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RELATIONSHIP OF DYNAMICS OF FIELDS OF ICE DRIFT IN THE ARCTIC BASIN AND ATMOSPHERIC CIRCULATION NORTHERN HEMISPHERE (SUMMER SEASONS)

[1]Zakharov V.G., [2]Kononova N.K.

[1]Geological Institute of Russian Academy of Sciences, Moscow, Russia
e-mail: zakharov_vg@mail.ru

[2]Institute of Geography of Russian Academy of Sciences, Moscow, Russia
e-mail: *ninakononova@yandex.ru*

Abstract. New data on the relationship of the dynamics of the atmospheric circulation in the Northern Hemisphere and fields of ice drift in the Arctic basin were obtained by means hydro-climatic parameters of 2004, 2007 and 2011. In results of analysis installed role of the elementary circulation mechanism 13s (ECM 13s) in formation of ice fields and promotion them to the fjords of Spitsbergen (summer 2004 and 2011). Shows the consistency of periods of actions ECM 13s and cyclonic circulation of drift ice in the Arctic basin in different years. It was also revealed that during of action of ECM 12a in the Arctic basin observed the anticyclonic circulation of ice drift (summer 2007). At this time Spitsbergen was in the zone of warm anticyclonic weather. According to the materials of researches maps of atmospheric circulation and fields drift ice in the Arctic basin and maps with the same content for the Northern Hemisphere were prepared.

Keywords: cyclone, anticyclone, atmosphere circulation, elementary circulation mechanism (ECM), drift ice.

INTRODUCTION

In July and August 2004 and 2011 close to the west coast of Spitsbergen (District of Is-fjord and Green-fjord and others) were observed unusual for mid-summer ice phenomenons. In either case in short periods of time water areas of fjords were filled with broken sea ice. On July 25 2011 in Green-fjord was quite high tidal waves with ice, which is clearly felt in the changes of water and ice surfaces (from eyewitness reports, village Barentsburg). Filling fjord with sea ice accompanied by a marked cooling. Later the air temperature came back to the summer norm, and partially melted ice has been taken away by the ocean. In 2004 a similar event occurred at the end of June - July.

Fig. 1 shows the two cases of filling the water area of the Gren-fjord (near the village Barentsburg) with sea ice in the summer.

It should be noted that for Is-fjord and Green-fjord processes of spring and summer seasonal outstations of thin ice and addition of ice (rapid advances of sea ice) in the fjords of different ages and different thickness of sea ice, are typical. These processes are caused by repeated change of the wind condition to the opposite that for Green-fjord is expressed in a change from northerly winds to the southern. Typically, the ice is formed mainly in March-April, reaching 60 cm, and is destroyed in the second half of May [8]. However, it is known that for the past 7 years Green-fjord was not fettered by ice in 2006, 2007, 2008 and partially freeze in 2013 (V.I. Kobzar observations, Barentsburg mine).

ANALYSIS OF CIRCULATION MECHANISMS OF THE SUMMER SEASONS (2004, 2007, 2011)

Similar to the dynamics of ice summer seasons 2004 and 2011 were investigated in terms of the frequency and the oscillation of circulation of macro-processes for the entire Northern Hemisphere. At the same time was considered the 2007 season, the summer months which were the warmest in the Arctic and at Spitsbergen. Invasion of sea ice in the Is-fjord and Gren-fjord at this time was not observed.

Comparative analysis of the seasons was carried out by classification of atmospheric circulation in the Northern Hemisphere, developed under the leadership of B.L. Dzerdzeevsky [2]. Calendar of sequential change of elementary circulation mechanisms (ECM) published in [6] (~~see www.atmospheric-circulation.ru~~).

Fig. 1. *Sea ice in the Green fjord near Barentsburg mine 25.07.2004 (a) and 25.07.2011 (b).*

To analyze ECM was used information about the relationship between the atmospheric circulation and glaciological and ice processes in the Arctic and in the Spitsbergen archipelago [4-6].

Table 1 shows the results of the research sets of ECM in the summer seasons of 2004, 2011 and 2007.

Table 1. Duration of ECM in July and August

July 2004				July 2011				July 2007			
ECM	Duration	Average 1899 - 2011	Variation	ECM	Duration	Average 1899 - 2011	Variation	ECM	Duration	Average 1899 - 2011	Variation
13s	15	5,5	9,5	13s	7	5,5	1,5	8ds	2	0,98	1,02
10b	4	2,2	1,8	3	1	2	-1	9a	11	2,24	8,76
8bs	2	0,5	1,5	12bs	3	0,63	2,37	3	4	2	2
4c	5	2	3	12a	11	0,8	10,2	12bs	7	0,63	6,37
4b	2	3	-1	8ds	6	0,8	5,2	8bs	3	0,5	2,5
8cs	3	0,35	2,65	6	1	1,1	-0,1	2a	2	1,17	0,83
				9a	2	2,2	-0,2	12a	2	0,71	1,29
August 2004				August 2011				August 2007			
13s	15	5,54	9,46	12a	11	1	10	10b	3	1,92	1,08
10b	2	1,92	0,08	9a	8	1,38	6,62	12a	6	0,95	5,05
8bs	2	0,72	1,28	10b	2	0,63	1,37	13s	9	5,54	3,46
4c	3	1,89	1,11	4c	2	1,89	0,11	12bs	10	1,69	8,31
6	2	0,85	1,15	8a	3	0,71	2,29	9a	2	1,38	0,62
3	3	1,84	1,16	12bs	5	1,72	3,28	2b	1	2,34	-1,34
9a	2	1,38	0,62								
7bs	2	0,83	1,17								

The data show that in July 2004 and 2011 repetition of ECM 13s was noted (feature - cyclonic circulation on the pole and four outlets of southern cyclones in the Arctic). In July 2007 this macroprocess was not observed at all, and in August it lasted less than a third of the month, but with already ice-free fjord. Suffice it to say that in August 2004 on the ECM 13s was accounted 15 days. In July 2011, ECM 13s was observed during 7 days: 21-24 and 29-31 of July, just at the culmination of ice shifting. With this character of atmospheric circulation of summer months sea ice can accumulate on the coasts and quickly fill the south-western and western fjords of Spitsbergen.

As can be seen from Table 1, in 2007 ECM 12a and 12bs were observed (feature - anticyclonic circulation at the pole and the formation of three - four blocking processes). Characteristically, that the ECM 12a in 2004 and 2011 were not met at all, and ECM 12bs in July 2011 lasted 6 days only. However, in July 2007 the share of ECM 9a, 12a and 12bs had a total of 20 days, in August had a total of 18 days. 9a ECM feature is the development of two blocking anticyclones directed from the North Pole to the Atlantic and the Pacific.

With this set of macroprocesses in the summer 2007 Spitsbergen was almost always in the zone of the anticyclonic sunny weather. So, in July 2007 the duration of cyclonic circulation was only 5 days and in August for 13 days. Days with cyclonic circulation were permanently interrupted with anticyclonic, so Spitsbergen fjords were free of ice.

Fig. 2 shows that it is possible to attribute the similarities between the summers of 2004 and 2011 and three series of cyclones, associated with the development of the ECM 13s [2, 6] in the Northern Hemisphere. These three series of cyclones followed each other in approximately the same manner. In both cases the originally observed series were continuously operating for 7 days in 2004 and for 5 days in 2011. Apparently, when these episodes occurred retention and formation of arrays of West Spitsbergen ice took place, because according to [1, 2, 6] with ECM 13s Atlantic cyclones moved towards ice drifting from the center of the Arctic Basin, and towards ice which was moving by Transarctic stream along the coast of the Eurasian. Further, in both cases breaks were following 14 days long (2004) and 24 days long (2011), which are characterized mainly by anticyclonic weather. Breaks were replaced by two successive series of cyclones lasting 14 (2004) and 11 (2011) days with small intervals 2 and 4 days respectively. It was during these two series of cyclones when rapid shifts of ice in Green-fjord occurred, with filling of all its waters with sea ice hummocks of different ages and up to 2 meters of height or more.

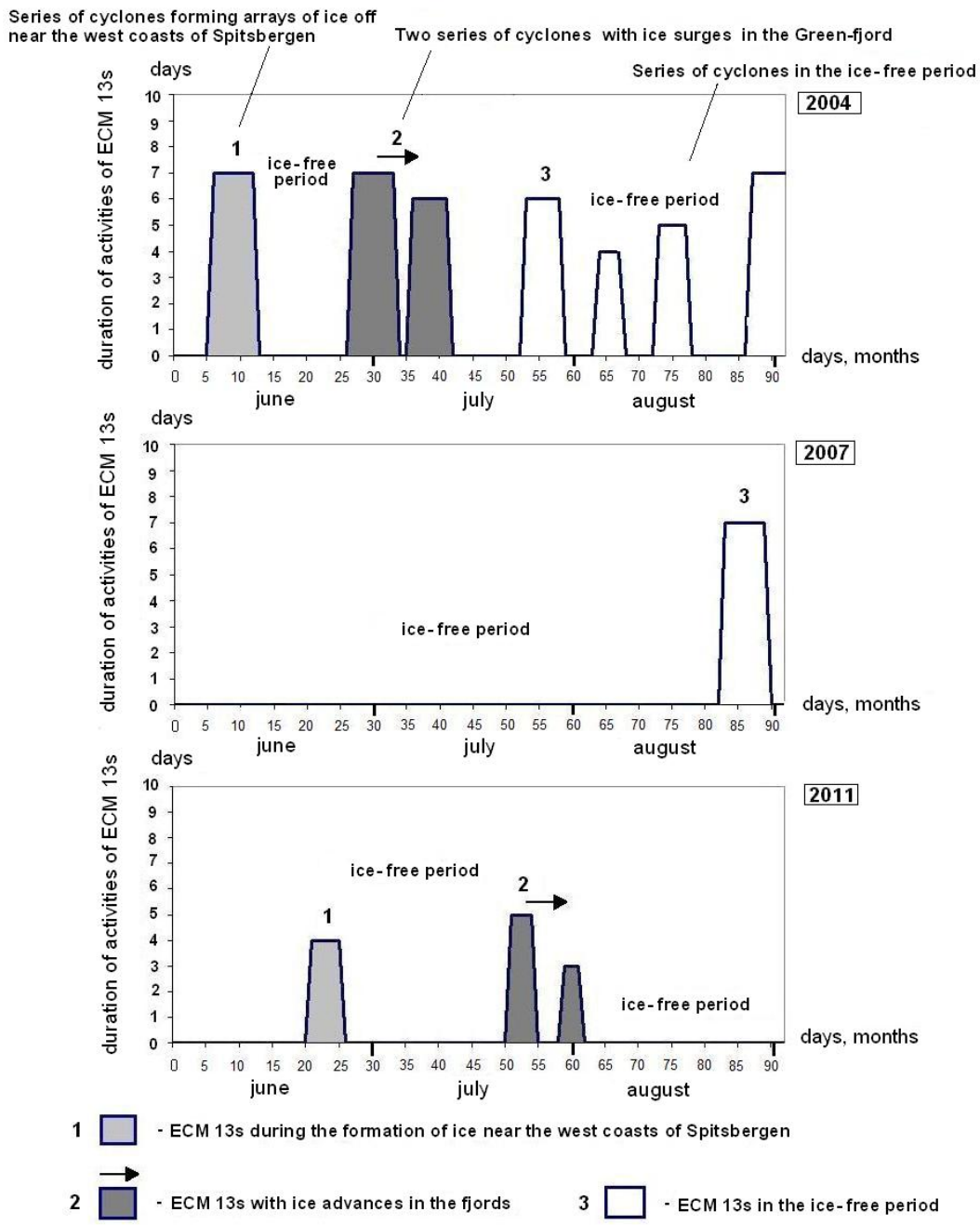


Fig. 2. *Duration of ECM 13s (series of cyclones in the summer seasons of 2004, 2007, 2011 and rapid advances of sea ice in the fjords of Spitsbergen (for example Green-fjord).*

CIRCULATION MECHANISMS AND FIELDS OF ICE DRIFT IN THE ARCTIC BASIN

For identified and discussed the ECM above, contributing to the formation of arrays Spitsbergen ice or removal it from its fjords and melting, were selected types of fields of atmospheric pressure and ice drift in the Arctic basin. This information is taken from the Reference Manual on the classification of baric situations and their respective fields of drift

ice [1]. The source data for creating manuals were coordinates from automatic buoys installed on the ice fields for 30 years. Below is a brief description of the two forms of classification series of fields pressure and ice drift. Maps Fig. 3 and 4 shows the character of the investigated circulation macroprocesses and the resulting by them drift of sea ice in the Arctic basin.

In the *First type* of classification of forms in the Arctic basin is marked clearly defined anticyclonic circulation of fields of ice drifting that is formed above the basin of anticyclone [1].

We considered *Type 1 zh*. During the period of its validity (5 days) and previously was observed only ECM 12a. Sampling was carried out according to the calendar of successive change of ECM in the Northern Hemisphere [6].

In this type included situations when the anticyclone and anticyclonic circulation in the fields of ice drifting are located in the Atlantic region of the basin. Ice drift is directed from the northern shores of the Canadian Arctic Archipelago to the Laptev sea, to the Barents sea and to the Kara sea (see. Fig. 3 A). However, removal of the ice through Fram strait is the most significant in *type 1 z* (anticyclone over the Beaufort sea), and with a similar *type 2 v* the drift velocity can exceed 20 km / day [1].

As an example of the action of the cyclone in the Arctic basin and cyclonic circulation in the fields velocity of ice drifting was chosen *type 3b* from the *third type* of classification. During the development of this type, according to the calendar of successive change of ECM [6], in the Northern Hemisphere ECM 13s was observed.

When situations are related to this type of classification, cyclone and the corresponding to it cyclonic circulation in the ice drifting shifted towards the Canadian Arctic Archipelago (see. Fig. 3 B). In the Siberian shelf seas is an area of high pressure. Ice drifting between the two baric systems aimed from the Atlantic region part of the basin to the Pacific region part of the basin. As a rule, this flow is well defined and has a large width. In the Beaufort Sea the drift the most frequently has Southeastern or Southern direction. Along the Canadian Arctic Archipelago ice flow go to the Fram strait, but the flow of ice in the strait is very weak and does not always happen [1].

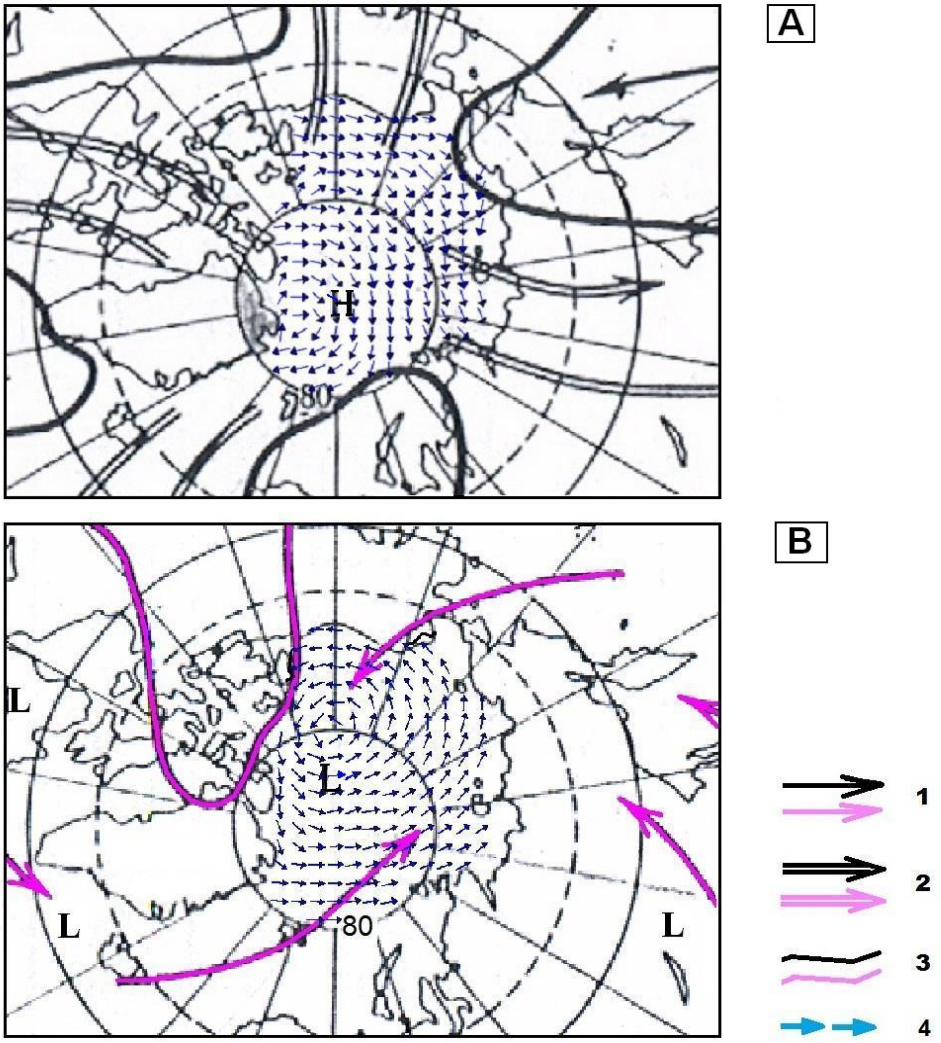


Fig. 3. *Atmospheric circulation processes and fields drift of sea ice in the Arctic basin. Dynamic schemes of elementary circulation mechanisms (ECM) by typing B.L. Dzerdzeevsrii [2; 6]: A. ECM 12a and direction of ice drift (antycyclonic circulation in the basin); B. ЭЦМ 13s and direction of ice drift (cyclonic circulation in the basin). 1 - general of the trajectory of cyclones; 2 - trajectory anticyclones; 3 - demarcation line separating the fields of cyclonic and anticyclonic activities; 4 - drift direction of automatic buoys.*

Fig. 4 allows to evaluate the development of ECM 12a and ECM 13s in the Northern Hemisphere and the nature of respective to them anticyclonic and cyclonic fields of ice drifting in the Arctic basin at this time.

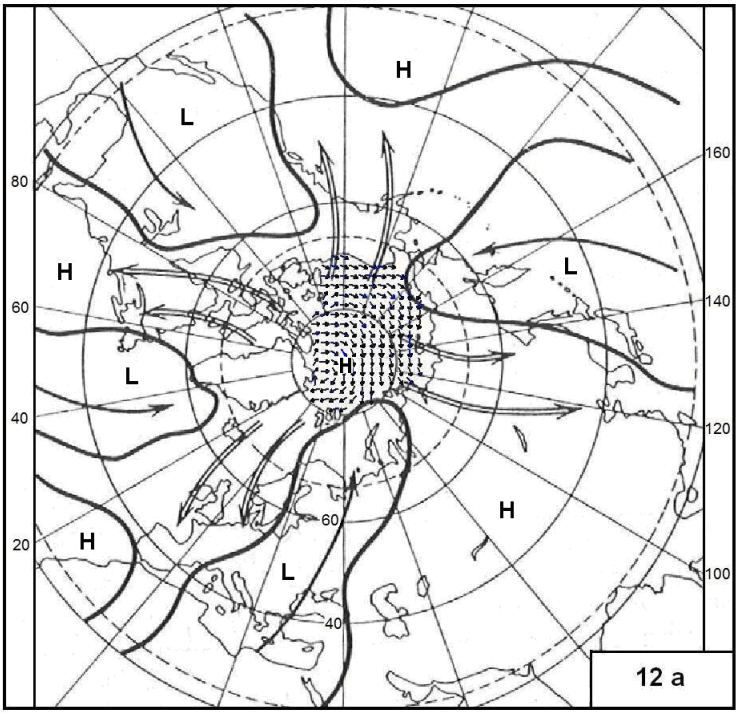
With ECM 13s and respectively forming arrays of Western - Spitsbergen ice, four break out of southern cyclones occur in the Arctic basin. Depression of this macro process in the Arctic is part of a very extensive area of low pressure, covering big part of the extra tropical latitudes of the Northern Hemisphere. At the same time a great development get both subtropical (ocean) anticyclones.

Honolulu anticyclone keeps high intensity, spreading to the Western half of North America, to the Canadian Archipelago and North of Greenland. Cyclones coming from the west and south-west are delayed, their trajectories get the Northern component.

Azores anticyclone is in the Southern latitudes of the Atlantic, and its crest is extended to Western Europe. Cyclonic activity develops in the northern half of the Atlantic. Cyclones move from the Gulf of Mexico along the coast of North America and join the Icelandic depression. Polar frontal cyclones pass through the more Eastern path, after regeneration move rapidly to the East or Northeast. Most often, they penetrate into the Arctic through the Greenland and Barents Sea or through Alaska and Chukotka (see. Fig. 4 B).

The maximum duration of the ECM 13s is in July and August (summer) [2, 6]. Characteristically, that with the action of winter type of this macro process ECM 13w over the Arctic Basin cyclonic activity also occur, respectively cyclonic character of the fields of ice drifting also set (Fig. 5 A, B). In this regard, in the winter but the ice-free for the fjords of Spitsbergen seasons, the action of ECM 13w could cause shifts of Arctic sea ice, like a summer shifts of ice in 2004 and 2007.

A



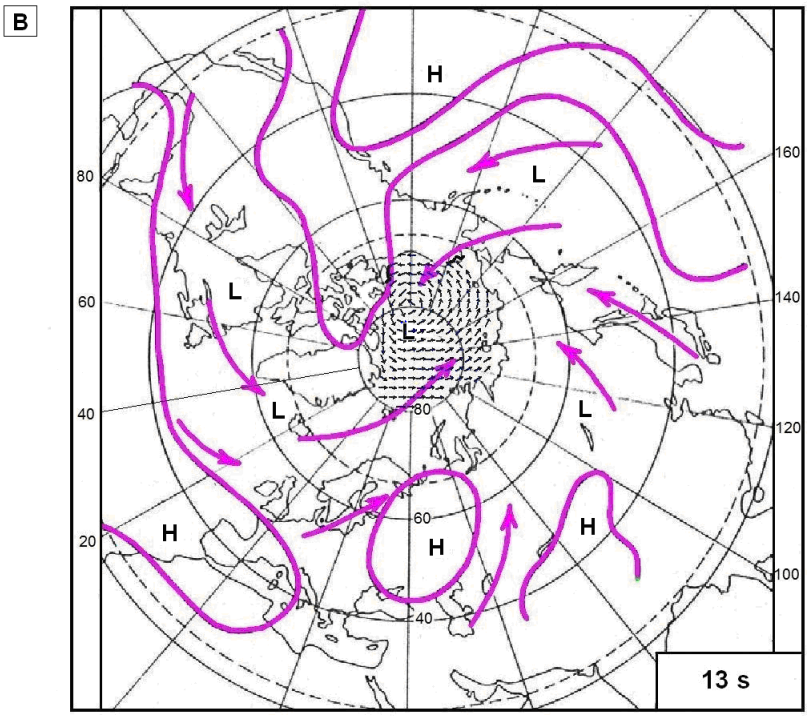


Fig. 4. *Dynamic schemes of elementary circulation mechanisms (ECM) of the Northern Hemisphere [2; 6] and fields of ice drift in the Arctic basin [1]: - ECM 12a and direction of ice drift (anticyclonic circulation in the basin); B - ECM 13s and direction of ice drift (cyclonic circulation in the basin). Legend as in Fig. 3.*

With ECM 12a (anticyclone on the pole, four polar invasion and four breakout of southern cyclones) removal of ice through the Fram strait is not always happen, there are no conditions for the formation of Western Spitsbergen ice arrays. Most often simultaneous polar invasions occur in the Eastern part of North America, in Asia and at the Atlantic and Pacific oceans. Cyclonic polar - frontal series are located over the Atlantic, Europe, near the Far Eastern coast of Asia and over the America (western and central regions).

ECM 12a appears often in the period of transition from the cold to warm half of the year, when the polar anticyclone usually reaches its maximum capacity, and in the southern latitudes the underlying surface is warm enough (see. Fig. 4 A).

The maximum duration of the ECM 12a is in May (spring) [2, 6].

Fig. 6 shows the dynamic ECM scheme operating in the spring and summer of 2011, prior to the fast shift of ice in the Is-fjord and Gren-fjord and after it. The diagrams also show the boundaries of the spreading of sea ice in the Arctic basin (white field). Ice conditions is shown according to Sea Ice Extent Index, NCIDC (see web-site ncidc.org).

In accordance with Fig. 6 A over the Northern Hemisphere with the action of ECM 8 gz on March 7, 2011 the spreading of the sea ice in the Arctic basin was close to the winter

type of spreading. In the central region of the Arctic Basin anticyclone is established, that according to the above cards, must be accompanied by an anticyclonic character of ice drifting fields in the waters of the basin. Fig. 6 B illustrates the development of the ECM 4c over the Northern Hemisphere and distribution of sea ice by August 14, 2011. By this time the area of sea ice has decreased significantly, as in parts of the Atlantic region and Pacific region, as at Eurasian coasts. Ice drift in the Arctic basin was also anticyclonic.

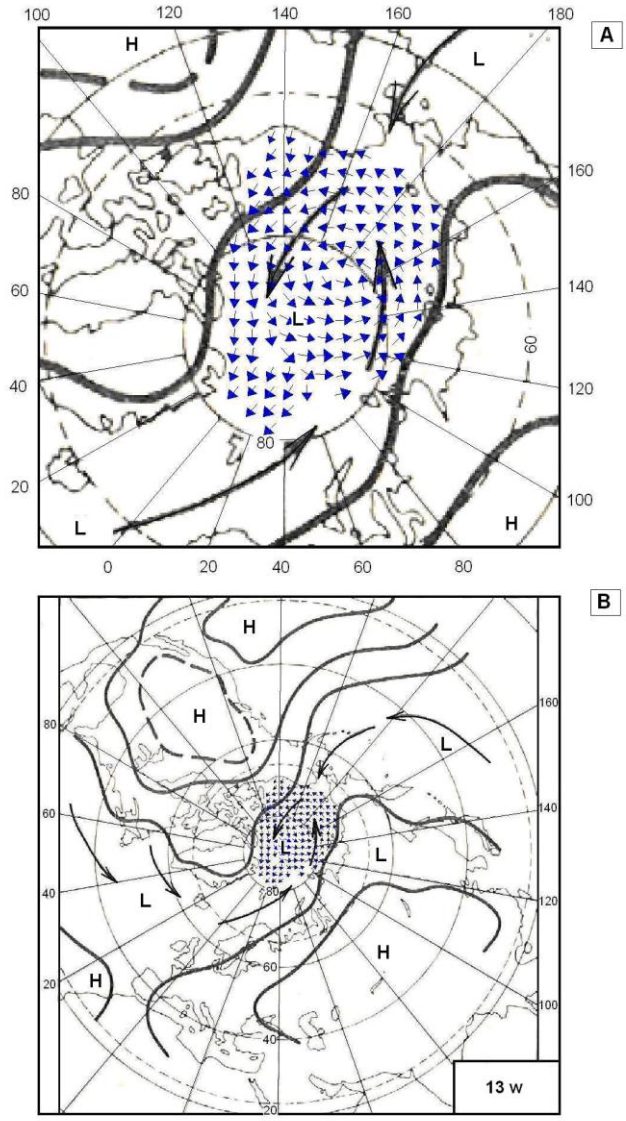


Fig. 5. *Dynamic schemes of elementary circulation mechanism ECM 13w [2, 6] and the character of the drift ice in the Arctic basin [1]. A. Arctic. ECM 13w and cyclonic circulation fields of ice drift; B. Northern Hemisphere. ECM 13w and cyclonic circulation fields of ice drift. Legend as in Fig. 3.*

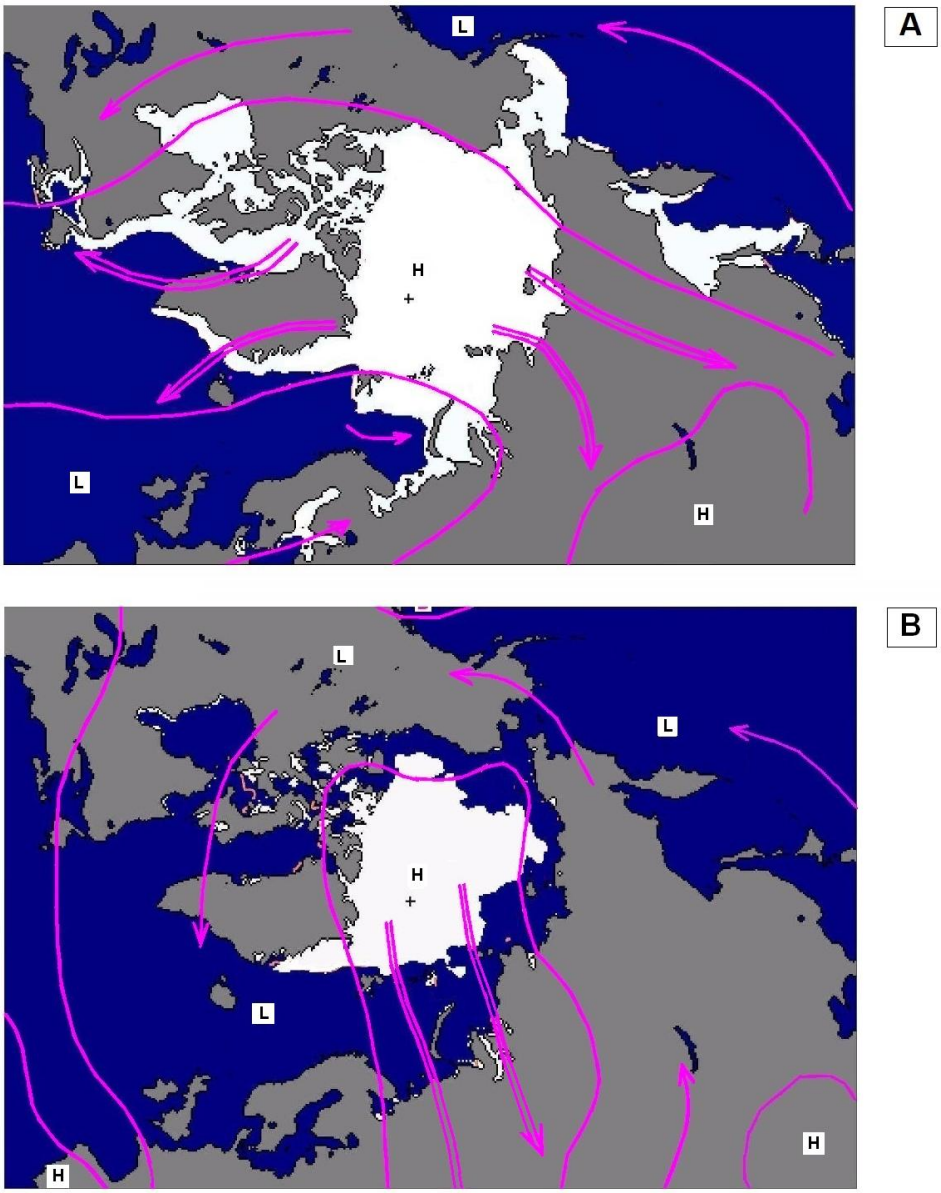


Fig. 6. *Atmospheric circulation processes in the Northern Hemisphere [2; 6] and character of distribution of sea ice in the Arctic basin in the spring and summer of 2011: A. Dynamic scheme of elementary circulation mechanism ECM 8dw and sea ice (white areas) 07.03.2011; B. Dynamic scheme of elementary circulation mechanism ECM 4c and sea ice 14.08. 2011. Legend as in Fig. 3.*

CONCLUSION

On the example of the three summer seasons of the XXI century (2004, 2007 and 2011) is showing how the different nature of macro processes of the Northern Hemisphere is

reflected on the circulation of the ice drifting fields in the Arctic basin and the dynamics of ice in the West Spitsbergen waters.

Was identified the effect of ECM 13s on the formation of ice arrays near the West coast of Spitsbergen in June - July 2004 and 2011, and fast shifts of the ice in the fjords. In these conditions there are the locations of the two Russian mines Barentsburg and Pyramid.
It is shown that with the ECM 13s in the Arctic basin observed a strong cyclonic character of ice drifting. It is under the strong influence of series of cyclones from the Northern half of the Atlantic there is a concentration and contraction of the ice arrays near the West coast of the archipelago. Ridging ice is redistributed to the main fjords, and then extruded on the side and quickly fill them. Under these conditions maritime traffic in coastal waters and fjords of Spitsbergen becomes extremely difficult.

It was found that for the summer months of 2007 characteristically were ECM 12a 12bs and 9a. These macro processes in the summer of 2004 and 2011 either were not observed at all (ECM 12a), or operated only for 2-6 days (ECM 9a). With this set of macroprocesses in the summer of 2007, Spitsbergen was almost always in the zone of anticyclonic sunny weather. Days with cyclonic circulation were permanently interrupted with anticyclonic circulation. There were no conditions for the formation of the West Spitsbergen ice, so the Western fjords of the archipelago remained ice-free. In the Arctic basin with ECM 12a indicated a clear anticyclonic circulation of the fields of ice drifting, and polar anticyclone usually reaches its maximum capacity.

The situation is similar to 2004 and 2011 often manifested in the culmination of the Little Ice Age (1780 - 1840) [3], when the summer Kochi Russian coast-dwellers found themselves jammed deep into the ice fjord and coast-dwellers were forced to stay for wintering. This could be repeated for several years and led to loss of human lives.

REFERENCES

1. Gorbunov Yu. A., Losev S.M., Dyment L.N. Fields of drift ice in the Arctic basin under typical of baric situations. *Spravochnoe posobie.* St. Petersburg: Publ. AANII, 2008, 35 p.

2. Dzerdzeevsky B.L., Kurganskaya V.M, Vitvitskaya B.L. Classification of circulation mechanisms in the Northern Hemisphere and characterization of synoptic seasons. *Trudy NIU GUGUMS.* Seriya II, vol. 21, Moscow, Leningrad: Publ. Gidrometizdat, 1946, 80 p.

3. Zakharov V.G., Derzhavin V.L. Tragic Pomors wintering on Spitsbergen and Novaya Zemlya in the culmination of the Little Ice Age. *Doklady XI Mezhdunarodnoy naychnoy*

konferentsii "Globalnye klimaticheskie izmeneniya i ich vliyanie na ekosistemy arkticheskikh i cubarkticheskikh regionov" Apatity, 2011, pp. 66 – 67.

4. Zakharov V.G., Kononova N.K. Global atmosphere classification and conjugation of glaciological processes in the Arctic and Antarctic. *Ice and snow*, Moscow, 2010, vol. 2, pp. 127 – 135.

5. Zakharov V.G., Khmelevskya L.V. Glacier fluctuations and circulation processes changes in the polar regions of the Atlantic and in Europe. *Materialy glaciologicheskikh issledovanii*, Moscow, 1997, vol. 83, pp. 127 – 135.

6. Kononova N.K. Classification of circulation mechanisms of Northern Hemisphere by B.L. Dzerdzeevskii. Moscow: Voentekhinizdat, 2009, 372 p.

7. Kononova N.K., Zakharov V.G. Communication of glaciological processes in Antarctic with the global atmospheric circulation. *Mezhdunarodnaya naychnaya konferentsiya "Morskie issledovaniya polyarnykh oblastey Zemli v Mezhdunarodnom polyarnom godu 2007/08"Programma i tezisy dokladov.* St. Petersburg: Publ. AANII, 2010, pp. 113-114.

8. Tarasov G.A. New data on the glacial transport of sedimentary matter in Gronfjord Bay. *Materialy X Mezhdunarodnoy naychnoy konferentsii "Priroda shelfa i arkhipelagov Evropeyskoy Arktiki. Kompleksnye issledovaniya prirody Shpitsbergena"*. Moscow: Publ. Geos, vol. 10, pp. 480-484.