RESULTS OF CLIMATIC–ECOLOGICAL MONITORING AT TOR STATION. 1. SYNOPTIC REGIME AND METEOROLOGICAL PARAMETERS

V.G. Arshinova, B.D. Belan, and T.M. Rasskazchikova

Institute of Atmospheric Optics, Siberian Branch of the Russian Academy of Sciences, Tomsk
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Meteorological and synoptic regimes observed during 1993 in Tomsk region, where a station of monitoring of atmospheric parameters is located, have been analyzed. The dynamics of most meteorological parameters, in contrast with the circulation ones during 1993, is shown to approach the long–term mean regime.

In the last few years many groups of researchers have concentrated on the study of long–term series of geophysical parameters. This is accounted for by the work started as part of the International Program Global Change. One of the directions of this program is determination of significant changes in natural medium and climate. The Institute of Atmospheric Optics (IAO) of the Siberian Branch of the Russian Academy of Sciences has wide experience in the study of the atmosphere. It has been deeply involved in the study of the above–indicated problem.

Since 1989, the atmospheric ozone has been monitored at IAO by the project TOR (Tropospheric Ozone Research) as part of the Program EUROTRAC.[1] In 1992, a set of controllable parameters was extended once the Project on Climatic–Ecological Monitoring of Siberia (CEMS) had been approved. The basic concepts of this project are outlined in Ref. 2. It is assumed to be an integral part of the Program Global Change. The TOR station was established to carry out these projects. Its basic characteristics and regime of operation were described in Ref. 3. The results obtained at the station in 1993 are discussed in this series of papers. The first paper is aimed at estimating the correlation between our data and the mean long–term climatic regime in Tomsk on the outskirts of which the TOR station is located.[3]

According to Ref. 4, the territory of Western Siberia can be divided into three climatic zones. The first zone extends between 55° and 65° N. The second zone is a forest. Its boundary passes from the Ural, to the north of Novosibirsk, to the east. The third zone is a forest steppe including Petropavlovsk region (Kazakhstan) and foothills of the Altai.

Tomsk is at the boundary of the first and second zones. This a region of the strongest cyclonic activity in Western Siberia which is kept all the year.[5]

An analysis of synoptic situation in Tomsk region made by daily synoptic maps and represented in Table I reveals that in 1993, the average annual recurrence of cyclones and anticyclones was 26 and 27%, respectively; small–gradient fields and contrast zones were observed in 17 and 9% of cases; and, various fronts passed through the town in 21% of cases. Taking into account that fronts, as a rule, are engendered by the cyclonic activity,[6,7] its prevalence may be concluded in 1993 as well (47%). This is in agreement with conclusions of Ref. 5.

According to Ref. 8, a salient feature of cyclonic recurrence over Western Siberia, as compared to the other regions, is its neutral annual behavior. Only a single insignificant maximum in May and two distinctly pronounced minima in July and December occur in the long–term plots.

Over the period under study, the annual behavior of cyclonic recurrence differed from the mean long–term one (Table I). Three maxima occur in it: January, June, and August–September, as well as three minima: March–April, July, and October–December. Hence, in 1993, except the recurrence minima in July and December, a character of the cyclonic activity in Tomsk region differed from the mean long–term one.

TABLE I. Recurrence (%) of basic synoptic objects in Tomsk region in 1993.

Month	Cyclone	Anti-cyclone	Front	Contrast zone	Small-gradient field	Fronts + cyclones
I	43	17	22	18	0	65
II	28	22	18	6	26	46
III*	13	39	18	6	24	31
IV	18	38	22	6	16	40
V	27	35	20	14	5	47
VI	33	16	8	3	40	41
VII	19	24	9	0	48	28
VIII	36	26	16	0	22	52
IX	40	21	24	10	5	64
X	22	34	38	4	2	60
XI	20	23	24	22	11	44
XII	18	29	31	12	10	49
Average – annual	26	27	21	9	17	47

* Analysis of incomplete data.

If we consider the recurrence of cyclones and fronts taken together which is listed in the last column of Table I, its annual behavior is seen to be smoother than that of cyclones alone and is representative of a character of general circulation of the atmosphere over Western Siberia, namely, of the enhancement of cyclonic activity in winter and in spring and fall.[5,8] In this case the observed annual behavior of cyclonic activity in Tomsk region in 1993 approaches the mean long–term one.

The role of synoptic processes in the formation of climatic regime of the atmosphere and composition of air of a specific region is different. Thus, while the meteorological regime is primarily determined by circulation condition, the composition of air depends on a type of air mass and a trajectory of arrival of synoptic object to the given point.

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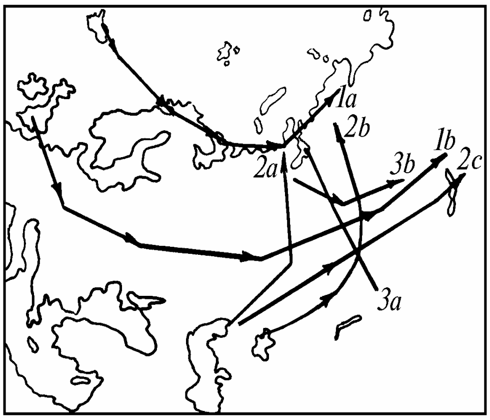

FIG. 1. Basic trajectories of arrival of three types of cyclones: western (1a and 1b), southern (2a, 2b, and 2c), and northern (3a and 3b) in the territory of Western Siberia.

Zonal circulation, which was rarely interrupted by meridional one, prevailed over the territory of this region in 1993.

With such circulation, the trajectories of anticyclones that followed a series of cyclones passed to the south of 56° N (Tomsk latitude). In 1993, the Asian (Siberian) anticyclone developed weakly and affected insignificantly the weather in Tomsk.

The dynamics of circulation during the year can be considered from the data in Table II which was compiled according to classification devised in Ref. 10.

For Western Siberia three types of cyclones can be identified depending on trajectory of their arrival: western, southern, and northern.[9] This is schematically depicted in Fig. 1.

Cyclones of *1a* type (Fig. 1), which arrived from the Atlantic region and shifted along the coast of the Arctic Ocean, prevailed in Western Siberia in 1993. Their southern periphery determined the weather in Tomsk.

TABLE II. Recurrence interval of synoptic conditions (%).

Month		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Cyclone	Center	–	–	0.6	0.7	–	3.5	–	–	–	–	–	2.8
	N	–	–	1.7	–	2.6	3.2	3.8	–	–	–	–	–
	NE	–	–	0.9	–	–	–	–	–	0.9	–	–	–
	E	–	1.9	–	2.9	–	5.0	7.4	1.4	6.2	–	–	–
	SE	23.9	9.8	4.7	1.4	6.2	5.4	–	4.6	10.4	5.4	6.7	5.3
	S	9.2	12.7	1.3	4.3	2.2	1.6	0.9	5.0	5.1	8.5	5.0	1.5
	SW	3.7	–	–	2.6	2.8	1.1	2.0	6.0	0.6	4.4	–	1.3
	W	–	–	–	–	0.7	0.5	–	–	–	–	–	–
	NW	–	–	–	–	0.8	5.4	1.2	–	–	–	–	–
Hollow		5.9	3.9	3.4	6.4	11.1	6.9	3.8	19.3	16.5	3.8	8.3	7.2
Front		22.2	17.7	17.8	21.9	19.9	7.9	9.0	15.9	24.0	37.9	24.0	31.1
Contrast zone		18.4	5.8	6.4	6.0	13.7	3.5	–	–	9.6	4.0	21.8	12.3
Small-gradient field		0.1	25.9	23.8	16.2	5.0	39.7	48.2	21.6	5.3	2.3	11.1	10.0
Anticyclone	Center	2.0	–	–	2.4	0.9	0.5	–	1.4	–	3.6	3.4	–
	N	1.3	9.4	15.0	6.7	9.5	9.1	–	5.4	8.1	11.7	3.2	16.1
	NE	–	9.6	4.5	3.5	7.7	–	0.9	–	3.8	4.0	2.4	2.6
	E	–	–	–	2.2	2.4	–	2.8	–	–	–	0.4	–
	SW	0.7	–	–	1.0	2.8	1.4	12.0	–	–	–	–	–
	S	–	–	–	1.2	–	–	1.2	–	–	–	–	–
	SW	–	–	0.8	1.9	4.4	–	–	–	–	–	–	–
	W	2.4	–	–	0.8	2.7	–	0.3	2.8	0.6	1.2	–	–
	NW	3.9	–	4.5	13.0	0.4	1.0	–	2.2	2.1	6.2	–	8.1
Ridge		6.3	3.3	14.6	4.9	4.2	4.3	6.5	14.4	6.8	7.0	13.7	1.7

In January and February of 1993, most of cyclones moved over Northern Siberia and the weather in Tomsk was determined by their southern parts.

In contrast, the trajectories of anticyclones were mainly southern, and their northern periphery affected the weather in the region.

The town was affected by various fronts one–fifths of 1993. In winter at night fronts reduce the heat loss, thereby increasing the mean temperatures and smoothing the diurnal variations.

In January in 23% of cases the thermal regime in Tomsk was determined by the air arrived from subtropics though its recurrence did not usually exceed 2% over this period (Ref. 11).

In February circulation approached the norm.

In March one thirds of cyclones moved to the south of Tomsk, and the trajectories of anticyclones by and large retraced those in January and February.

The trajectories of cyclones in April retraced winter ones, and the paths of anticyclones were more diversified.

The circulations in May differed strongly from those in the previous months. During this period one could observe the large contribution came from meridional circulation, while zonal circulation predominated from January to April (here we use Vangengeim classification[12]). Therefore, the mean temperature in May was lower than the long–term one. Moreover, in May a small–gradient field was formed more rarely, and the recurrence of fronts that reduced daytime heating of the ground air was high.

The trajectories of cyclonic formations were highly diversified in June, while recurrence of anticyclones was low, and they mainly moved to the south. In that month a small–gradient baric field prevailed. It was observed in 40% of cases.

In July the duration of cyclone effect on the regional weather became somewhat shorter but at the same time the recurrence of cases with small–gradient field increased to 48%, what correlated with the long–term circulation regime. This is accounted for by summer heating of the continent and decrease of horizontal pressure gradients.

Zonal circulation was enhanced in August. The recurrence of cyclones and anticyclones was in fact the same.

In September the recurrence of the effect of cyclones on the weather increased almost to 50%, and the meridional circulation became more pronounced. This resulted in influxes of arctic air and temperature decrease.

In October, the anticyclonic activity became stronger. As to November, meridional processes enhanced so that the mean temperature was lower than that in December.

In December zonal circulation started to enhance, and the rate of subtropic air influx to the territory of Western Siberia also increased (18%).

On the whole, in Tomsk region a moderate air mass was present in 49%, an arctic one – in 45%, and a subtropic one – in 6% of cases during the year. Tropical air did not penetrate the town in 1993.

In the subsequent papers of this series, we will give the data on variations in gaseous and aerosol composition of air obtained at the TOR station. The effect of synoptic conditions on variability of these parameters also will be considered based on the correlation between composition of air and meteorological parameters. To this end let us look at Fig. 2 where the annual behavior of recurrence of basic synoptic parameters of processes and average monthly coefficients of correlation between the meteorological parameters and the composition of air are depicted. To calculate the coefficients in each month, we used about 700 pairs of values excepting March in which statistics was about 300 pairs. The figure shows the correlation coefficients at a confidence level of 0.1% during at least one month.

It is seen from Fig. 2 that in some cases the temporal variations of the correlation coefficients approach the annual behavior of recurrence of one or another synoptic process.

Thus, the coefficients of correlation between O_3 and CO, O_3 and CO_2 have a behavior similar to the annual behavior of recurrence of anticyclones (Fig. 2*a*). Deviations are observed only during significant increase of recurrence over the region of northern periphery of anticyclone (Table II).

The curve of the annual behavior of the coefficients of correlation between O_3 and V has bending points almost similar to those of the curve of recurrence of cyclones (Fig. 2*b*).

Similarity between the curves of coefficients of correlation between T and O_3 (a and O_3) and annual behavior of recurrence of cyclones and contrast zones is seen from Fig. 2*c*. However, in summer they change in antiphase, which is probably due to ozone generation in the process of convectional thunderstorm activity.

Fairly good agreement between the curves of recurrence of contrast zones and the coefficient of correlation between f and O_3 is seen from Fig. 2*d*. Taking into account that $R(f,\ O_3)$ has a negative value almost all the year, we may assume that large gradients of the aforementioned parameters have opposite directions in the contrast zone.

Close similarity of the curves of recurrence of small–gradient fields and correlation between wd and O_3 is seen from Fig. 2*e*. This similarity is regular since in small–gradient fields there is no transport of air mass, and variations in ozone content are determined by local processes that are manifested through the wind direction.

Finally, Fig. 2*f* depicts the annual behavior of recurrence of anticyclones and correlation between N and O_3 that show almost complete coincidence. This can be manifestation of similarity of processes of ozone and aerosol generation in air, i.e., in situations where diurnal behavior is distinctly pronounced and air mass exchange is absent. That is specific for anticyclonic conditions.

Thus, it follows from our data that circulation processes in Tomsk region in 1993 differed from long–term ones. At the same time, different correlation between meteorological parameters and composition of air testifies significant and regular contribution of synoptic processes to their variability.

By virtue of the fact that the composition of air was not regularly measured in Tomsk region previously, to estimate reliability of the obtained data, we must validate them. The same is needed for the data on temporal variability of meteorological parameters. Taking account of the aforementioned correlation between meteorological parameters and composition of air, we estimate reliability of the data reported in Ref. 13 by comparing the meteorological parameters measured at the TOR station and their climatic characteristics.

The climate of Tomsk is continental and has an amplitude of annual variation of air temperature of 37.7°C from the long–term data. The amplitude of annual variation from the data obtained at the TOR station was 36.2°C in 1993.

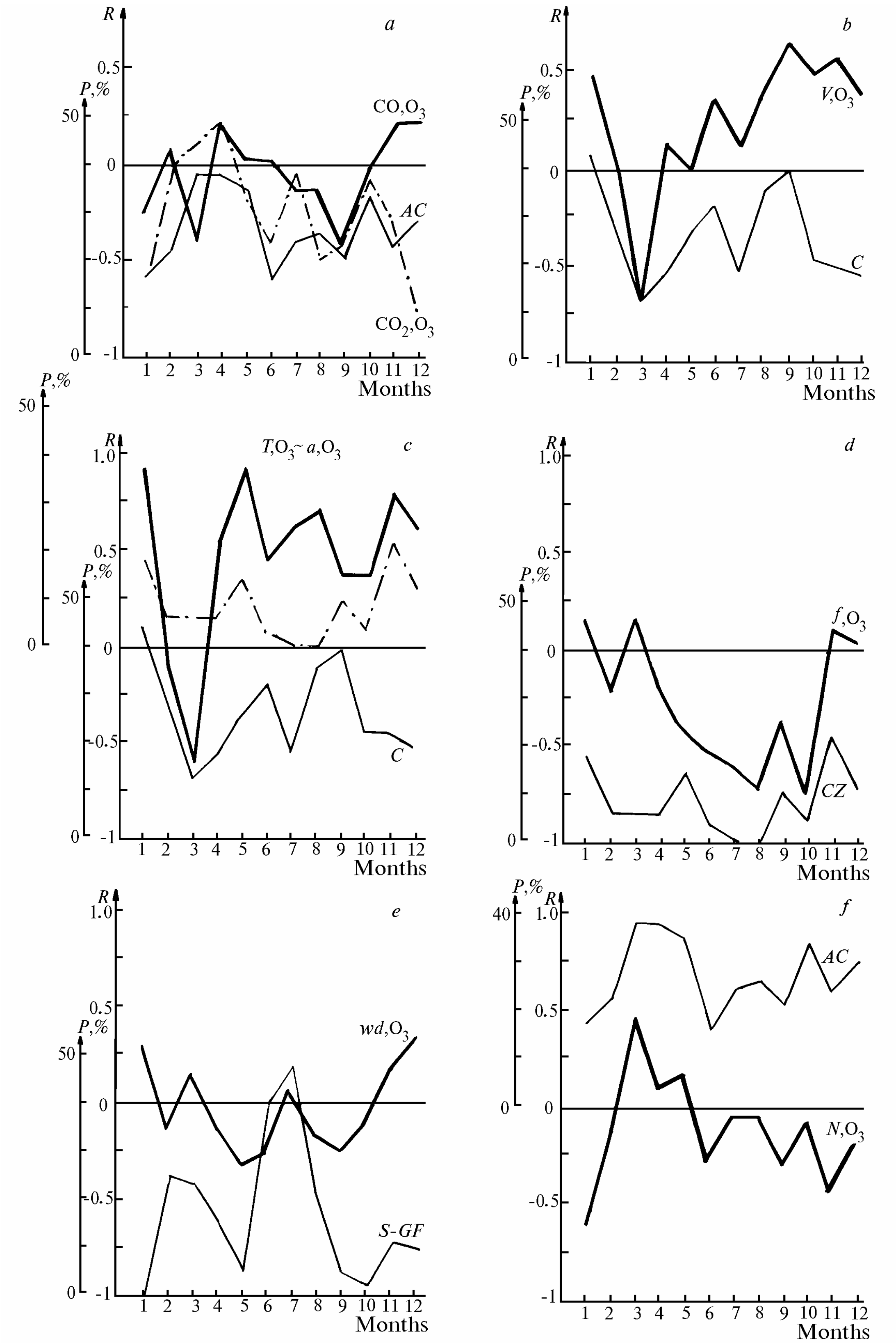

FIG. 2. Annual behavior of recurrence of synoptic conditions: S–GF is for small–gradient field, C is for cyclone, AC is for anticyclone, and CZ is for contrast zone. Annual behavior of average monthly correlation coefficients of air temperature (T), absolute humidity (a), wind direction (wd), wind velocity (V), relative humidity (f), ozone O_3, *and aerosol particle number density (N) (d* ≥ 0.4 μm*).*

A plot of annual behavior of average monthly temperatures is similar to that of mean long–term data, but in most cases the mean temperatures in 1993 were higher than long–term ones. And only in May, September, and November they did not exceed the long–term values (Fig. 3).

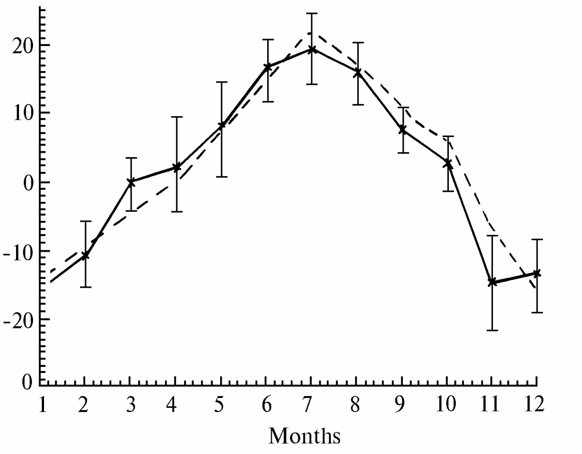

FIG. 3. Annual behavior of temperatures in Tomsk: measured in 1993 (solid line), mean long–term (dashed line), and standard deviation (vertical bar).

Moreover, contrary to the mean long–term annual behavior, the mean temperature in November was lower than that in December. This had not been observed during the entire period of instrumental observations in Tomsk.[13] Such deviations were caused by peculiarities of circulation both in November and December of 1993, what was mentioned above. The fact that the mean temperature in March was almost 10° higher than the mean long–term one was accounted for by lack of data for half the month.

The annual behaviour of air humidity in the ground layer differed slightly from the long–term one (Fig. 4). The minimum values of relative humidity (53%) were observed in May and maximum ones (89%) – in January. The amplitude of annual variations of relative humidity was 35%, and from the long–term data it was 22%. They differed significantly at a 0.05% level. At the same time, in 1993 during summer months the values of humidity almost coincided with the mean long–term ones, and the increase of amplitude of annual variations was caused by a significant increase of humidity in summer months when zonal circulation enhanced and air masses arrived from the Atlantic Ocean.

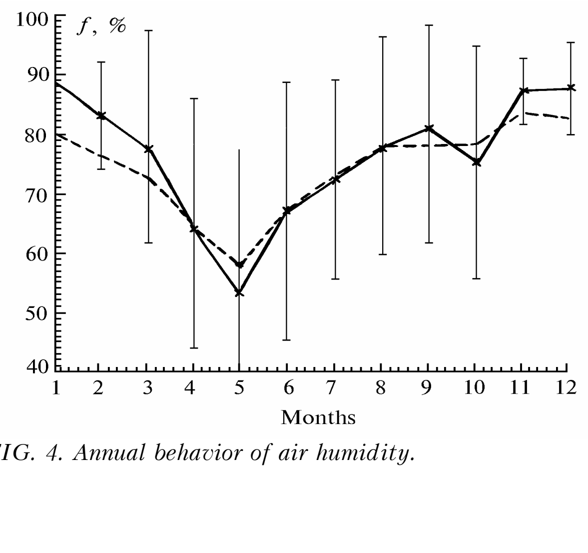

FIG. 4. Annual behavior of air humidity.

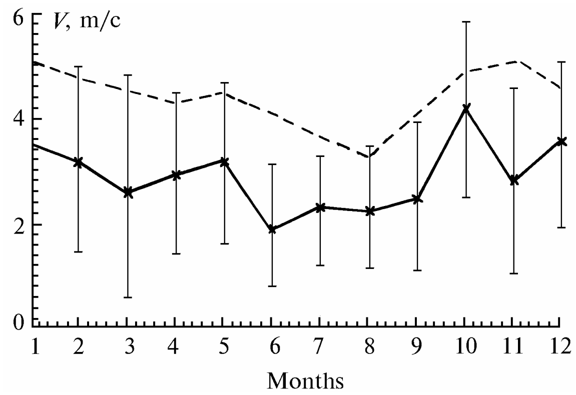

FIG. 5. Annual behavior of wind velocity.

Based on the long–term data the annual behavior of wind near the Earth's surface was complicated with the principal minimum in August. From the results obtained at the TOR station, this behavior turned out to be more complicated, and the wind velocities were lower than the long–term ones (Fig. 5). This can be accounted for by predominant zonal circulation in 1993, which was characterized by its smaller values than the meridional one.[14]

In conclusion, it should be noted that the circulation regime in Tomsk region in 1993 differed from the mean long–term one. At the same time the annual variability of meteorological parameters differed slightly from their climatic values except the wind velocity that was somewhat lower. This was accounted for by prevailing zonal circulation during the period under consideration. The proximity between measured and climatic values of meteorological parameters testifies reliability of the data obtained at the TOR station.

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