METHODS OF CONSTRUCTION LONG-RANGE WEATHER FORECASTS

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Meteorologiya i Gidrologiya, No 3 (1949(, pp 45-53.

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For constructing long-range weather forecasts it is necessary to visualize the different types of air-mass exchange between the pole and the Equator.

As a basis for this, baric formations, air masses and fronts appearing on synoptic charts should be used. B. P. Mul'tanovskiy, whose method we employ in our work, succeeded in doing so. We believe that his idea of the general circulation of the atmosphere is precisely the basis for the school of long-range weather forecasting. Phases of macroprocesses, datum points, analogues, etc., are only the technical side of the method, which will change in due time.

We have to dwell on the principles of the method as they are usually expounded along different lines.

Mul'tanovskiy arrived at his types of general circulation of the atmosphere on the basis of two hypotheses:

(1) all synoptic processes are a reflex of centers of atmospheric action, and

(2) traveling cyclones and anticyclones are directed by a flow of air masses in the medium layers of the troposphere.

Therefore, by their very motion, these baric formations convey cold air masses from the north and warm ones from the south. This is the so-called "dominator" hypothesis.

Formation of moving anticyclones was conceived by Mul'tanovskiy as "tearing of a drop" of cold air off a polar anticycl ne (center of cold). In case of anticyclones moving north, it was "tearing of a drop" of warm air off an Azores anticyclone (center of warmth). According to Mul'tanovskiy, convection of a torn-off air mass in the shape of an anticyclone took place in the following manner:

Air masses are involved in the first place in the closed circulation of, as it were, a stationary anticyclone, andsecondly, in the transfer of the entire formation as a whole. To the composite transfer Mul'tanovskiy gave the name "dominator" [1], [2], [3].

The air masses exchange between the pole and the Equator presents itself as a traveling of anticyclones along different trajectories (axes). To the foci where anticyclones "originate" (points of "origin" of the axes), Mul'tanovskiy gave the name "center of atmospheric action."

The centers of atmospheric action "act" upon the continent by "bombing" it, as it were, with shots of high pressure (warm and cold). Predominance of the "action" of a polar or an Azores center of atmospheric action determines the type of circulation of the atmosphere (polar, western, or combination type) [4].

This led to the notion of the natural macroprocesses of a period or a season, which is so important and fruitful in constructing long-range weather forecasts.

Before elaborating on the method, it is necessary to ascertain the correctness of the hypotheses on which it is based.

THE DOMINATOR HYPOTHESIS

We obtained a physical corroboration of Mul'tanovskiy's dominator hypothesis in the research done by S. I. Troitskiy. S. I. Troitskiy saw the reason for the circulation of the atmosphere in the horizontal distribution (or dislocation, as he put it) of air masses.

We have shown that:

(a) Mul'tanovskiy's dominator is the same as Troitskiy's leading current;

(b) the flow which carries a baric formation according to Mul'tanovskiy is the geometric increment of wind with height, perpendicular to the direction of the horizontal gradient of mean temperature of the layer (according to Troitskiy). According to Mul'tanovskiy, no flow means no trajectory. According to Troitskiy, no temperature contrast means no temperature wind (or Mul'tanovskiy's flow), i.e., no movement of the baric formation. Mul'tanovskiy's axis is, therefore, the indicator of distribution of air masses with different temperatures;

(c) Multanovskiy's stationary anticyclone corresponds to Troitskiy's distribution of air pressure at the lower level.

In elaboration of Mul'tanovskiy's ideas, the following conclusions were reached:

1. Dominator (or basic transfer of air masses) constructed for all the baric formations of the synoptic chart of a given day is completely consonant with the 500-millibar baric topography chart for

the same period.

2. This convection retains its general features during a natural synoptic period.

3. Confrontation of the synoptic kinematic chart for the period with the dominator of this macroprocess, and of the pencil of trajectories for a season with the dominator of the season, showed full concordance. The dominators were obtained from 500- and 500/1,000-millibar baric topography charts by way of averaging for a given period of time, as well as on the basis of the predominant paths of anticyclones.

The results obtained are, first of all, of practical importance, since they allow a three-dimensional analysis of synoptical processes for previous years (where there are no baric topography charts); secondly, the ascertained lengthy duration of transfer (or leading current) in the course of a macroprocess indicates a durative distribution of various large-size air masses.

The starting point in all our forthcoming work must be the thesis: all macroprocesses, regardless of their kind, are caused by dislocation of air masses of proper size.

The zone where warm and cold air masses meet and develop a gradient flow (dominator or leading current of a macroprocess) we call the macrofrontal zone. This name serves to emphasize the lasting character of distribution of air masses (which determine a frontal zone) as well as their very large size (as against small air masses kAB, mPV, etc.

THE CENTER OF ATMOSPHERIC ACTION HYPOTHESIS

Centers of atmospheric action have, in our opinion, first of all to reflect the dislocation of air masses (which determines the formation of a macroprocess on the whole); on the other hand they must determine the dynamic advective formation of cyclones and anticyclones.

The concept of centers of atmospheric action was originated by Teisserenc de Bort. By centers of atmospheric action he understood baric formations which retain their position for a long time and determine the circulation over a large area.

Mul'tanovskiy's centers of atmospheric action, which have been defined by him as "points of origin" of anticyclones, are centers of warmth and of cold. A polar anticyclone cannot determine the dynamic advective formation of anticyclones. At the same time, we do not consider a traveling anticyclone to be a drop torn off a polar anticyclone. Therefore, a polar anticyclone is not a "point of origin" of axes, and thus does not determine the character of the circulation of the atmosphere, as Mul'tanovskiy believed.

All this indicates that a polar anticyclone is not a center of atmospheric action.

Central cyclones and stationary anticyclones are not only in conformity with Teisserenc de Bort's definition, but also are centers of warmth and of cold. We have ascertained that distribution of such centers of atmospheric action determines the centers of warm and cold air masses (distribution of mean temperature of the layer), the macrofrontal zone and the structure of high-latitude currents, the trajectories and the dynamic advective origination of baric formations, the trajectories of isallobaric nuclei of increase and decrease in atmospheric pres ure, the anomalies of air temperature, and, finally, the mean atmospheric pressure for a natural synoptic period at sea level and at different altitudes.

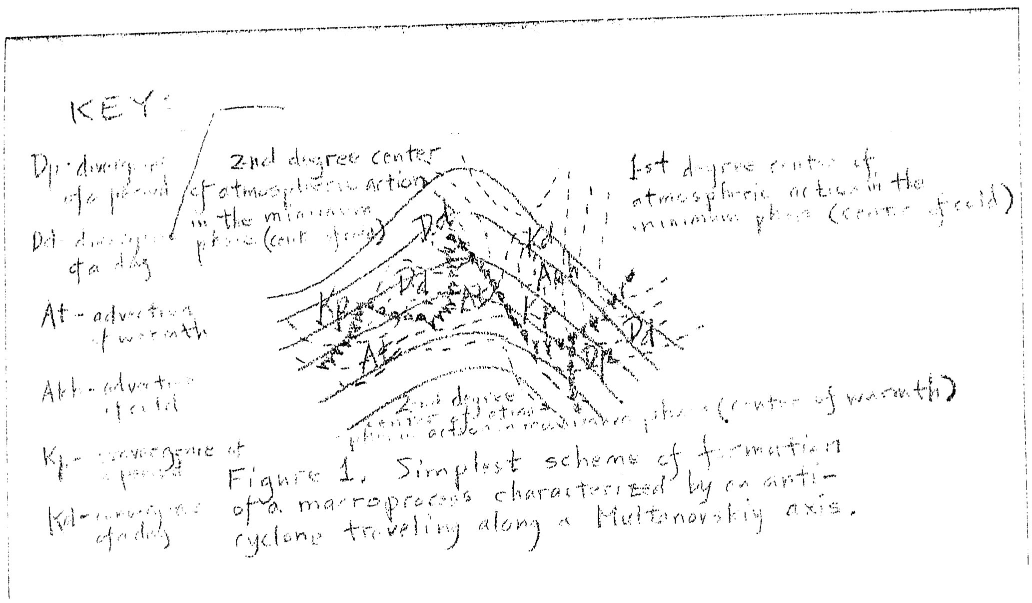

Figure 1. Simplest scheme of formation of a macroprocess characterized by an anti-cyclone traveling along a Multanovskiy axis.

Knowledge of the distribution of such centers of atmospheric action fully determines a macroprocess in space and time.

However, stationary anticyclones and central cyclones are not reported too often. It is natural to assume that such important objects must be constantly in existence, but that in most of the cases they are barically formed to an insufficient extent, and thus remain unnoticed.

This assumption has been corroborated by the analysis. It has been found that a center of atmospheric action, being active, is the high baric formation of macroprocesses and at the same time the center of warmth and cold.

In this case quasi-stationary baric formations of different intensity are in question. Practically, they are determined in the following way: an active center of atmospheric action in the minimum phase is marked by a decreased pressure at the earth's surface, and by a cold hollow above that point on absolute (500-millibar) and on relative (500/1,000-millibar) baric topography charts.

An active center of atmospheric action in the maximum phase is an increased pressure at the earth surface, and a warm crest above that point in the medium layers of the troposphere (on baric topography charts). The central cyclone and the stationary anti-cyclone constitute a particular case of activation of the center of atmospheric action.

There are 1st-degree (polar and tropical) and 2nd-degree (moderate-latitude) centers of atmospheric action. At the time of activation, polar centers of atmospheric action are mostly in the minimum phase (particularly central cyclones), and tropical ones in the maximum phase (stationary anticyclones). Location of all 1st-degree centers of atmospheric action (which have ever been active) may be determined climatologically. They may be found by comparing sea-level air pressure charts for a number of years ~~will~~ with 500-millibar surface topography charts for the same period.

Location of the 2nd-degree centers of atmospheric action may be determined only by typification of a large number of macroprocesses, since at the time of activation they pass different phases. We shall dwell below on this. We arrived at the following conclusions:

1. Multanovskiy's dominator is physically backed.

2. Polar anticyclone is not a center of atmospheric action.

3. Azores anticyclone is a center of atmospheric action and a center of warmth, but it participates in the origination of baric formations by interacting with a center of cold, and not by "discharging" a drop.

4. We detected new centers of atmospheric action which determine:

   (a) distribution of air masses;

   (b) macrofrontal zone;

   (c) dynamic advective origination of baric formations beneath the macrofrontal zone.

5. Natural synoptic period is a maintenance period of a given distribution of air masses. Its duration is determined by the period of rhythmical changes in the atmosphere which activate a center of atmospheric action.

6. Natural synoptic season depends on maintenance of the distribution of air masses of very large dimensions.

The foregoing was reported to as seminar at the TeIP on 26 June 1943, and to a conference of long-range weather forecasters in Moscow in September 1943.

THE FRONTOLOGICAL STRUCTURE OF A MACROPROCESS

The thesis "Dislocation of large-size Air masses causes formation of any kind of macroprocesses" unquestionably leads to a number of conclusions.

As has already been said, we assume that, due to certain causes, centers of warmth and of cold (centers of atmospheric action) originate in certain areas. Causes of their origination may be V. V. Shuleykin's thermobaric seiches or dynamic advective factors of higher order.

We neglect small air masses (kPV, kAV, etc) and turn to consideration of the synoptic process as a result of thermodynamic interaction of warm and cold air masses of large size which retain their location for a long period of time.

The first cause of formation of a macroprocess we see in the dislocation of air masses. It can be determined (in its initial phase) from the distribution of centers of atmospheric action.

This indicates the existence of a frontological structure in the macroprocess of a period and, possibly, of a season.

In 1944, the writer of this paper suggested a scheme of the three-dimensional structure of a macroprocess characterized by formation of an anticyclone, and of its traveling along Mul'tanovskiy's axis (Fig 1).

Two centers of atmospheric action in their minimum phase (centers of cold) and one interposed center of atmospheric action in its maximum phase (center of warmth) determine a macrofrontal zone (in this case, with crest circulation structure).

Macrofrontal zone is an approach area of air masses of diffe - rent temperature. The quasi-stationary front of a given macroprocess lies beneath it. At this front waves develop which travel with the gradient current in the macrofrontal zone. With further motion, they become occluded. Occluded fronts lie across the macrofrontal zone.

High-altitude and earh-surface processes are interconnected. Due to wave development at the front, waves develop on the macrofrontal zone. Increase and decrease in atmospheric pressure at the earth surface intensifies fluctuations in the macrofrontal zone. This, in its turn, causes increase or decrease in atmospheric pressure at the earth surface. Such an interconnection of different constituents of the macroprocess is illustrated by Fig 1. In the rear of the occlusion front beneath the ingress of the macrofrontal zone, conditions are most favorable to formation of an anticyclone.

In Fig 1, dotted lines present isobars, and thick lines show the macrofrontal zone of a period (in mean 500-millibar surface baric topography of a natural period). The ornamental line is the basic front of the macroprocess of the period. Undulatory fluctuations at this front cause origination of all traveling baric formations beneath the macrofrontal zone of the period. Frontological (short-range) synoptic meteorology employs, for analysis, patterns of frontological structure of baric formations. We suggest employing (even for analysis

ysis of current synoptic charts) patterns of frontological structure of a macroprocess.

A pattern is determined by the distribution of centers of atmospheric action, which originate prior to the front, and influence the dislocation of air masses persisting, basically, throughout a macroprocess.

FORMATION OF PRESSURE FIELDS

We assert that, if the the macroprocess be considered a result of dislocation of large-size air masses, a different approach to the causes of changes in atmospheric pressure is also necessary. Distribution of atmospheric pressure on a synoptic chart and on an aggregate chart of a period or a season is obtained as a sum of contributing factors of various order.

(a) Pressure fields on an aggregate chart of a season are determined by the distribution of the basic 1st-degree centers of atmospheric action which are characteristic for the given season. This contributing factor in the distribution of atmospheric pressure will also be found in the corresponding area on the aggregate chart of a period as well as on the synoptic chart of a day of this season (Fig 1).

(b) Pressure fields of a given natural synoptic period are determined chiefly by the distribution of the 1st-degree (seasonal) and the 2nd-degree (period) centers of atmospheric action. The totality of these centers of atmospheric action determine the dislocation of air masses, which shapes the structure for that period (Fig 1). This contributing factor in the distribution of pressure will also be found in corresponding areas on each synoptic chart of the given period.

Contributing factors (a) and (b) are due to causes of some higher order.

(c) As the result of a given distribution of 1st-and 2nd-degree centers of atmospheric action, the macrofrontal zone of period develops. Beneath it, changes in atmospheric pressure are caused, in the first place, by present convergence and divergence of currents during the period and the current day, and secondly by traveling of waves at the basic front of the troposphere. The latter causes advection of warmth or cold, and, correspondingly, advection of high or low atmospheric pressure (Fig 1).

(d) Cyclones deepen when all contributing factors of different order lead to lowering of atmospheric pressure (Dp, Pd, At). Anticyclones gain strength when all contributing factors of different order tend to increase the atmospheric pressure (Kp, Kd, Akh).

Factors contributing to changes in atmospheric pressure are territorially separate (1st- and 2nd-degree centers of atmospheric action, and the macrofrontal zone) (Fig 1). Therefore, they can be easily distinguished qualitatively. Their distinction allows to distinguish, on the current synoptic chart, factors of a season and of a period from lesser factors.

We consider the structure of a process shown by isobars and fronts on synoptic charts from the standpoint of circulation of the atmosphere of a period and a season. With this in mind, analysis of any synoptic chart must be carried out in the following order:

1. Location of the centers of atmospheric action (contributing factors of the season and of the period) is determined.

2. Pattern is determined of the frontological structure of the macroprocess of the period (dislocation of air masses determinative of the period).

3. The frontological analysis is detailed in accordance with the rules of synoptic frontology.

4. Explanation is given of formation of various parts of every area of high and low pressure on the synoptic chart.

Detailing of this analysis after the distinction of the centers of atmospheric action is carried out along the lines of analyzing the dynamic advection.

(e) If the macroprocess be considered a result of dislocation of air masses, all baric formations may be classified in the following way.

Any high-pressure area is created due to the presence of:

(1) a center of atmospheric action in the maximum phase;

(2) increasing atmospheric pressure beneath the ingress of frontal zones to the west and to the east of the center of atmospheric action (Fig 1).

All these contributing factors are present at any time. If the largest contributing factor is that of the center of atmospheric action, we will obtain, on the synoptic chart, a stationary anti-cyclone with circumventing crests.

If the contributing factor is increased at the ingress of the western frontal zone, so-called "northward lifting of Azores nuclei" occur. In case of an increase at the ingress of the eastern frontal zone, "polar intrusion" takes place.

A low-pressure area is also a result of three contributing factors: a center of atmospheric action in the minimum phase and a pressure drop beneath the delta of the western and the eastern frontal zone.

Depending on predominance of one or another contributing factor, we obtain a central cyclone, so-called "diving" cyclone, or "egressions" of cyclones from the south.

Thus, we believe that the reason for development of a given microprocess [Sic] is the distribution of centers of atmospheric action, i.e., dislocation of air masses. The above-mentioned varieties of baric formations indicate different stages in the development of a given macroprocess.

Such an approach to the macroprocesses makes it possible to recognize them at different times of the year in their various manifestations. This is of great practical importance for checking datum points, for analyzing the season, and for studying the history of the macroprocess. All these stages of constructing of weather forecasts for a month and a season attain objectiveness. To visualize the obtained conclusions, we suggest the reader compare Fig 1 with synoptic charts.

CLASSIFICATION OF MACROPROCESSES

In 1943, the writer of this paper suggested the following principle for genetic classification of macroprocesses.

1. Classification is possible only for natural macroprocesses, i.e., those determined by a definite dislocation of air masses (the basis for distinguishing the periods).

2. Classification must be carried out on the same basis on which periods have been distinguished (the basis for classification).

Active centers of atmospheric action show us the dislocation of air masses, and determine the distribution of the mean temperature in the layer Tt as well as the distribution of atmospheric pressure at the lower level Po.

Mindful of our principle, we have both to distinguish the periods and to classify the macroprocesses with regard to the centers of atmospheric action.

Such work was carried out early in 1944 under the guidance of the writer, by DPP group weather forecaster T. L. Mazarova, on the basis of 80 periods. Later, in 1945-1946, a classification of macroprocesses characterized by anticyclones traveling along Mulltanovskiy's axes was undertaken on the basis of materials for 34 years (1912-1945). Axes were analyzed by different writers. Cases were selected of well formed anticyclones traveling along an axis, the anticyclones being classified separately by each writer.

The results of the classification fully corroborated the arrangement shown in Fig 1.

Type I of the North Cape and the Cape Kanin axes is described by this arrangement.

Different types of the western axis is described by the same arrangement.

By drawing Fig 1 to the scale of a chart which showed all the centers of atmospheric action, the writer obtained (by matching the arrangement against various clusters of centers of atmospheric action) the type I for all the polar axes, as well as different types for ramifications of the western axis.

In accordance with what has been said in Section 4, the analysis showed that well formed western anticyclones have only hollows along the polar axis, and on the contrary (with the same cluster of centers of atmospheric action), polar anticyclones have crests along the Western axis.

The rest of the types were obtained not for all the axes studied. Type III was found with the North Cape and the Cape Kanin axes; type IV only with the North Cape axis. These arrangements, as well as the arrangements for ultrapolar processes, were also developed by the writer.

On the basis of materials for 34 years, a chart of all centers of atmospheric action which become active at various seasons were obtained.

The arrangements are characterized by definite conjugate distances between centers of atmospheric action. A total of five arrangements for normal and three types for ultrapolar axes was obtained.

The obtained arrangements are three-dimensional.

On an arrangement location of centers of atmospheric action (as centers of warmth and cold), trajectories of cyclones and anticyclones, the line of demarcation between the high-pressure and the low-pressure fields on the aggregate charts of a period, and, finally, the structure of high-altitude currents are plotted. By matching the arrangement against various clusters of centers of atmospheric action, we obtain the same type of macroprocess for different axes.

The macroprocess of an anticyclone's traveling along a definite axis is fully determined by (1) the type of the circulation arrangement, and (2) the name of the axis.

The latter means attributing the arrangement to a certain geographical area as far as centers of atmospheric action are concerned. Of every axis, a certain cluster of centers of atmospheric action is characteristic. As an example, let us match the centers of atmospheric action in Fig 1 in the following manner: the centers of atmospheric action in the minimum phase with the Icelandic and the Lower Ob centers, and in the maximum phase with the Dnester center (this will be the type I of the North Cape axis). In the case of the Cape Kanin axis, this will be the Norwegian, Taymyr, and Lower Volga centers. In the case of the Kara Sea axis, the Swedish (the northern part of the Gulf of Bothnia), Yakut and Kazakh (between the Aral Sea and Lake Balkhash), and so on.

Difference of types with each axis is due to the fact that every center of warmth and of cold has its source not in one center of atmospheric action, as shown in Fig 1, but in two or three of them.

The 1st-degree center of atmospheric action in the minimum phase east of the axis remains there for all types of processes with the given axis.

This is why we called the ultrapolar influence, with which a 1st-degree center of atmospheric action (to the east of it) is characteristic of the North Cape axis, the ultrapolar North Cape influence, and so on.

Thus, we replaced the long Multanovskiy denominations of ultrapolar axes with shorter ones, and established the relation between North Cape and ultrapolar axes.

Practically, it turned out to be very useful for checking datum points. For instance, with the fourth type of the North Cape axis, the center in the maximum phase is the Skagerrak center of atmospheric action, and that in the minimum phase is the Lower Ob center of atmospheric action. With the first ultrapolar type of the North Cape axis, besides these centers of atmospheric action, also the Lower Volga center of atmospheric action in the minimum phase becomes active. This is exactly what makes the process ultrapolar. This is why an analogue to the first ultrapolar North Cape type will be the fourth normal North Cape type. The same is true for any axis.

Besides, it has been found that the first ultrapolar Cape Kanin type is the reverse of the first ultrapolar Scandinavian type, or the first ultrapolar North Cape type is the reverse of the first ultrapolar Kara Sea type.

These conclusions also make it possible to check datum points objectively. This can be ascertained by drawing arrangements on transparent paper and matching them against a chart of centers of atmospheric action (of the same scale).

The discovery that one 1st-degree center of atmospheric action is active with all types of a given axis made it possible to analyze a season in an objective manner.

We see that although we were dealing with different centers of atmospheric action (i.e., different from Multanovskiy's centers of atmospheric action), we still ascertained the possibility of characterizing a macroprocess (of a period or a season) by the axis along which it develops.

This is of great importance for the practical work. That which has been said in Section 4 broadens the notion of the macroprocess characterized by the given axis.

Thus, an aggregate chart of a season makes it possible to determine the basic centers of atmospheric action, even when no baric topography charts are available.

Classification of single days, periods, and seasons is carried out on the very same basis (on the basis of centers of atmospheric action). This makes it possible to establish genetic relationship among processes of different duration.

Dealing with centers of atmospheric action, we can find common centers of atmospheric action for different configurations of a high-altitude crest or hollow. Thus, Mul'tanovskiy's assertion has been proved that a season is characterized by its working axis. This conclusion, along with those obtained above, makes possible a three-dimensional analysis of macroprocesses of past years, even when no baric topography charts are available.

Existence of universal arrangements of the circulation of the atmosphere (independent of the geographical location) gives reason to assert that macroprocesses over Siberia are not different from those over Europe. This assertion is in contradiction with the widespread opinion that the Siberian anticyclone is a settled winter-season baric formation.

We expressed the opinion that the Siberian anticyclone develops due to activation, in various areas, of centers of atmospheric action in the maximum phase. Its powerful appearance is due to an anomalous reduction of atmospheric pressure at the sea level.

This problem will be dealt with in a special research work.

Finally, availability of pattern arrangements is of great importance in working with a clipped chart. Distribution of centers of atmospheric action is characteristic of any type of processes; therefore, the three-dimensional structure of the missing western part of the process can easily be extrapolated.

In conclusion, we shall mention that we put stress, first on that type of circulation of the atmosphere which is caused by the dislocation of air masses.

Within the same type, diversity of earth-surface situations may be explained by what has been said in Section 4. Later, we shall turn to the investigation of causes of origin of centers of atmospheric action, and to the study of detailing of earth-surface charts from the standpoint of difference in temperature contrasts in the microfrontal zone, caused by a similar distribution of centers of atmospheric action.

Bibliography

1 B. P. Mul'tanovskiy. Basic principles of the Synoptical Method of Long-Range Weather Forecasts. Published by TsUYeGMS USSR, Moscow, 1933.

2 T. A. Duletova, S. T. Pagova, A. A. Rozhdestvenskiy, and N. A. Shirkina. Elements of the Synoptical Method of Long-Range Weather Forecasts. Edited by S. T. Pagava. Publishing House for Hydrometeorology, Leningrad-Moscow, 1940.

3. N. A. Bulinskaya. Constructing of Long-Range Weather Forecasts for Three Days Ahead. NIU Proceedings, Series II, Issue 9, Moscow, 1943.

4. B. P. Mul'tanovskiy. "Influence of Centers of Atmospheric Action on the Weather of European Russia in Warm Seasons. I- Droughts." Geographical Magazine. Volume II, Issue 3, 1915.

LEGEND FOR FIGURE I [see page 6 here]

Figure 1

2nd-Degree Center of Atmospheric Action in the Minimum Phase (Center of Cold)

1st.Degree Center of Atmospheric Action in the Minimum Phase (Center of Cold)

2nd-Degree Center of Atmospheric Action in the Maximum Phase (Center of Warmth)

Figure 1. Simplest Scheme of Formation of a Macroprocess Characterized by an Anticyclone Travelling Along a Mul'tanovskiy's Axis.

Key: At- Advection of Warmth; Akh - Advection of Cold: Kp - Convergence of a Period; Kd- Convergence of a Day: Dp - Divergence of a Period; Dd - Divergence of a day.