C-DOGS 2015

Conference of Dalhousie Oceanography Graduate Students

Friday March 20, 2015
8:30 - 17:00, University Hall
Dalhousie University, Halifax, Nova Scotia

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Dust flux in the Eastern Equatorial Pacific over the last 30 ka: A tale told by two proxies.

Diksha Bista[1], Stephanie Kienast[1], Paul Hill[1], Markus Kienast[1]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at diksha.bista@dal.ca

Atmospheric dust is an important component in the global climate system, changing the radiative balance and composition of the atmosphere as well as affecting marine and terrestrial biogeochemical cycles. This talk will present dust fluxes over the last 30 ka derived from two different proxies from sediment cores collected in the Eastern Equatorial Pacific.

The first, and increasingly used method for reconstructing dust flux in the ocean is based on thorium-232 measurements. ^{232}Th is a primordial isotope and is significantly enriched in continental crust compared with oceanic crust and mid ocean ridge basalts. Because of this, ^{232}Th, in conjunction with ^{230}Th normalization, is useful, particularly in regions where there are no other significant terrigenic inputs. The second method uses Disaggregated Inorganic Grain Size (DIGS) distributions to derive dust flux. Long-range atmospheric dust shows a modal peak between 1- 5 μm in its grain size distribution. End member modeling was used to isolate this wind-derived input from the total sediment inventory. Together with ^{230}Th normalization, dust fluxes can thus be reconstructed independently of ^{232}Th. Both methods suggest that dust fluxes in this region were actually highest in the glacial-interglacial transition, rather than during the full glacial period, as previously observed. The relevance of this study in regional as well as the global climate system will be discussed during the talk.

Assessing the decline of Atlantic salmon with an optimized matrix model.

Rui Zhang[1] , Katja Fennel[1]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at Rui.Zhang@Dal.Ca

North American Atlantic salmon populations experienced a dramatic decline in the early 1990s and have persisted at a low abundance since then. Changes in climate patterns and multiple ecosystem conditions have likely contributed to this decline. In this study, we used an age-structured Leslie matrix population model to examine variations of Atlantic salmon abundance from 1971 to 2011. We used estimated abundances from the 2014 ICES Report of the Working Group on North Atlantic Salmon to optimize the model, and applied the model to short time segments, which greatly improved the model performance and produced temporal parameter variations. Sensitivity testing identified the four most important parameters, which are mortality of first year salmon in the river, mortality of second year salmon in the river, mortality during the smoltification year and mortality during the first year at sea. The temporal parameter variation inferred from the model indicates that mortality of the first year at sea age group played a key role in the population decrease.

Hurricane Arthur and its effect on the short term variability of pCO2.

Jonathan Lemay[1] , Helmuth Thomas[1]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at jcl.lemay@gmail.com

For the last several years pCO2 data has been collected offshore using a moored CARIOCA buoy on the Nova Scotian Shelf. From this data seasonal effects of pCO2 have been well studied. However, short term effects on pCO2 are not as well constrained. I have focused on developing an understanding of short term variability in pCO2 throughout the year, and the variables that cause them. Wind speed has been found to have a significant anti-correlation with pCO2 on the Scotian Shelf region. From this anti-correlation I looked into storm events and their effect on pCO2. Recently I have focused on Hurricane Arthur and its disruption of pCO2 cycling. Preliminary results show that Hurricane Arthur caused a micro bloom in its wake, causing a significant draw down of pCO2.

Song sharing and diversity in the Bering-Chukchi-Beaufort population of bowhead whales (*Balaena mysticetus*), spring 2011.

Hansen Johnson[1] , Kate Stafford[2] , Craig George[3] , Will Ambrose[4] , Chris Clark[5]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2
[2]Applied Physics Laboratory, University of Washington, Seattle, Washington 98105, U.S.A.
[3]Department of Wildlife Management, North Slope Borough, Barrow, Alaska 99723, U.S.A.
[4]Department of Biology, Bates College, Lewiston, Maine 04240, U.S.A.
[5]Cornell Laboratory of Ornithology, Cornell University, Ithaca, New York 14853, U.S.A.

Speaker may be reached at hansen.johnson@dal.ca

Bowhead whales (*Balaena mysticetus*) of the Bering-Chukchi-Beaufort population migrate in nearshore leads through the Chukchi Sea each spring to summering grounds in the Beaufort Sea. As part of a population abundance study, hydrophones were deployed in the Chukchi Sea off Point Barrow, (12 April to 27 May 2011) and in the Beaufort Sea (12 April to 30 June 2011). Data from these sites were analyzed for the presence of bowhead whale song. We identified 12 unique song types sung by at least 32 individuals during 95 h of recordings off Point Barrow. Six of these songs were detected at the Beaufort MARU site as well as six additional song types that were not analyzed. These results suggest a shared song repertoire among some individuals. This report represents the greatest number of songs to date during the spring migration for this population. We attribute this greater variety to population growth over the 30 yr since acoustic monitoring began in the early 1980s. Singing during early to mid-spring is consistent with the hypothesis that song is a reproductive display, but further research is necessary to understand the exact function of this complex vocal behavior.

Examination of Particle Tracking Techniques with Applications on the Scotian Shelf

Erica Rogers[1]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at ericarogers44@gmail.com

The complexity of ocean circulation makes it difficult to predict where objects may have originated from, and where they might go. Many practical applications such as Search and Rescue operations, prediction of the movement of biological organisms (e.g., rock lobster larvae), and mine origin resolution, all require the Lagrangian approach. Similarly, many scientific applications such as estimating the mean exchange between ocean basins, and mixing between the surface and deep basins, are sometimes tackled more effectively using the Lagrangian approach. One method of answering where objects come from and where they go to involves tracking particle movements by integrating a stochastic differential equation, either through the use of discrete time or discrete space. These methods of particle tracking are explored through the examination of two existing particle trackers: Ariane and LEEWAY. Both models are applied and evaluated on the Scotian Shelf.

Schlieren Affects the LISST-100 Instrument Measurements in the Columbia River Estuary

Jing Tao[1] , Paul Hill[1] , Emmanuel Boss[2] , Timothy Milligan[3]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2
[2]School of Marine Science, University of Maine, Orono, Maine, USA, 04469
[3]Bedford Institute of Oceanography, Dartmouth, NS, Canada, B2Y 4A2

Speaker may be reached at jing.tao@dal.ca

The high-stratified Columbia River Estuary (CRE) is strongly affected by large tidal currents, strong winds and seasonally varying river discharge, which influences the sediment dynamics and transport. Optical instruments that measure light scattering and transmission in situ have been widely used to understand suspended particle characteristics in environments like the CRE. In particular, the LISST-100 (Laser In Situ Scattering and Transmissometry; Sequoia Scientific, Inc.) is an in-water instrument designed to measure Particle Size Distributions (PSD) and beam attenuation at 670 nm in the field. In pycnoclines, the density differences can cause light scattering (schlieren), which produces an increase in beam attenuation that is independent of particle properties. Schlieren also affects PSDs derived from LISST. When the 1-m-bin-averaged buoyancy frequency, N, exceeds 0.05 s^{-1} in the CRE, inaccurate estimates of particle beam attenuation (c_p) and the PSD are observed. This critical value of N depends on the size of the depth bin chosen for averaging. The schlieren do not affect the c_p and b_{bp} (backscattering coefficient of particles) derived from WetLabs ac-9 and bb2fl. The WetLabs instrument has a larger acceptance angle than the LISST and water passes through a pump before reaching the sensing volume, which destroys the schlieren by mixing the water. Backscattered light is not affected strongly by schlieren. The c_p derived from LISST and ac-9 and b_{bp} correlate well with SPM (suspended particulate mass concentration) and TAC (total area concentration) after elimination all inaccurate estimates of c_p.

Modeling inorganic carbon in the northwestern North Atlantic

Krysten Rutherford[1] , Katja Fennel[1] , Helmuth Thomas[1] , Kumiko Azetsu-Scott[2]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2
[2]Bedford Institute of Oceanography, Dartmouth, NS, Canada, B2Y 4A2

Speaker may be reached at krys.eliz.ru@gmail.com

There is some controversy surrounding the air-sea flux of CO_2 on the Scotian Shelf, located just off the coast of Nova Scotia, with contradicting studies claiming that the Scotian Shelf is a source and others claiming it is a sink of CO_2. For example, both Laruelle et al. (2014) and Signorini et al. (2013) represent the Scotian Shelf as being an overall sink of CO_2. Conversely, there are many regional studies, for example Shadwick et al. (2011), that have reported that the Scotian Shelf is actually a net source of CO_2. The goal of this research is to determine, with the help of a biogeochemical model, what factors are influencing the transport and transformation of inorganic carbon and the air-sea flux of CO_2 on the Scotian Shelf. Specifically, we will focus on how the combination of dramatically different water masses (i.e., the warm and salty Gulf Stream vs. the cool and fresh Labrador Current) off the coast of Nova Scotia are creating a source of CO_2 to the atmosphere when most shelf regions are sinks of CO_2. As part of the process, we have established various property-property relationships to find the optimal relationships for initialization of Total Inorganic Carbon (TIC) and Total Alkalinity (TA) in the model. These relationships were created based on data from several sources, including: extensive Scotian Shelf data from the Atlantic Zone Monitoring Program (AZMP), Gulf of St. Lawrence data from McGill University and supplementary data from the Global Ocean Data Analysis Project (GLODAP) and the Carbon Dioxide Information Analysis Center (CDIAC) databases. With these data, TIC was expressed as a function of temperature and salinity, and TA was expressed as a linear function of salinity, both with strong coefficients of determination. We will soon be moving towards analyzing how these relationships are performing in the model and how the properties of the different water masses are creating a source of CO_2 on the Scotian Shelf.

Mixed sediment beaches: cusps and edge waves.

Tristan Guest[1]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at tristan.guest@dal.ca

Mixed sand and gravel (MSG) beaches are common on previously glaciated shorelines in the mid- to high-latitudes. Noted to be morphologically distinct from sandy beaches, gravel and MSG beaches have seen increasing consideration as effective and natural coastline defences, yet their sediment transport dynamics remain poorly understood. Beach cusps are common features on coarse- and mixed-grained beaches. Their formation, in some cases, makes up a significant component of the beach face response to incident wave forcing, and thus may provide an interesting avenue for enhancing knowledge of mixed beach sediment dynamics. Despite their ubiquity and the wide scale of features they encompass, there is still considerable debate surrounding the beach cusp formation mechanism(s). Presently relevant theories hinge upon either the presence of standing subharmonic or synchronous edge waves, or self-organizational processes involving positive feedbacks between hydrodynamics, morphology, and sediment properties. Some methods to be applied in a future study planned for Advocate Beach, Nova Scotia – a steep MSG beach on the Bay of Fundy – will be outlined, with particular focus on identifying edge wave motions using an array of buried pressure sensors.

Modelling the Nitrogen Cycle in Bedford Basin

Jonathan Izett[1] , Tim Kalvelage[1,2] , Katja Fennel[1] , Doug Wallace[1]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2
[2]Department of Environmental Systems Science, Aquatic Chemistry Group, ETH Zurich, Rämistrasse 101, 8092 Zürich, Switzerland

Speaker may be reached at jonathan.izett@dal.ca

The nitrogen cycle is one of the key marine biogeochemical cycles. Understanding the sources, sinks, and transformations of bioavailable oceanic nitrogen—including N_2 fixation and denitrification—is becoming increasingly important in a changing climate. The ^{14}N and heavier ^{15}N isotopic forms of nitrogen are useful in monitoring the nitrogen cycle as their ratio (^{15}N:^{14}N; commonly expressed as$\delta^{15}N$) within different nitrogen pools is mediated by the processes involved in converting nitrogen between its various forms. For example, nitrogen uptake by phytoplankton has been shown to favour lighter N-isotopes, thereby enriching the remaining DIN pool in ^{15}N (increasing $\delta^{15}N$ values). Currently, however, these fractionation values are poorly constrained in lab and field tests. To explore these fractionation processes in greater detail, and to better constrain the rates of transformation from one nitrogen pool to another, a numerical model of the nitrogen cycle within Bedford Basin (Halifax, NS, Canada) is being constructed as part of my MSc research. My work will be performed in conjunction with, and validated against a time-series of water column data collected from Bedford Basin (including temperature, salinity, nutrients, and recently collected N-isotope data). The model is a variation of an NPZD model, with pools of inorganic and dissolved organic nitrogen, phytoplankton, zooplankton, and detritus coupled to a vertically resolved physical water column model of the Basin. Inorganic nitrogen is split into three different pools (ammonium, nitrite, and nitrate). Oxygen is also parameterized within the model and regulates the chemical speciation of nitrogen. An overview of the model construction will be presented, along with a discussion of the available observations. Future steps of model development, including optimization of the model against available data from the Basin, and expected progress and results, will be outlined.

Ambient Noise in High Flow Tidal Channels, with Application to Tidal In-Stream Energy Conversion.

Anne Lombardi[1] , Alex Hay[1] , Greg Trowse[2]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2
[2]Fundy Tidal Inc., Westport, NS, Canada, B0V 1H0

Speaker may be reached at anne.lombardi@dal.ca

The marine environment in many high flow tidal channels, while very suitable for tidal energy, presents challenges for passive acoustic monitoring (PAM) of marine mammals: Strong flows can create high levels of sediment generated noise (SGN) from bedload movement; shallow, narrow channel geometry can constrain sound propagation and thus decrease detection range; and turbulent pressure fluctuations across the hydrophone can produce pseudo-noise that contaminates noise measurements. Additionally, the rotating motion of tidal turbines generates a noise footprint that could change or disrupt the ambient background noise, the implications of which are difficult to predict. A thorough understanding of the natural noise environment is crucial for the implementation of effective PAM programs, to mitigate the potential impacts of tidal energy on marine mammals. This research aims to characterize ambient noise in Grand Passage, Nova Scotia, prior to turbine installation, to maximize the probability of detection of marine mammals and to examine the acoustic impact of turbine operation. In this talk, I will present an initial analysis of sound levels from two long-term moored hydrophone deployments in Grand Passage and discuss planned methodologies for illustrating the soundscape of this unique environment.

Multi-scale simulation of sediment biogeochemical cycles in coastal areas: implications on ecosystem functioning and provision of benthic ecosystem services.

Francisco Bravo[1] , Jon Grant[1]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at francisco.bravo@dal.ca

Spatially-explicit models that consider the distribution of seascape features and driving forces have become a valuable tool to evaluate the variability of ecosystem processes and functions among different habitat types, and at spatial scales where the coverage of biogeochemical measurements is limited. Their application to ecosystem-scale assessments of benthic metabolism has gained increasing attention during recent years. One suitable framework to evaluate benthic ecosystem processes may include the integration of sediment diagenesis models, empirical parameterization, and benthic habitat mapping. This approach allows considering, among others, habitat-specificity, physical forcing, and human pressures. In this presentation we describe the current state and structure of spatially-explicit models of sediment geochemistry in coastal areas. Applications include (1) the comparative assessment of benthic fluxes among different habitat types and/or sedimentary environment, (2) the bay-scale evaluation of C and N recycling efficiency, and (3) the simulation of sediment aquaculture interactions. Current results are discussed in light of its potential implications for coastal management and understanding of spatial variability of sediment biogeochemical processes.

Broadband acoustic scattering from phytoplankton.

Dylan DeGrâce[1] , Tetjana Ross[1]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at dylan.degrace@gmail.com

The use of high frequency acoustics (> 500 kHz) has been used extensively to study the ocean at the small scale. Target objects range from sand to zooplankton and, more recently, phytoplankton. The literature involving phytoplankton is limited and would benefit from further study. Broadband scattering methods and models developed within the zooplankton literature can theoretically be applied to test the frequency dependence of morphologically distinct phytoplankton. My goal is to test their application with four different species with varying shape and shell composition. Tests involving the first test species, *Ditylum brightwelli*, were completed last week and the additional tests are scheduled over the next 2 months. Experimental theory and methods will be outlined and some preliminary results from the first test species will be presented.

Influence of Historical Inlet Configuration on Backbarrier Circulation

Colleen Wilson[1] , Ryan Mulligan[2]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2
[2]Department of Civil Engineering, Queen's University, Kingston ON, Canada, K7L 3N6

Speaker may be reached at colleen.wilson@dal.ca

Backbarrier lagoons are formed when sand spits or a series of barrier islands partially separate a bay from the greater body of water. The purpose of this study was to examine the impact that historical variation of barrier island configuration had on the water conditions within Wellers Bay, a backbarrier lagoon connected to Lake Ontario. The methods used in this investigation included: a site visit and a historical air photo analysis to define the barrier island configurations, and then numerical modelling with the hydrodynamic model Delft3D. The model was run for idealized fall storm conditions, and the currents, significant wave heights and water levels were analysed in Wellers Bay. The results showed that there was very little change of the currents and wave heights within the bay for varied inlet configuration. The most significant change was for the water levels in the bay, especially in combination with the changes in water levels over Lake Ontario. It was discovered in this research that long term water levels have decreased over the past 60 years, and may be the prime contribution to sediment deposition, vegetation growth and swamp development in parts of Wellers Bay.

Data assimilation for combined state and parameter estimation: application to a physical-biological model.

Liuqian Yu[1] , Katja Fennel[1]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at `liuqian.yu@dal.ca`

Numerical models are invaluable tools for understanding the dynamics of marine systems and for predicting responses to natural and anthropogenic perturbations. However, any model simulation contains errors due to the imperfect numerical schemes, insufficient model resolution, inaccurate parameter values, imperfect initial and boundary conditions etc. Observations and statistical methods that can optimally merge the information contained in observations and dynamical models, also referred to as data assimilation methods, can help quantify and correct errors.

A widely used multivariate sequential data assimilation method is the Ensemble Kalman Filter (EnKF). The multivariate nature of the EnKF enables it to provide updates for the whole model state even if only one variable is assimilated. The EnKF is also able to simultaneously estimate the state variables and parameters by simply augmenting the state vector with the parameters to estimate.

POSTER: Wave-Current Interactions in Digby Gut.

Emily J. Chua[1] , Greg Wilson[1] , Justine McMillan[1] , Alex Hay[1]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at `emily.chua@dal.ca`

In the ocean, water motion arises from a mixture of waves and currents of varying forms. The combined effects of wave refraction and diffraction by currents can significantly amplify wave heights. This has important implications for instream structures such as tidal turbines. Understanding the conditions under which large waves may form in tidal channels such as Digby Gut, which is located in the Bay of Fundy region, guides decisions on turbine placement. In this study, wave observations made in Digby Gut during January 2014 using an ADCP (Acoustic Doppler Current Profiler) are compare to model output from SWAN (Simulating WAves Nearshore) to predict wave heights and direction at the proposed turbine site.

POSTER: Acoustic backscatter amplitude from particles suspended in turbulent flow.

Kacie Conrad[1]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at `kacie.conrad@dal.ca`

Turbulent flow was examined using Particle Image Velocimetry and a pulse-coherent Doppler profiler. The decay of turbulence was displayed in velocity trends measured by both systems. A seiche wave in the tank was measured by the PIV system to be $T = 0.6$ s which was close to the theoretical value of $T = 0.4$ s. The measured settling velocity, $w_{settling} = 0.005$ m/s was also within the expected range of values for turbulent flow. Simultaneous measurements with PIV and the Doppler instrument examined how turbulence effects settling velocity, and the effects of pulse-pair correlation on the backscatter amplitude statistics.

POSTER: Coastal sea surface temperature reconstruction over the last 3000 years using alkenone analysis.

Alexandria McKechnie[1]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at al442331@dal.ca

Examining past sea surface temperature (SST) records based on geochemical analysis of marine sediments helps to gain insight into the coupled ocean-atmosphere system. In the open ocean, a commonly used approach for SST reconstruction is based on the analysis of C37 alkenones. These long-chained ketones are synthesized by some haptophyte algae species with slightly different chemical compositions depending on temperature in the euphotic zone of the ocean. Sachs (2007) used alkenone analysis in a sediment core from the margin east of Nova Scotia to show the cooling of SST throughout the Holocene (0- 10,000 years BP); a period that is climatically stable in other regions. The goal of this study was to apply the alkenone method in coastal sediment, which has not been previously attempted, and compare results to earlier SST records from the NW Atlantic. Total lipid content was extracted from sediment cores taken from coastal locations around Nova Scotia, Canada, and the concentrations of di and tri-unsaturated alkenones were analyzed by gas chromatography. Using the global core top calibration (Mller et al. 1998), a local SST record was reconstructed, likely representing the past 3000 years based on a 400 cm long core. The age model for the cores based on lead-210 dating has been further refined in this study by recent radiocarbon dating of wood fragments and shell debris. Results show that di and tri-unsaturated alkenones are detectable in shallow coastal sediment cores and can be used in SST reconstructions. The new SST record will be compared to the NW Atlantic site, and examined to see whether the coastal site has recorded globally significant climate events such as the Little Ice Age (1450-1850 CE). From an analytical perspective, the detection of alkenones in coastal sediments is significant. Furthermore the new coastal temperature record will allow for future pairing of SST data with other paleoclimate indicators, such as storminess, in Nova Scotia waters. Ultimately, these results will be useful to improve future predictions about the impacts of a changing climate in Nova Scotia.

POSTER: Reconstructing past sea surface temperatures from the last 170,000 years over the Iceland-Faroe Ridge.

Stefanie Mellon[1]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at `Stefanie Mellon`

Paleoceanography is the study of the geologic history of the ocean in terms of its chemistry, biology, climate, and circulation patterns. Understanding the ocean and its past behaviour is important because it gives insight into rates and amplitudes of environmental change. This thesis uses a paleoceanographic technique that measures the unsaturated alkenone ratios in deep-sea sediment cores to reconstruct sea surface temperatures (SST) during the last two glacial-interglacial cycles. The study site is located southeast of Iceland, which is of particular interest to oceanographers because it is a key region of deep-water formation. SST is an important parameter because it is the temperature of the interface between oceanic and atmospheric heat reservoirs. These data can be used to test the reliability of general circulation models (GCM). If GCMs can accurately simulate conditions of the past, then we can have more confidence in the models predictions for future climate change. Results of the study show a cooling throughout the Holocene (11,700 years BP - present), unexpectedly warm last glacial maximum SSTs, and a 9 ± 1.5°C amplitude between glacial and interglacial periods. Causes and implications will be discussed.

An Avalanching Story: Acoustic Measurement of Velocity and Thickness of Granular Flow on a Sloping Bed.

Jenna Hare[1] , Alex Hay[1] , Len Zedel[2]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2
[2]Department of Physics and Physical Oceanography, Memorial University of Newfoundland, St. Johns, NF, Canada

Speaker may be reached at jenna.hare@dal.ca

Simultaneous measurements of flow and sediment transport represent a major challenge in aqueous environments. Significant advances have been made in the development of acoustic remote sensing instrumentation for measuring the vertical structure of nearbed flow and sediment flux without disturbing either the flow or the bed. These developments have included broadband MHz frequency acoustic systems capable of simultaneous measurements of backscatter amplitude and phase across the O(1 MHz) system bandwidth at mm-scale range resolution. Our overall research objective is to extend acoustic measurements to allow an acoustic estimation of bedload parameters. As an analogue for bedload transport, we investigate sub-aqueous granular flow on a sloping bed at the angle of repose using broadband acoustics. Results are presented from a series of granular flow experiments in a rotating drum apparatus (50 cm diameter) submerged in a larger tank of water. Fine quartz sand having a median diameter of 0.25 mm is used. By rotating the drum to a fixed tilt position at the angle of repose, a thin layer of avalanching sediment is produced. The thickness and velocity of the avalanching layer are measured with a wide bandwidth coherent Doppler profiler. These acoustic estimates are compared to simultaneous ground truth estimates made with a video imaging system.

Modelling the impact of sound distortion on aural classifier performance for species identification of cetaceans

Carolyn Binder[1] , Paul C. Hines[2]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2
[2]Department of Electrical and Computer Engineering, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at carolyn.binder@dal.ca

Passive acoustic monitoring (PAM) is used to study cetaceans in their habitats, which cover diverse underwater environments. It is well known that properties of the ocean environment can be markedly different between regions inhabited by cetaceans, which can result in distinct propagation characteristics. These can in turn lead to differences in how a cetacean vocalization is distorted by propagation effects and may impact the accuracy of PAM systems. To develop an automatic PAM system capable of operating effectively in numerous environments one must understand how propagation conditions affect these systems; however, little research has yet been directed in this area. A prototype aural classifier developed at Defence R&D Canada has successfully been used for inter-species discrimination of cetaceans. The aural classifier achieves accurate results by using perceptual signal features similar to those used by the human auditory system to discriminate similar sounds. The current work uses a combination of at-sea experiments and pulse propagation modelling to examine the robustness of the perceptual features with respect to propagation effects. This talk will focus on insights gained from simulations in which bowhead and humpback vocalizations were virtually propagated over ranges of 1–20 km.

Ambient noise from turbidity currents in Howe Sound.

Matthew Hatcher[1] , Alex Hay[1] , John E. Hughes Clarke[2]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2
[2]Ocean Mapping Group, University of New Brunswick, Fredericton, NB, Canada, E3B 5A3

Speaker may be reached at mhatcher@dal.ca

The Squamish River enters Howe Sound near Squamish, British Columbia. Due to the sediment carried by the river the interface between the fjord and river is characterized by a fan delta and delta front descending into the several 100 m deep fjord. Sediment mass transport from the delta into the fjord is dominated by discrete turbidity current events which have incised semi-permanent channels on the delta front and out onto the prodelta. Subsequent turbidity currents flow through these channels modifying them and the bedforms within them. During a field trip in the spring of 2013 measurements were made which detected roughly 18 discrete turbidity currents with head speeds up to about 3 m/s. This presentation will summarize the broadband (100 Hz to 200 kHz) hydrophone data, focusing on the noise these turbidity currents produced and the mechanism involved in this sound production. Further, the variability in this noise is compared to independently measured turbidity current and sediment properties, with the potential future goal being passive acoustic monitoring of sediment transport events of this type.

Population dynamics of two deep-water octocoral species in the Gulf of Maine over 13 years.

Swaantje Bennecke[1] , Anna Metaxas[2]

[1]GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany. Wischhofstr. 1-3, 24148 Kiel, Germany
[2]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at sbennecke@dal.ca

Deep-water corals are known to provide habitat for a diverse associated fauna because of their structural complexity. Octocorals can occur in dense aggregations forming gardens or forests, where associated organisms are found on the corals and between colonies. These long-lived and slow growing coral communities are vulnerable to human impacts, such as bottom fisheries. To protect the two dominant octocoral species in the area, *Primnoa resedaeformis* and *Paragorgia arborea*, the 424-km2 sized Northeast Channel Coral Conservation Area (NECCCA) was established in the Gulf of Maine in 2002 and is largely closed to bottom fishing gear. The coral communities were monitored with video surveys during ROV dives in 2001, 2006, 2010 and 2014 at depths of 300 2000 m, inside and outside the NECCCA. Temporal changes in coral abundance and size frequency of *P. resedaeformis* and *P. arborea* between 2001 (before the NECCCA was established) and 2014 for two sites at each of 450 - 500 m and 650 - 700 m depth will be studied. Spatial variation in size frequency distributions between the four different sites within the NECCCA will be measured for 2014. Visual substrate classification and CTD data recordings will provide information on the environmental conditions at each site.

The Carbonate System in the Canadian Arctic Archipelago.

Jacoba Mol[1] , Helmuth Thomas[1]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at jacoba.mol@dal.ca

As global climate is altered through human activities it is important to understand the effects that rising carbon dioxide levels have on the ocean. Here, an analysis of the carbonate system takes place through the measurement of dissolved inorganic carbon (DIC) and total alkalinity (TA) in seawater. Samples were collected throughout the Canadian Arctic Ocean in the summers of 2013 and 2014 in order to better understand and quantify carbon cycling in this understudied region. The Arctic Ocean is particularly susceptible to future change as warming, sea-ice loss, water mass movements and biological changes all influence the complicated carbonate system. An analysis of the isotopic fractionation of carbon and oxygen will also aid in the assessment of the physical and biological factors changing the carbonate system in the Arctic.

Numerical Study of Wave-Current Interactions over the Eastern Canadian Shelf under Extreme Weather Conditions.

Pengcheng Wang[1] , Jinyu Sheng[1]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at wpc302@gmail.com

This study examines wave-current interactions (WCI) over the eastern Canadian shelf during Hurricane Juan in September 2003 using a coupled wave-current modelling system. The coupled modelling system is based on a three-dimensional (3D) ocean circulation model (DalCoast) coupled with a third-generation wave model (WAVEWATCH III) to enable integrating oceanic and wave processes in coastal and shelf seas. The 3D radiation stress formula and wave-enhanced vertical mixing are implemented in DalCoast to account for the effects of waves on the 3D ocean currents. In return, ocean currents modify wave fields by entering the wave action equation and changing the wind input to the wave model. The coupled wave-current system is driven by the Climate Forecast System Reanalysis (CFSR) winds. An asymmetric vortex is inserted to the CFSR winds to better resolve hurricane winds during Hurricane Juan. In addition, DalCoast is forced by tides, the net heat and freshwater fluxes at the sea surface and freshwater runoff. In comparison with in-situ wave observations, the simulated wave fields are significantly improved during and after the highest winds by accounting for the effect of currents on waves. On the right-hand side of the hurricane track, where currents are strong and almost propagated in the same direction as waves, the maximum significant wave height (SWH) is reduced by up to 18% due to the WCI. On the left-hand side of the track, the storm-induced currents are relatively weak and the maximum SWH is not affected significantly by the WCI, even though the propagation directions of waves and currents are opposite. For the effects of waves on currents, relatively strong wave-induced surface currents (up to 30 cm/s) are generated near the coast, over the shelf break and along the hurricane track, due to the strong radiation stress gradient forcing produced by hurricane Juan over these areas.

A Modelling Study of Coastal Upwelling on the Scotian Shelf

Shiliang Shan[1] , Jinyu Sheng[1]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at sshan@dal.ca

Wind-driven coastal upwelling on the central Scotian Shelf has important implications for the supply of nutrients to the surface layer. Two major upwelling events in the summer of 2012 were identified from the sea surface temperature (SST) observations made by the Halifax Harbour Buoy and satellite remote sensing. A multi-nested circulation model developed recently over the central Scotian Shelf (DalCoast-CSS) is used to better understand the spatial and temporal evolution of the upwelling and its associated filaments. The model has four submodels downscaling from the eastern Canadian Shelf to the central Scotian Shelf using a one-way nesting method. The model is forced by tides, wind, river discharges, and heat/freshwater fluxes. Comparing with the observed SST fields and time series, the model is able to represent the development of coastal upwelling events and the characteristics of the filament on the Scotian Shelf. The modelled vertical temperature structure in the upwelling plume region is also compatible with glider observations on the Halifax Line through the Ocean Tracking Network project. A process study using DalCoast-CSS is conducted to quantify the roles of successive upwelling-favourable wind impulse, stratification, coastal irregularities, the Nova Scotia Current on the development of coastal upwelling on the Scotian Shelf.

Kelp in hot water: Warming seawater temperature induces weakening and loss of kelp tissue

Erika Simonson[1] , Robert E. Scheibling[1] , Anna Metaxas[2]

[1]Department of Biology, Dalhousie University, Halifax, NS, Canada, B3H 4R2
[2]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at `erika.simonson@dal.ca`

Recent declines and losses of highly productive kelp beds worldwide have been linked to increases in ocean temperature. We investigated the impacts of 4 temperature treatments (11, 14, 18 and 21 C) on growth, tissue loss and mortality of the dominant kelp species in Nova Scotia, *Saccharina latissima*, *Laminaria digitata* and *Agarum clathratum*. Growth rate of *A. clathratum* was reduced at 18 C over 3 wk of exposure, and all species experienced negative net changes in length at this temperature. Exposure to 21 C led to severe tissue loss and mortality within 2 wk of exposure. 1-wk exposure to 21 C reduced tissue strength (breaking stress) and extensibility (breaking strain) by 40 70% in *S. latissima* and *L. digitata*, and all 3 species exhibited reduced strength after 3-wk exposure to 18 C. Histology of the blade tissue showed temperature-induced damage to the cellular structure that could weaken tissue. Our findings provide a mechanism by which rising temperatures could contribute to observed population declines of kelp species.

Alternative regression model and investigation of the U^k_{37} SST relationship for Atlantic Ocean suspended particulate alkenones: Implications for U^k_{37} paleothermometry

Jessica Gould[1] , Markus Kienast[1] , Mike Dowd[2]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2
[2]Department of Mathematics and Statistics, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at jlagould@gmail.com

Paleoceanographers rely on biological and geochemical proxies preserved in the sedimentary record to reconstruct past ocean and climate dynamics. Biomarkers, in particular, are principle components of a paleoceanographers proxy toolkit. The exact make-up of these organic molecules is a result of the systematic response to environmental conditions during their biosynthesis, such as sea surface temperature (SST) in the case of alkenones (Rosell-Mel, A. & McClymont, E.L., 2007).

The U^k_{37} index is one of the main proxies used to reconstruct past SSTs. The index describes the proportion of unsaturated alkenones, which are uniquely synthesized by a specific group of phytoplankton called prymnesiophytes. This index has been shown to strongly correlate with growth temperature (Marlowe, 1984) making it possible to quantitatively reconstruct past SSTs from U^k_{37} values determined in sediment cores. Although the U^k_{37} index is a reliable proxy, uncertainties concerning the relationship between measurable U^k_{37} values and phytoplankton growth temperatures remain. Defining both an accurate calibration curve for the U^k_{37}-SST relationship, as well as teasing out systematic non-thermal factors affecting U^k_{37} have been research foci in recent years.

This study analyzed U^k_{37} data extracted from suspended particulate samples collected by filtration from a transect of the Atlantic Ocean from approximately $60°N$ to 60°S in 2010. Based on a combined dataset consisting of these Atlantic Ocean samples and a number of previously published U^k_{37} data, both the calibration model and seasonality effects on the U^k_{37}-SST relationship were investigated. Similar to previous studies that have utilized non-linear polynomial regression models to describe the U^k_{37}-SST relationship, we established a new and unique non-linear regression model; the Richards Curve, to quantify the U^k_{37}-SST relationship for the combined data set. This results in a reduced uncertainty of prediction, as well as in a better description of the non-linear behavior of U^k_{37} at very high and low SSTs. In addition, we explored the effect of seasonality on the U^k_{37}-SST relationship, finding that the regression results in a statistically stronger relationship between U^k_{37} values and World Ocean Atlas average *monthly* SSTs than that found between U^k_{37} and World Ocean Atlas average *annual* SSTs, which have been used as reference in most previous studies.

Dispersion, and hydrodynamic connectivity over the Scotian Shelf, a numerical investigation using a nested-grid ocean circulation model

Yi Sui[1] , Jinyu Sheng[1] , Kyoko Ohashi[1] , Yongsheng Wu[2] , Shiliang Shan[1]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2
[2]Bedford Institute of Oceanography, Dartmouth, NS, Canada, B2Y 4A2

Speaker may be reached at yz966445@dal.ca

A nested-grid ocean circulation modelling system is used to simulate circulation and hydrography over the Scotian shelf. The modelling system consists of a coarse-resolution (1/12°) barotropic storm surge outer model covering the eastern Canadian shelf, and fine-resolution (1/16°) baroclinic inner modeling covering the Gulf of St. Lawrence, the Scotian Shelf and the Gulf of Marine. The model performance is assessed by comparing models results with in-situ oceanographic observations and satellite-tracked surface drifters data. A particle-tracking model is used to track particle movements from hourly simulated ocean currents. Particle movements are then used to calculate dispersion, retention, and hydrodynamic connectivity of surface waters on the study region. The near-surface dispersion is higher on the shelf break and lower on the coastal waters and inner shelf regions. The upstream and downstream retention areas for several sensitive areas on the Scotia Shelf are also examined.

The case of the missing copepod: Transport and retention mechanisms for copepods in Roseway Basin using an echosounder-equipped ocean glider

Gennavieve Ruckdeschel[1]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at gn972288@dal.ca

Calanoid copepods are small crustaceans that are the most abundant marine zooplankton on Earth. The copepod *Calanus finmarchicus* is the most common copepod in the Northwest Atlantic and plays an important role in pelagic marine food webs. These copepods are the prey of other zooplankton hardly bigger than their own 1 mm length, up to the endangered 18 m long North Atlantic right whale (*Eubalaena glacialis*). Under stressful conditions, *C. finmarchicus* enter diapause (hibernation) and sink to form a suspended layer 100 m or more below the surface. Right whales rely on energy-rich diapausing copepods for food, especially *C. finmarchicus*, and are commonly sighted in key feeding grounds where copepods accumulate in the Northwestern Atlantic, such as Grand Manan Basin in the Bay of Fundy and Roseway Basin off the Scotian Shelf. In years when the feeding grounds contain few copepods, right whales are known to abandon these areas. Where do the copepods in these feeding grounds go? How did they accumulate in the first place? And how are they resupplied to right whale feeding grounds? These questions are important for understanding how bathymetry and hydrography interact to determine the distribution of an important component in the marine food web, and also for future right whale conservation. As they are transported by water masses that surround them, diapausing copepods act as living tracers of water movement. With this idea, I will use data from a 300 kHz echosounder mounted to a Slocum ocean glider to visualize the distribution of copepods in Roseway Basin and look for clues about how currents affect their vertical and horizontal distribution. By combining copepod distributions with water column information (such as salinity, temperature, and current velocity), I will investigate the transport and retention mechanisms in Roseway Basin to help improve our understanding of copepod advection dynamics and its impacts on right whale prey fields.
