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A Study of effect of floating vegetation on the formation of exchange flow

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Abstract
This study is concerned with the effect of floating vegetation on the exchange flow resulting from negative heat flux on open water by surface cooling. The problem configuration is comprised of two regions: open water and aquatic canopy area with floating vegetation. The negative heat flux resulting from night cooling, for example, makes a density difference between open water and canopy area, and hence drives an intrusion of warm water into the open region at the surface. Velocity distribution is measured by PIV method. The experiments are done for a range of vegetation density (0 to 15%) and root depth ratio (0 to 0.6). It is found that the drag in the canopy area is the most important factor affecting the exchange flow. The velocity of exchange flow is measured to be of the order 2 mms^{-1}.
Keywords: exchange flow, surface cooling, PIV method, floating vegetation.

1. INTRODUCTION

Exchange flow arising from heat flux was studied by Patterson (1984)[1]. He explored unsteady natural convection due to internal heat source analytically. Trevisan & Bejan (1986) studied similar problem, but their heat source was generated by sorption solar radiation [2]. Jamali & Zhang & Nepf (2008) used a lock exchange model to study exchange flow between open water and aquatic canopy area theoretically and experimentally [3]. They observed the exchange flow decrease whit time because canopy drag increase.

Tanino & Nepf & Kulis (2005) quantified properties of exchange flow in canopy area [4]. The plants were modeled with circular cylinders. They distinguished two flow regimes in the exchange flow: inertia and drag regimes. The exchange flow is initially inertia-dominated but it is controlled by the canopy drag ultimately. They propsed a relation for drag-dominated velocity that was confirmed by their experiments.

Zhang & Nepf (2008) studied density-driven exchange flow between open water and canopy area [5]. They used lock-exchange flow to studied exchange flow assuming the reduced gravity (g') was constant. They observed the velocity of gravity current in the open region is constant, while in the canopy area it is controlled by the canopy drag and decreases whit time.

Zhang & Nepf (2009) studied thermally-driven exchange flow between a region of open water and an aquatic canopy [6]. Temperature difference was generated by two spotlights that were used to produce a uniform heat source. They did laboratory experiments and scaling analysis to determined flow regimes and characteristics of exchange flow. Scaling analysis proposed different flow regimes, including inertia-dominated, drag-dominate and energy-limiting regimes.

Davari (2011) perused thermally driven exchange flow in a canopy area over a slope [7]. She observed the velocity depends on light intensity, canopy density, and light intrusion depth. Her experiments showed the light intrusion depth affect the flow rate and velocity of the front. She saw the slope doesn't have an appreciable effect on velocity.

Zhang & Nepf (2011) studied exchange flow between a region with open water and a region with floating vegetation [8]. They used lock-exchange flow to model density difference due to shading by the vegetation. The velocity distribution is measured in the lab using PIV[3]. The magnitude of exchange depends on the fluid density difference, the root depth, and the vegetation drag.

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