CLIMATIC STRUCTURE OF THE JAPAN (EAST) SEA WATER MASSES

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Introduction

The researchers have been studying the Japan (East) Sea water masses for over 100 years (Biryulin *et al.*, 1970; Fukuoka, 1962; Gamo & Horibe, 1983; Gamo *et al.*, 1986; Kim & Chung, 1984; Kim & Kim, 1999; Kim *et al.*, 1997a, 1997b; Leonov, 1948, 1960; Miyazaki, 1953; Moriyasu, 1972; Nitani, 1972; Noh *et al.*, 1999; Radzihovskaya, 1961; Senjyu & Sudo, 1994; Senjyu, 1999; Senjyu & Minami, 1999; Shrenk, 1869, 1874; Suda, 1932; Sudo, 1986; Uda, 1934; Yasui *et al.*, 1967; Zuenko & Yurasov, 1995). Nevertheless, despite the evident simplicity of the sea water structure the researchers did not come to any uniform point of view about number of water masses at present. It is connected to the morphological and physical-geographical conditions. The straits of the Japan (East) Sea are shallow and the Japan Sea deep waters are isolated from the adjacent seas and the Pacific Ocean. Therefore high activity and essential variability of the surface layer and weak intensity of the deep layer processes are observed in the Japan (East) Sea. Complexity of the classical methods *T*, *S* – analysis application, the absence of the uniform point of view the law of the water mass formation, first of all, on the deep water give various interpretation of the obtained results.

Data and Analysis Method

The data collected of oceanographic stations have been used in this work. All available oceanographic data were combined. The joint database contains oceanographic data that have been collected from different institutes located in Russia, the USA and Japan. Nowadays a joint oceanographic database contains 140 000 oceanographic stations covering 1932-1999 period. Main part of the database was taken from different Russian organizations (Hydrometeorological Service; Navy Hydrographical Service; Russian Academy of Sciences; TINRO and other fishing and oceanographic organizations). The western data were taken from US NODC, JODC and KODC. Then quality control of data was made. Doubled and unreliable stations were excluded.

At standard depths, we calculated the mean parameters of temperature and salinity. Data were gridded (1° of latitude by 1° of longitude). The monthly averaged values of temperature and salinity in the centers of one-degree squares were used for analysis.

To determine the water mass parameters of the Japan (East) Sea a comprehensive/complex approach has been used. It includes: the statistical method of *T*, *S* (temperature-salinity)-diagrams; the method of *T*, *S* – curves; the method of the water volume analysis.

Results

Figs. 1 and 2 show the statistical *T*, *S* – diagrams at different levels. The diagrams demonstrate, that in the Japan (East) Sea is confidently possible to reveal only the Deep Water Mass. The changes of temperature and salinity in this water mass were shown in the diagrams at the levels from 600 м down to bottom (Fig. 2). The upper boundary of this water mass is shown in Fig. 3. In accordance with our estimations the deep water mass covers more than 70% of water volume of the Japan (East) Sea. The deep water mass has the temperature from 0.12 to 0.38 °C, and salinity – from 34.04 to 34.09‰. Uda (1934), Sudo (1986), Senjyu & Sudo (1994) name this water mass as the Japan Sea Proper Water.

The upper (0-600 m) layer structure of the Japan (East) Sea was studied by the method *T*, *S* – curves has been used. Fig. 4 shows the main types of *T*, *S* – curves. The variety of *T*, *S* – curve forms is reduced to three types.

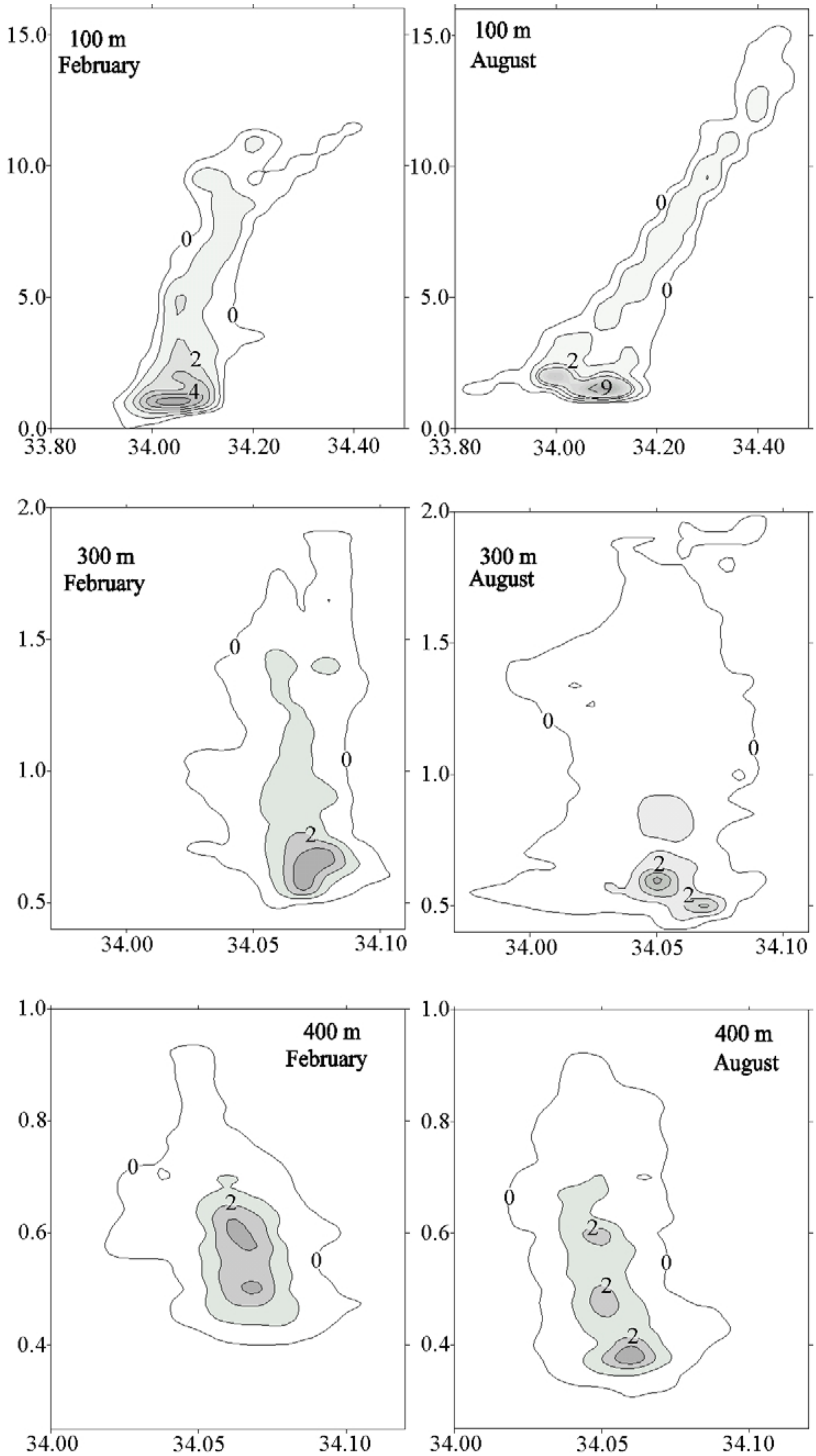

Fig. 1. Statistical T, S - diagrams at depths of 100 m, 300 m, and 400 m

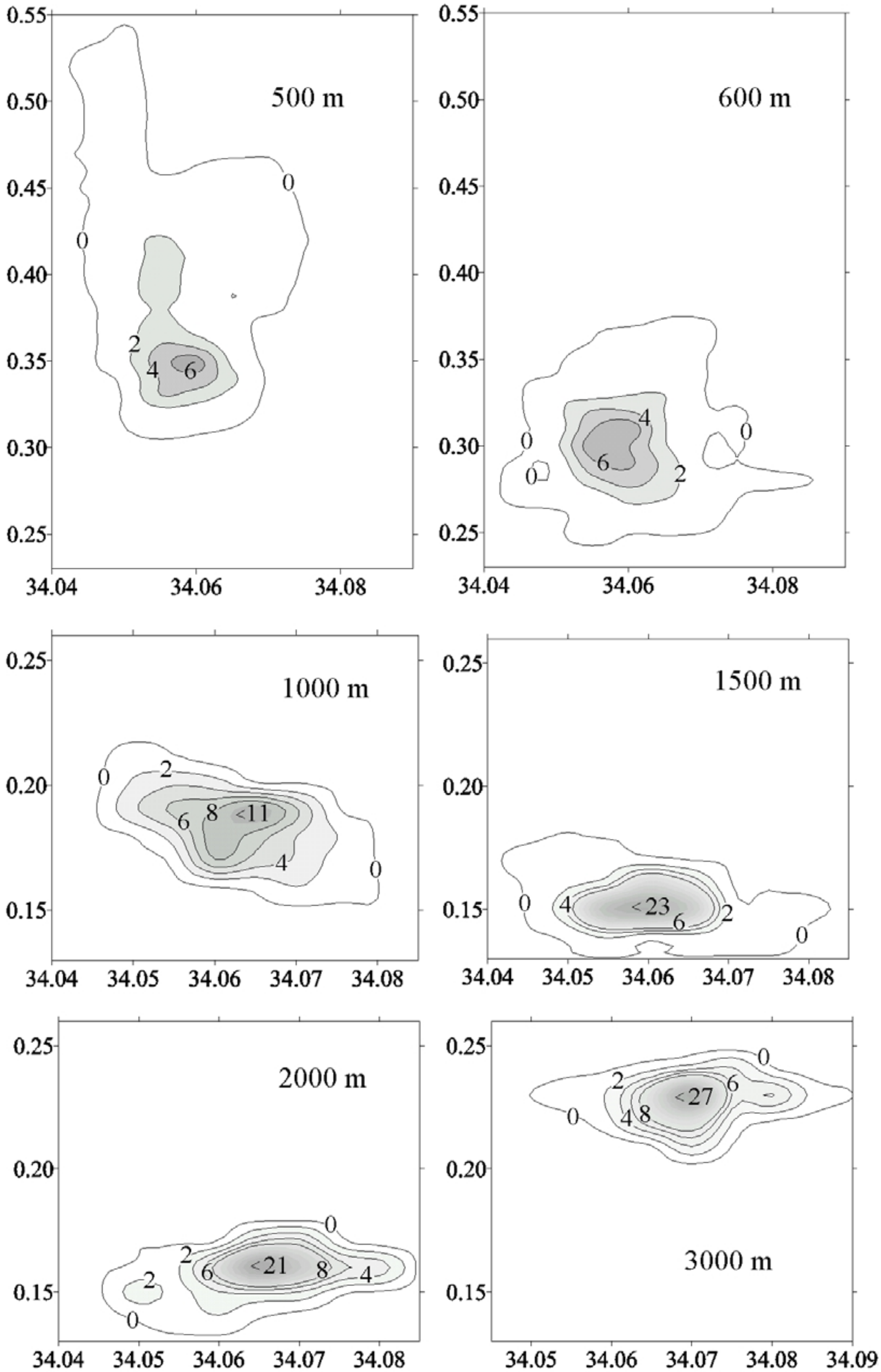

Fig. 2. Statistical T, S - diagrams at depths of 500 m, 600 m, 1000 m, 1500 m, 2000 m, and 3000 m

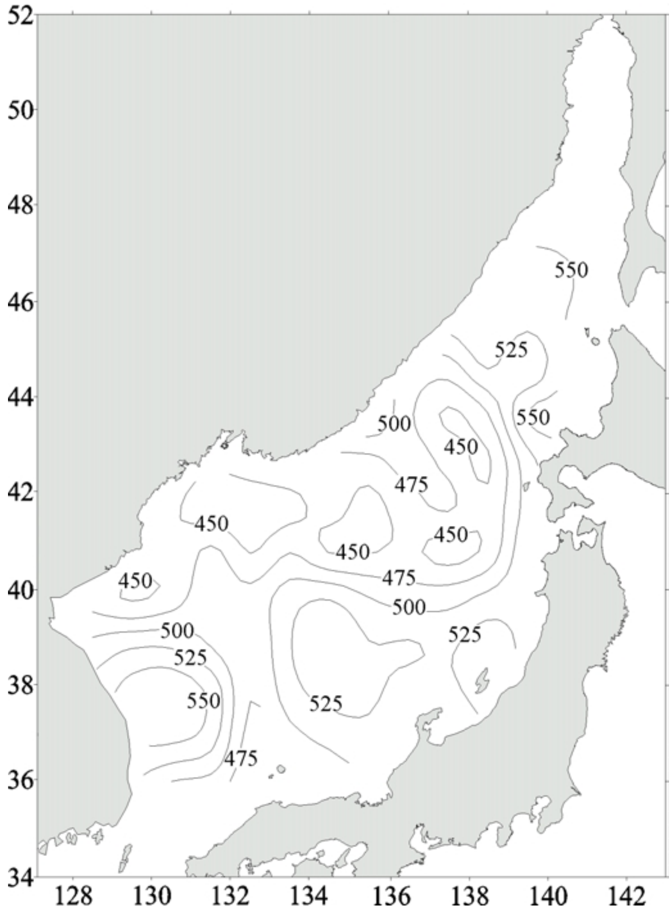

Fig. 3. The upper boundary (in meters) of the Japan Sea Proper Water

The first type is characteristic of the northern and northwestern parts of the sea (Fig. 4, 5). In this part of the sea besides the deep water mass the Northern Japan (East) Sea water mass has been revealed as well. It is registered to the north of the subpolar front. Its core is at the surface in winter and at the levels below seasonal pycnocline in the warm season. The lowest temperatures (from 0 to 1.0 °C) are observed in the western and northwestern sea parts with the maximum (2-4 °C) – near the Polar Front. Salinity of the water mass varies from 33.0-33.5‰ (along Primorye and Korea coast) to 34.0‰ near the Polar Front.

Second type of the water structure is observed in the southern and eastern sea parts (Fig. 4, 5). In the warm period it is characterized by the presence of the subsurface layer with increased salinity. This is the Pacific Ocean water mass (or the Tsushima Warm Water). Kim & Kim (1999) name it as the Intermediate Water Mass with higher salinity. A gradual Pacific water transformation is observed northward from the Tsushima (Korean) Strait. In winter its core is registered at the sea surface, and in other seasons – it is seen at the subsurface levels (Fig. 6).

In the Tsushima (Korean) Strait the core temperature of this water mass is 11-14 °C. On the northern periphery of water mass it does not exceed 2-3 °C (Fig. 7). Salinity in the core of water also undergoes significant changes (from 34.25-34.50‰ close to the Korean Strait to 34.05-34.10‰ on the northern periphery of the water (Fig. 8).

Third type of the water structure is observed in the local area eastward the Korean Peninsula (Fig. 4, 5). The distinctive feature of the given type is availability of the intermediate waters with lower salinity.

The water layer with lower salinity, demonstrated by *T*, *S* – curve, we classify as the Intermediate Water Mass of the Japan Sea (or Japan (East) Sea Intermediate Water, according to Kim *et al.* (1997a), Kim & Kim (1999), Senjyu (1999), Senjyu & Minami (1999). Its formation is related to autumn – winter-convective mixing in the western and northwestern parts of the Japan Sea. The Liman and the North Korea Cold Currents transport these waters to the region eastward of the Korean peninsula. On the way of their migration these waters change their parameters (mixing with the deep and Pacific waters). Part of them also sink below the Pacific water mass. The Intermediate water mass of the Japan Sea core occupies at the levels of 100-400 m. The maximal values of the parameters are always observed in the southern part of this water mass, and the minimal – on its northern and western peripheries (Fig. 9). The maximum temperature is observed in winter (to 2-7 °C). In other seasons it does not exceed 0.5-1.5 °C (Fig. 10). Salinity in the core of these waters changes from 34.00 to 34.06‰ during a year.

The surface water mass. It is formed as a result of water warming and dilution (rivers, precipitations), as well as convective surface layer mixing. Its temperature changes from -1.8 to 27 °C, and salinity – from 30.0 to 34.7‰ (in the northern part of the Tatar Strait salinity of the surface waters does not exceed a few ppt. in spring and summer)

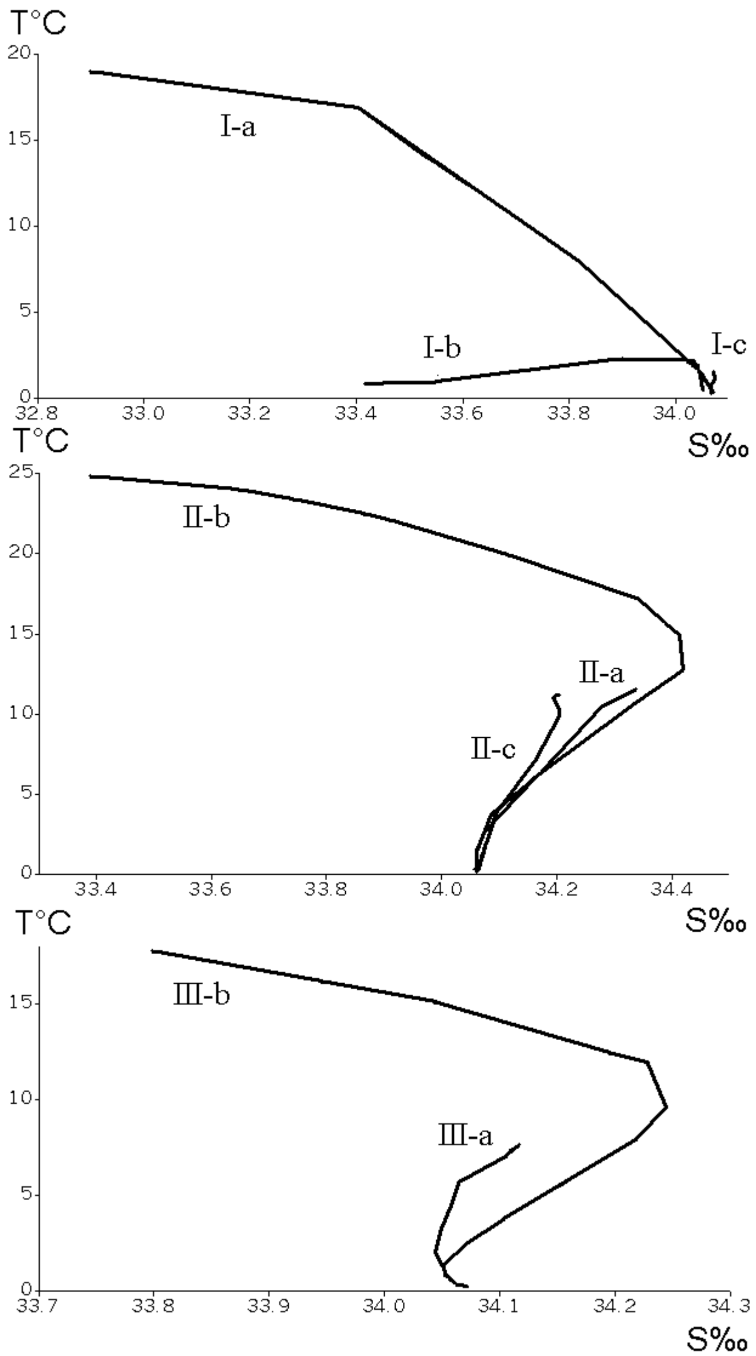

Fig. 4. Typical T, S-curves for the Japan (East) Sea

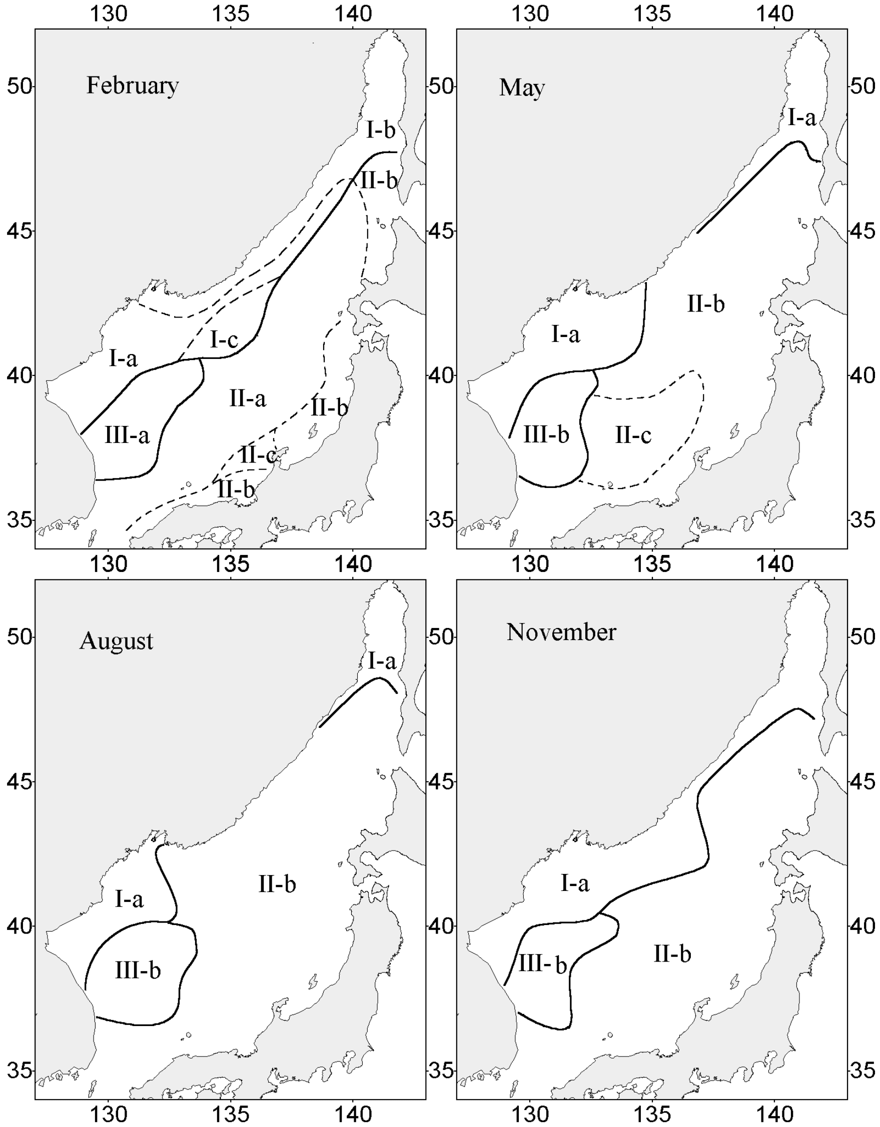

Fig. 5. Water structures of the Japan Sea

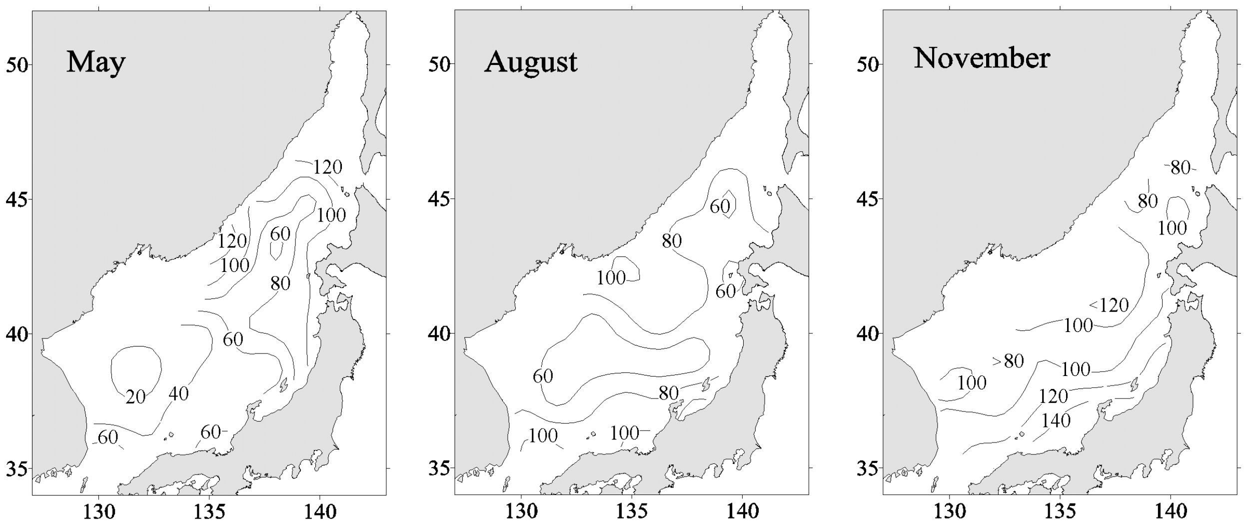

Fig. 6. Location depth of the core (in meters) of the Pacific Ocean water mass

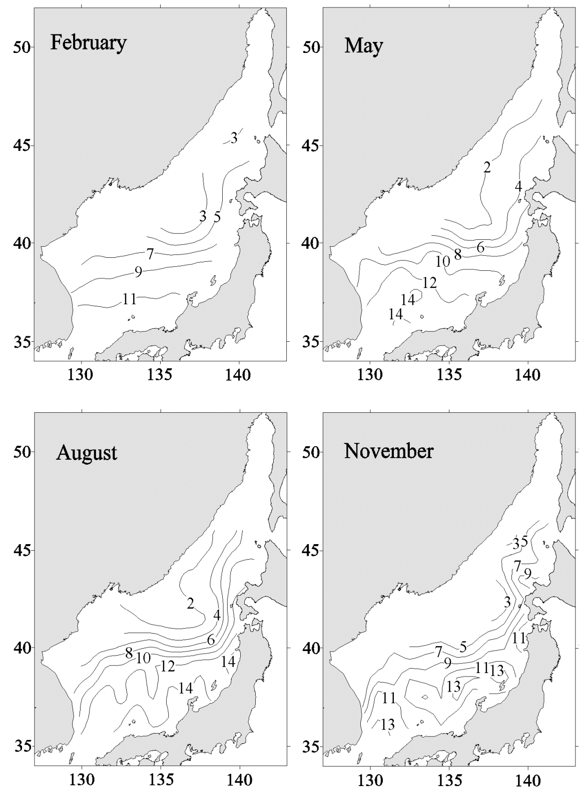

Fig. 7. Temperature of the core (°C) of the Pacific Ocean water mass

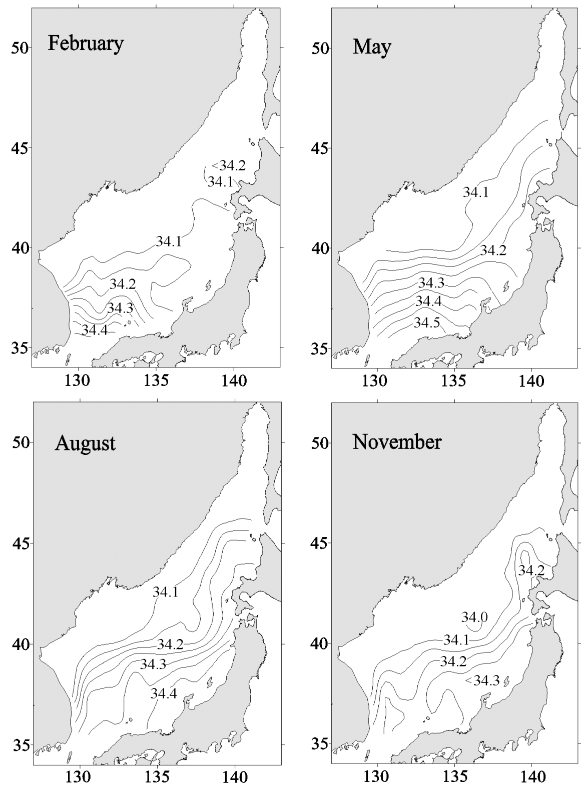

Fig. 8. Salinity of the core (°C) of the Pacific Ocean water mass

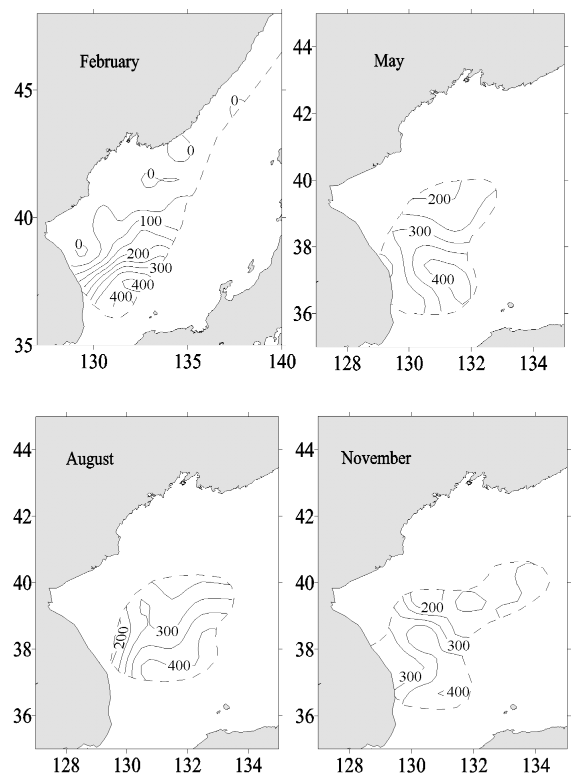

Fig. 9. Location depth of the core (in meters) of the Japan (East) Sea Intermediate Water

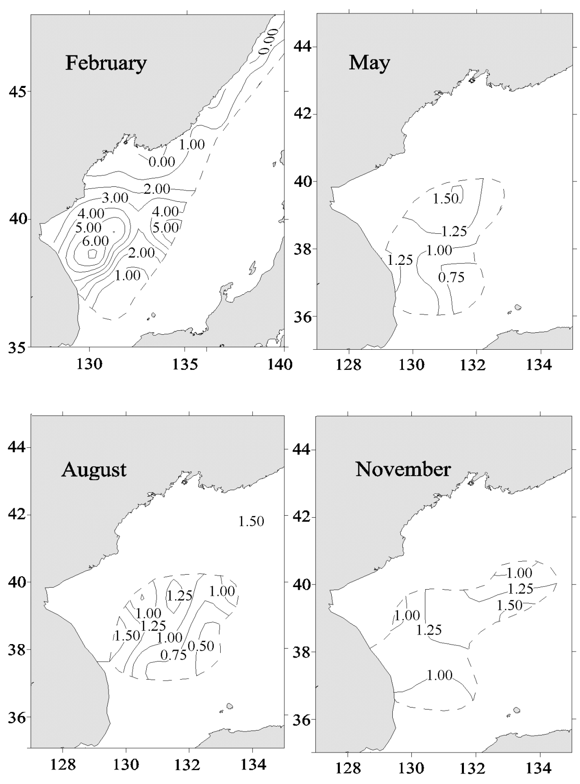

Fig. 10. Temperature (°C) of the core of the Japan (East) Sea Intermediate Water

Conclusions

The deep water mass has the temperature from 0.12 to 0.38 °C, and salinity – from 34.04 to 34.09‰. The upper boundary of this water mass changes from 450 to 550 m.

In the Tsushima (Korean) Strait the core temperature of the Pacific Ocean water mass (or Tsushima Warm Water) is 13-15 °C. On the northern water mass periphery it does not exceed 1-3 °C. Salinity in the water core also undergoes significant changes (from 34.25-34.55‰ and close to the Korean Strait to 34.08-34.10‰ on the northern periphery).

The Intermediate water mass of the Japan Sea core occupies the levels of 100-400 m. The maximal temperature is observed in winter (to 2-7 °C). In other seasons it does not exceed 0.6-1.8 °C. Salinity in the core of these waters changes from 34.00 to 34.06‰ during a year.

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