Variability of the Japan and Okhotsk Seas ice cover depending on the geoptential field H500 average over the Far Eastern region

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Introduction

Ice cover of the Japan and Okhotsk seas is one of the elements of the climatic system of the Far East and depends on a large number of the factors (Kryndin, 1964; Stolyarova, 1975; Biryulin, 1970; Yakunin, 1966; Plotnikov, 1996). Despite the extensive data on ice cover of the Far Eastern seas, the reasons for interannual and long-term variability are still vague.

The object of this work is to reveal the features in variability of the Japan and Okhotsk Seas' ice cover that depend on atmospheric large-scale processes above the Far East sector of the northern hemisphere.

Data

The following have been used:

1. Data on area of ice cover (%) of the Japan and Okhotsk Seas (1928–1960) published by Kryndin (1964) and obtained from the Far Eastern Regional Center of Data Reception and Processing (Khabarovsk) – 1961–1992. Data on ice cover of the Okhotsk Sea for 1993–1998 were received by satellite images (TV- and IK-images by "Meteor" and NOAA).

2. Data on water temperature at the Holmsk Hydrometeorological Station (1913–1996) were provided by the Sakhalin Hydrometeorological Administration.

3. Average monthly data on geopotential H500 (dam) at airological stations for January, 1950–1998 were given by the Primorskiy Hydrometeorological Service.

Results

The long-term variability of ice extent in the Tatar Strait (Japan Sea) and Okhotsk Sea is presented in Figure 1. Two periods of ice cover are found in the Tatar Strait: one large (1930–1960), the other small (1962–1992). Extrenal low ice cover was marked in 1957 and 1991, and high in 1951, 1954 and 1960. The curve of the course of the Okhotsk Sea ice cover differs significantly from a curve of ice cover in Tatar Strait. The period of high ice cover in winter is for 1966–1988 (22 years) in the Okhotsk Sea; within this large period 6–7 year cycles are observed. The cycle of warm winters began in 1989, with ice cover reaching a minimum in 1996.

During the almost 70-yr period for the Okhotsk Sea, there were observed two cycles of low ice cover winters: the first from 1952–1958 and the second from 1990–1997, with a minimum in 1996 (the duration of cycles is 6–7 years).

Ice cover changes have to be examined in the context of other elements of the climatic system of the Far Eastern sector (30°–60°N, 120°–160°E). From temperature data at GMS Holmsk for 1913–1996 (Fig. 2) the warming of coastal waters at western Sakhalin in the 1990s can be seen. The beginning of warming goes back to the 1960s and coincides with the ice cover change in the Japan Sea. The warming of waters in a surface layer in the southeast and northwest parts of the sea was noted also by satellite and hydrological data (Dyakov, 1996; Ponomarev et al., 1997; Shatilina et al., 1998).

Long-term variation of geopotential anomalies H500 for regions (I, II, III) are shown in Figure 3. The location of selected domains (regions) and airological observatory stations is shown in Figure 4. The amplitude of geopotential oscillations over the northern part of the Japan Sea. is much higher than over the Okhotsk Sea. After 1970 in the northern areas (II) strong peaks prevailed there, which were especially characteristic for 1990s (Fig. 3b). The last decade is especially extremal, based on the number of large anomalies. They show changes which occurred in eastern Asia.

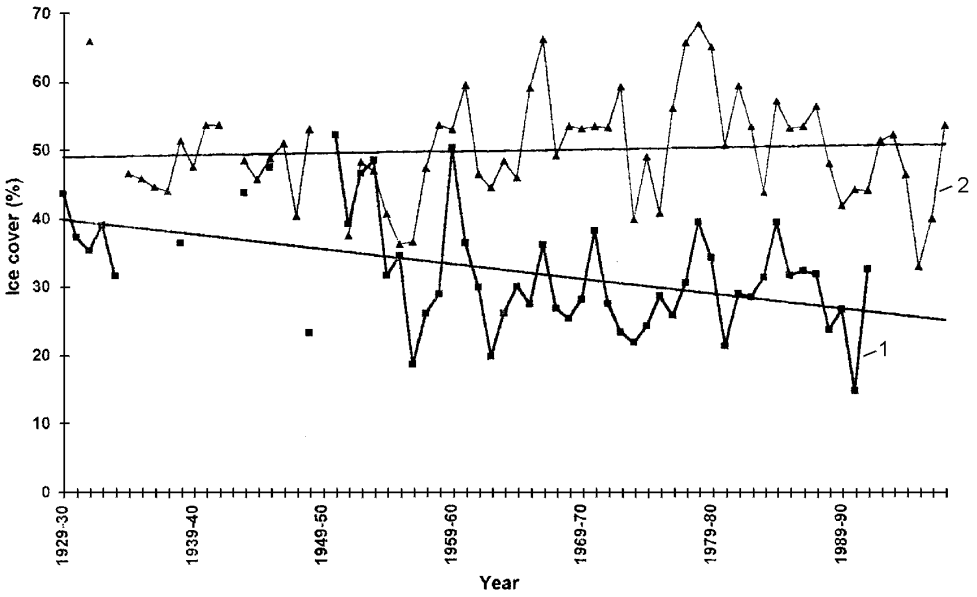

Fig. 1 Variability of ice extent in the Japan Sea (1) and Okhotsk Sea (2) 1930–1998.

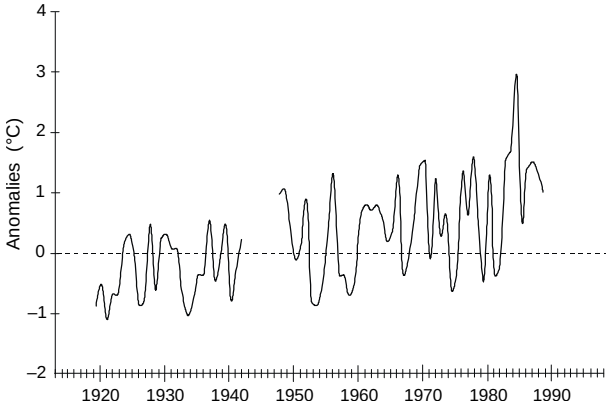

Fig. 2 Water temperature anomalies at Holmsk in January of 1913–1996.

Above the Okhotsk Sea are two periods (Fig. 3), distinguished by frequency of recurrence of strong peaks of pressure, 1950–1969 and 1970–1998. Great decreases of pressure were marked in 1966, 1967, 1978, 1979, 1988. Strong peaks occurred in 1963, 1974, 1991 and 1997. The general trend of pressure is increasing. It is traced more strongly in the second area.

The course of anomalies of geopotential H500 clearly testifies that a new period in variation of atmospheric circulation over the Far East has begun since 1989. These variations have started from a sharp growth of pressure in 1989. In contrast to the northern regions (II and III) after 1989 in the southern region (I) is a marked pressure drop (Fig. 3).

A completely contrasting picture in distribution of a field structure H500 in extremal ice cover in winter is observed in Figure 4. So during the extremal ice winters (1954) the Okhotsk minimum in the Tatar Strait is above the northwest part of the Okhotsk Sea (Fig 4a). The cold centers are located there. The Okhotsk minimum is extensive in extremal ice cover in winter (1979) in the Okhotsk Sea and the high-altitude ridge is not observed above western Kamchatka (Fig. 4). The cold centers are also located there.

In low ice cover winters the Okhotsk minimum in the Japan Sea is substituted for a field of high pressure. For example, in 1991 and 1996 in the Okhotsk Sea the Okhotsk minimum shifts to continental regions, and the Pacific ridge to the whole sea (Fig 4). The warm air masses are transferred to the northeastern part of the Okhotsk Sea, and a powerful center of warmth is located there. It is possible to assume that while a ridge of warmth stretches to the Okhotsk Sea, Pacific warm water inflow increases and it promotes an open water region to be larger.

The highest coefficient of correlation (r = –0.59) was obtained between the ice cover of the Tatar

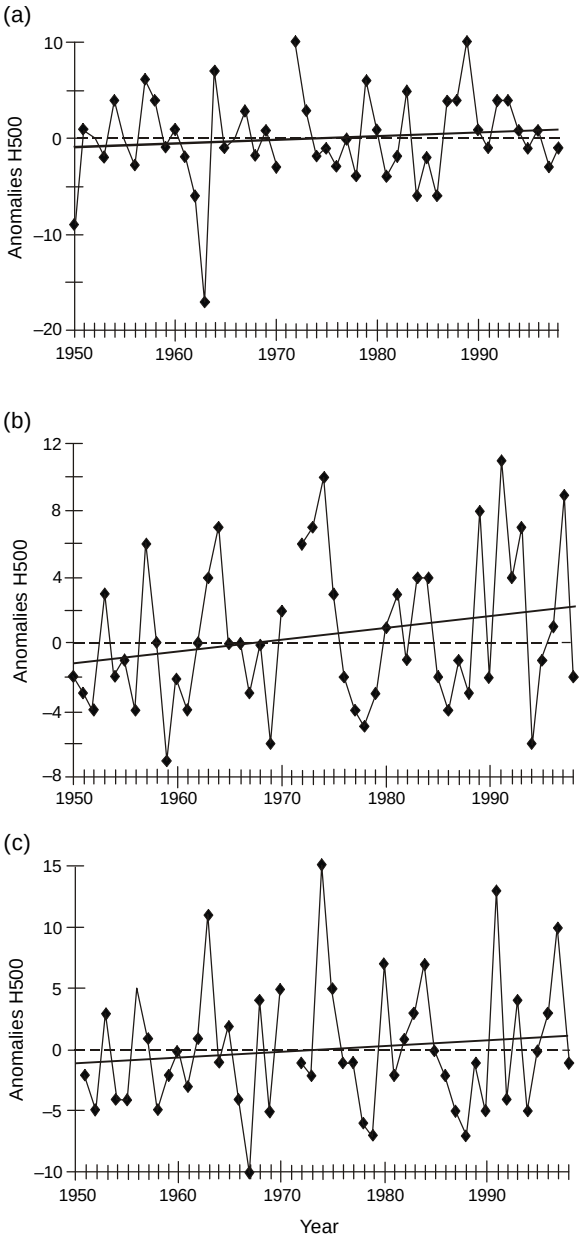

Fig. 3 Long-term variability of geopotential anomalies H500 (dam) over (a) the southern part and (b) the northern part of the Japan Sea and (c) the Okhotsk Sea in January of 1950–1998.

Strait and anomalies of geopotential H500 for Nikolaevsk-on-Amur. (Fig. 5a). The correlation between the ice cover of the Okhotsk Sea and anomalies of geopotential H500 for Nikolaevsk-on-Amur is equal (r = –0.46) (Fig. 5b).

In 1990s there was a displacement of the climatic center of low pressure above the Okhotsk Sea which testifies to the variation of circulation mechanisms above the Far Eastern region. In this connection, it is interesting to note that in the 1990s processes such as El Niño (1991, 1994–95) took place which have found a response in the Far Eastern sector of the northern hemisphere.

Conclusions

The comparison of ice cover changes in the Japan and Okhotsk Seas has shown a favourable correlation with changes of H500 structure. Ice cover of these seas is a result of circulation processes above the Far Eastern region. All low ice cover winters were observed when a high depression above the Okhotsk Sea was absent, which changed the transport of cold air masses to the Okhotsk Sea. Weak ice cover in winter was observed in Tatar Strait when there was a sharp increase in pressure over the northern part of the Japan Sea.

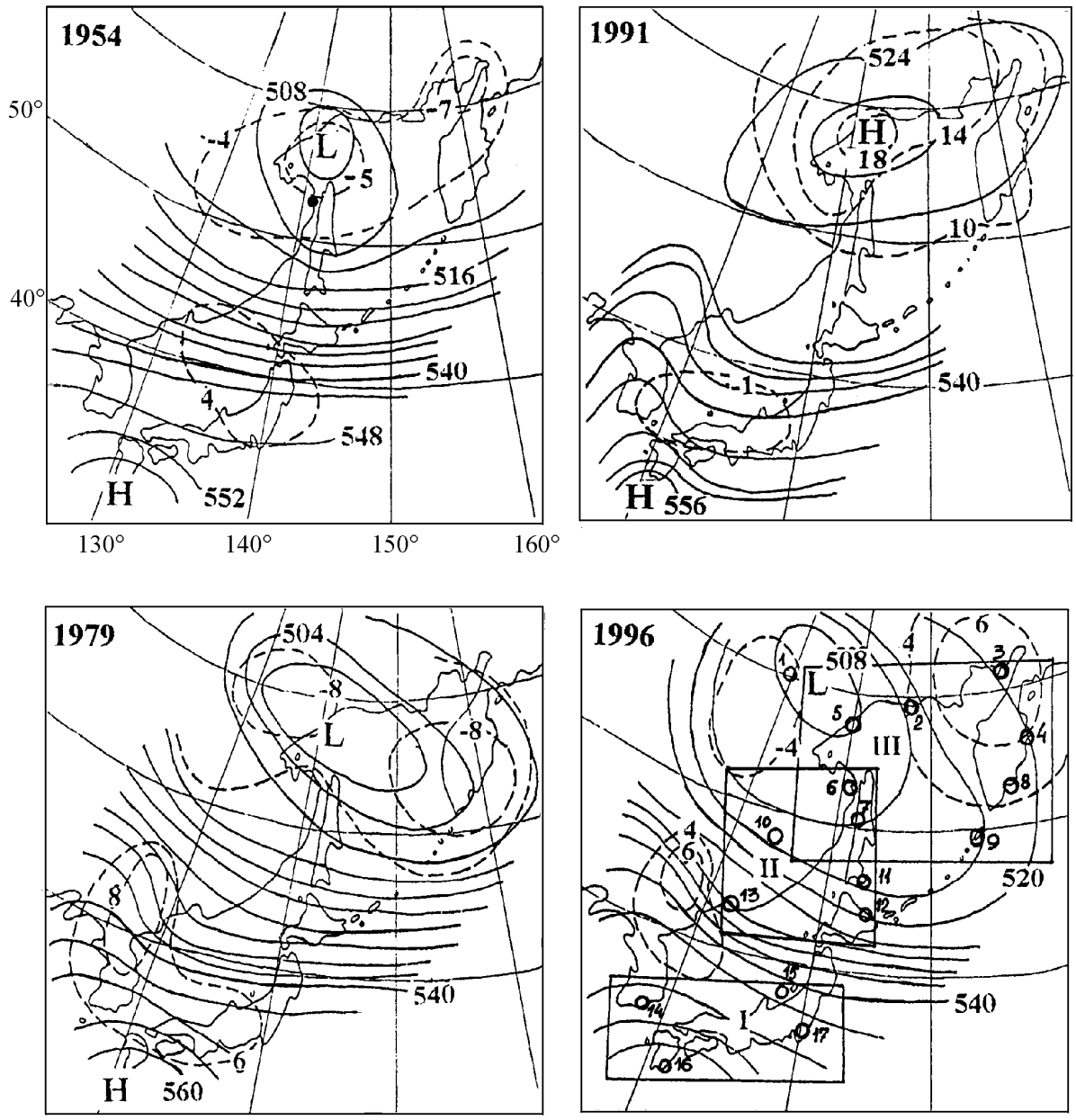

Fig. 4 Structure of geopotential field H500 in January of 1954, 1991, 1979 and 1996. Location of aerological observatory stations and domains (I – southern part of the Japan Sea), II – northern part of the Japan Sea, III – Okhotsk Sea) are shown. Stations are: 1 Yakutsk, 2 Magadan, 3 Tayganos, 4 Ust-Kamchatsk, 5 Okhotsk, 6 Nikolaevsk-on-Amur, 7 Aleksandrovsk-Sakhalinsk, 8 Petropavlovsk-Kamchatskiy, 9 Vasilyevo, 10 Khabarovsk, 11 Yuzhno-Sakhalinsk, 12 Abashiri, 13 Vladivostok, 14 Pusan, 15 Aikawa, 16 Aburatsu, 17 Tokyo.

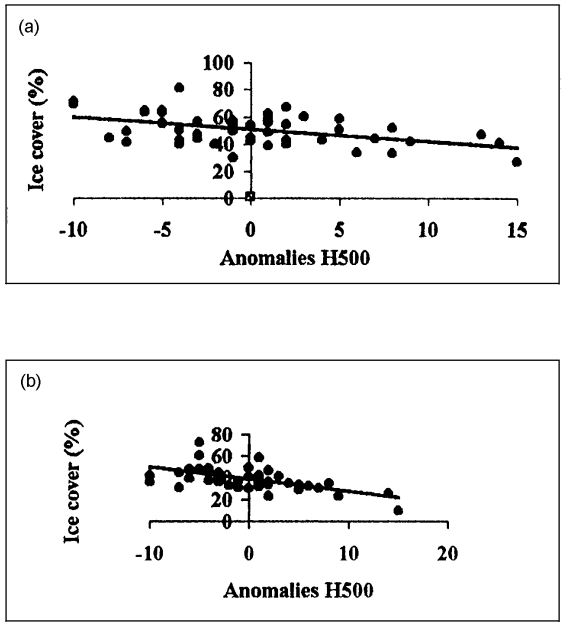

Fig. 5 Correlation between geopotential H500 for Nikolaevsk-on-Amur and ice cover of (a) the Tatar Strait and (b) Okhotsk Sea.

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