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LONG-TERM FLUCTUATIONS OF THE NORTHERN HEMISPHERE ATMOSPHERIC CIRCULATION ACCORDING TO DZERDZEEVSKII'S CLASSIFICATION

ABSTRACT

The long-term series of fluctuation of monthly and annual Northern Hemisphere atmospheric circulation in non-tropical latitudes from 1899 to 2008 according to Dzerdzeevskii classification have been discussed. The differences in atmospheric circulation between circulation epochs have been identified. The circulation and climatic characteristics of extreme decades of circulation epochs in the Northern Hemisphere and its six sectors – Atlantic, European, Siberian, Far East, Pacific, and American – have been given. The recent, the 1981–2008 period, is characterized by the increase in frequency (number of cases) and duration (number of days) of the southern meridional circulation group

KEY WORDS. Macro-circulation processes, atmospheric circulation fluctuations, circulation epoch, climate fluctuations, Northern Hemisphere, Russia

INTRODUCTION

Atmospheric circulation is one of the most dynamic components of the climate system. Its changes may be quantitatively assessed with the help of the classification of global atmospheric circulation. In the Institute of Geography RAS, the elementary circulation mechanism classification according to B.L. Dzerdzeevskii [Dzerdzeevskii, 1975; Dzerdzeevskii, 1962; Dzerdzeevskii, Kurganskaya, Vitvitskaya, 1946] has been applied. The important feature of this classification is that it characterizes the entire Northern Hemisphere and the trajectories of cyclones and anticyclones over specific regions. Therefore, this classification has been used to study solar – earth relationships [Chernavskaya, Kononova, Val`chuk, 2006]; global and regional changes of climate [Rubinshtein, Polozova, 1966.]; fluctuations of atmosphere – ocean system [Byshev, Kononova, Neiman, Romanov. 2004; Byshev, Nejman, Romanov, 2006], water, snow and ice regimes [Kononova,2003; The Nature of Long-Term Fluctuations of River Discharge, 1976; Titkova, Kononova, 2006] and natural hazardous events in different regions of the Northern Hemisphere [Kononova, 2007; Kononova, Malneva, 2003; Kononova, Malneva, 2007; Kononova, Mokrov, Seliverstov, Tareeva,. 2005].

At the present time, the analysis of long-term fluctuations of atmospheric circulation is lacking proper attention. However, without studying these fluctuations it is impossible to explain alternation of the periods of increase and decrease in air temperatures and total precipitation in isolated regions and the entire Northern Hemisphere; it is also impossible to explain global and regional distinctions in warming of the 1920s–1940s and the last warming.

Studies of long-term air temperature and precipitation fluctuations in different sectors of the Northern Hemisphere have shown their correlation with fluctuations of atmospheric circulation.

The purpose of this paper is to present the results of studies of long-term fluctuations of atmospheric circulation during the 1899–2008 period based on the classification by B.L. Dzerdzeevskii and co-authors and to demonstrate how these fluctuations are reflected in the climate of the Northern Hemisphere and different regions of Russia.

METHODS AND DATA

Analyses of synoptic daily maps allow one to isolate 41 elementary circulation mechanisms (ECM). They differ in direction and quantity of blocking and of southern cyclone outlets. The important feature of ECM is that they are seasonal in nature. Each ECM has a unique cyclone and anticyclone trajectory scheme and description [Dzerdzeevskii, 1968; Dzerdzeevskii, Kurganskaya, Vitvitskaya, 1946], maps of see level pressure and temperature, height of AT 500 and temperatures at AT 500 for 1970–1978 [Savina, Khmelevskaya, 1984], annual series and long-term series of fluctuation for 1899–2008 [Kononova, 2009].

ECM have been grouped in 13 types, and 4 groups (Table 1, Figure 1). The first group is the *zonal* (types 1 and 2: anticyclone on the North Pole, 2–4 of southern cyclone

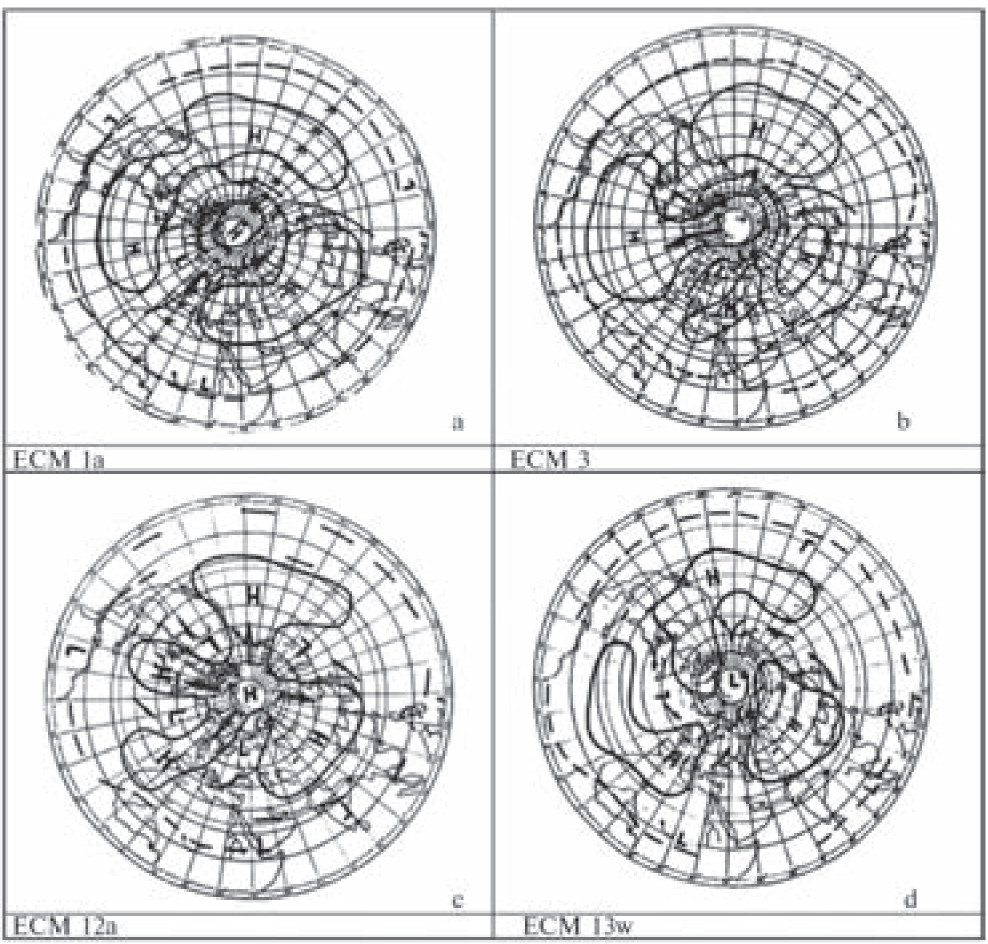


Figure 1. Examples of dynamic schemes of elementary circulation mechanisms (ECM) of different circulation groups according to Dzerdzeevskii: a) zonal, ECM 1a; b) disturbance of zonal circulation, ECM 3; c) northern meridional, ECM 12a; d) southern meridional, ECM 13w. (See also Table 1). Arrows show the cyclonic tracks (dark) and anticyclonic tracks (light). Letters "H" and "L" denote high atmosphere pressure (anticyclone) and low one (cyclone), respectively

Table 1. Characteristic of elementary circulation mechanisms groups according to classification of the Northern Hemisphere extra tropical atmospheric processes [10]

Group of elementary circulation mechanisms	Elementary circulation mechanisms (ECM)	Atmospheric pressure at the Arctic region	Amount of simultaneous blocking processes	Amount of southern cyclones outlets	Example
Zonal	1a*–2b	High	0	2–3	Fig. 1a
Disturbance of zonal circulation	3–7bs	High	1	2–3	Fig. 1b
Northern meridi-onal	8a–12g	High	2-4	2–4	Fig. 1c
Southern meridi-onal	13s**–13w	Low	0	3–4	Fig. 1d

* Numbers of ECM (1 to 13) are labeled by letters "a", "b", "c", "d" according to geographical locations of blocking processes and southern cyclones outlets.
** Letters "s" and "w" indicate summer and winter seasons correspondingly

outlets in 2–4 sectors without blocking). The second group is the zonal disturbance (types 3 through 7: high pressure on the Pole, one blocking over the Hemisphere). The third group is the *northern meridional*, (types 8 through 12: high pressure in the Arctic, 2–4 blockings and 2–4 southern cyclone outlets). The fourth group is the *southern meridional* (type 13) that is characterized by cyclone circulation over the Arctic as a result of cyclonic action on the arctic front especially the regeneration of southern cyclones. Such processes occur during all seasons, but more often in summer: there are only 3 southern cyclone outlets over the Hemisphere in winter, while 4 outlets happen in summer)

The History of alternation of ECM has been given for the entire period beginning in 1899. First, the see level pressure maps [Historical weather maps, 1899–1948] were used and then, the entire collection of maps of Hydrometcentre Synoptic Bulletin (from 1997 – in electronic format).

The History of alternations of ECM has been first developed at by B.L. Dzerdzeevskii and his colleagues, and, then, by his colleagues. The History of alternations of ECM has been published for the period 1899–2008 [Kononova, 2009]. The results obtained using this classification (background material, archives, most recent publications, list of all publication where this classification was used) for the period 1899–2008 are placed on the website www.atmosphertc-circulation.ru.

FLUCTUATION OF ATMOSPHERIC CIRCULATION

The basic purpose of the classification of the atmospheric circulation over the Northern Hemisphere is the analysis of long-term climatic fluctuations and forecast. To address this goal, ECM were grouped in different categories using the History of the alternation of ECM and the ECM duration was calculated on a monthly, circulation season, and yearly basis for the entire period beginning in 1899 (Table 1). These data are also placed on the website www.atmospheric-circulation.ru.

First results of research efforts to study multi-year atmospheric circulation over the Northern Hemisphere based on the History of alternation of ECM, have been published in 1956 [Dzerdzeevskii, 1956]. At that time, the first representations of generalized (composite) circulation groups (i.e., the zonal (the zonal itself and disturbances of the zonal) and the meridional (the northern and southern)) and circulation epochs (i.e., periods with positive or negative deviations of the zonal circulation from its long-term average duration value) were made.

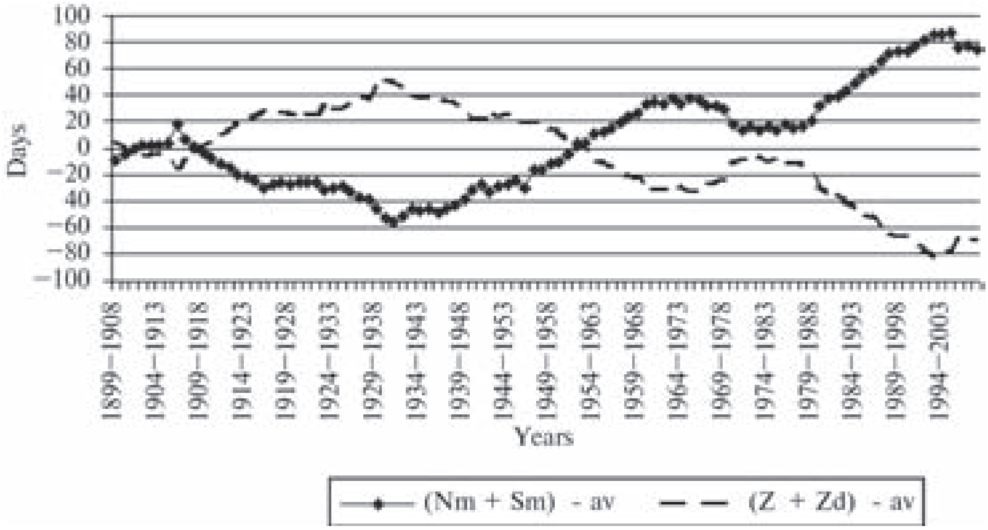


Figure 2. Deviations of the total annual duration of the generalized zonal and meridional circulation groups from corresponding average values (10-year moving average)

There were 3 alternations in circulation epochs form 1899 to 2008 (Fig. 2): 2 meridional (form 1899 to 1915 and form 1957 to the present time) and one zonal (1916–1956). During the modern, the meridional epoch, the duration of the meridional ECM is greater than during the first epoch, as it has been previously suggested by B.L. Dzerdzeevskii [Dzerdzeevskii,. 1968]. The maximal total duration of all meridional ECM was 319 days per year on average in 1997–

Table 2. Summary annual circulation groups duration (dais) in extreme decades of circulation epochs

Period	Duration.	Circulation groups					
		N.m.	Z.d.	S.m.	Z.	N.m.+S.m.	Z.+Z.d.
1899–2007	Average	196	95	45	29	241	124
	Max., year	274 (1915)	163 (1945)	201 (1989)	86 (1938)	346 (2000)	230 (1932)
1906–1915	Average	246	97	4	18	250	115
	Max., year	274 (1915)	116 (1910)	7 (1910)	30 (1913)	278 (1915)	140 (1913)
1930–1939	Average	168	135	13	49	181	184
	Max., year	206 (1933)	159 (1931)	45 (1937)	86 (1938)	209 (1933)	230 (1932)
1960–1969	Average	216	71	52	26	268	97
	Max., year	268 (1969)	93 (1964)	94 (1964)	53 (1962)	314 (1969)	130 (1962)
1988–1997	Average	155	42	149	19	304	61
	Max., year	215 (1995)	57 (1995)	201 (1989)	63 (1992)	338 (1993)	98 (1992)
1998–2007	Average	197	42	119	7	316	49
	Max., year	241 (2007)	59 (1998)	143 (2000)	21 (2004)	346 (2000)	74 (1998)

Note: N.m. – north meridional, Z.d. – zonal disturbance, S.m. – south meridional, Z. – zonal.

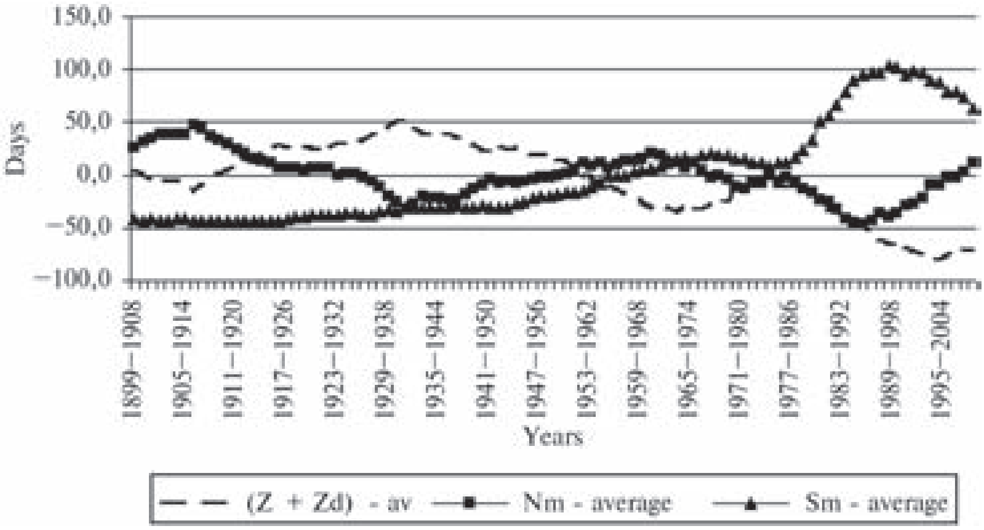


Figure 3. Deviations of the total annual duration of the generalized zonal group, northern meridional and southern meridional groups of circulation from their long-term average values for 1899–2008 (10-year moving average)

2006 (Figure 2) with the absolute maximum in 2000 (346 days, Table 2).

Differences between the first and modern meridional epochs are also associated with the duration of northern and southern ECM (Figure 3).

There were almost no meridional southern processes in the beginning of XX century (Fig. 3). Their duration started to increase in 1920s; only in 1963, it reached the mean value for the 1899–2008. Beginning in 1980s, it grew fast and now, the duration of the meridional southern circulation is over one-third of the year with weather patterns determined by alternations in meridional northern and southern processes.

Figure 4 shows the structure of circulation epochs and the annual duration of each ECM

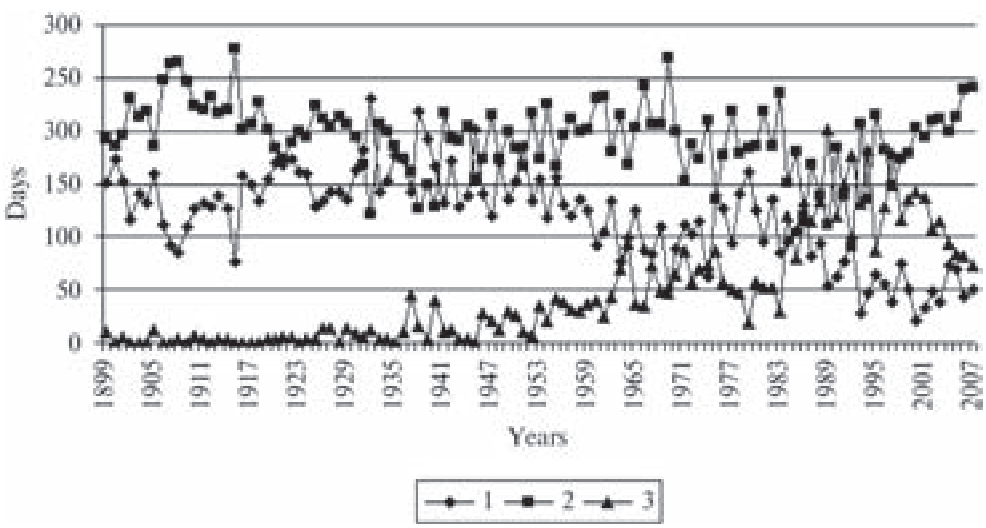


Figure 4. A long-term change in the total annual duration of the generalized zonal circulation and disturbance of zonal circulation and northern meridional and southern meridional circulation groups in 1899–2008

group. The meridional northern circulation group prevails practically during the entire period (the average duration of 193 days per year). The years 1932, 1938, 1939, 1940, 1945, 1951 and 1975 represent the exception. During these years, the zonal circulation was longer in duration than the meridional northern. All years, except for 1975, can be referred to the zonal epoch. In 1989, 1991, 1992, 1994 и 1997, the meridional southern circulation was the longest.

During the meridional epoch, the duration of northern processes was the longest (246 days per year on average, with a 274 days maximum in 1915 (Table 2)). During the zonal epoch and especially in the period from 1932 to 1951, years with the prevalence of the meridional northern circulation alternated with years when the zonal circulation prevailed. A new increase in the duration of the meridional northern circulation that started in 1957 led to its absolute dominance in 1969 (268 days per year with a further decrease to a 91 days per year minimum in 1992 (Figure 4). By that time, the duration of meridional southern processes increased significantly while the duration of the zonal processes reached even greater minimum than in the beginning of XX century. As a result, during the period from 1965 to 1977, the durations of the zonal and meridional southern processes were almost similar. In 1977–1985, at an absolute dominance of the meridional northern circulation, the duration of zonal processes increased and took over the meridional southern processes. From 1986 to 1977, the durations of the meridional northern and southern circulation groups was about the same and exceeded substantially the duration of the zonal group. The duration of the southern group more than by a factor of three exceeded the mean value. This situation determined an extremely instability of atmospheric circulation that has not been seen during the entire previous period. A sharp alternation in atmospheric processes became a reason for a fast growth in re-occurrence of meteorological extremes and hazardous natural events resulting from these meteorological conditions [Kononova, 2007]. In 1997, the duration of the meridional northern processes was 147 days per year compared to 196 days on average for 1899–2008; the duration of the meridional southern processes was 179 days per year compared to 45 days on average for the entire period, i.e., it was four times greater than the long-term average value. From 1998, the duration of meridional southern processes started to decrease, while the duration of the northern processes grew (Figure 4).

From 1998 to the present time, there is a decrease in the duration of the meridional southern circulation with the dominance and a new increase in the duration of the meridional northern circulation and minimal duration of the zonal group. In 2007, the

Table 3. Borders of circulation epoch and the periods inside them

Circulation epoch	Years	The periods inside epoch	Years
Northern meridional	1899–1915		
Zonal	1916–1956		
southern meridional	1957 to present	Simultaneous increase of northern and southern meridional processes duration	1957–1969
		The increase of zonal processes duration	1970–1980
		Fast growth of southern meridional processes duration	1981–1997
		Decrease of meridional southern and growth of meridional northern processes duration	1998–2007

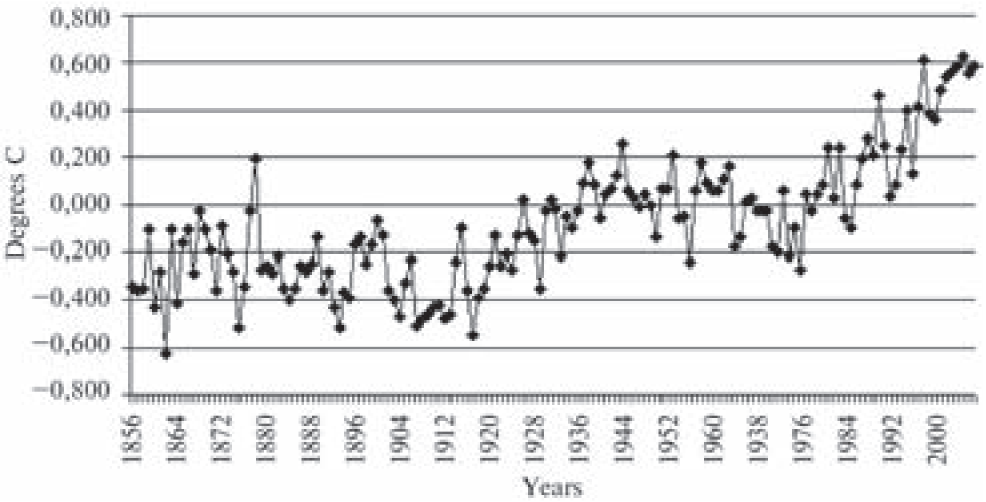


Figure 5. Deviations of the average annual air temperature over the Northern Hemisphere for 1856–2008 from average for 1961–1990 [28]

meridional southern circulation still remained 1,6 times longer than the average (73 days at the average value of 45 days), but was 106 days shorter than in 1997.

Thus, while the meridional northern and zonal epochs were relatively uniform, the meridional southern epoch can be subdivided into 4 periods with different combinations of the circulation group durations (Table 3). Table 2 presents the durations of circulation groups in extreme decades of circulation epochs and specific periods of the third epoch, including the last decade.

FLUCTUATIONS OF CLIMATE OF THE NORTHERN HEMISPHERE

Fluctuations of climate during the period under consideration agree well with fluctuations of atmospheric circulation in the Northern Hemisphere. The data [http://www.cru.uea.ac.uk/cru/data/temperature/] were used to analyze air temperatures of the Northern Hemisphere and fluctuations of atmospheric circulation.

The first epoch over the Northern Hemisphere was cold (Fig. 5). There were negative deviations of average annual air temperature over the Northern Hemisphere for 1899–1915 from the average value for 1961–1990. The years 1917 and 1913 were the coldest for the entire 1899–2008 period with the deviations of –0,542°C and –0,53°, respectively.

Increase in duration of zonal processes in 1920th–1940th was accompanied by the rise in temperatures that was referred in history to as "warming of Arctic regions." There were positive deviations of average annual air temperature over the Northern Hemisphere in 1931, 1937–1941, 1943, 1944 from the average for 1961–1990. The warmest, for this zonal epoch, was the year 1944, with the deviations of 0,163°C.

During the period of decrease in zonal and increase in northern meridional ECM during modern epoch (1957–1985, Fig. 4), there was some decrease in temperature over the Northern Hemisphere (Fig. 5). The year 1976 was the coldest for this period with the deviations of –0,294°C. The last negative deviation (–0,134°C) was noted in 1985.

The period from 1986 to 1997 when there was maximal duration of the meridional southern ECM, was marked with a warming (Fig. 5). A sharp increase in the duration of southern meridional processes correlated to climatic changes in the system "ocean – atmosphere" [Byshev, Kononova, Neiman, Romanov, 2004]. The tropical zone of the Pacific Ocean and the Mediterranean are the basic generators of the southern cyclones that move far north along almost meridional trajectories and bring southern heat and precipitation to high latitudes.

The year 2005 was the warmest for the meridional southern epoch over the Northern Hemisphere with the deviation of 0,625°C. However, in the last 11 years, anomaly of the annual average air temperature over the Northern Hemisphere of approximately 0,6° occurred in four years (0,608°, in 1998, 0,586° in 2004, 0,625° in 2005, and 0,590° in 2007); in other years, the anomalies varied from 0,36° to 0,55°. Thus, in comparison with the previous decade, warming has slowed down.

Now, the system "ocean – atmosphere" is changing [Byshev, Nejman, Romanov, 2006]. There is a decrease in water temperature in the top 600-m layer of the ocean. The Atlantic Ocean is cooling faster than Pacific.

The character of the modern atmospheric circulation is determined by a change in the duration of northern and southern ECM (Table 4). At the present time, the duration of ECM of type 12 (3 to 4 blocking processes and 3 to 4 southern cyclones outlets) is maximal (106 and 122 days in 2001 and 2006, respectively). There were approximately 7 more transitions from type 12a to type 13 during 1993–2002 compared to 1924–1954 (based on the data from [Chaplygina, 1961], and there were 11 times more reverse transitions from type 13 to type 12a. No such alternations happened in 1899–1923. Alternation in ECM types 12 and 13 provides for the best conditions for deepening of atmospheric fronts that leads to increase in re-occurrence of meteorological and ecological extremes registered in recent years.

CIRCULATION EPOCHS IN SECTORS OF THE NORTHERN HEMISPHERE

The elementary circulation mechanism that acts as a uniform and complete mechanism of macro-circulation exchange manifests itself in different ways depending on the location in the Northern Hemisphere: while there may be blocking in one area, a southern cyclone outlet or zonal circulation are possible in another. To study these processes, the Northern Hemisphere was subdivided into six sectors [Dzerdzeevskii, 1968; Dzerdzeevskii, 1970] with their boundaries drawn considering positions of the continents and oceans that determine seasonal character of development of atmospheric circulation. These boundaries are as follows: Atlantic –60°W–0°; European

Table 4. Frequency of change (%) ECM 12a, 13w and 13s in 1899–1954 and 1993–2002 [22]

ECM	PERIODS	ECM			
		12a	13w	13s	Type 13
12a	1899–1923				—
	1924–1954				4
	1993–2002		9	18	27
Type 13	1899–1923	–			
	1924–1954	2			
13w	1993–2002	10		1,5	
13s		12	1,7		
Type 13		22			

–0°–60°E.; Siberian –60°E–120°E; Far East –120°E–170° E; Pacific –170°E–120°W; American –120°W–60°W.

Circulation epochs in different sectors during the same Hemisphere epoch appear to also differ due to features discussed previously.

Relative prevalence of the duration of the zonal or meridional processes in a sector serves as a criterion for defining the circulation epochs in the sector and for the Hemisphere in general. However in this case, the terms "zonal" and "meridional" are applied to circulation processes for the entire Hemisphere, while, in individual sectors, the terms "latitudinal" and "longitudinal" are used. The principles of isolation of latitudinal and longitudinal circulation in individual sector have been developed by B.L. Dzerdzeevskii [Dzerdzeevskii, 1968; Dzerdzeevskii, 1970]. The direction of the air stream in the atmosphere over the sector was used as a criterion to describe a character of circulation. Trajectories of cyclones and anticyclones from weather maps and the direction of the air stream from maps AT 500 were used as input data. Breaking ECM into groups with similar circulation patterns in each of the six sectors of the Northern Hemisphere is presented in [Dzerdzeevskii, 1968; Dzerdzeevskii, 1970]. Additional groups, compared to the ECM grouping in the Northern Hemisphere as a whole, were isolated to characterize, for example, such a poison when Arctic intrusion is displaced to one of the boundaries of the sector. In this case, there may be a penetration of a southern cyclone far north within the rest of the sector, or the latitudinal circulation may be maintained. For such cases, combined definitions of circulation processes over the sector, i.e., "longitudinal northern and longitudinal southern" or "longitudinal northern and latitudinal western" were applied. Similar to these instances, there can be various descriptions of a direction of the air stream in the northern and southern parts of the sector. For example, when there is an intrusion of the air from the north into a stationary anticyclone located in the middle latitudes, the group "longitudinal northern and stationary position" is defined. When there is interfluence of a southern cyclone with cyclones formed on the Arctic front, the term "latitudinal western and longitudinal southern" is used. The maximal number of groups in one sector is 9 (American) and the minimal is 5 (Far East).

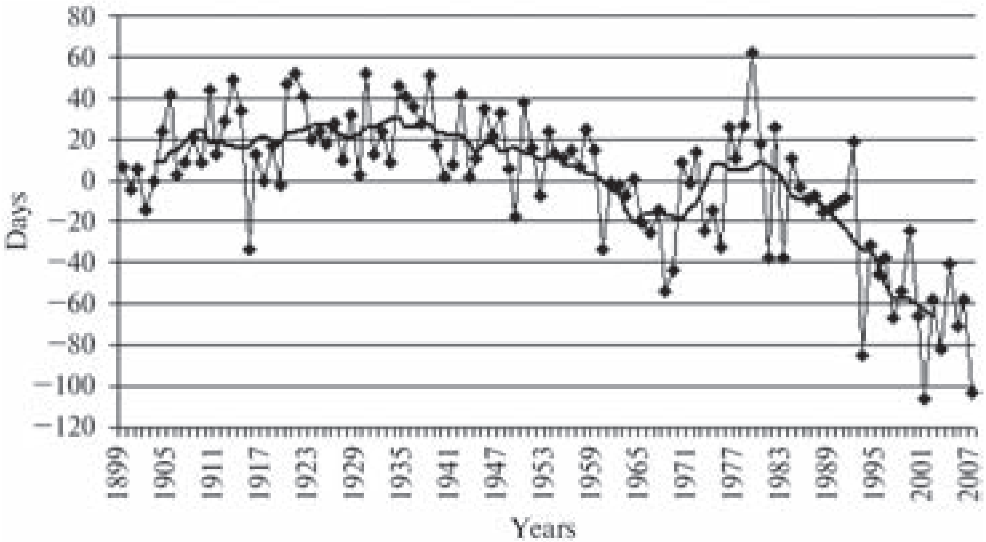
To solve some problems (e.g., establishment of boundaries of circulation epochs in different sectors and defining their seasonal character) it is necessary to use, as in the case of the Northern Hemisphere, only two generalized groups: latitudinal which includes all ECM when latitudinal trajectories of cyclones and anticyclones prevail over the sector, and longitudinal. The generalized latitudinal group includes 3 groups: (1) latitudinal western, (2) latitudinal western and longitudinal southern and (3) latitudinal western and stationary position. All others groups form the generalized longitudinal group. The long-term variations in the duration of the generalized latitudinal groups in each of the six sectors are presented in Fig. 6.

Comparison of these graphs with the graphs for the zonal circulation for the entire Northern Hemisphere showed a shift in the boundaries of the circulation epochs in each sector relative to their boundaries within the Hemisphere.

The boundaries of the circulation epochs in the sectors are presented in Table 5. Analysis of this table indicates that the changes in relative prevalence of zonal over meridional processes and vice versa, occur in oceanic sectors earlier, than in continental.

Besides, the circulation epochs in different sectors during the same Hemisphere epoch, are different in character: they may be zonal in one sector and meridional in another. We will address a character of the circulation epochs of the Northern Hemisphere in each of its six sectors in more details.

There are a different number of circulation epochs in different sectors for the period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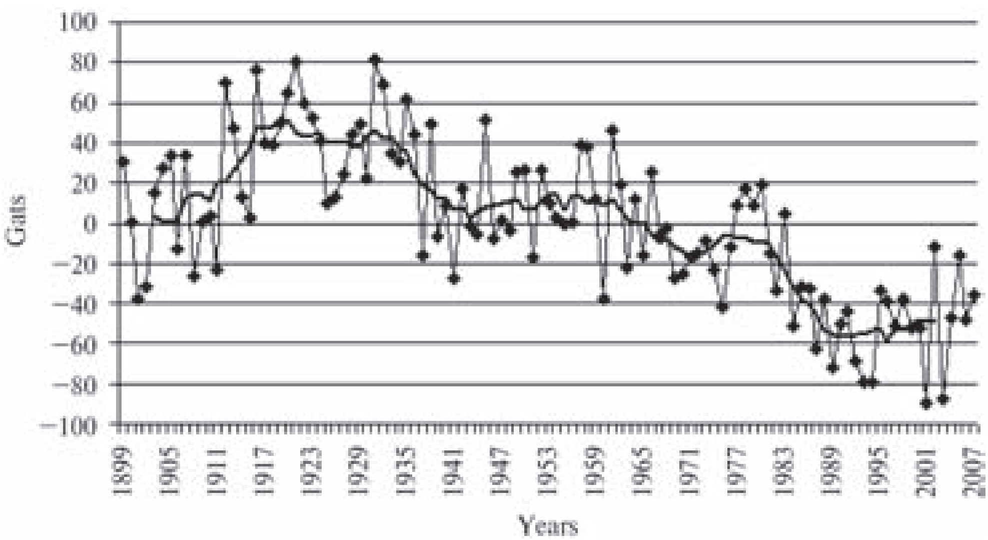
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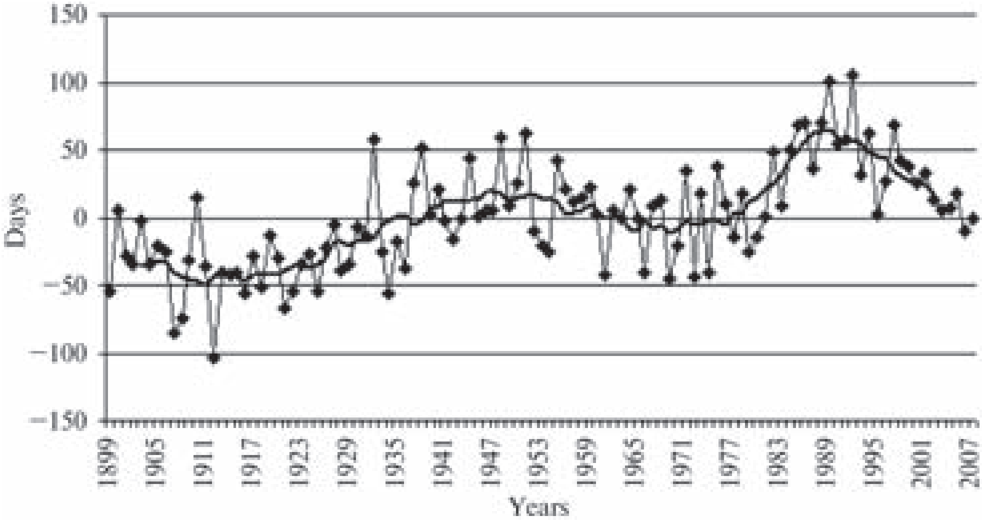
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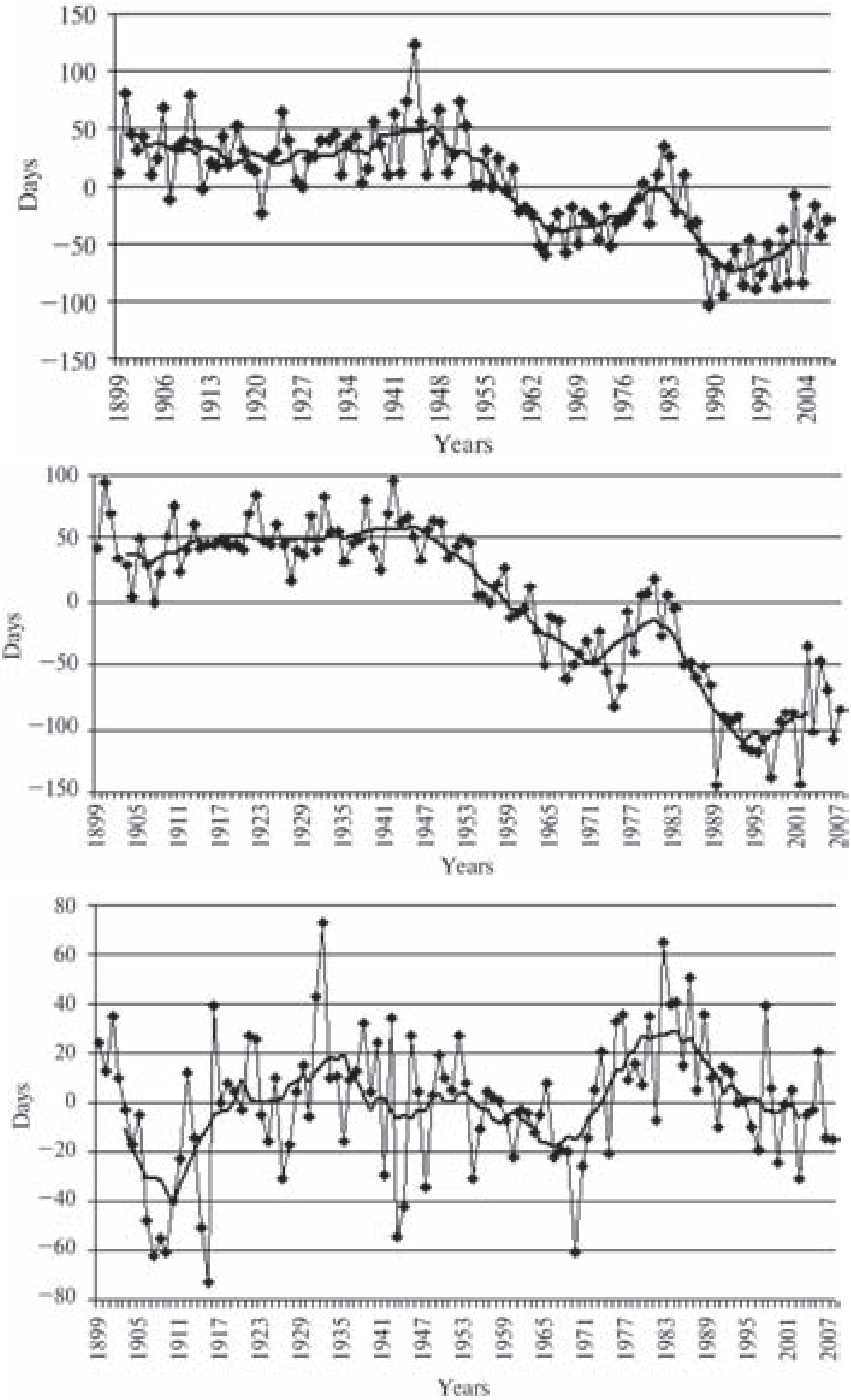

Figure 6. Deviations of the total annual duration of the generalized latitudinal circulation group in sectors of the Northern Hemisphere from the average for 1899–2008:
a – Atlantic, b – European, c – Siberian, d – Far East, e – Pacific, f – American

Table 5. Borders of circulating epoch in sectors of northern hemisphere in 1899–2007

Sector	Circulating epoch							
	I		II		III		IV	
	Borders	character	Borders	character	Borders	character	Borders	character
Atlantic	1899–1959	Zonal	1960–1975	Meridi-onal	1976–1984	Zonal	1985 to present	Meridion
Euro-pean	1899–1966	Zonal	1967 to prezent	Meridi-onal	–	–	–	–
Sibe-rian	1899–1931	Meridion	1932–1980	Fluctua-tion near average	1981 to present	Zonal	–	–
Far East	1899–1958	Zonal	1959 to present	Meridi-onal	–	–	–	–
Pacific	1899–1962	Zonal	1963 to present	Meridi-onal	–	–	–	–
Ameri-can.	1899–1915	Meridion	1916–1942	Zonal	1943–1971	Meridion	1972 to present	Zonal

of 1899-2008. As shown in Table 5 and Fig 6, there are 2 circulation epochs in the European, Far-East, and Pacific sectors: (1) zonal and (2) meridional; as it was noticed above, these sectors, since the second half of XX century to the present time, represent the generators of the southern cyclones.

In the Siberian sector, there are 3 circulating epochs: (1) meridional, (2) one without a clear prevalence of either latitudinal or longitudinal processes, and (3) zonal, with a substantial role of southern cyclones, i.e., the circulation group "latitudinal western in combination with longitudinal southern."

In the Atlantic and American sectors, there are 4 opposite in sign circulation epochs: during a zonal epoch in the Atlantic sector there is a meridional in the American.

Thus, the first, meridional, epoch in the Northern Hemisphere characterized by the development of the blocking processes in the Siberian and American sectors, has manifested itself in the meridional epochs specifically in these sectors. The zonal epochs in the very beginning of XX century occurred in the oceanic (the Atlantic and Pacific) and their dependant European and Far-East sectors. The epochs that coincide in time with the third, i.e., the meridional southern, Hemisphere epoch, reflect periods in its development presented in Table 3. At the present time, the Pacific, Far-East, and European sectors are experiencing the bulk of re-occurring southern cyclones [Byshev, Kononova, Neiman, Romanov, 2004].

Characteristic periods of fluctuations of the latitudinal circulation in all sectors may be identified from data presented in Fig. 7. Thus, from 1899 to 1934–1943, the duration of the latitudinal circulation differed significantly between individual sectors. From 1934–1943 to 1969–1978, it varied about the mean in all sectors, with the exception of the Far-East and Pacific sectors where it was above the average till 1954–1963, with a decrease in the future years. Beginning in 1970–1979 till the present time, the duration of the latitudinal circulation between individual sectors differed even to a greater degree then in the beginning of the century. The greatest differences in the duration of the latitudinal circulation are between individual sectors in 1989–1998. Therefore, during the periods of maximal development of the meridional Hemisphere circulation (both northern and southern) there are the maximal differences in the durations of latitudinal circulation between individual sectors.

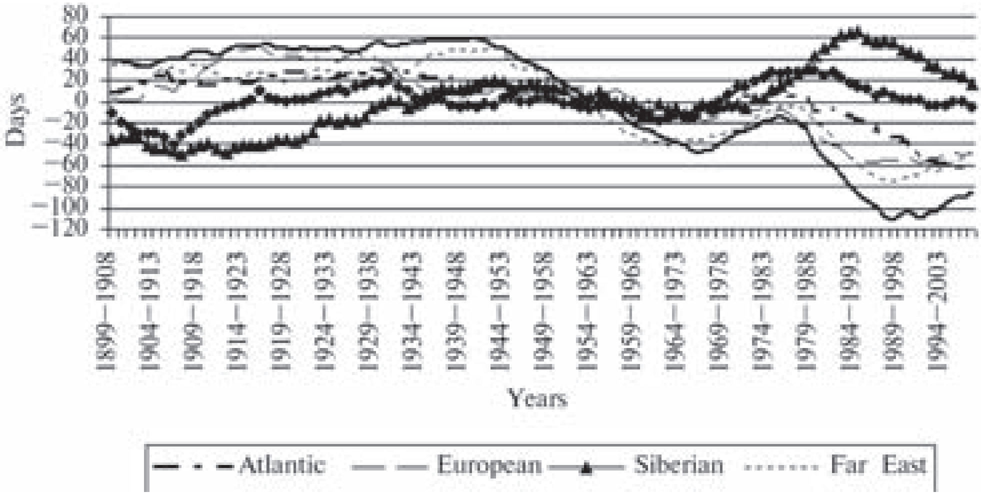

Figure 7. Deviations of the total annual duration of the generalized zonal circulation group from the average value in six Northern Hemisphere sectors (10-year moving average)

Analysis of fluctuations of the durations of all circulation groups in each sector indicated the maximal increase in the outlets of the southern cyclones and the maximal negative deviations in the latitudinal circulation group in the Pacific, Far-East, and European sectors in 1989–1998.

Changes in the duration of the latitudinal and longitudinal circulations impact the sectors' climate and meteorological extremes. Thus, under the same ECM in the Siberian and European sectors there are opposite in sign air streams. This leads to the formation of temperature extremes different in signs. For example, the winter of 1906/07 in Siberia was warm, while in Western Europe (based on [Easton, 1928], it was cold. The winter of 1911/12 was cold and snow free in Siberia but warm and with significant snow in Western Europe. A. Kosiba [Kosiba, 1962.] has noticed a decrease in summer temperature in Eastern Europe during the entire 1939–1959 period.

B.L. Dzerdzeevskii [Dzerdzeevskii, 1969] thought it was necessary to have a set of climatic data for each circulation epoch because just a mean value for the entire period alone can not be used to characterize modern climate. This thesis is especially important now when many regions are experiencing extreme weather evens with a low probability of occurrence of one in 20, 50, and even 100 years.

REGIONAL FEATURES OF ECM

Within each sector, individual ECM are characterized by different circulation modes in different parts of the sector. Often, within latitudinal ECM, in northern areas there is movement of cyclones, while anticyclones move or stationary within southern sectors. In longitudinal ECM, blockings in western sectors are accompanied by outlets of southern cyclones in their eastern parts. In order to describe circulation and climatic properties of individual territories within the sectors, each sector has to be broken into areas based on cyclonic or anticyclonic nature of ECM. This procedure has been applied to the territory of Russia [Kononova, 2005].

Using the Black Sea coast of Krasnodar region and the western steppe region of the Altai region as examples, we will demonstrate the relationships between circulation and climatic characteristics.

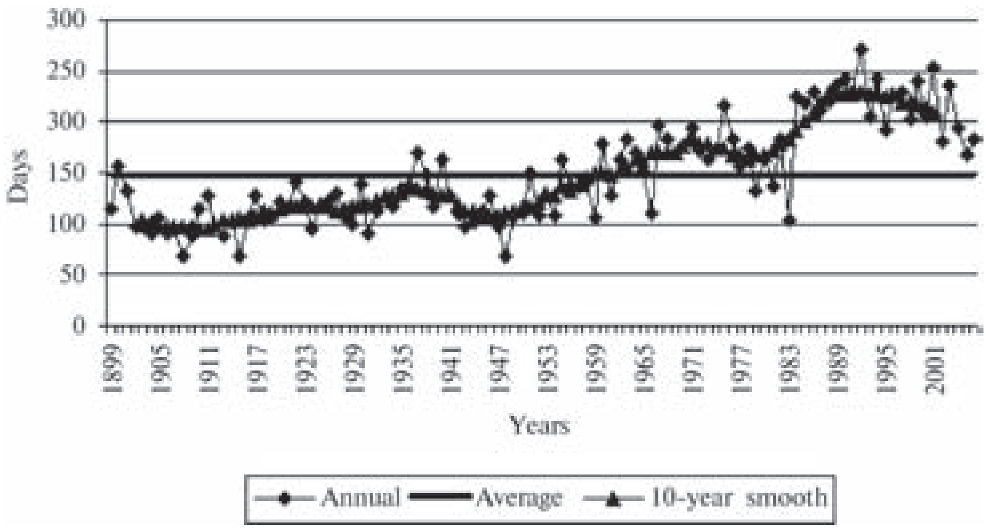

Figure 8. Fluctuation of the total annual duration of cyclonic circulation over the Black Sea coast of Krasnodarsky region

As shown in Fig. 8–11, fluctuations of annual precipitation sums in these regions are consistent with variations in the duration of their cyclonic circulation. This is important for the analysis of hazardous natural processes that occur due to meteorological conditions (mudflows, landslides, avalanches, etc.), for which monitoring is conducted from time to time. According to known data on hazardous natural processes for particular regions, there is a connection with certain ECM. Data on fluctuations of the duration of these ECM for 1899–2008 may be used to establish a degree of hazard from increased activity of analyzed processes in the present and near future.

CONCLUSIONS

Three circulation epochs with different ratios of the durations of the circulation groups were identified based on the analysis

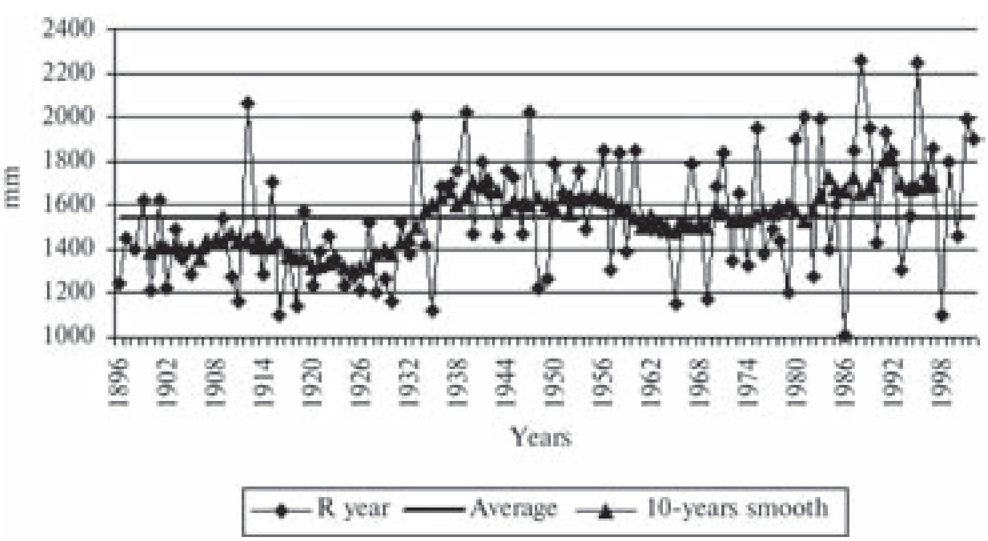

Figure 9. Fluctuation of the total annual precipitation in Sochi

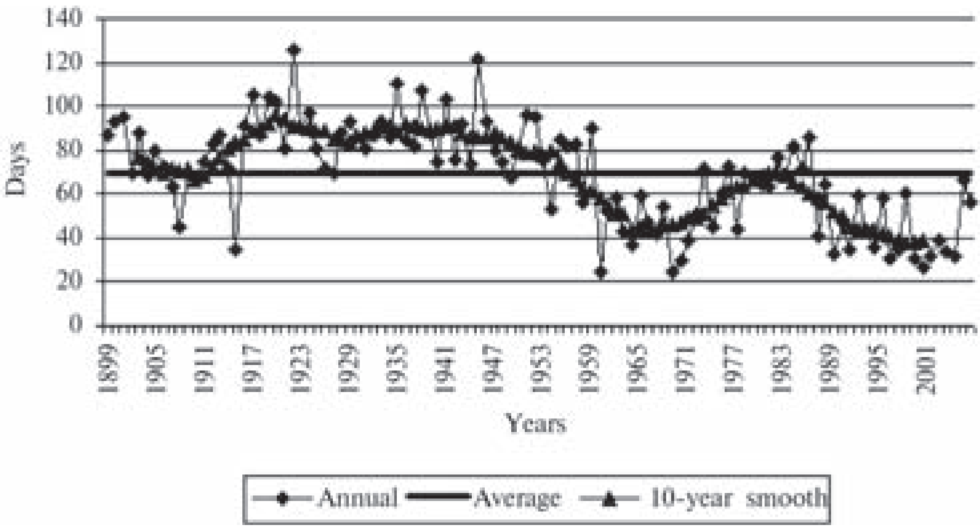

Figure 10. Fluctuation of the total annual duration of the cyclonic circulation over the Altai region

of long-term fluctuations of atmospheric circulation over the Northern Hemisphere; these epochs have determine the climate of the larger circulation epoch from 1899 to the present time.

The first circulation epoch (1899–1915) was marked by the deviation of the total annual duration of the meridional northern processes (types 8 through 12) from the average for the entire period (1899–2008). The average annual air temperature over the Northern Hemisphere during this period was lower than the average temperature for the period 1961–1990 accepted by WMO as the standard period.

The second circulation epoch (1916–1956) was marked by long deviations of the total annual duration of the zonal circulation from the 1899–2008 average. The average annual air temperature over the Northern Hemisphere during this period was above the average for 1961–1990. Especially significant

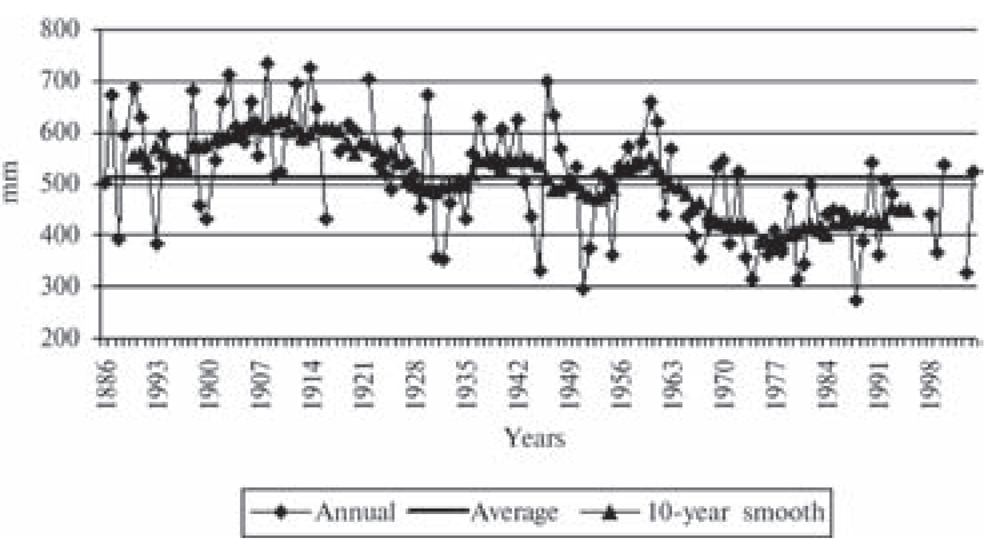

Figure 11. Fluctuation of the total annual precipitation in Barnaul

rise in temperatures was observed over high latitudes and this period was referred to in history as "warming of the Arctic."

During the third circulating epoch (1957 – present time), there were positive deviations of the total annual duration of the meridional southern processes (type 13), when cyclone circulation over the Northern Hemisphere was supported by three to four southern cyclone outlets in different sectors of the Hemisphere. During 1981–1997 of this epoch, there was the greatest increase in the annual duration of the southern processes with a simultaneous substantial increase in the average annual air temperature over the Northern Hemisphere. The greatest positive deviations of the average annual temperature over the Northern Hemisphere from the average for 1961–1990 were in 1998 (0,608°C) and in 2005 (0,625°C).

All processes have intensified during the extreme decade of 1906–1915 of the meridional northern circulation epoch, when in the Northern Hemisphere, the duration of the total annual meridional northern processes was the longest (274 days/year) with the most significant negative deviations from the average annual air temperatures (–0,523°C in 1907 and –0,542°C in 1917).

In the extreme decade of the zonal circulation epoch (1930–1939), there was the longest total annual duration of the generalized zonal group of circulations: 230 days/year. The greatest positive deviation of the average annual air temperature over the Northern Hemisphere during this decade was 0,141°C (1938). The year 1944 was the warmest with the deviation of 0,163°C.

The modern meridional circulation epoch is the most unstable. It has three extreme decades with the maximal duration of the meridional processes: northern (1960–1969), southern (1988–1997), and northern-southern (1997–2006).

In 1960–1969, the total annual duration of the meridional northern processes was comparable to the level for 1906–1915 (268 and 274 days/year, respectively). The duration of the meridional southern processes in 1963 reached its average long-term value for 1899–2008 and continued to grow. The average annual air temperature over the Northern Hemisphere decreased with the deviations of –0,222°C in 1964 and –0,294°C in 1976. The average annual total precipitation over the northern Hemisphere increased as a result of the development of atmospheric fronts.

In 1988–1997, the maximal total annual duration of the meridional southern processes was noted, with the maximum of 201 days in 1989. The maximal positive deviation of air temperatures in XX century occurred immediately after this decade (in 1998, 0,608°C).

In 1998–2008, the total annual duration of the meridional southern processed decreased with the increase in the duration of the meridional northern processes; as a result, the duration of the meridional processes on average for the decade was 319 days and has reached its maximal value in 2000 (i.e., 346 days/year). That year was marked with decrease in the average annual temperature of the Northern Hemisphere with the deviation of 0,357°C. This decade had the maximal (for the entire observation period) positive deviation of 0,625°C in 2005. Similar to the period 1960–1969, there was an increase in the annual total precipitation on average for the Northern Hemisphere.

The fluctuations of the duration of the atmospheric circulation processes of the Northern Hemisphere cause fluctuations of the air temperatures, precipitation, and, as a result, the increase in reoccurrence of the hazardous natural events in different regions of the northern Hemisphere.

It is important to consider the character of circulation epochs in modeling efforts that target circulation of atmosphere and climate because alternations of circulation epochs impact fluctuations of air temperatures and precipitation over the Northern Hemisphere.

ACKNOWLEDGEMENT.

This research was funded by the Russian Foundation for Basic Research (RFBR), project 08-05-00475. ■

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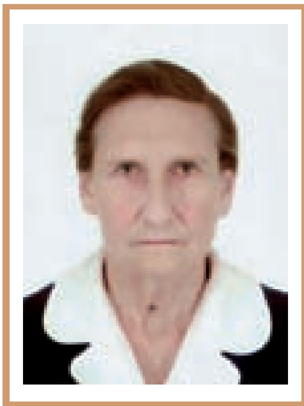

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