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HF radar-derived origin and destination of surface waters off Bodega Bay, California

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Abstract

As an integral part of the WEST study of the role of wind-driven transport in shelf productivity, HF radar currents are analyzed to determine typical surface flow patterns off Bodega Bay in northern California. Radar-derived surface trajectories and surface velocity divergences are used to determine the proximal origins and destinations of surface waters in the area. Surface trajectory results show a strong bimodality, with water over the entire shelf originating in the north under upwelling conditions and waters over the inner/mid-shelf originating in the south during relaxation conditions. Outer shelf waters have more variable transport patterns during relaxation conditions, with limited equatorward or onshore movements being most typical. The destinations of surface waters starting at the outer shelf are predominantly offshore, with the majority of particles exiting the radar domain west of Pt Reyes along the shelf edge in less than 2 days. Significant proportions of water from the inner/mid-shelf are exported southward and exit the radar domain inshore or within 20 km of the tip of Pt Reyes, creating possibilities for either nearshore retention in the Bodega region or entrainment of water into the Gulf of Farallons. Approximately 15% of all trajectories remained in the radar domain for 6 days, suggesting that a biologically significant percentage of larvae might be retained in the area for time periods approaching typical larval durations. Calculations of surface divergence indicate where vertical flux may be significant. An extensive area of positive divergence is observed off Bodega during upwelling conditions, while weakly convergent flow is observed where upwelling flows approach Pt Reyes. Positive divergence also is observed during relaxation periods when poleward flow separates from the shore just north of Pt Reyes. Estimates of vertical flux in these divergence zones point to a significant contribution of recently upwelled waters to the observed horizontal fluxes at the surface. Determination of the ultimate source and fate of phytoplankton-rich waters requires further analysis of the detailed time dependence of phytoplankton concentration relative to the time dependence of wind-forced currents.

Keywords: Transport processes; Upwelling and relaxation; Wind-driven currents; Oceanic divergences; Surface currents; Radio oceanography

1. Introduction

The objective of the WEST program is to obtain a better understanding of the role of wind-driven transport in shelf productivity. Specifically, while we

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know that upwelling of high-nutrient subsurface waters results in phytoplankton blooms, and that these blooms occur during periods of relaxation following upwelling (e.g., Fig. 1), it is not possible to assess the source nor the fate of these blooms without knowing more about the movement of surface waters in an upwelling area like that off Bodega Bay. The deployment of HF surface radars in the area in 2001 provided the data on surface currents necessary for an analysis of the source and fate of surface waters sampled at the key WEST sites off Bodega Bay.

This paper follows a paper by Kaplan et al. (2005) in which the HF radar data were analyzed as Eulerian data and the focus was on the structure and dynamics of surface flows over the shelf. In that paper, we describe a strong cross-shore gradient in the strength of alongshore currents, as well as strong gradients in tidal and inertial flow energy. Wind-driven currents over the outer shelf and slope tend to be strong and persistently equatorward, whereas nearshore currents are as often poleward as equatorward. Point Reyes is an important barrier to alongshore flow, producing an offshore deflection

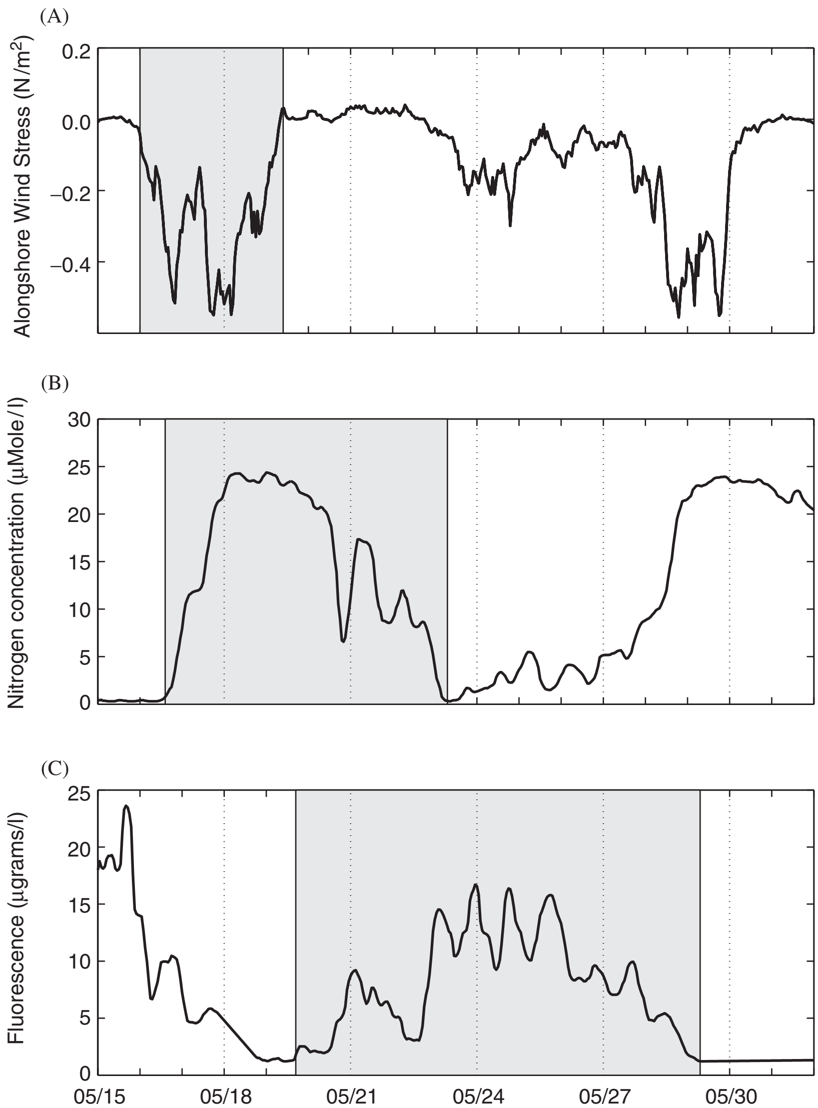

Fig. 1. Alongshore wind stress (A), dissolved nitrogen concentration (B) and fluorescence (C) for the second half of May 2001. Wind measurements were made at NDBC 46013. Nitrogen concentration and fluorescence were measured at the D90 WEST mooring at 1 m depth. Gray areas indicate a wind event (A), followed shortly by high nutrient levels (B), which in turn were followed by a phytoplankton bloom (C).