Effects of Physical Forces on Diurnal C, N, P, and Fe Dynamics and Submarine Groundwater Discharge within a Permeable Coastal Margin

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Rationale

Physical forces acting on the reef environment could significantly affect the frequency at which nutrients could become available to water column biota. Due to the shallow water depth of fringing back reefs, physical forces such as wind, waves, currents, and tides readily affect turbulence in the water column. Diurnal wind velocity patterns, mainly driven by island heating due to insolation have the energy sufficient to create white caps on the sea surface, generally inducing thorough mixing of the water column and re-suspension of bottom sediments (e.g. South Molokai, HI (Storlazzi et al. 2004), and north Kihei, Maui (Herzfeld et al. 2006)). Waves and diurnal wind patterns can also generate currents, and induce pressure gradients at the flow-facing faces of sand ripples, leading to flow of solutes through ripple troughs and out of the ripple crests (Precht and Huettel 2003). Therefore highly energetic conditions (high wind/waves) enhance the flushing of reduced pore-fluids and penetration of oxidants to the sediments. The end result of this enhanced exchange is the rapid remineralization of particulate and dissolved organic matter and reduction of organic carbon burial.

Great gaps exist in our knowledge about diurnal nutrient dynamics within permeable margins where coral reef systems dominate, and the in-field relationships between nutrient dynamics, physical forces, and aquifer interactions in space and time. Processes that enhance exchange within permeable coastal margins have been studied to great extent in the past few years (Moore 2000; Webster 2003), though no study has documented nutrient dynamics in the water column/sediment porewater system over coral backreef environments during short sampling periods as proposed in this study. We attempt to address such gap and strive to elucidate the major *mechanisms* affecting nutrient variability in these systems. Although it is well understood that nutrient dynamics are site-specific, we expect our results to significantly advance our understanding of factors regulating sediment/water-column nutrient and carbon flux, further constrain global estimates.

Objectives

To document diurnal and seasonal nutrient dynamics in the water column and sediment interstitial water within a permeable coastal margin, and to explore the relationship between sediment-water column CNPFe exchange and the physical forces that enhance such exchange under field conditions

Hypothesis

Ho1: Diurnal variability of dissolved nutrient concentrations in the water column and sediment interstitial water within a permeable coastal margin is equal-to or greater than seasonal variability

Ho2: Dissolved nutrient inventories in the water column and sediment pore spaces within a permeable coastal margin are dependent on changing physical forces that enhance exchange (wind, waves, currents, and tidal height).

Approach

Locations along the south shore of Maui, Hawaii, were selected for diurnal geochemical sampling to study mechanisms responsible for short-term nutrient variability within these coastal margins. Of special interest to the work proposed here are backreef regions near the city of Kihei where a general zone enriched with nutrients (**Figures 1 and 2**) appear to be subsidizing large nuisance macroalgal biomass (*Hypnea musciformis, Ulva fasciata*) that have been accumulating in the intertidal and sub-tidal regions for the past few decades. Nuisance macroalgae have caused great public concern and financial losses to the county via clean-up costs and reduced property value (~$30 million/year, Van Beukering and Cesar 2004). Sources of nutrient subsidies to macroalgae in the area are hypothesized to originate from submarine groundwater discharge, pulsed sediment inputs during heavy rainfall, or coastal erosion.

Field sampling strategy is shown in **Figure 3** and consisted of water column and sediment interstitial water collection in 3-hour intervals at all stations for 48 consecutive hours during spring and neap tides, encompassing 4 diurnal and 8 tidal cycles. Discrete porewater (Sites A and B only) and water column (all sites) samples were collected using plastic syringes, and split on-site for dissolved nutrient, DIC/TA, SRP/Fedissolved, salinity analysis. Solid phase data collection was performed within the top 5cm of sediments using 60cc syringe cores and extruded into pre-weighed centrifuge tubes along multiple shore-normal transects at each study location. Resident organic matter C:N:P ratio were obtained and utilized for stoichiometric calculations. Continuous data collection and analysis dissolved oxygen, pH, temperature, chlorophyll a, turbidity, temperature, and salinity data were collected with YSI instrumentation at 10-minute intervals. Near-bottom physical oceanographic data were collected using acoustic doppler velocimeters (Nortek Aquadopp) deployed along a shore-normal transect at each site and ENU data logged every 5 seconds. Wind data were collected at 5-minute intervals and obtained for the Kihei site weather station maintained by Weather Flow Inc (**http://www.iwindsurf.com**). Finally, in order to document the wave conditions during our sampling period, burst data (1 Hz) were collected for 20 minutes every hour using Nortek current meters.

Statistical Analyses

Time-series data analysis techniques will be utilized to analyze the datasets from this study using Matlab software. Cross-correlation and covariance between the different physical oceanographic signals and its coherence with nutrient concentrations will be explored using time-series analysis (e.g. harmonics analysis) coupled with multivariate data analysis techniques (e.g. principal components analysis, discriminant analysis) in order to better understand the factors that explain nutrient concentrations in both water column and interstitial waters of our study sites.

Preliminary and Expected Results

Preliminary results show co-variance between physical forcing and dissolved inorganic nitrogen, phosphorus, and carbon partial pressure dynamics in the nearshore water column and sediments (**Figures 4, 5, and 6**). Nutrient dynamics appear to be primarily dominated by aquifer (SGD) exchange with the nearshore environment. Diurnal dissolved nutrient (DIC, DIN, DIP, and Fe) variability is expected to be of equal or greater magnitude than seasonal variability. Seasonal water column and sediment interstitial water nutrient concentrations are expected to be explained by changes in seasonal rainfall patterns and its concomitant effect on submarine groundwater discharge to our site. In-field observations presented in this work are expected to illustrate interactions between CNP dynamics and physical forces, further reaffirming concepts that have previously been shown to lower boundary layer thickness and enhance exchange through permeable sediments under laboratory and flume settings.

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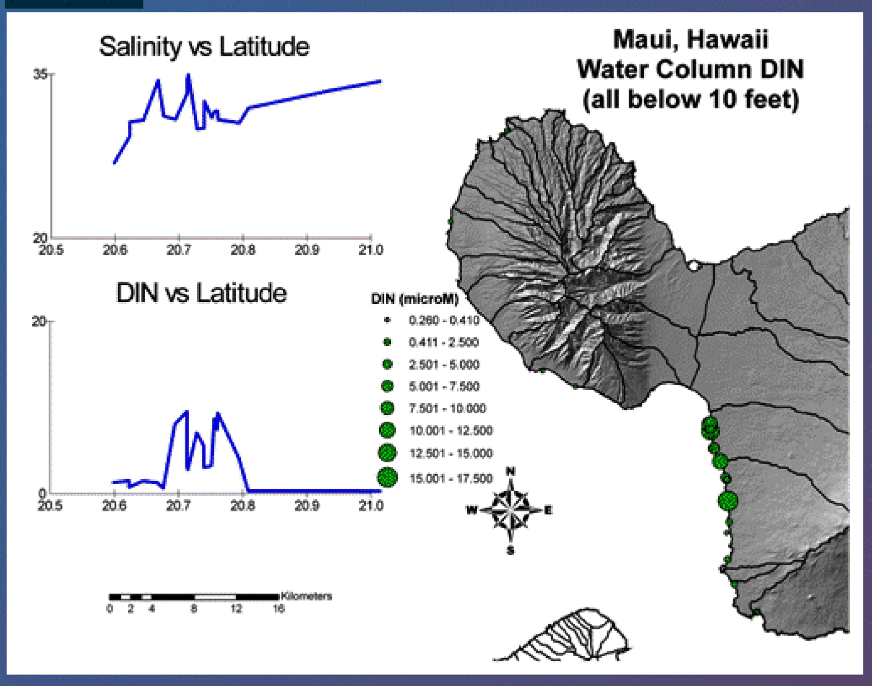

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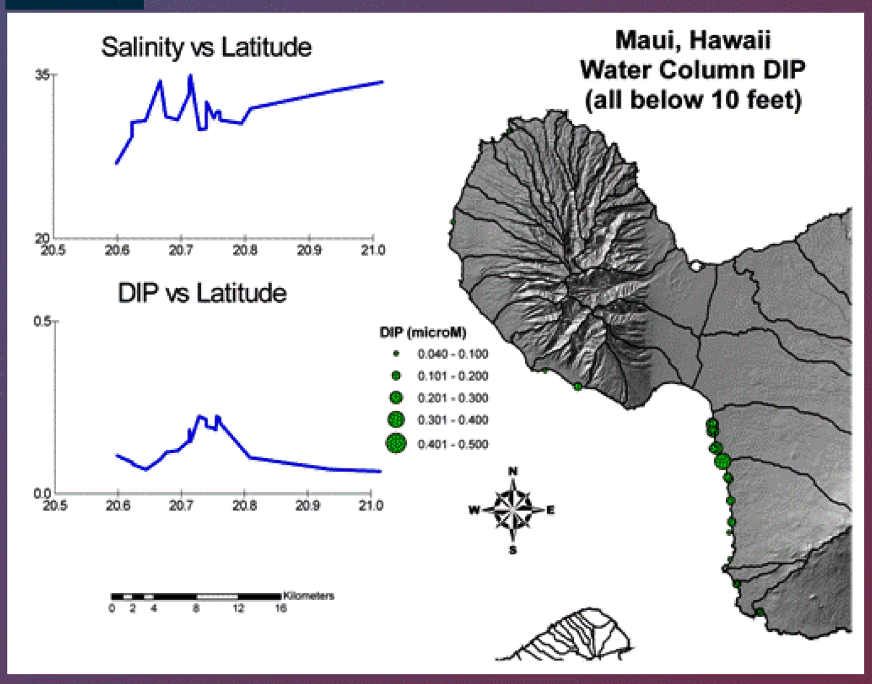

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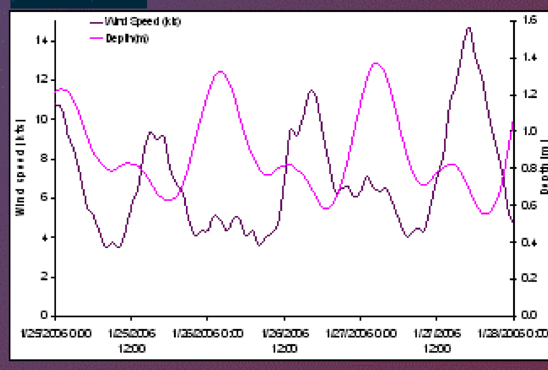
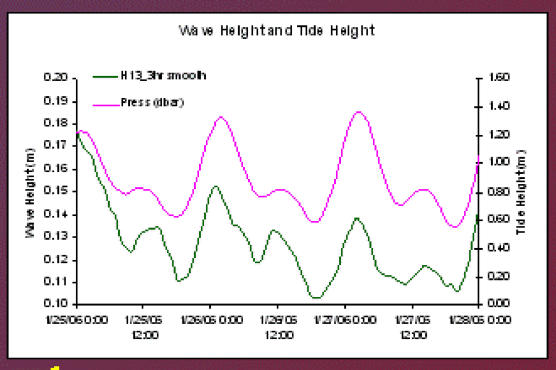
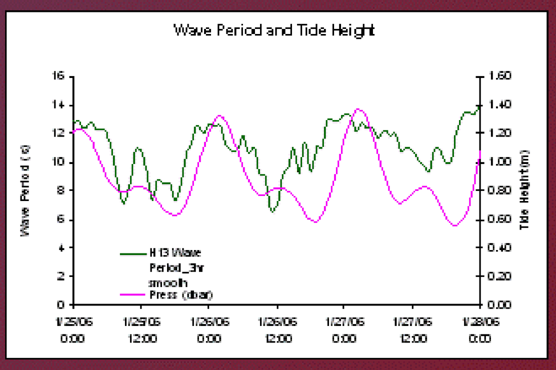




Tide – Local wind Energy Decoupling

Bigger, stronger waves penetrate into the back-reef region at higher tides



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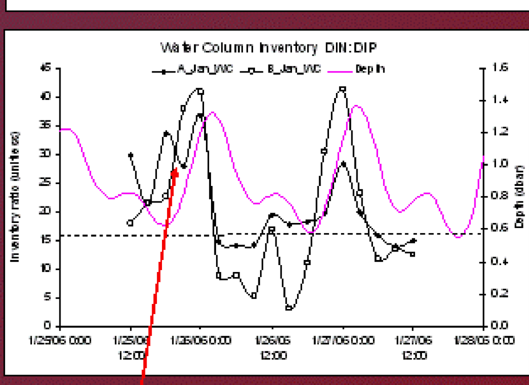
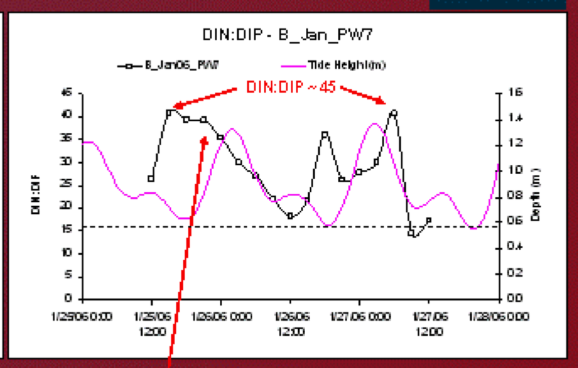


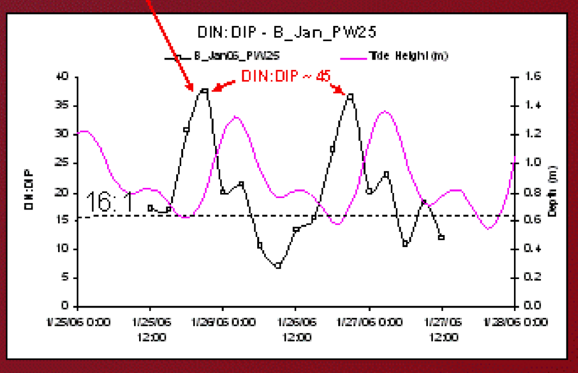


Increase at rising tide

Removal at rising tide

Water column DIN:DIP approximates 45:1 during rising tides (mean aquifer DIN:DIP = 45:1)

Sediment porewater infill with 45:1 DIN:DIP water during receding tides and approach 16:1 after high tide



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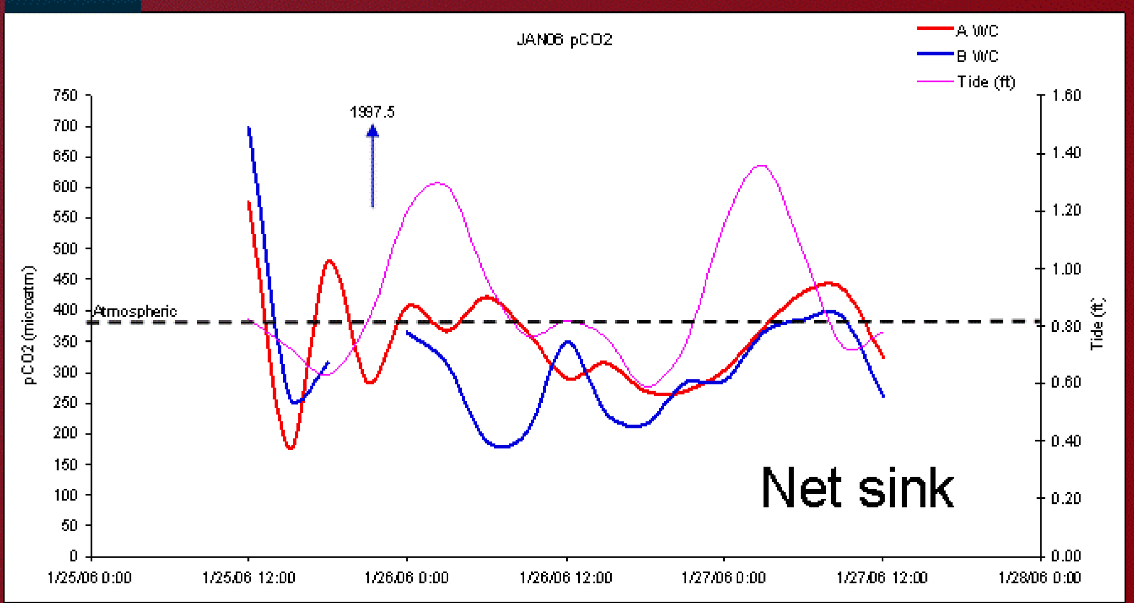

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