Some aspects of dynamic climatology

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ABSTRACT

Some new results of studying the general circulation of the atmosphere and fluctuations of climate in the northern hemisphere are given. Two circulation and climatic epochs in the 20th century are compared. The amount and distribution of internal and kinetic energy over extra-tropical latitudes of the hemisphere in extremely cold and warm months of January are presented. The circulation types over the Northern and Southern Hemispheres are compared; a good agreement among them can be seen.

Introduction

The author will begin this article with a citation from T. BERGERON's "Richtlinien einer dynamischen Klimatologie" (1930): "Hierbei sind Wettertypen als Gesamtprozesse bzw.—erscheinungen aufgefasst, was ihre Behandlung im Sinne einer dynamischen Klimatologie ermöglicht. Es wäre sicher lohnend, eine solche Untersuchung systematisch für W. Europa durchzuführen und später auf alle anderen Klimagebiete der temperierten Zone auszudehnen" (pp. 258–259).

The further development of dynamic climatology — in Bergeron's interpretation of this term—followed this way.

We can refer to a great number of papers dealing with typification of circulation patterns and connected with climatic regime on different territories. The increase of observation data in the last decade ensured the possibility of fulfilling the analysis of circulation of the atmosphere over the Northern Hemisphere and now—over the whole globe.

Some years ago the author had the opportunity to publish in "Tellus" the article about the main principles of the synoptic-climatological analysis applied by the author's coworkers and himself for studying the fluctuations of climate (DZERDZEEVSKII, 1962). The aim of the paper presented now is to inform about some new results obtained since that time.

I. Discussion

The cyclonic and anticyclonic tracks on the surface maps and blocking in the westerlies were used for definition of the homogeneous and typical circulation schemes over extra-tropical latitudes of the Northern Hemisphere, called "Elementary Circulation Mechanism" (ECM). It was confirmed by many authors (for our purpose see f.ex. DZERDZEEVSKII & MONIN, 1954), that the fundamental steering currents in the middle troposphere are satisfactorily described by the tracks of well developed cyclones and anticyclones.

But this method of indirect analysis was used because of lack of upper-air maps. Now detailed upper-air maps exist and once more we have compared our composite maps of cyclonic and anticyclonic tracks with the constant pressure surface maps from 850 to 200 and sometimes to 100 mb.

An analysis of such comparison for well developed zonal and meridional circulation types (DZERDZEEVSKII, 1945, 1962) is given on Figs. 1 and 2. These maps are plotted after the average values calculated from all the days of existence of each typical ECM (in these examples for 5 and 3 days).

It must be noted that the fundamental schemes of each type of ECM are developed much better on such average maps than on separate daily maps. Certainly, among more than 5000 ECM (1899–1965) we can often meet with different variations, but in general this conclusion is true. These differences are caused by the fact that the development of ECM from day to day corresponds to one of the schemes given on page 4.

It means that in the I scheme the circulation patterns are developed from low to high levels, in the II scheme—vice versa. Nevertheless the end of each ECM and the beginning of the

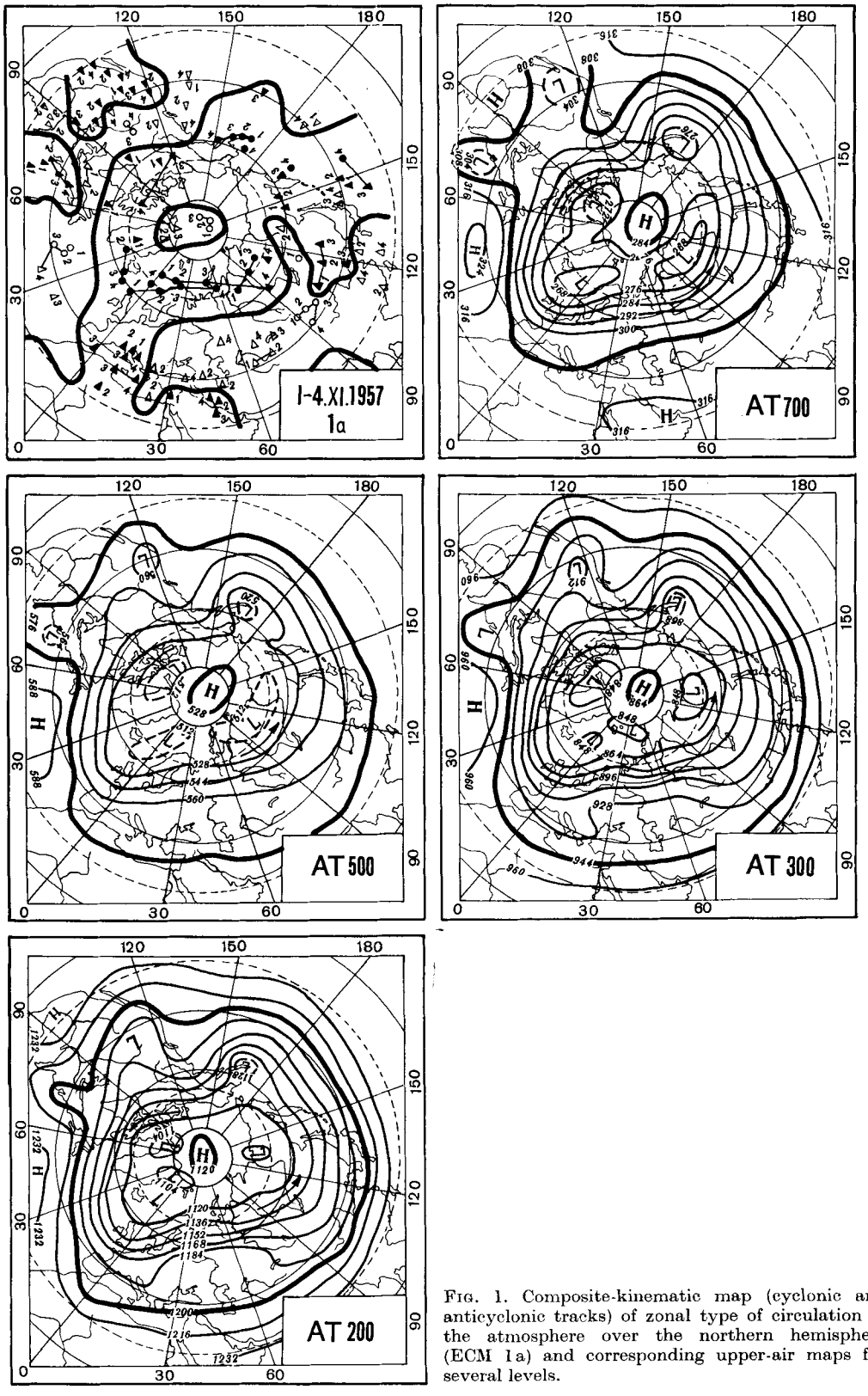

FIG. 1. Composite-kinematic map (cyclonic and anticyclonic tracks) of zonal type of circulation of the atmosphere over the northern hemisphere (ECM 1a) and corresponding upper-air maps for several levels.

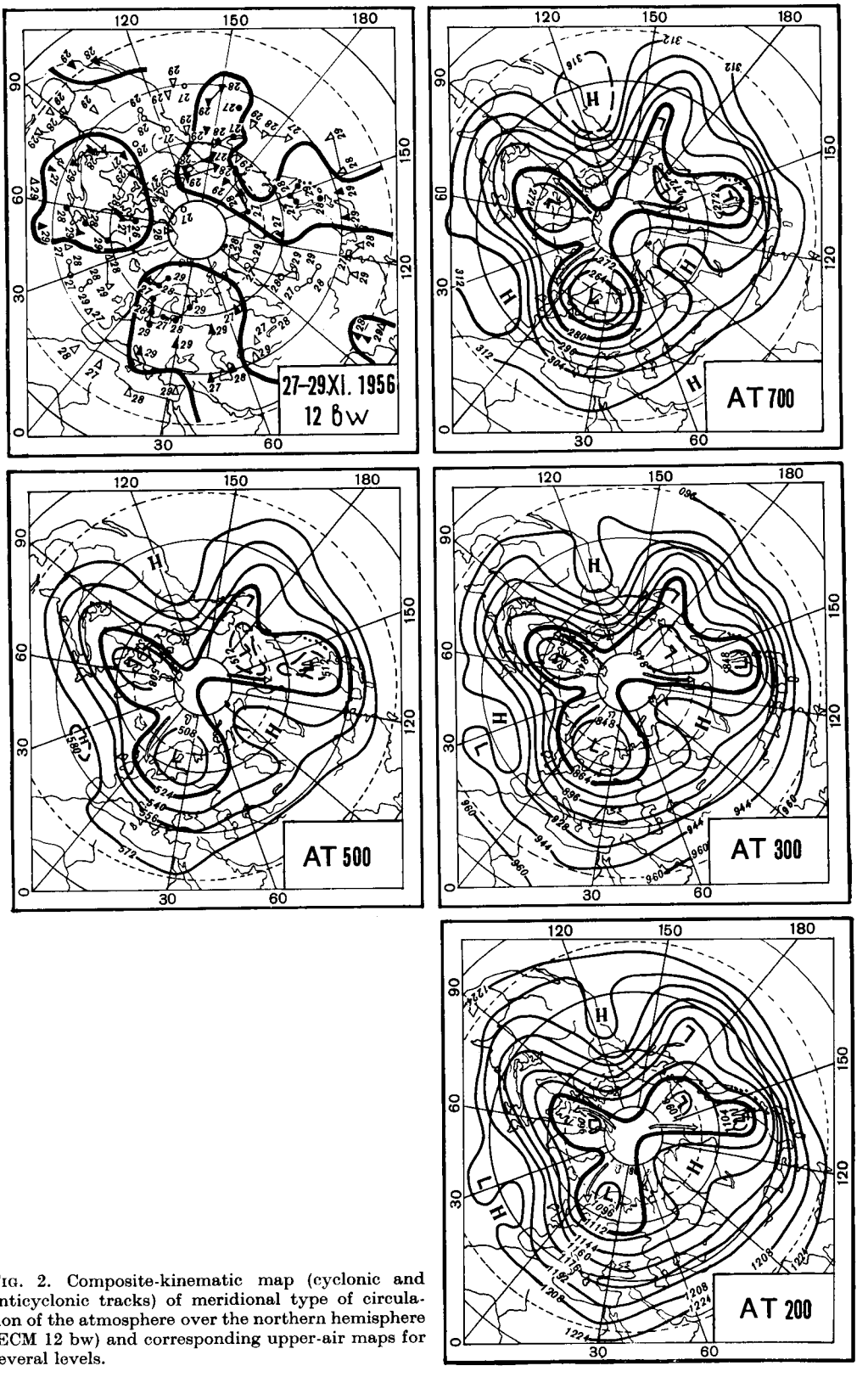

FIG. 2. Composite-kinematic map (cyclonic and anticyclonic tracks) of meridional type of circulation of the atmosphere over the northern hemisphere (ECM 12 bw) and corresponding upper-air maps for several levels.

	1000 mb	700 mb	500 mb	300 mb	200 mb
I.					
The 1st day	Very good	Good	Satisf.	Feebly	Badly
The 2nd day	Good	Very good	Good	Satisf.	Feebly
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
The last day	Feebly	Satisf.	Good	Very good	Very good
II.					
The 1st day	Badly	Feebly	Satisf.	Good	Very good
The 2nd day	Feebly	Satisf.	Good	Very good	Good
.	.	.	.	.	.
.	.	.	.	.	.
The last day	Very good	Good	Satisf.	Feebly	Badly

next one can be determined quite satisfactorily.

The confirmation of this rule according to circulation over the entire hemisphere is of great importance for the topic under discussion: (1) it makes clear the above mentioned conclusion why the average ECM maps are much more representative than the daily maps; (2) it confirms that generalization and typification of the circulation over the Northern Hemisphere satisfactorily reflect the basic distinguishing features of the hemispheric circulation.

The statistical analysis, with the application of Markoff's chains, also confirmed the point (2) (TCHAPLYGINA, 1961).

The author's assistant L. V. Khmelevskaya calculated the values of vertical motions at the 500 mb surface level for each ECM. An example is given in Fig. 3. Significant differences in values and directions of vertical motions well correspond to changes of ECM.

As it was reported in papers published before the longperiod trend of ECM, duration of activity of each of them in the months, seasons, years, decades and during the 65 years period was calculated. The attention was directed to the selecting of the zonal and meridional components of the general circulation of the atmosphere and their interrelations.

Fig. 4 shows the trend of zonal and meridional circulation over the Northern Hemisphere in the 20th century. The two circulation epochs, established before, are also well confirmed on Fig. 4. A meridional circulation is prevailing during the first epoch, a zonal one-during the second. The considerable change of long-period trend of weather and of several meteorological elements correspond to the above mentioned variations of circulation; they must be considered as fluctuations of climate (DZERDZEEVSKII, 1961, 1962, 1963).

Lately many geophysicists have confirmed the existence and duration of such "epochs". The author considers this statement as a very important one both for theory and for practice: analysis of the dynamics of the general circulation over the hemisphere—or over the globe—can essentially help to work out the theory of climate and to stimulate the development of extra long-range weather forecasting (i.e. prediction of main features for the next climatic epoch). The practical importance of such prognosis is self-evident.

It is worthwhile to emphasize that at the present time such forecastings are frequently published. The formal extrapolation of long-period trend of several meteorological elements is applied in majority of these cases. Sometimes the extrapolation is maintained by more or less accurate physical arguments. Nevertheless the above mentioned predictions are very similar. Taking into consideration that forecasting technique is rather simple one might consider such good results as a paradox. The explanation can be found in the fact that one deals in all these cases with cardinal processes. If their beginning has been established correctly one can for a long period of time expect similar development of circulation.

Analogous forecast was published by the author (DZERDZEEVSKII, 1956). The circulation trend over the Northern Hemisphere in the following years after the publication confirmed the expected change of circulation and climatic

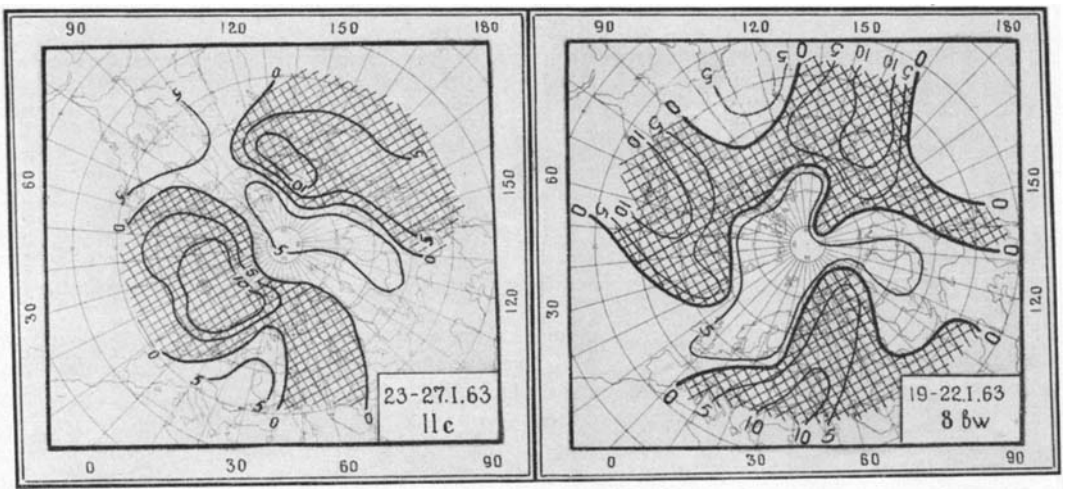

FIG. 3. Vertical motions at the 500 mb surface (mg/12 hrs) of two ECM (8 bw and 11b). ▭ = downdraft motions; ▨ = updraft motions.

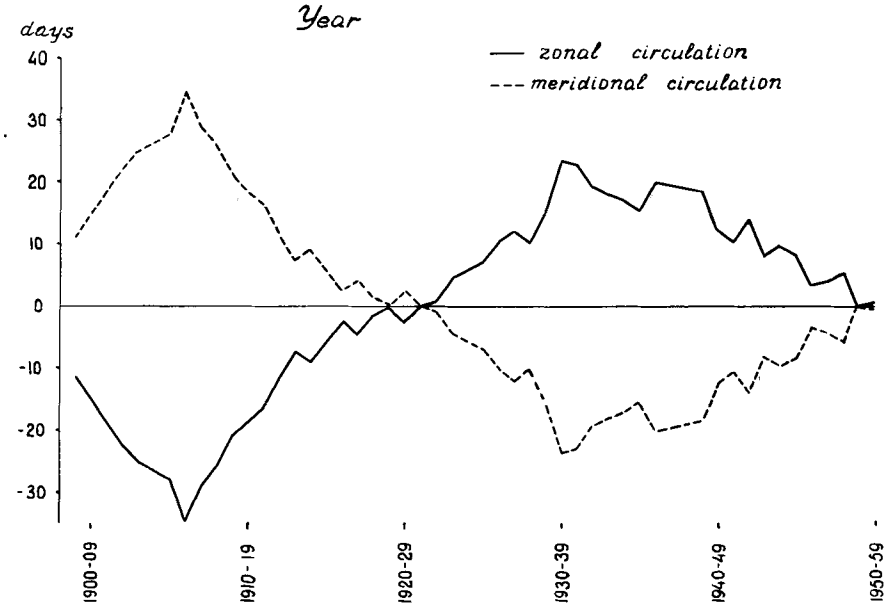

FIG. 4. Course of meridional and zonal circulation in the 20th century (circulation epochs).

epochs. Now we can consider that the prevailing meridional circulation provokes changeable weather in all the parts of the Hemisphere. It must be noted that the prediction was given by using the data till 1950, the curves on Fig. 4 were now prolonged using actual data.

The difference between two epochs was repeatedly accentuated in our publications. Two examples can give the idea of how big these differences were (Table 1 and Fig. 5).

In Table 1 the total numbers of days with contrasting types of circulation over the entire hemisphere are presented. Only well developed zonal and meridional circulation types are chosen here. The great difference between both epochs is well seen. The ratio between number

TABLE 1.

	Cold seasons			Warm Seasons			Year		
	Zon. c. days	Mer. c. days	Zon mer %	Zon. c. days	Mer. c. days	Zon mer %	Zon. c. days	Mer. c. days	Zon mer %
The 1st epoch	133	1158	11.5	430	669	64.3	563	1827	30.8
The 2nd epoch	435	916	47.5	638	554	115.1	1073	1470	73.0

of days with zonal and meridional circulation stresses this conclusion.

Another example. The author's co-worker K. V. Kuvshinova calculated the deviation of seasonal average temperatures from long-period "normal" values for each of six seasons (DZERDZEEVSKII, 1957, 1962) in the 1st and 2nd epochs over the European part of the USSR. The deviations of $\pm 3°C$ were used while they simultaneously covered not less than 90 % of the above mentioned territory (Fig. 5). One can see that the absolute values of temperature deviations in the 1st epoch were greater than in the 2nd one and that the amplitude of temperature oscillations in the 2nd epoch was smaller. It is true for five seasons and for the year. Exceptional is the summer season. But such a lack of coincidence in this case confirms the observed change of circulation from the 1st epoch to the 2nd. It must also be stressed that the change of positive and negative deviations of temperature in the 1st epoch occurs much more often than in the 2nd one and that the duration of periods with similar deviations (positive or negative) were smaller. It depends on a more frequent change of ECM: the average sums in the 1st epoch are 93 times, in the 2nd 86 times per year. It means that the 1st epoch was more continental and cooler than the 2nd one.

The direct, immediate causes of all observed fluctuations of climate are the displacement in space of all main circulation patterns. Fig. 6 shows an example of shifting of the axis of Polar air invasions during the two extreme decades from the 1st to the 2nd epochs. In all cases one can observe the eastward displacement of axis. Analogous phenomenon was described earlier for Atlantic and East Siberia (DZERDZEEVSKII, 1963).

Very important is the investigation of dis-

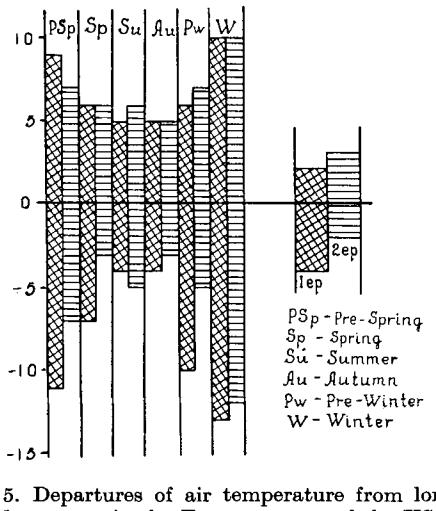

FIG. 5. Departures of air temperature from long-period average in the European part of the USSR in two circulation and climatic epochs in the 20th century.

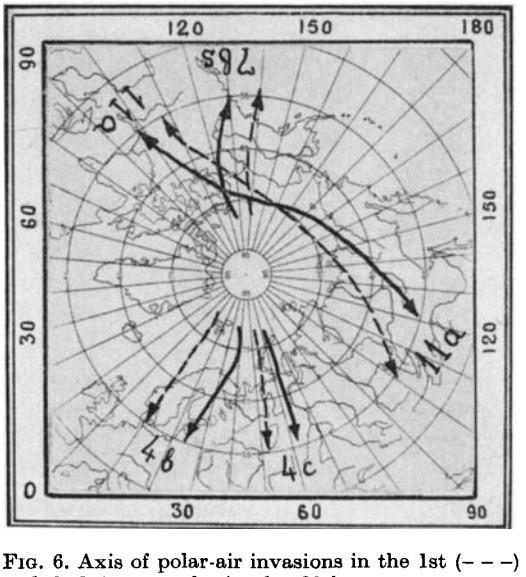

FIG. 6. Axis of polar-air invasions in the 1st (– – –) and 2nd (—) epochs in the 20th century.

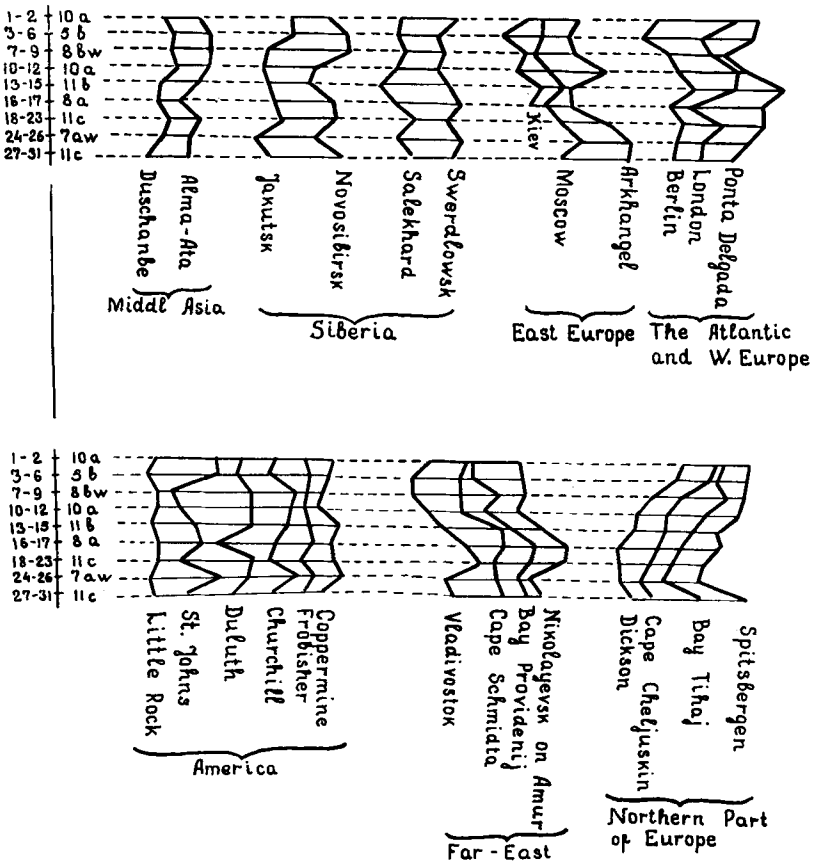

FIG. 7. Change of amount of internal energy in air column (10^8 erg/cm^2) over several points of the northern hemisphere and corresponding change of EMC (January 1950).

tribution and transformation of energy of atmospheric circulation. For our purposes the "continuous" (i.e. from day to day in the possibly longer periods) calculations of amount of energy must be carried out. It is a very hard work and precise calculations for long periods are practically almost impossible, the more so as we have no necessary aerological data from the beginning of this century. Therefore we have to use simplified formulas but which are valid for continuous calculation. Some examples of such calculations fulfilled by my assistant L. V. Khmelevskaya are mentioned below.

First of all it was established whether the change of ECM is connected with the change of the energy amount. Fig. 7 shows the results of such a comparison. The curves represent the variability of the amount of internal energy in the air column located over several points in the Northern Hemisphere; the figures at the bottom of the graph represent the changes of ECM. The coincidence of peaks in curves with the change of ECM is quite satisfactory.

A very interesting paper published by NEWTON and PALMEN (1963) contained detailed kinematic analysis of a large-amplitude wave in the westerlies on 12 Dec. 1957. EMC at this day, according to the author's system of typification, was 12 bw. Two maps by Newton—and Palmen and by the author—were superimposed. The coincidence in the American sector to which the Newton–Palmen's analysis was applied is very good.

L. V. KHMELEVSKAYA has calculated the amount of internal and kinetic energy over extra-tropical latitudes of the Northern He-

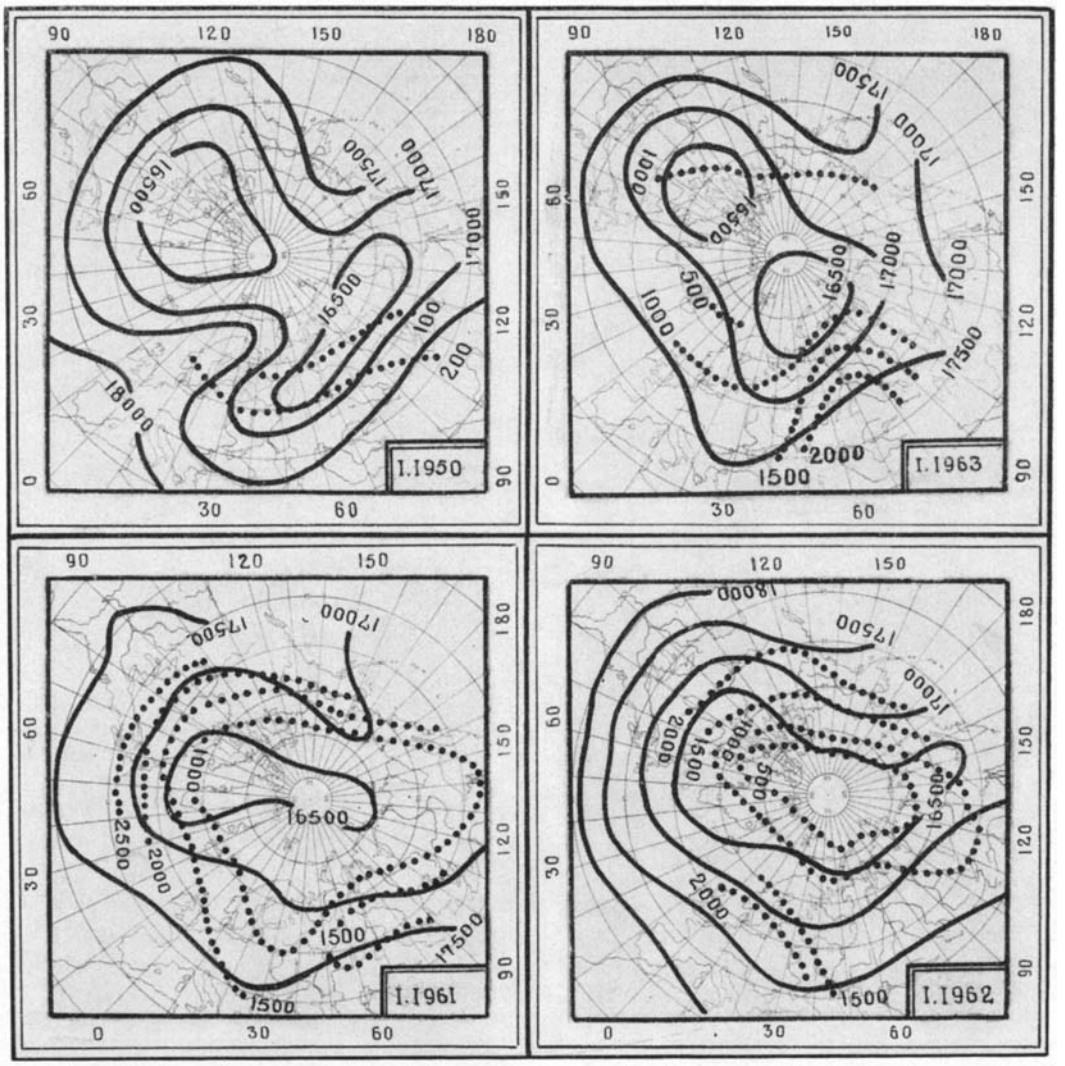

FIG. 8. Distribution of amount of internal (—) and kinetic (– – –) energy in air-column (consequently 10^8 erg/cm^2 and 10^6 erg/cm^2) over extra-tropical latitudes of northern hemisphere in extremely cold (1950, 1963) and extremely warm (1961, 1962) months of January.

misphere in extremely cold (1950, 1963) and extremely warm (1961, 1962) months of January (Fig. 8).

It is worth-while to emphasise the significant change in the amount and displacement of isolines of both kinds of energy, f. ex. two "curls" of minimal values of internal energy in cold months and shifting of the regions with maximal values of kinetic energy from cold to warm winters.

Now the author is going to say a few words about comparison of circulation patterns in the Northern and Southern Hemispheres.

The essential differences of circulation over both hemispheres are well known. Two reasons can be called for explanation: (1) the Earth's atmosphere absorbs selectively diverse kinds of solar radiation and is heated predominantly from the underlying surface; (2) the Earth's surface in the Northern and Southern Hemispheres is quite different and its influence on the atmosphere evidently is different too.

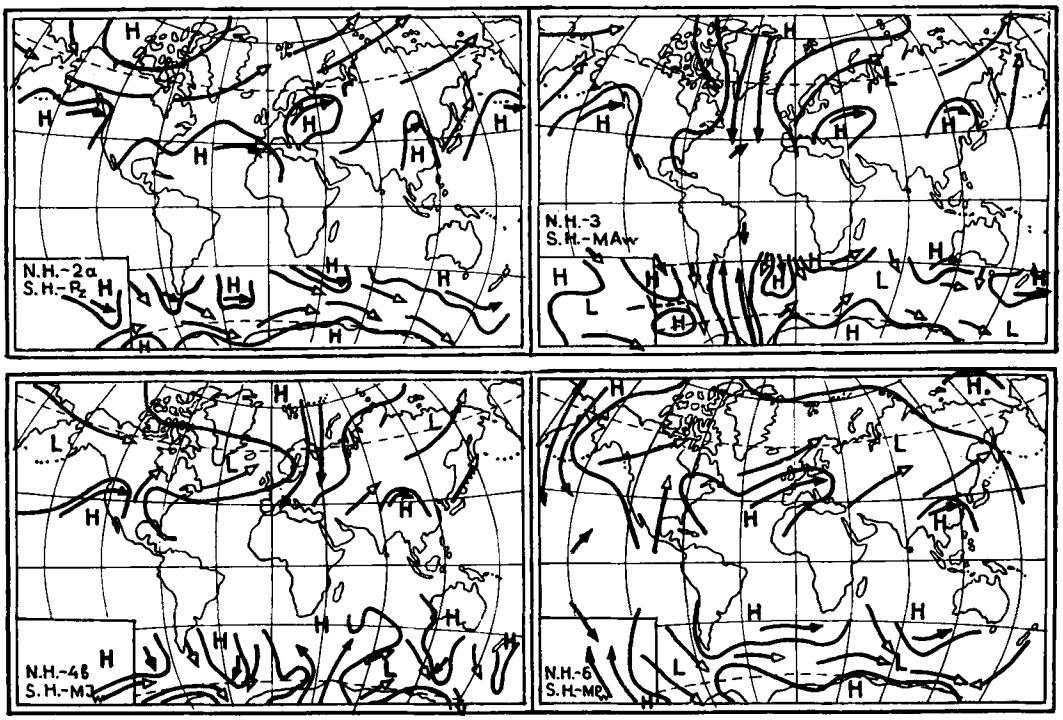

FIG. 9. Comparison of four types of circulation over the northern hemisphere (after B. Dzerdzeevskii) and over the southern hemisphere (after P. D. Astapenko). (Types of ECM are shown on the maps.)

However in the case when circulation of the Earth's atmosphere is stipulated by the energy coming from the underlying surface only the difference in circulation between the two Hemispheres should be much greater. As the logical conclusion from this concept the hypothesis of "autonomous" circulation over both Hemispheres, of the existence of "the wind barrier" in the fortieth, of the distinction of the composition of the atmosphere over Antarctica—were repeatedly expressed.

The new data obtained since the IGY provide the possibility to renew the analysis of the circulation over both Hemispheres with particular reference to other sources of energy (it means not only the long-wave radiation) which influence the circulation mechanism. One can "a priori" assume that these influences are equal—or very nearly equal— for both Hemispheres. It means that the attention should be turned to reveal not the differences but the similarities in the circulation patterns over both Hemispheres.

To avoid random results some precautions must be foreseen: (1) the comparative analysis of circulation patterns in both Hemispheres will be more valid if it begins from the low part of the troposphere; each of the revealed similar processes in such unfavourable conditions must be regarded as very active and independent (or rather not completely dependent) on underlying surface; (2) chosen circulation patterns similar for both Hemispheres must not be single and random but typical.

Fig. 9 shows the four main typical schemes of circulation over the Northern (DZERDZEEVSKII, 1945, 1954, 1957, 1962, 1963) and Southern (ASTAPENKO, 1960) Hemispheres. The principles of typification in both cases were similar. The detailed analysis was made for confirmation that relatively short-period data from the Southern Hemisphere gives not unstable and random results. The similitude of the processes and especially of location of regions with typical polar intrusions is clearly seen. Further investigations in this field can give a more correct conclusion concerning different influences of several factors on global circulation.

From the author's point of view the statisti-

cal synoptic-climatological analysis—it means the study of typical circulation patterns (BERGERON, 1930)—must be used not only as a preliminary method but as a parallel one, used together with strong mathematical techniques. Such combined analysis must help to sooner achieve the progress in studying of the global circulation of the atmosphere and consequently the dynamic climatology.

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НЕКОТОРЫЕ АСПЕКТЫ ДИНАМИЧЕСКОЙ КЛИМАТОЛОГИИ

Приводятся некоторые новые результаты изучения общей циркуляции атмосферы и флуктуации климата в северном полушарии. Сравниваются две циркуляционные и климатические эпохи в XX веке. Приводятся количество и распределение внутренней и кинетической энергий во внетропических широтах полушария в наиболее холодный и теплый январи. Сравниваются циркуляционные типы над северным и южным полушариями; между ними прослеживается хорошее согласование.