EDDIES AND CURRENTS OF THE HAWAIIAN ISLANDS

A DISSERTATION SUBMITTED TO THE GRADUATE DIVISION OF THE UNIVERSITY OF HAWAII IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN

OCEANOGRAPHY

DECEMBER 1998

By

Claude Frederick Lumpkin

Dissertation Committee:

Pierre Flament, Chairperson
John Learned
Doug Luther
Mark Merrifield
Bill Patzert
Bo Qiu

Abstract

Hawaiian lee eddies are examined in WOCE drifter trajectories. ADCP measurements. in-situ sea level records, satellite altimetry and AVHRR imagery. The mean currents, temperature. and their variance in the Hawaiian region are mapped from the surface drifter data and the historical hydrography. A regression analysis is used to identify the Ekman component of the drifter speed.

It is shown that the islands have a profound effect on the downstream flow: the island wake is composed of counter-rotating gyres over 800 km long. Eddy energy is greatly magnified in this region, and the mean propagation paths of cyclonic and anticyclonic eddies correspond to the vorticity of the gyres. These gyres are separated by a narrow countercurrent, the Hawaiian Lee Countercurrent. The northern edge of the cyclonic gyre is delineated by a westward current, which flows along the southwest shores of the islands. This current has not previously been identified, and is named the Hawaiian Lee Current (HLC) in this study. Once passing Kaua'i, the HLC joins with the North Hawaiian Ridge Current to form a westward jet extending to 180°.

Hawaiian lee eddies are generated at ~50–70 day intervals, and can be clearly identified in satellite altimetry. A generalized form of the Rankine vortex structure is described, which allows for nonzero vorticity in the vortex shell. This model is used to characterize the observed lee eddies, which range from quasigeostrophic to nonlinear length and velocity scales. A synthesis of the drifter data, altimetry and AVHRR imagery provides a description of the eddies' life cycle from birth to downstream propagation and spin-down. The maximum core vorticity of several newly-formed anticyclonic eddies may have been limited by centrifugal instability; possible azimuthal mode 2 instability leading to the production of a tripolar vortex is also noted for two cyclonic eddies. The eddies' propagation speeds compare favorably to existing theory, with deviations possibly due to advection and eddy-eddy interaction. The spin-down of the eddies is modeled by a simple entrainment model. Drifter observations suggest that anticyclonic eddies may occasionally merge as they drift west-southwest from Hawai'i, producing rapid jumps in their core vorticity and size.

Lagrangian statistics of individual drifters are calculated in several subregions, demonstrating an increase of 1.3-1.6 times in diffusivity due to the lee eddies. The zonal diffusivity is larger than the meridional diffusivity by an amount consistent with the background shear of the mean currents.