INTERNAL TIDES IN AN ISLAND COASTAL ZONE:

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By

Katharine Anne Smith

Dissertation Committee:

Mark Merrifield, Chairperson
Glenn Carter
Margaret McManus
Brian Powell
Megan Donahue

Abstract

The Hawai'i Ocean Mixing Experiment established the Hawaiian Ridge as a site of strong internal tide (IT) generation, but it did not resolve the propagation of ITs into the island nearshore regions. Ka'ena Ridge, off the northwest corner of the island of O'ahu, is known as one of the strongest IT generation sites along the Hawaiian chain, and the ridge offshore of Makapu'u Point on the southeast corner of O'ahu also generates ITs, exposing the island to locally as well as remotely generated ITs. The behavior of these ITs in nearshore O'ahu is characterized using observations from sites around the island and with regional numerical models.

The diurnal IT generated over Ka'ena Ridge is predicted by a high-resolution, primitive equation model to propagate clockwise around O'ahu in an island-trapped fashion. This is in contrast to the semidiurnal IT which, while much stronger than the diurnal, primarily propagates away from the Hawaiian Island chain. Observations support the diurnal island-trapped behavior as predicted in the model. The trapped behavior provides the east shore of the island, which is otherwise sheltered from locally generated ITs, with its dominant source of IT variability, and it may retain a higher proportion of the diurnal IT energy for dissipation in the island nearshore compared to the semidiurnal IT energy. Due to the role of the Coriolis acceleration in wave trapping, island-trapped waves have mostly been studied at subinertial frequencies, for which perfect trapping is possible. Around O'ahu, the diurnal tide is superintertial (~1.4*f*), making this an example of the understudied phenomenon of superinertial internal waves partially trapped by rotation. These results indicate that rotational effects on the behavior of ITs in coastal systems should be considered even at frequencies above the inertial.

Hanauma Bay is located just west of the IT generation site offshore of Makapu'u Point. Large semidiurnal ITs enter the bay, dominating temperature fluctuations in the deeper bay (> 15 m) but affecting temperatures in the bay as shallow as 5 m. During summer months when stratification is high, the semidiurnal IT is observed to cause consistent temperature drops of 1 °C (associated with a 50 m displacement) and occasional temperature drops up to 2.7 °C (100 m displacement) near the bay mouth at 20 m depth. Semidiurnal band currents are similarly strong in spring and summer, but spring temperature fluctuations are small due to low

stratification. These results highlight the importance of understanding ITs and the role of stratification in the physical variability of nearshore ecosystems, particularly close to IT generation sites.

In Mamala Bay, on the south shore of O‘ahu, the semidiurnal IT is observed to break and form internal tidal bores as large as 60 m in height at the bottom near the 500 m isobath. These bores are associated with enhanced turbulent dissipation and mixing. Near the 90 m isobath, frequent internal bores not associated with a tidal phase are observed at the bottom. While the temperature drops caused by the bores indicate displacements as large as 70 m, the duration of the decreased temperatures is generally less than 1 hour. Near the 300 m isobath, a high frequency band of internal waves (6–40 cycles per day) exhibit elevated energy near the slope. This elevated energy is not observed at the 90 m or 500 m isobaths and likely represents the concentration of energy at those frequencies by local critical slope interactions.

ITs shoaling at ocean boundaries provide significant contributions to ocean mixing and dissipation, making them an important part of understanding and characterizing ocean stratification and the ocean energy budget. Additionally, shoaling ITs can affect nearshore ecosystems by transporting water from depth into shallower habitats, giving ecological motivation for studying their behavior in nearshore systems. The findings of this work have implications for local physics and O‘ahu’s nearshore ecosystems, and they give insight into mechanics that are likely to be important in nearshore locations worldwide.