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REPORT

CD NO.

50X1-HUM

COUNTRY	Germany	DATE OF INFORMATION	--
SUBJECT	Scientific - Geophysics, long-range weather forecasting, Multanovskiy's methods	DATE DIST.	// May 1951
HOW PUBLISHED	Pericdical		
WHERE PUBLISHED	Not indicated	NO. OF PAGES	16
DATE PUBLISHED	Not indicated	SUPPLEMENT TO REPORT	
LANGUAGE	German		

50X1-HUM

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THE SYNOPTIC METHOD OF LONG-RANGE FORECASTING
BY B. P. MULTANOVSKIY'S SCHOOL (Part I)

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THE SYNOPTIC METHOD OF LONG-RANGE FORECASTING BY B. P. MULTANOVSKIY'S SCHOOL (Part I)

B. Neis

Author's summary: The introduction cites the sources on which the Multanovskiy method is based and gives Multanovskiy's personal history. For better understanding of the concepts developed by him, a short discussion of oscillation and wave phenomena is given. Then an explanation is given of the concepts of axis, composite maps, natural time intervals, natural synoptic periods, elementary synoptic process, natural synoptic seasons, phases, and rhythms. This is followed by an example and a short description of the developing of a long-range weather forecast by Multanovskiy's method. The article is concluded by a comparison with the long-range weather forecast methods of L. Weickmann and F. Baur.

I. Introduction

Very little or nothing at all has been reported in German periodicals on Multanovskiy's method. Even the Second Edition of the German translation of "Introduction to Synoptic Weather Analysis" by S. P. Khromov, published in 1942, merely states that the long-range forecasting method developed by B. P. Multanovskiy consists in the forecasting of synoptic processes, based on pressure distribution, using so-called "composite maps" of the position of baric centers, on which maps the displacement of the pressure fields is extrapolated.

It was thus a most worthwhile effort by the meteorologist, Mrs. Maria Wenzel, of the former Reichs Meteorological Office to translate the Russian material available on this topic, and to bring the subject to the attention of her colleagues by a report of 50 typewritten pages with 21 maps. The discussion between her and M. Rodewald in "Annalen der Meteorologie", VII/VIII (1948), was the direct stimulus for the publishing of a long overdue report on this fundamentally important matter in the "Zeitschrift fuer Meteorologie".

B. P. Multanovskiy was born in 1876 and died at Leningrad on 4 March 1938. He studied meteorology under A. Voyeykov, from whom he obtained a view of the large-scale meteorological phenomena extending over many millions of square kilometers, as they present themselves to Russian meteorologists. In 1913 he was appointed chief of the synoptics department for long-range forecasting. In 1915 he wrote "The Synoptic Conditions of Drought" and predicted the flood of the Lena River. Because of scientific attacks against him, he was forbidden, starting in 1916, to publish forecasts in the name of the Main Geophysical Observatory. During the winter of 1921/22 he forecast, upon request by the railroad administration, a disastrous flood of Lake Ilmen. On the basis of this forecast, the railroad administration was able to take proper precautions, so that the flood, when it did occur, did not disrupt railroad traffic. Starting in 1922, the Main Geophysical Observatory resumed publication of his forecasts. Agriculture, shipping and scientific expeditions used his forecasts. Multanovskiy was firmly convinced of the great value of meteorology, especially of long-range forecasting in a planned national economy, so that there was no agricultural planning in which he did not participate. He had become a practical meteorologist.

This report is based on the following material, translated from the Russian: Principles of the Synoptic Method of Long-range Weather Forecasting, by B. P. Multanovskiy, 1933;

The Bases of the Synoptic Method of Long-range Weather Forecasting, by T. A. Duletova, S. T. Pagava, A. A. Rozhdestvenskiy, and N. A. Shirkina, 1940;

Meteorologiya i Gidrologiya, No. 5, 1938: "On the Rhythmic Activity of the Atmosphere", by S. T. Pagava;

Mrs. Wenzel's report, mentioned above.

Our report has one shortcoming: It was compiled on the basis of translated material. There is a possibility that the sense of the terms has undergone some changes in the translation. However, since the entire system of concepts is one unified whole, based on most exact scientific observations, this shortcoming should be quite beside the point. If the long-range weather forecasting method of B. P. Multanovskiy is discussed by German meteorologists more than it has been until now, this article has served its purpose.

2. Auxiliary Concepts of Wave and Oscillation Theory

G. I. Vangengeym who wrote the introduction to the above-mentioned fundamental work states: "Multanovskiy uses in his work original expressions which usually have a deep hidden meaning. They are so characteristic that the editors made special efforts to retain the terminology and style of the author". This is probably the reason why the valuable ideas of Multanovskiy have not become internationally known.

In order to make these concepts clear, we shall preface them with a few words on oscillation and wave theory. If one perceives similar traits in comparing two phenomena, then he will understand them. This is not always easy. The periodic variations of atmospheric pressure in the tropic zones have been understood for 50 years and their causes known. The classification of the aperiodic pressure variations in the temperate zones by periods has so far been unsuccessful. In order to arrive at any understanding of periodic phenomena in the atmosphere, it is appropriate to recall the most simple periodic phenomenon in existence. The author of this article believes that the transition from these phenomena to atmospheric ones is a practicable method for comprehension of the system of concepts used by Multanovskiy. We can discuss this topic only to the extent to which it is required here for the purpose indicated. Details can be seen from the bibliography [1]. [The bibliography is not available].

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The mathematical pendulum with very small amplitude operates according to the equation

$$T = 2\pi \cdot \sqrt{l/g}.$$

It demonstrates the important fact that if a physical constant is added - namely, the acceleration due to gravity - a time interval can be expressed in terms of space; in other words, the period of the pendulum can be expressed by the length of the pendulum. Thus it is not strange if meteorologists would use the magnitude of certain air masses over areas of the earth's surface in order to determine time intervals of importance in weather development. For pendulum oscillations with greater amplitude, another factor is added - namely, the dependence on the magnitude of the amplitude. In the case of damped and forced oscillations, and also in the case of the physical pendulum, some other remarkable properties are added. First of all, the damping prevents the occurrence of a distaster due to resonance. One phenomenon in particular is of importance to the meteorologist, namely the circumstances that the natural oscillations of a oscillatory system will be replaced by externally-applied forced oscillations and that the body will then oscillate with the period of that force. However, the occurrence of this phenomenon requires that the body be solid. The significance of this observation can also be seen from the example of the physical pendulum. The period of its oscillation is given by the equation:

$$T = 2\pi \cdot \sqrt{\Theta/gMs}$$

where theta Θ is the moment of inertia of the mass, M its magnitude, and s the distance of its centroid from the axis of rotation. If the mass is increased, the moment of inertia in the numerator increases by r^5 while the mass in the denominator increases only by r^3. Thus, if the mass is increased the period becomes longer, and conversely. If we assume these changes of mass to be periodical, the type of differential equation representing these phenomena will also change and we will obtain a second-order homogenous linear differential equation with non-constant coefficients. The concept of period loses its meaning and must be replaced by the concept of rhythm, in which congruent repetitions do not take place after certain time intervals, as weather phenomena prove. Oscillations of elastic bodies extending over great surfaces expand the concepts. A circular membrane held at the edges has natural oscillations like a string, with the period of the oscillation given by the equation

$$T = \sqrt{\lambda \cdot \frac{\varepsilon}{S}}$$

where ε is mass per unit area, S is tension, and T is period of oscillation. The lambda factor λ is obtained as the zero of the Bessel function $J(\sqrt{\lambda})$. The appearance of this function in the oscillation problem is a consequence of the form of the edge of the membrane. In the case of fundamental oscillations the amplitudes increase from the edge toward the center, and in the case of harmonics node lines appear. It is appropriate to think of coupled pendulums whose oscillations show a periodically variable amplitude. Wave theory also supplies the concepts of interference, coherence, resonance, beats, phase velocities and group velocities.

The oscillations and wave motions in liquids are subject to still other special regularities. One of these factors which deserves mentioning is the effect of the joining of two originally separate bodies of flow. In an oscillating mass this extends the period of oscillation.

The application of the above phenomena to atmospheric conditions has none of the aspects of the pseudo-scientific. The works of the German meteorologists A. Schmauss, H. von Ficker, L. Weickmann, A. Defant, and J. Bartels, just to name the older ones of those still alive, confirm this concept. All weather events are an incessant conversion of the most varied kinds of energy. The conversions take place by means of circulations which are always coupled to each other within the entire atmosphere. The source of energy is the incoming short-wave radiation of the sun, and the negative source is the emitted long-wave radiation of the earth and of the atmosphere.

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Between these phenomena the processes of atmospheric energy conversion takes place in such a way that the processes taking place at the same time form one unit, creating a specialized field of the study of synoptic processes.

The above statements lead to one important conclusion: the magnitudes of certain regions of the earth's surface, defined e.g. by pressure configurations, may be used as a working hypothesis for the time periods in weather defined by the repetition of similar conditions. In place of the varying height of the pendulum mass above the transition point, the change of potential into kinetic energy is used. Obviously, these changes in the atmosphere must remain very small if harmonic oscillations are to be created. However, great conversions of energy are observed in weather, and simple oscillation phenomena cannot be expected to take place. This must be taken into consideration in the estimations of the "period". T. Bergeron in Meteorologische Zeitschrift, 1930, p. 261, in the article "Outlines of Dynamic Climatology" proved the existence of "wheels of circulation". It is permissible to speak of the "coupling" of these wheels and to attempt to interpret their action in the light of the phenomena occurring in coupled oscillating systems. Finally, the fact that these wheels of circulation are very variable in regard to position, size and energy conversion also allows us to penetrate into the mysteries of the atmospheric rhythms.

3. The Axes

The above concepts should facilitate the understanding of Multanovskiy's terminology. It turns out that this method is not an esoteric science. Multanovskiy's school sees the synoptic processes, from the study of the daily weather maps, as a general circulation. It includes the relationship of the polar "centers of action" with those of Mesopotamia, the Azores, etc., and thus, especially in the works of E. S. Lyr, investigates the dynamics of the atmosphere of the entire northern hemisphere. Attempts are also made to investigate the connection between the vortex movements in the atmosphere and the oceanic circulation in the depths. As far as the adaptability of

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the method is concerned, it is remarkable that during the past few years aerological data have been evaluated to provide additional characteristics and that attempts have been made to establish a connection between Multanovskiy's school and the Norwegian theory of V. Bjerknes.

Multanovskiy bases his theory on the investigation of mobile anticyclones, because they are more stable than cyclones, especially after Hildebrand-Hildebrandsson had pointed them out as controlling the weather and since stationary anticyclones are rare. Their centers of origin have been found and their paths determined. Two types were found, those from the West and those from the North, called Azores and Polar Paths. An anticyclone which moves first to the north and then turn to the southeast is taken to be a complex. Its path is resolved into two parts, the first of the Azores type and the second of the Polar type.

According to this pattern, the polar paths of the anticyclones for the years 1881-1915 were entered on two working maps, one for the warm season (April-September) and the other for the cold season (October-March). The two maps show a great fan of paths covering northwestern Europe, with one joint center of origin of the paths located northeast of the northern coast of Greenland and another joint center located in the northeast in the Taymyr region. The paths in the general west-east movement are called normal or polar paths, and those in the direction from northeast to west are called anomalous or ultrapolar paths. A discussion of these terms would be appropriate, but we must omit it because of lack of space. Instead of a bundle of paths established throughout the years, the mean path was taken and called the median. The median characterizes the peculiar direction of the anticyclones coming from the north during the particular half of the year. The medians are then entered on a map covering the entire 35 years - one map for each of the two seasons - and the medians are again determined. These medians are called the axes.

Of course, it had to be determined first whether these axes are not fictitious. The axes do provide data for paths and for the geographical distribution of anticyclones. Moving along the axis with its baric center, the anticyclone brings cold weather to the regions east of the axis, while air is transported from south to north on the west side of the axis. Since these processes are repeated, the axis must be a temperature dividing line and can represent the boundary line for the growth region of certain trees, and for the character and the duration of the rise of the water level in the rivers.

On the basis of the particularly great massing of pressure centers in various sectors of the "fan", Multanovskiy identified the following axes:

polar winter axes: Icelandic, Norwegian, North Cape - Kara axis.

ultrapolar winter axes: Kara, Azov, Hungarian, Scandinavian axis.

polar summer axes: Icelandic, Central Scandinavian, North Cape - Kanin, Kara axis.

ultrapolar summer axes: Kara axes: a) Kara Sea - Kama - lower course of the Volga, b) Kara Sea - upper course of the Oka - upper Dnepr - Hungary

The effect of individual axes on weather changes from section to section along the axis. Multanovskiy distinguishes in the polar winter Icelandic axis three sectors: the oceanic sector extending to the narrows of the Baltic, the second sector from there to the Carpathians, and the third sector from there to the foothills of the Caucasus. Each sector has its own weather characteristics.

The points of origin of the axes, according to Multanovskiy, have the role of "active centers of action of the atmosphere". The centers of action introduced by Teisserenc de Bort, Multanovskiy and his predecessor S. D. Griboyedov are assumed to be passive formations; that is, the primary cause of their origin is to be found at other points on the earth. The characteristic pressure field connected with them is merely the result of particular local conditions. For the Icelandic low-pressure area and the winter anticyclone of Asia this is easy to prove. The regions of intersection of polar and ultrapolar axes are regarded as active centers of action of the second order. The following confirms this idea: during his visit to the Weather Bureau of the Main Geophysical Observatory in 1928, L. Weickmann pointed out that his principle of "mirroring" in air pressure is shown best in the conditions over Hamburg and Hungary. Both these regions are active centers of action of the second order.

The weather of Eastern Europe, according to Multanovskiy, is affected primarily by the polar axes, while western Europe is under the regime of the Azores axes. Therefore in his opinion German meteorologists should concentrate their studies on these axes.

The question of the physical nature of these axes has so far not been answered. While they were derived by the finding of a mean value, the frequency of their geographic distribution was taken into account so that a whole system of axes was developed. Thus as regards their statistical origin the axes greatly differ from, let us say, isobars of mean air pressure in January. They have a decisive effect on the daily weather and correspond to real physical magnitudes. They can be interpreted as geophysical magnitudes of action, with a dimension of $[kg \cdot m^2 \cdot sec^{-1}]$ and a definite numerical value for different sections of the axes, and their manifestation are waves of the atmospheric ocean.

4. The Composite Map

After the intuition of large-scale weather phenomena, which led Multanovskiy to the concept of axes, he posed the question: What is the relation of each of the separate axes to the weather in Europe on the days on which the axes appear? In his chapter on "Axes and Location of the Pressure Regions" he uses the following method for drawing his map showing the pressure regions: For the time during which the baric maximum moves along a

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certain axis, the centers of maxima and minima of individual successive daily weather maps are entered on a working map. Since the movement of maxima along a particular axis, according to above statements, should be closely connected to the distribution of pressure areas over Europe, it was not surprising that the drawing of these working maps showed two regions one of which contained only maxima and the other only minima and which were separated by "lines of demarcation". In addition to these main pressure formations, the map can be supplemented by the centers of partial minima and the high-pressure ridges marked by special symbols. The centers are determined not only by the geometric center of the isolines, but also by the appropriate wind system.

Map 2 shows the composite of the synoptic processes during the warm season (April to September) when, from 1881 to 1915, anticyclones move along the Kara axis. The main region extends in bands from Franz Josef Land across the Kara Sea to the Ob, with a branch running to the Urals. Between the lower Irtysh and the middle Ob there is a small region of partial cyclones, undoubtedly a trace of the incoming breakthroughs of a system of the Taimyr minimum in the cyclone area, located in the Lake Ilmen Basin, the upper Dnepr, the upper Volga, and with a second cluster of centers on the Donets. This area also receives incoming cyclones from Southern Scandinavia and the Baltic across the Niemen, across the Western Dvina to the Northern Dvina, if the Kara minimum extends far enough to the northeast and absorbs the band of the incoming breakthroughs. If this situation prevails, the minima can move from the Donets to the middle Volga and Kama.

In atmospheric ocean, a strong displacement of high-pressure and low-pressure regions from the southwest takes place, and the former show well-developed cyclone troughs which can be interpreted as a sign of the energetic displacement. The Azores-cores receive an additional polar effect from the Jan-Mayen region, an effect which is directed toward the Oder and Hungary.

For western Europe, cyclone activity along the Rhone and the Marne, which has reached the continent from the south through the Tyrrhenian Sea, is characteristic. These conditions favor the development of the Sirocco winds in that sea and the Mistral in the Golfe du Lyon. Thunderstorms develop in a broad belt whose western border runs from the White Sea to Moscow, Kremenchug and Kishinev and whose eastern border runs from Novorossiysk to Stalingrad and Orenburg and to the upper Tobol river. North of the 60th parallel the thunderstorms turn into heavy precipitation (Pechora basin, Mesen, Northern Dvina), and they are highly developed along the middle Volga. In Western Europe, thunderstorms appear west of the 20th degree of longitude, and spread as far as the Niemen basin, Lake Ladoga and the Kola peninsula. The belt running from the Vistula southward to Hungary and probably also to the Balkan peninsula remain free of thunderstorms.

Multanovskiy writes: The composite map shows the change of dynamics of the atmosphere and must therefore have a dynamic character. In the concept of "general circulation" the composite map is an important element. In the sense of the attempted wave-theory interpretation of Multanovskiy's system it could be said that the positions of the lines of demarcation and the magnitude of the high-pressure and low-pressure areas outlined by them attain the dimension of a physical magnitude after multiplication by constants of elasticity, gravity and radiation. This apodeictic statement, however, is valid only within the limits of applicability of the working hypothesis presented here.

Composite maps can be drawn for any kind of weather phenomena. Map 3 shows atmospheric processes which cause increased southerly winds in the Gulf of Finland, and Lakes Ladoga and Onega. Investigation of daily weather maps showed that the winds increased on the following days: 8 June 1920, 13 Sep 1931, 18 July 1932, 4 Aug 1932, 24 Aug 1933, and 22 July 1935, among others. The phenomenon requires a particular pressure distribution over Europe. The composite map shows how the atmosphere solves the problem.

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On those six days chosen here, there was in every case a cyclone over the Baltic, a pressure trough in the Dnepr region and high pressure over the eastern half of European Russia with extensions to the White Sea. On none of these days according to M. Wentzel, was there any cyclone activity in the east or a high-pressure area south of the 55th parallel with an extension to Western Europe.

5. The Natural Intervals

The main problem of weather forecasting in the temperate zones of the earth consists in the knowledge of the periods within which the cyclones and anticyclones arise and vanish. The Multanovskiy school, by means of the concepts of axes and composite maps, has found certain time intervals in the synoptic weather maps which in their opinion are as characteristic for the weather as the period of oscillation is for a pendulum. The occurrences on the surface of the earth, on which the properties of the atmospheric masses depend, cause the two astronomical periods, the daily and annual period of insolation which are the basis of all weather phenomena, to be only of secondary importance in comparison with the circulation of the atmosphere in the temperate zones.

The attempts to understand the creation of the natural atmospheric intervals, depending on the astronomical periods of day and year, can be started by the study of the mixing of the air connected with the general circulation. Meteorologists who have worked on this problem agree that a quantity of heat supplied to the tropics by radiation takes on the average ten days to be distributed throughout the atmosphere. This time interval is of prime importance for the understanding of weather phenomena. As can be concluded by analogy with the theory of damped forced oscillations of physical masses in the liquid state, this large-scale mixing period determines the character of the daily weather. It is a statistical quantity which can be given only within absolute or most frequent limits of variation. It is thus not suited for use in ordinary life. The effect of the mixing process in the atmosphere is shown most effectively by the fact that the start and duration of seasons caused by insolation undergo extensive variations in the temperate zones.

It is thus understandable that Multanovskiy based his time interval for study of forecasting on real observed weather. He called it the "natural synoptic period". Likewise, he designated the seasons determined by the general circulation the "natural synoptic seasons". In the course of his research it was found necessary to introduce a shorter time interval, called the "elementary synoptic process". The term is not a very fortunate choice. Perhaps it should be called "time quantum" of synoptic weather occurrences for the sake of greater accuracy. The above three intervals of time are magnitudes of non-mechanical statistics. They have as mentioned an absolute and most frequent variation.

We should like to add to the above theories the statements by A. Duletova who writes in Chapter 12 of the second book cited in the introduction: "The air around the earth is subdivided into quasi-permanent air masses and is in constant motion. The cyclones and anticyclones of the temperate zones, which are a consequence of the front activity, form and disperse continuously. These motions, transformations and interactions of air masses proceed continuously and are interdependent. If we want to study this regularity in the creation of atmospheric processes, we must somehow subdivide this continous movement, pick out certain stages in the development of the processes and determine certain principles for their subdivision. We can distinguish two simulteneous moments in the development of atmospheric processes; namely, the continuous movement and a certain stability. The latter appears in two types: 1) stability as a quasi-stationary phenomenon, either in the form of a lack of motion or of very slight motion (anticyclones), 2) stability as a manifestation of motion or, in general, as the maintaining of some type of circulation during a certain period of time. The Multanovskiy school then developed the above three natural time intervals by basing the subdivision of the atmospheric processes on the stability principle".

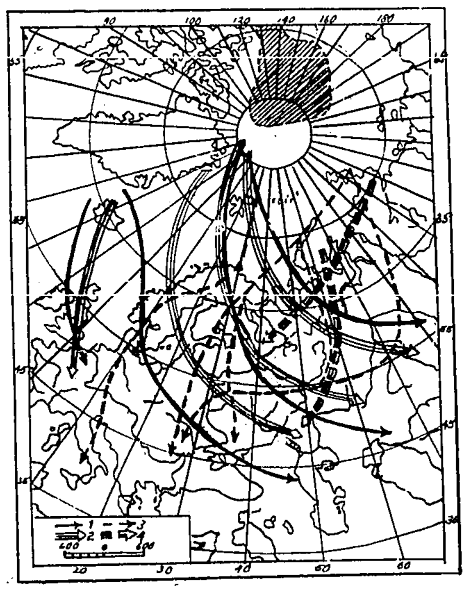

Figure 1. Distribution of the Axes of the Anticyclones According to Multanovskiy. Polar Axes: 1- winter, 2- summer. Ultrapolar Axes: 3- winter, 4- summer.

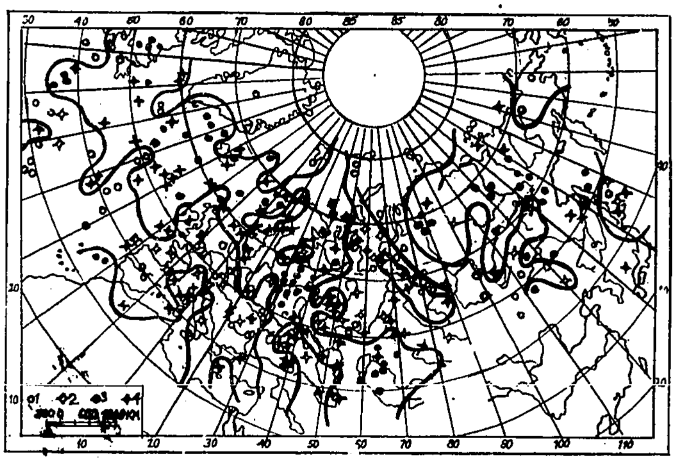

Figure 2. Combined Charts of the Synoptic Processes During the Warm Season (April - September) for Movement of the Anticyclones along the Kara Axis (1888 - 1915). 1 - Centers of the anticyclones, 2 - High-pressure ridge, 3 - Cyclone centers, 4 - Pressure-formed cyclonic characters.

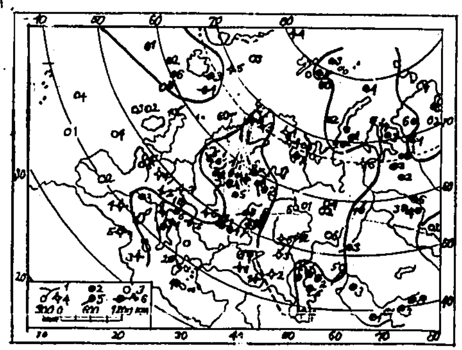

Figure 3. Combined Chart of the Synoptic Position of the Days with Strong Wind over the Finnis Gulf, Ladoga Sea, and Onega Sea.

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