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On the nature and origin of water masses in Herald Canyon, Chukchi Sea: Synoptic surveys in summer 2004, 2008, and 2009

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ABSTRACT

Hydrographic and velocity data from three high-resolution shipboard surveys of Herald Canyon in the northwest Chukchi Sea, in 2004, 2008, and 2009, are used to investigate the water masses in the canyon and their possible source regions. Both summer and winter Pacific waters were observed in varying amounts in the different years, although in general the summer waters resided on the eastern side of the canyon while the winter waters were located on the western flank. The predominant summer water was Bering summer water, although some Alaskan coastal water resided in the canyon in the two later years likely due to wind forcing. Both newly ventilated and remnant winter waters were found in the canyon, but the amount lessened in each successive survey. Using mooring data from Bering Strait it is shown that a large amount of Bering summer water in the western channel of the strait follows a relatively direct route into Herald Canyon during the summer months, with an estimated advective speed of 10–20 cm/s. However, while the winter water observed in 2004 was consistent with a Bering Strait source (with a slower advective speed of 5–8 cm/s), the dense water in the canyon during 2008 and 2009 was more in line with a northern source. This is consistent with sections to the west of the canyon and with previously reported measurements implying winter water formation on the East Siberian shelf. Large-scale wind patterns and polynya activity on the shelf are also investigated. It was found that the former appears to impact more strongly the presence of dense water in Herald Canyon.

1. Introduction

Pacific water flowing northward through Bering Strait impacts the ecosystem of the western Arctic Ocean in important ways. In wintertime the cold water provides nutrients that spur the growth of phytoplankton at the base of the food chain (e.g. Hill et al., 2005), which, through vertical export, strongly influences the benthic activity (Grebmeier, 1993). In summertime, the warm water melts pack ice (e.g. Weingartner et al., 2005) and represents an important contribution of freshwater to the Canada Basin (Woodgate et al., 2012). The Pacific water also contributes to the stratification of the water column over large areas of the western Arctic, helping to maintain the upper halocline (e.g. Jones et al., 1998; Anderson et al., 2013).

Seasonally, the temperature and salinity characteristics of the Pacific water vary significantly. There are two types of summer water: warm and fresh Alaskan coastal water, which originates from continental runoff into the Gulf of Alaska and the Bering Sea, and colder, generally saltier Bering summer water. The latter is primarily a mixture of Anadyr water and central Bering shelf water (Coachman et al., 1975). Both of these summer waters are present in the western Arctic Ocean and result in temperature maxima in the upper 100 m of the water column (Steele et al., 2004; Timmermans et al., 2014). During winter and spring, Pacific winter water at/near the freezing point flows through Bering Strait (Woodgate et al., 2005a) and can be further modified during its transit north due to re-freezing polynyas and leads (Weingartner et al., 1998; Itoh et al., 2012; Pacini et al., n.d.). The winter water spans a large range in salinity and ultimately results in a temperature minimum in the deep basin in the depth range of 100–150 m (Steele et al., 2004).

In order to reach the central Arctic Ocean, the Pacific water must first cross the wide and shallow Chukchi Sea. There are three main flow pathways by which this happens, dictated largely by the topography of the shelf (e.g. Woodgate et al., 2005a; Weingartner et al., 2005, see Fig. 1). On the eastern shelf the Alaskan Coastal Current flows northward into Barrow Canyon; on the central shelf a branch flows through the Central Channel; and on the western shelf a pathway extends through Herald Canyon. It is believed that a portion of the western branch is diverted to the east and joins the central pathway (Pickart

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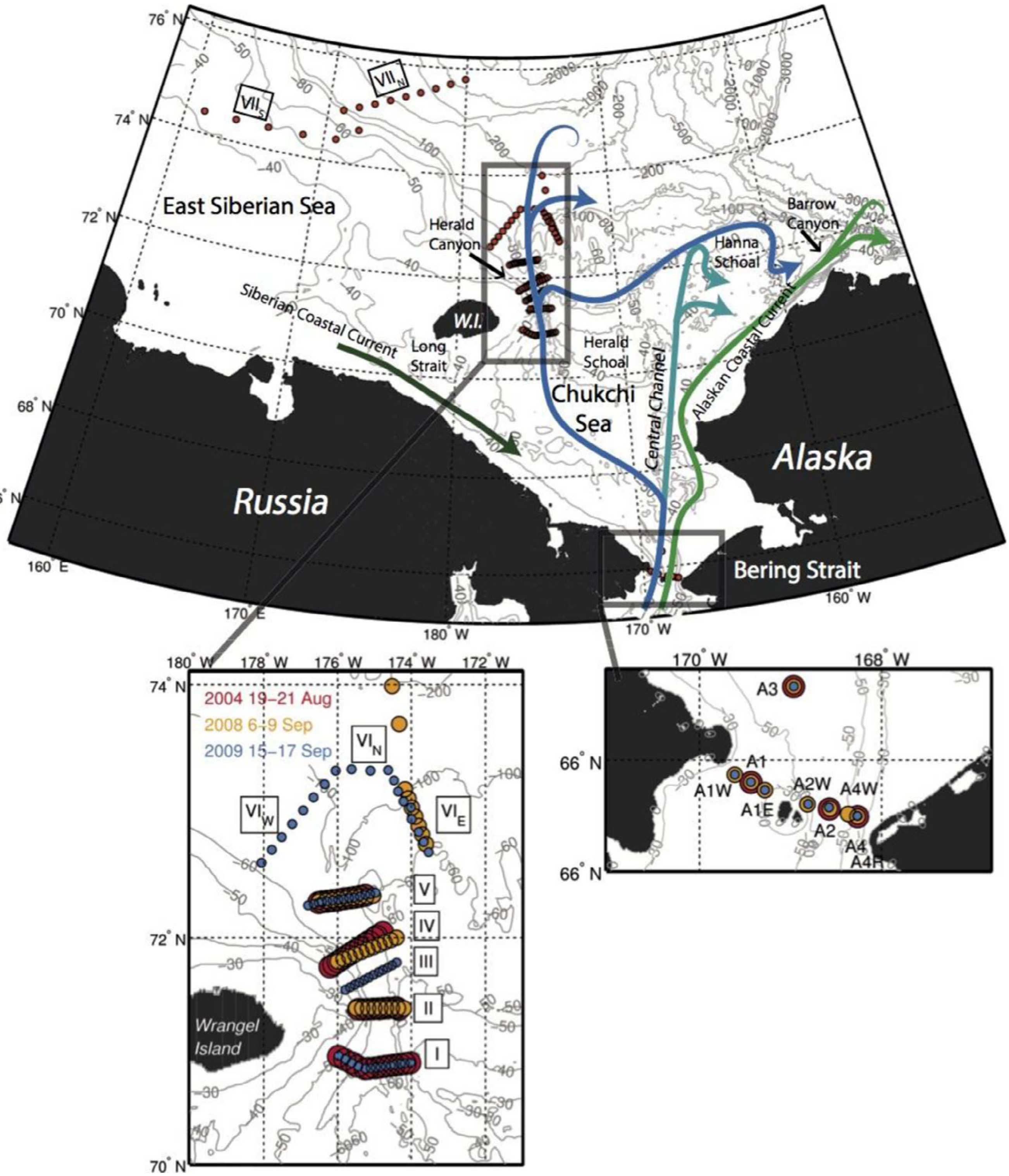

Fig. 1. (a) Map of the Chukchi Sea, including the Herald Canyon hydrographic sections and Bering Strait mooring array. Also shown is the western section VII, situated on the outer-shelf/upper-slope of the East Siberian Sea. A schematic depiction of the circulation of the region is overlain. (b) Detailed map of the Herald Canyon region showing the hydrographic sections used in the study: 2004 (red), 2008 (orange), and 2009 (blue). The dates of the surveys are indicated in the legend. (c) Detailed map of Bering Strait showing the mooring locations, color-coded as in (b). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

et al., 2010), and together these waters flow around both sides of Hanna Shoal into Barrow Canyon (Weingartner et al., 2005; Gong and Pickart, 2015; Pickart et al., 2016). There is possibly a fourth pathway through Long Strait into the East Siberian Sea (Weingartner et al., 1999; Woodgate et al., 2005a), although this has not yet been established as a permanent branch. This overall circulation pattern is generally supported by modeling studies (Winsor, 2004; Spall, 2007; Panteleev et al., 2010).

During its transit on the shelf the Pacific water can be modified locally via atmospheric forcing. For example, using data from an extensive set of moorings in the Chukchi Sea during 1990–91, Woodgate et al. (2005a) argued that solar heating during the spring and summer is