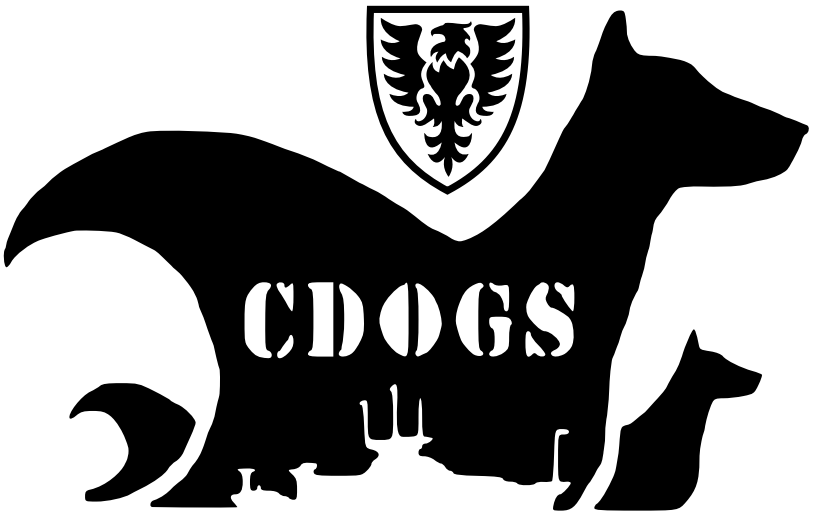

CDOGS 2018

Conference of Dalhousie Oceanography Graduate Students

Friday March 23, 2018
8:30 - 17:30, McInnes Room, Student Union Building
Dalhousie University, Halifax, Nova Scotia

Contents

Wave-Current-Turbulence Interactions in a High-Flow Tidal Channel

Colleen Wilson[1]

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Grand Passage has been identified for in-stream tidal turbine development as a predictable, high power density, renewable energy source, and is the site for this work. A shore-connected bottom mounted Acoustic Doppler Current Profiler (ADCP) sampling at 2 Hz for 10 days in January/February 2015 spanning a storm with 80 km/h northerly winds recorded tidal current maximum speeds of approximately 2 m/s. Wave height and wave number are estimated from the velocity variance vertical structure in the gravity wave band. Independent estimates of the wavenumber are obtained from the measured phase speed, and compared to the predictions of linear wave theory, including the effects of vertical shear. The analysis also yields an estimate of the turbulence dissipation rate. Maximum wave heights were approximately 2 m, when current and waves oppose. During low wave conditions, the mid-depth turbulent dissipation rate was O(10^{-4}) W/kg, and increased with larger waves.

Surface Wave Effects on the Wind-Power Input to Mixed Layer Near-Inertial Motions

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Surface gravity waves alter fluxes of momentum and energy from winds to currents across the air-sea interface. This study uses a simple slab model of the ocean surface boundary layer and a spectral wave model to evaluate the impact of surface gravity waves on the Wind-Power Input (WPI) to near-inertial motions (NIMs). Two experiments are specifically designed: a numerical model at a single point and a global ocean mean time analysis. The single point experiment found that WPI and near-inertial kinetic energy (NI-KE) are overestimated by 20% and 40% respectively when wave effects are not accounted for. The WPI is overestimated globally by 10% on average (12% in winter, 6% in summer) during 2005-2008 with two main regions of reduction: the mid-latitudes in the northwest Pacific and Atlantic Oceans and a band of winter storm-track regions in the Southern Ocean. These regions correspond to large inverse wave ages. However, the contributions from surface gravity waves to WPI are only significant in the presence of hurricanes or other high wind storms. Despite the relatively low frequencies of occurrence of wind seas, input from intermittent growing young waves on WPI (occurring less than 10% of the time) makes up the dominant contribution to WPI overestimations. Since NIMs play a large role in upper-ocean mixing (especially their shear at the base of the mixed layer), reductions of momentum fluxes to NIMs due to growing waves will in turn reduce the mixing. This highlights the importance of accounting for surface gravity waves in atmospheric-ocean coupled models in order to realistically represent upper ocean mixed layer physics.

Tidal Modulations of Surface Gravity Waves in the Gulf of Maine

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This study examines the tidal modulation of surface gravity waves in the Gulf of Maine (GoM) based on in-situ observations and numerical results. Analysis of observational data demonstrates significant semidiurnal tidal modulations in the mean wave variables in the region. The observed tidal modulation features significant spatial-temporal variabilities, with large magnitudes near the mouth of the GoM particularly during high sea states. The favorable conditions for the tidal modulation are found to be swell-dominated waves associated with relatively stable wave propagating directions. The large tidal modulation in the wave height occurs at several different tidal phases, indicating the effect of nonlocal tidal currents. The coupled wave-circulation model successfully reproduces the observed tidal modulation and associated spatial-temporal variabilities. Process-oriented numerical experiments demonstrate that the observed tidal modulation is associated with the current-induced advection, refraction, and wavenumber shift. The current-induced modulation of wave dissipation becomes as important as other three mechanisms during high winds by weakening the tidal modulation. Model results also demonstrate that the accumulated effects of nonlocal tidal currents across Georges Bank (GB) determine the observed unusual timing of the maximum tidal modulation in the wave height behind GB in the following tidal currents. Consequently, both amplitude and phase of the tidal modulation behind GB are indirectly controlled by the strong tidal currents on GB. The amplitude could reach 0.4 m behind GB, and the phase propagates towards the inner GoM with a wavelength of 40 km. Over GB, by comparison, the amplitude of the tidal modulation is relatively small (0.2 m).

Reducing vessel strike risk to North Atlantic right whales in the Gulf of St. Lawrence

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Vessel strikes serve as the leading source of mortality for endangered North Atlantic right whales (*Eubalaena glacialis*). During summer of 2017, an unusual mortality event took place in the Gulf of St. Lawrence, during which a minimum of 12 right whales died. Of 7 animals necropsied, at least 4 presented with acute blunt trauma consistent with vessel strike injuries. From 11 August through 31 December 2017 a slowdown zone (10 knot maximum) impacting vessels greater than 20 m was enacted by the Government of Canada in the western Gulf of St. Lawrence to prevent further mortality. To identify zones of elevated vessel strike risk, risk maps were constructed for both before and during the mandatory slowdown. Data regarding the spatiotemporal distribution of right whales were obtained from aerial and vessel-based cetacean surveys. Data regarding mean vessel speed and spatiotemporal distribution of class A vessels ($\geq$20 m) were obtained via Automated Information System (AIS). The relative probability of vessel strikes and lethal vessel strikes were calculated for before and during the mandatory slowdown. The results of this study will inform marine policy decisions by determining how vessel strike risk to right whales can be reduced most effectively in the Gulf of St. Lawrence.

A data-assimilative physical-biogeochemical model for the Gulf of Mexico

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The Gulf of Mexico is a site of significant oil and gas exploration and extraction activities with potentially harmful effects on the surrounding ecosystem, as seen, for example, during the 2010 Deepwater Horizon oil spill. In addition to such catastrophic events, ocean ecosystems, including those in the Gulf, are under increasing pressure from ocean warming, acidification and deoxygenation. Numerical models are useful tools for short-term prediction, and to improve our understanding of long-term changes, but thus far a lack of high-resolution ocean observations has made it difficult to validate and improve physical-biogeochemical models. We are developing a data-assimilative physical-biogeochemical model for the Gulf of Mexico with the goal of improving predictive power of how natural variability, anthropogenic effects, and climate change affect marine ecosystems now and in the future. The model will assimilate physical and biogeochemical observations from satellites and autonomous floats including sea surface height, seas surface temperature, sea surface chlorophyll, and profiles of temperature, salinity, chlorophyll, particulate organic carbon, and oxygen. Initial model results will be discussed in the context of our long-term objectives.

A First Step Toward Downscaling Subseasonal Predictions of Ocean Extremes

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Extreme events in the marine environment can have multiple negative impacts including loss of life, damage to infrastructure and ecosystems, and disruption of transportation. Early information about the likelihood of future extreme events is clearly critical for decision makers in order to issue effective warnings and develop strategies to mitigate potential negative impacts. A promising way of providing subseasonal-to-seasonal (S2S) predictions of the atmosphere and ocean with lead times of 10 to 30 days is based on numerical models of the atmosphere and ocean. Before using an ocean model for predictions, it is important to assess its ability to capture all relevant processes. Coupling across scales is of particular importance for ocean extremes and it is hence important to validate the representation of all scales and their interactions in ocean models.

The tilt of MDT along the coast can be used to make inferences about the nearshore and offshore circulation and is thus potentially useful for model validation on both local and regional scales. Direct comparison of models and observations can only be made at tide gauges with hourly records that exceed several years in length. This severely limits the locations at which both approaches can be compared as many records are only a few months long.

The number of tide gauges with long records is insufficient for validation of small-scale processes. In shallow, tidally-dominated regions, MDT is dominated by nonlinear interactions involving tidal currents and sea level leading to higher tidal harmonics in these regions. We will show that in these regions it is possible to use overtides (e.g., M_4) to independently assess the accuracy of the MDT predicted by ocean models. The advantage of this approach is that overtides can be estimated from relatively short (order one month) sea level records and this greatly increases the number of locations at which the ocean model can be evaluated. This approach also assesses the ability of the model to simulate correctly the underlying nonlinearities. In this presentation the mean tilts of sea level along the coast of Nova Scotia and the Gulf of Maine resulting from the hydrodynamic and geodetic approaches are compared. The then illustrate how observed amplitudes and phases of M_4 can be used for evaluating a nested configuration of the NEMO ocean model for the Gulf of Maine/Scotian Shelf system and the tidally-dominated Bay of Fundy system. The use of overtides in terms of specifying the horizontal resolution and the bathymetry of nested ocean models will be discussed.

Elucidating carbon transport mechanisms that drive air-sea CO_2 fluxes on continental shelves: A numerical modeling study for the Scotian Shelf

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Previous studies of the Scotian Shelf have yielded conflicting results, some identifying it as a source, others as a sink, of atmospheric CO_2. In order to resolve these inconsistent estimates of air-sea CO_2 flux, a quantitative understanding of the underlying carbon transport mechanisms is needed. Two main mechanisms have been proposed to explain the behaviour of continental shelves as either sinks or sources of CO_2. The continental shelf pump, which is thought to apply to continental shelves in general, posits that effective transport of carbon from the shelves to the subsurface open ocean creates a sustained sink of CO_2. In contrast, the Scotian Shelf has been described as an upwelling system, where carbon-rich water is brought from the deep ocean onto the shelf sustaining a source of CO_2 to the atmosphere. To investigate these mechanisms for the Scotian Shelf, we employ a biogeochemical model that reproduces inorganic carbon observations well. Implementation of passive dye and age tracers in the model allows us to elucidate transport pathways. Model results show that the shelf is, overall, neutral with regard to air-sea CO_2 flux, while the near-shore site of a carbon time series acts as a source of CO_2. Mean residence times on the shelf are relatively long. Analysis of transport pathways shows that water moves along the shelf, but does not cross the shelf break efficiently. The presence of a shelf break current, separating the broad Scotian Shelf from the adjacent deep ocean, effectively prevents both previously reported mechanisms, i.e. outgassing of upwelled inorganic carbon from the deep ocean and export of carbon via the continental shelf pump. This finding likely applies to other coastal regions with broad continental shelves that are bounded by shelf break currents.

Inorganic Carbon Cycling in Scotian Shelf waters

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The stable carbon isotopes of dissolved inorganic carbon (DIC) can be used as a strong signal of biological processes in carbon cycling, however, so far, few, if any, studies have been conducted on Scotian Shelf (NW Atlantic) waters focusing on $^{13}C/^{12}C$ (^{13}C). In this study, the spatial-temporal distributions of DIC and ^{13}C in Scotian Shelf waters are investigated. The data were collected in April and October of 2014 as a part of Atlantic Zone Monitoring Program. Throughout the research period, a combination of biological processes such as photosynthesis, river input and air-sea exchanges resulted in the changes of DIC concentration and ^{13}C in the surface waters. From the vertical profiles of DIC and ^{13}C, the Deep Western Boundary Current signals are captured and discussed, as these deviate from the biologically dominated pattern of the remaining water masses observed at the Scotian Shelf. Based on this research, a proper baseline of carbon cycling in Scotian Shelf waters is presented.

Timescales of beach cusp evolution on a megatidal mixed sand-gravel beach

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Observations are presented of beach cusp evolution on a steep (1:10 slope), megatidal (8-12 m range), mixed sand-gravel beach at the head of the Bay of Fundy, Nova Scotia. Cusps had mean wavelengths of 3-6 m and displayed pronounced horn-bay sediment size segregation, with their occurrence limited to the upper third of the beach face. Shoreline positions were estimated at three minute intervals from time-averaged video imagery, allowing the observation of cusp formation, evolution, and destruction at previously unreported temporal scales. One event that exhibited pronounced topographic relief is examined in detail. Forcing conditions were weak, with significant offshore wave heights of 10-20 cm and peak periods of 4-7 s. Relict cusp morphology was inundated with the rising tide and reworked during high tide, with new cusps being formed during the falling tide. Timescales of growth and decay were short, ranging from 10 to 30 mins. The results suggest the influence of grain-size dependent feedbacks on the timescale of observed beach cusp evolution.

Variability of Turbidity and Sea Surface Temperature from Landsat 8 Imagery within the Columbia River Estuary

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The higher spatial resolution imagery from Landsat 8 satellite was applied to characterize the spatial distribution of Sea Surface Temperature (SST) and near-surface turbidity in the Columbia River Estuary (CRE). The brightness temperature values from Landsat 8's Thermal Infrared Sensor Band 10 (100 m resolution) were atmospherically corrected and validated to create an SST product in the CRE. Turbidity was calculated over the CRE using atmospherically corrected remote sensing reflectance, R_{rs} (655 nm, 30 m resolution). The Landsat 8 SST retrievals and turbidity estimates correlated well with in situ temperature and turbidity, respectively. As a result, we can identify salinity fronts remotely using SST and turbidity gradients along the channel during a flood tide. Salty intrusion exhibits increased variation in the SST gradient downstream. In this work, the results show that turbidity gradually decreased seaward during the ebb tide. In contrast, a bulge with several peaks was found during the flood tide. The variation of turbidity is interpreted as being due to sediment resuspension on the flood tide. During the ebb tide, the river plume was moving out with no suspension, because the plume was isolated from the bed by a strong pycnocline. Therefore, the turbidity gradually decreased seaward as sediment deposited. In contrast, on the flood tide turbulent mixing broke down the stratification, which allowed resuspended sediment to reach the surface and produced along-estuary peaks in the turbidity. Our observations show the utility of remote sensing observations (Ocean Color and thermal) for studying estuarine dynamics and processes.

Using 226Ra and 228Ra isotopes to distinguish water mass distribution in the Canadian Arctic Archipelago

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^{226}Ra and ^{228}Ra are the two long-lived isotope species (^{226}Ra, $t_{1/2}$=1600y and ^{228}Ra, $t_1/2$=5.8y) derived from the Radium Quartet. Each isotope in the Quartet is radioactive, mostly water soluble, and unperturbed by biological activity. Compared to the short-lived radium species (^{223}Ra and ^{224}Ra) the slow decay rate of ^{226}Ra and ^{228}Ra allows for these isotopes to be traced over great distances, thus providing insight towards the water mass composition, mixing processes and distribution patterns and timescales throughout the Canadian Arctic Archipelago (CAA). For this study, samples for radium isotope measurements were collected at 17 stations during the 2015 Canadian GEOTRACES cruise through the CAA. Both long-lived Ra isotopes were found in a large range of activities, which may be attributed to the diverse coast, shelf and ocean environments present within the study area. Plotting the Ra, and ^{228}Ra data, as well as their ratio ^{228}Ra/^{226}Ra over salinity allowed for trends to be estimated from Pacific, Atlantic and polar mixed layer distinctive end members. From these trends an attempt will be made to assess the flow rate as the Pacific water works through the CAA from west to east. Alternatively, although the Atlantic water was observed on either side of the Archipelago, its is suspected that the shallow depth and underwater shelf found within the CAA prohibit the dense Atlantic waters from flowing through in eastward direction. Finally, under consideration of biogeochemical data such as dissolved inorganic carbon or alkalinity, an attempt will be made to forecast the effects of changes in the ocean trajectory through the CAA might have on biological life. This study aims to provide a stepping stone for future research initiatives within the Canadian Arctic Archipelago, indicating how quantifying disparities in radioactive isotopes can provide insight toward climate change within vulnerable areas.

Testing glucose supplements and UV-C treatment to stimulate growth rates of the green alga *Tetraselmis suecica*

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Tetraselmis suecica is a green alga which could be used for the production **k**eto-**d**eoxy**o**ctulosonate (Kdo). Kdo is a sugar found in the cell walls of *T. suecica* and in Gram-negative bacteria. In the bacteria, Kdo is a component of the endotoxin responsible for pathogenic activity and is therefore a promising target for next-generation anti-microbial drugs. Drug development is currently limited by the very high cost of synthetic Kdo. Kdo is a structural carbohydrate in *T. suecica* which means that the most effective way to produce large amounts of Kdo would be to maximize the growth rate. *T. suecica* is mixotrophic (capable of mixed nutrition by photosynthesis and heterotrophy), so its growth rate could be increased by the supplementing growth medium with organic nutrients. However, bacterial contamination could become significant with addition of a labile substrate such as glucose if the bacteria out-competed the alga. The objective of this study was to determine if the addition of organic supplements would increase the growth rate of *T. suecica* compared to a phototrophic culture with and without disinfection of bacteria by ultraviolet-C (UVC) radiation. Stock cultures of *T. suecica* were grown phototrophically in balanced growth. Acclimated cultures were divided into three treatments, the control (grown phototrophically), mixotrophic without UV treatments and mixotrophic with UV treatments. Glucose was not found to significantly enhance growth rates in UVC-treated and untreated cultures but did increase the accumulation of non-fluorescing particles (probably bacteria). UVC radiation reduced but did not completely eliminate bacteria indicating that a higher UVC dose might favor mixotrophy and growth enhancement in *T. suecica*.

A High Resolution Record of Sediment Deposition in the Gulf of Aqaba during the last ∼4000 years

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The Gulf of Aqaba is a narrow and deep basin at the northeastern tip of the Red Sea. Sedimentation is dominated by biogenic and aeolian material, as well as by material delivered by various wadis surrounding the Gulf. Here we present paleoenvironmental proxy records from a 108 cm gravity core, recovered at 720 m water depth at the northern end of the Gulf. Radiocarbon dating shows that this core covers the last 5,000 years. Bulk sediment elemental composition (determined by ICP-MS), foraminiferal abundances, and nitrogen isotopes will be discussed in the context of environmental and hydrographic variability. The carbonate content ranges between 25-45%, and generally co-varies with changes in planktonic foraminiferal abundances (0-50/wet gram of sediment). In contrast, both nitrogen concentrations and sedimentary dN15 are homogeneously low (0.040% +/- 0.002 and 5.00 +/- 0.27, respectively) throughout the core, possibly suggesting a decoupling of carbonate production and nutrient availability. The most prominent interval within the core is an instantaneous event deposit at 96-87 cm (ca. 5190 +/- 35 years BP) containing allochthonous material in a fining upward sequence. This period is tentatively ascribed to a turbidite triggered by an earthquake. Sediment flux directly sampled by co-located sediment traps deployed since 2014 shows that sedimentation is dominated by sporadic, short-lived flux events on the order of days. These events transport large quantities of terrestrial material, manifested by the down core Fe/Al record, which displays an inverse relationship to the carbonate (%) record. Several stratigraphic periods will be discussed in attempt to reconstruct recent geological and paleoceanographic patterns influencing the Gulf of Aqaba.

Marine Animal Biomass Shifts Under 21st Century Climate Change in Canada's Three Oceans

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Climate change is expected to alter the physical and biogeochemical properties of the global oceans with pertinent impacts on marine life, biodiversity, and ecosystem functioning and services. At mid to upper-latitudes, such as those that make up the Canadian Exclusive Economic Zone (EEZ), it is predicted that there will be substantial changes in species composition through shifts in species distribution and abundance. Using a modelling approach that simulates the ecosystems structure, dynamics, and production, this research examined temporal and spatial changes in marine ecosystems in the EEZ of Canadas three oceans under four emissions scenarios, two earth system models, and six ecosystem models from 1970-2100. The results suggest that over the 21st century there will be an increase in multi-model mean consumer biomass in the Arctic EEZ and a decrease in the Atlantic and Pacific EEZ, with the magnitude of change increasing with stronger emissions scenarios and climate change. Declines in consumer biomass were found to be spatially consistent in the Atlantic and Pacific EEZ under both low (RCP2.6) and high (RCP8.5) emission scenarios; however, in the Arctic EEZ consumer biomass mostly increased under RCP2.6 but was more variable, and in some regions decreased, under RCP8.5. The greater severity of projected changes under RCP8.5 highlights the benefits to be gained from strong climate change mitigation strategies. These results suggest that over the 21st century fisheries and marine ecosystem productivity in the Canadian Atlantic and Pacific EEZ will be negatively impacted, while new and changing fisheries will emerge in the Arctic EEZ. These results can inform decision-making regarding resource management and conservation in a changing climate, with a focus on the economic opportunities and upcoming management challenges in Arctic waters.

Determining the Optimal Nitrate Concentration and Time of Day for Maximal Growth of Laminaria saccharina

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The worlds population is expected to increase by 34% by 2050. As a result, between 2005 and 2050, the overall food production must increase by 70%. Research at Woods Hole Oceanographic Institution is determining the best places to put kelp farms based on nutrient availability in the environment to address the increased food demand. This experiment focuses on determining the optimal nitrate concentration to acquire the largest growth rate of kelp and determining if there is a diel impact on nitrate uptake in kelp. In this experiment, 5 pieces of kelp were placed into 12 seawater flow through tanks with four treatments varying nutrient addition: 1) a control receiving ambient water, 2) low steady state concentration of 1μ M nitrate, 3) medium steady state concentration of 5 μ M nitrate, 4) and high steady state concentration of 20μ M nitrate. These tanks were placed under lights, which turned on at 6:00 and off at 18:00. Mass and length growth rate, and uptake rate were measured in the kelp. In the first experiment we found that there was no significant difference in length growth rate ($F(3,44)= 0.37$, $p=0.77$) even though the nitrate uptake rate was higher in the high nutrient treatments. This could be due to the kelp storing excess nutrients in their tissues. On the other hand, mass growth rate was found to be highest in the control nutrient treatment ($p=0.04$) and decreased in the higher nitrate treatments, and this indicates that potentially excess nutrients promote the growth of bacteria that aid in the degradation of kelp. We think this makes sense especially in the first experiment where the kelp appeared less healthy from the beginning of the experiment. In a second experiment, where the kelp was fresher at the beginning of the experiment, the highest growth rate was in the high nutrient treatment ($p=0.04$), which indicated that in this scenario the growth of healthy kelp was limited by nutrients. On the other hand, there were no significant differences in mass growth rate ($F(3,45)= 2.1$, $p=0.11$) indicating that the kelp could also be limited by another factor such as wave activity. Lastly, there was no significant change in uptake rate between day and night . The lack of change between day and night could indicate that the kelp do not need more nitrate during the day when they are photosynthesizing, but instead absorb nitrate continuously throughout the day and night. Alternatively, we may have not sampled frequently enough in the night to measure any change in uptake rate between day and night.

Particulate Organic Carbon Fluxes in the Gulf of Aqaba: Does the Martin Curve Accurately Describe the Observations?

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Sinking particulate organic carbon (POC) from surface water primary production represents a significant portion of the biological pump and is remineralized by bacteria as it sinks. The depth of POC remineralization has important implications for atmospheric CO_2 concentrations and depends on the particle sinking speed and the rate of POC decay. POC flux with water depth is typically modeled by an exponential equation known as the Martin Curve, where by $\text{POC Flux}_z = \text{POC Flux}_{z\ \text{ref}} \times \left(\frac{z}{z\ \text{ref}}\right)^{-b}$, where z is the water depth of interest and b describes the attenuation of the vertical POC flux. Earlier studies show that higher b values indicate more remineralization in the water column and ultimately higher CO_2 flux to the atmosphere. Warmer water temperatures correlate well with high b values and a shallower remineralization depth, which renders the ocean less capable of storing CO_2. The Gulf of Aqaba, the oligotrophic northern extension of the Red Sea, is representative of the large oligotrophic sup-tropical gyres found in the Atlantic and Pacific oceans. Therefore, changes in the b value in the Gulf may potentially be extrapolated to these gyre regions, providing important insight into the future behavior of the atmosphere-to-ocean CO_2 exchange in these regions. POC flux data were derived from sinking particulates collected over 29 consecutive months in the Gulf of Aqaba using sediment traps. The objective of this project is to determine how well the Martin Curve represents POC flux in the Gulf of Aqaba.

From Farming to Fallowing: Marine Benthic Sediment Health and Recovery Rates Below a Finfish Aquaculture Lease in Shelburne, Nova Scotia

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Organic matter loading from finfish inshore aquaculture, and the ecological issues it can produce, is of great interest to industry, government regulators, and the public. Such organic matter loading is caused by higher than normal concentrations of faecal matter and unconsumed fish feed, producing so-called benthic dead zones underneath and within a short radius beyond the edges of these finfish pens. A comprehensive understanding of the characteristics of how these dead zones grow and decay, both in time and structure, would be a valuable tool for future regulations and science communicators. Lease #0602 in Shelburne, Nova Scotia, Canada grew salmon from 1991 until it was surrendered to the province in September 2011. Annual environmental assessment data is available for the site from 2004 - 2017, allowing for the creation of time series to be formed from the data relevant to benthic organism diversity and health, including dissolved sulfides, organic matter content, redox potential, and porosity. Sediment redox potential and dissolved sulfides are inter-related and serve as indicators of the shift from oxic respiration to sulfate reduction as the primary metabolic pathway for organisms. A healthy benthic environment uses oxic respiration as the primary metabolic pathway: high levels of free oxygen and low levels of dissolved sulfides represent a healthy environment. Echo-sounding was also performed over the entirety of both the lease and reference sites, providing a more complete characterization of potential bottom types present when compared to sediment samples collected. All sampling and analyses at the lease and reference sites were performed in accordance with either the New Brunswick or Nova Scotia provincial SOPs for the environmental monitoring of marine finfish aquaculture, allowing a reliable comparison between sampling years. By dividing the 2017 Shelburne sampling sites collected for this study into various categories that 1) encompass the lease itself; 2) are located outside the affected area on the same shore, and; 3) provide a reference site with similar benthic and water column characteristics (i.e. bathymetry and sediment type), a more comprehensive understanding of spatial variability can be composed. Generating time series of both the most recent and historical data will allow for the assessment of recovery rates and the correlations between the geochemical variables of the sediment.

Controls on Nitrification in the Surface Ocean

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Surface waters in the oligotrophic Atlantic Ocean are characteristically nitrogen-limited resulting in decreased primary production. Nitrogen in the form of ammonium can be used for the microbe-mediated nitrification process where ammonium is oxidized to nitrite, which is further oxidized to nitrate. The goal of this project is to determine the controls on nitrification rates with varying depths and geographical locations along a transect sampled from Bermuda to the Northern South American coast where Amazon Plume waters protrude. A total of eleven stations were sampled at varying depths for nitrogen concentrations (ammonium, nitrite and nitrate), temperature, salinity, and oxygen. Nitrogen concentrations were determined using a Bran+Luebbe Continuous-Flow Analyzer III (AA3) and vanadium (III) reduction with chemiluminescence detection. Nitrification rates were determined by isotopically-labeled $^{15}NH_4^+$ incubations and then measuring the isotopic composition of the nitrate produced via the denitrifier method. The NO_3^- : PO_4^{3-} ratio with depth was plotted along the transect and revealed that the oligotrophic surface waters were depleted with respect to nitrate while the stations near the coast had less nitrate limitation. The nitrate limitation in the oligotrophic ocean corresponded with the deepening of the mixed layer. Increased availability of nitrogen and warmer surface water temperatures corresponded with the largest rates of ammonia oxidation in the subsurface found along the South American coast near Guyana. Increased nitrification rates were found in the surface waters of the coastal stations as well where nitrification would classically be inhibited by sunlight. Upwelling and terrestrial nutrient runoff near the coast of Northern South America may have caused increased turbidity which would inhibit light penetration and allow nitrification to occur. The results of this study conclude that nutrient limitation constrains nitrification in the oligotrophic Atlantic Ocean while nutrient delivery from the Amazon Plume and upwelling fuel nitrification near the coast of Northern South America.

Terrestrial and Oceanographic Forcing of Seacliff Erosion in a Macrotidal Estuary

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Over the past 50 years, an increase in cliff retreat rate has been observed along the coastline of Minas Basin in the Bay of Fundy in Nova Scotia, but the causes have not been determined. To mitigate losses of coastal land and infrastructure, understanding the mechanisms and rates of cliff retreat in the Minas Basin are essential. The lack of understanding is attributable primarily to previous inability to survey cliffs at frequencies that were adequate to discriminate the effects of seasonally varying erosion processes. This thesis uses archived datasets of wind speed and direction, precipitation, temperature and water level in the Minas Basin from 1945 to 2017 to identify the potentially most active periods of erosion during the year. High water levels and moderate precipitation in spring follow a long period of wind abrasion and multiple freeze-thaw cycles during the winter. Therefore, the most intense period of erosion is expected in April and May. A new photogrammetric technology called Structure from Motion (SfM) is applied to the Unarmed Aerial Vehicle (UAV) surveys of a selected west-facing cliff in Thomas Cove in Economy, Nova Scotia. Two surveys were chosen to observe the episodic process after the first major precipitation event of the fall season. High-resolution digital surface models (DSMs) were produced with a mean systematic error less than 0.04m. Volumetric loss from a selected cliff face below high tide level is $8.7m^3$, suggesting that gully erosion on cliff surface is the dominant process over the mass deposition after heavy precipitation

SPIRITed seas; inferring sea surface roughness with a custom built sensor

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Over larger scales, (1-10 km), sea surface roughness and wave height can be measured effectively by plane or orbital radar. On small to medium (0.1-100 m) scales, sensors including floats, pressure transducers, Baylor wave staffs, and lasers rangefinders have met relative success. However they have limitations in range resolution of the sea surface and in deployment method; requiring tuning to a particular region of the spectrum, facing false measurements due to spray, and generally not being mobile once installed. The objective of this project is to design, build, and test the Single Point Interface Roughness Inferring Transducer (SPIRIT), a wide spectrum surface roughness sensor for mobile platform use. The instrument is composed of a downward pointing ultra-sonic range finder, a co-located nine degrees of freedom inertial motion sensor and global positioning system, along with a data acquisition system. It is mounted topside, on an adjustable boom extending perpendicular to the centerline, at a sufficient distance to place the sensor outside the wake of the ship. The instrument package records the range from sensor to the sea surface, as well as the pitch, roll, yaw and three-axis linear acceleration of the sensor head. A recursive particle motion filter is used to isolate ship and sensor movement from sea surface measurements prior to the spectral analysis of the surface range time series, which is then compared to a Pierson-Moskowitz surface gravity wave spectrum. Applications of this new sensor platform with respect to under-sea acoustic communications are discussed. Sea trials of SPIRIT were completed off the coast of Nova Scotia and aboard the RV Neil Armstrong on the Blake Plateau in 2017. The reported ocean surface spectra will be used to investigate the effect of surface roughness on under sea acoustic communications and transmission loss.

Organic Carbon deposition in the Labrador Shelf over the Common era

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In order to understand global climate, it is important to study the processes occurring in the North Atlantic Ocean, such as deep water formation, oxygen uptake and export production. Past changes in organic carbon export production have not been well studied in this region. This thesis assesses export production changes over time by looking at cores recovered off the coast of Labrador in the North West Atlantic in 2015 during research expedition 45 on the *Maria S Merian*. The results of this analysis provide the first down core record of organic carbon content on the Labrador Shelf and help describe climate variability in this region on multi-decadal time scales. Age models show high sedimentation rates and thus high temporal resolution (25 centimetres is approximately 100 years). Total carbon (TC) and total inorganic carbon (TIC) were measured by CHN Analyser and Coulometry respectively; these results were then used to determine total organic carbon (TOC). The data from both cores studied exhibited a trend of decreasing organic carbon with depth (change of approximately 0.5% organic carbon). This can be associated with increasing surface production in Gulf of Labrador over the last 100 years.

Temporal and Spatial Trends in Microbial Plankton Communities of the Northwest Atlantic Ocean and Influence of Methodology on Perceived Diversity

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Marine microbes (Bacteria, Archaea, and picoeukaryotes) play essential roles in global energy and nutrient systems. They exhibit large variability on temporal and spatial scales, with the distribution of most taxa unknown. The Scotian Shelf, Northwest Atlantic Ocean, is an area of ecological and economic importance for which the diversity of microbes has only recently began to be described. The purpose of this work was twofold. Firstly, to investigate seasonal and interannual changes in the microbial plankton community of the Scotian Shelf by genetic analysis. Secondly, to compare the results of sequencing this community using different variable regions (V) of the 16S rRNA gene: V4-V5 (n=48) or V6-V8 (n=259). While the V6-V8 has been more commonly used in the past, there is growing evidence that the V4-V5 is preferable across taxa, especially as it provides a better representation of Archaea and Pelagibacter groups. Samples were collected in spring and fall 2014 and 2016 along a transect beginning in Halifax and moving offshore past the continental shelf. DNA was sequenced with miSeq Illumina, then the QIIME bioinformatics pipeline was used to classify Operational Taxonomic Units (OTUs). Alpha and beta diversity of Bacteria and Archaea were examined in relation to year, season, mixed layer depth, distance offshore, size fraction, and environmental parameters such as temperature and nutrient concentrations. The results of this study further our knowledge of marine bacterial communities in the Northwest Atlantic Ocean and their variability with the environment. This may be used to inform predictions of changes associated with anthropogenic impacts and climate forcing. The comparison of sequencing methods will provide insight into the potential differences in perceived community diversity based on primer choice.

Dynamical modeling of the marginal ice zone: a process study in one dimension

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Historically, waves were neglected in sea ice because of their rapid attenuation. With the increasing resolution of operational forecasting models, the marginal ice zone, the area where waves and ice interact, can now be better represented. Wave energy loss increases with frequency. This energy is transferred to the ice, breaking it into smaller floes and mobilizing it, as well as exerting a stress on the ice similar to winds and currents. This double effect can lead to rapid movements of sea ice in the presence of waves which are not captured by current forecast models. A one-dimensional, fully integrated wave and ice model has been implemented to assess the importance of waves in the dynamics of sea ice under a variety of conditions. The model is used to simulate coastal ice at a variety of scales. Results are then compared to observations from the Saint-Lawrence estuary and the Greenland Sea.

Numerical Study of the strom-induced circulation in the South China Sea during typhoon Linfa using a nested-grid ocean model

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A nested-grid ocean circulation modelling system based on the Regional Ocean Modelling System (ROMS) is used to examine the ocean response of the South China Sea (SCS) to tropical cyclone Linfa in June 2009. The modelling system consists of a coarse-resolution outer model domain covering the northern South China Sea, and a fine-resolution inner model domain covering the area affected directly by Linfa. Three numerical experiments (Control, Vortex, and Smooth) are conducted with different combinations of wind fields and sea surface air pressures but with the same net heat flux at the sea surface to examine the impact of Linfa. In Run Vortex, a parametric vortex is inserted into the original coarse-resolution CFSR forcing to better represent the atmospheric pressure and wind stress associated with the tropical cyclone. In Run Smooth, the model is forced by the smoothed CFSR winds and air pressures that both have hurricane features eliminated, representing the ocean response to the large-scale atmospheric forcing. Analytical results of three different runs demonstrate the upper ocean response of the SCS to Linfa is characterized by large divergent surface currents forced by the local wind forcing under the storm, and intense near-inertial currents in the wake of the cyclone. The sea surface temperature (SST) cooling produced by the model is biased to the right of the storm track, which agrees well with a satellite-derived analysis. In comparison with the outer model results, the inner model captures more meso-scale structures, greater SST cooling and stronger near-inertial currents in the study region.

Spatiotemporal patterns of paralytic shellfish toxins and their relationships with environmental variables in British Columbia, Canada from 2002 to 2012

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Harmful algal blooms produce paralytic shellfish toxins that accumulate in the tissues of filter feeding shellfish. Ingestion of these toxic shellfish can cause a serious and potentially fatal condition known as paralytic shellfish poisoning (PSP). The coast of British Columbia is routinely monitored for shellfish toxicity, and this study uses data from the monitoring program to identify spatiotemporal patterns in shellfish toxicity events and their relationships with environmental variables. The dinoflagellate genus Alexandrium produces the most potent paralytic shellfish toxin, saxitoxin (STX). Data on all STX measurements were obtained from 49 different shellfish monitoring sites along the coast of British Columbia for 2002-2012, and monthly toxicity events were identified. We performed hierarchical cluster analysis to group sites that had events in similar areas with similar timing. Machine learning techniques were used to model the complex relationships between toxicity events and environmental variables in each group. The Strait of Georgia and the west coast of Vancouver Island had unique toxicity regimes. Out of the seven environmental variables used, toxicity in each cluster could be described by multivariable models including monthly sea surface temperature, air temperature, sea surface salinity, freshwater discharge, upwelling, and photosynthetically active radiation. The sea surface salinity and freshwater discharge variables produced the strongest univariate models for both geographic areas. Applying these methods in coastal regions could allow for the prediction of shellfish toxicity events by environmental conditions. This has the potential to optimize biotoxin monitoring, improve public health surveillance, and engage the shellfish industry in helping to reduce the risk of PSP.

Assessment of wind input and wave dissipation parameterizations in a spectral wave model under hurricane conditions

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The performance of four different growth-dissipation source terms in a spectral wave model (WAVEWATCH III) is assessed in the Gulf of Mexico during Hurricane Rita. This study focuses on identifying the strengths and limitations of these four source terms using observations from buoys and satellites. Since the model results depend on the accuracy of wind forcing, we first compare the wind fields from the Climate Forecast System Reanalysis (CFSR) and Cross-Calibrated Multi-Platform (CCMP) with observations. The CCMP winds are found to have less scatter and thus adopted in this study, and the hurricane wind forcing from NOAAs Hurricane Research Division (H*WIND) is additionally blended with an optimal gust factor. The influences of surface elevations and ocean currents are considered in the wave model by using the HYCOM reanalysis data. The model results show that the observation-based source term known as ST6 is reasonably accurate but the model still has problems with an underestimation of wave heights during low sea states and an overestimation during high sea states. By comparison, the other three source terms (ST2/3/4) perform less well with general underestimations of wave heights. All the source term packages, however, have relative large errors in representing the direction and frequency spreading of wave energy. The directional wave spectra produced by the model reveal very different features at four quadrants of the hurricane center. The wave spectra are mostly swell-dominated and the rear-left quadrant is most complex, where the combination of wind seas and swells propagating against winds. It is shown that a classification of different sea states (following, cross and opposite swell) for the negative wind input in the source term ST6 can effectively reduce the overestimations of wave heights on the left side of hurricane track.

An Autonomous Hovercraft for Bathymetric Surveying in Shallow Waters

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An autonomous hovercraft was created to provide a low-risk method for collecting bathymetric data in very shallow waters (<1m) and in environments with strong surface currents or large tidal ranges. The hovercraft prototype has dimensions of 0.9 by 1.9 meters and is powered by a small gas engine attached to a fan, mounted at an angle to produce both lift and forward thrust. The steering, which consists of twin rudders placed in the fan's exhaust, and the throttle are controlled by servo motors, and a linear actuator controls an arm capable of raising ad lowering an instrumented outrigger hull. The outrigger is a boat-shaped appendage mounted with high frequency side-scan Sonar transducers (800 kHz) and a single beam echo sounder (675 kHz). An on-board computer controls the Sonar data collection. The vehicle may be flown remotely via a radio-lined controller, or can be pre-programmed to travel between defined waypoints using an autopilot. A Global Positioning System (GPS), with Real Time Kinetic (RTK) capabilities is used to determine the hovercraft's instantaneous position with a possible resolution of 2.5 centimeters. A set of three orthogonal gyros, three orthogonal accelerometers, and three magnetometers are used to determine the orientation of the craft. The hovercraft is able to fly seamlessly over land and water, and can thus survey along the waterline. Additionally, the prototype has a very low hull drag, allowing efficient operation in high speed currents. [Work supported by Innovacorp]

Shallow water ray-tracing and measured channel estimation comparison

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Underwater acoustic communication is a key enabler for civilian and military applications such as ocean sampling networks, offshore exploration, pollution monitoring and underwater surveillance. Being able to understand and model the impact of time-varying environmental properties on the communication link would improve ray-tracing simulation fidelity which is currently one of the few tools available to test, analyze, and compare underwater communication schemes and performances. DalComms1 sea trials took place in the summer of 2017 in an effort to better understand the impact of the environment on the underwater acoustic link performance, to test spread spectrum modulation techniques and to validate signal processing algorithms. The experiment was conducted on the Scotian shelf and included transmissions of channel sounding sequences, such as low frequency modulated and pseudo-random noise sequences, at ranges between one and ten kilometers. Other instruments such as an acoustic data current profiler, a conductivity-temperature-depth profiler, and a surface roughness measuring instrument complemented environmental data such as surface wind velocity, significant wave height and dominant wave period obtained from a nearby weather buoy and visual observations. The processing of the received signals allowed the extraction of important performance metrics such as estimated channel impulse responses, Doppler and delay spreads, as well as coherence times. Ray-tracing simulations through BELLHOP revealed an acceptable degree of agreement between the simulated deterministic result and the measurements. Ongoing work includes the statistical modelling of the behavior of the underwater acoustic channel using a series of simulations with varying sound speed profiles, surface roughness, and relative motion between the source and receiver. This statistical model will be used to augment the deterministic ray-tracing simulation to provide a more realistic output. The series of simulations will also allow for the determination of the underwater acoustic channel's sensitivity to a variety of environmental perturbations. The result is an increasing agreement between the models and measurements and a better understanding of the channel's variability.

Reconstruction and Meta-analysis of Ocean Climate Variability at Ocean Station Papa

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There are not many ocean time series that have been in place long enough to observe decadal ocean cycles, but the time series at Ocean Station Papa (OSP) is one of the few. With a time series that spans over 60 years, and a variety of sampled ocean variables, such as temperature, salinity, nitrate, phosphate, silicate, chlorophyll, and dissolved oxygen, OSP has the potential for linking changes in the climate to ocean cycles. One issue that must be confronted is that the OSP time series is too incomplete (gappy) to allow us to carry out statistical analyses for climate variability. The Kalman Filter is an algorithm that can make use of the relationship between oceanic variables to estimate missing data points in the time series. Using sections in the time series where all the variables were sampled regularly a dynamic matrix is created to provide the relationships between all of the variables. Those relationships are then applied to the entire time series, and an estimate of the various ocean variables on a regular time axis is provided. Now that the OSP time series has been reconstructed, it can be more thoroughly analysed and linked to climate indices. Preliminary results from the climate indices are promising and indicate that there is a strong correlation between certain climatic cycles (e.g. Pacific Decadal Oscillation) and the surface ocean variables at OSP.

Surface wave effects on the upper ocean responses to moving storms

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Forecast models generally have problems in the prediction of storm intensity by underestimating the upper ocean mixing and related upper ocean responses to storms. Although ocean waves have been regarded as essential roles in the upper ocean mixing, their effects are not always explicitly incorporated in model simulations. This study is to examine the surface wave effects on upper ocean responses to moving storms with both observational measurements and numerical simulations. We modified a one-dimensional general ocean turbulence model (GOTM) by incorporating surface gravity wave effects including wave breaking, Langmuir circulation and Coriolis-Stokes force. This newly-modified model is applied to simulate the upper ocean responses to Arthur (2014) for the coastal ocean and Felix (1995) for the open ocean. The results show that the incorporation of wave effects does improve GOTM simulations, with the wave breaking and Langmuir circulation effects playing important roles. Wave effects improve the simulations of ocean thermal responses in the following respects: 1) significantly reducing the underestimation of the upper ocean cooling; 2) remarkably deepening the simulated mixed layer depth which leads to better agreement with observations; 3) providing a faster response especially in the early forcing stage. Wave effects have a minor impact on the phase and frequency of near-inertial current responses, whereas they do significantly improve the simulation of near-inertial amplitude especially within the ocean mixed layer. With the incorporation of wave effects, near-inertial energy is transported more efficiently to deeper layers rather than trapped at the very surface.

Just what is an impulse? Impulsive noise and it's effects on marine life.

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Until the 1950's we believed that most of the world's oceans were dark, cold, and silent. However, newly developed naval sonars revealed a huge variety of biologic sounds as well as abiotic sounds from wind, waves, ice, and earthquakes. We now know that sound is a vital sensory modality for most marine life and it is particularly important in the life processes of marine mammals. Human activities that introduce sound into the ocean have the potential disturb the behaviour and even injure marine life. Predicting the effects of human sounds on the marine life is extraordinarily difficult due to the huge number of marine species groups, each with different hearing mechanisms, the wide variety of human sound sources, most of which are mobile, and the complexities of sound propagation in the ocean. To date regulations have focused on minimizing injury to marine life from human sounds using the weighted cumulative sound exposure level as a metric for prediction and mitigation. There are many knowledge gaps in our understanding of the cumulative sound exposure level and how to apply it in real-world settings in particular when sounds from seismic airguns and pile driving transform from highly injurious impulses to less harmful continuous sounds. This presentation provides an introduction to the effects of noise on marine life, the differences between impulsive and continuous sound exposure, and metrics used to assess impulsiveness.

Quantifying coastal cliff erosion using Structure-from-Motion photogrammetry in the Minas Basin, Nova Scotia

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Rising sea levels have been correlated with increased rates of retreat of cliffed coastlines around the globe, threatening infrastructure and complicating risk assessment. The frequency of coastal cliff erosion events historically has been poorly constrained on the time scales associated with major terrestrial and oceanographic forcings, which include, among others, heavy precipitation, repeated freeze-thaw cycles, and large waves associated with high water levels. The volume of material introduced to the marine environment from cliff erosion at these time scales also is not well quantified. Here we employ Structure-from-Motion (SfM) analysis to survey actively eroding cliffs along the northern shore of the Minas Basin at Thomas Cove Coastal Reserve in Economy, Nova Scotia at frequencies required to delineate rates and mechanisms of cliff erosion. On five visits, photographs were taken using both a camera mounted on an Unmanned Aerial Vehicle (UAV aka drone) and a dSLR camera mounted on a photomast. Temporary Ground Control Points (GCPs) were surveyed in using real-time kinematic (RTK) GPS. Images were used to create three-dimensional point-clouds and associated Digital Elevation Models (DEMs) with Pix4D, which is a commercially available SfM software package. Preliminary comparison of DEMs produced before and after major rainfall events reveal slumping of unconsolidated material from the upper part of the cliff, and reworking of a tidal stream-bed. We plan to evaluate volumetric changes between surveys by measuring absolute distances between meshed surfaces from their corresponding DEMs. This will help to evaluate the frequency and magnitude of cliff failures by various mechanisms, and will refine the sediment budget of the Minas Basin.