1. Introduction

Mesoscale eddies are generally thought to play important roles in ocean circulation, heat and mass transport, mixing, biological productivity, upper ocean ecology, fisheries, and biogeochemistry including elemental cycling and fluxes (e.g., Cheney and Richardson, 1976; Olson, 1980; Lobel and Robinson, 1986; Falkowski et al., 1991; Dickey et al., 1993; Allen et al., 1996; McGillicuddy and Robinson, 1997; McGillicuddy et al., 1998; Oschlies and Garcon, 1998; Honjo et al., 1999; McNeil et al., 1999; Letelier et al., 2000; Fischer et al., 2002; Garcon et al., 2001; Leonard et al., 2001; Oschlies, 2001; Seki et al., 2001, 2002; Flierl and McGillicuddy, 2002; Lewis, 2007; Bidigare et al., 2003; Taupier-Letage et al., 2003; Sakamoto et al., 2004). The horizontal dimensions of mid-latitude mesoscale eddy features generally range from about 100 to 250 km in diameter with scaling roughly dictated by the Rossby radius of deformation (e.g., Richman et al., 1977). Fully developed eddies are often in near geostrophic balance although the ageostrophic component can be important. A variety of physical processes have been hypothesized to contribute to mesoscale eddy formation. For example, eddies or rings in the vicinity of western boundary currents like the Gulf Stream and the Kuroshio may be generated through inertial instabilities, open ocean eddies may be produced through baroclinic instabilities, and eddies formed in the vicinity of sea mounts may be caused by barotropic instabilities.

Islands can clearly perturb ocean circulation patterns as well documented for the Hawaiian Island chain (e.g., Qiu et al., 1997; Lumpkin, 1998). Further, mesoscale eddies are also often evident near islands as indicated by the observations reported here and elsewhere (Patzert, 1969; Barton, 2001; Lumpkin, 1998). It has been suggested that instabilities associated with current flow past islands or through island passages can generate eddies (Aristegui et al., 1994, 1997; Barton et al., 2000). Another mechanism for generating eddies involves the acceleration of winds through island channels with high mountains on either side. Gradients in the wind fields on the lee sides of such islands can produce wind-stress-curl distributions that result in localized oceanic upwelling and downwelling and both warm-core and cold-core mesoscale eddies. The latter mechanism appears to explain the production of eddies in the lee of the Hawaiian Islands based on the results of previous investigators and our current study (Patzert, 1969; Lumpkin, 1998; Holland and Mitchum, 2001; Chavanne et al., 2002). It is worth emphasizing that warm-core anti-cyclonic eddies are also produced via the wind-stress-curl mechanism as well as by a shear instability mechanism by drawing energy from the North Equatorial Current as it impinges on Hawaii and separates at the southern tip of the island (Lumpkin, 1998). As noted by an anonymous reviewer, these warm-core eddies may interact with adjacent cold-core eddies and act to suppress biological productivity where they originate and propagate. Our focus here is principally on cold-core eddies, which were sampled directly during our studies. Interaction among eddies is considered in other E-Flux papers.

The central goal of the E-Flux experiment was to improve our fundamental understanding of the coupling of physical, biological, and biogeochemical processes that occur within mesoscale eddies. Importantly, some researchers have suggested that mesoscale eddies are major contributors of carbon to the deep sea (McGillicuddy et al., 1998) while others argue that they may have less of an impact than suggested by McGillicuddy et al. (1998) (e.g., Oschlies and Garcon, 1998). This controversy bears directly on establishing the roles and modeling of mesoscale features as they may affect elemental budgets, fluxes, and the ecology of the upper ocean. More specifically, the effects of such features on nutrient availability, primary production, biological community structures and size distributions, and fluxes of elements including carbon and silicon to the deep sea remain contentious.

The recurrent nature of eddies to the west of the Hawaiian Islands during persistent trade wind conditions was a primary stimulus for the present E-Flux experiment. In particular, it has been previously reported that westward propagating cyclonic eddies are produced in the lee of the Hawaiian Islands on time scales of 50–70 days (Lumpkin, 1998; Seki et al., 2002). Previous studies in the lee of the Hawaiian Islands and North Pacific environs have demonstrated that cold-core mesoscale eddies play significant roles in the region's biogeochemistry, biology, and fisheries (Lobel and Robinson, 1986; Falkowski et al., 1991; Leonard et al., 2001; Seki et al., 2001, 2002; Bidigare et al., 2003; Vaillancourt et al., 2003). Thus, E-Flux investigators conducted a series of three dedicated field experiments to address the various biogeochemical mechanisms hypothesized to lead to enhanced carbon export. This paper reviews the general background of each of the three separate field experiments, the sampling strategies and methods employed, and general observational results with emphases on physical and bio-optical aspects.

2. Observational site, objectives, and methods

2.1. Site

Although mesoscale eddies are rather ubiquitous in the ocean, they remain difficult to study in sufficient detail because they are generally ephemeral and evolve too quickly in geographically diverse locations to be easily sampled using present-day observational tools (Bidigare et al., 2003; Dickey and Bidigare, 2005). With these constraints in mind, the site for the E-Flux field experiments, to the west of the southeastern Hawaiian Islands of Maui and Hawai'i, was chosen on the basis of several criteria. First, it was deemed important to choose a region where mesoscale eddies regularly form. Historical hydrographic and satellite data sets (Patzert, 1969; Lumpkin,