Dynamics of current climatic indices in Tomsk and their relation with the state of global atmospheric circulation

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The results of studying the dynamics of monthly average air temperature, precipitation, sunshine duration, and periods with atmospheric drought and excessive moistening in the second part of the 20th century in Tomsk are presented, as well as the results of its comparison with peculiarities of anticyclonic activity in the region and the state of global atmospheric circulation.

It is well-known that in the recent years the regional climate became more variable and the frequency of extreme weather conditions and natural calamities increased. At the same time, the global-scale mean characteristics of the climate have only weak tendencies of different direction. A typical example confirming this statement is the weather in Tomsk in the second part of the 20th century. Thus, Ref. 1 presents the evidence that the growth of the annual temperature observed everywhere in the Tomsk Region (2.0–4.9°C for 100 years) considerably exceeds the corresponding growth calculated for the Northern Hemisphere as a whole (0.6°C for 100 years). The thermal conditions in Tomsk for 1950–1998 are also characterized by significant fluctuations of the annual temperature T_{an}. The value of T_{an} on the average for the period is equal to (0.15 ± 0.19)°C (Fig. 1*a*).

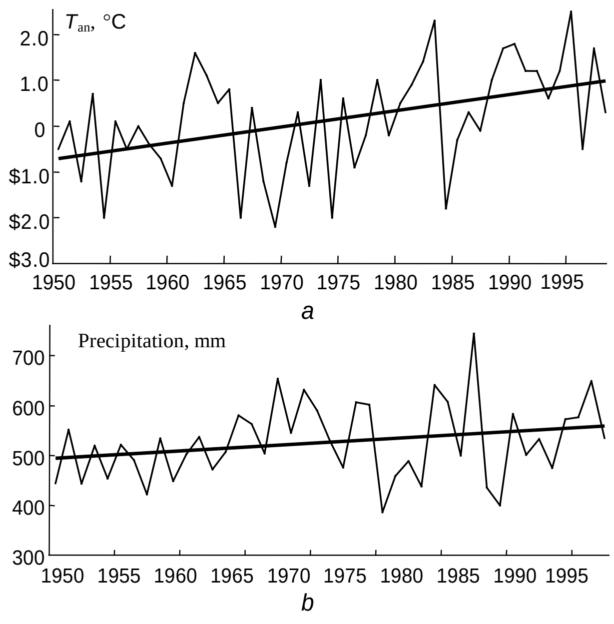

Fig. 1. Annual air temperature and precipitation amount in Tomsk.

The period under study started with small negative and close to zero values of T_{an}. The absolute minimum of T_{an} (−2.2°C) began in 1969. In winter 1968/69 the number of days with the temperature below −30°C was as large as 61, what was three times larger than the standard value.

The second minimum of T_{an} falls on 1974 (−2°C), and starting from 1980 T_{an} becomes steadily positive. Thus, we can see two periods with low (mostly negative) T_{av}: 1950–1960 and 1966–1974, and two periods with high (mostly positive) values of T_{an}: 1960–1965 and 1980–1998, except only for 1984.

The data on the frequency of months (n) with the monthly average temperature (T_m) within the climatic norm (T_n) for this month in Tomsk, i.e., with $T_m - T_n = \Delta T \leq 1$°C, anomalously cold and warm months (c and w) $1.2\,\sigma_{T_n} > \Delta T > 1$°C, and extremely cold and warm months (e.c and e.w) with $\Delta T \geq 1.2\,\sigma_{T_n}$ (σ is the standard deviation of the T_n value) for the cold season of 1980–1998 are given in Table 1, from which it follows that cold and extremely cold months account for less than 14% of cases.

Table 1. Frequency (number of cases) of thermal condition classes in Tomsk for 1980–1998

Thermal conditions	Month			
	XII	I	II	III
e. w	8	8	6	8
w	5	5	6	5
e. c	1	2	1	0
c	2	0	3	1
n	3	4	3	5

In other cases, warm, extremely warm, and close-to-norm months were observed, and extremely warm months account for about a half of all cases. This supports the opinion about increasing variability of the current climate and a large contribution of the temperature of winter months to the global warming. Besides, these data evidence the global climate warming and the obvious change of the precipitation conditions in the region under study.

The consequences of extreme thermal and precipitation conditions are such phenomena as atmospheric drought and excessive moistening revealed with the Ped index (S_i).[2] In Tomsk these phenomena are most often observed in the warm season and their

Table 2. Frequency (number of cases) of atmospheric drought and excessive moistening of moderate and high intensity in 1980$1997

Phenomenon	Month											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Drought	1	2	8	4	6	4	4	2	1	4	2	1
Moistening	0	0	0	1	1	3	1	1	3	0	0	1

month distribution here is uniform. However, droughty months (except for September) were observed more often in both the cold and warm half years. In August and February the probability of the both phenomena is the same. March also became extremely droughty (no one case of excessive moistening was observed for 50 years). The revealed tendencies became even more pronounced in 1980$1997 (Table 2).

In these years, excessive moistening of moderate and strong intensity was not formed in October, November, January, February, and March, i.e., the tendency to the decrease of precipitation amount was observed in the cold season. The tendency of the same sign, but less pronounced, is characteristic of April, May, and July. Thus, the tendency to climate warming in Tomsk is mostly caused by formation of extreme thermal conditions in the cold season and more frequent atmospheric droughts.

The revealed indications of climate warming in Tomsk are also supported by peculiarities of the radiative conditions presented in Table 3. It follows from this table that the sunshine duration in Tomsk increases in all seasons. This conclusion somewhat contradicts the opinion[3] that the maximally possible influx of the solar radiation in the Northern Hemisphere decreases by 4$10%, and this decrease is especially pronounced in winter months. Our results confirm once again the above opinion that the global tendencies at the regional level may be weaker and even have the opposite direction.

Table 3. Sunshine duration in Tomsk (mean number of hours in numerator and standard deviation in denominator) and its trend

Month	January	April	July	October	Year
Duration	55.0 / 15	223.4 / 38	315.2 / 43	84.7 / 24	2003 / 170
Trend (hours for 10 years)	4.3	2.1	2.8	4.8	3.5

Formation of the weather conditions, including extreme ones, is connected with both regional synoptic processes and a state of the global atmospheric circulation. In this paper regional processes were characterized by the frequency of anticyclonic situations according to the Vitels typification,[4] as well as the data on the state of the Siberian High and the activity of processes of eastern transport blocking, the initial information for which was borrowed from Refs. 5 and 7.

Analysis of the data for four central months of the seasons revealed the decrease of the number of anticyclonic situations (Table 4). The most pronounced tendency is the decrease of the number of days in January and April (from 2.5 to 2.1 days for 10 years), in which the effect of the Siberian High is traditionally strong. In the summer and fall periods, the changes are far less significant (less than one day for ten years), what agrees with the above conclusion that just in winter and spring the temperature growth is most pronounced.

Table 4. Trend equations for the number of days with anticyclonic situation in southwestern Siberia

Month	Trend equation
January	*Y* = 26.7 $ 0.25·*u*
April	*Y* = 25.3 $ 0.21·*u*
July	*Y* = 15.4 $ 0.08·*u*
October	*Y* = 19.0 $ 0.05·*u*

Analysis of the data on the position and intensity of the Siberian High revealed the pronounced tendency to the growth of atmospheric pressure at its center and its displacement to the west at least for the period since the 1960s until now. Besides, the yearly averaged west displacement of the center became active in 1966$1967, 1986$1987, and 1994$1995 (Fig. 2), what is indicative of the presence of favorable conditions for anticyclogenesis over southwestern Siberia in winter and the transient seasons.

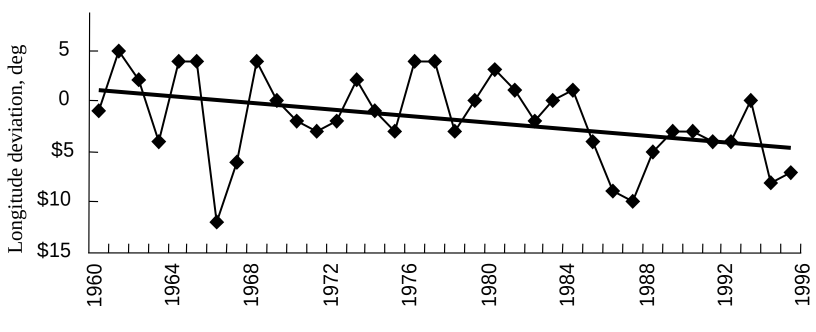

Fig. 2. Longitude deviation of Siberian High from the mean climatic value.

At the same time, as was noted in Refs. 5$7, since 1986 the number of days with blocking anticyclones in the European-Asian sector steadily decreased at least till 1994. The previous minimum was observed in 1973$1974.

Thus, the Vitels typification reflects the effect of both the Siberian High and blocking anticyclones on synoptic processes in southwestern Siberia. The comparison of the data on anticyclonic activity and sunshine duration points to the presence of common tendencies. Thus, the decrease in the number of sunshine hours in the warm season can be explained by weakening of the blocking processes, what is especially typical of summer months (July). To the contrary, the increase of sunshine duration in April and October is the result of intensification of the Siberian High.

The state of the global circulation was assessed with invoking such its characteristics as the angular momentum of zonal wind (δh), the resulting zonal transport (o), the angular speed of Earth's revolution (ν), and the Southern Oscillation Index (SOI). Their description can be found in Ref. 5. Figure 3 shows the dynamics of these indices in the second part of the 20th century. This dynamics was compared with the behavior of temperature and precipitation (see Fig. 1) and the frequency of periods with atmospheric drought and excessive moistening of different intensity as judged from observations in Tomsk for the corresponding period. As a result, the following conclusions were drawn.

1) During El Niño episodes (SOI < 0), the precipitation amount in Tomsk decreases, and the anomalously dry months are observed twice as often as the wet ones. The more intense is El Niño, the more pronounced is this tendency (for example, in 1957, 1965, 1977, and 1986). The air temperature in these cases is usually higher than the normal one (1963, 1965, 1980, 1982, 1983, 1990$1995). During the La Niño episodes (SOI > 0), the monthly mean temperature in Tomsk is equal to or lower than the normal one (1956, 1970, 1974, 1996).

2) As the eastern phase establishes in the quasi-biennial cycle in the equatorial stratosphere, monthly precipitation amounts in Tomsk are equal to or less than the climatic norm, that is, the tendency to drought is observed. The western phase attends the equiprobable formation of both droughty and overwet periods with prevalence of days close to the norm. Besides, during the western phase, the frequency of cold and extremely cold months increases. The eastern phase corresponds to some increase of the cases with extremely warm weather. The most prominent example of this tendency is the temperature in Tomsk in 1968$1970. Thus, from March 1968 to July 1969, when the eastern phase occurred, the record-breaking low (even for Siberia) temperature was observed. From August 1968 to August 1970, the temperature was much higher (within the norm and higher than the norm).

3) A close direct relation is observed between the annual behavior of ν and the precipitation amount. The increase of the speed leads to the increase of precipitation in Tomsk, and deceleration of the Earth's revolution leads to the decrease. At the same time, no stable relations between this characteristic and the temperature were revealed.

4) The inverse relation is observed between the angular momentum of zonal wind and the precipitation amount, while the direct relation exists between this characteristic and the monthly mean temperature.

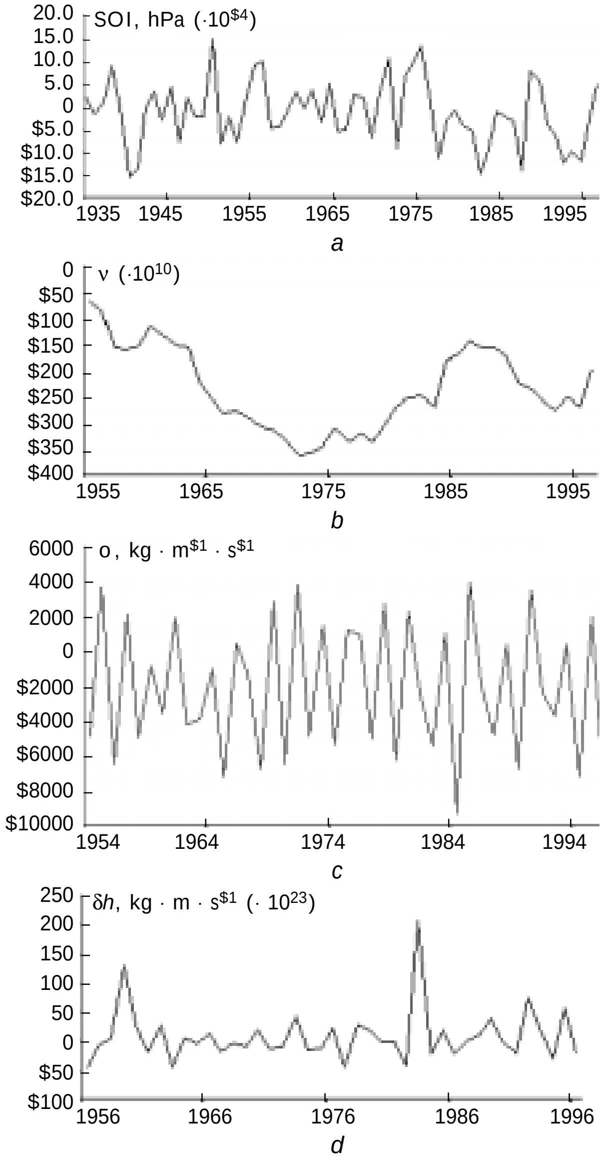

Fig. 3. Mean annual values of Southern Oscillation Index (*a*), variation of the angular speed of Earth's revolution (*b*), resulting zonal transport (*c*), and angular momentum of zonal wind (*d*).

It was found that during the El Niño events the frequency of the extreme conditions according to the Ped index (S_i) is twice as high as during the La Niño events. The eastern transport in the equatorial stratosphere mostly corresponds to the droughty conditions in Tomsk. The maximal values of ν also correspond to high positive values of S_i, but with a one-month shift.

The correlation analysis of geodynamic factors and the index S_i, whose results are presented in Table 5, revealed some relations promising for the further study: between the angular momentum δh and slight drought (r = $ 0.41) and between the resulting zonal transport and strong drought (r = 0.7).

Table 5. Correlation coefficients between S_i and parameters of global circulation

Geodynamic parameter	Atmospheric drought			Excessive moistening		
	weak	moderate	strong	weak	moderate	strong
δh	$0.41	0.2	$	$0.15	$0.23	0.63
SOI	$	0.16	$	$	$0.32	$0.31
ν	0.15	$0.13	$0.19	$	0.45	$0.22
o	$	$	0.7	0.24	$0.22	$0.83

The overwet phenomena on the whole are related more closely with the parameters of global circulation. Thus, strong moistening has the direct relation with the angular momentum (0.63) and the negative relation ($0.83) with the resulting zonal transport. Excessive moistening of moderate intensity is related most closely with the angular speed of the Earth revolution (0.45).

Thus, some peculiarities of temperature and precipitation behavior in Tomsk can be explained using geodynamic factors. The revealed peculiarities of the global circulation, dynamics of its main quantitative indices, and the presence of some relations with the weather conditions in Western Siberia can be used to understand and explain the tendencies of the current climate, as well as to predict its further evolution.

Acknowledgments

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