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Quantifying eddy–chlorophyll covariability in the Coastal Gulf of Alaska

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ABSTRACT

Many analyses of the interaction between ocean physics and biology in the Coastal Gulf of Alaska (CGOA) resolve chlorophyll variability separately from eddy-induced circulation, but eddy–chlorophyll covariability has not received much attention. The present research quantified eddy–chlorophyll interaction from the covariability of observed chlorophyll and eddy kinetic energy (EKE) in the CGOA for 1998–2002. Analyses with coupled empirical orthogonal functions (CoEOFs) showed that covariability between the two fields resulted in strongly coupled modes—a feature absent from standard-EOF analyses. Timescales of covariability were also incorporated into the analyses. The temporal evolution of each CoEOF mode was decomposed with the cross-wavelet power spectrum, and instances of covariability for synoptic timescales (2–6 months) were attributed to eddy–chlorophyll interaction. Further analyses in the present research included CoEOF decomposition for the output of a coupled physical–biological model in the CGOA. Model-observation comparisons with CoEOFs offer a new and important way to evaluate coupled models for eddy–chlorophyll interaction across multiple temporal and spatial scales. Implications for cross-shelf transport and spatiotemporal sampling for both observation and model data fields are also discussed.

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1. Introduction

The Coastal Gulf of Alaska (CGOA; from 140°W to 164°W along the Alaska Peninsula; see Fig. 1) supports biologically rich and diverse marine resources. As a result, the U.S. GLOBEC program designated the CGOA a study site to investigate the effects of climate variability on ecosystem dynamics. Synoptic-scale eddies (commonly referred to as "Sitka" and "Yakutat" eddies) modulate primary production along the CGOA shelfbreak by transporting chlorophyll and nutrients across the shelf (Crawford et al., 2007; Ladd et al., 2005a; Okkonen et al., 2003). These eddies propagate along the shelfbreak entraining chlorophyll- and iron-rich shelf water while simultaneously transporting nitrate- and silicate-rich basin water onto the shelf (Ladd et al., 2005b). But the lower-trophic-level-ecosystem response to synoptic-scale eddies depends on the eddies coinciding with the availability of nutrients, chlorophyll, and solar irradiance (Fiechter et al., 2011)—all three have strong seasonal cycles: summer drawdown of nutrients, spring and fall chlorophyll blooms, and light-limited phytoplankton growth during winter.

Concurrency of eddies with seasonally varying nutrients, chlorophyll, and solar irradiance is one factor complicating the analysis of eddy-induced biological variability (hereafter referred to as "eddy–chlorophyll interaction") in the CGOA. Others include scarcity of in situ nutrient observations and difficulty distinguishing advected from locally produced chlorophyll in satellite observations. And while coupled physical–biological models are capable of tracing the origin of nutrients and chlorophyll production, they may lack the coupled dynamics present in observations. Past research of eddy–chlorophyll interaction, as a result of these difficulties, has mainly resolved chlorophyll variability and ocean-eddy circulation separately (e.g., Crawford et al., 2007, 2005; Ladd, 2007; Brickley and Thomas, 2004). The task then for research is to quantify interaction by examining eddy–chlorophyll covariability.

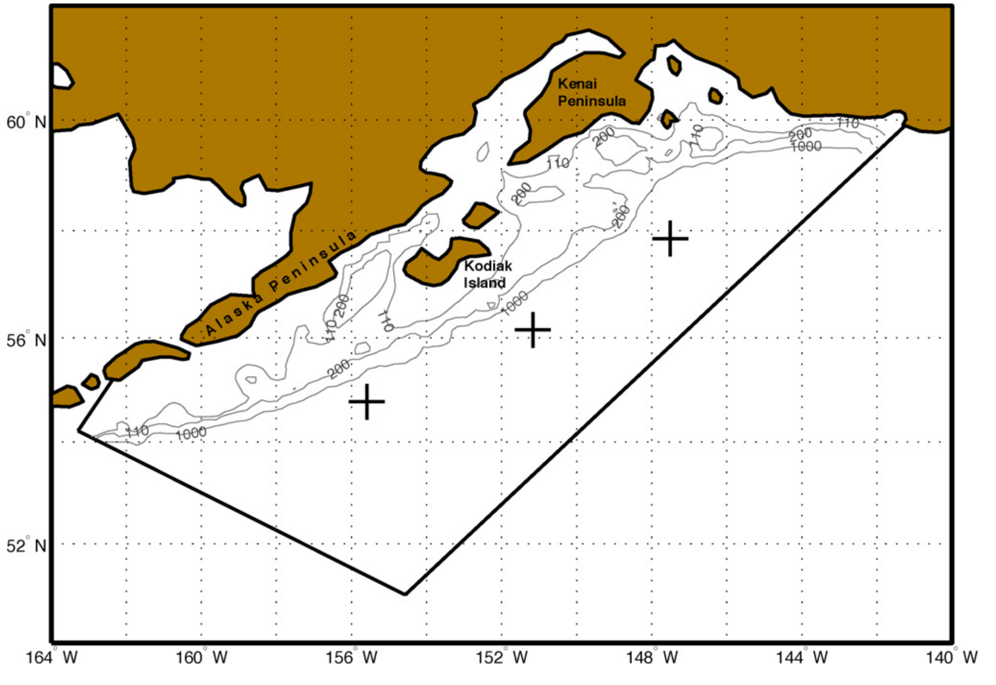

Fig. 1. CGOA domain. Three locations—referred to geographically, from left to right, as southwest, central, and northeast locations—are designated as markers for reference to chlorophyll and EKE activity. Contours denoting bottom topography (in meters) are shown.