OBSERVATIONS OF THE IMPACT OF MESOSCALE CURRENTS ON INTERNAL TIDE PROPAGATION

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By
Cédric Chavanne

Dissertation Committee:

Pierre Flament, Chairperson
Eric Firing
John Learned
Doug Luther
Mark Merrifield

ABSTRACT

High-Frequency Radio Doppler surface current meters and Acoustic Doppler Current Profilers observations during the Hawaiian Ocean Mixing Experiment and the Dynamics of Localized Currents and Eddy Variability in the Adriatic programs were analyzed to describe the tidal and mesoscale currents and their interactions in two very different oceanographic settings.

The northwestern Adriatic Sea has a shallow seasonal thermocline in spring and summer, when fresh water spreads from the Po over the northern Adriatic, which disappears during fall and winter in the interior of the basin where the water column is mixed to the bottom by outbreaks of cold dry Bora winds, but persists near the Italian coast along which the Po outflow is confined. The two-year DOLCEVITA deployment was along the Italian coast of the northwestern Adriatic. In the middle of the basin, the M_2 and K_1 currents oscillate along the basin axis, but become more circular toward the Italian coast. Comparison with a 3-D finite-element numerical model of the tides show a good agreement, except in a 10-20 km wide strip along the Italian coast, where the laterally-sheared and intermittent Western Adriatic Current flows southeastward. Observations suggest that tides in this area have a strong baroclinic component, possibly affected by the mesoscale currents, which could account for the discrepancies between observations and model predictions.

In contrast, the ocean around the main Hawaiian islands is strongly stratified yearlong. The Hawaiian Ridge is an abrupt topographic feature, rising from depths of 5000 m to the surface within O(50 km). M_2 barotropic tides propagate nearly perpendicular to the ridge, generating strong internal tides over the ridge flanks. The 9-month HOME deployment was along the west shore of O‘ahu. The instruments covered the southern side of the Kauai Channel, one of the strongest internal tides generation site of the Hawaiian Ridge. Comparisons with 3-D finite-difference numerical models of the tides show good agreement for the phases, but the kinetic energy pattern and amplitude differ significantly. The models predict a surfacing area of energetic internal tidal beams 30-40 km from the ridge axis, which is 20 km further away and weaker in the observations. The mesoscale variability was dominated by eddies in Fall 2002, with Rossby numbers reaching one, and vorticity waves in Spring 2003, both surface intensified with strong vertical shears. The interaction of the internal tides with the mesoscale currents is studied using a standard ray tracing model, whose results agree qualitatively with the observations, showing that the energy and phase of the tidal beams are modulated by the mesoscale fields near the surface. The net effect of mesoscale variability over long periods of time is to low-pass filter the vertical modes of internal tides, the resulting surface pattern resembling that one would obtain from the summation of only the first few lowest vertical modes. Significant energy is smeared out of the phase-locked tides, and energy transfers between internal tides and mesoscale currents occur near the surface, with implications on tidal energy budgets.

The dynamics of a strong submesoscale anticyclone west of O'ahu are also described. It was generated in October 2002, possibly as a barotropic instability of the flow associated with a cyclone south of O'ahu, with an initial surface vorticity of $\sim -0.8f$, where f is the inertial frequency. Within three days, the anticyclone reached an extremum vorticity of $\sim -1.5f$, possibly as a result of non-linear Ekman pumping by the trade winds, with a solid-body core of 17 km radius and azimuthal velocity of $\sim 35\,\mathrm{cm.s^{-1}}$. It then slowly decayed to less than f five days later, possibly as a result of centrifugal instability. It was in cyclogeostrophic balance to first order. During this period, the anticyclone was trapped between the coast, the cyclone to the south, and a larger cyclone to the west. A front developed between the western cyclone and the anticyclone, as warm water from the southwest was advected northward, and cold water from the northeast southward. The front was divergent ($\sim 0.2f$) and anticyclonic ($\sim -0.25f$) on its warm side, and convergent ($\sim -0.25f$) and cyclonic ($\sim 0.15f$) on its cold side, counteracting the production of density gradient by eddies straining the temperature field.