PROJECT 4

Title: Mass transport and dispersion with combined current and waves in an open channel flow

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Introduction

The assessment of the environmental impact due to effluent discharges in a river requires a good understanding of the associated dispersion processes. At the moment, the dispersive effects due to currents are typically included in the assessment, but the effects due to waves are usually ignored, in part because we do not have good theoretical models capable of predicting wave modifications to current structure and mixing. Yet, in many shallow coastal systems, surface waves may dominate (Monismith and Fong 2003). Hence, there is a need for improvement in the area of the mass transport and dispersion caused by combined current and waves. Physical mechanisms for wave effects on mean current profiles have been explored by Groeneweg and Klopmans (1998), although it is not clear that their theory gives a convincing explanation of the observations reported in Nepf (1992) and Monismith et al (unpublished). Nonetheless, the corresponding longitudinal dispersive effect due to waves has been explored in Law (2000) who finds that they may indeed be significant.

Objectives

This study will focus on the mass transport and dispersion in an open channel flow with and without the presence of waves. Specific objectives are to

1) Investigate both analytically and experimentally the modifications of the current profile in the open channel flow in the presence of waves.
2) Resolve the analytical issues on wave drift raised in Monismith et al. (unpublished).
3) Identify and develop predictive models to explain the enhancement of dispersion by surface waves in combined current-wave systems

Scope

The student will first perform a vigorous analytical examination of the Lagrangian and Eulerian velocities under the combined current-waves system. This model will couple changes in waves and currents due to their interaction and, unlike current radiation stress theories used in coastal engineering, will resolve vertical variations in currents. It will also include turbulence models that appropriately model the effects of wave strains on turbulence. Subsequently the student will design laboratory experiments to measure the velocity profile in an open channel flow with and without the presence of waves. The experiments will include quantitative measurements on the velocity distribution as well as measurements on the transport of pollutants under different combinations of current and wave conditions. The measurements will be performed through laser imaging techniques of Digital Particle Tracking Velocimetry (DPTV), Particle Image Velocimetry (PIV) and Planar Laser Induced Fluorescence (PLIF). These laboratory experiments and theoretical developments will be used to help interpret field data on plume dispersion in the presence of waves that is planned to be collected in Hawaii in the summer of 2004.

Organization and Training

The subject of wave-current interaction has been studied extensively in the Stanford's Environmental Fluid Mechanics group in the past, while there has been an ongoing interest in CEE, NTU on the assessment of the mixing and dispersion of effluent discharges. Hence, this study complements the ongoing research interests on both sides. The principal investigators have published recent papers related to the general area. It is anticipated that the student will initially spend some time at Stanford University on courses as well as equipping himself with knowledge in the subject of wave-current interaction and the wave-induced dispersive effects, and subsequently carry out bulk of the experimental work at NTU.