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Seasonality of the inshore Labrador current over the Newfoundland shelf

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ABSTRACT

The seasonality of the inshore Labrador Current over the Newfoundland Shelf is investigated using GLORYS (GLobal Ocean ReanalYses and Simulations, hereafter GLORYS) ocean reanalysis product and current meter data. This study finds that the seasonality of the current tends to change as it passes its bifurcation zone between 48 °30′N and 49 °30′N. In this study, the inshore Labrador Current to the north and south of the bifurcation zone are termed as the North Inshore Labrador Current (hereafter NILC) and the South Inshore Labrador Current (hereafter SILC), respectively. The NILC reaches its maximum (~2.7 Sv) in autumn, and relaxes in late winter and early spring (~1 Sv), while the SILC achieves its maximum (~1 Sv) in late autumn and early winter, and weakens in summer (~0.5 Sv). The SILC is significantly weaker than the NILC. In particular, during July and August, the northern segment of SILC is about 4 times weaker than the NILC. Change of wind patterns is found to be linked with the summer weakening of the SILC.

1. Introduction

The main features of circulation over the Newfoundland shelf consist of the equatorward inshore Labrador Current along the coast, the offshore Labrador Current along the shelf edge, and the cross-shelf flows following the topography of seaward trenches and canyons (Fig. 1). The circulation in this region exhibits significant temporal and spatial variability (Petrie and Anderson, 1983; Narayanan et al., 1996; Loder et al., 1998). The current system has been studied by means of observational data synthesis and numeric modeling efforts (Petrie and Anderson, 1983; Petrie and Isenor, 1985; Greenberg and Petrie, 1988; Sheng and Thompson, 1996; Narayanan et al., 1996; Loder et al., 1998; Han, 2005; Han et al., 2008). The offshore Labrador Current has been investigated in numerous studies because of its climatic significance, e.g., Lazier and Wright, 1993; Eden and Willebrand, 2001; Fischer et al., 2004; Häkkinen and Rhines, 2004; Böning et al., 2006; Dengler et al., 2006, among others, however the inshore Labrador Current over the Newfoundland Shelf has not been fully investigated, especially its seasonality.

The Labrador Current (including inshore and offshore branches) is a continuation of the southward flowing Baffin Island Current (Lazier and Wright, 1993), it transports the cold and relatively low salinity waters flowing out of Baffin Bay, outflow from Hudson Strait, and the warmer and more saline waters of a branch of the West Greenland Current which leaves the Greenland Slope and turns westward at Davis Strait. As the Labrador shelf widens at the Hamilton Bank, the current starts to appear more clearly as a system of branches, known as, the inshore Labrador Current and the much stronger offshore branch (Lazier and Wright, 1993). To the south of the Hamilton Bank, bifurcations of the off-shore Labrador Current to the north and south of the Belle Isle Bank join the inshore Labrador Current (Narayanan et al., 1996). After passing through the northern end of the Labrador Shelf, a small branch of the inshore Labrador Current flows into Gulf of St. Lawrence through Strait of Belle Isle, and the remaining portion continues southward onto the Newfoundland Shelf. On the Newfoundland Shelf, the inshore Labrador Current flows near the coast. This current bifurcates at a zone between 48°30′Nand 49°30′N with one branch heading offshore along a deep channel, eventually merging with the offshore Labrador Current, and the other branch continuing southward onto the shallower Grand Banks (Petrie and Anderson, 1983; Petrie and Isenor, 1985). The deeper more rugged northern Newfoundland Shelf and the shallower smoother Grand Banks over which the Inshore Labrador Current flows, together with the eastbound outgoing branch, make the currents, particularly the Inshore Labrador Current as a whole, undergo significant changes in this region.

An analysis of CTD and current meter data collected off southern Labrador Shelf between 1978 and 1988 undertaken by Lazier and Wright (1993) (hereafter, LW93) revealed two distinct regimes of seasonal variability of the Labrador Current. The first regime observed over the shelf and upper slope is characterized by

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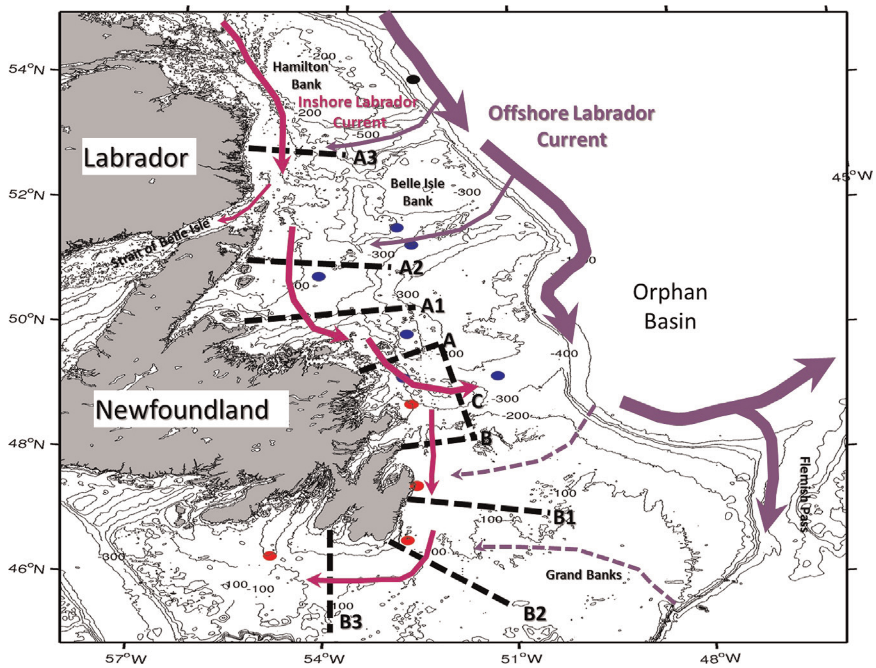

Fig. 1. Map of the Newfoundland Shelf and the southern part of Labrador Shelf, values shown in the map are the isobath (unit in m). Locations of the moorings are indicated by solid circles (blue ones for those in NILC zone; red ones for those in SILC zone; black one for the one in LW93), and the transects-A, A1, A2, A3, B, B1, B2, B3 and C are those defined in this study to represent NILC (As) and SILC (Bs), C represents the branch joining the off-shore Labrador Current. The Inshore and Offshore Labrador Currents are indicated by the arrowed bold lines in the map, and the stream branched off the Inshore Labrador Current joining the off-shore branch is also indicated by a bold arrowed line. The bifurcated flows from the off-shore Labrador Current are shown by the thin arrowed lines, and those dashed lines on the southern Newfoundland Shelf indicate changing pathways in different seasons. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

a current reaching its seasonal minimum in March–April, and maxima in October. The second regime found over the lower continental slope has its weakest current in summer and strongest in winter. The first regime is the natural origin of, later evolves into, the Inshore Labrador Current. Some flows bifurcated from the off-shore Labrador Current merge with the inshore one, but their contribution to the seasonality of the Inshore Labrador Current is unclear. Modeling studies by Han (2005) (hereafter, H05) and Han et al. (2008) (hereafter, H08) demonstrated that the inshore Labrador Current has a consistent seasonality on the Newfoundland Shelf from north to south despite the strong bathymetric changes and those bifurcated currents over this shelf zone, stronger in December and weaker in summer, which is different from the first one over the shelf reported by LW93. On the contrary, the seasonality of the inshore Labrador Current in H05 and H08 is more consistent with the second one over the lower slope in LW93. LW93 suggested that the JEBAR (the Joint Effect of Baroclinicity and Relief) results in fluid being drawn offshore to feed the Labrador Current over the upper slope. Other studies, e.g., Thompson et al. (1986) and Greatbatch and Goulding (1989), attempted to investigate the seasonality of the Labrador Current through other approaches. Thompson et al. (1986) (hereafter, T86) got a maximum Sverdrup return southward flow in February using the topographic Sverdrup relationship, reflecting the impact of the basin scale wind forcing on the Labrador Current transport. Greatbatch and Goulding (1989) showed that the Labrador Current reached its maximum in winter from a barotropic model driven by wind stress, which supports T86. LW93 suggested that seasonal variations in Sverdrup transport are carried in the deep water seaward of the Labrador Current reported by T86. So some question remains as to the nature of the seasonality of the Labrador Current, particularly that of inshore branch over the Newfoundland Shelf, which is the focus of the present study.

Here, we undertake a step in this direction investigating changes in the seasonality of the inshore Labrador Current over the Newfoundland Shelf based on both the GLORYS reanalysis product (Ferry et al., 2010) and available current meter data, particularly focusing on changes in the regions to both north and south of the bifurcation zone between 48 °30′N and 49 °30′N. Note: the bifurcation zone mentioned in the remainder of the paper refers to this region.

2. Material and methods

2.1. GLORYS product

GLORYS (GLobal Ocean ReanalYses and Simulations) uses the NEMO model, and it covers the years from 2002 to 2008. The model configuration is ORCA025, a global ocean grid with a horizontal resolution of 1/4° and 50 vertical levels with thickness ranging from 1 m at top to 200 m at bottom, forced by ECMWF ERA-Interim reanalysis. The assimilation method is the reduced order Kalman filter based on SEEK formulation. GLORYS assimilated satellite altimetry data, sea surface temperature data, and temperature and salinity data from ARGO (www.argo.net) and also ship-based CTD data. Wang and Greenan (2013) compared velocities from GLORYS with the current meter data (the current meter database will be detailed in Section 2.2) for the Northwest Atlantic Ocean from 2002 to 2008, and they reported the GLORYS reanalysis product can well represent the observed velocities. Note: the GLORYS provides monthly mean quantities.

Two transects, A and B (shown in Fig. 1) are selected to represent the inshore Labrador Current before and after the bifurcation zone, and the width of each section is chosen by velocities from the GLORYS through the transects, so the transports through the transects can be representative of the Inshore Labrador Current. The inshore Labrador Current is mostly constrained within the 300 m isobath to the north of transect A over the Newfoundland Shelf (A ends at 300 m isobath). To the south of