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Cases of mass development of intrusions in Lake Baikal and the correlation of intrusions with atmospheric circulation processes

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ABSTRACT. The cases of the development of mass intrusions in some basins of Lake Baikal were reviewed based on the measurements of water temperature and dissolved oxygen in water in 1993-2022. It was shown that in Southern, Middle and Northern Baikal during the development of intrusions in the spring-summer period, the heat deficit value was within –0.5-103.0, –3.1-15.8, –0.2-3.6 MJ/m^2, dissolved oxygen amount was 0.2-161.3, 14.7-46.0, 0.6-6.3 g/m^2 and the renewed bottom layer thickness was 36-318, 48-176, 38-94 m respectively. In winter in Southern Baikal, the heat deficit value varied within –0.8-5.2 MJ/m^2, the amount of dissolved oxygen was 9.9-19.2 g/m^2, and the thickness of the renewed bottom layer was 24-124 m. Analysis of the correlation between the heat deficit values and the circulation indices revealed that mass intrusions in Southern and Northern Baikal during the spring-summer period were associated with the prevailing meridional transport of air masses from the Eastern Atlantic and blocking zonal transport of air masses from the Atlantic and Pacific Oceans. On the contrary, in Middle Baikal, mass intrusions during the spring-summer period were developing under the conditions of zonal transport of air masses simultaneously from the Eastern Atlantic and northern and western areas of the Pacific Ocean. The development of mass intrusions in Southern Baikal in winter was related to the intensification of circumpolar circulation and zonal transport of air masses from the Atlantic Ocean.

Keywords: Baikal, intrusions, deep convection, teleconnection indices

1. Introduction

Intrusions of surface water into deep or near-bottom water layers are observed in Lake Baikal before the ice cover period and after melting of the ice cover, when a change in thermal stratification of waters occurs (Shimaraev and Granin, 1991; Weiss et al., 1991; Shimaraev et al., 1993; 2016; Wuest et al., 2005; Schmid et al., 2008; Tsimitri et al., 2015; Bouffard and Wuest, 2019). Intrusions are a consequence of deep convection, which forms during thermobaric instability in the upper 300-m layer of the water column. Thermobaric instability may occur under conditions of the decrease in temperature of maximum density with increase in depth/pressure in May-June after ice cover melting and in November-January before ice cover period (Shimaraev and Granin, 1991; Weiss et al., 1991). The instability may be originated by inhomogeneity of the atmospheric pressure field, winds in the coastal zone, which cause downwellings, and, the increase in water density at the thermobar front (Shimaraev and Granin, 1991; Weiss et al., 1991; Shimaraev et al., 1993; Wuest et al., 2005; Schmid et al., 2008; Tsimitri et al., 2015). In Baikal, the deep convection reaches a large scale causing intrusions of waters up to 200 km^3 to the near-bottom zone of the lake (Wuest et al., 2005) and renewal of waters deeper than 250 m by 10% per year in Southern and Middle Baikal and by 15% in Northern Baikal (Hohmann et al., 1997).

Aeration of deep zone waters takes place due to intrusions (for example, Shimaraev et al., 2016). Oxygen from intrusions supports the life of benthic fauna and is also involved in geochemical processes in the upper layer of the bottom sediments (Pogodaeva et al., 2017), and in the oxidation of methane in areas of gas discharge (Van Rensbergen et al., 2002).

The phenomenon of deep convection was found in Canadian lakes Kamloops (143 m) and Lake Babine (186 m) before ice cover period (Farmer and Carmack, 1981), in Lake Crater (USA, 594 m; Crawford and Collier, 2007), in Japanese lakes Towada (326,8 m) and Shitotsu (363 m; Boehrer et al., 2009).

Our study was aimed to identify the cases of mass development of intrusions, evaluate their

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characteristics, and analyze the correlation with atmospheric circulation over Southern Baikal.

2. Materials and methods

The data of expedition measurements of water temperature T (±0.002 °C) and oxygen (±0.01 g/m^2) made by SBE-25 probe in May-October 1993-2022 were used in this work. Measurements were taken at 21 stations of the longitudinal section along the lake thalweg and at 8 sections in Southern (24-48 stations), Middle (19-39 stations) and Northern (20-40 stations) Baikal (Fig. 1). During the open water period from 1993 to July 2002 and from 2018 to the present time, the stations of the sections were 3 and 7 km from the shore and in the middle of the section. In August 2002-2017, additional measurements were taken 1, 5, and 10 km from both shores. In addition, in 1993, measurements were made at additional stations in the areas of maximum depths in some basins of Baikal, and in different years at cross sections (from south to north) of Cape Ivanovsky – Murino settlement, Bolshoe Goloustnoe settlement – Babushkin town, Anga River – Sukhaya River, Cape Pokoiniki – Cape Orlovsky, Tyya River – Nemnyanka River.

Ice conditions as well as the proximity of the location allowed to held winter expeditionary works in Southern Baikal. Therefore, the paper also used the data of water temperature and oxygen measurements in January-April 1996-2022 to analyze the cases of intrusions in before ice cover period.

In our paper, we studied the cases of lower water temperature and higher dissolved oxygen concentration near the bottom as intrusions of surface waters due to deep convection (Fig. 2). When the benthic water renewal stations were identified due to intrusions, their characteristics were evaluated: h – height of the near-bottom cold layer of the BCL, $\Delta Q_{(-)}$ – heat deficit, ΔO_2 – an increase in dissolved oxygen concentration, W – volume of surface waters entering the near-bottom zone with intrusions.

An indicator of intrusions was an increase (for T) and decrease (for O_2) in the absolute value of vertical gradients up to 6-8 times. Thermal effect of cold intrusions or heat deficit $\Delta Q_{(-)}$ (MJ/m^2) in the layer h (m) is calculated as the difference between the real and background (with undisturbed water layer in the near-bottom zone) thermal content of the layer:

$$\Delta Q_{(-)} = \rho \cdot c_p \cdot h \cdot \left(\bar{T}_{real} - \bar{T}_{bg}\right). \quad (1)$$

Value h (m) was determined by vertical distribution T (°C) in the near-bottom zone (Fig. 2), ΔT – average measured T in the layer h, ΔT_{bg} – average background T in the layer h at typical distribution of T in the near-bottom zone and in 200-400-meter water column above the BCL (Fig. 2). The density of water ρ was taken as 1000 kg/m^3, and the specific heat capacity – as 4.19 kJ/ (kg·K).

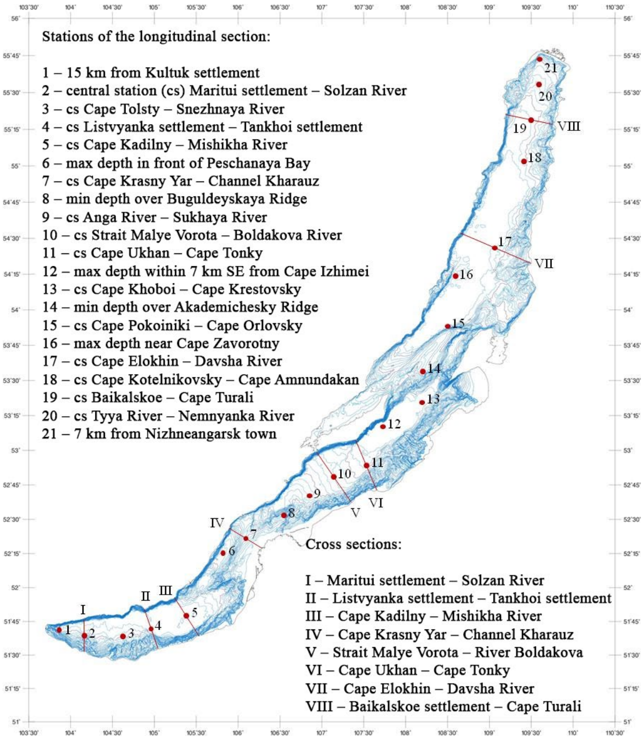

Fig.1. Bathymetric map of Lake Baikal (De Batist et al., 2002) and the scheme of measurements on the longitudinal (stations 1-21) and transverse sections (I-VIII).

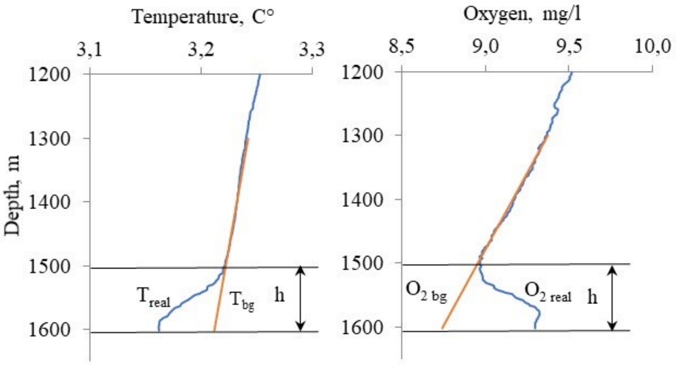

Fig.2. Vertical distribution of water temperature (leftward) and dissolved oxygen concentration (rightward) under the surface water intrusions to the benthic zone (station 3 km from the Cape Ukhan, June 7, 2021).

The influence of cold intrusions on the amount of dissolved O_2 is expressed by the value of the excess of its actual content in the BCL over the content at the background distribution of O_2. Value of the amount of oxygen supplied to the BCL ΔO_2 (g/m^2) is

$$\Delta O_2 = h \cdot \left(\bar{O}_{2real} - \bar{O}_{2bg}\right), \quad (2)$$

where h is the height of the BCL (m), $\Delta O_{2\ real}$ is an average measured concentration of dissolved O_2 in the layer h (mg/l), $\Delta O_{2\ bg}$ is background concentration of O_2 (mg/l) at the undisturbed layer of water in the near-bottom zone of h (Fig. 2).

In some cases, when there were no measurements of the concentration of dissolved O_2, the ΔO_2 value was restored from the dependence $\Delta O_2 = f(\Delta Q_{(-)})$, obtained from intrusion data for 1993-2021 (Fig. 3).

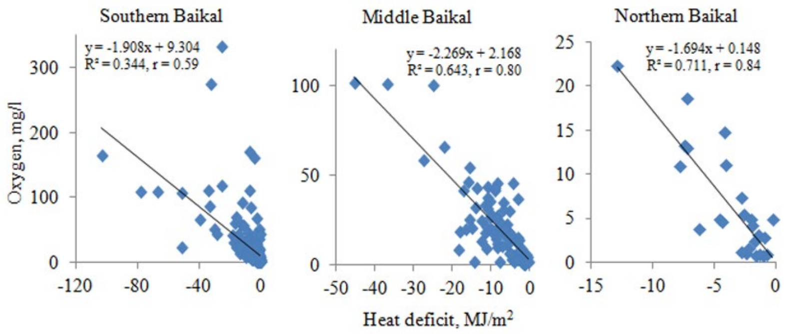

Fig.3. Diagram of the correlation between the amount of dissolved oxygen in water and heat deficit $\Delta O_2 = f(\Delta Q_{(-)})$ in separate basins of Lake Baikal.

The value of W was determined according to the diagrams of the dependence of water volume from the depth, below which the H renewal water occurred, obtained for each basin. The depth H (m) was calculated by the formula

$$H = H_{local} - h, \quad (3)$$

where H_{local} is the depth of the place at the station where measurements were taken, h is the height of the BCL.

Usually, the circulation indices, known as Northern Hemisphere Teleconnection Patterns (Barnston and Livezey, 1987), are used to assess the influence of atmospheric processes on air and water temperature and precipitation. However, the indices themselves are calculated on the basis of atmospheric pressure field data over the Northern Hemisphere. As the thermobaric instability in the upper layers of the water column, due to which deep convection develops and intrusions are formed, occurs mainly with inhomogeneities of the atmospheric pressure field and related winds, we can trace the relationship between atmospheric circulation indices and the development of surface water intrusions in the near-bottom zone of Lake Baikal. For this purpose the dependencies were considered $\Delta Q_{(-)}$ with indices of atmospheric circulation NAO, EA, EAWR, POL, SCAND, WP and PNA in 1993-2022 (IRI/LDEO Climate Data Library).

For intrusions developing after the ice-breakup, the values of atmospheric circulation indices for April-October were used. For intrusions formed before ice-cover period, circulation indices for November of the previous year to March of the current year were considered. On the one hand, the periods were chosen taking into account the fact that the conditions for the formation of the temperature field, in which deep convection can occur due to the thermobaric instability, are created in the months preceding the intrusions. On the other hand, after sinking of intrusions into the near-bottom zone, their influence on the water temperature and dissolved oxygen content in this part of the lake can be traced for some more time.

3. Results

Analysis of the characteristics of intrusions observed in 1993-2022 revealed their mass development in Southern Baikal in May-June 2018 and March 2005, in Middle Baikal in July-August 2011, and in Northern Baikal in June-July 2001. In Southern Baikal, there were several other cases of mass intrusion development during the spring-summer period, but they were of a smaller scale, so they were not included in this paper.

3.1. Southern Baikal

The main characteristics of the intrusions determined in Southern Baikal are presented in Tables 1 and 2. During the spring-summer period, the maximum values of $\Delta Q_{(-)}$ (–103.0 MJ/m²) and ΔO_2 (164.3 mg/l) were observed in the area of Bolshie Koty settlement (Table 1), minimum – at the southern end of the lake (western side of the section of Maritui settlement – Solzan River, central station Cape Ivanovsky – Murino settlement). On average, the values of $\Delta Q_{(-)}$ and ΔO_2 were 20.8 MJ/m² and 40.7 g/m², respectively. Layer thickness of the BCL varied from 36 m (mud volcano Malenky) to 318 m (7 km from Bolshie Koty settlement), and on average, the value h was 134 m (Table 1).

In winter, the values $\Delta Q_{(-)}$ and ΔO_2 were considerably less. It is rather connected with the fact that in March the influence of intrusions on the characteristics of the near-bottom water layer was already compensated from upside by the incoming heat from the water column due to diffusion, downside – from the bottom sediments, and oxygen was used for the life activity of benthic hydrobionts and geochemical processes. Values $\Delta Q_{(-)}$ and ΔO_2 varied within small ranges (–0.3-5.2 (average –1.9) MJ/m² and 9.9-19.2 (13.0) g/m²), although the layer capacity of the BCL was comparable to that of the spring-summer period (24-124 (62) m).

Taking into account the average values of H_{local} and h, the volume of the surface water incoming with intrusions into the deep zone was 380 and 340 km³ in May-June 2018 and March 2005, respectively. The calculated volumes of incoming water indicate the renewal of the near-bottom waters deeper than 1230 m and 1244 m horizons, respectively.

Analysis of changes in the values of the circulation indices (Fig. 4) showed that in the spring and autumn period of 2018 there were conditions for the prevailing meridional transport of air masses over the Baikal region (Fig. 4). The Scandinavian mechanism contributed greatly to the spring period of 2018 (April-May) in creating conditions for intrusive

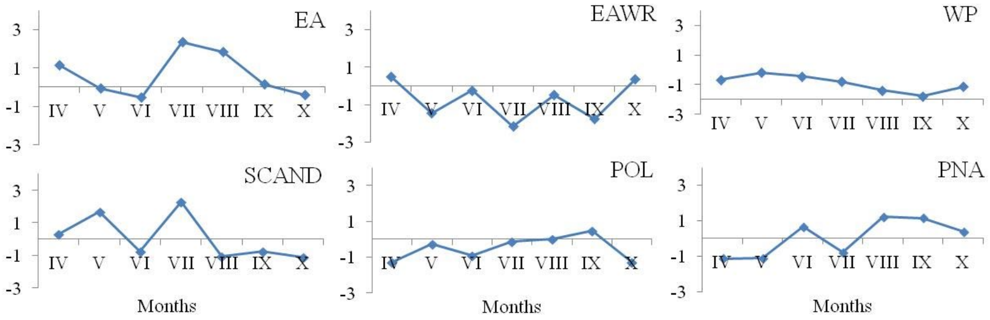

Fig.4. Change of indices of atmospheric circulation in April-October, 2018.

development (SCAND+), which blocks the zonal transport of air masses, and the Eastern-Atlantic mechanism of meridional transport of air masses (EA+). The mechanisms of zonal transport of air masses from the Pacific and the Arctic (EAWR–, WP–, PNA–, POL–) were weakened (Fig. 4). In June, a weakening of both meridional and zonal transport of air masses was observed. An increase of meridional transport was in July-August (EA+), while the zonal transport decreased (SCAND–). In August-October, the zonal transport of air masses (PNA+) began to intensify by blocking the transport of air masses from the North Pacific sector (Fig. 4).

In winter period 2004-2005 (Fig. 5), zonal transport of air masses from the Northern Atlantic region (EA–, NAO+) with simultaneous meridional transport of air masses from the Atlantic (AO+) and enhanced circumpolar circulation of air masses in November (POL+) contributed to creating conditions for the formation of intrusions before the permanent ice cover (November-January). Air masses transported from the Pacific (PNA+, WP+) also to the enhancement of zonal transport (Fig. 5). Later (February-March) there was a weakening of the meridional transport of air masses from the Atlantic (AO–) and an increase in the circumpolar circulation in March (POL+) and zonal transport from the Atlantic (EAWR+) and the Pacific Ocean (WP+, PNA+).

3.2. Middle Baikal

In this part of the lake, mass intrusions were observed in May-August 2011. The intrusions were not only mass, but their influence on the bottom water layer was traced up to the first half of August (Table 3). The characteristics of intrusions from May-June to July and August, respectively, did not change much: $\Delta Q_{(-)}$ – –3.1-15.8 (–11.1), –3.7-27.4 (–10.6) and –4.6-17.1 (–9.2) MJ/m^2, ΔO_2 – 14.7-46.0 (30.8), 13.1-45.5 (33.5) and 3.0-41.0 (24.3) g/m^2, and h – 48-176 (128), 104-254 (143) and 70-156 (117) m. The W value varied from 146 km^3 in May-June to 135 km^3 in July and 23 km^3 in August that resulted in the renewal of waters deeper than 1386, 1379 and 1480 m, respectively.

Table 1. Characteristics of intrusions in Southern Baikal on 25 May – 6 June, 2018.

Station	H, m	h, m	$\Delta Q_{(-)}$, MJ/m^2	ΔO_2, g/m^2
3 km from Maritui settlement	1338	56	-1.9	1.8
7 km from Maritui settlement	1340	44	-1.7	2.4
Central station (Cs) of Maritui settlement – Solzan River	1260	50	-1.2	4.2
Cson Cape Ivanovsky – Murino settlement	1344	60	-2.8	0.2
Cs of Listvyanka settlement – Tankhoi settlement	1422	126	-10.0	12.7
10 km from Listvyanka settlement	1408	126	-9.1	11.2
7 km from Listvyanka settlement	1406	128	-9.9	13.3
5 km from Listvyanka settlement	1404	98	-9.4	7.9
3 km from Listvyanka settlement	1402	40	-0.5	4.2
Mud volcano Malenky	1308	36	-1.7	0.7
7 km from Mishikha River	1362	120	-6.2	18.4
Cs Cape Kadilny – Mishikha River	1434	114	-7.3	6.9
7 km from the Cape Kadilny	1410	120	-7.9	10.1
3 km from the Cape Kadilny	1374	120	-4.1	7.8
9 km from Bolshie Koty settlement	1420	308	-77.9	108.0
7 km from Bolshie Koty settlement	1418	318	-39.4	64.5
5 km from Bolshie Koty settlement	1408	198	-51.3	105.8
2 km south-westward from station 7 km from Bolshie Koty settlement	1416	316	-103.0	164.3
1 km south-westward 7 km from Bolshie Koty settlement	1418	214	-66.9	108.5
Maximum depth at the Peschannaya Bay	980	96	-4.4	161.3
Average	1364	134	-20.8	40.7

Table 2. Characteristics of intrusions in Southern Baikal in March, 2005.

Station	H, m	h, m	$\Delta Q_{(-)}$, MJ/m^2	ΔO_2, g/m^2
Cs Listvyanka settlement – Tankhoi settlement	1406	124	-4.6	*18.1*
Cs Listvyanka settlement – Tankhoi settlement	1410	122	-4.3	*17.5*
7 km from Listvyanka settlement	1394	62	-2.1	*13.3*
4.5 km from Listvyanka settlement	1392	36	-0.8	*10.7*
3 km from Cape Kadilny	1250	76	-2.4	*13.9*
7 km from Cape Kadilny	1400	76	-2.4	*13.8*
Cs Cape Kadilny – Mishikha River	1424	70	-5.2	*19.2*
7 km from Mishikha River	1398	86	-1.6	*12.4*
5 km from Goloustniye settlement	1054	50	-0.8	*10.9*
10 km from Goloustniye settlement	1232	58	-1.2	*11. 7*
Mud Volcano Malenky	1308	96	-2.2	*13.4*
3.5 km from Cape Ivanovsky	1308	40	-0.3	*9.9*
7 km from Cape Ivanovsky	1354	24	-1.2	*11.6*
10 km from Murino settlement	1008	38	-0.8	*10.8*
Cs Cape Ivanovsky – Murino settlement	1270	32	-1.5	*12.2*
3 km from Maritui settlement	1326	46	-1.4	*12.1*
7 km from Maritui settlement	1326	38	-1.0	*11.1*
Cs km from Maritui settlement – Solzan River	1250	38	-0.8	*10.8*
Average	1306	62	-1.9	*13.0*

Note: hereinafter the restored values are italicized ΔO_2.

Most indices indicate (Fig. 6) the enhancement of zonal transport of air masses in April-June from the Atlantic (EA–, SCAND–) and Pacific Oceans (WP+, PNA+) under weakened meridional air masses transport (EAWR–). In July-September (Fig. 6), an intensification of meridional transport was observed (EA+, EAWR+) with blocking of zonal transport of air masses (WP–, SCAND+, PNA+). The circumpolar circulation (POL–) was weaken for the whole period, except October.

3.3. Northern Baikal

Northern Baikal is characterized by rarer occurrences of intrusions and smaller values of individual intrusion characteristics. However, a year with mass development of intrusions, the influence of which on the near-bottom water layer was observed in June-July 2001, was identified.

The characteristics of the intrusions changed insignificantly from June to July (Table 4): $\Delta Q_{(-)}$ – –0.2-3.6 (–2.0) and –0.4-2.0 (–1.5) MJ/m^2, ΔO_2 – 0.6-6.3 (3.5) and 0.7-3.6 (2.7) g/m^2, and h – 38-94 (62) and 40-86 (56) m. The W value varied from 140 km^3 in June to 81 km^3 in July, resulting in renewal of waters deeper than 773 and 793 m, respectively.

The analysis of the indices (Fig. 7) indicates generally intensification of the meridional transport in April-May due to the transfer of air masses from the Eastern Atlantic (EA+, EAWR+), weakening of blockage of the zonal transport from the Northern Atlantic (SCAND–) and zonal transport from the Pacific Ocean (PNA–). Summer months are characterized by enhancement of meridional transport of air masses from the Atlantic (EA+, EAWR+) under the weaken transport of air masses from the Pacific Ocean (PNA–, WP–). The circumpolar circulation (POL) had an increasing influence on zonal transport only in some months (April, July, October).

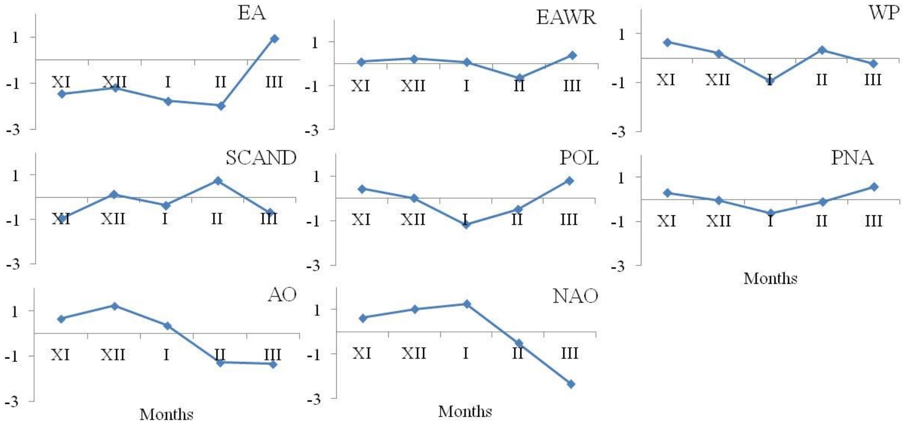

Fig.5. Change of atmospheric circulation indices in November 2004 – March 2005.

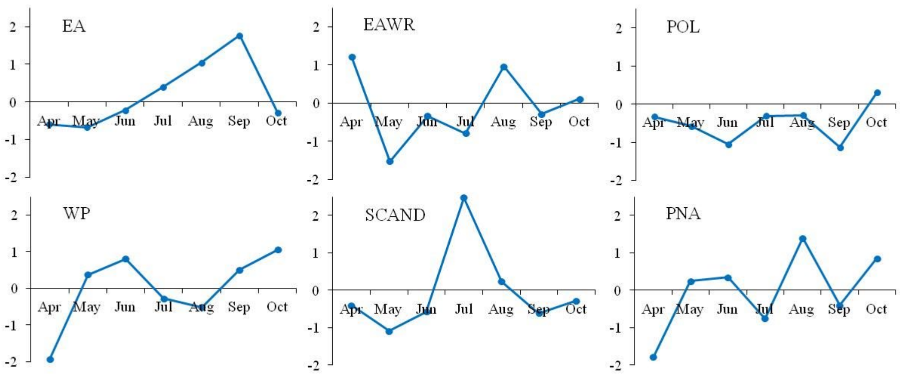

Fig.6. Change of atmospheric circulation indices in April-October, 2011.

4. Discussion and conclusions

This paper touched four cases of mass intrusions of separate basins of Lake Baikal. All cases of intrusions are united by the fact that conditions for formation of all three basins are created near steeper western underwater slope and in the pelagic zone of the lake in the areas of maximum depths. Intrusions have the greatest influence on the bottom water layer in Southern and Middle Baikal. The values of the heat deficit and the amount of dissolved oxygen incoming with intrusions are close and are in 2-4 times more compared with similar characteristics of Northern Baikal.

Intrusions observed in May-June 2018 are distinguished by their characteristics in the area of Bolshie Koty settlement (5 stations, Table 1), where values $\Delta Q_{(-)}$, ΔO_2 and h approached 318 MJ/m^2, 164 g/m^2 and 318 m, respectively. It may be assumed that such large values may be related to the formation of anticyclonic vortices in the field of cyclonic currents. The area of Bolshie Koty (Fig. 8) is located in the zone of currents strengthening due to the Selenga River waters, which differ greatly from the Baikal waters in temperature, salinity, and the amount of dissolved substances, including oxygen. Stream of the Selenga waters and currents strengthening are noticeable throughout the year, even when currents are weakened in other areas of Southern Baikal (the ice-cover period, the beginning of summer stratification). When flowing around the Capes Kadilny and Sobolev, which strongly

Table 3. Characteristics of cold water intrusions at separate stations in Middle Baikal in May-August, 2011.

Station	H, m	h, m	$\Delta Q_{(-)}$, MJ/m^2	ΔO_2, g/m^2
26 May – 6 June				
Cs Strait Malie Vorota – Boldakova River	1378	48	-3.1	14.7
Cs Strait Malie Vorota – Boldakova River	1370	172	-11.5	17.7
Cs Cape Ukhan – Cape Tonky	1566	152	-15.8	46.0
7 km from Cape Izhimei	1628	90	-11.5	33.3
Cs Cape Khoboi – Cape Krestovsky	1630	176	-13.6	42.3
Average	1514	128	-11.1	30.8
21-28 July				
7 km from Strait Malie Vorota	1372	104	-3.7	13.1
Cs Strait Malie Vorota – Boldakova River	1370	118	-5.8	22.0
3 km from Cape Ukhan	1604	132	-8.4	45.5
7 km from Cape Ukhan	1600	130	-15.6	25.3
Cs Cape Ukhan – Cape Tonky	1562	118	-3.0	36.8
7 km from Cape Izhimei	1624	254	-27.4	58.0
Average	1522	143	-10.6	33.5
1-10 August				
Cs Strait Malie Vorota – Boldakova River	1362	84	-5.8	*15.3*
7 km from Cape Izhimei	1584	114	-8.3	27.0
Cs Cape Khoboi – Cape Krestovsky	1628	156	-17.1	41.0
Cs Cape Ukhan – Cape Tonky	1562	124	-5.3	29.4
7 km from Cape Ukhan	1600	94	-8.1	21.0
5 km from Cape Ukhan	1604	142	-12.3	24.3
3 km from Cape Ukhan	1604	70	-4.6	3.0
Average	1597	117	-9.2	24.3

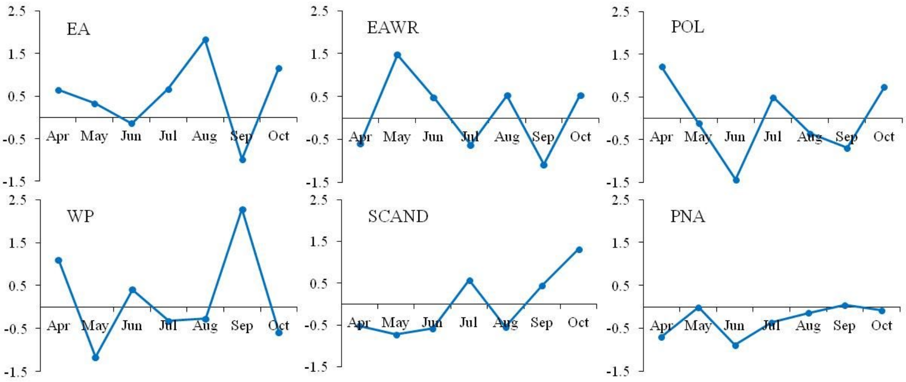

Fig.7. Variations of indices of atmospheric circulation in April-October, 2001.

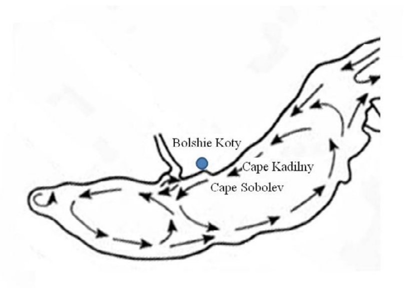

Fig.8. Scheme of currents in Southern Baikal.

protrude into the lake, the current may narrow, vortex and form anticyclonic vortex just opposite the settlement of Bolshie Koty. In this case there will be a sinking of surface water in the center of the vortex. However, this case requires additional research for more exact conclusion.

In the case of the development of mass intrusions, their influence on the parameters of the near-bottom zone waters remains for a long time. In Southern Baikal as well as in Northern Baikal, intrusions influence was also observed in July, but only at half of the stations where intrusions were recorded in May-June. In Middle Baikal, intrusions influence was observed not only in May-July, but also in the first half of August.

The obtained values of the volume of incoming surface water are comparable with the results of previous studies of water renewal due to intrusions (Wuest et al., 2005; Thimitri et al., 2015). Considering the volume of all water in separate basins and the volume of surface water brought in with intrusions to the near-bottom region, there was a renewal of water by 6% in Southern Baikal in spring-summer 2018, by 5% in winter 2004-2005, by 1.6% in Middle Baikal in May-June 2011. In Northern Baikal, like in Middle Baikal, water renewal was small and was 1.7% in June 2001.

Thus, an analysis of the correlation between intrusions and circulation indices showed that the considered cases of mass intrusions in the spring-summer period in Southern and Northern Baikal are associated with the prevailing meridional transport of air masses from the Eastern Atlantic region and the blocking of zonal transport of air masses from both the Atlantic and Pacific Oceans. In Middle Baikal, during the spring-summer period mass intrusions developed under conditions of zonal transport of air masses from the Eastern Atlantic region and at the same

Table 4. Characteristics of cold water intrusions at separate stations in Northern Baikal in June-July, 2001.

Station	H, m	h, m	$\Delta Q_{(-)}$, MJ/m^2	ΔO_2, g/m^2
15-21 June				
Cs hydrometeorological station Solnechnaya – Ushkany Island	886	82	-3.6	*6.3*
Cs Cape Zavorotny – Sosnovka Bay	816	58	-2.4	*4.3*
Cs the Cape Cheremshany – Cape Kabany	888	70	-3.0	*5.2*
3 km from the Cape Elokhin	882	54	-0.7	*1.3*
7 km from the Cape Elokhin	888	94	-3.1	*5.3*
Cs Cape Elokhin – Davsha River	866	68	-2.5	*4.3*
Cs Cape Kotelnikovsky – Bay Bolshoi Amnundakan	804	54	-1.0	*1.8*
7 km from Baikalskoe settlement	800	34	-0.2	*0.6*
Cs Baikalskoe settlement – Cape Turali	800	38	-1.5	*2.7*
7 km from the Cape Turali	716	70	-1.8	*3.3*
Average	835	62	-2.0	*3.5*
17-22 July				
Cs hydrometeorological station Solnechnaya – Ushkany Island	888	56	-1.8	*3.1*
Cs Cape Zavorotny – Sosnovka Bay	816	56	-2.0	*3.6*
3 km from the Cape Elokhin	878	52	-2.0	*3.6*
7 km from the Cape Elokhin	888	58	-2.0	*3.5*
Cs Cape Elokhin – Davsha River	872	50	-1.6	*2.8*
Cs Cape Cheremshany – Cape Kabany	888	58	-1.5	*2.7*
Cs Cape Kotelnikovsky – Cape Shignanda	804	86	-2.0	*3.6*
7 km from Baikalskoe settlement	804	40	-0.4	*0.7*
Cs Baikalskoe settlement – Cape Turali	802	50	-0.5	*0.9*
Average	849	56	-1.5	*2.7*

time from the Northern and Western Pacific Ocean regions. In summer, their development was supported by the meridional transport of air masses from the Eastern Atlantic region. During the winter period, the development of mass intrusions in Southern Baikal was related to an intensification of circumpolar circulation and zonal transport of air masses from the Atlantic Ocean.

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Conflict of interest

The authors declare no conflict of interest.

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