OBSERVATIONAL AND NUMERICAL STUDY ON THE DYNAMIC FORCING OF HANAUMA BAY: A SMALL SEMI-ENCLOSED BAY AND FRINGING REEF

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ABSTRACT

Current, temperature, bottom pressure, wave buoy, and meteorological observations in conjunction with numerical experiments are used to describe the dynamical response of Hanauma Bay, Hawaii to wave, tide, and wind forcing. During the 3-month field experiment (March-May 2009), temperature structure (0-25m) in the bay was nearly homogeneous during March and April with a seasonal stratification developing in May. Barotropic tidal flow is shown to be the strongest at the mouth of the bay. Tidal analysis explains ~45% of the total current variance for the outer bay sensors (>12 m water depth) and ~10% of the variance for the inner bay sensors. Spatial structures derived from M_2 tidal ellipses, empirical orthogonal functions (EOFs), and drifter deployments show a rotational tidal circulation with inflow/outflow at the bay's sides. Numerical experiments are able to simulate the observed tidal currents and they depict a persistent tidal eddy and flow separation at the mouth of the bay during strong alongshore flow. Secondary circulation associated with the tidal eddy may contribute to persistent convergence zones observed in the bay. Low frequency ($< (40\ \mathrm{hr})^{-1}$) current variability correlates with significant wave height and wind stress. Numerical experiments indicate that low frequency current response to wave forcing is substantially greater than to wind stress. Rip current variability within reef channels correlates with wave height, with an inverse correlation to water level over the reef top. Maximum rip currents during wave events thus occur at low tide due to enhanced wave breaking and water level setup over the shallow reef. At tidal frequencies and higher, cold temperature intrusions and enhanced baroclinic current energy are prevalent after the summer stratification develops. EOFs of temperature measurements suggest that the heat content of the bay is significantly altered by the observed cold intrusions.