Mooring measurements off Shiretoko Peninsula, Hokkaido in 1997-1998

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Abstract

The region of the Okhotsk Sea off Hokkaido is known as a "confluence zone" of cold and fresh water from the northwestern Okhotsk, and warm and saline Soya Warm Water (SWW). These two water masses show strong seasonal variability in this region. In order to study this seasonal variability, a mooring was deployed at (44°32'N, 144°44'E, 1555 m deep) over the continental slope off Shiretoko Peninsula for a year in 1997-1998. The mooring consisted of two current meters at 247 and 1330 m, three thermistors at 165, 341, and 443 m, and a pressure sensor at 165 m. Average current speeds at the upper and lower current meters were 15.3 cm/s and 3.8 cm/s, respectively. This indicates that strong currents did not penetrate into the deeper ocean. Temperature time series clearly show the seasonal variability in the upper ocean. There were warm events up to 6°C at the upper thermistor from mid-December to mid-January. It is likely that this high temperature was caused by the advection of SWW into the region of the mooring. From late February, the temperature in the upper ocean decreased starting from the upper thermistor and approached the freezing point. The nearly freezing water is seen even at the middle thermistor (at 341 m) in early April. This indicates the development of a thick, surface-mixed layer in this season.

Introduction

Water properties in the southwestern part of the Okhotsk Sea show strong seasonal variability due to the influence of two distinct water masses. One is cold and fresh water that originates in the northwestern Okhotsk and was transported by southward flowing East Sakhalin Current. Another is warm and saline Soya Warm Water (SWW). The latter is dominant near the Hokkaido coast from spring to fall and is largely replaced by the former from late fall to winter. The latter becomes denser and exists near the bottom in winter and early spring. A detailed review of seasonal variability in this region is given in Talley and Nagata (1995). Watanabe and Wakatsuchi (1998) suggested the isopycnal mixing of these two water masses along density surfaces between 26.8 and 26.9 σ_t in early spring produces relatively cold, fresh, and oxygen-rich water mass (called Kuril Basin Intermediate Water). They also suggested that this Kuril Basin Intermediate Water contributes to the production of the North Pacific Intermediate Water.

Ohshima et al. (in prep.) examined the results of a hydrographic survey in this region during early February 1997. In the region of thick ice cover, a surface-mixed layer with a nearly freezing temperature penetrates down to 300 m. This upper-layer structure is quite different from the typical one, which has strong stratification at depths of 50-100 m due to the discharge from Amur River. The similar upper-layer structure was also observed during early February 1998, but its thickness was <200 m.

In order to study the seasonal variability of water properties, it is useful to carry out long-term mooring observations. Previously, several mooring observations were carried out in this region (Aota and Kawamura, 1978; Aota and Kawamura, 1979; Aota and Matsuyama, 1988;

Odamaki, 1994). However, most of the observations were limited to periods of less than a few months due to heavy fishing activity in the region. These studies concentrated on the examination of tides and tidal currents.

The purpose of this research is to examine seasonal variability of water off Hokkaido using one-year mooring data obtained northwest of Shiretoko Peninsula. We are especially interested in the development of the thick, surface mixed layer in winter.

Data

The mooring was located at 44°32'N 144°44'E (1555 m deep) over the continental slope off the Shiretoko Peninsula (Fig. 1). It was moored for 356 days from September 30, 1997 to September 20, 1998. Table 1 lists nominal depths and sampling intervals of current meters (Union RU-1), thermistors (Nichiyu-Giken NWT-SN), and a pressure sensor (Rigo NEW-RMD). Note that four temperature sensors were moored in the upper ocean in order to monitor the seasonal development of the thick, surface-mixed layer. In addition to these instruments, two sediment traps were moored at 443 and 1444 m but the results from these sediment traps will be reported elsewhere.

Figure 2 displays daily-averaged data from the pressure sensor at the top of the mooring. They show the occurrence of significant tilts during several periods. Assuming that the mooring line was always straight, the depth range and average depth of each instrument was estimated as listed in Table 1. When the data from the current meters and thermistors are examined, caution should be taken because the time series include variations due to vertical displacement in addition to temporal variations.

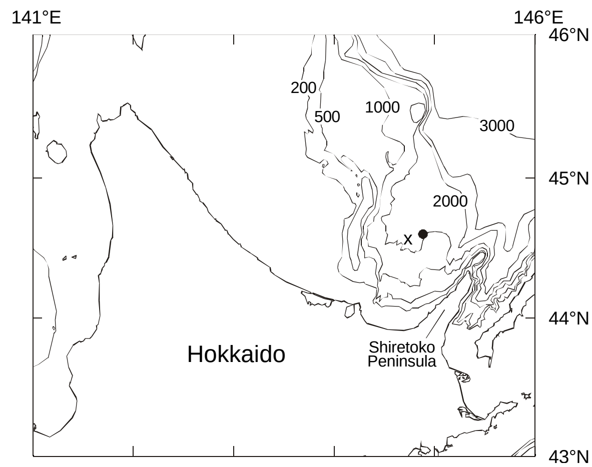

Fig. 1 Bathymetry of the observation region in the southwestern part of the Okhotsk Sea based on the GEBCO data. A cross indicates a mooring location at 44°32'N 144°44'E. A solid circle denotes the nearest SSM/I grid to the mooring site used to calculate sea-ice concentration in Figure 5.

Table 1 Nominal depth, sampling interval, average depth, and depth range of the moored instruments.

	Nominal depth (m)	Sampling interval (min.)	Average depth (m)	Depth range (m)
Pressure sensor (Rigo NEW-RMD)	165	30	177	165-246
Thermistor (Nichiyu-Giken NWT-SN)	165	5	177	165-246
Current meter (Union RU-1)	247	60	258	247-324
Thermistor (Nichiyu-Giken NWT-SN)	341	5	352	341-413
Thermistor (Nichiyu-Giken NWT-SN)	443	5	453	443-508
Current meter (Union RU-1)	1330	60	1332	1330-1343

Results

Figure 3 shows daily-averaged current-meter data at 247 and 1330 m. Current speeds are much larger at the upper current meter than the lower one. Their average (maximum) speeds are 15.3 (38.7) cm/s and 3.8 (14.5) cm/s, respectively. These data clearly show that relatively strong currents do not penetrate deep into the water column. Current directions for both of these current meters are rather variable and do not persist longer than a month

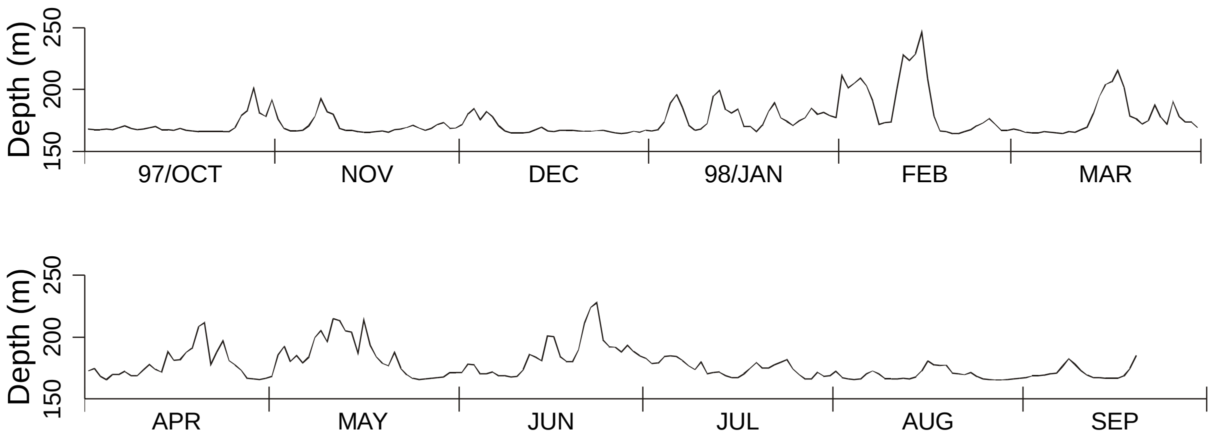

Fig. 2 Daily-averaged data from the pressure sensor at the top of the mooring. Note that the mooring tilts significantly several times.

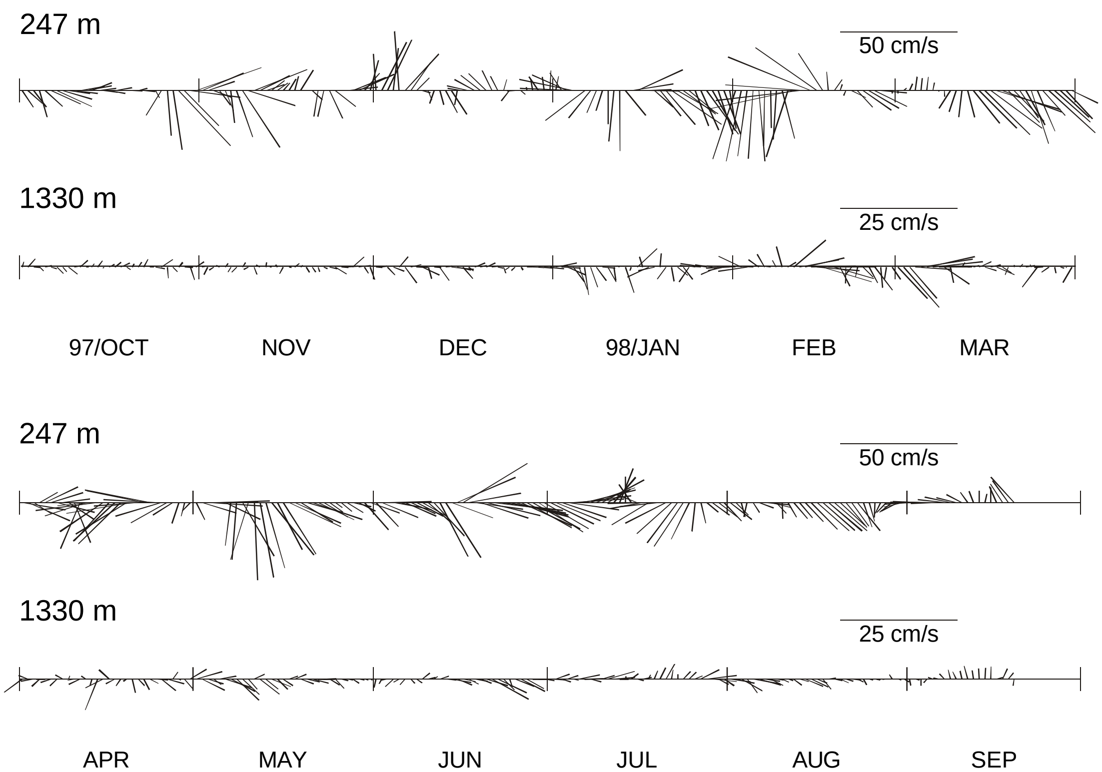

Fig. 3 Stick plots of daily-averaged current-meter data obtained at 247 m and 1330 m. The data at the upper (lower) current meter are shown along the first and third (second and fourth) axes. Note that the calibration stick for the lower current meter is twice as long as that for the upper current meter. Strong currents do not reach to the deeper part of the ocean.

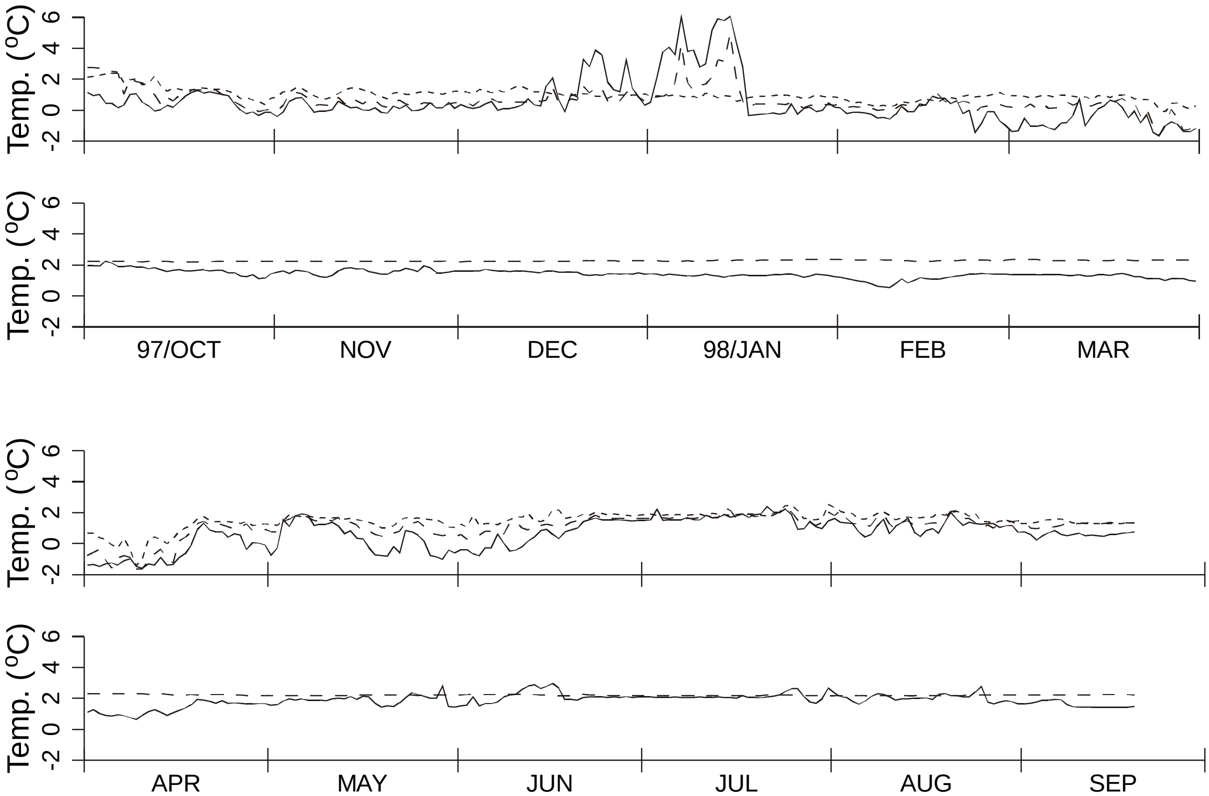

Fig. 4 Daily-averaged temperature data of the two current meter and three thermistors. The data along the first and third axes were obtained at the upper thermistor at 165m (solid curve), the upper current meter at 247 m (long dashed curve), and the middle thermistor at 341 m (short dashed curve). The data along the second and fourth axes were obtained at the lower thermistor at 443 m (solid curve) and the lower current meter at 1330 m (dashed curve). From mid-December to mid-January, warm events occur in the upper ocean. From late February to early April, temperature in the upper ocean decreases close to the freezing point.

Figure 4 displays daily-averaged temperature data of the two current meters and three thermistors at 165 m, 341 m, and 443 m. Temperature data at the upper three sensors clearly show seasonal variability. Several warm events are observed from mid-December to mid-January. These events in December are seen only at the upper thermistor (165 m), but those in January are stronger and are seen down to the upper current meter (247 m). The warmest temperature recorded at the upper thermistor exceeded 6°C in January. It is likely that these warm events are associated with the advection of SWW into the mooring
region. After the warm events in February, temperature differences among the upper three sensors are small until late February when temperature at the upper thermistor (165 m) decreases close to the freezing point. By late March, the temperature at the upper current meter (247 m) also approaches the freezing point. Moreover, in early April, a temperature close to the freezing point is also observed at the middle thermistor (341 m). Note that temperature is very similar at these three sensors at this point, indicating the development of a cold, surface-mixed layer thicker than 300 m.

Summary and Discussion

In this study, the mooring data obtained over the continental slope off Shiretoko Peninsula are examined in order to reveal seasonal variability in this region. The data indicate the advection of

SWW in winter and the development of a thick, cold, surface-mixed layer during winter and early spring at the mooring site. A hydrographic survey in early February 1998 showed that the thickness of the surface-mixed layer, with a temperature near the freezing point, near the mooring location was < 100 m. The data presented here show that it becomes > 300 m by early April. This may suggest that the region of a thick, surface mixed layer becomes larger than those observed in early February by early spring.

Since the upper ocean interacts with sea ice in the study area during winter, a time series of sea-ice concentration is compared with those of the mooring data. Figure 5 shows the sea-ice concentration obtained from SSM/I data at the nearest grid from the mooring site. (See Figure 1 for the location of the grid.) Because the grid is close to a landmass, this time series contains the effect of land contamination. In particular, the values are inaccurate before mid-January when ice started to appear in this region. However, it is clear that the concentration increases from late January to late February and remains around the maximum till mid-March. The advent of sea-ice cover in mid-January coincides with the end of warm events in the upper ocean (Fig. 4). The nearly freezing temperature starts to appear at the end of February when the concentration approaches the maximum. These data show that the increase of sea-ice cover is closely associated with the decrease of temperature in the upper ocean. As a matter of fact, from the mid-January to late March, currents were predominantly southward or southeastward at the upper current meter. This may be evidence of the sea-ice transport to the study area by the extension of East Sakhalin Current.

During the mooring period, several hydrographic surveys were carried out in the southwestern part of the Okhotsk Sea and we are currently analyzing these data. One of the limitations of the present study is the lack of salinity time series. A similar mooring with a conductivity sensor is currently deployed at the same location. The data from this sensor should give us further understanding about seasonal variability in this region.

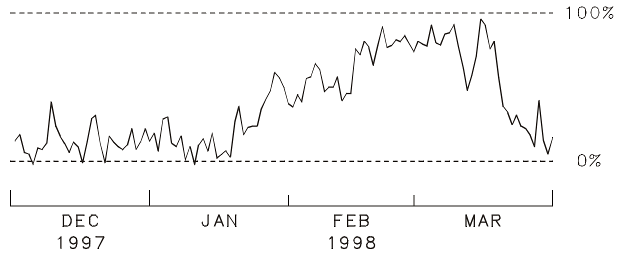

Fig. 5 Daily sea-ice concentration derived from the SSM/I data at the nearest grid (44°36'N 144°53'E) from the mooring site. (See Figure 1 for the location of the grid.) Note that concentration starts to increase from late January and remains around the maximum till mid-March.

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