Synoptic pattern in Tomsk since 1993 until 2004

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We describe a pattern of synoptic processes observed in Tomsk region during the period from 1993 to 2004. The pattern of synoptic processes has been reconstructed based on multilevel classification of atmospheric processes, we have proposed earlier. The lowest and the most detailed level makes it possible to investigate the geophysical processes not only in the main synoptic objects, cyclones, anticyclones, fronts, but also inside each of them.

The problems caused by possible global change of the environment and climate call for the necessity to study in detail the dynamics of as large number of geophysical parameters as possible. In interpreting the geophysical parameters, a demand arose for synoptic information, which would enable one to take into account not only the advective transfer but also the transformation of atmospheric processes. In earlier times, such information was accessible to a wide research community and, as a result, many reviews were published on this subject. At present, the dissemination of information is limited. The city of Tomsk is one of the scientific centers of Russia where geophysical investigations are being performed in different fields at the academic and university research facilities. To use the geophysical studies when interpreting the results of investigations of synoptic information, the present review of synoptic processes has been prepared covering a 12-year period.

Tomsk is located in Western Siberia. This territory is mainly in midlatitudes and partly in high latitudes of the northwest Asia thus being exposed to all fluctuations of the general circulation of the atmosphere of the northern hemisphere. At the same time, the synoptic conditions here depend on the peculiarities in the landscape. The region is bounded from the west, southeast and the east by the mountain ranges of Ural, Altai, Central Siberian Plateau and is open to the Arctic Ocean from the north and vast areas of Kazakhstan and Middle Asia in the south. This region is subjected to both the arctic and tropical air masses that may cause the development of intense atmospheric processes.[1]

Western Siberia can be subdivided into three main climatic zones,[2] the north zone with the south boundary at 65°N, the second zone is located between 65°N and the line passing from the Ural to Tyumen', Tara, to the north from Novosibirsk, and further to the east. The south boundary of the third zone passes in the region of Petropavlovsk (Kazakhstan) to the foothills of Altai. Tomsk is located at the boundary between the second and third zones.

The zone where cyclones are observed most frequently lies in the central part of Western Siberia between 65°–85°E and 55°–65°N. This region is characterized by the strongest cyclonic activity, which is retained during the whole year.[3] During winter period, the developed cyclones are observed most often in the arctic fronts and in summer period in the polar fronts.[1] In summer the circulation processes are weakened on the entire territory of the Western Siberia. Depending on the transfer trajectory one can isolate three types of cyclones in Western Siberia, namely, the west (1*a*), south (2*a*, 2*b*, 2*c*) and north cyclones (3*a*, 3*b*) (Fig. 1). In winter Siberian, or the so-called Asian anticyclone, makes a great impact on the circulation conditions in Western Siberia. The center of this anticyclone is located in Mongolia or in the south of Eastern Siberia. Depending on the degree of the development of this anticyclone the frequency of cyclones in the south-east Siberia can vary within wide limits.[1]

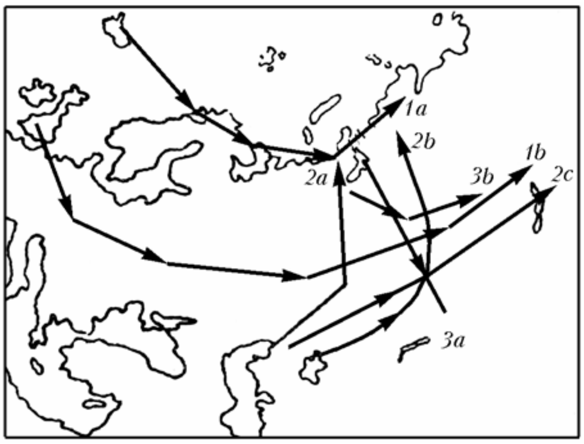

Fig. 1. Trajectories of cyclone invasions to the territory of Western Siberia.

Western cyclones formed on the waves of arctic and polar fronts, are often generated in a series, in which each subsequent cyclone is transported to the south from a preceding one. And, at the end of each series the anticyclone or its ridge are shifted.

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The north or the so-called “diving” cyclones are formed at the arctic front at highly developed meridional transfer. However, the north cyclones are observed in the case when the altitude frontal zone forms a blocking high-pressure ridge over the Ural, and along its east periphery, these cyclones drop down from the Arctic to the territory of Western Siberia down to the south regions. The trajectory of these formations depends on the orientation of the ridge axis. If the axis has the north or northwest direction, then the intrusion of cyclones is designated as a polar one, and if the axis direction is northeast, the intrusion of cyclones is designated as the ultrapolar one. These processes are typical for a cold half-year. In summer they are not observed.[3]

The emergence of the south cyclones are due to the cyclonic activity in the polar front. The main peculiarity of thermo-baric field, necessary for the emergence of the south cyclone, is the presence of a deep trough oriented toward the Black, Caspian, or Aral seas. Besides, the formation of local cyclones and anticyclones over Western Siberia also takes place quite often.

The peculiarity of anticyclone activity in the Western Siberia is the impact of the Siberian anticyclone on the weather conditions of the north and northwest periphery as well as anticyclones completing the cyclonic series. The Siberian anticyclone produces its effect during cold half-year, but with increasing intensity of general atmospheric circulation, its ridge affecting the territory of Western Siberia, is broken.

In the case of the *1a* circulation type the trajectories of final anticyclones pass through Tomsk and to the north of Tomsk that results in the fact that the weather in this city is affected first by the east and central, and then west parts of the formation.

At circulation of type *1b* the final anticyclones pass to the south and then the northern half of the formation makes an impact on the weather formation in the region.

For optical prediction we have classified the types of synoptic situations. The degree of decomposition of synoptic position into separate synoptic situations can be different. Our classification consists of several levels.

I. All situations are subdivided by genetic sign – origin of air mass, observed in a given geographic region. This is a geographic type of air mass.

II. The classification recognizes, in the thermobaric field available, the characteristic elements, namely, cyclones, anticyclones, low-gradient fields, saddles, and contrast zones occurring in the pressure field without a marked temperature change.

III. Because all synoptic objects are three-dimensional and are characterized by definite vertical and horizontal lengths, then it is quite clear that in their separate parts the deviations from general characteristics will certainly take place.

Using such prerequisites, the area of cyclones and anticyclones was subdivided into nine parts: north, northeast, east, southeast, south, southwest, west, northwest, and central.[4]

At the laboratory of optical weather of IAO the automated station is being operated in a routine mode, which determines meteorological parameters of the atmosphere and some its gas components in an hour interval, therefore in creating the database we described the synoptic conditions in Tomsk using this same interval. The repetition of hour intervals with the given conditions implies the repetition of one or other type of situation.

Analysis of synoptic situation in Tomsk, performed using daily weather maps (Table 1), shows that over the period from 1993 to 2004 the mean repetition of cyclones and anticyclones was 18.8% and 25.9%, respectively; the contrast zone – 11.7%, the trough and ridge – 12.7% and 8.4%, the low-gradient field – 14.1%, and the saddle point – 5.8%.

The period of investigations was chosen with the account of that the daily analysis of synoptic conditions was conducted from the beginning of the station operation up to the present time.

Figure 2 shows that the repetition of cyclones and anticyclones is not constant and from year to year varies within wide limits. Thus more often the cyclonic conditions in Tomsk were observed in 1994 and their repetition this year was 28.1%, and in 2003 this value was only 3.8%. The variability in the frequency of occurrence of anticyclones from year to year is much less and varies from 30.9% in 1997 to 17.6% in 2004. The repetition of synoptic formations in the region depends on the general circulation of the atmosphere observed during this period.

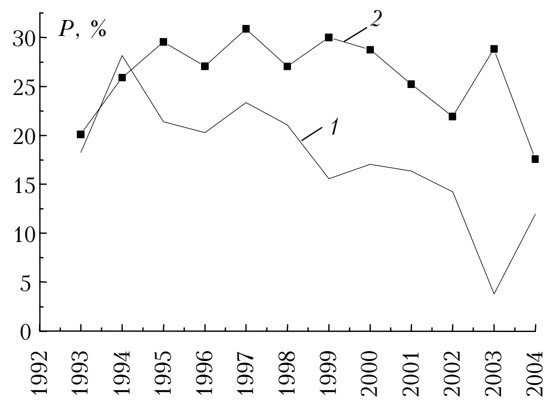

Fig. 2. The long-term variation of the occurrence of cyclones (*1*) and anticyclones (*2*) in Tomsk.

Based on data of long-term observations[3] Figure 3 shows that the annual variation of the frequency of occurrence of cyclones over the research period is weakly expressed and has three minima, with the main in July.

During cold half-year the change of frequency of occurrence is less than in summer and on the average it varies from 15.6% in March to 22.6% in December, and in warm half-year from 10.2% in July to 22.2% in August.

Table 1. Mean frequency of occurrence (%) of the synoptic conditions in Tomsk since 1993 until 2004

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Per year
						Cyclone							
North	0.8	0.6	0.8	0.4	0.7	0.9	1.1	1.4	1.5	0.4	0.8	0.8	0.9
North-east	0.8	1.0	0.9	0.8	0.8	0.5	1.0	0.8	0.9	0.8	1.3	1.1	0.9
East	1.5	2.1	1.2	2.2	3.6	2.6	2.4	3.0	2.8	1.0	2.2	2.6	2.3
South-east	8.0	7.5	5.1	4.5	5.0	4.1	2.0	6.1	5.2	5.7	5.2	7.0	5.5
South	4.3	4.0	4.0	5.1	4.5	4.0	1.8	5.4	6.3	6.0	6.5	6.7	4.9
South-west	1.7	0.9	2.0	3.0	3.1	1.3	0.6	2.9	2.0	1.9	2.3	0.9	1.9
West	0.9	1.0	0.5	0.5	1.0	0.8	0	0.5	0.3	0.6	1.2	1.2	0.7
North-west	0.4	0.7	0.3	0.9	0.7	0.8	0.1	0.6	0.9	0.4	0.3	1.0	0.6
Center	1.3	1.3	0.9	0.9	1.1	2.4	1.2	1.5	1.2	1.3	1.3	1.4	1.3
Total	19.7	19.1	15.7	18.3	20.5	17.4	10.2	22.2	21.1	18.1	21.1	22.7	18.8
						Anticyclone							
North	9.1	11.9	11.6	7.1	6.7	3.8	0.8	1.6	6.8	7.3	12.3	10.2	7.4
North-east	1.3	1.7	3.4	5.3	3.4	1.6	1.1	0.8	3.6	2.5	2.1	1.3	2.3
East	0.5	0.4	2.4	5.6	2.2	3.4	0.9	1.5	1.8	1.0	1.4	0.4	1.8
South-east	0.5	0.8	2.2	3.0	2.8	2.3	3.2	1.2	2.1	1.2	1.7	0.8	1.8
South	0.9	1.6	1.6	1.0	2.6	2.0	2.3	0.8	2.6	0.8	1.9	0	1.5
South-west	1.9	0.6	0.5	1.5	1.5	0.5	2.9	2.4	3.1	1.1	0.7	1.7	1.5
West	6.1	4.0	2.8	1.2	1.7	0.4	1.1	1.6	1.8	6.1	1.7	2.9	2.6
North-west	10.5	7.8	3.1	4.9	3.8	2.7	0.4	1.3	3.7	6.5	4.8	9.4	4.9
Center	1.3	0.3	2.4	3.8	2.0	2.8	1.9	2.2	1.9	2.0	2.5	1.2	1.8
Total	32.1	29.1	30.0	33.4	26.7	19.5	14.6	13.4	27.4	28.5	29.1	27.9	25.9
						Contrast zone							
	12.6	15.0	12.0	8.6	8.3	5.8	11.5	8.6	10.2	16.5	16.1	15.5	11.7
						Trough							
	16.204	13.906	13.495	9.979	9.989	9.967	9.236	11.568	15.667	11.831	14.32	16.216	12.7
						Ridge							
	9.308	5.733	8.997	9.03	8.828	8.684	11.508	11.643	8.008	5.033	7.408	6.355	8.4
						Low-gradient zone							
High pressure	3.947	5.473	8.554	7.401	9.297	15.097	12.384	13.388	7.041	6.054	4.268	2.109	7.9
Low pressure	2.425	2.975	3.773	2.437	6.507	12.16	20.953	11.745	3.997	2.813	2.161	2.676	6.2
						Saddle							
	1.994	4.144	6.526	6.593	8.1	9.466	8.939	6.435	4.475	4.49	3.825	4.219	5.8

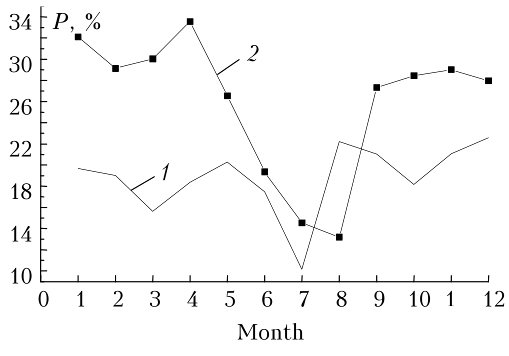

Fig. 3. Annual variation of the frequency of occurrence of cyclone (*1*) and anticyclone (*2*) in Tomsk.

The frequency of occurrence of anticyclones has a more pronounced annual variation, and in this case the minimum, as in cyclones, falls on the summer period. When it becomes warm in May the occurrence of anticyclones decreases and reaches its minimum of 13.2% in August and in September it increases to 14%. In the cold half-year, if the transition months are not taken into account, their frequency of occurrence varies from 28% to 32%.

The frequency of occurrence of contrast zone in the vicinity of Tomsk reaches its maximum in the cold half-year, and its minimum in June, about 5.8%. The frequency of occurrence of the trough is minimum in summer, in July it is 9.2% and reaches maxima in December and January ~16%. The frequency of occurrence of the ridge, on the average, is 8.4% and varies from 5% in October to 11.6% in August.

Low-gradient fields both of high and low pressure have maximum occurrence in summer (Table 1). The reason is that the planetary contrasts of temperatures are shifted to the north and the altitude-frontal zones are often observed to the north of Tomsk.

In analyzing synoptic situations in the past period, we have arrived at a conclusion that the most part of cyclones passed to the north of Tomsk. The predominance of paths of cyclones from the west was observed; in this case, the type *1a* occurred most frequently, that is supported by the maximum occurrence in Tomsk of the south and southeast parts of cyclones (Table 1).

Because in cyclones formed in the arctic front the midlatitude and arctic air is observed, a comparatively large, ~11% number of cases, repeated occurrence of air masses, passing from the subtropics (Table 2) indicates that the south cyclones and formations of the type *1b* are often observed.

Table 1 shows that the northwest part of the cyclone is observed more rarely near Tomsk. This suggests that during the period being studied the probability of north cyclones to pass through Tomsk is minimum.

The trajectories of anticyclones over the period from 1993 to 2004 passed mostly to the south of Tomsk or directly through the investigated region. Such situations are commonly observed when Siberian anticyclone prevailed in Tomsk. Also such situations are possible in the final anticyclones of a series of cyclones of type *1b*. More northern trajectories are observed rarely, but almost twice more often than the cyclone trajectories passing to the south of Tomsk.

In considering the annual variation of cyclone trajectories special attention must be given to the fact that during the whole year a dominance of northern territories is retained. It is only in July that almost equally probable are the ways of formations both to the north and to the south of the city.

In anticyclones throughout the year the predominance of cyclone trajectories to the south of Tomsk is also retained and only in July the north trajectories are observed more often. It is of interest to consider how the trajectories of formations vary from year to year.

Table 3 shows that the periodic repetition of different synoptic situations may vary with time. Thus in 1993 the western part of cyclones was observed most seldom, then from 1995 to 2004 their northwest part was observed rarely. The repetition of the south and southeast parts of the formations are maximum during the entire period of the investigation.

From the standpoint of circulation characteristics, 2003 is of special interest. Throughout the year only the south and southwest parts of cyclones were observed that indicates that in November (Table 3) the appearance of southern cyclones was observed, whose centers passed to the west of Tomsk.

The behavior of anticyclones looks rather complicated. During the entire period of observations, the north periphery of cyclones frequently occurred and only in 2004 the maximum fell on the northwest periphery. This fact is in favor of the predominance of trajectories of air masses passing to the south of Tomsk, and it shows that the influence of the Siberian anticyclone is of a decisive importance.

The south and southwest periphery of anticyclones was most rarely observed during the entire period of observations and only in 1994 the minimum fell on the central part, and in 1998–1999 the east periphery was most rarely observed.

The year 2003 is anomalous not only due to the appearance of cyclone formations but also anticyclones. Over the entire period of observations the frequency of occurrence of anticyclones in January, May and September was 70.8% for all synoptic conditions (Table 4), and in April it was maximum 83.3%. In March and from June to August the anticyclones were not observed at all, although during other years of the period under study rather high anticyclonic activity was observed (Table 4).

Clearly, the other synoptic situations are not constant during the entire period under study and vary from year to year (Tables 3–4).

Table 2 shows the annual variation of the frequency of occurrence of different types of air masses. If we consider its annual variation, then an interesting picture is seen. From January to July we can observe the excess of the frequency of occurrence of midlatitude air over all the rest air masses. However, starting from August the situation changes and we can observe the increase of the frequency of occurrence of arctic air and the midlatitude air goes to the background. In considering the distribution of the frequency of occurrence of air masses coming from south latitudes we can observe that most often the air masses are seen in the area under study in winter and in the transition periods, and in summer, when the intensity of processes decreases and the south cyclones can only rarely be observed, the occurrence is minimum. The most frequent occurrence of the SA and TA is observed in May.

Table 2. Annual behavior of the frequency of occurrence of different air masses near Tomsk (AA – arctic, MA – midlatitude, SA – subtropical, TA – tropical)

Type	Month												Per year
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
AA	33.7	37.1	36.6	41.4	31.4	28.5	43.3	56.1	59.6	46.5	47.0	50.6	42.6
MA	52.9	46.5	50.3	43.4	40.8	53.7	49.4	37.3	35.4	40.8	44.6	41.6	44.7
SA	13.0	12.9	12.8	13.1	25.3	15.8	7.3	6.3	4.3	8.3	8.1	7.2	11.2
TA	0.1	0.1	0.3	0.1	2.3	0.9	0	0.1	0.1	0.025	0	0.7	0.4

Table 3. Frequency of occurrence (%) of the synoptic situations (1993–2004)

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
					Cyclone							
North	0.8	2.1	1.0	1.4	0.8	0.8	0.4	0.5	0.3	0.6	0.0	0.5
North-east	0.2	1.5	0.4	1.6	0.6	0.7	0.7	0.5	1.3	1.0	0.0	1.0
East	2.1	3.6	2.4	1.5	3.4	2.6	1.8	1.6	2.7	2.4	0.0	0.8
South-east	7.2	6.7	6.2	4.0	6.7	5.2	5.2	5.5	4.9	5.0	0.0	4.4
South	4.7	7.1	6.1	5.1	7.3	6.2	3.9	4.5	3.8	2.6	2.8	2.3
South-west	2.0	3.4	1.8	2.0	1.8	3.1	1.4	1.4	1.5	1.1	1.0	1.3
West	0.1	1.7	1.3	1.3	0.7	0.8	0.5	0.7	0.2	0.3	0.0	0.3
North-west	0.6	1.3	1.0	0.8	0.5	0.3	0.5	0.5	0.4	0.1	0.0	0.7
Center	0.6	0.8	1.2	2.7	1.6	1.5	1.2	1.9	1.3	1.1	0.0	0.7
Total	18.3	28.1	21.4	20.3	23.4	21.1	15.6	17.0	16.4	14.2	3.8	11.9
					Anticyclone							
North	8.0	7.8	11.3	8.6	8.5	9.4	5.3	8.4	5.9	4.7	8.0	7.8
North-east	3.4	3.1	2.6	2.1	1.9	2.3	1.9	2.4	2.3	1.8	3.4	3.1
East	0.7	1.2	2.5	2.9	3.3	1.6	1.3	1.6	1.7	1.3	0.7	1.2
South-east	1.5	0.7	1.5	2.1	2.0	2.1	3.5	1.6	2.0	1.7	1.5	0.7
South	0.2	1.8	0.8	3.2	2.4	2.1	2.6	1.4	0.9	0.4	0.2	1.8
South-west	0.6	2.3	0.8	0.3	1.9	1.8	3.3	1.1	1.8	1.9	0.6	2.3
West	0.9	1.6	1.6	1.2	3.9	2.3	4.3	5.6	2.8	2.8	0.9	1.6
North-west	3.6	6.9	6.4	4.4	4.3	3.0	5.8	3.6	5.9	4.8	3.6	6.9
Center	1.2	0.4	2.0	2.1	2.6	2.5	2.1	3.0	2.0	2.5	1.2	0.4
Total	20.1	25.9	29.5	27.1	30.9	27.1	30.0	28.7	25.2	21.9	20.1	25.9
					Contrast zone							
	8.5	11.8	14.0	10.3	9.6	15.0	16.5	10.8	10.5	10.4	13.2	11.3
					Trough							
	8.0	5.6	9.9	10.1	9.9	9.4	10.6	13.5	16.3	22.5	24.0	21.8
					Ridge							
	7.1	3.8	7.1	7.8	9.7	8.1	7.0	7.0	5.8	11.9	8.3	15.9
					Low-gradient field							
High pressure	0.0	12.3	9.9	12.3	5.9	7.9	7.8	8.4	6.2	6.7	13.5	7.8
Low pressure	0.0	10.9	6.3	8.3	4.4	5.8	6.5	7.9	6.3	5.6	1.7	5.7
					Saddle							
	17.6	1.6	1.8	3.8	6.3	5.7	5.9	6.7	5.7	5.6	6.6	5.3

Table 4. Frequency of occurrence (%) of the main synoptic formations near Tomsk (1993–2004)

Month	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
						Cyclone						
January	36.8	33.3	11.5	16.6	37.3	14.1	18.9	15.2	13.0	23.6	0.0	5.6
February	24.4	44.4	24.4	14.1	18.7	31.6	4.1	14.8	7.1	7.9	0.0	21.3
March	8.0	14.8	20.4	5.2	18.4	3.9	23.7	14.4	15.1	27.8	0.0	18.8
April	12.0	26.8	9.9	21.4	26.7	32.0	31.2	17.6	6.1	6.8	0.0	12.8
May	15.5	33.3	31.2	25.6	17.7	19.8	18.4	16.0	16.5	19.0	0.0	10.6
June	25.8	12.8	17.0	30.4	13.6	16.2	15.5	11.0	23.2	15.3	0.0	12.5
July	15.4	14.5	12.5	6.5	10.9	7.8	0.3	4.3	24.1	4.3	0.0	8.3
August	16.9	28.4	17.2	25.3	37.8	20.4	12.9	31.8	31.7	5.6	0.0	7.9
September	23.4	29.0	21.3	35.9	5.3	26.1	23.2	32.2	9.2	16.8	0.0	9.4
October	18.3	23.4	25.5	23.8	16.8	23.4	11.7	14.1	21.0	13.7	0.0	8.6
November	11.7	41.9	28.8	5.1	26.5	38.5	14.6	16.3	17.5	15.4	45.8	9.7
December	11.0	35.1	37.1	33.5	32.2	19.0	12.3	16.5	12.0	14.2	0.0	17.6
						Anticyclone						
January	10.3	30.9	58.2	39.7	24.4	44.0	43.9	31.7	30.0	13.1	70.8	24.7
February	18.8	20.4	35.9	54.3	22.5	21.2	44.0	36.1	20.5	25.1	12.5	20.0
March	28.8	28.2	33.4	31.3	22.0	47.4	34.5	42.8	35.2	17.5	0.0	15.5
April	32.9	36.1	38.5	23.6	48.3	23.5	26.7	46.9	35.6	43.2	83.3	13.5
May	30.8	21.7	21.8	34.4	25.9	34.1	28.5	18.9	33.2	11.3	70.8	29.6
June	12.0	22.0	16.8	14.6	34.1	19.8	23.4	33.9	14.0	3.8	0.0	19.2
July	17.3	17.7	12.1	7.8	26.1	18.0	18.5	18.8	2.4	23.4	0.0	2.3
August	11.7	8.0	14.4	1.1	13.1	23.7	9.2	11.2	24.1	25.8	0.0	10.1
September	14.6	27.6	39.0	20.1	52.6	26.9	39.0	23.3	13.8	25.7	70.8	13.9
October	27.8	46.6	11.7	25.0	39.4	24.2	35.8	30.1	24.2	33.2	16.7	15.2
November	9.3	31.3	41.8	36.9	49.6	18.3	22.3	31.0	31.8	10.0	8.3	31.0
December	27.0	20.4	30.9	36.3	31.1	23.7	34.3	19.8	38.3	31.0	12.5	16.3

Figure 4 shows the variation of the mean annual frequency of occurrence of types of air masses over the entire period studied.

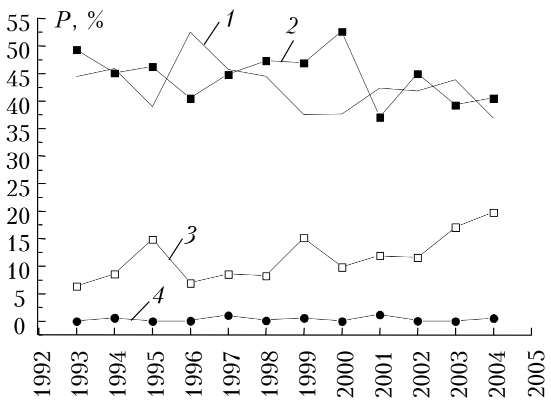

Fig. 4. Frequency of occurrence of different air masses in Tomsk: AA (*1*), MA (*2*), SA (*3*), TA (*4*).

As one could expect, during a period with maximum occurrence of subtropical air we observed the decrease in the frequency of occurrence of the arctic air mass.

The results of analysis of synoptic situations from 1993 to 2004 made enables us to draw the following conclusions:

1. In the southeast of Western Siberia, zonal processes prevail, which are often interrupted by meridional processes.

2. Weather conditions in the region depend on the general atmospheric circulation. In addition, there occur both cyclogenesis and anticyclogenesis in the region.

3. Weather conditions are not constant in different years that is expressed in a wide scatter of the frequency of occurrence of various weather situations.

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