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A data assimilative, coupled physical–biological model for the Coastal Gulf of Alaska

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A B S T R A C T

A data assimilative, coupled physical–biological model for the Coastal Gulf of Alaska (CGOA) is used to investigate the extent to which improvements to oceanic circulation yield improvements to lower trophic level ecosystem predictions, especially in relation to mesoscale variability at the shelfbreak. The ocean circulation component is an implementation of the Regional Ocean Modeling System (ROMS), the lower trophic level ecosystem component is a six-compartment Nutrient-Phytoplankton-Zooplankton-Detritus (NPZD) model with iron limitation, and the data assimilation component is the adjoint-based, four-dimensional variational (4D-Var) system available in ROMS. Assimilated observations consist of weekly satellite sea surface height and temperature, as well as bimonthly *in situ* temperature and salinity measurements. Simulation results for 1998–2002 indicate that assimilation of physical observations significantly improves the accuracy with which the model reproduces the frequency, duration, and intensity of eddy events along the CGOA shelfbreak. Improvements to oceanic mesoscale processes lead to substantial improvements to the biological response predicted by the NPZD model. Observed and simulated correlations between eddy kinetic energy and surface chlorophyll concentrations suggest that ecosystem dynamics at the shelfbreak is tied to eddy activity in the northern CGOA (i.e., off the Kenai Peninsula and Kodiak Island). In the southern CGOA

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(i.e., off the Shumagin Islands), mesoscale processes and ecosystem response at the shelfbreak are uncorrelated, as eddies tend to occur during winter when phytoplankton growth is severely light-limited. Based on observation and control vector impact calculations for physical (eddy kinetic energy) and biological (surface chlorophyll concentrations) processes, improvements to oceanic circulation and ecosystem dynamics are primarily associated with the assimilation of satellite sea surface height observations, and occur mainly through adjustments of the model initial conditions. These similarities in the observation and control vector impacts lend further evidence to the linkages between mesoscale activity and primary production along the CGOA shelfbreak.

1. Introduction

The northwestern coastal Gulf of Alaska (CGOA; from ca. 140° to 164° W, along the Alaskan Peninsula) (Fig. 1) has a highly productive shelf, and supports rich and diverse marine resources. As such, the region has been designated by the U.S. GLOBEC (Global Ocean Ecosystem Dynamics) program as a study site to investigate the potential impact of global climate change on ecosystem dynamics and fisheries. Ocean circulation dynamics in the CGOA is influenced by the Alaska Coastal Current (Royer, 1981) on the shelf and by the Alaskan Stream (Reed, 1984) at the shelfbreak, which leads to significant physical and biological variability on monthly, seasonal, and interannual timescales. In addition, anticyclonic mesoscale eddies propagate southwestward seasonally along the CGOA shelfbreak, modulating the cross-shelf exchange of physical and biological properties (Okkonen et al., 2003; Crawford et al., 2007). Two types of anticyclonic eddies occur in the CGOA region, the so-called Yakutat and Sitka eddies. Yakutat eddies typically form during winter on the relatively broad shelf south of Yakutat, Alaska, and propagate southwestward along the CGOA shelfbreak (Ladd et al., 2005a). Sitka eddies also form during winter, but further south and east of the CGOA on the relatively narrow shelf off Sitka, Alaska (Tabata, 1982). Sitka eddies have been observed to follow two distinct paths: either they propagate westward into the interior of the Alaska Gyre, or they

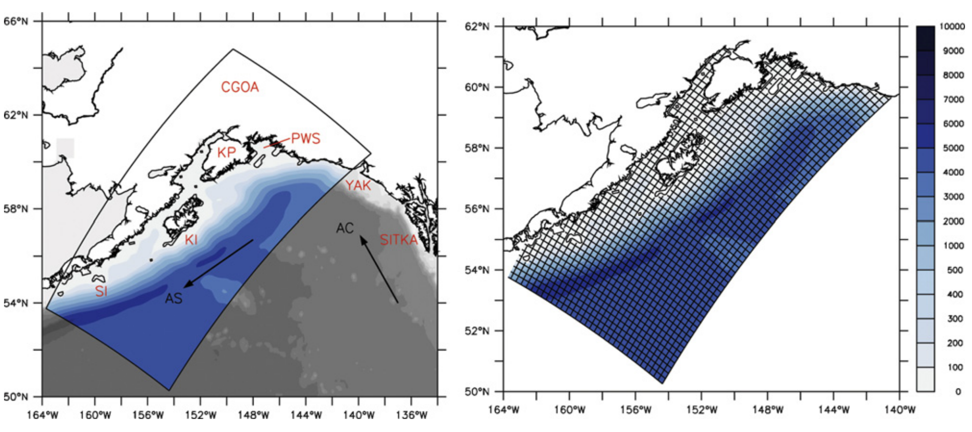

Fig. 1. CGOA geographical map and model domain. Left: map of the Gulf of Alaska superimposed with the region covered by the CGOA model (black outline) and, for reference, the geographical locations of Sitka, Yakutat (YAK), Prince Williams Sound (PWS), Kenai Peninsula (KP), Kodiak Island (KI), and Shumagin Islands (SI); also indicated is the direction of the two dominant boundary currents, the Alaska Current (AC) and the Alaskan Stream (AS). Right: CGOA model domain and computational grid (subsampled by a factor of two for clarity). Bottom topography (m; colorscale) is indicated in both panels.