Characterizing surface gas transfer driven by turbulence from submerged vegetation-wave interactions

Rafael Tinoco , Pallav Ranjan , Chien-Yung Tseng , Michael Molloy

Department of Civil & Environmental Engineering, University of Illinois at Urbana Champaign

Urbana, IL 61801, United States of America

Aquatic vegetation generates turbulence at multiple scales, from stem- to patch-scale. Vegetation-generated turbulence has been shown to drive sediment transport and gas transfer under unidirectional flow conditions. In this study, we assess the effect of submerged aquatic vegetation on the surface gas transfer rates under waves, to mimic conditions in vegetated coastal areas. We conduct a series of laboratory experiments in a wave flume, using arrays of rigid cylinders as surrogates for vegetation. Oxygen in the flume is depleted and the reaeration rates are measured for a broad range of submergence ratios, vegetation density, Reynolds and Keulegan-Carpenter numbers. Particle image velocimetry is used to characterize mean, phase averaged, and turbulent velocity metrics; optical dissolved oxygen sensors are used to record oxygen recovery; and acoustic wave gages are used to track wave dissipation through the vegetation array. Based on a modified surface-renewal model for unidirectional flows, we investigate the applicability of existing predictors by incorporating turbulent metrics from the measured waves. We develop a simplified model to use vegetation-generated turbulence to estimate gas transfer rates in coastal regions with the presence of submerged vegetation or similar benthic populations, to provide a tool to improve predictions for oxygen and carbon dynamics and sequestration on estuarine and coastal ecosystems.