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VEGETATION HYDRODYNAMICS TO INFORM CLIMATE MITIGATION AND ADAPTATION

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1 INTRODUCTION

Coastal ecosystems, such as seagrass, provide many ecosystem services, including coastal protection and carbon sequestration, which make them an integral part of climate mitigation and adaptation (e.g., Fourqurean et al. 2012). Predicting the value of these ecosystem services requires an understanding of the interaction of fluid motion with vegetation. While seagrass meadows are recognized as global hotspots for carbon storage, the verification of seagrass carbon is complicated by significant heterogeneity. For example, Lavery et al. (2013) reported an 18-fold range in carbon stock across 17 different seagrass habitats (260 to 4800 g C m^{-2}). This variability is a major source of uncertainty in assessing carbon stocks, motivating work to understand what drives it. Recent studies have highlighted how hydrodynamic conditions can be an important factor (e.g., Oreska et al. 2017, Novak et al, 2020). In this talk, we consider a combination of modeling and field measurement that explores the influence of wave and current conditions on carbon accretion in seagrass meadows.

2 RESULTS

Since organic matter and associated carbon are easily mobilized by currents and waves, the spatial pattern of current and wave velocity can be imprinted on the spatial distribution of carbon stock. Figure 1 illustrates how currents and waves respond differently to submerged vegetation, which may promote different patterns of carbon accretion. To illustrate the difference, this talk presents case studies at both a wave-dominated and current-dominated site.

Continuous Meadow at Wave-Dominated Site [Nahant, Massachusetts, USA]

While vegetation can diminish waves, which favors sediment retention, vegetation-generated turbulence can enhance resuspension and sediment mobility. The interplay of these affects defines the spatial scale at which the retention of sediment and associated carbon is enhanced by vegetation. The spatial variation in sediment and carbon accretion rates across the contiguous seagrass meadow is shown to correlate with spatial variation in wave conditions. Further, combining models for resuspension and wave dissipation, a minimum restoration scale needed to eliminate wave-driven sediment resuspension can be estimated.

Patchy Meadow at Current-Dominated Site – Gloucester, Massachusetts, USA

Field measurements confirmed that current velocity is reduced within patches and elevated in bare regions between patches, which is associated with diminished resuspension within patches, relative to bare regions. Because resuspension can diminish sediment carbon (Dahl et al.2018), differences in sediment carbon were expected between the patches and unvegetated regions. However, sediment carbon was not correlated with the present-day spatial distribution of seagrass. This was explained by the temporal variation in patch location determined from historic aerial images. While individual patches continually shifted over time, each persisting less than a decade, the full meadow has persistent for more than a century. The dynamic patchy state may be explained using percolation theory.

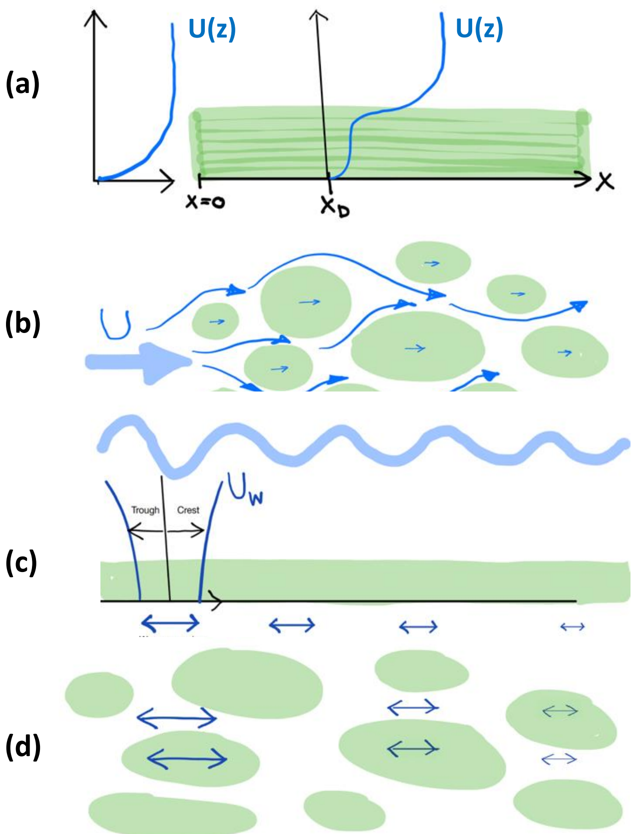

Figure 1 Current and waves respond differently to seagrass, shown with green shading.

(a) Side-view of continuous meadow. Within meadow vegetation drag reduces current velocity, altering vertical profile, U(z), shown in blue. The adjustment occurs over distance X_D from meadow edge.

(b) Top view of patchy meadow. For patches larger than X_D, current velocity in patch is reduced (short blue arrows) compared to bare regions between patches (long blue arrows), which is expected to preferentially promote carbon accumulation within the patches compared to surrounding unvegetated regions.

(c) Side-view of continuous meadow with waves. Wave excursion denoted by blue double arrow. Meadow drag does not significantly alter the vertical profile of wave velocity (U_w), shown in blue. However, wave amplitude is diminished with distance traveled over the meadow, resulting in a decrease in wave velocity, illustrated by the decrease in wave excursion at the bed, which may be correlated with spatial gradient in sediment carbon at the meadow scale.

(d) Top view of patchy meadow with waves. If seagrass patches do not significantly alter vertical profile of wave velocity, the near-bed wave velocity is similar within patch and over adjacent bare bed, shown by similar scale of wave excursion. The similar near-bed hydrodynamics may promote spatially uniform carbon accretion at the patch scale.

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