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Wave-frequency Flows Within a Near-bed Vegetation Canopy

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Abstract

We study water flows and wave dissipation within near-bed pneumatophore canopies at the wave-exposed fringe of a mangrove forest on Cù Lao Dung Island, in the Mekong Delta. To evaluate canopy drag, the three-dimensional geometry of pneumatophore stems growing upward from the buried lateral roots of *Sonneratia caseolaris* mangroves was reconstructed from photogrammetric surveys. In cases where hydrodynamic measurements were obtained, up to 84 stems per square meter were observed, with stem heights <0.6 m, and basal diameters $0.01-0.02$ m. The parameter $a =$(frontal area of pneumatophores blocking the flow)/(canopy volume) ranged from zero to $1.8\,\mathrm{m}^{-1}$. Within-canopy water velocity displayed a phase lead and slight attenuation relative to above-canopy flows. The phase lead was frequency-dependent, ranging from 0 to 30 degrees at the frequencies of energetic waves (>0.1 Hz), and up to 90 degrees at lower frequencies. A model is developed for wave-induced flows within the vertically variable canopy. Scaling suggests that acceleration-induced forces and vertical mixing were negligible at wave frequencies. Consistent with theory, drag-induced vertical variability in velocity scaled with $\Lambda = T_w/(2\pi T_f)$, where $T_w =$ wave period, $T_f = 2/(C_D a|u|)$ is the frictional time scale, $C_D \approx 2$ is the drag coefficient, and $|u|$ is a typical flow speed. For fixed wave conditions ($|u|$ and T_w), theory predicts increasing dissipation with increasing vegetation density (i.e. increasing a), until a maximum is reached for order-one Λ. For larger Λ, within-canopy flow is so inhibited by drag that further increases in a reduce within-canopy dissipation. For observed cases, $\Lambda \leq 0.38$ at energetic wave frequencies, so wave dissipation near the forest edge is expected to

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