Currents and Tidal Observations by the Hydrographic Department of Maritime Safety Agency, off the Okhotsk Coast of Hokkaido

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Introduction

The Soya Warm Current, originating from the Japan Sea, flows into the Okhotsk Sea through the Soya Strait and along the Okhotsk Coast of Hokkaido. The warm and saline Soya Current Water may influence not only the coastal region along Hokkaido but also the entire Okhotsk Sea. The transport and structure of the Soya Warm Current show considerable seasonal variation. The Soya Warm Current almost disappears in the winter season, but the warm and saline water can be found near the bottom. The Soya Warm Current in the other seasons is strongest in the surface layer and it does reach the bottom. In the region just off the Soya Warm Current, very cold water is found in an intermediate layer, which is called the Okhotsk Intermediate Cold Water. This water originates from the northern Okhotsk Sea. The Soya Current Water may mix with these surrounding waters while flowing along the Hokkaido Coast. The tide of the diurnal K_1 component in the Okhotsk Sea is strong and influences water-mass modifications through mixing processes. The nature of tides and tidal currents just off the Hokkaido Coast is somewhat peculiar, reflecting large differences in tidal amplitude between the Japan Sea and the Okhotsk Sea. In this paper, the current and the tidal observations by the Hydrographic Department of the Maritime Safety Agency of Japan are introduced.

Sea ice and oceanic condition in winter

The Hydrographic Department of the Maritime Safety Agency of Japan and each of the Regional Maritime Safety Headquarters publish bimonthly Prompt reports of the Oceanographic Condition for all of the seas around Japan and for regional seas. The reports are mainly based on ocean current observations from various ships, satellite images, and other sources. The Hydrographic Department sometimes sends its survey vessels to the Okhotsk Sea, and the First Regional Maritime Safety Headquarters often conducts ocean current observations using its patrol vessels.

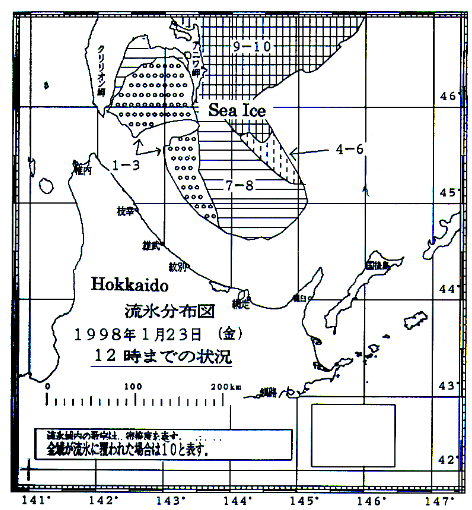

Fig. 1 An example of the Sea Ice Condition Chart published daily by the Sea Ice Information Center of the First Regional Maritime Safety Headquarters. Numerals in the figure indicate sea ice concentration (January 23, 1998). Sea ice area is shaded depending on sea ice concentration. The chart is accessible at http://www.jhd.go.jp.

Sea ice appears in coastal regions of Hokkaido usually in late January. Since sea ice severely influences ship navigation, fisheries and other maritime activities off the Okhotsk Coast of Hokkaido, one of the duties of the Hydrographic Department and the First Maritime Safety Headquarters is to make sea ice surveys and rescue operations in this season. When sea ice is seen off the Hokkaido Coast (usually from late December to April), the Sea Ice Information Center operates in the First Regional Maritime Safety Headquarters. The center collects sea ice information from patrol vessels and air-craft, sea ice radar images (obtained by Sea Ice Research Laboratory of Hokkaido University), available satellite images and so on, and publishes the daily Sea Ice Condition Chart. An example of the chart is shown in Figure 1. The chart is accessible at www.jhd.go.jp.

The First Regional Maritime Safety Headquarters sends its patrol vessel to the area off the Hokkaido Coast almost every December in order to know oceanographic conditions just prior to the sea ice season (First Regional Maritime Safety Headquarters, 1997). Usually, XBT and ADCP observations are carried out on board the patrol vessel. Also, headquarters sends its icebreaker *Soya* at the first appearance of sea ice in the region to carry out sea ice patrol, ship-rescue, and observations of sea ice and oceanographic conditions using CTD and XBT (First Regional Maritime Safety Headquarters, 1998).

An example of the ocean current distribution at 10m depth observed by the patrol vessel *Sorachi* is shown in Figure 2a. The observations were made from 6 to 7 December, 1997. The current field at this time is atypical: the flow in the Soya Strait (observed on December 7) is westward, even in the vicinity of the Hokkaido Coast, where the Soya Warm Current usually flows eastward. The current distribution taken two days later (9 December) is shown in Figure 2b. The weather condition was very severe, and the ADCP records were not clean and included much noise. The observed current might be less accurate especially in its magnitude, but the currents near the Hokkaido Coast in the Soya Strait appear to be northeastward or southeastward as is the usual flow direction of the Soya Warm Current. It is difficult to explain such an atypical Soya Warm Current on December 7, and such a large variation in current field within two days, but it is plausible that the strong tidal currents in and near the Strait played important role in this curious phenomenon.

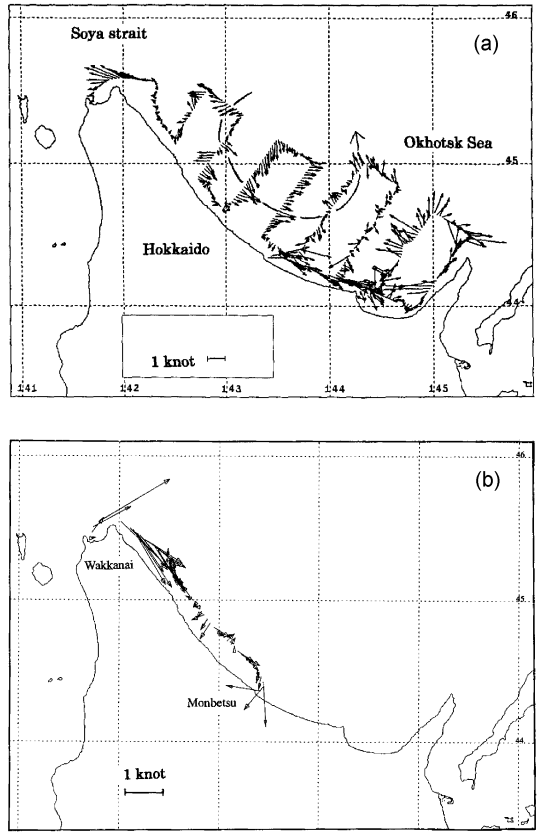

Fig. 2(a) Current distribution (10m depth) observed by ADCP on board the patrol vessel *Sorachi* in the period from December 6-7, 1997. (First Regional Maritime Safety Headquarters, 1997). **2(b)** Current distribution (10m depth) along the course from Wakkanai to Monbetsu observed on December 9, 1997 just after Figure 2a.

The surface temperature distribution in the same period is shown in Figure 3. The warm area extends along the Hokkaido Coast from just off Cape Soya (the southern end of the Soya Strait), indicating that the warm Soya Current Water was flowing into the Okhotsk Sea even though the temporary current field in Figure 2 indicates that the flow was in the opposite direction. The warm water tongue along the coast disappears before reaching Line B. The temperature cross-section along line B is shown in Figure 4. Warm water is found above the bottom slope of the Hokkaido

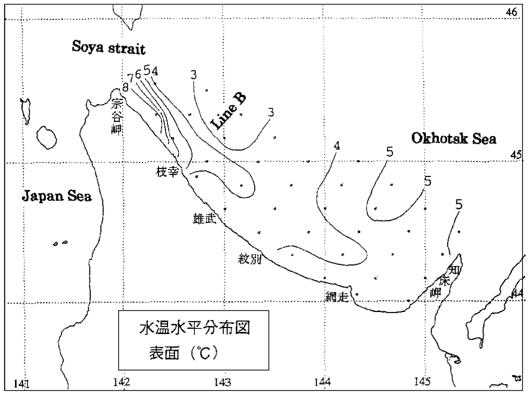

Fig. 3 Same as Figure 2(a), except for surface temperature distribution (in °C). Dots indicated XBT observation stations. The temperature cross-section along Line B is shown in Figure 4.

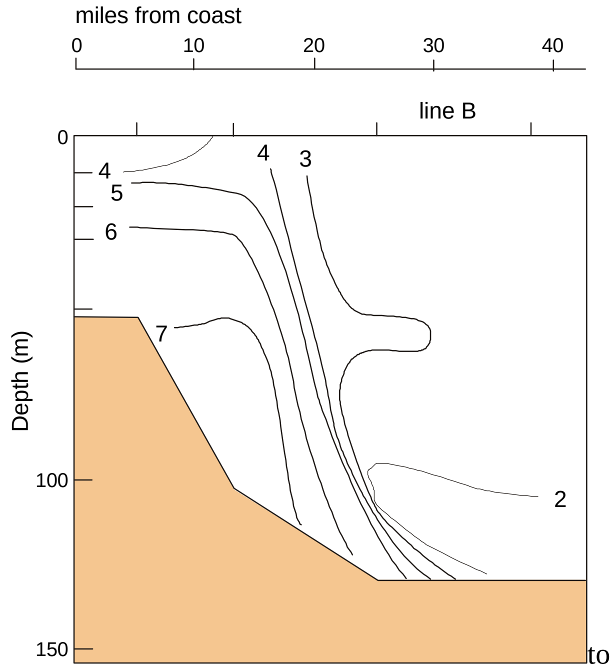

Fig. 4 Temperature cross-section (in °C) along Line B (see Figure 3 for the position of the line). Warm Soya Current water is found above the bottom of Hokkaido side.

side in this section. The source of this warm but dense (very saline) water cannot be found in the Okhotsk Sea, so the water should be Soya Current Water. The Soya Current Water tends to subside while it is flowing along the Hokkaido Coast due to its high salinity nature.

Tides and tidal currents in the Soya Strait and off the Okhotsk Coast of Hokkaido

The amplitude of tides is generally small in the Japan Sea except near the Tsushima Strait. On the other hand, tides and tidal currents are quite large in the Okhotsk Sea. It is well known that the strong tidal mixing near shoals and in straits plays an important role in water-mass modifications in the Okhotsk Sea. The amplitude of tides is not so large in the Soya Strait, but the current velocity of the diurnal K_1 tide reaches about 1.5 knots, reflecting the large tidal amplitude difference between the Japan Sea and the Okhotsk Sea. It is highly possible that the temporary current measurement by ADCP in and near the Soya Strait would be affected by the tidal current as discussed above.

The Hydrographic Department has responsibility to compile the Basic Maps in the western North Pacific Ocean. Further, the survey project related to the Basic Maps of the Seas in Coastal Waters has been conducted in the Okhotsk Coast area of Hokkaido from 1988 to 1991, including tide and tidal current observations which were carried out for a period of one month each summer. The results of the observation are shown in Figure 5 for the dominant tidal component, K_1. An amphidromic point exists just in the Soya Strait. The co-tidal line rotates counterclockwise around the amphidromic point. The co-tidal lines in the offshore area are rather parallel to the Hokkaido Coast, but they are bent in the nearshore area and hit the coast. The tidal phase distribution indicates that the tide travels southeastward along the coast. The interval of the co-tidal lines becomes large in the central part of the Okhotsk Sea, reflecting bottom topography. The tidal amplitude tends to increase away from the Soya Strait.

Though the tidal amplitude tends to increase towards offshore, the prominent tidal current is found only in the nearshore area and diminishes rapidly to offshore. The phase propagation of the tidal current was much slower than that of tide

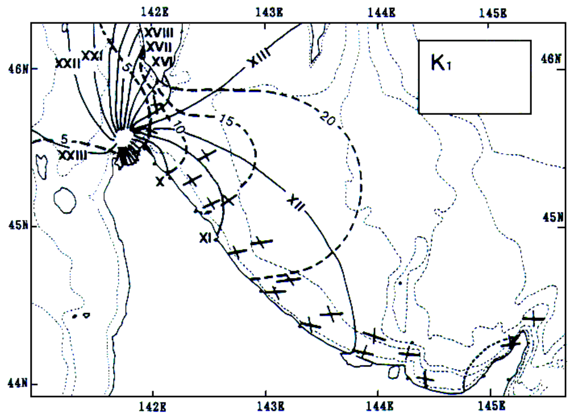

Fig. 5 Co-tidal lines (full lines) and co-amplitude lines (dashed lines) of K_1 tide near the Soya Strait and in the southern Okhotsk Sea. Roman numbers attached to co-tidal line indicate the tidal hour, and numerals attached to co-amplitude line the amplitude (in cm). Crosses indicate the positions of the tidal current observation.

(see Fig. 4a of Odamaki, 1994). Odamaki (1994) explained these characteristics of the tidal current just off the Hokkaido Coast as a shelf wave propagating southeastward along the Hokkaido Coast from the Soya Strait.

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