Oceanographic conditions of the western north Pacific based on oceanographic data during the JARPN II

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ABSTRACT

Oceanographic conditions in the offshore and the coastal components of JARPN II (off Kushiro) were examined using output from an operational ocean prediction system (FRA-JCOPE). Oceanographic observations with CTD and XCTD were conducted in the cetacean prey surveys in JARPN II. These observations were incorporated into the prediction system. The survey covered from subarctic area to the adjacent area of the subtropical area where common minke, Bryde's and sei whales were found. The survey area was located between the Kuroshio Extension and the Subarctic Front, where the water mass was characterized by the subarctic water, subtropical water and mixed water.

INTRODUCTION

Full scale JARPN II has been conducted since 2002. JARPN II has three components (three regional survey areas) namely off Sanriku, off Kushiro and offshore. Cetacean prey species surveys were conducted in JARPN II. Oceanographic observations have been conducted in the prey surveys. Data were collected by using CTD (Conductivity-Temperature-Depth profiler) and XCTD (expendable CTD) in JARPN II. The purpose of the oceanographic observations is to obtain fundamental information of the ecosystem in the JARPAN II area.

There are a lot of water masses and fronts in the western North Pacific. The Oyashio flows southwestward along the Kuril Islands and turns eastward from the

northern coast of Japan. The Kuroshio flows northward from the tropical area to Tohoku area east of Japan. The Kuroshio turns eastward from the eastern coast of Honshu, Japan, and the strong eastward flow is called the Kuroshio Extension. Both major currents, the Kuroshio Extension and the Oyashio, form Kuroshio-Oyashio Inter-frontal Zone. Waters originated in the Kuroshio and the Oyashio are mixed each other in this zone. They interact with the atmosphere and form new water masses.

In the high sea of the North Pacific Ocean, there are Subarctic Front and the Subarctic Boundary with a weak eastward flow. The Subarctic Front is south limit of the subarctic water and the Subarctic Boundary is north limit of the tropical water. The area between these fronts is called the Transition Domain (Favorite *et al*. 1976).

Each oceanic area in the western North Pacific, like Kuroshio, Oyashio, warm-core ring, etc, has unique oceanic environment and ecosystem. Because distribution of cetaceans as well as their preys is associated with the oceanographic conditions, realization of the oceanographic conditions is important. In this paper, distributions of water masses and fronts in the survey area (offshore and off Kushiro) were described to make clear the environment. Though oceanographic observations were also conducted off Sanriku, they were not considered in this paper.

MATERIALS AND METHODS

Hydrographic observations were carried out in the JARPN II area from 2002 to 2007 on board R/Vs *Shunyo-Maru, Kaiko-Maru, Kyoushin-Maru No. 2,* and *Kaiyou-Maru* No. 7 (Table 1). Oceanographic data were collected by either CTD (SBE 19, SBE 19plus or SBE 911plus) or XCTD profiles. Figure 1 showed station maps in the survey area. In the offshore component, CTD and XCTD casts were conducted at 160 and 16 stations, respectively. In the coastal component off Kushiro, CTD casts were conducted at 156 stations. Note that salinity correction using water sampling data was still not done with the CTD data reported in this paper.

The output from FRA-JCOPE (Fisheries Research Agency - Japan Coastal Ocean Predictability Experiment) were used to analyze the oceanographic conditions in JARPN II area from 2002 to 2006. FRA-JCOPE is an operational ocean forecast system. The observation data collected during JARPN II as well as GTSPP (Global Temperature and Salinity Profile Program) data were incorporated into FRA-JCOPE.

Indices for the oceanic fronts are used here to classify the water masses in the survey area (Table 2). Since the sea surface temperature distributions are obscure in this area, the indices are usually defined by subsurface temperature. The Kuroshio Extension is defined by the 14℃ isotherm at the depth of 200m (Kawai, 1969). The warm water spread from Kuroshio Extension is defied by temperature more than 10℃ at the depth of 100 m . The first and the second Oyashio Intrusions are defined by temperature lass than 5℃ at the depth of 100 m (Murakami, 1994). Subarctic front and the Subarctic Boundary is defined by 4℃ temperature contour at the depth of 100 m and sea surface

34.0psu salinity contour, respectively (Favorite *et al.* 1976). We use these indices to depict the distribution of water mass in the survey area.

RESULTS AND DISCUSSION

Oceanographic conditions in the offshore survey region

The offshore region around 164º-166ºE, 156º-159ºE and 145º-151ºE was observed by using CTD and XCTD in 2002-2005 and 2007 (upper panel of Fig. 1).

Figure 2 shows the meridional temperature, salinity and density sections along 165ºE in August 15 by using FRA-JCOPE output. Two major front systems are found in the subarctic gyre region of the North Pacific. The northern one is called the subarctic front as indicated by a drop of 4ºC contour in the temperature section (Favorite *et al.*, 1976). The front shows the southern boundary of the region characterized by the near-surface temperature minimum and the strong halocline. The southern one is called the subarctic boundary that marks the southern boundary of the subarctic low saline surface water. The subarctic boundary is indicated by a drop of 34.0 psu contour to 300m in the salinity section (Favorite *et al.*, 1976). The subarctic front occurred near 46ºN in 2003 and 2004, near 48ºN in 2004, 2005 and 2006. The subsurface temperature minimum layer is clearly formed in the area north of the subarctic front. The temperature below 3ºC was detected. The subarctic boundary clearly occurred near 41ºN.

Figure 3 shows the meridional temperature, salinity and density sections along 157ºE in August 15. The subarctic front occurred near 42 ºN in 2006, 43 ºN in 2003, 2004, 2005, 44ºN in 2002. The subarctic boundary occurred near 40ºN in all of 2002- 2006.

Figure 4 shows the horizontal temperature distributions at 100m overlapping over 14ºC region at 200m to detect the Kuroshio region (striped area in Fig. 4). Northern side of the 5ºC contour line in the 100m temperature indicates the subarctic water (gray-shaded area in Fig. 4). These figure shows that observation was carried out from the subarctic region to the Kuroshio region.

Oceanographic conditions in the survey area southeast of Hokkaido

The area south of Hokkaido was observed by using CTD in 2002 and 2004-2007 (lower panel of Fig. 1).

Figure 5 shows meridional temperature, salinity and density sections along 144º12'E. The temperature minimum layers below 2ºC, which is original Oyashio water, was observed southeast of Hokkaido every year. Surface salinity at Hokkaido coastal region was below 32 psu in 2002, 2003 and 2006.

Figure 6 shows temperature distributions at 100m and surface current in September 15 from 2002 to 2006. Warm water mass from the Tsugaru warm current occupied the area west of 143ºE. In the area east of 143ºE, the cold and low-saline Oyashio water were occupied. Fig. 6 shows that almost all of the observation points were in the

Oyashio area. In 2006, warm water mass from the Tsugaru warm current enlarged to 143º20'E. The warm water ring was observed in 2005 southeastern part of the observation area. The southern limit of the first Oyashio Intrusion generally moves northward from April (38º30'N) to November (41º30'N). The position of the first Oyashio Intrusion was at 40º10'N, 143º20'E and second Oyashio Intrusion was at 39ºN, 146 º E in September 2002. It shows first Oyashio Intrusion was normal position but second Oyashio Intrusion spread southward stronger than first Oyashio Intrusion. In 2003, second Oyashio Intrusion was not clear but its position was 40ºN, 145ºE, and first Oyashio Intrusion spread strongly to the position of 39º20'N, 142º20'E, nearby the coastal area off Tohoku. In 2004, the Oyashio area was restricted in narrow two bands, and southern limit of first and second Oyashio Intrusion were at 41ºN, 142º40'E and 40º20'N, 146ºE, respectively. The Oyashio water widely distributed in 2005, but southern limit of first and second Oyashio Intrusion did not show distinctive southern position. In 2006, the Oyashio water was spread through narrow area similar with 2004, however the first Oyashio Intrusion spread to southern area south of 39 ºN. Year-to-year variation was dominant in the first Oyashio Intrusion during JARPN II observation periods.

References

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Kawai, H. (1969): Statistical estimation of isotherms indicative of the Kuroshio axis, *Deep-Sea Res.*, Suppl. to **16**, 109-115.

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Table 1. Detail of observation data in JARPAN II area from 2001 to 2007.

Vessel	Observation periods	Area
Shunyo -Maru	17 July – 9 Aug., 2002	Offshore
Shunyo -Maru	15 June – 9 July, 2003	Offshore
Shunyo -Maru	15 - 19 Sep., 2004	Offshore
Shunyo -Maru	13 – 23 July, 2005	Offshore
Shunyo -Maru	30 July – 8 Aug., 2005	Offshore
Kaiko -Maru	24 Aug. – 4 Sep., 2007	Offshore
Kyoushin -Maru # 2	10 – 24 Sep., 2002	Off Kushiro
Shunyo -Maru	23 – 29 Sep., 2004	Off Kushiro
Kaiyou –Maru #7	11 – 25 Sep., 2005	Off Kushiro
Kaiko -Maru	12 – 26 Sep., 2006	Off Kushiro
Kaiko -Maru	9 Sep. – 6 Oct., 2007	Off Kushiro

Table 2. Extraction method from temperature map to determine the position of each water mass.

Target characteristics	Extraction method
Kuroshio Extension Axis	14℃ isotherm at 200 m
Warm-core ring	Temperature front at 200 m
Oyashio front	5 ℃ isotherm at 100 m
Oyashio water	Area with T<5 ℃ at 100 m
Cold water	Area with 5℃<T<10 ℃ at 100 m
Warm water	Area with T>10 ℃ at 100 m and T<14 ℃ at 200 m
Subarctic Boundary	Salinity front defined by 34.0 psu
Subarctic Front	Temperature front defined by 4℃

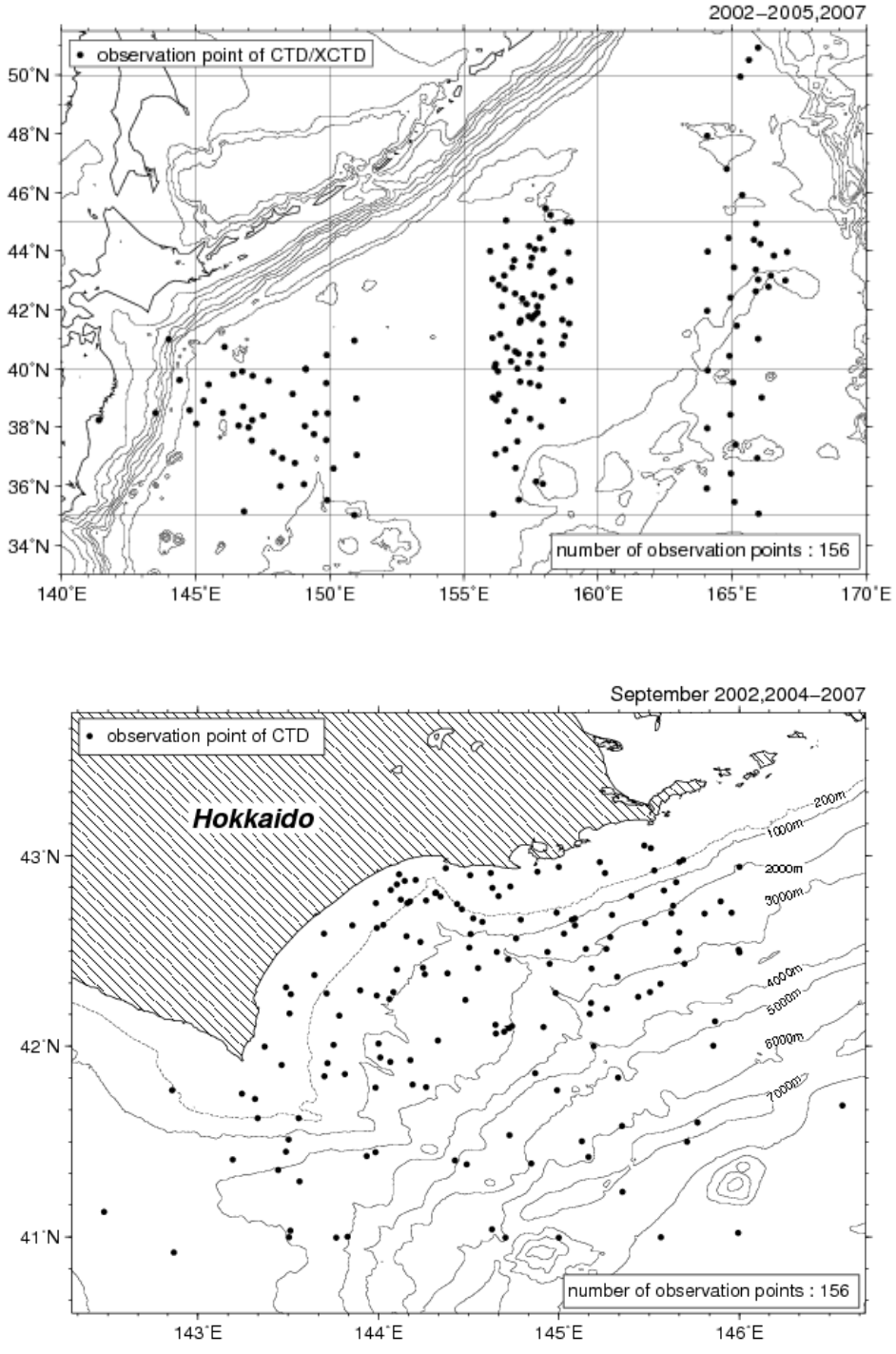

Fig. 1 Station maps observed in the JARPN II area (offshore (upper panel) and off Kushiro (bottom panel)) from 2002 to 2007.

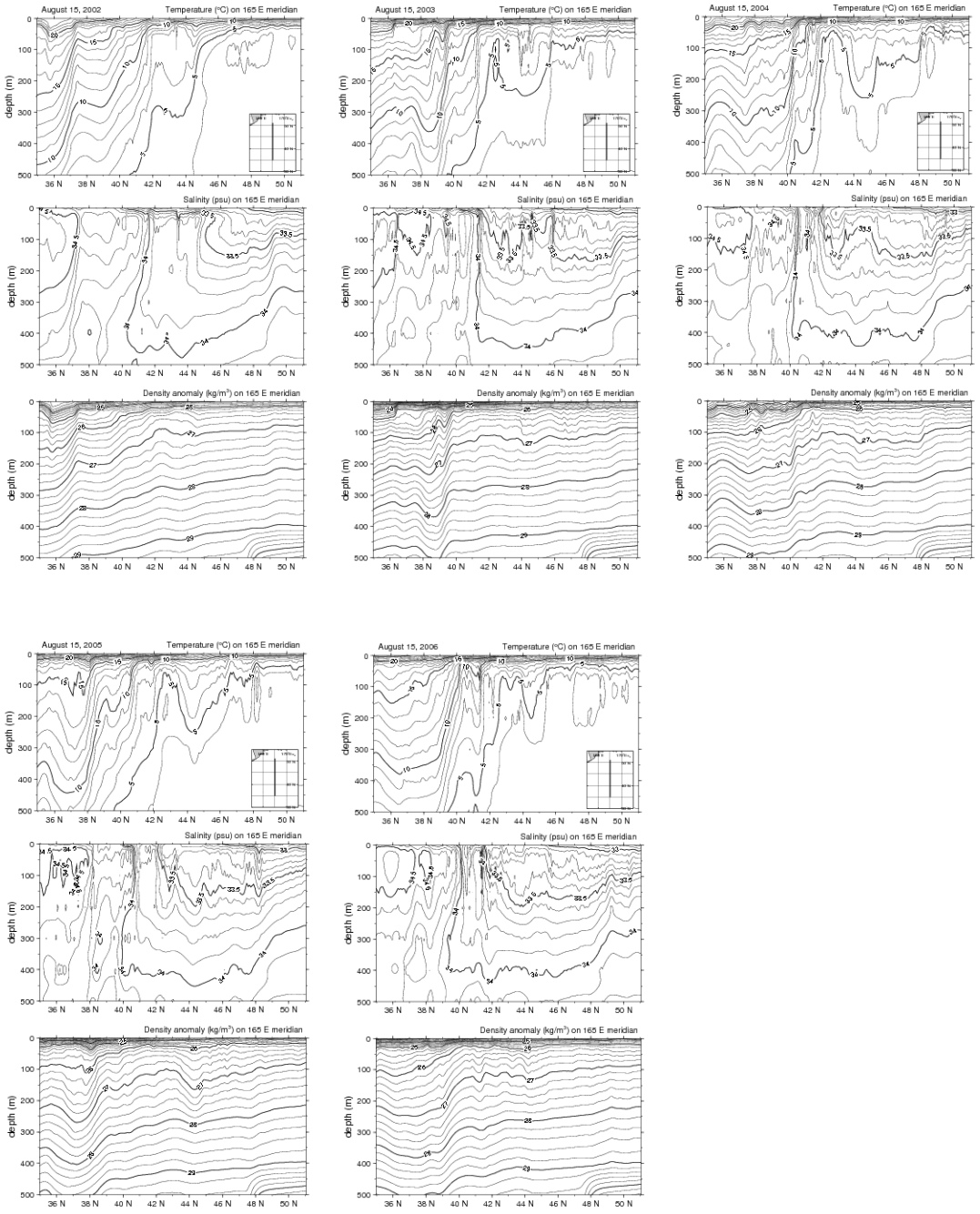

Fig. 2. Vertical sections of temperature (upper panel), salinity (middle panel) and density (lower panel) along 165ºE on August 15 from 2002 to 2006.

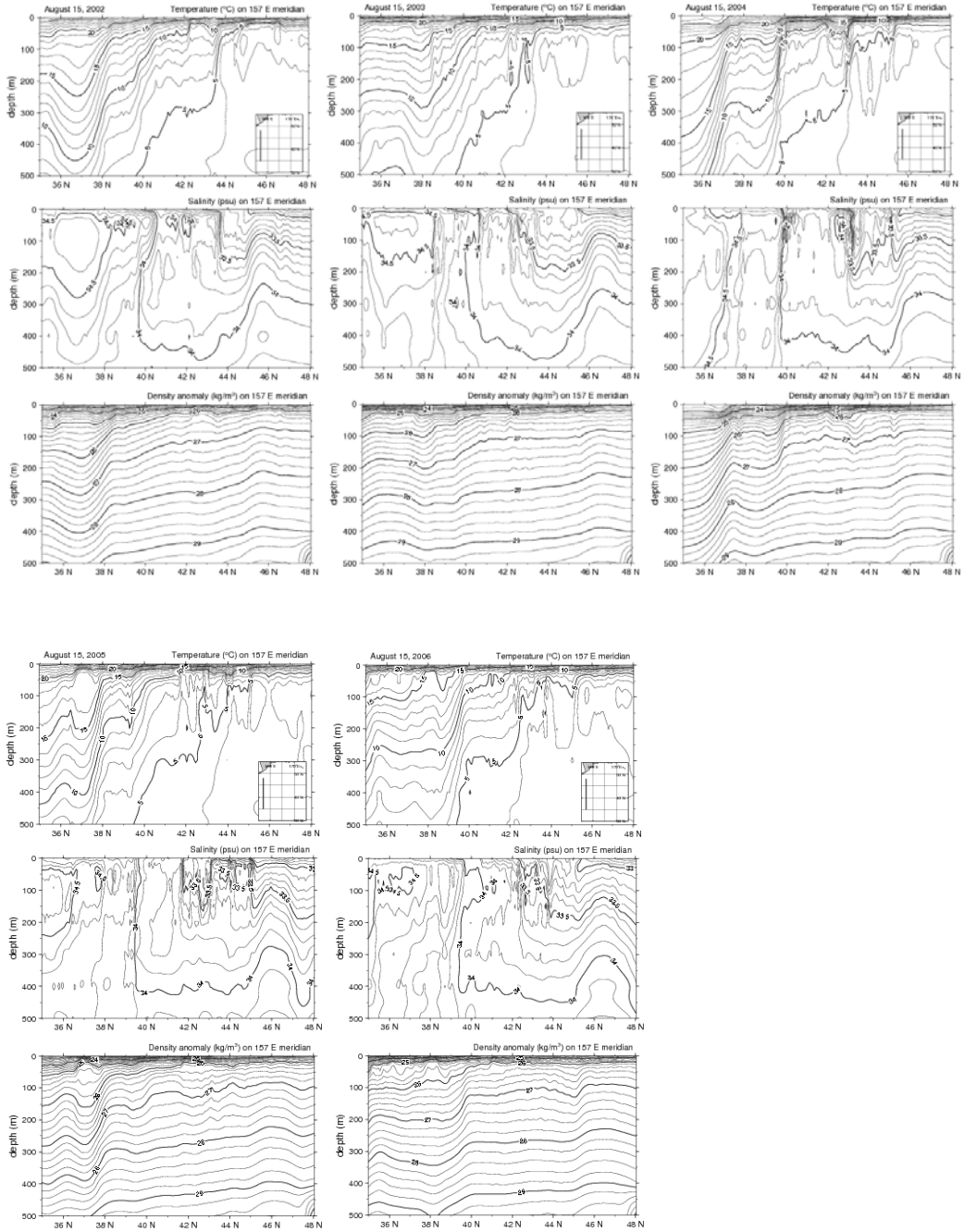

Fig. 3. Vertical sections of temperature (upper panel), salinity (middle panel) and density (lower panel) along 157ºE on August 15 from 2002 to 2006. .

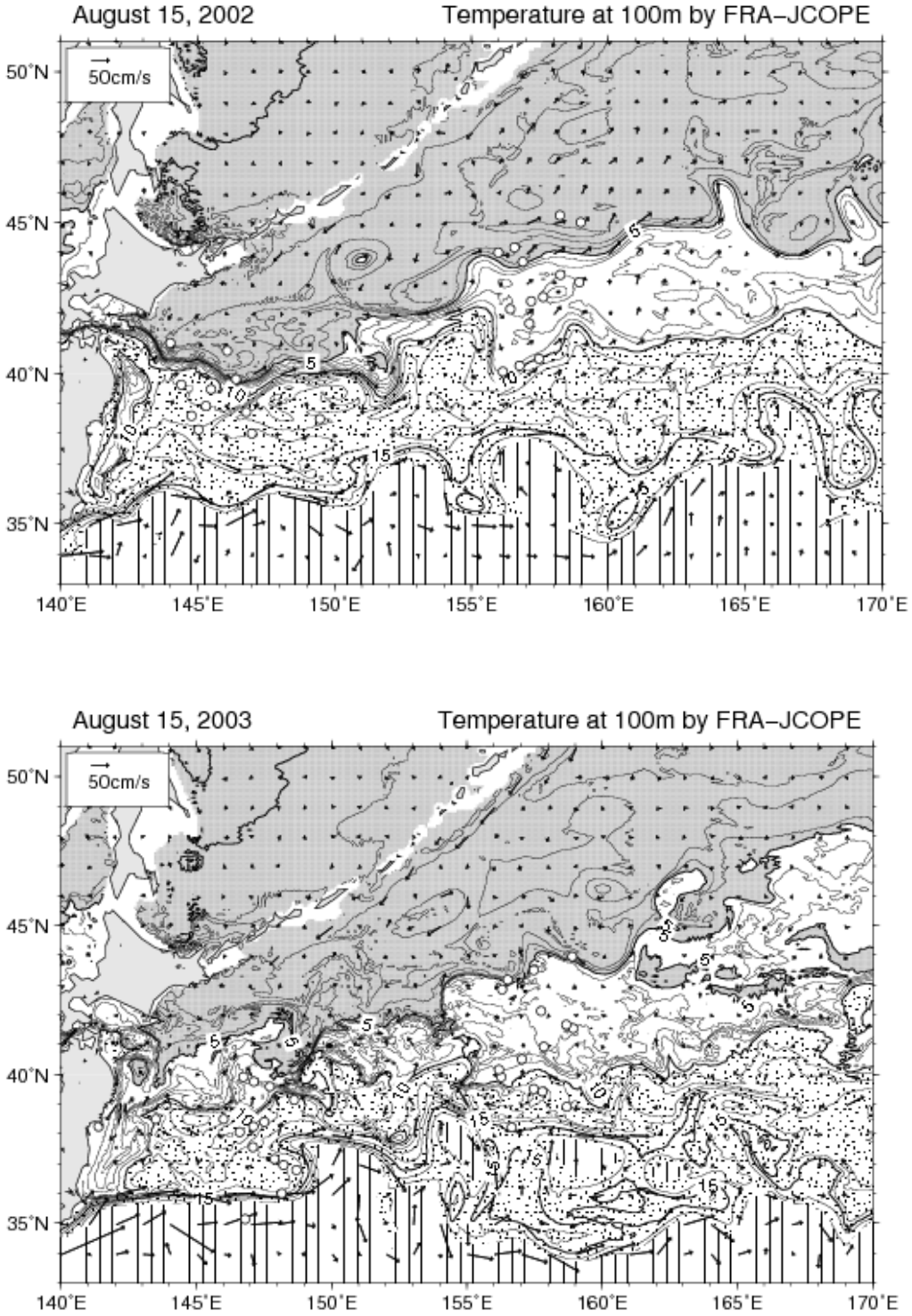

Fig. 4. 100 m temperature maps in offshore area, on August 15 in 2002 (upper panel) and 2003 (lower panel) with positions of observation stations in JARPN II (white circle). Northern dark area is Oyashio region, white area is Cold region, dotted area is warm area, and vertically striped area is Kuroshio region. Arrows denote the velocity vector at the sea surface.

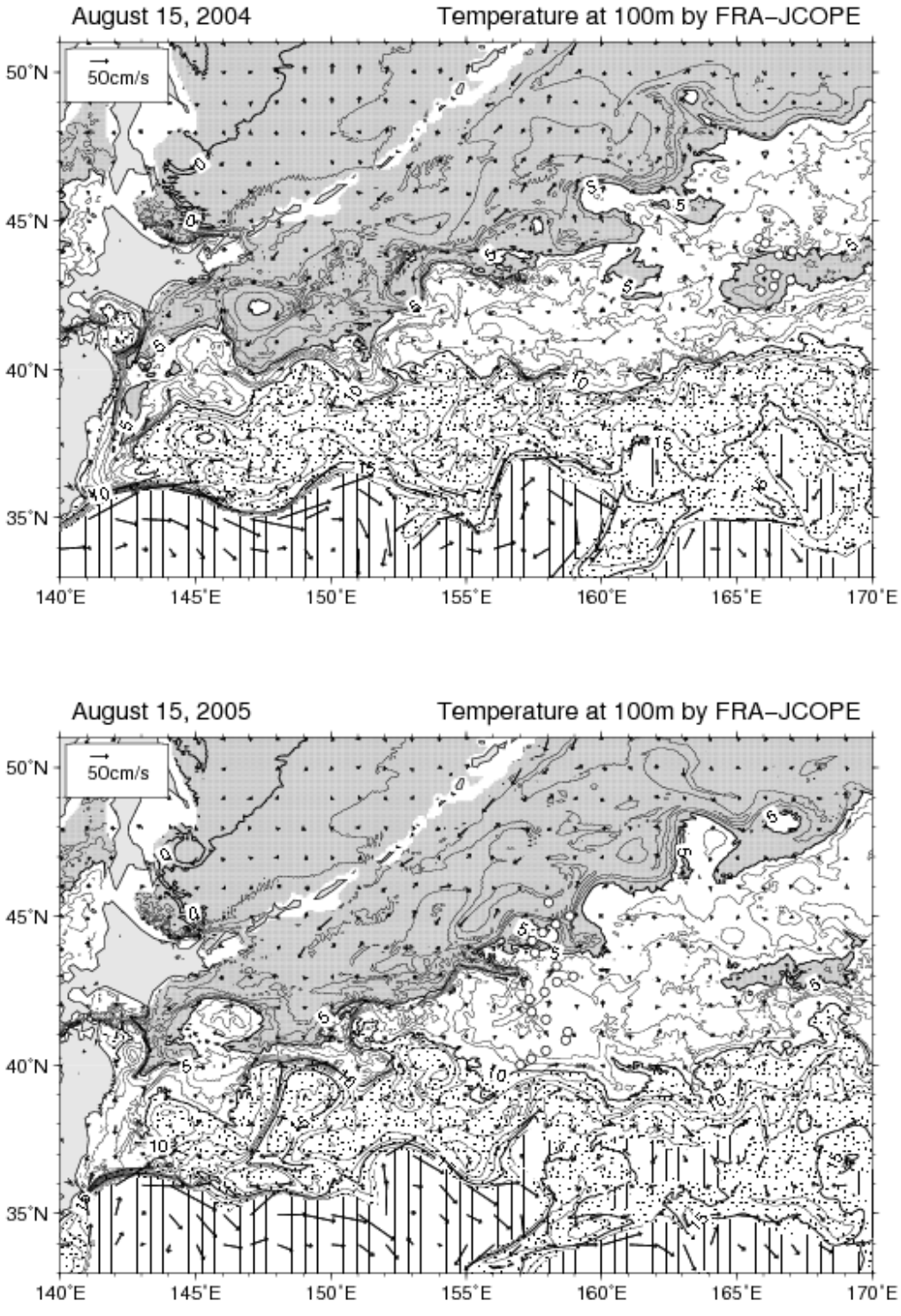

Fig. 4. (cont.) 2004 (upper panel) and 2005 (lower panel).

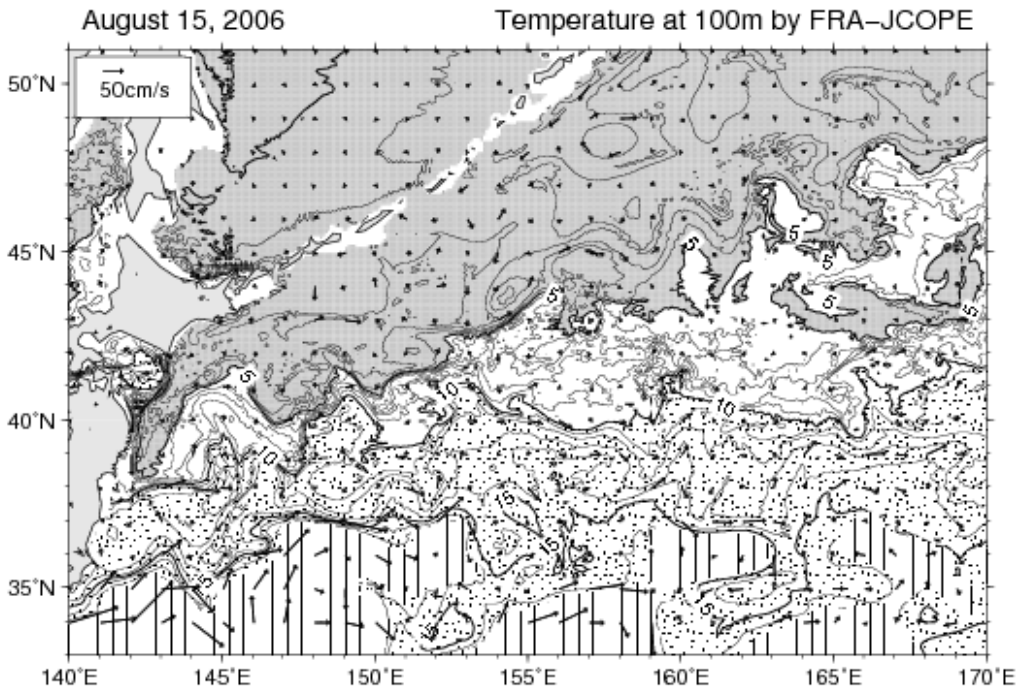

Fig. 4. (cont.) 2006.

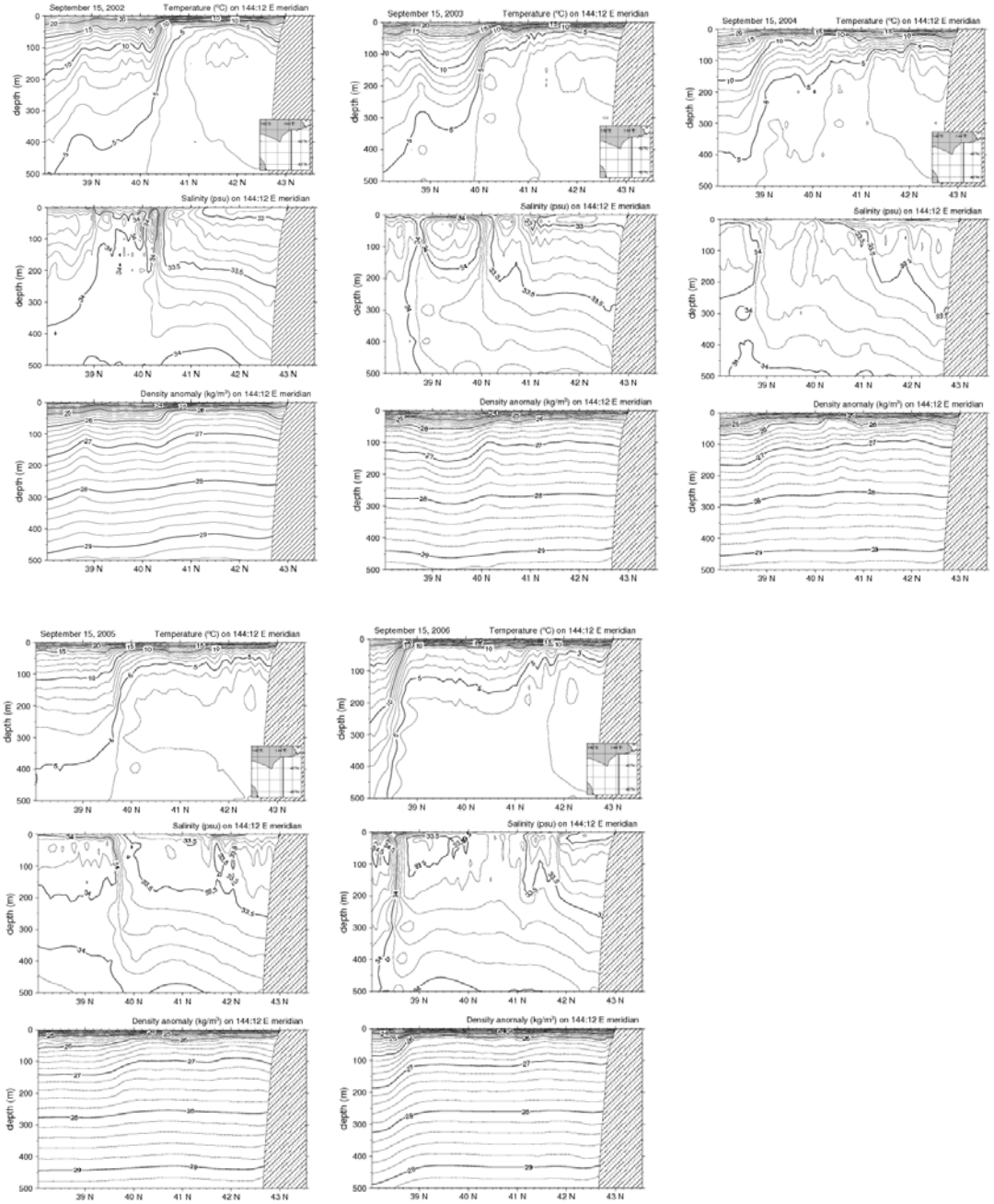

Fig. 5. Vertical sections of temperature (upper panel), salinity (middle panel) and density (lower panel) along 144º12'E on September 15 from 2002 to 2006.

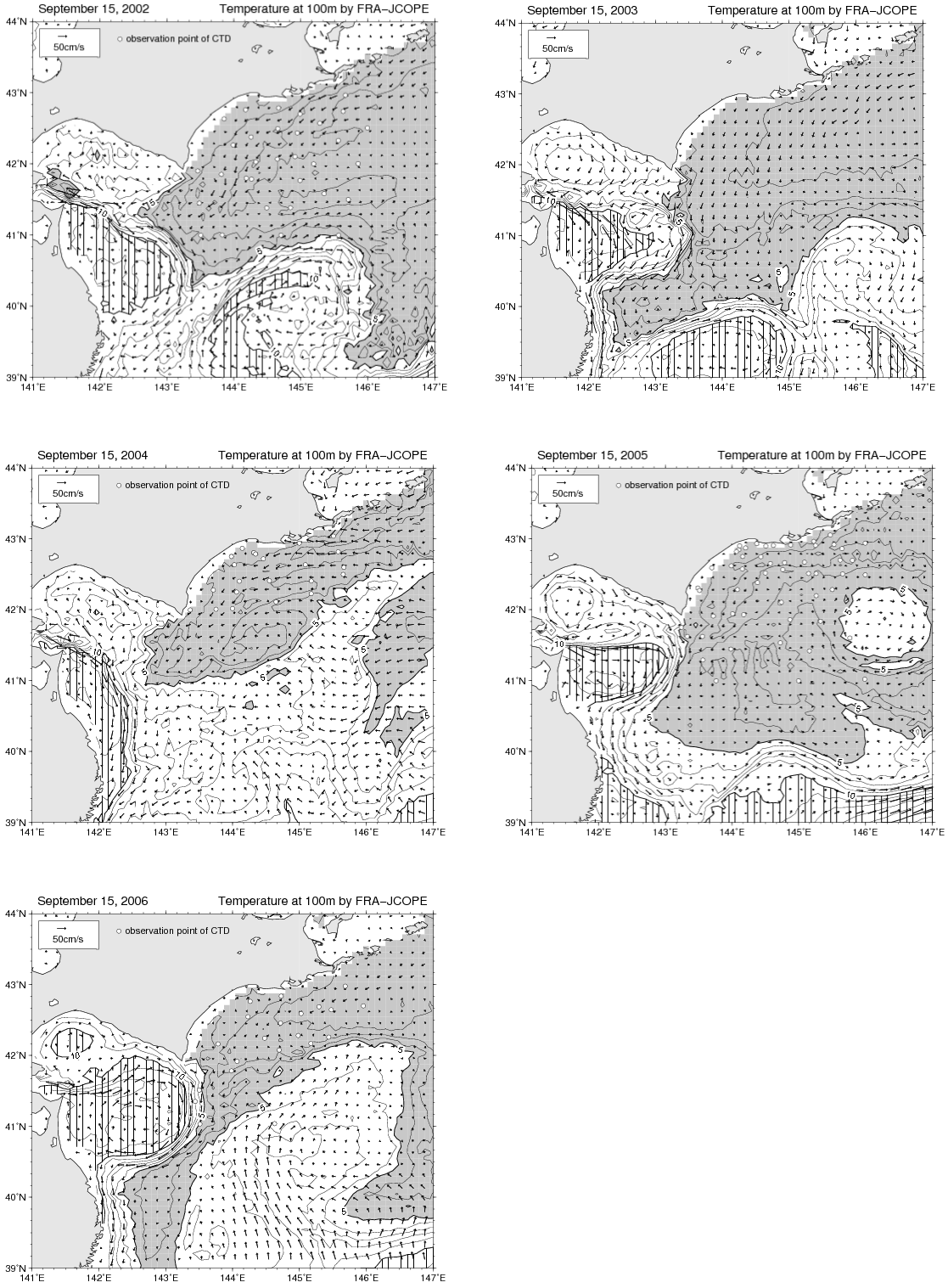

Fig. 6. 100 m temperature maps in the survey area southeast of Hokkaido, on September 15 from 2002 to 2006. White circles in the maps denote observation stations in JARPN II. Northern dark area is Oyashio region, white area is Cold region, and vertically striped area is the Tsugaru warm current region. Arrows denote the velocity vector at the sea surface.