elusive ocean features. As a result, the dynamics associated between the horizontal and vertical disturbances of a natural system, the displacements of isopycnal layers in relation to the surface expression and our understanding of the physical processes linking the various life-cycle stages of mesoscale eddies and succeeding effects to the biogeochemistry are also still limited (Flierl and McGillicuddy, 2002; Sweeney et al., 2003). Eddy life-cycle stages are often connected to biological evolutions, but high resolution *in situ* observations of the physical transformations are still required. Further, some Hawaiian eddies have a tendency to become semi-elliptical in shape (Lumpkin, 1998; Vaillancourt et al., 2003). In particular, we know very little about the internal structure of elliptical eddies, the eddies' structural relationship to life-cycle stages and implications on biological evolutions.

The present study is part of the E-Flux interdisciplinary program to investigate the specific physical, chemical and biological characteristic of Hawaiian cyclonic eddies. Here we report the detailed observations of the physical dynamics and the biological implications of cyclonic eddy *Noah* during the first E-Flux I field experiment, which occurred in November 2004. The quantification of the horizontal and vertical anomaly structures, interior dynamics, velocity field and biogeochemical–biological distributions with respect to the physical gradients of the observed eddy feature are examined and compared with Cyclone *Opal* observed during E-Flux III (Nencioli et al., 2008) as well as other reported field studies from this region. Particular attention is given to the description of the quasi-elliptical structure of Cyclone *Noah*; Noah's life-cycle is compared with that of Cyclone *Opal*. Nutrient-phytoplankton dynamics and particle export associated with *Noah* are treated in detail by Rii et al. (2008).

2. Material and methods

The E-Flux experiments utilized satellite- and ship-based observations as discussed in detail by Dickey et al. (2008). Satellite data were used to help guide the field measurements. For example, inspection of NOAA Geostationary Operational Environmental Satellite (GOES) and the NASA Moderate Resolution Imaging Spectroradiometer (MODIS) satellite sea-surface temperature (SST) imagery, which was obtained for August 2004 and prior to the E-Flux I research cruise, indicated that a cool SST anomaly had formed to the west of the ʻAlenuihaha Channel. Initial satellite-based estimates suggested that its surface manifestation was ~40 km in diameter and 2–3 °C cooler than surrounding waters. The surface feature, later named Cyclone *Noah*, appears to have spun up due to increased northeasterly trade wind gusts through the ʻAlenuihaha Channel. In the following section, we present some of the salient aspects of the E-Flux I field study.

2.1. Field observations

Shipboard hydrographic surveys and biological measurements were performed within mesoscale Cyclone *Noah* and the surrounding waters from November 4–22, 2004 aboard the R/V *Ka'imikai-O-Kanaloa* (*KOK*) approximately 2.5 months after the initial signature of the eddy was detected from remote sensing satellites. The surface expression of *Noah* was less apparent from satellite imagery a few days prior to the beginning of our shipboard survey, limiting our ability to determine the optimal sampling locations for the survey field. The weakness of the surface expression of the eddy forced increased reliance upon ship-based observations and also suggested that the eddy may have begun to physically decay. However, weakness in SST expression also can be caused by factors such as diurnal heating effects and advection of adjacent near-surface waters (Chavanne et al., 2002). The eddy center of *Noah*, based on tracking estimates using GOES SST observations, appeared to have traversed from its initial satellite-determined position at 20.1°N, 156.4°W during the week between August 13–21, 2004 to 19.6°N, 156.5°W (~74 km to the south), by the time of shipboard sampling. This position was then maintained during the E-Flux I ship survey.

Four transect lines averaging 150 km in length (in a star configuration) with survey station spacing ca. 20 km were completed over the course of about 4–5 days (Fig. 1). The initial "star" sampling pattern was centered on the best estimate of the center of the eddy based on coarse satellite SST data. A total of 38 STAR-station hydrographic profiles (Casts 10–48) including the collection of *in situ* water samples were performed across each radiating transect line to determine the spatial extent of the mesoscale feature. In addition, a total of 23 separate eddy IN-station (Casts 49–71) hydrocasts were conducted as close to the estimated center of the eddy as possible to conduct biological experiments and to determine the anomalous structure of the estimated center of the eddy with respect to 18 additional OUT-stations (Casts 1–9, 72–80). The far-field OUT-stations were deemed to be outside the influence of the eddy and were used as a background reference for physical, chemical, and biological conditions surveyed during the STAR- and IN-stations. None of the STAR-stations were used for the analysis of the IN- and OUT-stations and vice versa. Profiles were generally made to a depth of +500 m and were utilized to measure temperature, conductivity, dissolved oxygen and chlorophyll *a* fluorescence using a SeaBird 9/11+ CTD, SeaPoint fluorometer and a rosette equipped with 24 12-L sampling bottles. Downcast CTD data were processed and binned into 1-m depth bins. Current velocity was measured during the entire cruise using a ship-mounted VM-150 kHz acoustic Doppler current profiler (ADCP). The ADCP provided vertical profiles of the horizontal water velocity with 10-m vertical resolution from 30 to 450 m. Inorganic macronutrients and total chlorophyll *a* analyses were performed using *in situ* water samples, which were collected during Transect 3 at 14 discrete depths (for details, see Rii et al., 2008). The sampling depths were based on the vertical structure of the physical and biological variables (i.e. mixed-layer depth, specific isopycnal surfaces, euphotic layer depth, and depth of the deep chlorophyll maximum depth (DCML)).

2.2. Analytical calculations

In order to characterize the properties of Cyclone *Noah*, we computed differences between those properties within the cyclone field (STAR-stations) with respect to those external to it (OUT-stations). These differences are called differential property anomalies or DPAs (following Simpson et al., 1984). The DPA calculations of the temperature, salinity, density and other water properties are used to quantify the magnitudes of the anomalies of specific variable as functions of the radial distance from the center of the eddy relative to typical measurements within the surrounding oligotrophic waters (OUT-stations). Reference properties of surrounding waters may be considered far-field properties. The differential property anomaly (DPA) is defined mathematically as:

$$\mathrm{DPA}(r,z) = \mathrm{STAR}_{\mathrm{CAST}}(r,z) - \mathrm{OUT}_{\mathrm{AVG}}(z), \quad (1)$$

where $\mathrm{STAR}_{\mathrm{CAST}}(r,z)$ is the vertical profile of a particular property as measured at a given STAR-station at a specified radial distance r from the eddy center, and $\mathrm{OUT}_{\mathrm{AVG}}(z)$ is the reference vertical profile of the arithmetic average computed using the data