2.7. Characteristic of the Chukchi Sea ice conditions

2.7.1. Physical-geographical sea characteristic

Depth, borders. The Chukchi Sea is located between the two continents: Asia and America. It has a northern boundary with the East-Siberian Sea, in the most extreme north-east – with the Beaufort Sea, in south through Bering Straight it is connected with the Bering Sea. In the north, the sea has an open boundary with Arctic Basin. It conventionally comes along the edge of continental shelf between meridian 180° in the west and Cape Barrow meridian in the east (Fig. 2.7.1).

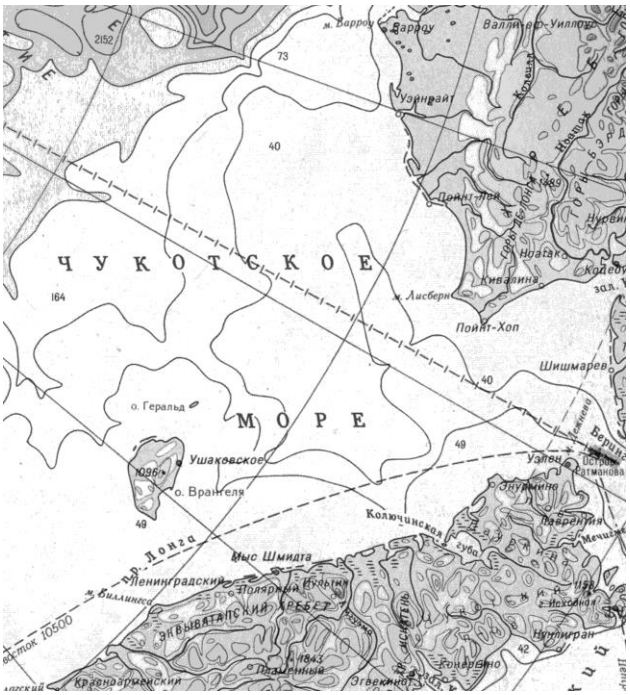

Fig. 2.7.1. Geographical location of the Chukchi Sea

Western sea border comes from crossing point of meridian 180° with northern coast of Wrangel Island, along its northern, eastern and southern coasts to Cape Blossom, then it comes along conventional line to Cape Yakan, further - along Chukchi Peninsula coast to Bering Straight. Eastern border comes along meridian of Cape Barrow, further - along Alaska coast to Bering Straight. The Sea border in Bering Straight comes between Capes Dezhnev and Prince of Wales.

Dominant depth in the Chukchi Sea reaches 50 m. Shoal Gerald with depth of 20-30 m is located in the northern sea region (on latitude of Wrangel Island). Between shoal and Gerald Island shelf is crossed by Gerald trough (depth up to 90 m). In the north-eastern Chukchi Sea Barrow trough is located on a depth of more than 50 m, approaching to Cape Franklin.

During all observational history AARI provided ice-hydrologic observations not in entire water basin, but within sea borders, limited from the north by 73° N and from the east by meridian of Cape Lisbern. These boundaries are located along the line 73° N 180° – 73° N 166°

W in the north, then southwards to Cape Lisbern – along coast to Cape Hop – then to Cape Espenberg, and further to Bering Straight (Fig. 2.7.2).

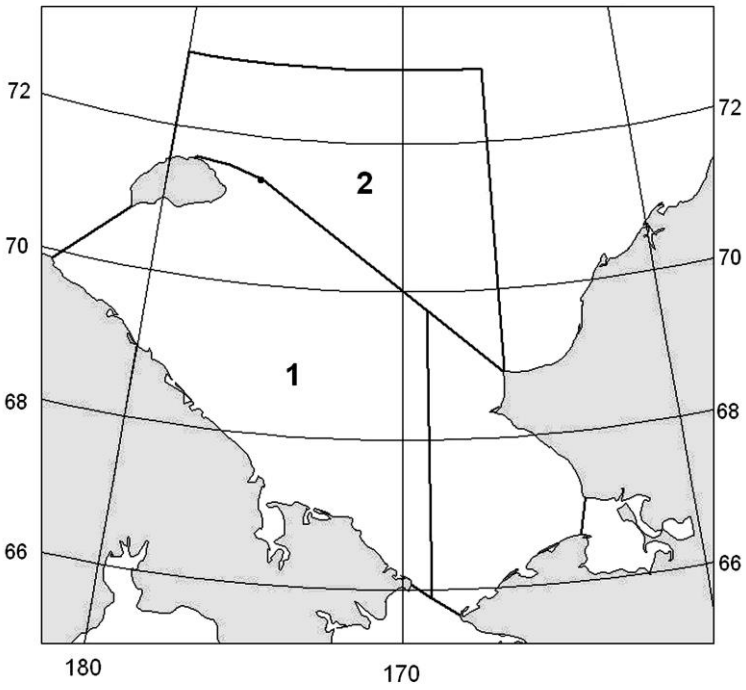

Fig. 2.7.2. Borders and regions of the Chukchi Sea. 1 – south-western region, 2 – northern region;

Northwards from Wrangel Island border with the East-Siberian Sea comes along the line 73° N – by 180° meridian to island coast. Two sea regions are separated in borders, accepted by AARI: south-western and northern. Area of south-western sea region is 176000 km^2, northern sea region – 132000 km^2 (Fig. 2.7.2). Routes of the eastern Northern Sea Route come through south-western sea regions.

Climate. The Chukchi Sea climate is caused both by its high latitude location and influence of two oceans – Arctic and Pacific, and two continents – Asia and America. Solar radiation is essential for the Chukchi Sea climate, but baric-circulation regime plays the most significant role. It is determined by interaction of three atmosphere centers: Arctic anticyclone (which is replaced by depression in summer) and Aleut depression.

Dominance of air fluxes of eastern direction over the Chukchi Sea is determined by seasonal changes of atmosphere circulation over the Pacific sector of the Arctic. In autumn and winter eastern fluxes have northern component. In June-July south-western fluxes are observed over the sea, and in the area of Bering Straight – southern.

Negative air temperatures are observed over the Chukchi Sea during most of the year. Period with positive temperatures lasts from 4 months in the area of Bering Straight to 1 month in the northern sea region. In winter average monthly air temperature changes from –18÷–22 °C in the Bering Straight area and to –26÷–28°C in its northern region.

In spring (April-May) air temperature rapidly increases from –8÷–18°C in April to –2÷–8°C in May.

Average air temperature in July-August changes from 3-4 °C in the southern sea region to 0÷–1 °C in the northern sea periphery. In October sea is rapidly cooling, and in its northern region average temperature reaches –10÷–12°C.

The lowest temperatures, ever observed in winter, are equal to –40÷–45°C. The highest air temperatures in coastal zone and in Bering Straight reach 28–30°C, in open sea they are less than 15–20°C.

Pacific waters are transported by the Bering current through Bering Straight to the Chukchi Sea. Further they propagate by three branches: Alaska, Gerald and Long. Role of these waters is significant in hydrologic and ice regimes. Heat content of the warm Pacific waters is enough for complete ice melting in approximately half of the sea area. Coastal Chukchi current is located near Asian coast zone, coming through Long Straight from the East-Siberian Sea south-eastwards. Sea ice is transported by this current from the Chukchi Sea to the Bering Sea through western part of Bering Straight (Fig.2.7.3).

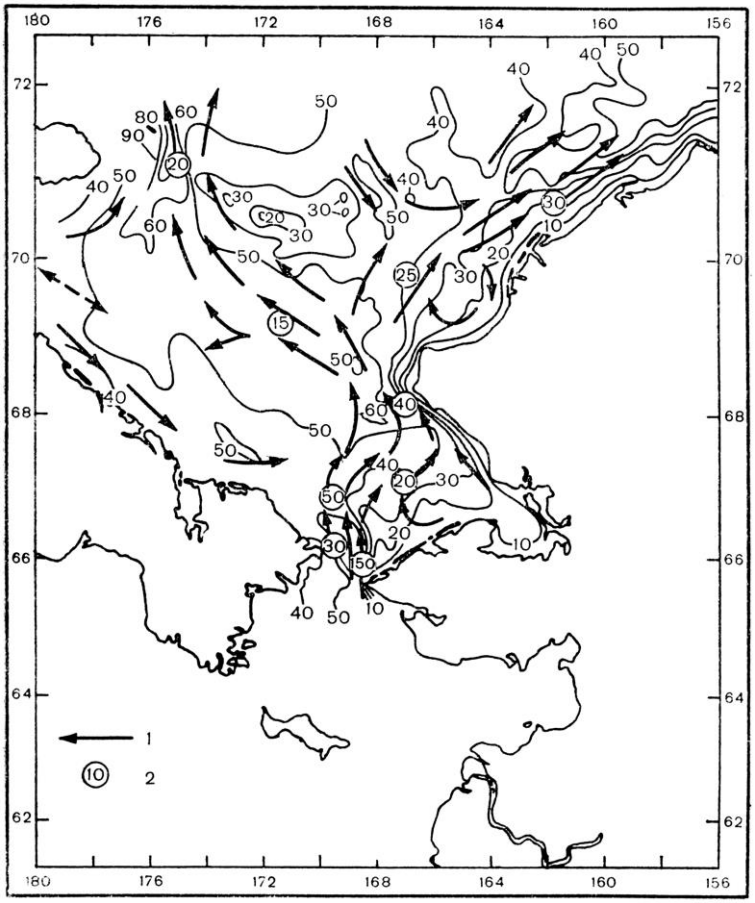

Fig. 2.7.3. Scheme of surface currents in the Chukchi Sea. 1 – currents, 2 – velocity in cm/s. Depth in m.

2.7.2. Sea ice characteristic in period of its growth

The Chukchi Sea has the most southern location among the Arctic Seas, nevertheless, from November to May it is completely covered with ice. Ice regime of the Chukchi Sea is formed, from one hand, under influence of the Arctic Basin due to open border, and from the other hand, under influence of advection of rather warm Bering Sea water, coming through Bering Straight.

South-western region of the Chukchi Sea is separated by ice conditions peculiarities (Fig. 2.7.2). In this region melting starts earlier than in other Siberian Arctic shelf seas under influence of Gerald and Long branches of Bering current.

Ice formation. Stable ice formation starts in the mid-September on its northern and north-western boundaries among compact (9-10/10-th) ice. Then it propagates southwards to zone of open and very open ice (4-6/10-th and 1-3/10-th), and then ice formation continues in open water. In coastal sea parts and in Long Straight ice formation on average starts on 5-10th of October. Large heat content of the sea, formed during summer and supplied by inflow of the Bering Sea waters, restrain cooling processes in the central and southern sea regions, and on average, the sea freezes completely only in mid-November. Direction of the Bering Sea current meanders form typical for this sea bend of isochrones of stable freeze-up terms (Fig. 2.7.4).

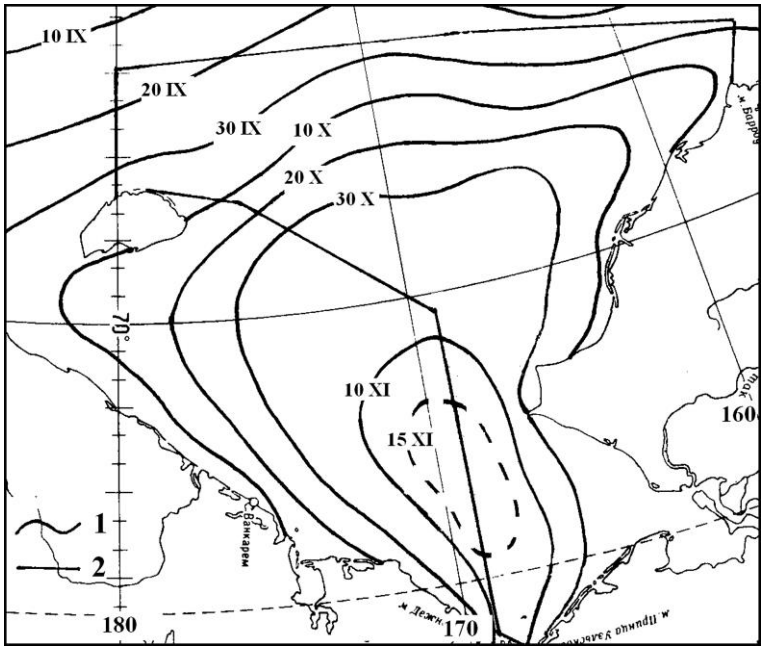

Fig. 2.7.4. Isochrones of average terms of stable ice formation in the Chukchi Sea.

Ice growth. In the Chukchi Sea ice forms slower than in other Arctic Seas as a result of later freeze up. In February, when in other seas thick first-year ice prevails (more than 120 cm), less than a half of south-western sea region is occupied by medium first-year ice (70-120 cm) (Table 2.7.1).

Table 2.7.1 – Composition of ice age in the Chukchi Sea regions in autumn-winter period, (% from region area)

No ice			Ice age															
			Young			Thin first-year			Medium first-year			Thick first-year			Second-year, multiyear		
			Months															
X	II	V	X	II	V	X	II	V	X	II	V	X	II	V	X	II	V
63	0	0	24	3	2	5	5	1	0	45	8	0	35	73	8	12	16

Second-year and multiyear ice is transported to northern sea region from the Arctic Basin. This ice occupies on average 20% of sea in the end of ice growth period, the same area is occupied by thin first-year and medium ice, located mostly behind fast ice along Alaska coast. About 60% of sea basin is normally occupied by thick first-year ice (Fig. 2.7.5).

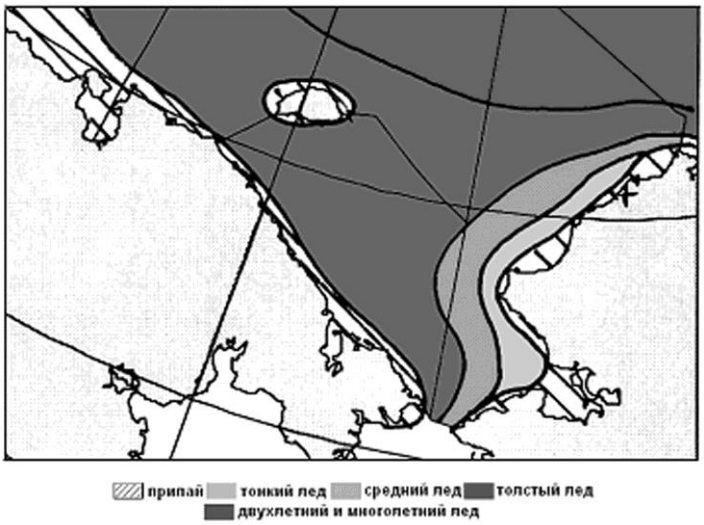

Fig. 2.7.5. Average propagation of different ice age in the Chukchi Sea in ice growth period

Fast ice. Interannual changes of terms of stable fast ice formation in coastal zones of the southwestern Chukchi Sea are 7-10 weeks (Table 2.7.2). At that, the biggest probability of fast ice formation on largest part of coast from Cape Yakan to Cape Heart Stone is less than 20-30% (as a rule in the first 10-day period of November). In most extreme eastern coast fast ice formation starts two 10-day periods later, and most often fast ice is formed in third 10-day period of November with probability 56% (Table 2.7.2).

Such variability of terms is caused by interannual changes of terms of stable ice formation in the Chukchi Sea. As it is shown on Fig. 2.7.6, multiyear range of terms of stable ice formation along coast in south-western sea region is more than two months.

Table 2.7.2 – Probability of stable fast ice formation terms in coastal regions of the south-western Chukchi Sea from the satellite data for 10-day periods 1980-2007, %

Coast regions	October			November			December			January
	10-day periods									
	1	2	3	1	2	3	1	2	3	1
C. Yakan – C. Vankarem	11	15	11	31	14	9	10	0	0	0
C. Vankarem – C. Heart Stone	9	9	9	20	13	6	20	5	5	3
C. Heart Stone - C. Dezhnev	0	0	6	7	15	56	7	3	3	3

They mostly occur in the first 10-day period of October, and the largest frequency of occurrence of terms of fast ice establishment is observed in a month (Fig. 2.7.6).

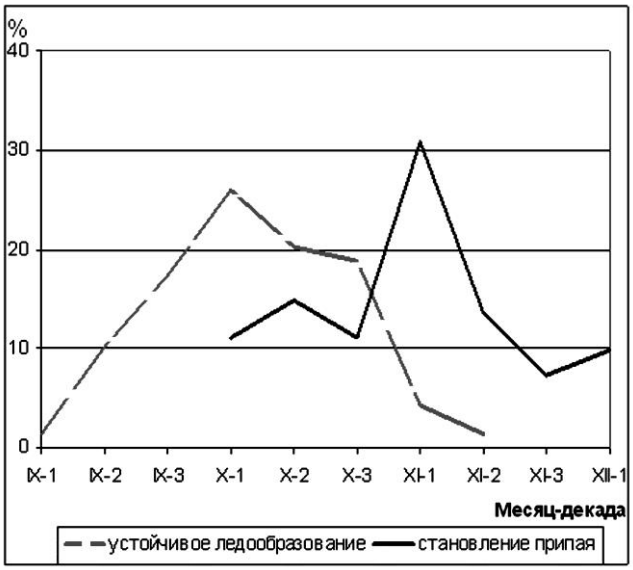

Fig. 2.7.6. Frequency of occurrence of terms of stable ice and fast ice formation in zone Cape Yakan - Cape Vancarem, %

From Table 2.7.2 it is known, that fast ice establishes along Chukchi coast in November more often, than in other autumn-winter months (Table 2.7.3).

Table 2.7.3 – Probability of stable fast ice formation terms in coastal regions of the south-western Chukchi Sea from the satellite data in autumn-winter months for 1980-2007, %

Coast regions	Months			
	X	XI	XII	I
C. Yakan – C. Vankarem	37	53	10	0
C. Vankarem – C. Heart Stone	28	39	30	3
C. Heart Stone - C. Dezhnev	6	78	13	3

Fast ice is less developed in the Chukchi Sea because of deep water coastal zone (Fig. 2.7.7). Maximum fast ice development is observed in March-April. Its width along south-western sea coast changes within 10-30 km. Long-term range of fast ice width changes within 5-70 km.

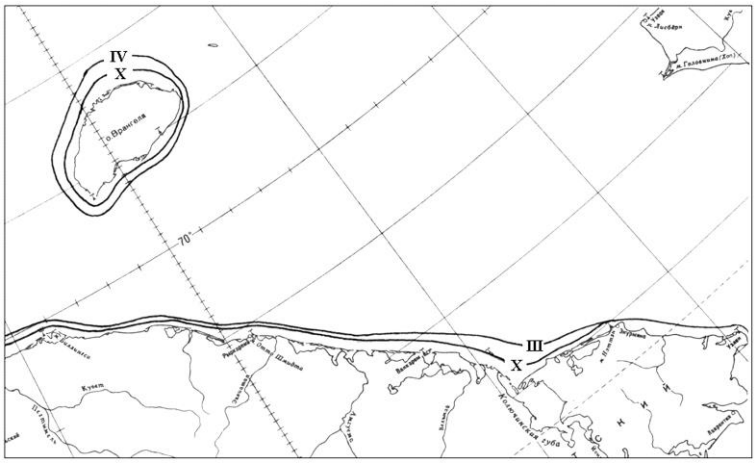

Fig. 2.7.7. Average location of fast ice boundaries in period of its growth in the Chukchi Sea

The fast ice area near the Chukchi coast after achieving about 7 thousand km^2 in early November slowly increases to about 11 thousand km^2 in March, preserving this size until the beginning of melting. In the years favorable for the fast ice development, its area is more than twice greater than the average value (Table 2.7.4).

Table 2.7.4 – Average and maximum areas of fast ice in period of its growth in the south-western Chukchi Sea in the middle of month from satellite data for 1980-2007, km^2

Area	Months							
	X	XI	XII	I	II	III	IV	V
Average	5,7	7,3	7,6	9,8	10,6	10,9	10,9	10,9
Maximum	8,8	14,3	15,5	17,2	18,7	23,4	23,4	23,4
Minimum	2,3	2,5	2	4,7	5,1	5,1	5,1	5,1

The average area of the Chukchi fast ice at the end of its development comprises 6% of the southwestern sea area. It can occupy 13% and only 3% of the sea area in the years of its maximum and minimum development, respectively.

Fast ice around Wrangel Island is more developed compared to that along the Chukchi coast. Its maximum development is achieved in the second 10-day period of April. Its average width comprises 23 km near the northwest coast (changing within 10–110 km), 33 km – near the northern coast (20–55 km) and 13 km – along the southern coast of the island (7–22 km).

Mean multiyear area of fast ice around Wrangel Island during the maximum development is equal to 9.0 thousand km^2, which comprises 5% of the area of the southwestern Chukchi Sea and can achieve 14% in extreme years.

Near the Alaskan coast, between the Cape Hope and Cape Barrow, the fast ice formation begins in the middle of October, on average. In the third 10-day period of October, it spreads to the regions adjoining Kotsebu Bay and Bering Strait. By the time of its maximum development, the fast ice width along the section from Bering Strait to Cape Lisbern can comprise 5 to 65 km, and farther northward to Cape Barrow – 10–40 km.

Flaw polynyas. Eastern Chukchotskaya polynya is episodically formed behind fast ice along the Chukchi Sea coast (with frequency of occurrence less than 50%). This mostly narrow and long polynya is also called the Chukchi flaw lead. Lead rapidly closes, when western winds become northern. Its average frequency of occurrence is less than 30% (Table 2.7.5). The lead is the most stable in the second half of June. Its frequency of occurrence in June reaches 60% (Table 2.7.6). In the years of active shipping along the NSR, the flaw lead was used for early routing of the ship convoys to Pevek and Kolyma.

Table 2.7.5 – Average frequency of occurrence (P, %) and characteristic of the Chukchi Sea flaw polynyas from satellite data for the period 1980-2005.

Polynya name	P, %	Characteristic					
		Length, km		Width, km		Area, km^2	
		average	range	average	range	average	range
Eastern Chukchi (flaw polynya)	29	350	9-780	22	1-126	9,3	0,4-98,3
Chukchi lead	76	485	50-1040	24	4-52	13,9	1,0-45,6

In the eastern Chukchi Sea near the Alaskan coast, a stationary polynya is formed that was called the Chukchi lead (frequency of occurrence more than 75%). The stability of this polynya slightly decreases in January (to 50%), when the frequency of occurrence of the easterly winds decreases. In April–May, its frequency of occurrence is greater than 80% (Table 2.7.6), and it often serves as an initial ice-clearance source in the Chukchi Sea.

Table 2.7.6 – Average frequency of occurrence of the Chukchi Sea flaw polynyas from satellite data for the period 1979-2005, %

Polynya name	Months							
	XI	XII	I	II	III	IV	V	VI
Eastern Chukchi (flaw polynya)	24	23	19	28	26	18	38	61
Chukchi lead	-	76	50	79	72	86	85	-

In winter south-western and south-eastern ice drifts prevail in the Chukchi Sea, when large ice floes (length up to 5000-10000 m) are transported from the Arctic Basin to northern sea regions. In south-western sea region ice floes with length 3000-5000 m and their pieces are sometimes observed.

The most ridged ice is observed in south-western sea region in winter period, its ridging is 3 marks. In coastal zone near Chukchi coast ridging can exceed 5 marks.

Grounded hummocks. Underwater parts of the largest hummocks and ridges reach sea bottom and become stamukhas, which are mainly distributed in the fast ice of the southwestern part of the sea (Fig. 2.7.8).

Fig. 2.7.8. Location of grounded hummocks in the south-western Chukchi Sea in the end of winter from data for 1962-1995

2.7.3. Sea ice characteristic in period of its melting

Melting and sea clearing from ice. Sea clearing from ice starts from regions, adjoining to Bering Straight. Warm current from the Bering Sea facilitate this process, and about 10% of ice in south-western sea region disappears to late May. Alaska polynya is a place of active sea clearing (Chukchi lead). Its area significantly increases under influence of eastern and south-western winds (Fig. 2.7.9, 2.7.10).

Fast ice breaks up in the eastern part of Chukchi Sea coast in May in some years, but from data of polar station Uelen it is known, that fast ice breaks up here more often in third 10-day period of June (Fig. 2.7.9). “Break up wave” sequentially propagates to western coast. Fast ice breaks up most often in first and second 10-day periods of June, but process of ultimate fast ice break up can be delayed till early August (Fig. 2.7.9).

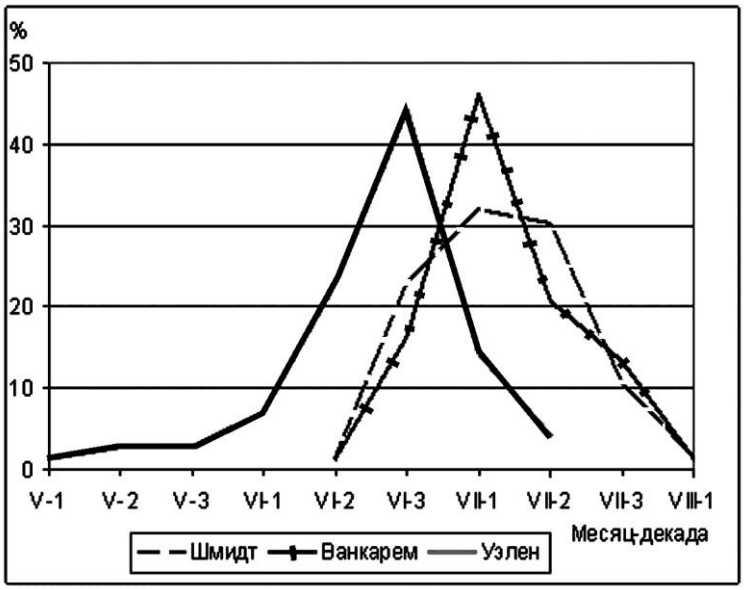

Fig. 2.7.9. Frequency of occurrence of terms of fast ice break up in zones of polar stations in the Chukchi Sea coast

According to polar stations data, fast ice ultimately breaks up in central and western parts of Chukchi Sea coast in July in 81% and 73% of cases, respectively. Near eastern coast in 74% of cases fast ice melts in June (Table 2.7.7).

Table 2.7.7 – Average terms of frequency of occurrence of fast ice break up in the south-western Chukchi in zones of polar stations

Polar stations	Months			
	V	VI	VII	VIII
Schmidt		25	73	2
Vancarem		17	81	1
Uelen	7	74	18	

During melting sea clears from ice on average from Alaska coast north-westwards (Table 2.7.7, Fig. 2.7.10). Sea clears from ice in June and July the most intensively, to late July about 60% of sea basin and its south-western region is free from ice.

Table 2.7.8 – Area of the Kara Sea ice-free regions in the melting period, %

Sea regions	June			July			August			September		
	Decades											
	1	2	3	1	2	3	1	2	3	1	2	3
South-west	11	19	29	39	50	60	68	74	78	83	85	86
All seas	12	20	30	40	48	56	64	69	77	81	82	84

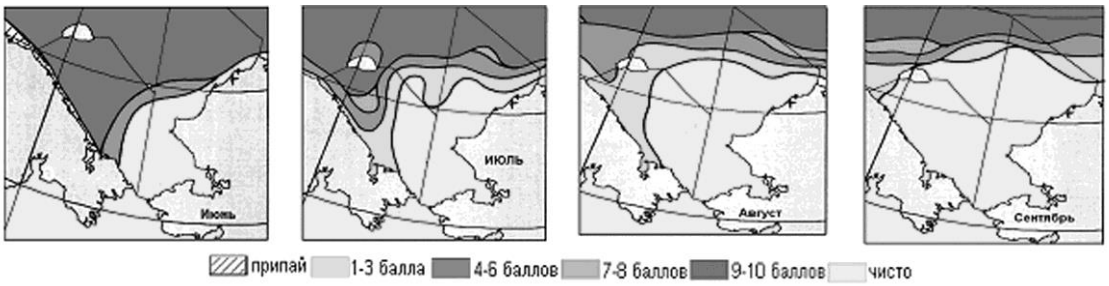

Fig. 2.7.10. Propagation of ice with different concentration in June-September (probability 50%)

When sea is clearing from ice, ice edge moves northwards and north-westwards, in direction of Bering warm water propagation (Fig. 2.7.11). More than 80% of sea basin is ice-free to late September under average conditions (Table 2.7.8).

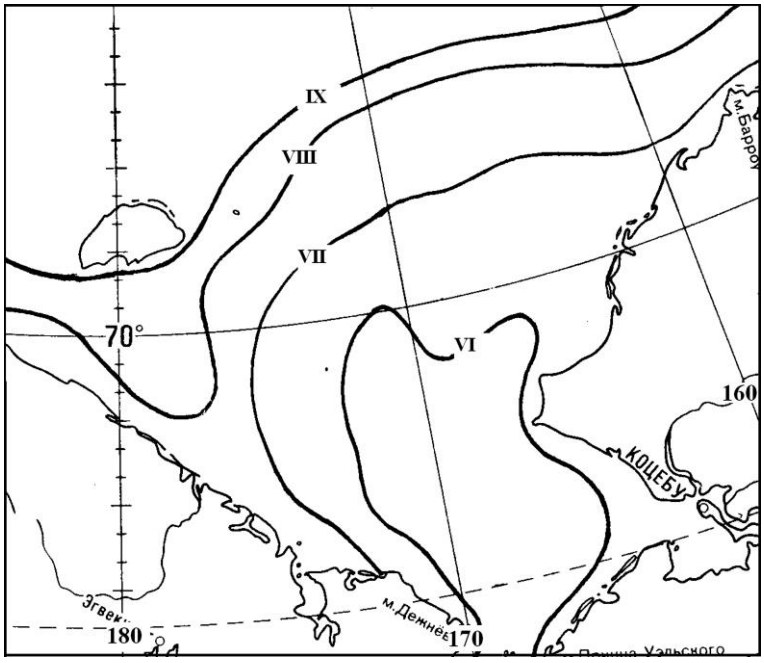

Fig. 2.7.11. Average location of ice edge in the Chukchi Sea in June-September

Ice massifs. During process of ice cover melting compact ice (7-10-th) of the Chukchi Sea is located into two ice massifs – the Wrangelevsky and Northern Chukchi (Fig. 2.7.12). Gerald branch of Bering current separates the Wrangelevsky ice massif, located in south-western sea region, from the Northern Chukchi massif, located in northern sea region. The Wrangelevsky massif consists from local first-year ice, but sometimes it includes transported multiyear ice. The Wrangelevsky ice massif blocks the eastern approaches to Long Strait in summer months, complicating navigation in June-July. In average years the Wrangelevsky massif occupies only about 25% of south-western sea area to late July, and to September its area decreases to 6% (Fig. 2.7.13). However, cases, when in August-September

massif was filled by ice from the eastern East-Siberian Sea, are not rare. Ice is propagated through Long Straight to the east along Chukchi Sea coast and it leads to significant navigational difficulties.

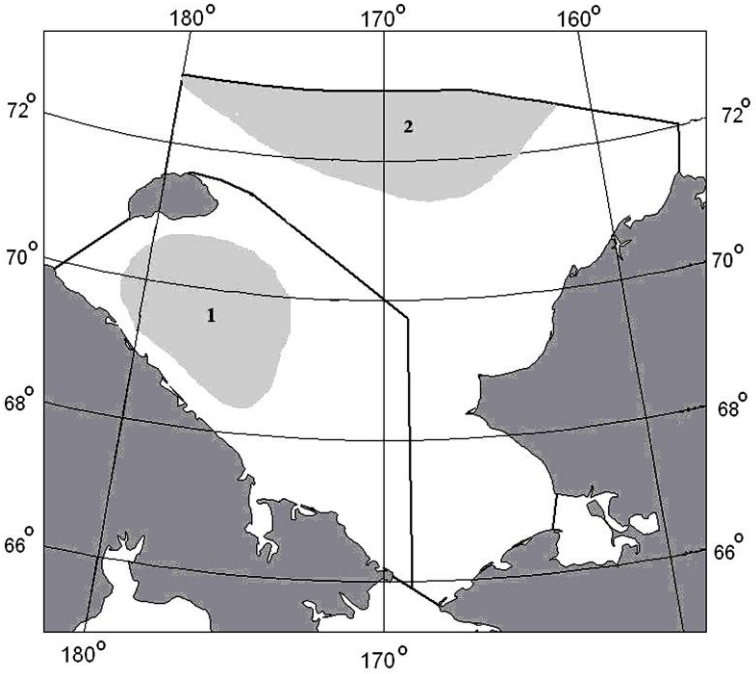

Fig. 2.7.12. Scheme of ice massifs location in the Chukchi Sea. 1 – Wrangelevsky and 2 – Northern Chukchi

The Northern Chukchi ice massif is a spur oceanic massif of Arctic basin. Multiyear ice comprises significant part of massif. During summer ice of the Northern Chukchi massif partly melts away and partly is transported out of sea limits. On average about 15% of massif area remained within sea limits before freeze up (Fig. 2.7.13).

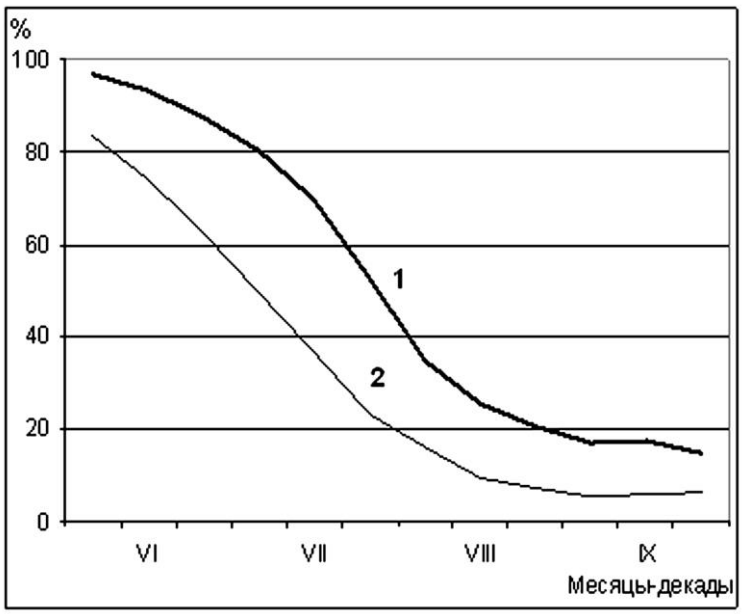

Fig. 2.7.13. Area changes of Wrangelevsky (1) and Northern Chukchi (2) ice massifs in June-September, %

During all observations, the Wrangelevsky ice massif ultimately disappeared in more than 50% of cases, and in most cases, 36%, occurred in August. Chukchi ice massif is more persistent, in 57% of cases it remained to the end of melting period (Table 2.7.9).

Table 2.7.9 – Number of cases of ice massif disappearance in the Chukchi Sea for 1939-2007, %

Ice massif	Months		
	VII	VIII	IX
Wrangelevsky	1	36	16
Northern Chukchi	-	23	20

Icebergs. From time to time insignificant amount of small icebergs come from the Beaufort Sea to northern sea regions and to Wrangel Island zone.