C-DOGS 2011

Conference of Dalhousie Oceanography Graduate Students

Friday March 18, 2011
8:30*am* - 5*pm*, Great Hall
Dalhousie University, Halifax, Nova Scotia

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Satellite remote sensing of turbidity in the Mackenzie River Delta

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High-resolution MODIS bands can be utilized to remotely infer turbidity levels. We present initial methods and results applying this technique to the Mackenzie River Delta.

Exploring the effect of turbulence on copepods using copepod size as the proxy.

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Biophysical relationships are complicated and experiments examining them often have inconclusive results. The relationship between turbulence and copepods is not fully understood, hence reliable, coincident, in-situ observations of both turbulence and copepods are needed to explain the interaction. A new biophysical instrument, a Vertical Microstructure Profiler/Video Plankton Recorder was deployed in Bedford Basin in Fall 2010 to study the interaction between the the zooplankton and turbulence. Using these data and published studies, I will explore whether copepod size is the primary factor in determining the effect of turbulence on copepods. This will further knowledge of how and if copepod distributions are altered by turbulence and if turbulence is triggering a behavioural response in copepods.

Implementation of the two-scale approximation for increased accuracy in the wave energy balance equation.

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Accurate evaluation of the non-linear wave-wave energy transfer represents a significant proportion of the computation time of ocean wave models. Being the only way to calculate the wave-wave interactions rapidly enough, the Discrete Interaction Approximation (DIA) developed within the first version of the WAM model (WAMDI, 1988) is still the only algorithm to be used today in operational wave modelling. The implementation of a mathematical equivalent of the Two-Scale Approximation (TSA) in a modern third generation wave model, WAVEWATCH III (WW3), should demonstrate the possibility of having an accurate representation of the spectral distribution of wave energy in wave models. Preliminary results (Perrie et al., 2009) have shown that the TSA offers a better representation of wave interactions, while the theory behind the TSA should allow for a computation time similar to the DIA. A brief introduction to the theory of wave modelling will be presented, along with results such as fetch curves and output from SWAMP-type tests, for the DIA, TSA and an exact method.

Carbon allocation to lipid vs. carbohydrate in four species of microalgae as influenced by environment and genotype

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Efficient biofuels production from the mass culture of microalgae requires high rates of lipid synthesis, often stimulated by nutrient stress; however, carbohydrate synthesis directly competes for available carbon. The effect of environment vs. genotype on lipid synthesis was studied by subjecting four species of microalgae to nitrogen starvation at two different irradiances and measuring lipid and carbohydrate during a 12 h : 12 h light : dark cycle. We found that during nutrient-sufficient balanced growth, concentrations of non-energy storage compounds (chlorophyll and protein) relative to energy storage compounds (lipid and carbohydrate) varied between species, with more lipid than carbohydrate at low light. As nutrient stress increased, carbon primarily accumulated as lipid and carbohydrate; with carbon allocated more towards carbohydrate as stress continued. The approximate final ratio for carbon present in non-energy-storage compounds vs. energy-storage compounds (70%) was similar between irradiances. Our results show that carbon allocation, to non-energy storage compounds vs. energy storage compounds, varies with environment and genotype, supporting existing literature. Our data also show that nutrient stress is an important lipid synthesis stimulator, and suggest that genotype is more influential than irradiance during nutrient starvation.

Estimation of carbon fluxes using a Radium isotopic method

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Tracing the flows of various chemical constituents or pollutants in coastal and near-shore environments is of interest to marine scientists and ecologists alike. While the open ocean carbon system is relatively well understood, coastal environments remain a significant area of uncertainty in global ocean carbon budgets. More recently, short-lived dissolved Radium isotopes (223Ra and 224Ra) have become increasingly popular tracers for various studies in these environments. This is mainly due to the fact that they decay on timescales similar to many coastal processes, and their distribution is influenced only by the distributions of their sources (ie. no biological affects). The objective of our work is to develop a Radium isotope method to make estimates of diffusive coefficients and determine carbon fluxes. Preliminary results indicate the potential for describing diffusion both veritcally near sediments in Bedford Basin and offshore in the Halifax area. The reliability of the method and the further use of the diffusive estimates in determining carbon fluxes will also be explored.

Turbulence measurements on an internal beach

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Measurements of turbulent dissipation in the ocean can be used to infer vertical mixing. Here we present a technique for quantifying turbulence in an estuary, toward understanding contributions to mixing from breaking internal waves.

A War Zone: Ice formations in the Minas Basin

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Minas Basin has the largest tidal range in the world. The currents responsible for moving the enormous volumes of water make the Basin an effective site for tidal power generation. In winter, blocks of ice build up along the banks of the Basin. Blocks with high concentrations of sediment can be negatively buoyant and could pose a threat to downstream turbines. This talk will be a qualitative discussion of how sediment-laden ice blocks form and how they are released from the banks into the currents.

Spatial Distribution and Habitat Characteristics of Cold-Water Corals and their Associated Fauna in the Gulf of Maine

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The conservation of cold-water corals requires high-quality information on their spatial distribution and habitat characteristics. Off the continental margin of the Gulf of Maine, the Northeast Channel Coral Conservation Area (NECCCA) was established in 2002. The present research aims to provide crucial baseline information on coral populations, and habitat distribution within the NECCCA, and to determine other conservation needs in the region. In order to determine the spatial variability of cold-water corals and their associated fauna, we performed in 2006 and 2010 video transects in the NECCCA, outside of the NECCCA (but within Northeast Channel), and deeper seaward of the NECCCA down to a depth of 3,000 m. Moreover, photographic surveys were performed in other regions of the Gulf of Maine in 2009. Such data will reveal habitat characteristics by associating coral abundance (number of colonies and height) with physical parameters from the sampled areas (depth, bottom temperature, salinity, current speed, substrate and slope). Additionally, spatial analyses, through the use of georeferenced occurrences, will identify patterns of abundance at various scales (10s m-km).

Dissolved hydrogen concentrations in the North and South Atlantic - a possible indicator of nitrogen fixation

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It has been shown that nitrogen fixation is a source of hydrogen (H_2) to the ocean and therefore measurements of H_2 supersaturation may be used as a possible indicator of nitrogen fixation. However, the limited number and sparse distribution of measurements of dissolved hydrogen and nitrogen fixation rates made in the open ocean in the past have made it difficult to demonstrate. A new method of equilibrating seawater samples for H_2 measurement was employed along a 13,000km transect from the UK to Chile, allowing H_2 to be measured every 3.5 minutes. In addition to continuous measurements made on underway samples, measurements were also made on vertical profiles sampled at pre-dawn and solar noon stations. High concentrations of H_2 were observed at $\sim$10°N in the same region as a bloom of *Trichodesmium*, an important nitrogen fixer. These high-resolution measurements will be compared with nitrogen fixation rates measured by a collaborating group using a $^{15}N_2$ tracer method, to assess the practicality of using H_2 supersaturation to indicate regions of nitrogen fixation.

Relating grain size to meltwater plume dynamics during Heinrich event 1

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Throughout the last glacial period (10–85 kyrs BP), massive amounts of icebergs were discharged periodically from the Hudson Strait region during so-called Heinrich (H) events. These iceberg armadas transported sediments that were deposited in distinct layers across the North Atlantic as they melted. The occurrence of H events has been correlated with disruptions in deep ocean circulation and cold events recorded in Greenland ice cores. While the presence of H layers in marine sediments is well-documented, the causal mechanism and many of the details surrounding the events are still debated. My thesis research focuses on H1, the most recent Heinrich event, which occurred ∼16 kyrs BP. The H1 layer was sampled in 11 piston cores located along-slope from the mouth of the Hudson Strait to the southern Scotian shelf, and grain size distributions were determined using a Coulter counter. Sedimentological concepts relating grain size observations to meltwater plume dynamics are applied to H1 layer sediments in these cores to determine whether this ice-rafting event was accompanied by significant meltwater discharge. Results suggest that H1 layer sediments were mainly delivered by ice-rafting and that the H1 event was not accompanied by significant single-source meltwater discharge, as has been suggested previously. However, the occurrence of a meltwater plume not carrying suspended sediment cannot be ruled out.

Application of a Multi-Nested Ocean Circulation Model for Investigating Circulation, Flushing Time and Dispersion in Halifax Harbour and Adjacent Waters

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A multi-nested coastal ocean circulation modelling system is used to simulate the three-dimensional circulation and hydrography of Halifax Harbour forced by tides, wind and sea level pressure, surface heat fluxes and terrestrial buoyancy fluxes associated with river and sewage discharge. The multi-nested modelling system has a five-level downscaling with a coarse-resolution (1/12°) outer-most model for the eastern Canadian shelf and a fine-resolution (200 m) inner-most model for Halifax Harbour, Bedford Basin and adjacent waters. The results produced by the inner-most model are used to examine the role of tides, wind forcing and freshwater discharge in driving circulation and dispersion in the study region. The dispersion and retention in the Harbour are studied based on numerical passive tracer and particle tracking experiments. The e-folding flushing time is estimated to be about 40 and 90 days in the upper and entire Bedford Basin, 2-5 days over the Inner and Outer Harbour, and about 1 day in the Narrows. Hydrodynamic connectivity in the Harbour is also examined using a transition matrix calculated from particle trajectories. Within five days under calm conditions, about 75% and 85% of particles remain in Bedford Basin and the Northwest Arm,

respectively; and nearly 90% of particles are flushed to the open sea in the Outer Harbour. Our results also demonstrate that particle movements and hydrodynamic connectivity in the Harbour vary significantly during different storm events.

Random walk based modelling of green sea urchin larvae in response to thermal stratification

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The transport of larvae in the ocean can be affected by their vertical position in the water column. Biophysical models are often used to predict dispersal of larvae, but vertical positions are often assumed. The purpose of this investigation is to evaluate the skill of one dimensional random walk based model at predicting the vertical distribution of *Strongylocentrotus droebachiensis* larvae in response to thermal stratification. Vertical swimming velocities were recorded at various temperatures and used to parameterize the model. Data from a previous laboratory study on the effects of thermal stratification on the vertical distribution of *S. droebachiensis* were compared to the model results to assess model skill. Preliminary results indicate that the model predicts general trends in vertical distribution fairly well, but lacks accuracy at temperature extremes. Collectively, the findings suggest that behavioural models parameterized using simple lab experiments can be very useful in estimating the vertical distributions of invertebrate larvae.

Measuring large temporal scale water mass variation in a dynamic basin: Sparse data considerations

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In order to broaden the applicability of sparse physical data, the spatial and temporal variability of physical variables in water masses is compared. Variability in water masses is tied to the abundance of yummy whale food (copepods and plankton friends) in Roseway Basin. Salinity, temperature and density variations over time and space are compared to evaluate the representative nature of a spatial mean. Results indicate that spatial variation of physical variables is of a comparable scale to the temporal variation; therefore, it is likely that spatial averaging is not representative of the basin scale temporal variation in physical variables that would influence copepod availability. These results suggest that Kim will have a hard time explaining the results of her thesis.

Quantitative estimation of the radiance distribution in the dynamic sea surface water

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This is an update to our last reports at Ocean Optics XX Conference in 2010. We developed a unique instrument (radiance camera, a.k.a. RadCam) for measuring the radiance along every direction in air and in water. The camera has a fisheye lens (180° FOV) and a high-dynamic range (up to 106) CMOS imager. The calibrate camera is capable of imaging the full radiance field, including the sun, in absolute sense, and at a fairly fast speed (up to 15 Hz). Our recent observations in oliotrophic, mesotrophic and eutrophic waters have captured the dynamic features and fine structures of the radiance field. In this presentation, we will describe the general picture of the underwater radiance field, as well as its variability due to the Sun's glitter pattern and wave disturbance. We demonstrate the derivations of optical properties (irradiance, average cosine and absorption coefficient) from the measured radiance distribution in three optically distinct waters. Last we'll show the data-data and model-data agreements. The current study uses a wavelength of 555 nm.

Comparative assessment of a two-layered and a multi-layered sediment model

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Coastal sediments are in continuous interaction with the overlying water column, collecting and decomposing the incoming rain of organic detritus into inorganic nutrients, and consuming oxygen in the process. Here we compare the ability of two qualitatively different sediment models, a two-layered and a multi-layered model, to quantify the biogeochemical transformations that occur when detritus is decomposed in the sediment. We have optimized both models by estimating unknown model parameters as well as organic matter inputs to the sediment by means of parameter optimization using an evolutionary algorithm. This method represents a systematic way of minimizing the misfit between model simulations and observations. The observations are from a mesocosm eutrophication experiment carried out at the University of Rhode Island's Mesocosm Experimental Research Laboratory. We have optimized selected model parameters and the mean depositional fluxes of organic matter. Simulations with constant depositional fluxes outperformed simulations where deposition was dependent on proxies of biomass concentration in the overlying water. Given optimal depositional fluxes, both models produced similar nutrient fluxes across the sediment-water interface, although the two-layered model was able to match the observation slightly better. Both models show an increase in nitrification and denitrification rates under more eutrophic conditions.

A simple conceptual model of plankton dynamics in aquatic systems

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Phytoplankton biomass in aquatic systems results from the balance between the time scales of biological processes (growth, losses) and transport. To describe the phytoplankton response to changes in transport, and hence to predict the dynamics of a pelagic system, the rates of phytoplankton growth and loss must therefore be known. Here, we present a simple nondimensional conceptual model that describes plankton dynamics in an aquatic system directly from the nutrient concentration available in source waters and the flushing rate of the system. The model is based on a simple plankton ecosystem (PZND) and is represented in a graphical form by scaling nutrient concentration and flushing rate with the appropriate phytoplankton physiological variables. The patterns that emerge from the model reveal the existence of an optimum 'window' for the accumulation of phytoplankton biomass in an aquatic system at intermediate transport time scales when nutrient is sufficient. Within this range, the balance between the rates of nutrient delivery, losses to secondary producers and phytoplankton export is optimal for the local accumulation of phytoplankton. This model is a useful, first order tool to describe or predict plankton dynamics in an aquatic system given limited knowledge of the system.

Chlorophyll chaos - Uncovering time dependence of optimal parameter values in a biological ocean model

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High-resolution physical-biological models of coastal ocean regions are becoming increasingly sophisticated and realistic. However, one major difficulty with these models is the need to specify biological parameters, many of which are poorly constrained and not directly observable. Variational methods have been used extensively to identify optimal biological parameters, typically by assuming that parameters are constant in space and time. As an alternative method that does not rely on this assumption, we present polynomial chaos, a technique for stochastic models that relates the uncertainty in the model inputs (parameters, initial or boundary conditions) to uncertainty in its outputs. For many stochastic dynamic systems, it can be used as an alternative to Monte Carlo methods, which are often computationally much more costly. We explore the utility of polynomial chaos as a parameter and state estimation technique for a 3D biological ocean model of the Middle Atlantic Bight. Our model is based on the Regional Ocean Modeling System (ROMS) and includes a biological module describing the nitrogen cycle. Using a 1-year dataset of chlorophyll satellite observations of this region, we apply polynomial chaos to estimate the time-dependent model-data

distance function. This data assimilation exercise shows that optimal biological parameters are time-dependent and that biological parameters with a seasonal cycle provide better agreement with the observations than the optimal fixed parameter set.

Direct measures of particle dispersion and application to numerical model validation

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Dispersion estimates were measured through the use of magnetically attractive particles (MAPs) and moored magnetic-collector arrays. Collectors were moored within predicted dispersal domains (nominally $2 - 4 \times 10^3$ km^2) enveloping putative "sink" locations based on empirically-driven, 200 m and 2 km resolution, 3D hydrodynamic models. At a source location within a given array, $\sim 10^9$ MAPs (nominally 300 μm diameter) of a near-surface buoyancy were released and allowed to disperse over time (nominally 5-7 d) after which the collector array was retrieved and the number of MAPs captured by each collector were enumerated. These numbers were then used to estimate dispersion and the relative probability of physically-driven Lagrangian exchange within the dispersal domain. The estimates were then used to validate the hydrodynamic models (real-time conditions) by comparing the time integral of the model-particle concentrations at each of the collector locations (expected) against the MAP abundance estimates at each collector in the field (observed). Deviations between the expected and observed were used to assess model parameters. Our results show that a higher than expected random walk diffusion parameter is necessary for the models to best reproduce the observed MAP dispersion.

Reconstructing the Madden-Julian Oscillation Index Over the Last Century

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The most widely accepted characterization of the Madden-Julian Oscillation (MJO) is the bivariate index developed by Wheeler and Hendon [Monthly Weather Review, 2004]. This index relies in part on satellite-based observations of outgoing longwave radiation and thus is not defined for the pre-satellite era. The MJO is known to have a strong signature in surface pressure and daily measurements of this variable are available as far back as the late 19th century. This study undertakes a

statistical reconstruction of the Wheeler and Hendon MJO index from 1905 to 2008 based on tropical surface pressures estimated recently by the 20th Century Reanalysis Project. The reconstructed index is validated by first demonstrating that its temporal and spectral properties are consistent with the Wheeler and Hendon index over the common period (1979-2008). It is then shown that (i) the low frequency variability of the reconstructed index is also found in independent observations and (ii) relationships between the reconstructed index and various meteorological and oceanographic properties are consistent with the Wheeler and Hendon index.

Effects of biofilms on sediment sortability

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Microorganisms living on the sediment surface form biofilms, which are thought to preferentially retain fine grains. This process should, in turn, promote microbial growth due to increased nutrient availability. Our study compared the sediment artificially re-suspended from cores with a destroyed biofilm to the sediment re-suspended from intact cores, in order to investigate size-specific grain retention by biofilms. The talk will offer exploratory results, as well as additional details on the methods employed.

Patterns in the vertical distribution of larvae of marine benthic invertebrates

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Meroplanktonic larvae have been traditionally considered to behave as passive particles in the water column, and their dispersal attributed to advection along dominant directions of flow. However, these larvae may influence their horizontal transport by sinking or swimming between layers of different velocities. We investigated whether the vertical distribution and abundance of different functional groups of meroplankton (e.g. gastropods, bivalves, bryozoans, polychaetes), with contrasting life history strategies and swimming mechanisms and abilities, vary periodically on lunar, tidal, and/or diel cycles in the field. Plankton samples were collected at 6 depths (3, 6, 9, 12, 18, 24 m) using a pump, at each tidal phase over a 25- and a 36-h period, during a spring and neap tide, concurrently with measures of temperature, salinity, and current velocity. Preliminary results indicate that larval vertical distribution varies on each of the measured cycles, but differently among functional groups and among species within a functional group. Interestingly, variation in relation to the density structure of the water column was not observed. For many of the functional meroplankton groups we

sampled, their responses to cues (e.g. salinity, temperature, food) have been measured in laboratory experiments, allowing us to associate changes in larval vertical distribution in the field with measured behavioural responses in the laboratory. Quantifying the role of larval behaviour in the field can augment the quality of estimates of dispersal potential of different larval functional groups.

Is there a tilt in mean sea level along the east coast of North America?

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The mean sea surface topography (MSST), and hence the mean surface geostrophic circulation, can be estimated using a geoid model and a satellite altimeter-derived mean sea surface. Near to shore, where the accuracy of the satellite altimeter measurements is lower, tide gauges referenced to a common geodetic datum provide an alternative estimate of mean sea level. Earlier work identified tilts of MSST along the east coast of Canada and along the US east coast south of Cape Hatteras. We calculate MSST using a new geoid model, developed by Natural Resources Canada, and tide gauge data from 29 stations along the east coast of North America for the period from 2000 to 2009. We will show that the improved accuracy of the geoid model removes the tilt along the Canadian coastline but a tilt remains south of Cape Hatteras. We compare the results with sea surface heights from an ocean model and suggest a mechanism to explain this tilt.

Application of Spectral Nudging to NPZD-type Models.

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A spectral nudging technique was proposed by Thompson et al. (Ocean Modelling, 2006, 13:109-125) to reduce model drift and bias in a 3-dimensional physical ocean model. A desirable feature of the spectral nudging technique is that it can preserve high frequency variability that would be dampened with conventional nudging techniques. Here, we aim to apply the spectral nudging method to simple Nitrogen-Phytoplankton-Zooplankton-Detritus (NPZD) models. A first step is to show that the method works for idealized models. We show here the difficulty in combining high frequency nutrient upwelling events (on time scales of days to weeks) with a climatological annual cycle in a system with nonlinear (state-dependent) transfer function.
