C-DOGS 2016

Conference of Dalhousie Oceanography Graduate Students

Friday March 18, 2016
9:00 - 17:30, University Hall
Dalhousie University, Halifax, Nova Scotia

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Will Lawrencetown Beach turn into Copacabana? A look into Inter-annual variability and the 2012 warm anomaly in Nova Scotian waters

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In 2012, abnormally warm and saline water was observed and reported over the Scotian Shelf and the Gulf of Maine (Hebert et al, 2013; Chen et al., 2015; Pershing et al., 2015). Nevertheless, the physical mechanisms involved in this anomaly are not well understood. We propose to combine datasets from near-bottom CTDs and underwater gliders to characterize the inter-annual variability of the hydrography along the Halifax Line. We show that, despite being dubbed the "2012 anomaly", the warm event first started in 2011 and is present until the end of the 7-year record (2008-2015). The analysis also reveals that this anomaly is superimposed onto a long-term linear increase of the temperature and salinity. The warming rates are included between 0.34 and 0.43 ^{o}C/year, while the salinity increases by 0.06 to 0.12 salinity unit per year. A water mass analysis demonstrates that the anomalous event was advected into the domain, and not locally-formed by a change in water composition.

Investigation of the U^k_{37} Paleothermometer for Atlantic Ocean suspended particulate alkenones: An alternative regression model

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Paleoceanographers rely on biological and geochemical proxies preserved in the sedimentary record to reconstruct past ocean and climate dynamics. The U^k_{37} index is one of the main proxies used to reconstruct past sea surface temperatures (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 a robust proxy, uncertainties concerning the relationship between measurable U^k_{37} values and phytoplankton growth temperatures remain. Defining an accurate calibration curve for the U^k_{37}-SST relationship has been a focus 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. 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 a combined dataset consisting of these Atlantic Ocean samples and a number of previously published U^k_{37} data. The Richards curve accounts for the fact that the U^k_{37} index is a proportion, and so must lie between 0 and 1, as well as the sigmoidal shape that captures the observed reduction in slope at the warm and cold ends of the temperature range. Using this relationship we are able to invert the model to produce a SST lookup table of paleo-SST estimations with uncertainties from U^k_{37} values.

Additionally, we have identified a pronounced seasonal sampling bias in the surface particulate dataset utilized in this study, which may be contributing to a reported offset between surface particulate and core-top U^k_{37}-SST calibrations for this proxy (Conte et al 2006). A systematic consequence of this sampling bias has not yet been borne out, however it is a finding that draws attention to these types of intrinsic biases in oceanographic data.

Exchange of Dissolved Inorganic Carbon and Carbon Isotopes on the Beaufort Shelf

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The transport of inorganic carbon from shallow continental shelf waters into the deep ocean is important in the long-term storage of carbon dioxide within the world oceans. Arctic Ocean shelves have experienced large changes in the past several decades as warming, sea-ice loss, and increased river discharge have altered carbon cycling in these areas. Profiles of dissolved inorganic carbon (DIC), total alkalinity (TA), and the stable isotopes of carbon (δ^{13}C-DIC) are used to investigate the cycling of inorganic carbon in the Southern Beaufort Sea. The transport of inorganic carbon from the Beaufort Shelf into Canada Basin, contributing to the persistent DIC maximum in the halocline layer, is quantified using velocity fields from model output of the Arctic and Northern Hemisphere Atlantic (ANHA) NEMO Simulation. The sources of DIC to the deep basin, including the remineralization of organic matter, brine formation, and air-sea gas exchange are further considered using δ^{13}C-DIC as an independent tracer of biological activity. TA and δ^{18}O are used to examine the water mass distributions in the study area and analyze the influence of Pacific Water, Mackenzie River freshwater, and sea-ice melt on carbon dynamics and air-sea fluxes of CO_2 in the surface mixed layer. Understanding carbon transfer in this seasonally dynamic and largely changing environment is key in order to quantify the importance of Arctic shelf regions in the global carbon cycle.

Improvement of the MOHID Oil Spill Model for Prediction of the Fate/behaviour of Oil Spills on Scotian Shelf

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MOHID water modelling system is a 3-dimensional water modelling system, consists of hydrodynamic, wave, sediments transport, sand, water quality, turbulence, Lagrangian transport, and oil spill modules. The oil spill module is a three-dimensional model that uses the Lagrangian tracers to simulate the oil fate and transport processes. To improve the performance and accuracy of MOHID, a new oil natural dispersion algorithm and a biodegradation module have been implemented into the model. The dispersion algorithm is based on SINTEFs latest semi-empirical model. The model introduces a non-dimensional number, Modified Weber Number, to calculate the oil droplet size distribution resulting from the actions of breaking waves. The biodegradation module uses a first order biodegradation equation to calculate the removal of oil by microbial-biodegradation process. The biodegradation coefficients for different oil components were obtained from laboratory experiments. A case study of a hypothetical oil spill has been conducted to evaluate the effects of this new development on the overall oil mass balances and fate and transport process. The selected study area was the Scotian Shelf where the hourly currents from a high resolution (1/36) NEMO model and winds from NCEPs Climate Forecast System Reanalysis (CFSR) dataset were used to force the oil spill model. Results from the MOHID model were compared with a state-of-the-art oil spill model, Oil Spill Contingency and Response (OSCAR), for model cross-validation.

Source or Sink? A modeling study of inorganic carbon cycling on the Scotian Shelf

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Continental shelves account for a large proportion of global primary production, and potentially a disproportionate fraction of the carbon dioxide (CO_2) flux between atmosphere and ocean. The continental shelf pump hypothesis proposes that continental shelves at high latitudes act as net sinks of atmospheric CO_2. However, direct measurements on the Scotian Shelf, off eastern Canada, indicate that this shelf region acts as a net source of CO_2 to the atmosphere. The mechanisms underlying this deviation from the continental shelf pump mechanism are poorly understood. We employ a biogeochemical model of the northwestern North Atlantic continental shelf, and aim to improve our understanding of processes influencing air-sea CO_2 flux, and transport and transformation of inorganic carbon on the Scotian Shelf. Numerical models are useful tools for investigating the complex interactions of processes affecting carbon cycling. Models can help interpret sparse measurements through mechanistic representations of the relevant processes. Our model is initialized for total inorganic carbon and total alkalinity, and extensively compared against observations from the region, including data from the Atlantic Zone Monitoring Program (AZMP) cruises and global databases from Global Ocean Data Analysis Project (GLODAP) and Carbon Dioxide Information Analysis Center (CDIAC). Using the validated model, we perform a series of tests to explore the role of key processes contributing to the observed carbon fluxes on the Scotian Shelf.

Pressure response of a sand and gravel bed to water waves

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Measuring wave-field characteristics using instrument arrays in the nearshore typically involves mounting pressure or current sensors above the seabed. However, the sensitive nature of these instruments makes their deployment untenable in energetic coastal environments, where wave energy coupled with unconsolidated gravel- and cobble-sized sediments has the potential to inflict significant damage. By burying pressure sensors beneath the bed, in situ observations of surf and swash zone hydrodynamics can be obtained with comparatively low risk of instrument damage, but attenuation and phase shifting of wave pressure signals through the porous medium must be considered.

A field study was conducted on a steep, megatidal, mixed-sand-gravel beach in the Bay of Fundy, wherein a vertically stacked array of four pressure sensors was buried in the beach near mid-tide. The array spanned from the beach surface to 50 cm sediment depth, with sensors sampling synchronously near 50 Hz. The principal objective was to quantify attenuation and phase shifting of wave-induced pore pressures with sediment depth, in order to establish the feasibility of using an array of buried pressure sensors to monitor wave-field conditions in the surf and swash zones. Results indicate rapid attenuation and a high degree of phase shifting of wave pressure signals through the sampling region, as well as significant sensitivity to the restructuring of beach material by energetic wave events. Comparison of observed profiles to a poro-elastic bed response model yields strong agreement, with best-fit model parameters indicating that entrainment of air in pore spaces plays an important role.

Modeling hypoxia off the Changjiang Estuary in the East China Sea

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Changjiang is the largest river in China and the third largest river in the world in terms of freshwater discharge, with an annual discharge of 9×10^{11} m^3 $year^{-1}$ emptying into the Yellow Sea (YS) and the East China Sea (ECS). Hypoxia (dissolved oxygen concentration <2 mg L^{-1} or 62.5 mmol m^{-3}) off the Changjiang Estuary in the ECS is one of the largest hypoxic areas in the world, usually from June to October and serious in August (Chen et al., 2007; Wang, 2009; Wang et al., 2012). In order to investigate the development mechanism of hypoxia, a 3D coupled physical-biological model was employed in this study. Results from a 6-yr simulation (2006 - 2011) show that the model can reproduce hypoxia development and present seasonal and annual variability of hypoxia. Oxygen budget is evaluated in hypoxic regions which indicates that water column respiration, sediment oxygen consumption (SOC) are major factors for dissolved oxygen (DO) loss in the whole water column. But for the near bottom waters, SOC is the dominant contributor for the oxygen depletion.

Habitat Suitability Mapping: Separating Lobsters from Fish Pens

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The conflict between the finfish aquaculture industry and the traditional American lobster (*Homarus americanus*) fishery in Nova Scotia is a significant one, consistently making the news at the local, provincial, and national levels. The two industries share not only a large spatial overlap but social and economic ones as well, and the amount of misinformation and distrust surrounding the situation makes resolution a difficult thing to achieve. One potential solution is contained within the concept of Marine Spatial Planning (MSP), a process that allocates the spatial and temporal distribution of human activities on the coast and ocean in the most efficient, practical, and socially aware manner. A physical separation of the two industries via the designation of lobster habitat will ideally ease tensions and increase the social license of the aquaculture industry. My project seeks to locate lobster habitat within a number of bays in Nova Scotia and New Brunswick for the purpose of creating habitat suitability maps to be used by Cooke Aquaculture with these maps, Cooke will be able to avoid placing new fish pens on or near potential lobster habitat. In this presentation, I will speak on the structure and composition the habitat suitability maps, as well as the preliminary results of my work in Maces Bay, NB, where I've made use of echosounder technology to map out and classify seafloor substrate.

Variability of Particle Distribution Using Optical Measurements within the Columbia River Estuary

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Optical and particle instruments were profiled at a series of stations in the highly stratified waters of the Columbia River Estuary (CRE). In the CRE, schlieren produce an increase in particle beam attenuation (c_p) that is independent of particle properties and affects Particle Size Distributions ($PSDs$) derived from LISST-100. When the 1-m-bin-averaged buoyancy frequency, N, exceeds 0.05 s^{-1}, inaccurate estimates of (c_p and the PSD are observed. The schlieren do not affect the c_p and b_{bp} (backscattering coefficient of particles) derived from WET Labs ac-9 and bb2fl. The reason is that the ac-9 has a large acceptance angle and measures mixed water. Backscattered light is not affected strongly by schlieren. As a result, the c_p derived from ac-9 and b_{bp} are good proxies for SPM (suspended particulate mass concentration). The Sauter mean diameter (D_s) was calculated from the combined data from a LISST and a floc camera, and beam attenuation slope (γ) was estimated from the ac-9 c_p spectrum, which responds to particle size variation. The particulate backscattering ratio was calculated as b_{bp} divided the scattering coefficient of particles. This proxy is used to characterize composition. Observations in CRE demonstrated that the organic-rich river water brings smaller and denser particles to meet with salty ocean water, and then particles aggregate and settle into the salt wedge seaward of the density front. Large tidal currents resuspend mineral-rich, larger and loose aggregates from the seabed, which accumulate at density front.

Seasonal and spatial variation in the acoustic presence of large baleen whale species on the Scotian Shelf

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Several species of large baleen whales frequent the waters of Atlantic Canada, but we have a poor understanding of their important habitat areas. The status of blue and right whales as endangered, fin whales as threatened, and sei whales as data deficient emphasizes the need for increased monitoring effort to better inform effective management and conservation. My project seeks to describe seasonal and spatial variation in acoustic presence of five baleen whale species (right, blue, sei, fin, and humpback) and compare it to co-located oceanographic characteristics to better understand the environmental factors that drive whale distribution. I make use of ocean gliders that concurrently record whale sounds and collect near continuous hydrographic data for 3 - 12 weeks (or 500 - 2000 kilometers). Monitoring of several sites in the Gulf of Maine and Scotian Shelf began in the fall of 2014 and will likely continue through the fall of 2017. I will present preliminary results and challenges arising from analysis of the fall 2015 glider deployments in Roseway Basin, a known right whale critical habitat area on the western Scotian Shelf, as well as a perspective roadmap of future research directions.

Soundscape characterization in a dynamic acoustic environment: Grand Passage, Nova Scotia, a planned in-stream tidal energy site

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The marine environment in the Bay of Fundy hosts a dynamic and diverse soundscape that is a fundamental component of the local ecosystem. The emergence of new anthropogenic marine activities and infrastructure, such as tidal turbine installations, introduces new sound sources that change or disrupt the existing acoustic environment, but the full extent of these changes is not well understood and is not predictable. To better evaluate the effects of future tidal energy development on the local soundscape in Grand Passage, Nova Scotia, a thorough understanding of the pre-development characteristics must be established. This research quantifies and analyzes the acoustic environment as a dynamic compilation of various discrete and semi-continuous sound sources, to characterize the soundscape as a function of its governing biological and physical processes and conditions. Passive acoustic measurements have been conducted using long-term moored omnidirectional hydrophones, a moored 5-channel array, and drifting hydrophone arrays, enabling identification of dominant signals and source direction, assessment of broadband noise sources, estimation of pseudonoise masking effects due to turbulent flow, and analysis of diurnal, daily, seasonal, and annual variability as well as spatial variability within the study area. The results provide a comprehensive baseline assessment that will support accurate evaluation of anthropogenic acoustic impacts.

Estimating the Efficiency of Cross-Shelf Transport of Terrestrially Derived Materials in River Plumes

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Rivers connect land and sea, delivering large amounts of terrestrially-derived materials (such as nutrients, sediments, and pollutants) to the coastal ocean. Understanding the fate of this delivery is critical: nutrients can accumulate on shelves, driving high levels of production which can ultimately lead to negative ecological impacts such as hypoxia, or they can be exported rapidly across the shelf to the deep ocean where their impact is minimized. Many previous studies into river plume transport have explored the influences on alongshore coastal transport within river plumes; however, little attention has been paid to the controls on cross-shelf transport. The presented work will show the results of an idealized river plume model developed using the Regional Ocean Modelling System (ROMS), examining the impact of latitude, river discharge, and the influence of winds and tides on cross-shelf transport. Nutrient budgets for the adjacent shelf seas will also be presented, describing the fate of terrestrial nutrients within river plumes and determining the degree to which river plumes are able to successfully export material to the deep ocean.

POSTER: Diving deep with *Somniosus microcephalus*: Inferring behaviour from satellite tag measurements of vertical movements of the Greenland Shark

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The Greenland shark (*Somniosus microcephalus*), a deep-sea shark, is the largest known Arctic fish species and an apex predator within ecosystems in the Canadian Arctic. These ecosystems are at risk due to the impacts of climate change and the rapid development of commercial fisheries, and the Greenland shark is particularly vulnerable as a bycatch species. It is necessary to understand the habitat preferences, ecological roles, and movements of the *S. microcephalus* in order to guide fisheries management practices and to ensure the conservation of the species given its importance as an apparent apex predator. This study aims to examine the vertical movements of Greenland sharks in the Canadian Arctic and to use these movement patterns to infer specific behaviours, particularly travelling, hunting and feeding. The vertical movement patterns of this species will also be examined for temporal variability; movement is not expected to vary with time of day but may vary seasonally due to prey availability or movement between geographic regions. From 2012-2014, eight sharks were caught and tagged at three locations in Nunavut, Canada during the months of August-September using pop-off archival satellite tags. The tags were programmed to collect data for 375 days, with the exception of one tag that was programmed for 45 days. The data collected was then examined within the R package diveMove in order to test the ability of the package to summarize dive movements of a deep-sea shark species. All sharks that provided usable data displayed several different types of movements over the data collection period; time series of depth observations revealed that all individuals remained at relatively constant depths of 200-400 m in addition to displaying oscillatory movements with greater ranges in depth. Several of the sharks also performed occasional deep dives, with at least one shark moving to a depth of greater than 1000 m. From visual analyses, vertical movements did not appear to vary as a function of time of day, but may vary seasonally. Mixed effects model are being used to examine dive duration, dive distance, and maximum depth as a function of number of daylight hours, temperature, and time spent at constant depths. Additionally, the amount of time spent at constant depths will be analyzed as a function of number of daylight hours and temperature.

POSTER: Is what we see, what we hear? Temporal variation in right whale (*Eubalaena glacialis*) population indices and vocalizations measured concurrently in Roseway Basin

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North Atlantic right whales (*Eubalaena glacialis*) are one of the most endangered species of baleen whales in the world, therefor effective monitoring is critical to their conservation and protection. This species has been monitored for many years using both visual and acoustic methods, each of which provides different information about the population. In recent years, visual surveys have revealed unusual changes in the abundance and demographic distributions of this population in certain habitats. Acoustically detected vocalisations are known to vary with population indices, but have mainly been used to establish species presence or absence. The objective of my thesis is to compare and contrast the information obtained from the two monitoring methods over multiple years in Roseway Basin, a well-studied critical habitat of right whales. I hypothesize that changes in the type and rate of vocalisations detected will vary positively with visual observations. Population and abundance indices were developed from sightings-per-unit-effort and photo-identification data recorded during spatial sightings surveys in the basin spanning August through September for the years 2004, 2005, 2013, and 2014. A subset of the acoustic data collected concurrently was manually examined for 3 types of right whale calls with documented demographic associations. The call detections were categorised by uncertainty levels based on the context of the calls and were used to quantify the variation in rates of detections. Preliminary results show that sightings of the whales varied inter- and intra-annually, and that the sex ratios changed from high numbers of males (∼6-10) relative to females in 2004 to more equal ratios (∼2-3) in 2013 and 2014. Comparison between the visual and acoustic data remains to be completed. Visual results and preliminary analysis of the acoustic data will be discussed.

POSTER: Distribution and Microhabitats of Mushroom Coral, Fungia, Recruits on Palmyra Atoll

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The present study uses two novel techniques, a photomosaic and a digital elevation model derived from a 3-D construction of the reef, to analyze the microhabitats where Fungia (mushroom coral) recruits settle. From our observations at Palmyra Atoll, Fungia recruits at the two test sites on the reef aggregate in rubble habitats. The data is digitized in the unique photomosaic technique so that analysis of the spatial distribution can be more precise than when in the field. From the photomosaic, the distribution of the Fungia recruits in relation to rubble patches at two sites is non-random ($p<0.001$). We then qualitatively asses the depth of the Fungia recruits from a digital elevation model to determine if the coral are in depressions in the rubble patches. In both sites, the Fungia recruits were observed predominantly in deep areas nearby deeper areas of the reef, but not in holes. Therefore, the recruits were observed in reef depressions rather than in holes. To our knowledge, this is the first attempt to use a digital elevation model to study coral location. While only qualitative data can be extracted from digital elevation models currently, our study shows that this technique has promising potential in understanding coral locations. By analyzing the spatial pattern of the Fungia recruits, we have new insights into the microhabitats conducive to recruit settlement. Understanding the spatial distribution of Fungia species recruits in relation to microhabitats can lead to new insights into their role as reef builders, which is becoming more urgent with climate change.

POSTER: Can carbon export in the North Atlantic Ocean be quantified by combining bio-optical Argo observations with a simple model?

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The yearly phytoplankton spring bloom in the North Atlantic Ocean is thought to be an important mechanism for carbon transport to the deep ocean through sinking aggregates, but to date this transport has been difficult to measure in situ. Emerging bio-Argo observations combined with biological models may enable quantification of carbon export, and its inter-annual variations and trends. Argo is a global array of free-drifting profiling floats that measure temperature and salinity. More recently, some floats have been equipped with bio-optical and chemical sensors. The resulting bio-optical data not only give insights into the temporal dynamics of organic matter in the upper ocean, but can also be used to optimize and validate biological models. Here, physical and bio-optical Argo data is used from the North Atlantic Ocean to constrain a 1D, float-following Nutrient-Phytoplankton-Zooplankton-Detritus (NPZD) model. The model parameters are optimized with the aid of an evolutionary algorithm in order to replicate float-based chlorophyll and particulate organic matter estimates. Analysis of the combined dataset and model with specific focus on carbon transport to the deep ocean and its relation to the spring bloom is performed.

POSTER: Export Production in the Gulf of Eilat: A New Time Series of Particulate Organic Matter

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The transport of particulate organic carbon (POC) from the upper to lower layers of the ocean is important as both a carbon sink for atmospheric carbon and as a source of organic carbon for benthic ecosystems. This study represents the first real-time study of POC export in the Gulf of Eilat (Bay of Aqaba) in the northern Red Sea, an oligotrophic area, and therefore provides an opportunity to determine the relationship between nutrient input and POC export to deep water.

Two sediment traps were deployed in the Gulf of Eilat, one a McLane trap anchored at 400 m which took daily samples beginning in April 2014. A KC Denmark trap took monthly samples at 120 m, 220 m, 350 m, 450 m, and 570 m water depth beginning in January 2014. Total percent nitrogen and carbon in each sample were determined using CHN analysis, while percent inorganic carbon in the samples was determined by couloumetry. To determine percent organic carbon, inorganic carbon was subtracted from total carbon. The flux of POC to depth was found by multiplying percent organic carbon by bulk material flux.

The new data from the McLane trap show that organic carbon flux data peaks during the winter months, from January to February 2015. This was expected, since the seasonal stratification in the Gulf of Eilat significantly weakens in winter. Further analysis of the data will reveal whether this seasonal peak in vertical POC transport is an annual occurrence, and may also show the influence of extreme weather events such as flash floods on POC export.

POSTER: Modeling mid-frequency scattering and reverberation in the northern Gulf of Mexico during the TREX13 sea trial

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One of the greatest limitations to sonar target detection is the degradation of the target signal by reverberation. Therefore the prediction of reverberation through numerical modeling is a critical component of active sonar. Scattering and reverberation at mid-frequencies has not been as well studied as high-frequencies. Thus, in this study the validity of a high-frequency reverberation model for mid-frequencies was tested using environmental data collected during TREX13 (Target and Reverberation Experiment 2013). During the TREX13 sea-trial it was observed that reverberation varied counterintuitively: with peak reverberation occurring within the troughs of the sand dunes. In order to investigate this spatial variation in reverberation environmental data collected during the TREX13 was utilized in a high-frequency seafloor scattering model known as the composite roughness approximation (CRA). The results from this model were incorporated into a high-frequency reverberation model and compared to measured reverberation. Sub-bottom profiler data was used to visualize and quantify the spatial variation and physical mechanisms of scattering. Results from both the CRA and sub-bottom profiler indicate that volume scattering is the dominant scattering mechanism at mid-frequencies in the northern Gulf of Mexico. The peak scattering appears to be caused by the concentration of deep discrete scatterers in the transition zones between the peaks and troughs of the sand dunes at depths of 2m. This study found the CRA empirical estimates of volume scattering underestimated the measured volume scattering, suggesting the CRA model should only be utilized for mid-frequency scattering if the volume scattering parameter can be calculated. Despite this correction to the CRA model there is still significant disagreement between the modeled and measured reverberation, indicating that the other sub-models utilized in the reverberation model need to be validated for mid-frequencies.

POSTER: Modeling Optimum Culture Conditions for the synthesis of Photoprotective Carotenoids in the Chlorophytes *Dunaliella viridis* and *D. salina*

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Dunaliella is a genus of extremophilic green algae capable of surviving prolonged exposure to high irradiance due to an ability to accumulate excessive quotas of photoprotective carotenoids. These carotenoids, primarily lutein, β-carotene and their isomers, act to protect against photodamage to the photosystems by dissipating excess light energy. Similar anti-oxidant properties are also proving to be advantageous for reducing the occurrence of various diseases and ailments in humans when taken as dietary supplements. The mass culturing of carotenoid-lade *Dunaliella* for commercial production is only economically plausible in an optimized system. We aim to characterize and model the ideal growth irradiance that optimizes the growth rate and synthesis of these photoprotective carotenoids. Currently, *D. viridis* (strain UTEX 200) and *D. salina* (UTEX 1644 & CCAP 19/12) are being cultured in balanced growth at light levels ranging from just above compensation irradiance to $\sim$30% of full sunlight in nutrient-replete conditions. Cultures acclimated to each irradiance are harvested so as to measure the cellular carotenoid quota, optical properties of the cells, and rate of biomass production to populate a bio-optical productivity model. The model assumes a fixed incident irradiance, with the effective irradiance modeled from the density of the culture within the optical path and the cells optical properties. Absorbed light is used to estimate carotenoid production based on the quantum yield of biomass production and the cell fraction of biomass accounted for by carotenoids. The quantum yield of biomass production is calculated for each acclimated culture from the absorption spectrum, the specific growth rate, and the cellular carbon quota. The biomass-specific carotenoid quota is measured against an authenticated standard using High Performance Liquid Chromatography. Ideally, our model will give us a neat solution for predicting at what stocking density the growth rate and cellular quota will be optimized. Preliminary results indicate that *D. viridis* experiences light saturated growth at a fairly low growth irradiance with daily lutein production maximized at low stocking densities. This will likely be an interesting contrast to *D. salina*, which has demonstrated excessive accumulation of β-carotene in high stress environments.

3T's: Tides, Turbines and Turbulence

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The measurement of turbulence at a tidal energy site is a critical component of a resource assessment because it provides insight into the fluctuating loads that will be applied to an in-stream turbine. Unfortunately, the characterization of turbulence is nontrivial because it is highly intermittent and contains length and time scales that span several orders of magnitude. To make matters worse, turbulence is not well understood and is even described as "the most important unsolved problem of classical physics" by Richard Feynman – a physicist who is far more intelligent than me.

Despite these difficulties, insight into a turbulent flow can be gained using a variety of measurement techniques. In this talk, I will summarize data obtained in a high Reynolds number tidal channel using both acoustic Doppler current profilers and shear probes. I will demonstrate that the two instrumentation techniques yield comparable estimates of the dissipation rate and I will discuss the temporal and spatial variability of the turbulence levels within the channel. I can guarantee that I have not [yet] solved the "problem of classical physics" that Feynman alluded to, but I am excited to share some of the insight I've gained about turbulent flows.

Exploring the carbon isotopic composition of *Ascophyllum Nodosum* as a record of coastal ocean acidification

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Ocean acidification (OA), often referred to as the "other CO_2 problem", increases the likelihood for calcium carbonate to dissolve in the water column. Under these conditions, calcifying organisms such as shellfish and bivalves have more difficulty forming their shells, which could have deleterious effects on marine ecosystems and Canadian fisheries. The trend in OA has not been thoroughly described in the coastal ocean, which acts as a barrier for predicting future trends and environmental impacts.

The objective of this research project is to develop a new technique for measuring OA trends around Nova Scotia. This involves measuring the carbon isotopic composition ($^{13}C/^{12}C$, expressed as $\delta^{13}C$) of a robust, long-lived rockweed plant called *Ascophyllum Nodosum*. Determining the historical OA trend will be based on the assumption that the $\delta\ ^{13}C$ of the rockweed is intimately coupled to the $\delta\ ^{13}C$ of the dissolved inorganic carbon pool ($\delta\ ^{13}C_{DIC}$) in ocean surface water, and thus, in turn, to atmospheric $\delta\ ^{13}C$. The latter has been changing as a direct result of the combustion of fossil fuels because the carbon released is enriched in the ^{12}C species. As the ocean absorbs more isotopically light atmospheric CO_2, the $\delta\ ^{13}C_{DIC}$ should reflect this change. Using this concept, I will present preliminary results of rockweed samples from the southern shore of Nova Scotia, and discuss intentions for further investigation.

Evaluating Wind Power Input to the General Oceanic Circulation Estimated in CMIP5 Climate Models

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Wind power input (WPI) on general circulation is the main energy supplier for maintaining the stratification of the global ocean and is considered to be one of the most important indicators of the interactions between the atmosphere and ocean. In the present study, we evaluate the ability of CMIP5 models to simulate WPI to the general oceanic circulation, with wind and surface currents extracted from 19 climate models over the time period 1950-2100. For comparison, WPI is also calculated with CFSR reanalysis wind and geostrophic currents from AVISO altimetry satellite measurements over 1993-2014. The result shows that about one third of CMIP5 models give the global WPI ranging from 0.75 to 1.1 TW, similar to the observational reference value (0.88 TW) and previous studies (0.76 - 1.1 TW), but the other two thirds give significant underestimates. In terms of the spatial distributions, most models capture the major global distribution characteristics, with spatial correlation coefficients of around 0.6 - 0.7, but demonstrate underestimations in magnitude, especially in the major wind work input area. For the temporal variance, model results of WPI reveal quite different temporal variability compared with the observational reference over the global oceans, the Southern Ocean and the tropical area, but they do appear to reliably reflect the seasonal variance in the North Atlantic and North Pacific. In terms of the estimated long-term future climate change simulations, there is a notable WPI increasing trend that is evident in the global oceans; moreover, the ensemble- averaged model results for WPI in the Southern Ocean account for around 50% of the global energy input, increasing by almost 24% (0.92 TW) over the 151 years from 1950 to 2100. In the Northern Atlantic, there appears to be a remarkable decreasing trend in WPI which can be explained by estimated reductions in the mean winds and the total number of winter cyclones over mid-latitudes, as shown by previous studies.

The Alongshore Tilt of Mean Dynamic Topography and Implications for Nearshore Circulation

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Coastal tide gauge observations in combination with the latest generation of geoid models are providing observations of the alongshore tilt of mean dynamic topography (MDT) with unprecedented accuracy. Additionally, high-resolution ocean models are providing better representations of nearshore circulation and the associated tilt of MDT along their coastal boundaries. The alongshore tilt of MDT is an important component of the alongshore momentum balance. As shown by Stewart (1989), it can also be related to the stress gradient at the coastal boundary and vorticity transport to the ocean interior. In this study, we explore how different boundary conditions and stress parameterizations affect the alongshore tilt of MDT and, conversely, what the observed tilts of MDT can tell us about nearshore circulation.

Using a regional-scale configuration of the NEMO ocean model with a grid spacing of 1/36°, the tilt of MDT along the coast of Nova Scotia and Gulf of Maine is predicted, using different lateral boundary conditions and stress parameterizations. These predictions are then compared to independent estimates of MDT based on tide gauge observations referenced to the Canadian Gravimetric Geoid model (CGG2013). We first show that the observed and predicted tilts are in good agreement. It is next shown that the nearshore circulation depends on the form of the coastal boundary condition, but, somewhat counterintuitively, the associated alongshore tilt of MDT does not. Reasons for this are given. Furthermore, we discuss the possibility of using observed alongshore tilts of MDT to validate ocean models, and monitor shelf circulation.

Baroclinic topographic Rossby waves on the Northern slope of Flemish Cap

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The Flemish Cap region is an area of high biodiversity, intense fishing pressure and active hydrocarbon exploration. Substantial concentrations of deep water corals and sponges have been observed from in situ benthic camera surveys, and this resulted in closure to bottom trawling activity in areas defined as vulnerable marine ecosystems. These closures presented an opportunity to deploy oceanographic moorings on the northern slope of Flemish Cap. We will present results from the moored measurements which indicate significant variability in currents at a period of about 20 days and show evidence that this is caused by bottom-trapped topographic waves on the slope of Flemish Cap.

Extreme low-light photosynthesis in a microbial mat from a sulfidic underwater cave

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We report extreme low-light-adapted anoxygenic photosynthesis on the surface of a thick microbial mat from 30 m depth at the cave wall of Magical Blue Hole situated on Abaco Island (Bahamas), which thus represents one of the most light-limited habitats for phototrophs known to date. In situ irradiance on a sunny December day was between 0.021 and 0.084 mol photons m^{-2} s^{-1}. We directly demonstrated light-dependent carbon uptake under slightly elevated irradiance (0.27 mol photons m^{-2} s^{-1}) and estimated a photoautotrophic carbon fixation rate of 14.5 nmol C cm^{-2} d^{-1}. A 16S rRNA clone library of the green surface mat layer was dominated (74%) by clones affiliated with green sulfur bacteria (GSB), obligate anoxygenic phototrophs. Typical photopigments of brown-colored GSB, bacteriochlorophyll e and (β-)isorenieratene, were detected in mat samples and their absorption properties are well-adapted to harvest blue-green (475-530 nm) and possibly even UV-A (350-400 nm) light, which was identified as the most abundant part of the in situ light spectrum. Hydrogen sulfide (3.4-8.3 mol S L^{-1}) is available as electron donor from the anoxic saltwater surrounding the mat below a halo-chemocline at 25 m water depth. Phylogeny, physiology and function of the mat bacteria resembles phototrophic assemblages from other low-energy environments such as the chemocline of the Black Sea. Our findings may extent the scope of environments in which phototrophy can be expected and may help to increase our understanding of low-light adapted photosynthesis.

Sound Attenuation in Water-Saturated Sand at MHz Frequencies

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During the past 20 years, significant advances have been made using acoustic remote sensing for the study of sediment dynamics in the ocean. Under energetic waves, sheet flow is thought to be the dominant sediment transport process, but there has yet been no measurement of the thickness of this thin, high-concentration moving layer in the nearshore environment. High (MHz) frequencies are needed to resolve the moving layer, but sound attenuation at these frequencies may limit penetration through the layer and thus, prevent the measurement. In order to explore the range of frequencies which might be suitable, we measured sound attenuation in water-saturated sand with median diameters of 0.22 mm, 0.4 mm and 0.5 mm. A wide-bandwidth sonar was used to obtain backscatter amplitude profiles for frequencies between 1.0 and 2.1 MHz as a function of range. Attenuation coefficients were determined based on the change in amplitude of the return signal travelling through different thicknesses of sand resting on a reflective surface. Our estimates are compared to model predictions as well as to previous experimental results reported in the literature. As acoustic frequency and/or sediment size increases, the scattering contribution to attenuation dominates the viscous loss. In this frequency range, our measurements agree with multiple scattering theories.

Fine-scale substrate features influence epibenthic megafaunal diversity on the deep eastern Canadian margin

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The influence of sediment heterogeneity on deep-water benthic megafauna may depend on the range of particle grain size, since the availability of substrate, in particular hard substrate, is an important habitat requirement. On glaciated continental margins, sediment heterogeneity varies at fine to local spatial scales (less than 1 - 100 m), but remains difficult to quantify. In this study, we performed benthic video transects with the remotely-operated vehicle ROPOS at 5 locations along a depth gradient (∼1100 - 3000 m; total transecting length: 7995 m) in the Northeast Fan on the continental margin off the Gulf of Maine (northwest Atlantic). Substrate complexity was quantified using object-based image analysis, a novel approach that uses image complexity to infer fine-scale substrate features. The density of epibenthic megafauna was recorded, and diversity was calculated with rarefaction and indices (Shannon-Wiener Index, Pielous evenness, morphospecies richness). Megafaunal abundance decreased markedly between the shallowest (∼1100 m) location and the remaining locations, mostly due to a diverse and abundant community of deep-water corals (alcyonaceans). Both diversity and substrate complexity were highest at the shallowest and deepest (∼3000 m) locations, and lowest at mid-depths (∼2000 m). We concluded that sediment heterogeneity influences diversity, but not abundance of megafauna in the area. In particular, the sporadic presence of boulders provided heterogeneity at a local scale in an otherwise homogeneous substrate of fine-grain sediment. Given their potential ecological importance in the deep sea, seafloor fine-scale features should be included into habitat studies, but quantifying their distribution at larger spatial scales remains challenging.

Seasonal mortality trends for *Calanus* in the Northwest Atlantic: managing sampling variability and explaining regional differences

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Copepods are key trophic linkages in marine ecosystems, dominating zooplankton biomass, regulating primary production, and serving as food for many higher predators, with mortality shaping these processes. Since mortality varies among life stages, regions, and seasons, accurate estimates are essential for understanding copepod dynamics, associated trophic linkages, and predicting ecological responses to climate change. Mortality is commonly estimated using the vertical-life table (VLT) methods, estimating average mortality across a stage-pair using the ratio of stage abundances from field samples. Many sources of uncertainty are associated with these methods, some well-known, while others subtle and perhaps unrecognized. Few studies have investigated data application, such as different approaches to generate regional mean mortalities (i.e. multi-station averaging), or coping with discontinuities in stage abundance data (e.g. zero values) whether real or a result of sampling variability. Here, we examine how these issues affect our confidence in mortality for *Calanus finmarchicus* copepodites from the Newfoundland shelf and Labrador Sea. We consider four averaging approaches from the literature; (A) mean station-specific mortality, (B) mean station-specific abundances, (C) mean station-specific stage-ratios, and (D) non-linear regression (not exactly an averaging technique but is a method commonly used throughout the literature), and for each we investigate the effect of including discontinuities. We show that different approaches generate similar means, but differ regarding variance. In particular, we show that confidence intervals of certain approaches do not capture the true range of estimates, and choices to include or neglect discontinuities result in different trends among stages or seasons. We conclude by recommending best present-day practices and suggest future studies that would improve forecast reliability by reducing uncertainty.

Hurricane Arthur and its effect on the short term variation of pCO2

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Seasonal changes in carbon cycling over the years have become better understood on the Scotian Shelf, however little is resolved in short term variation. Hourly measurements were collected from an autonomous moored instrument (CARIOCA) stationed at Halifax Line 2 (HL2), roughly 30 km off the coast of Halifax for the 2014 year. Data from the 2007 deployment of the SeaHorse vertical sampling mooring at HL2 was also collected. Focusing on the storm event, Hurricane Arthur, July 5th 2014 reveals a significant drop in pCO2. With the shelf having carbon rich deep water, a reduction of pCO2 due to mixing went against current understanding. It was revealed that slightly above the mixed layer there is a sustained population of phytoplankton. When wind mixing from storms occurs, this population moves to the surface allowing greater light and nutrients for short term growth. This growth then reduces pCO2 for a short period of time until wind speeds slow down reducing mixing of the water column.

Colonization and Early Development of Sessile Benthic Invertebrate Communities on Tropical Artificial Reef Structures

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Coral reefs are being severely degraded by multiple anthropogenic and climatic disturbances. Active restoration methods are being used increasingly to mitigate further damage and possibly restore coral-dominated ecosystems. One of these methods is the deployment of artificial reefs (ARs). In 2010, a floating AR was suspended in open water at the northern end of the Gulf of Aqaba (Israel) as a novel conservation measure. Our objective is to quantify rates and patterns of colonization and early development of the sessile benthic invertebrate community on the suspended AR, a benthic AR, and adjacent natural reefs for 12 months. This study will be the first to examine the efficacy of the suspended AR. Understanding the role of AR structures in sustaining reef assemblages has direct applications for the management and restoration of coral reefs in a changing climate. The interpretation of results from this experiment will provide recommendations for future AR design and implementation to maximize benefits to coral-dominated ecosystems.

The recipe of water entering the Laurentian Channel

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Under-water submarine canyons are recognized as conduits that enhance the shelf-ocean exchange. The Laurentian Channel extends about 1400 km from the shelf-edge to the St. Lawrence River Estuary. Connecting the North Atlantic Ocean and the Gulf of St. Lawrence via the Cabot Strait. The transport entering the GSL through the Cabot Strait constitutes the major avenue (∼80%) of water exchange between the Gulf of St. Lawrence and the North Atlantic Ocean. And observations suggest that up to two thirds of the long term decline in oxygen levels in the bottom waters of St. Lawrence estuary can be attributed to changes in the constituents of waters entering the Laurentian Channel. However, the whole picture is not fully revealed. A coupled circulation-ice model based on the NEMO, driven by a suite of external forcing including tides, atmospheric forcing and river runoff, is used in this study. The model captures a warm tongue centered at ∼250 meters depth, below the Cold Intermediate Layer, which is coherent to observations. The implication of the impact of the variability of Slope Water at the mouth of the Laurentian Channel on the Gulf of St. Lawrence is discussed.

Identifying optimal sets of ecosystem indicators: A comparative study of data analysis methods and regional results

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Many living marine resources are overexploited, and there is a global call to adopt more holistic ecosystem- based fisheries management (EBFM) approaches, which consider interactions among multiple species in the context of changing environment and socio-economic priorities. Implementing this type of management requires scientists and decision-makers have information on the ecosystem status and trends, which can be provided by data-based indicators. Recommendations on how to select and integrate sets of indicators that can address EBFM objectives are vague and largely qualitative.

We investigated quantitative approaches to identifying indicator sets that can simultaneously predict several measures of ecosystem status while accounting for connections among biological communities, environmental factors, and human activities. We defined ecosystem status by the biomasses of three key functional groups (benthivores, planktivores, and piscivores) for two distinct regions of the Northwest Atlantic (Grand Banks and Georges Bank), which each represent data-rich, historically important fishing grounds with different management strategies and environmental conditions. Indicators were synthesized from diverse data sources, including research surveys, commercial data, and environmental monitoring for the past 30 years. Sophisticated regression and neural network methods were each used to identify sets of indicators with the highest explanatory power and least redundancy. Pros and cons of each method are presented, and preliminary results are discussed in the context of management decisions and environmental drivers associated with each region.