ARGO floats, *Geophys. Res. Lett.* 31, L13307, doi:10.1029/2004GL020191.

Pellerin, P., H. Ritchie, F.J. Saucier, F. Roy, S. Desjardins, M. Valin, V. Lee**,** 2004. Impact of a two-way coupling between an atmospheric and an ocean-ice model over the Gulf of St. Lawrence. *Monthly Weather Rev*. 132(6): 1379-1398 .

Pena, M.A., 2003. Plankton size classes, functional groups and ecosystem dynamics: an introduction. *Progress in Oceanography* 57(3-4), 239-242.

Pena, M.A., 2003. Modelling the response of the planktonic food web to iron fertilization and warming in the NE Subarctic Pacific. *Progress in Oceanography* 57(3-4), 453-479.

Perrie, W., C.L. Tang, Y. Hu and B.M. DeTracey. 2003. The impact of waves on surface currents. *Journal of Physical Oceanography* 33, 2126-2141.

Perrie, W., X. Ren, W. Zhang, and Z. Long, 2004a. Simulation of extatropical Hurricane Gustav using a coupled atmosphere-ocean-sea spray model. *Geophys. Res. Lett*. 31, L03110, doi:1029/2003GL018571.

Perrie, W., W. Zhang, X. Ren, and Z. Long, 2004b. The impact of Hurricane Gustav on air-sea CO2 exchange. *Geophys. Res. Lett.* 31, L09300, doi:10.1029/2003GL019212.

Perrie, W., W. Zhang, X. Ren, Z. Long, and J. Hare, 2004c. The role of midlatitude storms on air-sea exchange of CO2. *Geophys. Res. Lett. 31*, L09306, doi:10.1029/2003GL019212, 2004.

Perrie, W., E. L. Andrews, W. Zhang, W. Li, J. Gyakum, and R. McTaggart-Cowan, 2005. Sea spray impacts on intensifying midlatitude cyclones. *J. Atmos. Sci*. 62, 1867-1883.

Perrie, W., W. Zhang, X. Ren, Z. Long and J. Hare. 2006. Midlatitude Storm Impacts on Air-Sea CO-2 Fluxes. *Atmosphere-Ocean Interactions*. 2, 143-154.

Peterson, I.K., S.J. Prinsenberg and J.S. Holladay, 2003. Sea-Ice thickness measurement: Recent experiments using helicopter-borne EM-Induction sensors. *Recent Res. Devel. Geophysics* 5, 1-20.

Peterson, T.D., F.A. Whitney and P.J. Harrison, 2005. Macronutrient dynamics in an anticyclonic mesoscale eddy in the Gulf of Alaska. *Deep-Sea Research II* 52(7-8), 909-932.

Petoukhov, V., M. Claussen, A. Berger, M. Crucifix, M. Eby, A. V. Eliseev, T. Fichefet, A. Ganopolski, H. Goosse, I. Kamenkovich, I. Mokhov, M. Montoya, L. A. Mysak, A. Sokolov, P. Stone, Z. Wang and A. Weaver, 2005. Climate Dynamics 25, 363-385, doi: 10.1007/s00382-005-0042-3.

Pinardi N., I. Allen, E. Demirov, P. DeMey, A. Lascaratos,G. Korres, P-Y. Le Traon, C. Maillard, G. Manzella, C. Tziavos, 2003. The Mediterranean ocean Forecasting System: first phase of implementation (1998-2001). *Annales Geophysicae* 21, 3-20.

Plourde, J., J.-C. Therriault, 2004. Climate variability and vertical advection of nitrates in the Gulf of St. Lawrence, Canada. *Mar. Ecol. Prog. Ser*. 279, 33-43 .

Polyakov, I. , D. Walsh, I. Dmitrenko, R. Colony, J. Hutchings, L. Timokhov, M. Johnson and E. Carmack, 2003. A long term circulation and water mass monitoring program for the Arctic Ocean. *EOS, Transaction of the American Geophysical Union* 84(30), 284-285.

Prinsenberg, S.J., 2003. Canadian Arctic Throughflow Study (CATS-BIO), a contribution to *ASOF-West. Report* to ASOB (J. Cooley), ACSYS-CLIC (E. Fharbach), SEARCH (J. Morison) and PERD CCIS POL (A. Clarke), 6 pp.

Prinsenberg, S.J. and I.K. Peterson, 2003. Comparing ice chart parameters against ice observations. *Proceedings of the 13th Int. Offshore and Polar Eng. Conf. (ISOPE-2003).* Honolulu, HI, USA. Vol. 1, 733-738.

Prinsenberg, S.J. and J. Hamilton, 2003. Oceanic Fluxes through Lancaster Sound of the Canadian Arctic Archipelago. *Arctic & Sub-Arctic Ocean Flux (ASOF) Newsletter* 2, 6 pp.

Prinsenberg, S., and J. Hamilton, 2004. The ocean fluxes through Lancaster Sound of the Canadian Archipelago. *Arctic/Subarctic Ocean Fluxes Newsletter* 2, 8-11.

Prinsenberg, S., and J. Hamilton, 2005. Monitoring the volume, freshwater and heat fluxes passing through Lancaster Sound in the Canadian Archipelago. *Atmosphere-Ocean* 43(1), 1-22.

Rabinovich, A.B. and R.E. Thomson, 2007. The 26 December 2004. Sumatra tsunami: Analysis of tide gauge data from the World Ocean. Part 1. Indian Ocean and South Africa. *Pure Appl. Geophys.* 164(2-3), 261-308.

Rabinovich, A.B., R.E. Thomson and F.E. Stephensen, 2006. The Sumatra tsunami of 26 December 2004 as observed in the North Pacific and North Atlantic Ocean. *Surveys in Geophysics* 27, doi: 10.10007/s10712-006-9000-9.

Rabinovich, A.B., R.E. Thomson, B.B. Bornhold, I.V. Fine and E.A. Kulikov, 2003. Numerical modelling of tsunamis generated by hypothetical landslides in the Strait of Georgia, British Columbia. *Pure Appl. Geophy.* 160, 1273-1313.

Rahmstorf, S., M. Crucifix, A. Ganopolski, H. Goosse, I. Kamenkovich, R. Knutti, G. Lohmann, B. Marsh, L.A. Mysak, Z. Wang, and A. Weaver, 2005. Thermohaline circulation hysteresis: a model intercomparison. *Geophysical Research Letters* 32, L23605, DOI: 10.1029/2005GL023655.

Rattan, S.S.P. and W.W. Hsieh, 2005. Complex-valued neural networks for nonlinear complex principal component analysis. *Neural Networks* 18, 61-69, DOI:10.1016/j.neunet.2004.08.002.

Ren, X., W. Perrie, Z. Long, J. Gyakum, and R. McTaggart-Cowan. 2004. On the atmosphere-ocean coupled dynamics of cyclones in mid-latitudes. *Mon. Weather Rev.* 132, 2432-2451.

Robinson, C.L.K., J. Gower and G. Borstad, 2004. Twenty years of satellite observations describing phytoplankton blooms in seas adjacent to Gwaii Haanas National Park Reserve, Canada. Canadian *Journal of Remote Sensing* 30(1), 36-43.

Robinson, C.L.K., J. Morrison and M. Foreman, 2005. Oceanographic connectivity among marine protected areas on the north coast of British Columbia, Canada. *Canadian Journal and Fisheries and Aquatic Sciences* 62, 1350-1362.

Ross, T., and R. Lueck , 2005. Estimating turbulent rates of dissipation from acoustic backscatter. - *Deep-Sea Research II* 52, 2353-2365.

Ross, T., C. Garrett and R. Lueck, 2004. On the turbulent co-spectrum of two scalars and its effect on acoustic scattering from oceanic turbulence. *J. Fluid Mech. 514*, 107-119.

Ross, T., and R. Lueck, 2003. Sound scattering from oceanic turbulence. *Geophys. Res. Lett. 30*, 1343, doi:10.1029/2002GL016733.

Ruddick, B.R., 2003a. Sounding out Ocean Fine Structure, *Science, Perspectives* 301, 772-773.

Ruddick, B.R., 2003b. Laboratory studies of interleaving, *Progress In Oceanography* 56 (3-4), 529-547.

Ruddick, B.R., and Anne E. Gargett, 2003. Oceanic double-infusion: introduction, *Progress in Oceanography* 56 (3-4), 381-393.

Ruddick B.R., and Oliver Kerr, 2003. Oceanic thermohaline intrusions: theory, *Progress in Oceanography* 56 (3-4), 483-497.

Ruddick, B.R., and K. Richards, 2003. Oceanic thermohaline intrusions: observations, *Progress In Oceanography* 56, (3-4), 499-527.

Samelson, R.M., T.A. Agnew, H. Melling and A. Münchow, 2006. Evidence for atmospheric control of sea-ice motion through Nares Strait. *Geophysical Research Letters* 33 (L02506). doi: 10.1029/2005GL025016.

Sathyendranath, S., T. Platt, B. Irwin, E. Horne, G.A. Borstad, V. Stuart, L. Payzant, H. Maas, P. Kepkay, W.K.W. Li, J. Spry and J.F.R. Gower, 2004. Multispectral remote sensing study of coastal waters off Vancouver Island. *International Journal of Remote Sensing* 25(5), 893-919.

Schwing, F.B., H.P. Batchelder, W.R. Crawford, N. Mantua, J. Overland, J.J. Polovina and J.-P.Zhao, 2005. Decadal-scale climate events. In: King, J. [Ed.]. *PICES Scientific Report 28. Report of the study group on fisheries and ecosystem responses to recent regime shifts.*

Saucier, F. J., F. Roy, D. Gilbert, P. Pellerin, and H. Ritchie, 2003. Modeling the formation and circulation processes of water masses and sea ice in the Gulf of St. Lawrence, Canada, *J. Geophys. Res.* 108(C8), 3269, doi:10.1029/2000JC000686.

Shen, H., W. Perrie and Y. He. 2006. A new hurricane wind retrieval algorithm for SAR images. *Geophysical Research Letters* 33, L21812, doi:10.1029/2006GL027087.

Shen, H., W. Perrie and Y. He. 2006. Correction to "A new hurricane wind retrieval algorithm for SAR images". *Geophysical Research Letters* 34, L01811, doi:10.1029/2006GL029089.

Sheng, J., R.J. Greatbatch, X. Zhai and L. Tang, 2005. A new two-way nesting technique based on the smoothed semi-prognostic method. - *Ocean Dynamics* 55, 162-177.

Sheng, J., X. Zhai and R.J. Greatbatch, 2006. Numerical study of the storm-induced circulation on the Scotian Shelf during Hurricane Juan using a nested-grid ocean model. - *Progress in Oceanography* 70, 233-254.

Shimada, K., F. McLaughlin, E. Carmack, A. Proshutinsky, S. Nishino and M. Itoh, 2004. Penetration of the 1990's warm temperature anomaly of Atlantic water in the Canada Basin. *Geophysical Research Letters* 31(20), 1-4.

Shimada, K., M. Itoh, S. Nishino, F. McLaughlin, E. Carmack and A. Proshutinsky, 2005. Halocline structure in the Canada Basin of the Arctic Ocean. *Geophysical Research Letters* 32, 1-5. doi: 10.1029/2004GL021358.

Shimada, K., T. Kamoshida, M. Itoh, S. Nishino, E. Carmack, F. McLaughlin, S. Zimmermann and A. Proshutinsky, 2006. Pacific ocean inflow: influence on catastrophic reduction of sea ice cover in the Arctic Ocean. *Geophysical Research Letters* 33 (L08605). doi: 10.1029/2005GL025624.

Sinha, B., and B. Topliss, 2006. A description of interdecadal time-scale propagating North Atlantic sea surface temperature anomalies and their effect on winter European climate, 1948-2002. *Journal of Climate* 19 (7), 1067-1079.

Sinclair, A.F., and W.R. Crawford, 2005. Incorporating an environmental stock recruitment relationship in the assessment of Pacific cod (Gadus macrocephalus), *Fisheries Oceanography* 14(2), 138-150.

Sinclair, A.F., Conway, K.W., and Crawford, W.R., 2005. Associations between bathymetric, geologic, and oceanographic features and the distribution of the British Columbia bottom trawl fishery, *ICES* CM 2005/L:25.

Smyth, C., and Hay, A.E., 2003. Near-bed turbulence and bottom friction during SandyDuck97. - *J. Geophys. Res. 108(C6),* 3197, doi:10.1029/2001JC00092, 28-1 - 28-14.

Sparnocchia S., N. Pinardi, E. Demirov, 2003. Multivariate empirical orthogonal function analysis of the upper thermocline structure of the Mediterranean Sea from observations and model simulations, *Annales Geophysicae* 21, 167 - 187.

Stacey, M.W., 2005. Review of the partition of tidal energy in five Canadian fjords. *Journal of Coastal Research* 21, 731-746.

Stacey, M.W. and S. Pond, 2005a. On deepwater renewals in Indian Arm, British Columbia: sensitivity to the production of turbulent kinetic energy caused by horizontal variations in the flow field. *J. Phys. Oceanogr*. 35, 897-901.

Stacey, M.W., S. Pond., 2005b. Energy fluxes due to the surface and internal tides in Knight Inlet, British Columbia. *J. Phys. Oceanogr*. 35, 2219-2227.

Stacey, M.W., J.A. Shore, D.G. Wright, K.R. Thompson, (Accepted *JGR-Oceans* Feb. 2006). Spectral nudging in an eddy permitting model of the northeast Pacific Ocean.

Stacey, M. W., J. Shore, D. G. Wright, and K. R. Thompson, 2006. Modeling events of sea-surface variability using spectral nudging in an eddy permitting model of the northeast Pacific Ocean, *J. Geophys. Res. 111*, C06037, doi:10.1029/2005JC003278.

Stein, R. and R.W. Macdonald, 2004a. Arctic Ocean organic carbon accumulation and its global significance. In: Stein, R. and Macdonald, R. W. [Eds.]. *The Arctic Ocean organic carbon cycle present and past* 8. Berlin - New York, Springer Publishing Company.

Stein, R. and R.W. Macdonald, 2004b. Organic and inorganic geochemical proxies used form organic carbon source identification in Arctic Ocean sediments. In: Stein, R. and Macdonald, R. W. [Eds.]. *The Arctic Ocean organic carbon cycle present and past* 1.4, 24-32. Berlin - New York, Springer Publishing Company.

Stein, R., C. Schubert, R.W. Macdonald, K. Fahl, H.R. Harvey and D. Weiel, 2004. The central Arctic Ocean: distribution, sources, variability and burial of organic carbon. In: Stein, R. and Macdonald, R. W. [Eds.]. *The Arctic Ocean organic carbon cycle present and past.* 7.9. Berlin - New York, Springer Publishing Company.

Steiner, N., G. Holloway and T. Sou, 2003. Estimation of Arctic windspeeds and stresses with impacts on ocean-ice snow modeling. *Journal of Marine Systems* 39, 129-151

Steiner, N., G. Holloway, R. Gerdes, S. Hakkinen, D. Holland, M. Karcher, F. Kauker, W. Maslowski, A. Proshutinsky, M. Steele and J. Zhang, 2004. Comparing modeled streamfunction, heat and freshwater content in the Arctic Ocean. *Ocean Modelling* 6, 265-284.

Stemmann L., Jackson G. A. and Ianson, D. 2004. A vertical model of particle size distributions and fluxes in the midwater column that includes biological and physical processes - Part I: model formulation. *Deep Sea Research I* 51, 865-884.

Steiner, N., K.L. Denman, N. McFarlane and L. Solheim, 2006. Simulating the coupling between atmosphere-ocean processes and the planktonic ecosystem during SERIES. *Deep-Sea Research II* 53, 2334-2454.

Stern, G.A. and R.W. Macdonald, 2005. Biogeographic provinces of Hg in the Beaufort and Chukchi Seas: Results from the SHEBA drift. *Environmental Science & Technology* 39(13), 4707-4713.

Stramma, L., D. Kieke, M. Rhein, F. Schott, I. Yashayaev and K.P. Koltermann, 2004. Deep Water changes at the western boundary of the subpolar North Atlantic during 1996 to 2001, *Deep-Sea Res. I* 51 (8), 1033-1056.

Stucchi, D., R.F. Henry and M.G.G. Foreman, 2005a. Modelling the transport and dispersion of IHN pathogens in the Broughton Archipelago, British Columbia. *Bulletin of the Aquaculture Association of Canada* 105-1, 52-59.

Stucchi, D., T. Sutherland, C. Levings and D.A. Higgs, 2005b. Near-field depositional model for finfish aquaculture waste. *The handbook of environmental chemistry*. 5(M). Environmental Effects of Marine Finfish Aquaculture (8). New York, Springer, Berlin Heidelberg.

Sundermeyer, M.A., J.R. Ledwell, N.S. Oakey and B.J.W. Greenan. 2005. Stirring by small-scale vortices caused by patchy mixing. *J. Phys. Oceanogr*. 35, 1245-1262.

Sutherland, B.R., 2006a. Weakly Nonlinear Internal Gravity Wavepackets, *J. Fluid Mech.* 569, 249-258.

Sutherland, B.R., 2006b. Internal Wave Instability: Wave-Wave Vs Wave-Induced Mean Flow Interactions, *Phys. Fluids* 18 Art. No. 074107.

Sutherland, B. R., M. R. Flynn and K. Dohan, 2004. Internal Wave Excitation from a Collapsed Mixed Region, *Deep-Sea Res. II* 51, 2889-2904.

Sutherland, B. R., P. J. Kyba and M. R. Flynn, 2004. Intrusive Gravity Currents in Two-layer Fluids, *J. Fluid Mech.* 514, pp 327-353.

Sutherland, B. R., and K. Yewchuk, 2004. Internal Wave Tunnelling, *J. Fluid Mech.* 511, 125-134.

Sutherland, B. R., J. Nault, K. Yewchuk and G. E. Swaters, 2004. Rotating Dense Currents on a Slope. Part I: Stability., *J. Fluid Mech.* 508, 241-264.

Sutherland, G., C. Garrett and M. Foreman, 2005. Tidal resonance in Juan de Fuca Strait and the Strait of Georgia. *Journal of Physical Oceanography* 35(7), 1279-1286.

Sutherland, G., M. Foreman and C. Garrett, 2006. Tidal current energy assessment for Johnstone Strait, Vancouver Island. *Journal of Power and Energy* 221, doi: 10.1243/09576509JPE338.

Suthers, I. M., C. T. Taggart, D. E. Kelley, D. Rissik, and J.H. Middleton, 2004. Entrainment and advection in an island's tidal wake, as revealed by light attenuance, zooplankton and ichthyoplankton. *Limn. Oceanogr*. 49, 283–296.

Swaters, G. E., 2006a. The meridional flow of source-driven abyssal currents in a stratified basin with topography. Part I. Model development and dynamical properties. *J. Phys. Oceanogr.* 36, 335-355.

Swaters, G. E., 2006b. The meridional flow of source-driven abyssal currents in a stratified basin with topography. Part II. Numerical simulation. *J. Phys. Oceanogr.* 36, 356-375.

Swaters, G. E., 2006c. On the frictional destabilization of abyssal overflows dynamically coupled to internal gravity waves. *Geophys. Astrophys. Fluid Dynamics* 100, 1-24.

Swaters, G. E., 2004. Spectral properties in modon stability theory. *Stud. Appl. Math.* 112**,** 235-258.

Swaters, G. E., 2003. Baroclinic characteristics of frictionally destabilized abyssal overflows. *J. Fluid Mech.* 489**,** 349-379.

Tang, Y. and W.W. Hsieh, 2003. Nonlinear modes of decadal and interannual variability of the subsurface thermal structure in the Pacific Ocean. *J. Geophys. Res*. 108(C3), 3084, DOI: 10.1029/2001JC001236

Thompson, K.R., D.G. Wright, Y. Lu and E. Demirov, 2006. A simple method for reducing seasonal bias and drift in eddy resolving ocean models. *Ocean Modelling* 13, 109-125. doi:10.1016/j.ocemod.2005.11.003. (Erratum in *Ocean Modelling*, 14, 122-138. doi:10.1016/j.ocemod.2006.06.001).

Thompson, K.R., J. Sheng, P.C. Smith and L. Cong, 2003. Prediction of Surface Currents and Drifter Trajectories on the Inner Scotian Shelf. - *J. Geophys. Res. 108, No. C9*, 3287.

Thomson, R.E. and I.V. Fine. 2003. Estimating mixed layer depth from oceanic profile data. *J. Atmos. Oceanic Tech.* 20, 319-329.

Thomson, R.E., M.M. Subbotina and M.V. Anisimov, 2005. Numerical simulation of hydrothermal vent-induced circulation at Endeavour Ridge. *Journal of Geophysical Research.* 110, 1-14. doi:10.1029/2004JC002337, C01004.

Thomson, R.E., S. F. Mihaly, A.B. Rabinovich, R.E. McDuff, S. R. Veirs and F.R. Stahr, 2003. Constrained circulation at Endeavour ridge facilitates colonization by vent larvae. *Nature* 424, 545-549.

Thorpe, S.A., T. R. Osborn, D.M. Farmer and S. Vagle. 2003. Bubble clouds and Langmuir circulation: observations and models. *J. Phys. Oceanogr*. 33, 122-145.

Timmermans, M.L., H. Melling, L. Rainville, 2007. Dynamics in the Deep Canada Basin, Arctic Ocean, Inferred by Thermistor Chain Time Series, *Journal of Physical Oceanography* 37(4), 1066-1076.

Timothy, D.A., C.S. Wong, Y. Nojiri, D. Ianson and F.A. Whitney, 2005. The effects of patch expansion on budgets for C, N, and Si for the Subarctic Ecological Response to Iron Enrichment Study (SERIES). *Deep-Sea Research II* 53(20-22), 2034-2052.

Titov, V., A.B. Rabinovich, H.O. Mofjeld, R.E. Thomson and F.I. Gonzalez, 2006. The global reach of the 26 December 2004 Sumatra tsunami. *Science* 309, 2045-2048. doi: 10.1126/science/1114576.

Tsurumi, M., D. Mackas, F.A. Whitney, C. DiBacco, M. Galbraith and C.S. Wong, 2005. Pteropods, eddies, carbon flux, and climate variability in the Alaska Gyre. *Deep-Sea Research II* 52(7-8), 1037-1054.

Vagle, S., P. Chandler and D.M. Farmer. 2005. On the dense bubble clouds and near bottom turbulence in the surf zone. *Journal of Geophysical Research - Oceans* 110(C09018). doi:10.1029/2004JC002603.

Van der Baaren A., B. Petrie and S.J. Prinsenberg, 2003. Low-frequency variability in Lancaster Sound. *Canadian Technical Report of Hydrography and Ocean Sciences* 223, xii + 124 p.

Wang, J., M. Ikeda and J.F. Saucier, 2003. A theoretical, two-layer, reduced-gravity model for descending dense water flow on continental shelves/slopes. *J. Geophys. Res.- Oceans* 108(C85), 3161-3179 .

Whitney, F.A., W.R. Crawford and P.J. Harrison, 2005a. Physical processes that enhance nutrient transport and primary productivity in the coastal and open ocean of the subarctic NE Pacific. *Deep-Sea Research II* 52, 681-706.

Whitney, F.A., D.W. Crawford and T. Yoshimura, 2005b. The uptake and export of silicon and nitrogen in HNLC waters of the NE Pacific Ocean. *Deep-Sea Research II* 52, 1055-1067. doi:10.1016.j.dsr2.2005.02.006.

Whitney, F.A., K. Conway, R.E. Thomson, V. Barrie, M. Krautter and G. Mungov, 2005c. Oceanographic habitat of sponge reefs on the Western Canadian Continental Shelf. *Continental Shelf Research* 25, 211-226.

Williams, W., E. Carmack, K. Shimada, H. Melling, K. Aagaard, R. Macdonald and R.G. Ingram, 2006. Joint effects of wind and ice motion in forcing upwelling in Mackenzie Trough, Beaufort Sea. *Continental Shelf Research* 26, 2352-2366.

Wong, C.S., S.E. Wong, W.A. Richardson, G.E. Smith, M.D. Arychuk and J.S. Page, 2004. Temporal and spatial distribution of dimethylsulfide in the sub-arctic North East Pacific Ocean: A high nutrient-low chlorophyll region. *Tellus* 57B, 1-15.

Wright, D.G., K.R. Thompson and Y. Lu, 2006. Assimilating long-term hydrographic information into an eddy-permitting model of the North Atlantic. *Journal of Geophysical Research* 111, C09022, doi:10.1029/2005JC003200.

Wright, D.G., and Z. Xu, 2004. The Double Kelvin Wave and its relation to Continental Shelf Waves. *Atmos.-Ocean* 42, 101-111.

Wu, A., W.W. Hsieh and B. Tang, 2006a. Neural Network forecasts of the tropical Pacific sea surface temperatures. Neural Networks. 19: 145-154.

Wu, A., W.W. Hsieh, A. Shabbar, G.J. Boer and F.W. Zwiers, 2006b. The nonlinear association between the Arctic Oscillation and North American winter climate. *Clim. Dynam*. 26, 865-879. DOI: 10.1007/s00382-006-0118-8.

Wu, A., W.W. Hsieh and A. Shabbar, 2005. The nonlinear patterns of North American winter temperature and precipitation associated with ENSO. *J. Climate* 18, 1736-1752. doi: 10.1175/JCLI3372.1

Wu, A. and W.W. Hsieh, 2003. Nonlinear interdecadal changes of the El Nino-Southern Oscillation. *Clim. Dynam*. 21, 719-730. DOI 10.1007/s00382-003-0361-1.

Wu, A., W.W. Hsieh, and F.W. Zwiers, 2003. Nonlinear modes of North American winter climate variability detected from a general circulation model. *J.Climate* 16(14), 2325-2339.

Xu, Z., and J.W. Loder, 2004. Data assimilation and horizontal structure of the barotropic diurnal tides on the Newfoundland and southern Labrador Shelves. *Atmos.-Ocean* 42(1), 43-60.

Yao, T. and C.L. Tang, 2003. The formation and maintenance of the North Water Polynya. *Atmosphere-Ocean* 41, 187-201.

Yamamoto-Kawai, M., E. Carmack and F. McLaughlin, 2006. Brief communications: Nitrogen balance and Arctic throughflow. *Nature* 443, doi: 10.1038/443043a.

Yasuda, I., S. Osafune, H. Tatebe, 2006. Possible explanation linking 18.6-year period nodal cycle with bi-decadal variations of ocean climate in the North Pacific. Geophys. Res. Lett. 33, L08606, doi:10.1029/2005GL025237.

Ye, Z. and W.W. Hsieh, 2006. The influence of climate regime shift on ENSO. *Clim. Dynam*. 26, 823-833. DOI: 10.1007/s00382-005-0105-5.

Yelland, D. and W.R. Crawford, 2005. Currents in Haida Eddies. Topical Studies in Oceanography: Haida Eddies: mesoscale transport in the Northeast Pacific. *Deep-Sea Research II* 52(7-8), 875-892, doi: 10.1016j.dsr2.2005.02.010..

Zakardjian B.A., J. Sheng, J.A. Runge, I. McLaren, S. Plourde, K.R. Thompson, Y. Gratton, 2003. Effects of temperature and circulation on the population dynamics of *Calanus finmarchicus* in the Gulf of St. Lawrence and Scotian Shelf: Study with a coupled, three-dimensional hydrodynamic, stage-based life history model. *Journal of Geophysical Research-Oceans* 108, 8016, DOI:10.1029/2002JC001410.

Zamon, J.E. and D.W. Welch, 2005. Rapid shift in zooplankton community composition on the northeast Pacific shelf during the 1998-1999 El Nino - La Nina event. *Canadian Journal and Fisheries and Aquatic Sciences* 62, 133-144.

Zhai, X., R. J. Greatbatch, and J. Sheng, 2004a. Diagnosing the role of eddies in driving the circulation of the northwest Atlantic Ocean, *Geophys. Res. Lett. 31*, L23304, doi:10.1029/2004GL021146.

Zhai, X., R. J. Greatbatch, and J. Sheng, 2004b. Advective spreading of storm-induced inertial oscillations in a model of the northwest Atlantic Ocean, *Geophys. Res. Lett.* 31, L14315, doi:10.1029/2004GL020084.

Zhai, X., R. J. Greatbatch, and J. Zhao, 2005. Enhanced vertical propagation of storm-induced near-inertial energy in an eddying ocean channel model, *Geophys. Res. Lett.* 32, L18602, doi:10.1029/2005GL023643.

Zhai, X., and R. J. Greatbatch, 2006a. Inferring the eddy-induced diffusivity for heat in the surface mixed layer using satellite data, *Geophys. Res. Lett.* 33, L24607, doi:10.1029/2006GL027875.

Zhai, X., and R. J. Greatbatch, 2006b. Surface eddy diffusivity for heat in a model of the northwest Atlantic Ocean, *Geophys. Res. Lett.* 33, L24611, doi:10.1029/2006GL028712.

Zhai, X., and R. J. Greatbatch, 2007. Wind work in a model of the northwest Atlantic Ocean, *Geophys. Res. Lett.* 34, L04606, doi:10.1029/2006GL028907.

Zhang, S., J. Sheng, and R. J. Greatbatch, 2004. A coupled ice-ocean modeling study of the northwest Atlantic Ocean, *J. Geophys. Res.* 109, C04009, doi:10.1029/2003JC001924.

Zhang, W., W. Perrie and W. Li. 2006a. Impacts of waves and sea spray on mid-latitude storm structure and intensity. *Mon. Wea. Rev*. 134, 2418-2442.

Zhang, W., W. Perrie and S. Vagle. 2006b. Impacts of Winter Storms on Air-Sea Gas Exchange. *Geophys. Res. Lett*. 33, L14803, doi:10.1029/2005GL025257.

Zhao, J., J. Sheng, R.J. Greatbatch, K. Azetsu-Scott and E. P. Jones. 2006. Simulation of CFCs in the North Atlantic Ocean using an adiabatically-corrected ocean circulation model. *J. Geophys. Res*. 111, C06027, doi:10.1029/2004JC002814.

Zou, Q.-P., Hay, A.E., Bowen, A.J., 2003. Vertical structure of surface gravity waves propagating over a sloping sea bed: theory and field measurements. *J. Geophys. Res.* 108 (8), 3265, 10.1029/2002JC001432, 21-1 - 21-15.

Zou, Q.-P., and Hay, A.E., 2003. The vertical structure of the wave bottom boundary layer over a sloping bed: Theory and field measurements. *J. Phys. Ocean.* 33, 1380-1400.

Internet Sites: Academic Oceanographic Research:

These academic organizations are spread among a wide variety of university departments, such as Physics, Earth and Ocean Sciences, and Meteorology & Oceanography. Only occasionally is Oceanography a department itself. This wide distribution is an indication of the varied affiliations that physical oceanographers have formed over the past century of research.

Université Laval
http://www.quebec-ocean.ulaval.ca/

University of Alberta
http://easweb.eas.ualberta.ca/
http://www.math.ualberta.ca/

Université du Québec à Rimouski
http://www.pqm.net/ismer/index.html

McGill University
http://www.mcgill.ca/meteo/

Memorial University
http://www.physics.mun.ca/Ocean/

University of British Columbia
http://www.eos.ubc.ca/

Dalhousie University
http://oceanography.dal.ca/index.html

Royal Military College
http://www.rmc.ca/academic/physics/index_e.html

Internet Sites: Fisheries and Oceans Canada

Fisheries and Oceans Canada hosts the main government physical oceanographic research centres in Canada, at locations spread across the country.
A general listing of all centres is at the following internet site
http://www.dfo-mpo.gc.ca/science/Facilities/facilities_e.htm

Listed below are Internet links to some of these labs with research activities in physical oceanography.

Pacific Region
Institute of Ocean Sciences, BC
http://www-sci.pac.dfo-mpo.gc.ca/sci/facilities/ios_e.htm

Central and Arctic Region
http://www.dfo-mpo.gc.ca/regions/central/science/index_e.htm

Quebec Region
Maurice Lamontagne Institute, PQ
http://www.qc.dfo-mpo.gc.ca/iml/en/intro.htm
http://www.osl.gc.ca/

Maritimes Region
Bedford Institute of Oceanography, NS
http://www.bio.gc.ca/
http://www.mar.dfo-mpo.gc.ca/science/ocean/home.html

Gulf Region
http://www.glf.dfo-mpo.gc.ca/sr-sc/index-e.html

Newfoundland Region
http://www.nfl.dfo-mpo.gc.ca/home_accueil.asp?Lang=English

Access to real-time and archived oceanographic observations over the Internet has continued to increase since the last IASPO review. A rich collection of oceanographic data and products are provided by a number of research institutes and government agencies, in both English and French, specifically;

Marine Environmental Data Service (MEDS)
http://www.meds-sdmm.dfo-mpo.gc.ca/

Bedford Institute of Oceanography (BIO)
http://www.mar.dfo-mpo.gc.ca/science/ocean/home.html

L'Observatoire du Saint-Laurent (OSL)
http://www.osl.gc.ca/

Institute of Ocean Sciences (IOS)
http://www-sci.pac.dfo-mpo.gc.ca/osap/data/default_e.htm
http://www-sci.pac.dfo-mpo.gc.ca/osap/data/default_f.htm

Topics covered by one of more of the locations cited include ocean contaminants, real time oceanographic observations and archival data from moored and drifting buoys, archived observations of ocean profiles and currents, tides and water levels, including tidal and drift prediction models, monitoring of oceanography, biology and ocean chemistry, ocean forecast models of sea ice, ocean currents, waves and water levels, thermosalinograph observations from research vessels and commercial shipping, coastal temperature from moored thermographs, and remote sensing of sea-surface temperature and ocean color.

Fisheries and Oceans Canada has recently established the Centre for Ocean Model Development and Application (COMDA). The mandate of COMDA is to provide national leadership, coordination and advice in areas of ocean model development and application that are departmental priorities. COMDA is hosted by DFO Maritimes Region at the Bedford Institute of Oceanography, but includes participants from DFO research labs in all regions and collaborative projects with other agencies and organizations. More information can be found at:
http://www.mar.dfo-mpo.gc.ca/science/ocean/comda/comda-e.html
http://www.mar.dfo-mpo.gc.ca/science/ocean/comda/comda-f.html

Universities have become active in providing real-time access to data from ocean observatories which serve a testbeds for instrument and computer model development.
Centre for Marine Environmental Prediction (CMEP)

Dalhousie University
http://cmep.ca

Victoria Experimental Network Under the Sea (VENUS)
University of Victoria
http://www.venus.uvic.ca/

Bonne Bay Observatory
Memorial University
http://bbo.physics.mun.ca/background/