2.6. Characteristics of the East-Siberian Sea ice conditions

2.6.1. Physical-geographical sea characteristic

Borders, depth. The East-Siberian Sea is one of the Siberian shelf seas. It has an open border with Arctic basin in the north, with the Laptev Sea - in the west, with the Chukchi Sea - in east. The East-Siberian Sea is a shallow water basin with extremely level bottom, generally inclining north-eastwards. Level and sloping coast smoothly changes into sea bottom. Dominant depth in western sea region is 10–20 m, in eastern region – 30–40 m (Fig. 2.6.1).

Siberian rivers Indigirka and Kolyma flow into sea.

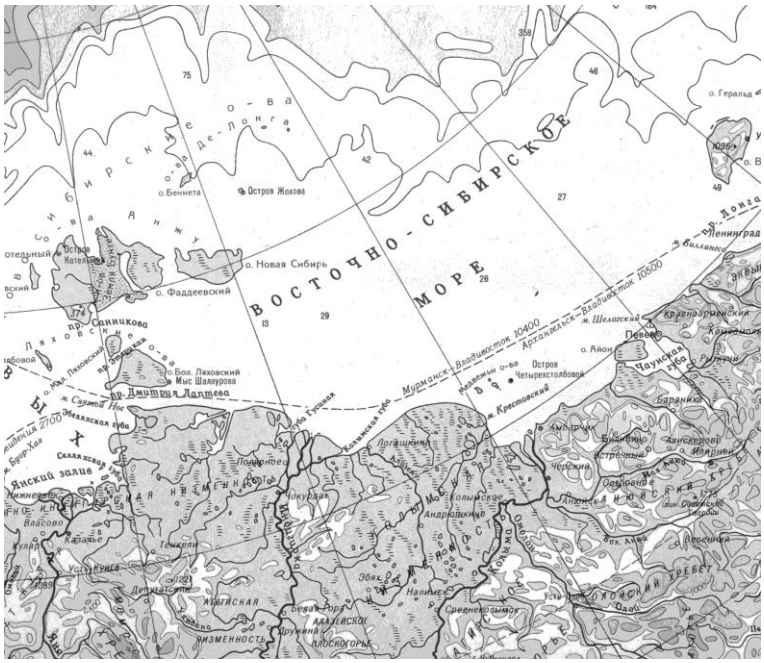

Fig. 2.6.1. Geographical location of the East-Siberian Sea

Northern sea boundary, accepted by AARI, goes a bit northwards isobath 50 m by line: 78° N 139° E – 78° N 160° E – 73° N 180°. Western border: 78° N 139° E – Cape Anysiy – northern, eastern and southern coasts of Islands Kotelniy and Fadeevsky – Sannikov Straight – eastern coast of Lyakhovskiy Island – Dm. Lapteva Straight. Eastern border: 73° N 180° E – by 180° to Vrangel Island – north-western coast of Vrangel Island – Cape Blossom – Cape Yakan (Fig. 2.6.2).

Taking into account physical-geographical features (bottom relief, ice and hydrologic regime) sea is divided into two regions – western and eastern, with virtual border between them by meridian 160° E (Fig .2.6.2). In accepted borders total sea area is 770000 km^2, western region – 363000 km^2, eastern region - 407000 km^2.

Climate. Peculiarities of the East-Siberian Sea climate are caused by its high latitude location between 69 and 78° N and influence of cool Arctic basin from one side, and large Asian continent – from the other.

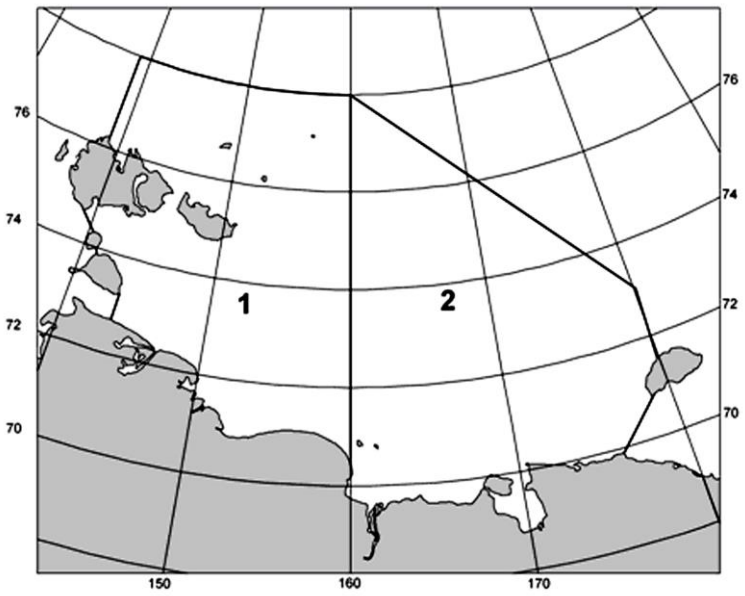

Fig. 2.6.2. Borders and regions of the East-Siberian Sea. 1 – western region, 2 – eastern region;

From November to March, atmosphere circulation over the sea is determined by small gradient field of atmosphere pressure, which is formed between Siberian and Canadian anticyclones and Aleut depression (in the eastern sea). Wind fluxes are less stable at this time. Western fluxes prevail insignificantly in western sea region.

In spring alteration of atmosphere circulation occurs in April-May. Siberian and Canadian anticyclones disappear, Aleut depression becomes weaker. At the same time northwards the Beaufort Sea arctic anticyclone is formed, branch of which defines circulation regime over the sea. Eastern fluxes also prevail over the sea, becoming northern with move off from continent, what is typical for summer period.

Low pressure hollow, connected with Siberian depression and coming along Arctic coast, influences circulation regime over the sea. Atmosphere circulation changes into winter type in September-October. At this time southern fluxes prevail insignificantly in western sea region, in the east – northern.

Most year negative air temperatures are observed over the sea. Average daily temperatures are positive less than 2 months in northern sea region, and 3–3,5 months – in southern. Over the northern sea region stable air temperature about 0°C is observed in July-August, near coast it is 4-5°C, and in gulfs and bays, jutted into continent, temperature reaches 7-8°C. The highest air temperatures in summer months are less than 15°C in northern sea half and reach 25-30°C near coast.

Changes of level and currents in the East-Siberian Sea are caused mostly by hydro meteorological factors (wind, atmosphere pressure, water exchange with Arctic basin and neighbor seas, river flow). Constant current coincides in the northern region with main

Transarctic current and ice drift westwards and north-westwards. Direction of currents is variable west-eastern. Eastern coastal current is observed in eastern sea region, which has a constant pattern till Cape Billings and further through Long Straight. The highest current velocity is observed in straights and in shallow sea regions.

2.6.2. Characteristics of sea ice cover in period of its growth

The East-Siberian Sea is ultimately covered with ice from October to May-June (eight-nine month a year).

Ice formation. Stable ice formation starts among compact ice on the northern sea boundary on 25-30th of August. Ice formation processes propagate southwards during September, and on 5th of October young ice forms in coastal zone. Thus, sea ultimately freezes up during on average 35 days (Fig. 2.6.3).

Ice mostly has local origin in western sea region and in Novosibirsk Straights. Transformation of ice, survived summer melting, into two-year ice is observed in some years. In eastern sea region ice cover consist from new formed ice, multiyear ice, located in central and northern regions, and ice, survived summer melting.

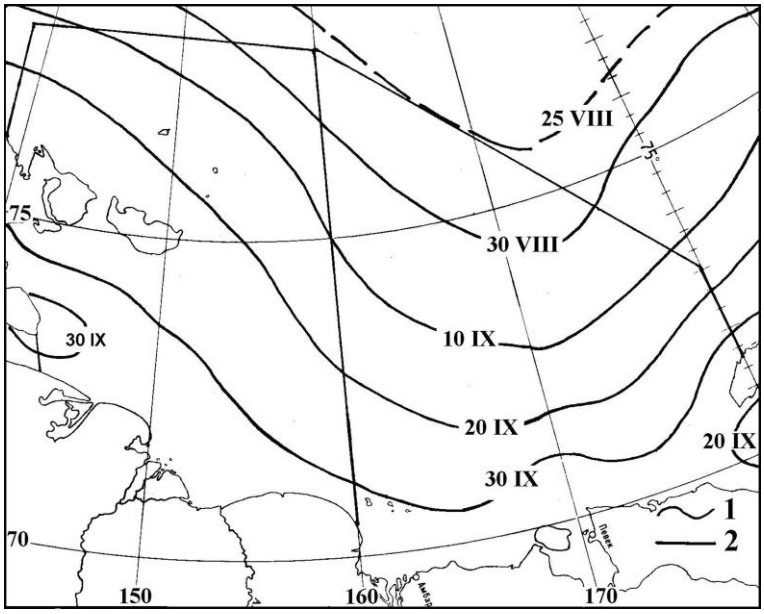

Fig. 2.6.3. Isochrones of average terms of stable ice formation in the East-Siberian Sea. 1 – isochrones, 2 – sea and region boundaries

Ice growth. Ice thickness rather intensive increases in sea. All ice age stages are already presented in October: thick first-year (thickness more than 120 cm); more than half of sea is occupied by young ice (thickness less than 30 cm), thin first-year ice (30-70 cm) and medium first-year ice (70-120 cm) occupies about 6% of area. In the East-Siberian Sea about 24% of ice, survived melting, with inclusion of multiyear ice occurs after summer period in contrary to other Arctic Seas. Most ice (about 30%) is located in the eastern sea region (Table 2.6.1).

Таблица 2.6.1 – Возрастной состав льда в районах Восточно-Сибирского моря в осенне-зимний период, (% от площади районов)

Районы моря	Возраст льда														
	Молодой			Однолетний тонкий			Однолетний средний			Однолетний толстый			2-летний, многолетний		
	М е с я ц ы														
	X	II	V	X	II	V	X	II	V	X	II	V	X	II	V
Запад моря	64	5	4	4	3	2	5	17	2	0	60	80	17	15	12
Восток моря	47	2	2	8	2	1	6	10	2	0	54	65	30	32	30
Все море	55	3	3	6	2	1	6	13	2	0	57	72	24	24	22

Thick first-year ice is formed till February in most water area, and amount of two-year and multiyear ice isn't practically changed (Table 2.6.1, Fig. 2.6.4).

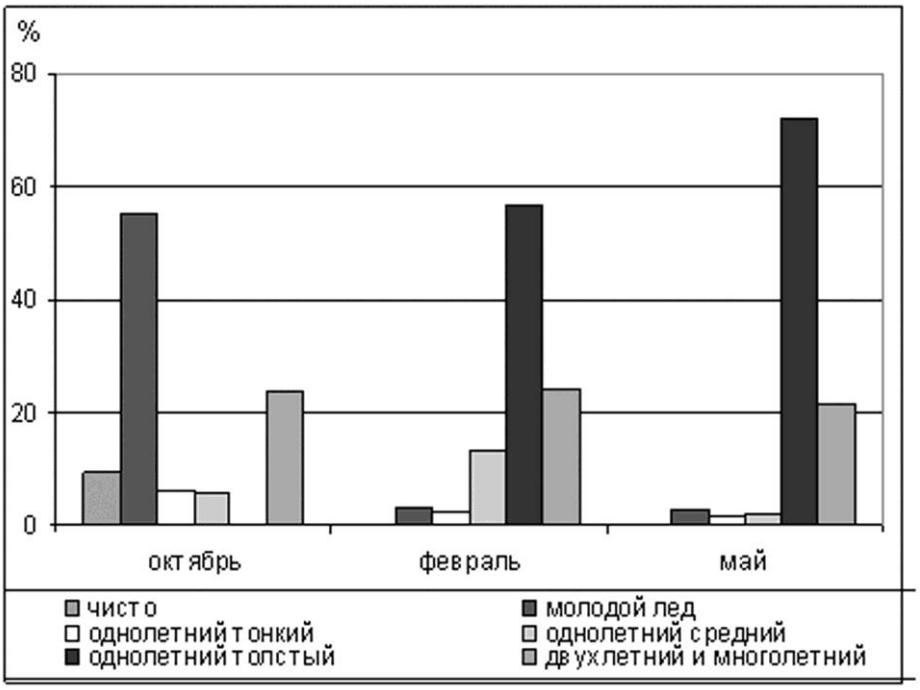

Fig. 2.6.4. Histograms of different ice age propagation in the East-Siberian Sea in ice growth period

In the end of winter ice cover consists from fast ice and drift ice, formed by thick first-year ice, two-year and multiyear ice, located in 30% of eastern sea area (Fig. 2.6.5, Table 2.6.1).

Fast ice. Fast ice in the East-Siberian Sea is the widest and largest among Arctic Seas. The most extensive fast ice forms mainly in the western part, which is relatively shallow (Fig. 2.6.5). As a rule, fast ice in the East Siberian Sea forms in open water. However, in the years when residual ice remains in the sea, fast ice forms with inclusion of this ice.

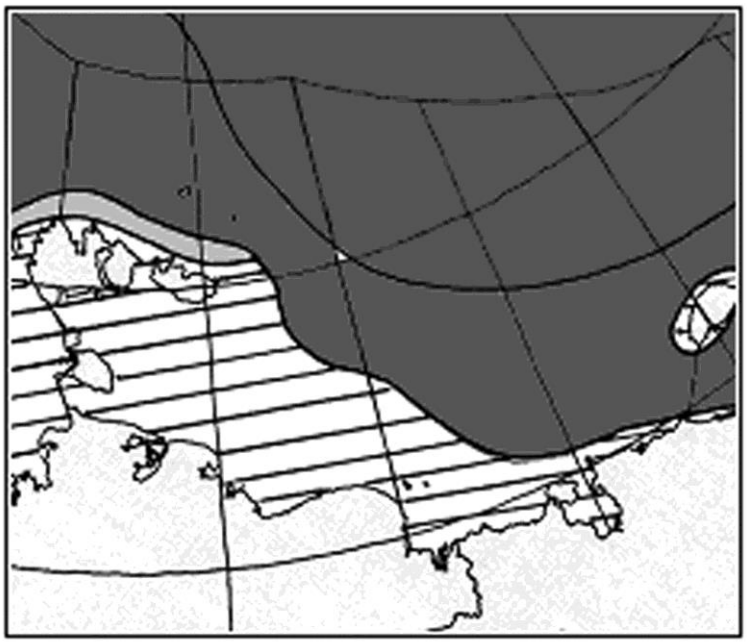

Fig. 2.6.5. Average propagation of different ice age in the East-Siberian Sea in ice growth period

Interannual changes of terms of fast ice formation are 5-6 decades in sea regions. Early terms are in the first decade of October, late ones – in the last decade of November (Table 2.6.2). From 70 to 90% of cases fast ice formation occurs in October. However, frequency of occurrence terms of fast ice formation occurs inside month in different decades in each region (Table 2.6.2).

Таблица 2.6.2 – Вероятность сроков образования устойчивого припая в районах Восточно-Сибирского моря по данным ИСЗ за 1980-2007 гг., %

Районы моря	Октябрь			Ноябрь		
	Декады					
	1	2	3	1	2	3
Новосибирские о-ва, проливы Санникова, Дм. Лаптева	15	19	48	11	5	2
Южный берег западной части моря	41	28	23	6	2	
Колыма – о.Айон	16	34	38	5	7	
Чукотское побережье	21	21	29	19	7	3

In region, including New Siberian Islands and Sannikov and Dm. Laptev Straights, fast ice forms in the third 10-day period of October (about half of all cases). In coastal sea region three zones are separated. Along southern coast of western region (zone from Dm. Laptev Straight to Kolyma mouth) fast ice is mostly formed in the first 10-day period of October. In zone from Kolyma mouth to Ayonsky Island fast ice with equal probability can form in the second and

third 10-day periods. Most unstable terms of fast ice formation are along the Chukchi Sea coast. Here, fast ice with equal probability can form in any 10-day period of October (Table 2.6.2).

Interannual changes of terms of fast ice formation depend on hydro meteorological and ice conditions variability, occurred before stable ice formation in sea, autumn conditions in periods of ice formation and growth, necessary for fast ice formation. Fast ice forms on average in 10-15 days after stable ice formation. On Fig. 2.6.6 comparison between terms of stable ice formation and fast ice formation in Sannikov Straight is shown. As it is seen from Fig. if most probable terms of stable ice formation - in the first 10-day period of October - occur, fast ice forms in two 10-day periods – in the third 10-day period of month.

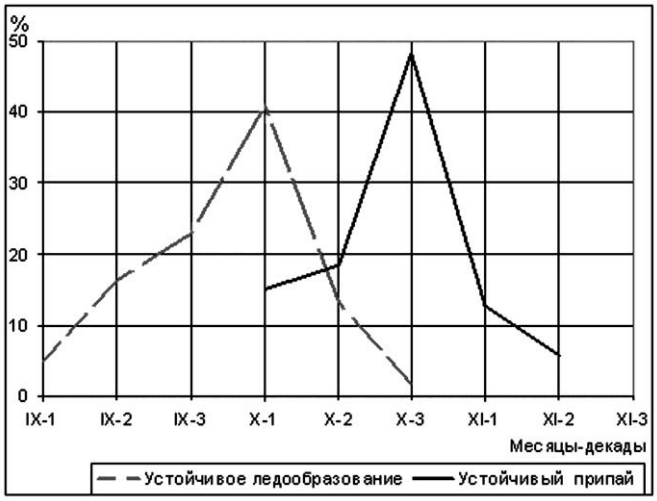

Fig. 2.6.6. Frequency of occurrence of terms of stable ice and fast ice formation in Sannikov Straight zone, %

From the moment of stable fast ice formation, its boundary moves seaward and, depending on winter conditions, reaches its maximum extent from the coast in April (sometimes in May) In some regions its external boundary is retained by stamukhas formed during the periods of strong onshore winds.

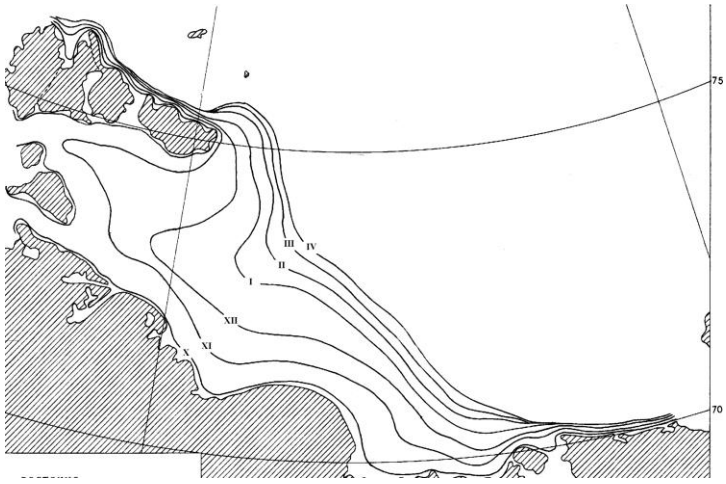

Fig. 2.6.7. Average location of fast ice boundaries in period of its growth in the East-Siberian Sea from satellite data for 1980-2005

After fast ice establishment in Dm. Laptev and Sannikov Straights its boundary moves eastwards. The most intensive fast ice formation in the East-Siberian Sea occur from October to January, at that, the largest growth of fast ice is observed in December-January (Fig. 2.6.7). From November to December on Sannikov Straight latitude boundary on average moves for 300 km. Then fast ice boundary motion decreases and in March its position stabilizes near northern coast of New Siberian Islands and Chukchi coast, and in April – in central sea regions (Fig. 2.6.7).

On average, the distance between the fast ice boundary and the Indigirka mouth in the northeastern direction comprise 285 km. To the north of the New Siberian Islands, the maximum distance of the fast ice boundary from the coast during the period of its greatest development (March–May) comprises 50–80 km. On average it extends not more than 25–30 km from the Chukchi coast.

If fast ice boundaries move seaward, its area changes. In western sea region intensive increasing of fast ice area occurs till January-early February, then it slows down, in eastern sea region fast ice area equally increases during whole growth period (Fig. 2.6.8).

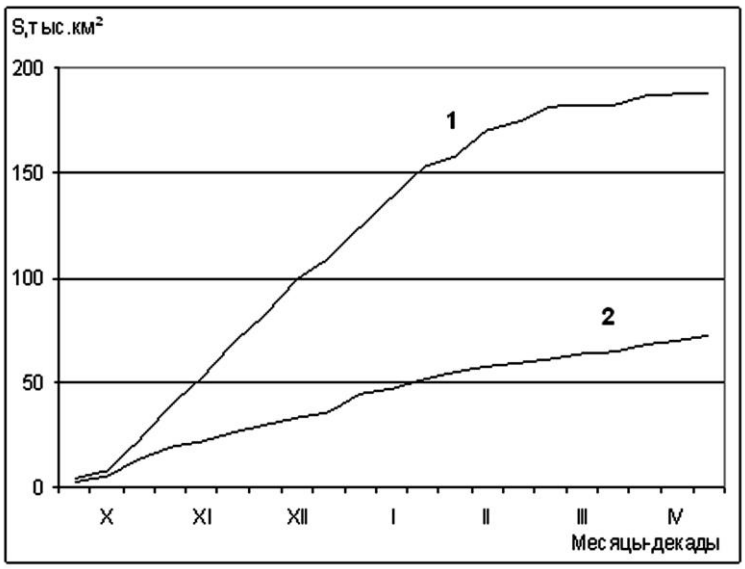

Fig. 2.6.8. Changes of fast ice area in the western (1) and eastern (2) East-Siberian Sea in ice growth period

Average area of fast ice in entire sea is 260 000 km^2. Interannual changes of fast ice area occurs within limits 154-354 000 km^2, i.e. fast ice in the East-Siberian Sea can occupy from 20 to 46% of its water area.

Offshore winds are often observed in winter in the East-Siberian Sea. They facilitate ice exporting from Arctic basin to eastern sea region. However, part of ice, moving along fast ice boundary north-westwards, is transported to Arctic basin, where it is involved in Transarctic drift northwards New Siberian Islands.

In summer frequency of occurrence of transporting winds in the East-Siberian Sea significantly increases, and area of ice, transported from sea is on average 100 000 km^2.

Ice ridging in sea is 2 marks and increases near fast ice boundary up to 3 marks.

Flaw polynyas. The East-Siberian Sea polynyas, formed behind fast ice, are mostly unstable and can be referred to episodic polynyas (frequency of occurrence less than 50%). Exception is Northern Novosibirskaya polynya, formed behind fast ice northwards New Siberian Islands (Table 2.6.9). This polynya is stable, its frequency of occurrence is more than 75%, and under favorable conditions its width can reach tens of kilometers.

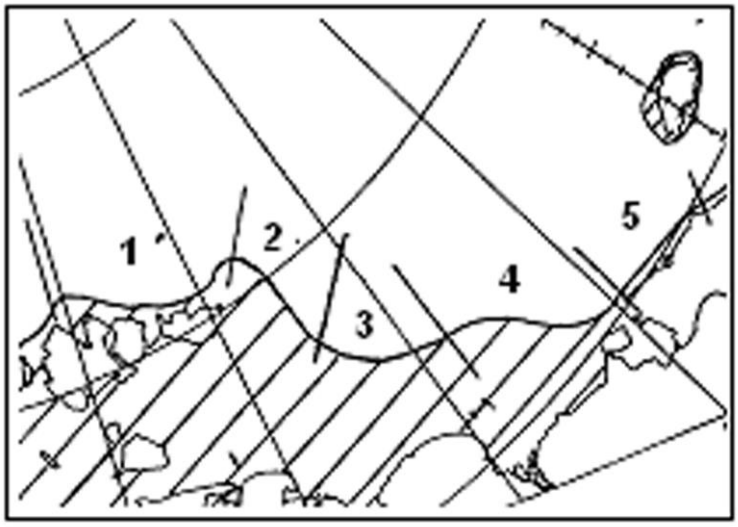

Fig. 2.6.9. Location of flaw polynyas in the East-Siberian Sea 1 - Northern Novosibirskaya; 2- Eastern Novosibirskaya (west); 3 - Eastern Novosibirskaya (east); 4 - Ayonsky; 5 - Western Chukchi

The Northern Novosibirskaya polynya was first detected at the beginning of the 19th century by the Russian Hydrographic Expedition. The expedition participants were thunderstruck when they saw open water during winter at such high latitudes. Their observations resulted in the idea of the open Northern Ocean to the north of the New Siberian Islands – an idea that was refuted only in the early 1880s by the participants who stayed alive during the *Zhannetta* drift under the command of De Long. It became obvious that the open water space over fast ice is formed under the offshore wind influence and presents a “Siberian polynya”.

The flaw polynyas of the East Siberian Sea to the north of the New Siberian Islands are formed episodically. Their average frequency of occurrence decreases from 44% to 25% with advance to the Chukchi coast. However, in some months, the polynyas exist stably and their frequency of occurrence is slightly more than 50% Thus, Eastern Novosibirskaya (west) polynya can be referred to stable polynyas in December and June, Western Chukchi – in June (Table 2.6.4).

Таблица 2.6.3 – Характеристика заприпайных полыней Восточно-Сибирского моря

Название полыней	Характеристика						
	P,%	Длина, км		Ширина, км		Площадь, тыс. км^2	
		средняя	диапазон	средняя	диапазон	средняя	диапазон
Северная Новосибирская	80	321	50-480	32	5-125	10,6	0,4-44,4
Восточная Новосибирская (запад)	44	244	30-650	25	5-187	6,7	0,5-69,2
Восточная Новосибирская (восток)	37	297	80-530	24	5-163	7,7	0,5-58,8
Айонская	38	225	50-440	24	5-108	5,4	0,4-26,9
Западная Чукотская	25	182	40-440	21	5-73	4,1	0,3-16,6

Таблица 2.6.4 – Средняя месячная повторяемость заприпайных полыней Восточно-Сибирского моря по данным ИСЗ за период 1979-2005 гг., %

Название полыней	М е с я ц ы							
	XI	XII	I	II	III	IV	V	VI
Северная Новосибирская	67	87	67	64	77	76	90	91
Восточная Новосибирская (запад)	32	57	44	43	49	46	29	50
Восточная Новосибирская (восток)	28	42	32	42	46	44	34	38
Айонская	22	41	42	38	45	39	29	44
Западная Чукотская	18	10	20	20	19	28	30	51

Total area of polynyas is about 5% of sea area. Total area of polynyas changes within 3 to 8%. Minimum values occur in late January-early March (Fig. 2.6.10).

2.6.3. Characteristics of sea ice cover in period of melting

Melting and sea clearing from ice. Beginning from July and till late September ice cover melts and sea clears from ice under thermal and dynamic processes. Clearing occurs in near-mouth areas of rivers Indigirka and Kolyma, which significantly influence ice regime of shallow western sea region. Sea clearing occurs slower, than in other Arctic Seas. Clearing velocity increases in August after ultimate fast ice break up.

Fast ice starts melting in the edge zone on average in late May-early June. Its break up occurs during two months, and fast ice ultimately disappears in late July, rarely in early August. On Fig. 2.6.11 location of average fast ice boundaries (isochrones) in melting period is shown.

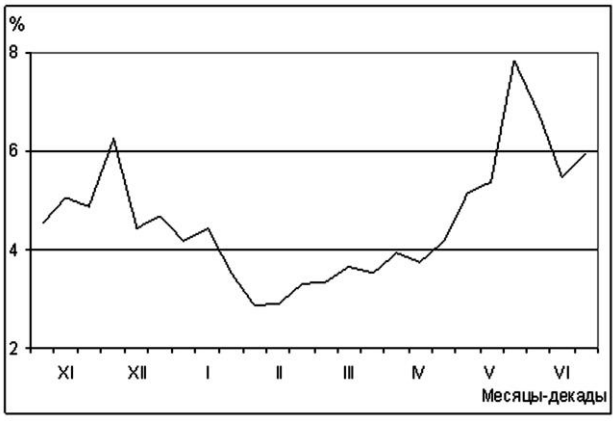

Fig. 2.6.10. Seasonal changes of total flaw polynyas area in the East-Siberian Sea

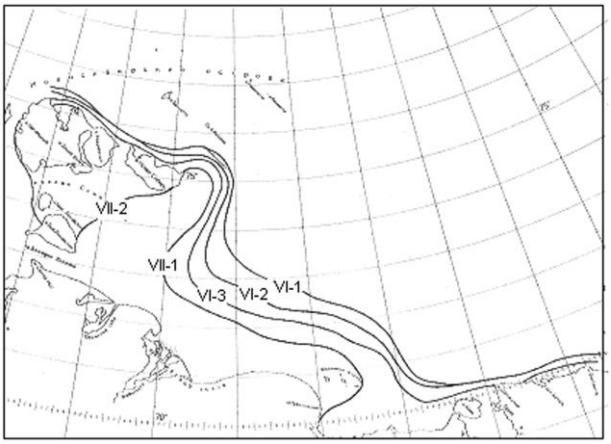

Fig. 2.6.11. Location of fast ice boundaries in the East-Siberian Sea in period of its melting (probability 50%)

Fast ice boundary slowly moves off during June. Its most part melts and becomes drift ice during July (Fig. 2.6.11, 2.6.12).

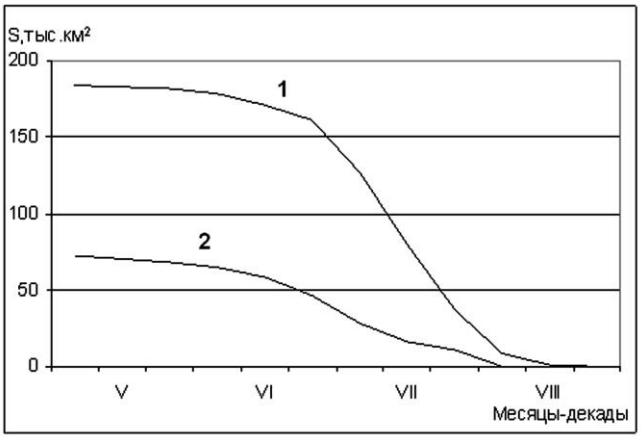

Fig. 2.6.12. Changes of fast ice area in the western (1) and eastern (2) East-Siberian Sea in melting period

Ultimate fast ice melting (fast ice breaks drift floes) depends on stage of its development in autumn-winter period. As it is seen from Fig. 2.6.13, ultimate fast ice melting in the western sea region, when its area is maximum, occurs in the second 10-day period of August, and when fast ice area is minimum - in early July. When fast ice size is close to average (50% probability), it ultimately disappears in late June.

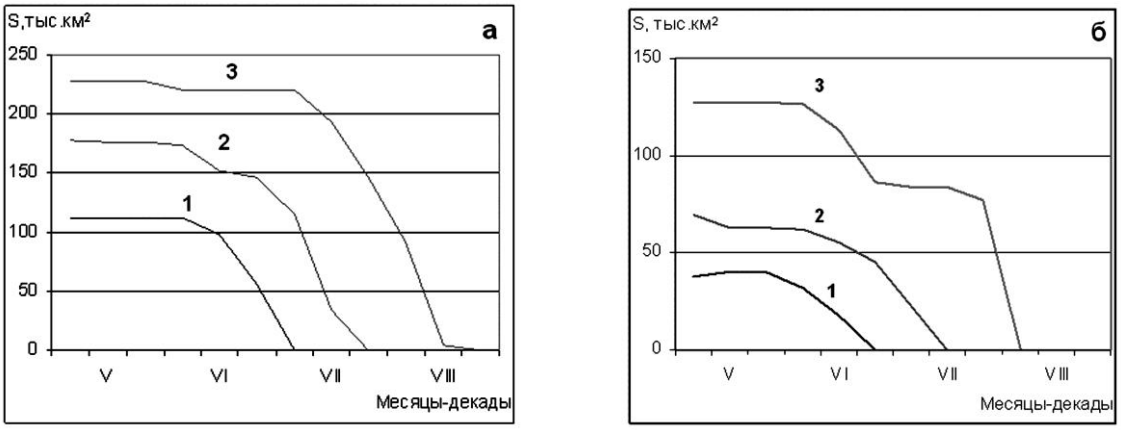

Fig. 2.6.13. Changes of fast ice area in the western (a) and eastern (б) East-Siberian Sea in melting period with different development stage: 1-minimum, 2-average, 3-maximum

Interannual changes of terms of ultimate fast ice melting are about one month in the East-Siberian Sea regions. In Table 2.6.5 characteristics of fast ice break up terms are shown in the most important for navigation regions: in approaches to Sannikov sand Dm. Laptev Straights and to Kolyma river shoal.

Таблица 2.6.5 – Характеристика сроков взлома припая в районах Восточно-Сибирского моря за период 1980-2007 гг.

Район	Сроки взлома			Размах колебаний, сутки
	средние	поздние	ранние	
Подходы к проливу Санникова	22 VII	3 VIII	6 VII	28
Пролив Санникова	22 VII	9 VIII	7 VII	33
Подходы к проливу Дм.Лаптева	19 VII	31 VII	3 VII	28
Участок бар реки Колымы – о.Айон	9 VII	27 VII	21 VI	36

According to general regularity of fast ice melting (Fig. 2.6.10) the earliest break up occurs in zone of Kolyma river shoal – Ayonsky Island, it occurs on average two weeks earlier than in zone of straights. The earliest terms of fast ice break up occur in the beginning of third 10-day period of June, and in zone of straights – in the first 10-day period of July (Table 2.6.5).

Drift ice of different concentration is observed in sea after fast ice break up. In late July only 10% of water basin is free from ice (Table 2.6.6), and ice edge locates close to continent coast and islands (Fig. 2.6.14). During entire melting period eastern sea region gets ice-free two times slower, than western. Before ice formation in September, more than sea half is free from ice, and eastern part – less than a third (Table 2.6.6).

Таблица 2.6.6 – Площади акваторий в районах Восточно-Сибирского моря, освобождающиеся ото льда в период таяния ледяного покрова, %

Район моря	Июнь			Июль			Август			Сентябрь		
	Декады											
	1	2	3	1	2	3	1	2	3	1	2	3
Запад моря	4	4	6	8	10	14	24	34	44	51	54	56
Восток моря	1	1	2	3	4	7	10	14	20	26	30	31

The most intensive ice melting and sea clearing occur in August. 40% of western sea part and 20% of eastern part are ice free in the end of month. Sannikov Straight is free from ice in August.

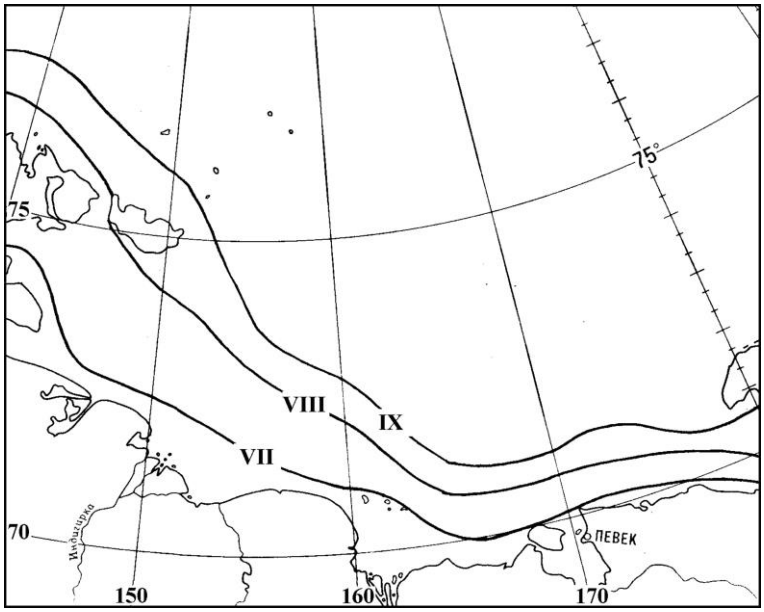

Fig. 2.6.14. Ice edge location in the East-Siberian Sea in late June-September

In September sea clearing finishes. Ice edge in western sea region locates 60-90 miles northwards New Siberian Islands. In the east – comes through Long Straight under southern coast of Vrangel Island (Fig. 2.6.13). Only 30% of eastern sea region and only about 50% – of western are ice-free before new freeze-up.

During processes of melting and ice cover decay amount of compact (7-10-th) ice decreases and amount of open and very open (1-6-th) ice increases (Fig. 2.6.15). Open and very open ice is

formed both as a result of melting and compact ice decay, and dynamic influence, resulting in partly ice transporting of sea limits (Table 2.6.7).

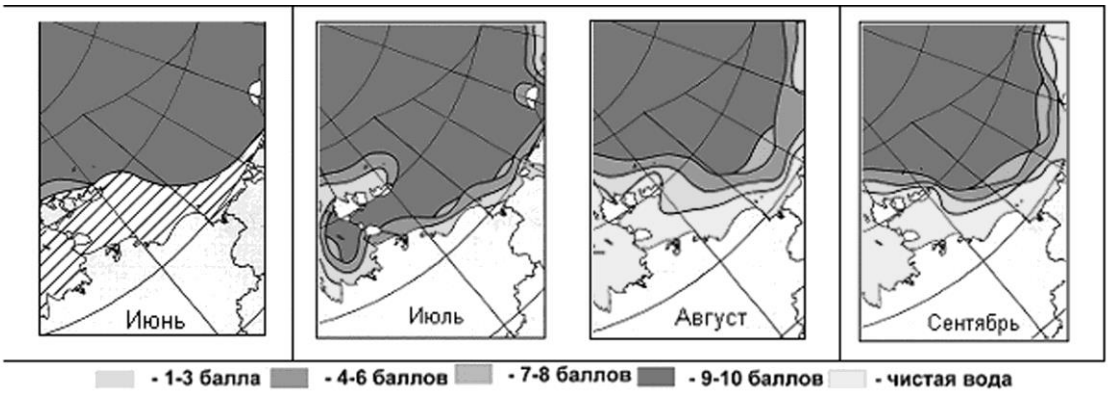

Fig. 2.6.15. Ice propagation of different concentration in June-September (probability 50%)

In late September about 40% of sea area is absolutely free from ice. Compact ice stays on more than a third of water basin, mainly due to of eastern sea region (Table 2.6.7).

Таблица 2.6.7– Количество сплоченных (7-10 баллов), редких и разреженных льдов (1-6 баллов) и чистой воды в Восточно-Сибирском море в период таяния

Сплоченность льда, баллы	Июнь			Июль			Август			Сентябрь		
	1	2	3	1	2	3	1	2	3	1	2	3
7-10	98	98	97	91	84	76	66	56	45	41	38	36
1-6	2	2	3	9	16	13	17	20	23	21	21	21
чисто	0	0	0	0	0	10	17	23	32	38	42	43

Ice massifs. Quasistationary accumulations of compact ice in the East-Siberian Sea form two ice massifs: Novosibirsky, occupying southern part of western sea region, and Ayonsky (Fig. 2.6.16).

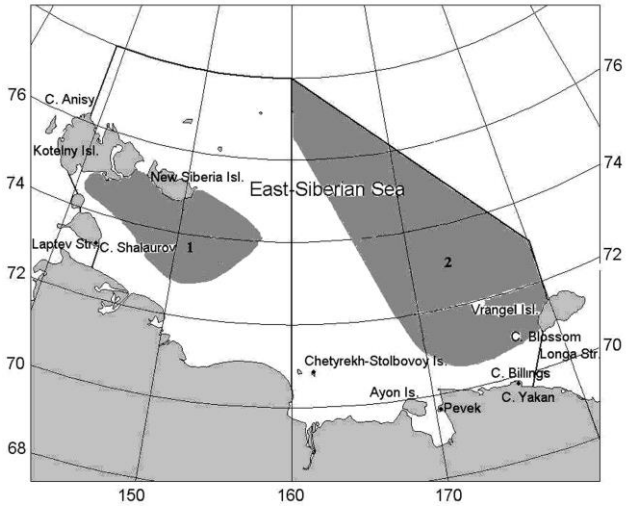

Fig. 2.6.16. Scheme of ice massifs location in the East-Siberian Sea. 1 – Novosibirsky and 2 – Ayonsky massifs

Novosibirsky ice massif is comprised from broken fast ice first-year floes of local formation. In some years inclusions of multiyear ice are observed in ice massif. In June-August ice massifs block eastern approaches to Sannikov and Dm. Laptev Straights. In most cases ice massif ultimately melts away during September (Fig. 2.6.17, Table 2.6.8). In separate years Novosibirsky ice massif can join with Ayonsky and stay till the end of melting period.

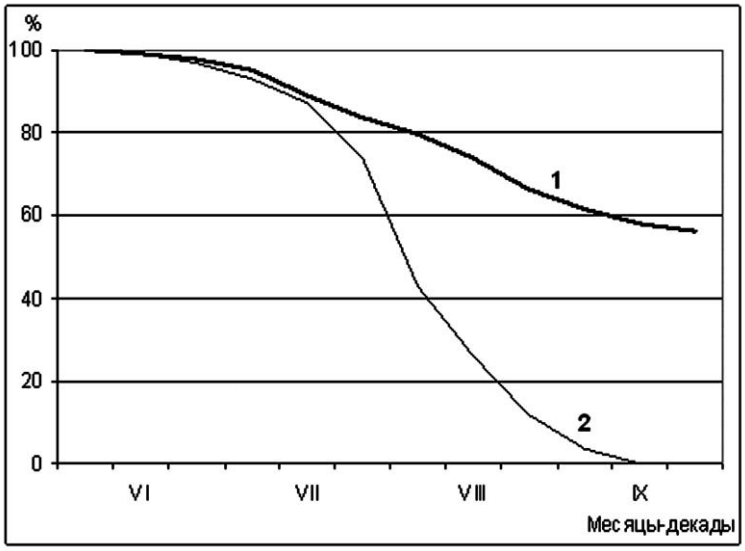

Fig. 2.6.17. Area changes of Ayonsky (1) and Novosibirsky (2) ice massifs (probability 50%) in June-September, %

The Ayonsky ice massif is the largest spur massif in the Arctic Seas. It is located in the eastern East Siberian Sea. Depending on its location (western, central or eastern), the massif blocks the central sea areas or Long Strait from the west. It is comprised due to local first-year ice of different age and multiyear ice, transporting from Arctic basin. Massif is characterized by high ice capacity and low decay in summer. Normally about 50% of ice massif doesn't melt till the end of ice formation start (Fig. 2.6.17).

Ayonsky ice massif almost never disappears, but Novosibirsky ice massif is less stable and can disappear in any of 10-day periods, beginning from third 10-day period of July (Table 2.6.8).

Таблица 2.6.8 – Число случаев полного исчезновения ледяных массивов Восточно-Сибирского моря за период 1973-2007 гг., %

Массивы	Июль			Август			Сентябрь		
	Декады								
	1	2	3	1	2	3	1	2	3
Новосибирский	-	-	3	3	13	29	39	52	52
Айонский	-	-	-	-	3	3	3	-	-

Grounded hummocks. Grounded hummocks are formed in fast ice zone, and sometimes out of its limits (Fig. 2.6.18). Rather often grounded hummocks reach giant sizes and are seen in entire fast ice sea zone on depth up to 20 m (sometimes up to 30 m).

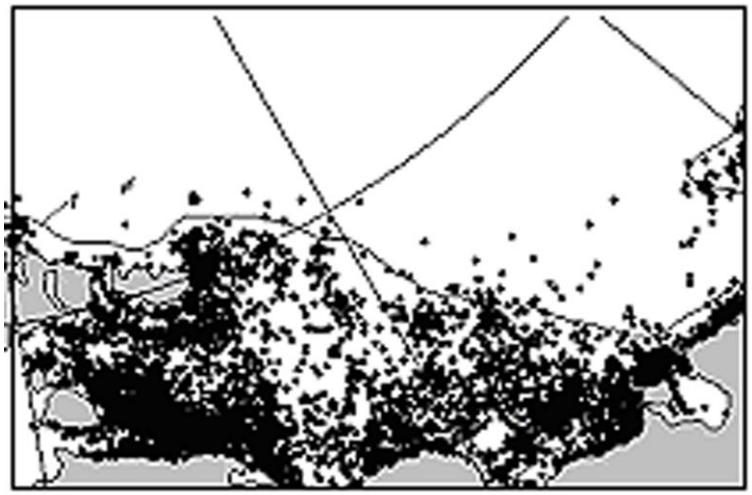

Fig. 2.6.18. Location of grounded hummocks in late winter from data for 1962-1995

Icebergs. Small icebergs and ice islands are sometimes observed in sea. Insignificant quantity of small icebergs comes down in sea from Genrietta and Benetta Islands, and also can be transported from other regions.