Resonant Coastal Waves and Superinertial Oscillations

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By

Claude Frederick Lumpkin

Thesis Committee:

Pierre Flament, Chairperson
Doug Luther
Mark Merrifield
Dennis Moore

Abstract

Simple models of free and forced waves around a cylinder are reviewed and applied to simulate trapped waves around the Hawaiian Islands. Correspondences between theoretical eigenfrequencies obtained from these models and observed spectral peaks in sea level and current records provide evidence for low mode subinertial trapped waves, some not previously identified. Azimuthal phase differences estimated from multiple sea level stations around Kauai, Oahu and Hawaii are also consistent with a trapped wave description.

Superinertial, intertidal peaks are observed in sea level spectra, but not in current spectra. Coherence amplitude and phase suggests a propagating wave of low azimuthal mode around Kauai and Oahu. There is not conclusive phase evidence of superinertial wave propagation around Hawaii. Significant coherence between sea level at Kauai and Hawaii suggests a large-scale component to the intertidal signal. Hypotheses are presented for the superinertial oscillations, including resonance in the forcing, seiche motion, and a high-frequency eigenmode of the Pacific basin.

A simple model is developed describing direct wind forcing of trapped waves around a cylindrical island. In the model, a north-south wind stress acts as a body force on a surface mixed layer. Stratification is described by a constant buoyancy frequency. A rigid lid is imposed, and the depth-independent (barotropic) response is neglected. Length-scale independent linear dissipation is assumed. The baroclinic response in this model displays resonance at the eigenfrequencies of the free azimuthal mode one island-trapped wave. With a dissipation time scale of 15.8 days, first baroclinic mode subinertial trapped waves forced by a wind stress of 0.10 N/m^2 reach rms equivalent sea surface displacements of 1.1 cm, maximum alongshore velocities of 7.2 cm/s, maximum isopycnal displacements of 16 m, and a Q of 14. This response is of the order of observed trapped waves at the island of Hawaii, suggesting that direct atmospheric forcing plays a significant role in the generation of island-trapped waves. Excitation of the baroclinic modes produces isopycnal displacements and alongshore currents well below the mixed layer near the island. A comparison with observations reveals that the higher baroclinic mode response is too large in the model. Suggestions are offered for future modeling endeavors.

Evidence that island-trapped energy from Hawaii leaks to the Maui group of islands (Maui, Molokai, Lanai and Kahoolawe) is demonstrated in time-dependent coherence peaks between sea level at Hilo (Hawaii) and Kahului (Maui). Energetic trapped wave events at Hilo correspond to periods of enhanced coherence between Hilo and Kahului. Hilo sea level and the north and east wind at Kahului are treated as inputs forcing Kahului sea level; the empirically-derived transfer function between Hilo and Kahului sea level has a significantly nonzero peak at the observed trapped wave period at Kahului. It is concluded that leakage is the dominant forcing mechanism for the observed trapped wave peak at Kahului.