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An Offshore Eddy in the California Current System

Preface

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"Upwelling and downwelling
Mixing and shear
Advection and rotation
The ingredients are here.

Pressure from above
Resistance from below
Neither prevails
We go with the flow.

The chlorophyll is deep
The water is blue
Carbonate and nutrients
Give us a clue.

Interactions are many
The systems complex
Two weeks still to go
We're not yet wrecks."

R.V. *New Horizon* Weekly Report
to Director's Office, SIO, January 1981

Evidence (Fig. 1) collected over the past 28 years in the California Current System (CCS) by the California Cooperative Oceanic Fisheries Investigations (CalCOFI) shows that offshore mesoscale undulations and closed circulations, some of which are quasi-permanent and semi-stationary, exist throughout the CCS. Typically, the length scale at the surface associated with these offshore features is about 200 km. This mesoscale variability has been interpreted as the signature of subsurface offshore eddies (Bernstein, Breaker and Whritner, 1977; Burkov and Pavlova, 1980; Simpson, 1982).

In the fall of 1980 infrared satellite imagery was used to monitor the surface signature of the mesoscale eddy field in the offshore California Current. These observations were used to select a quasi-stationary anticyclonic eddy-like surface pattern for detailed shipboard study. From January 9 to 17, 1981, two orthogonal vertical sections through the approximate center of this infrared sur-

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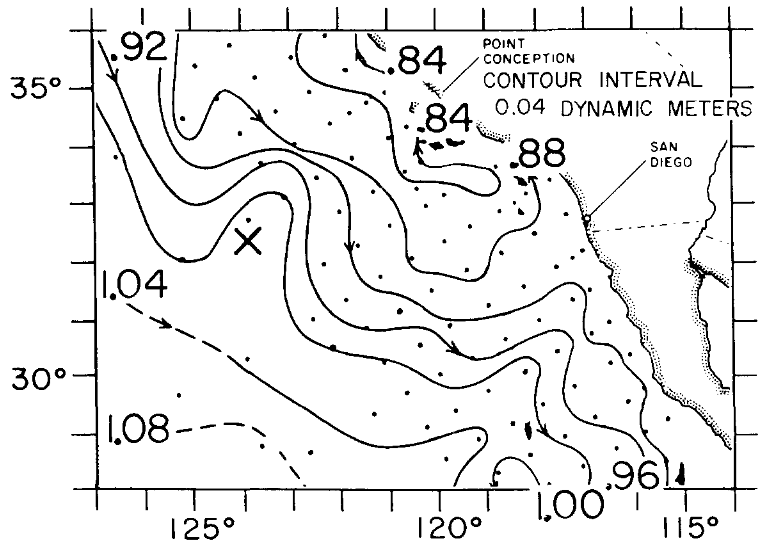

Fig. 1. Mean geostrophic flow at the surface relative to the 500 db surface for October, 1950-1964 (from Wyllie, 1966). The center of the CCS eddy observed during January, 1981 is marked with an X.

face pattern were made from R.V. *New Horizon*. Station spacing along each section generally was 20 km or less. At each station vertical profiles of temperature, salinity, dissolved oxygen, optical transmissivity and *in situ* chlorophyll *a* fluorescence were made with a Neil Brown CTD/O_2 system to a depth of about 1500 m. A twelve bottle 5-liter rosette was attached to the CTD system from which discrete samples for salinity, oxygen, nitrate, nitrite, phosphate, silicate, titration alkalinity, total inorganic carbon dioxide, chlorophyll *a* and phaeophytin analyses were drawn. Most of the bottles were used to sample the upper 200 m. Counts of microplankton species were made from these bottles on the transect through the eastern quadrant of the pattern. At each station of both transects, vertically integrated zooplankton net tows were taken from 400 m to the surface.

The shipboard observations showed the presence of an eddy-like system beneath the surface infrared signature. The four papers in this volume discuss various aspects of the eddy system. Part I uses the density field and associated water properties to investigate the physical dynamics of the system. Part II relates the subsurface processes to the surface infrared signature. Part III uses chemical tracers to identify the origin and relationship of the eddy to the CCS, as well as to suggest the possible effects of the eddy on phytoplankton production. The distributions of microplankton and zooplankton are described in Part IV and used to provide independent evidence in support of the hypotheses concerning the origin, physical dynamics, and productivity of the eddy system.

The water properties of the eddy system demonstrate that, while the feature behaved as a dynamical unit, there were at least three separate layers that had evolved by the time of the observations. A warm-core eddy centered between 250 m and at least 1400 m was the dominant dynamical feature. This feature had a Gaussian dynamic height distribution which suggests an equilibrium configuration. Potential vorticity and density showed that the warm-core eddy did not exchange mass with the coastal or oceanic waters of the California Current. The source water for the warm-core eddy was the California Undercurrent. A mixed layer extended from the surface to 75 m over the warm-core eddy. The water in this layer is a mixture of coastal water that was entrained from an upwelling streamer and offshore oceanic water. The infrared surface manifestation which identified this layer apparently resulted from the geostrophic readjustment of the mixed layer to the subsurface warm-core eddy. The strongest surface fronts occurred on the eddy boundaries and were at least two orders of magnitude greater than the mean gradients. The evolution of the surface confirms earlier numerical models by other authors. A cold-core region was located between the mixed layer and the warm-core eddy; chemical and biological data suggest that the major source of this water was of coastal origin. The most likely mechanism for the origin of the cold-core region is the lateral entrainment of near-surface water, primarily of coastal origin, into the eddy system. Entrainment of oceanic and coastal water was still active during the shipboard study. The presence of zooplankton species characteristic of different water types throughout the region of the eddy system provided an indication of the mixing that occurred since the system originally formed. Chemical properties, together with chlorophyll *a* and plankton distributions, showed that primary and secondary productivity were enhanced in the frontal regions and in the central dome of the cold-core region.

The results of our integrated study of one California Current eddy demonstrate that these eddies can interact in a complex way with coastal and oceanic waters, as well as with other major components of the CCS. This type of eddy is ubiquitous in the offshore California Current, thus they provide an important mechanism for the lateral transport and stirring of chemical properties and biological populations in the CCS. The overall biological productivity, water property mixing, heat transport and circulation of at least the offshore California Current may be largely determined by processes associated with the offshore mesoscale eddy field.

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