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Long-term observations of Alaska Coastal Current in the northern Gulf of Alaska ☆

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ABSTRACT

The Alaska Coastal Current is a continuous, well-defined system extending for ~1700 km along the coast of Alaska from Seward, Alaska to Samalga Pass in the Aleutian Islands. The currents in this region are examined using data collected at >20 mooring sites and from >400 satellite-tracked drifters. While not continuous, the mooring data span a 30 year period (1984–2014). Using current meter data collected at a dozen mooring sites spread over four lines (Seward, Gore Point, Kennedy and Stevenson Entrances, and the exit to Shelikof Strait) total transport was calculated. Transport was significantly correlated with alongshore winds, although the correlation at the Seward Line was weak. The largest mean transport in the Alaska Coastal Current occurred at Gore Point (1.4×10^6 m^3 s^{-1} in winter and 0.6×10^6 m^3 s^{-1} in summer), with the transport at the exit to Shelikof Strait (1.3×10^6 m^3 s^{-1} in winter and 0.6×10^6 m^3 s^{-1} in summer) only slightly less. The transport was modified at the Seward Line in late summer and fall by frontal undulations associated with strong river discharge that enters onto the shelf at that time of year. The interaction of the Alaska Coastal Current and tidal currents with shallow banks in the vicinity of Kodiak Archipeligo and in Kennedy–Stevenson Entrance results in mixing and prolonged primary production throughout the summer.

1. Introduction

The northern Gulf of Alaska (GOA) is an ecosystem dominated by advection, with the well-defined Alaska Coastal Current (ACC) transporting $\sim1\times10^6$ m^3 s^{-1} anti-clockwise along the coast (Royer, 1982; Stabeno et al., 2004; Weingartner et al., 2005). The ACC is driven by along-shore winds, with a hydrographic signature that is characterized by a low salinity core along the coast. This core results from river runoff, which is confined to the coast by downwelling-favorable winds. Along the shelf break, the slope and basin circulation is dominated by the cyclonic subarctic Alaska Gyre, which consists of the northward flowing Alaska Current, an eastern boundary current, and southwestward flowing Alaskan Stream, a western boundary current (Favorite and Ingraham, 1977).

While an ACC-type current exists along much of the North American coast from Vancouver Island to the arctic (Carmack et al., in preparation), it is not a continuous feature (Stabeno et al., 2016). Some of these disruptions in the coastal flow are caused by deep submarine canyons, such as at Cross Sound, which cut across the entirety of the shelf. Others are caused by lack of downwelling favorable winds such as occurs between Cross Sound and Yakutat Bay (Stabeno et al., 2004, 2016). The focus of this manuscript is the region from the Kenai Peninsula to Samalga Pass. In this region, the ACC is largely continuous, although it can be interrupted for short periods of time (days) by gap winds (Ladd et al., 2016) and upwelling favorable winds (Stabeno et al., 2004). In addition, it interacts with bathymetry (e.g. troughs, canyons, banks) which both divert water to the slope and introduce slope water onto the shelf (Ladd et al., 2005a).

While from May to August there can be episodes of upwelling, downwelling dominates the northern GOA most of the year (Stabeno et al., 2004). In spite of this dominance of downwelling-favorable winds, high productivity occurs in the northern coastal GOA. Nutrients are supplied to the northern GOA shelf through several mechanisms including: advection, particularly associated with canyons; the relaxation of summer downwelling winds (Childers et al., 2005; Ladd et al., 2005a); estuarine circulation (Stabeno et al., 2004); sediment resuspension; river discharge (Royer and Grosch, 2007); and, during winter, Ekman transport of

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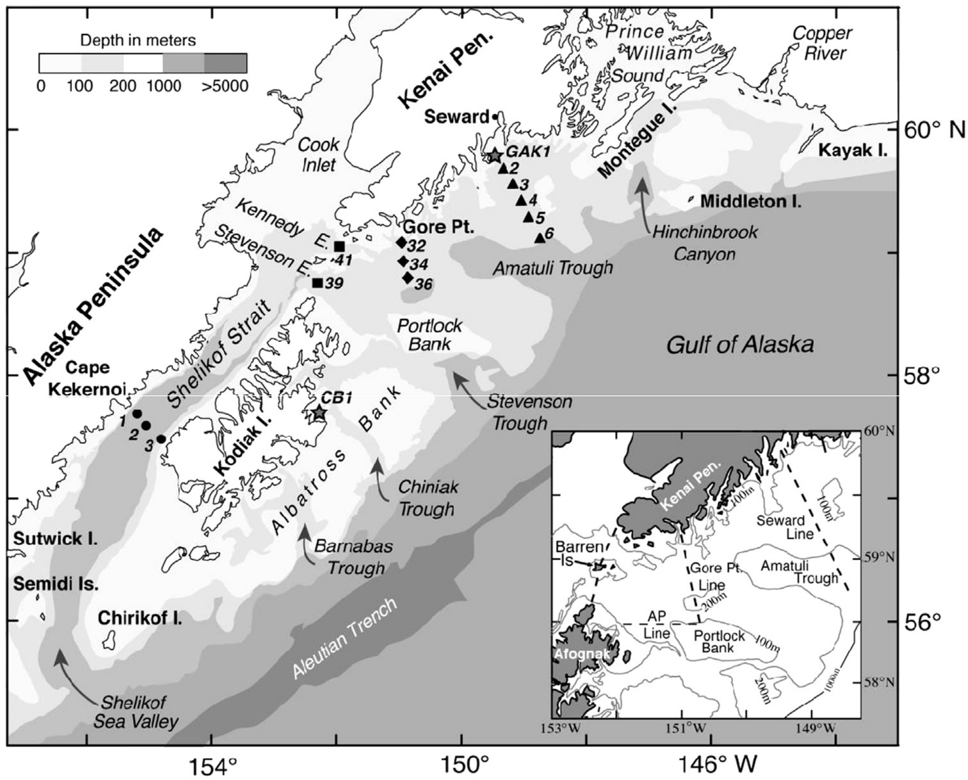

Fig. 1. Map of the coastal Gulf of Alaska from Kayak Island to the exit of Shelikof Strait. Mooring locations are indicated by names or numbers. The inset shows the primary hydrographic lines along the Kenai Peninsula. The hydrographic line at Cape Kekurnoi coincides with the moorings there and is referred to as Line 8. The star on the east side of Kodiak Island is the long-term mooring site CB1, and the one on the Seward line is GAK1. The inset shows the Seward Line (GAK), and the Gore Point (GP), Kennedy–Stevenson (KE–SE), and Afognak–Portlock (AP) lines.

surface water from the central GOA basin onto the shelf (Stabeno et al., 2004). Collectively, these physical processes support enhanced primary and secondary production during the spring and summer (Strom et al., 2007; Coyle et al., 2012, 2013; Stabeno et al., 2004).

The GOA's pelagic production supports some of the nation's largest fisheries and vast numbers of birds and mammals. The region around Kodiak Island (Fig. 1) is of particular importance as a habitat for numerous economically and ecologically important fishes including walleye pollock (Brodeur and Wilson, 1996), Pacific cod (Abookrie et al., 2005), juvenile Pacific halibut, arrowtooth flounder (Meuter and Norcross, 2002) and capelin (Doyle et al., 2002). Kodiak Island is the site of major haul-out and rookery areas for Steller sea lions. Its nearshore region and adjacent troughs support an abundance of juvenile and adult walleye pollock (Wilson, 2000; Hollowed et al., 2007).

Since the early 1980s, multiple papers have been published describing the ACC in the northern GOA – its properties, seasonal variability and dynamics (e.g. Royer, 1981; Reed and Schumacher, 1986; Schumacher et al., 1989; Stabeno et al., 1995, 2004; Weingartner et al., 2005). Most of the papers concentrated on the long-term, hydrographic transect at Seward and those in Shelikof Sea Valley and Strait. These hydrographic data were often used to estimate the geostrophic velocity in the ACC. In 1984, the first arrays of moorings measuring current velocity were deployed in Shelikof Strait and Sea Valley providing estimates of total transport (Schumacher et al., 1989). In the 1990s mooring arrays measuring currents expanded to include Gore Point and Kennedy–Stevenson Entrances (Stabeno et al., 1995). With the deployment of a moored array of current meters on the Seward Line in 2001–2004, four lines existed at which transport could be calculated (Fig. 1). These four cross-shelf mooring arrays were deployed as parts of several large ecosystem studies, including the US GLOBal Ocean ECosystems Dynamics (GLOBEC) Northern Gulf of Alaska program (2001–2005) and the more recent North Pacific Research Board (NPRB) Gulf of Alaska Integrated Ecosystem Research Project (2011–2014).

Most of the moorings in the northern GOA have been deployed intermittently. Only two of the mooring sites (Fig. 1) have been maintained nearly continuously for more than a decade – GAK1 (since 1998) and CB1 (since 1999). The GAK1 mooring records water properties at multiple depths, while CB1 measures both currents and water properties, but only near the bottom.

In this paper we integrate time series from 16 mooring sites (a total of 169 deployments distributed on four mooring array lines listed in Table 1 and Fig. 2) and >400 satellite-tracked drifters, along with model simulations, to explore the temporal and spatial variability in the ACC from Seward to Cape Kekurnoi, including the differences between the cold "season" (October–April) and the warm "season" (May–September), spatial coherence and the relationship to winds. This large data set, together with other published results, permits the development of a schematic of the transports in ACC during the warm and cold seasons from Seward, Alaska to the eastern Aleutian Passes.

2. Methods

2.1. Winds

Reanalysis data was obtained from the North American Regional Reanalysis (NARR) and from the National Centers for Environmental Prediction Reanalysis 2 (NCEPR2) for the North American Region. NARR uses the high resolution NCEP Eta model ($\sim$32 km grid size compared to NCEPR2's 2.5° grid) and includes additional assimilated parameters to improve the reanalysis