METHOD OF FORECASTING THE ANNUAL TREND OF METEOROLOGICAL CONDITIONS FOR PROBLEMS OF ATMOSPHERIC MONITORING

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Feasibilities are studied to determine the prognostic parameters in the temporal hydrometeorological series by their transformation into sets of increments Δ_i^1–Δ_i^k of the order k. Empirical tests for estimation of the trend sign as well as the sign of anomaly of a geophysical element in the forthcoming year compared to the preceding one are presented by the example of the air temperature. The proposed method can be applicable to problems of atmospheric and ecological monitoring.

As is known, the meteorological information provides a basis for atmospheric and environmental monitoring.[2] Therefore, at present long–term forecast of anomalous state of the geophysical atmospheric characteristics acquires a special significance. In this case, a possibility appears to elaborate more objective long–term strategy of measures of salvaging our environment, and efficiency of measures intended to prevent natural and anthropogenic catastrophes increases.

In spite of difficulties caused by uncertainty in our knowledge about the physical principles of long–term forecast of weather and climate, now there are some prerequisites for scientific statement of the problem. However, new factors and new approaches are required to solve this problem. In Refs. 1, 4, and 5–7, the necessity to develop the empirical statistical methods and approaches together with the construction of rigorous physical theory providing a possibility of such forecasts was emphasized. We note that the scientific research program of the Russian Committee on Hydrometeorology on Weather Forecast, implemented in 1981–1985, considered an extended forecast (as well as forecast beyond the limits of predictability in 2–3 weeks) as the forecast of average meteorological conditions for specific periods and years.

The purpose of the present paper is to study the feasibility to determine the prediction of process trend by transformation of the temporal sequences by an example of meteorological series x_i into the sets of increments Δ_i^1–Δ_i^k of the order k. Our supposition is that in this case in the consecutive sets of increments quasideterministic structures appear that can be used to estimate the sign trend and possible order of anomalies for the subsequent year A_{i+1} compared with the preceding one A. Moreover, tabular and geographical representations of the sets A_i–Δ_i^k and their estimations can be used as one of tests for diagnostics of the state of global and local geophysical systems over a period preceding any forecast regardless of the environment, the essence of employed method, and the term of forecast.

METHODOLOGICAL CONCEPTION

A basis for elaboration of statistical approaches to forecast is that the time sets of hydrometeorological processes contain all basic information on the factors contributing to their evolution at least for available observation period.

In the search for the prognostic properties and recommendations, the absolute series of differences (increments) Δ_i^k and these series Δ_i^k/σ_k normalized by the standard deviation σ_k

$$\Delta_i^1 = X_i - X_{i-1}\,,$$

$$\Delta_i^2 = X_i - 2\,X_{i-1} + X_{i-2}\,,$$

$$\Delta_i^3 = X_i - 3\,X_{i-1} + 3\,X_{i-2} - X_{i-3}\,,$$

. . . .

$$\Delta_i = X_i^k - C_i^k X_{i-1} + C_i^{k-2} X_{i-2} - \ldots \pm C_k^m X_{i-(k-m)} \pm X_{i-k} \quad (1)$$

were used, where C_k^m are the binomial coefficients, i is the serial number of year, k is the order of increments of pressure, air temperature, precipitation, synoptic process types, etc. anomalies of the order $k = 1$–14 for the given year. Owing to the properties of the difference operator $\Delta_{i+1}^{k+1} = \Delta_i^k - \Delta_{i+1}^k$ considered as a filter of binomial type, the absolute series of the increments Δ_i^k (Table I*a*), sums $A_i + \sum_i^k \Delta_i^k$, and forms Φ_i of the normalized sets $A_{i/\sigma_A} - \Delta_i^k/\sigma_{\Delta^k}$ (see Table I*b* and Fig. 1) acquire quasicyclic oscillations with increase of the order k. These sets, sums, and forms are easier interpreted using the relations between acceleration of the external source oscillations and local oscillations.

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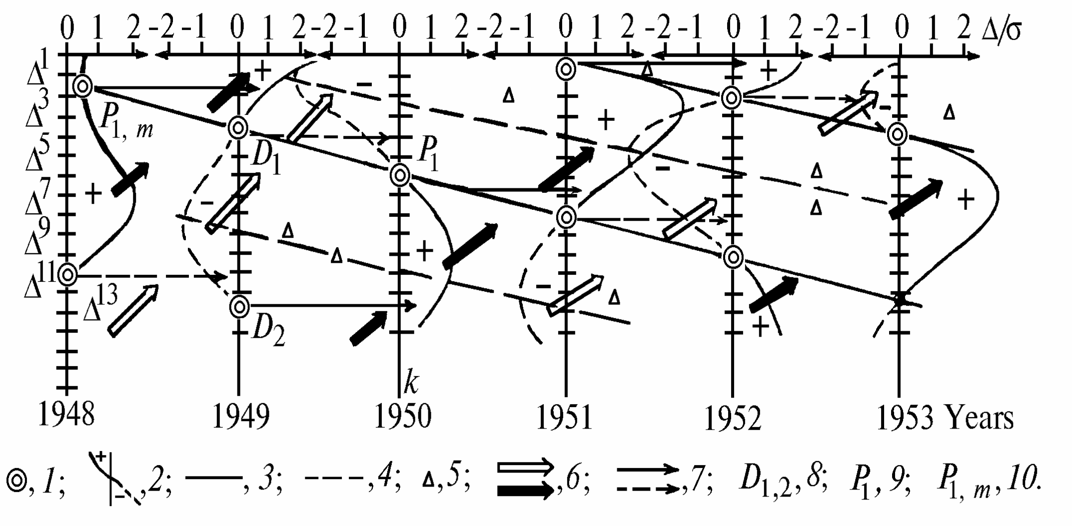

FIG. 1. Plots of the normalized anomalies A and normalized increments Δ_i^k of the air temperature (Moscow, January, 1948–1953): nodal points at which the change of the increment signs from + to – and from – to + occurs (1), positive (+) and negative (–) half–waves of increment oscillations in σ fractions (2), straight line connecting nodal points 1 (3), straight line connecting the prognostic maximums (4), mirror mapping of the prognostic maximums (5), corridor of displacement of the prognostic half–waves of the same sign from deep within prehistories to the forecast year (6), illustration of displacement of the lower signs of the nodal points and prognostic maximum signs (7), upper (D_1) and lower (D_2) diagnostic nodal points (see 1949) (8), upper P_1 (on the right side of the axis k) prognostic nodal point expected in the forecast year (1950) of the type of sign change (the axis y = k is crossed) (9), and upper prognostic nodal point ($P_{1,\,m}$) expected in the forecast year (1948) of the type of sign maintenance (the axis y = k is not crossed) (10).

Our conception[3] is that the inner causality underlying an individual property of the structure of temporal series of local system is created by the factors external to this system. At the same time, the acceleration (the increments Δ_i^k) of local system, under impulse and sudden changes of external controlling oscillations, oscillates in conformity with the inner properties of local system that primarily allows for its own history k and on this basis forms the forthcoming structure of anomalies at times $i + \theta$ (θ = 1, 2, 3, 4, etc. years) compared with i. Table I and Fig. 1 show the fragments of the absolute values of the increments of different orders and increments normalized by σ_A–σ_{Δ^k}. One can see that displacement of the areals "plus–warmth, minus–cold" occurs upwards and from the left to the right, from the increments $\Delta_{i-\theta}^{k}$ of the higher order to the increments of the lower order $\Delta_{i+\theta}^{<k}$ $A_{i+\theta}$, i.e., from deep within prehistory $(i - \theta)$ which is identical to the increment order k.

ANALYTICAL STATEMENT

The process trend is usually assumed to be a change of sign of estimation of the process characteristics at times $i + 1$ compared with their estimations at the preceding moments i. In our case, the sign of the first increment Δ_{i+1}^{1} compared with A_i will be the estimation of the annual trend (rate of the process change). Allowing for a structure of calculation of the increments Δ_i^k from relation (1), the estimation of the anomaly A_{i+1} in the subsequent year equals to

$$A_{i+1} = A_i + \sum_{1}^{k} \Delta_i^k + \Delta_{i+1}^{k+1} . \qquad (2)$$

As is clear from relation (2), the determination of the sign and the order of the modulus $|\Delta_{i+1}^{k+1}|$ is prerequisite for obtaining the desired sign and estimation of the anomalies A_{i+1}.

As empirical analysis shows (see Table I), the terms in the right–hand side of Eq. (2), starting from Δ_{i+1}^{3}, practically always have the signs opposite to that of Δ_i^2 owing to quasicyclic atmospheric properties. Hence, two conditions follow that determine the sign of change in estimation of anomaly of the subsequent year A_{i+1} relative to the preceding anomaly A_i.

1. The sign of A_i is maintained if

$$|A_i + {}_1^k\Delta_i^k| > |\Delta_{i+1}^{k+1}| . \qquad (3)$$

In this case, the modulus of estimation A_{i+1} in Eq. (2) becomes:

a) larger than A_i if $|\,{}_1^k\Delta_i^k| > |\Delta_{i+1}^{k+1}|$;

b) equal to A_i if $|\,{}_1^k\Delta_i^k| = |\Delta_{i+1}^{k+1}|$;

c) smaller than A_i if $|\,{}_1^k\Delta_i^k| < |\Delta_{i+1}^{k+1}| < |\,{}_1^k\Delta_i^k + A_i|$.

2. The sign of A_i changes if

$$|A_i + {}^k_1\Delta^k_i| < |\Delta^{k+1}_{i+1}| . \qquad (4)$$

In this case, the modulus of A_{i+1} increases insignificantly compared with the modulus of A_i if in Eq. (4) the term difference is $\delta < \sigma_A$ and increases essentially if $\delta > 2\sigma_A$.

TABLE I. Fragment of a set of anomalies A_i and increments Δ^k_i of the average monthly air temperature in Moscow (TSKhA) in January of 1947–1953.

A_i, k	$\sigma_A - \sigma_{\Delta^k}$	Years					
		1947	1948	1949	1950	1951	1952
a) absolute value of $A_i - \Delta^k_i$ according to Eq. (1)							
A_i	2.7	−0.2	+1.0	16.5	−7.7	−1.1	+5.7
Δ^1	4.2	−1.4	+1.2	+5.5	−14.2	+6.6	+6.8
Δ^2	6.2	−2.9	+2.6	+4.3	−19.7	+20.3	+0.2
Δ^3	12.0	−10.0	+5.5	+1.7	−24.0	+40.5	−20.6
Δ^4	21.7	−32.3	+15.5	−3.8	−25.7	+64.5	−61.1
Δ^5	38.8	−75.6	+47.8	−19.3	−21.9	+90.2	−125.6
Δ^6	72.4	−133.9	+122.4	−67.1	−2.6	+112.1	−215.8
Δ^7	133.0	−187.5	+256.3	−189.5	+64.5	+114.7	−327.9
Δ^8	259.7	−176.9	+443.8	−445.8	+254.0	+50.2	−442.6
Δ^9	507.6	+43.1	+620.7	−889.6	+699.8	−203.8	−492.8
Δ^{10}	1012.0	+784.3	+577.6	−1510.3	+1589.4	−903.6	−289.0
Δ^{11}	2641.0	+2641.0	−206.7	−2087.9	+3099.7	−2493.0	+614.6
b) normalized by $\sigma_A - \sigma_{\Delta^k}$ (forms Φ_i)							
		Φ_i	Φ_{i+1}	Φ_p	Φ_i	Φ_{i+1}	Φ_p
A_i		−0.074	+0.370	+2.407*	−2.852	−0.407	+2.111
Δ^1		−0.333	+0.286	+1.310	−3.381*	+1.571	+1.619
Δ^2		−0.468	+0.419	+0.694	−3.177	+3.355	+0.032
Δ^3		−0.833	+0.458	+0.142	−2.000	+3.375*	−1.717
Δ^4		−1.488	+0.714	−0.175	−1.138	+2.922	−2.816
Δ^5		−1.848	+1.232	−0.497	−0.564	+2.324	−3.237*
Δ^6		−1.849*	+1.692	−0.927	−0.036	+1.548	−2.981
Δ^7		−1.410	+1.927*	−1.425	+0.485	+0.862	−2.465
Δ^8		−0.681	+1.709	−1.717	+0.978	+0.193	−1.704
Δ^9		+0.085	+1.223	−1.753	+1.379	−0.401	−0.971
Δ^{10}		+0.775	+0.571	−1.492	+1.570	−0.893	−0.286
Δ^{11}		+1.341	−0.105	−1.060	+1.673	−1.265	+0.812
Δ^{12}		+1.678	−0.724	−0.478	+1.318	−1.421	+0.789
Δ^{13}		+1.840	−1.233	+0.126	+0.922	−1.406	+1.135
Δ^{14}		+1.747	−1.540	+0.681	+0.399	−1.167	+1.247
Test on ρ		–	+	+	+	+	+

Note: + denotes coincidence, – denotes incoincidence, * denotes maximum of normalized increments $\Delta^{k+1}_{i+1,\,\max}$, nodal points are underlined.

One of the approaches to determination the prediction the process trend Δ_{i+1}^{1} follows from above–considered relations (2)–(4). This approach is connected with the necessity to estimate the unknown Δ^{k+1}_{i+1} in any case. This estimation can be obtained by the regression equation based on interpretation of the prehistory of the temporal sets $A_{i/\sigma_A}\ \Delta^k_i/\sigma_{\Delta^k}$ in conformity with the complex Markov chain in which the start and length of influencing prehistory relative to Δ^{1}_{i+1} are changed. In this case, this influence is taken into account by integration of the normalized values of Δ/δ from the start of the nodal points in every row Δ^k along the contours denoted by the straight lines in Table I*b*. As a test shows (Table II), retrospective calculations of the estimations $\Delta^{k+1}_{i+1,\,\max}/\sigma$ and A_{i+1} by regression equation (5) are possible. The correlation coefficients in Table I *b* between sums of modules $\Sigma\Delta/\sigma$ are high: $r = -0.97 \pm 0.20$. Estimation $\Delta^{k+1}_{i+1,\,\max}$ was carried out by the regression equation

$$\Delta^3_{i+1,\,\max} = (-0.08 - 1.65\ \Sigma\Delta/\sigma) \pm 1.41°C . \qquad (5)$$

The error in calculating A_{i+1} by Eq. (2) is smaller than the errors in climate forecast: $\bar{\sigma}/\bar{\sigma}_{cl} = 0.62 < 1$. However, because of errors in the initial data and errors and possible instability of the regression equations for the estimation of $\Delta^{k+1}_{i+1,\,\max}$, we will apparently never reconstruct the diagnostic or prognostic sets with absolute accuracy. In this connection, we will consider the feasibilities to estimate the anomaly trends by qualitative way using the so–called method of successive analysis of increment forms.

Principles and stages of successive analysis of the sets (forms) A_i–Δ^k_i. The principle of successive analysis implies an analysis of the sets of absolute and normalized forms of increments (columns in Table I*b* and plots in Fig. 1) relative to their reference* or preceding positions $\Phi_{p-\theta}$–$\Phi_{p+\theta}$ and is based on interconnection of the corresponding prognostic structures in the rows A and Δ^k over the period of prehistory of one year or longer. As a simplified alternative, the successive analysis assumes available bulk of information (Table I and Fig. 1) and includes the stages of diagnosis and forecast of the trend Δ^{1}_{i+1} against qualitative and quantitative criteria from inequalities (3) and (4).

Let us determine the general quantitative prerequisites following from an empirical analysis of the vast volume of information and leading to inequality (4) and the sign

* The reference forms $\Phi_{i,\,p}$ (usually corresponding to such extreme conditions as drought and drop in temperature[3]) are assumed to be the cases in which the anomaly estimations $A_i > A_{i-1} > \sigma_A$, as a rule, exceeding all absolute values of Δ^1_i–Δ^k_i are observed in the adjacent forms (sets of normalized increments) Φ_i–Φ_{i+1}, and in the subsequent set $\Phi_{i+1} \equiv A_{i+1} - \Delta_{i+1}$, the maximum of the normalized values $\Delta^{\ k}_{i+1}/\sigma$ falls on $\Delta^{k+1}_{i+1}/\sigma$. In our case, $\Phi_{i,\,p}$ occurs in 1949 (see Table I*b*).

change or to inequality (3) with the sign of Δ_{i+1}^{1} being maintained. The sign change of Δ_{i+1}^{1} occurs under the following conditions:

1) in the year preceding the forecast, the signs of anomalies A_i and increments Δ_i^k (in the rows with k 4) are repeated for 2–3 consequtive years;

2) expected prognostic maximum $\Delta_{i+1,\max}^{k+1}$ is localized at increments of the order $k \simeq 1$–2. In the opposite case of $k > 3$, the prognostic nodal point P_1 may appear in columns Δ_{i+1}^{k} (see Fig. 1, 1948) before the anomaly A_{i+1} with the anomaly sign of the preceding year A_i;

TABLE II. Retrospective estimations of the air temperature anomalies A_{i+1} by the linear regression method (5) with the use of the equation of reverse smoothing (2): Δ^3 denotes maximum increments (st. Moscow, TSKhA) in May–June of 1891–1983; $\Delta^3_{\max}$ was observed in 15 cases.

Parameters of estimation	Year of forecast (i+1)														
	1898	1902	1905	1908	1911	1915	1919	1923	1927	1942	1954	1957	1967	1970	1977
Real Δ^3_r	−7.6	−9.7	16.5	7.5	−6.2	−12.0	9.3	6.2	−5.4	11.9	−2.6	−9.9	−9.4	5.6	16.4
Calculated Δ^3_c	−9.4	−8.3	15.6	6.9	−0.1	−10.2	9.1	4.5	−5.7	12.7	−3.5	−9.2	−9.4	5.4	18.1
Real A_r	1.3	−0.5	1.8	−2.4	−0.5	−1.9	−1.1	−0.4	−1.2	−1.1	1.7	0.8	2.9	0.4	1.7
Calculated A_c	−0.5	0.9	1.0	−3.0	−0.4	−0.1	−1.3	−2.1	−0.1	−0.3	0.8	1.5	2.9	0.2	3.4
Difference $\delta = A_c - A_r$	1.8	−1.4	0.8	0.6	−0.1	−1.8	0.2	1.7	0.3	−0.8	0.9	−0.7	0.0	0.2	−1.7

3) in the year preceding the forecast year (especially the year after reference form Φ_p with $A \gg \sigma_A$), there are no anomaly or the first increment with the normalized absolute values of Δ^k lying within the limits 0.1–0.3 or being equal to zero, i.e., no diagnostic nodal point D_1 (see Fig. 1) falling on the coordinate of the anomaly A_i or Δ_i^1;

4) the absolute values of increments Δ_i^k in the preceding year are larger than the standard deviation σ_D^k. In this case, as a rule, the sign of Δ_i^k changes if

$$|\Delta_i^k| \gtrsim \pm 0.5\, \sigma_{i-\theta}^{k}\,, \tag{6}$$

is maintained, if

$$|\Delta_i^k| \lesssim \pm 0.5\, \sigma_{\Delta i-\theta}\,, \tag{7}$$

and the more so if

$$|\Delta_i^k| \ll \pm\, 0.5\, \sigma_{\Delta i-\theta}\,, \tag{8}$$

where the prehistory period $i - \theta \approx 4$–8 years. From the point of view of classical oscillations, the constant ± 0.5 can be interpreted as boundary conditions for stagnant oscillations in individual increments in the phase diagram $\Delta_{\theta+1}^{k+1} = f(\Delta_{i+\theta}^{k})$. The condition (6) is satisfied practically always for the half–wave increments nearest to anomaly (see Fig. 1) in the preceding and subsequent years from $\Delta_{i,\max}^{k}$ to $\Delta_i^{k<2}$, i.e., for the increments nearest to the maximum in year i preceding the forecast;

5) gradients of increments of adjacent years on the temporal plots $\Delta^k = f(i-\theta)$ of the preceding (i–2) years are smaller than the expected gradients in two subsequent (i + 2) years, from which the first plot is for the year preceding to the forecast year, for example,

$$|\Delta_i^{k-1} - \Delta_{i-1}^{k-1}| < |\Delta_{i+1}^{k+1} - \Delta_i^{k+1}|\,, \tag{9}$$

or when calculating the sums over the increment columns in Table I,

$$|A_i + \sum_1^k \Delta_i^k| - |A_i + \sum_1^k \Delta_{i-1}^{k}| < |\Delta_{i+1}^{k+1} - \Delta_i^{k+1}|\,. \tag{10}$$

Empirical rule for estimation of the process trend on the basis of the data obtained in the forecast year. This rule is based on the inertial structures in oscillations of the increment forms Φ_i being manifested through pairwise (seldom triple) combinations of increments of the same sign in the rows Δ^k. Such increments in Table I show themselves in step diagrams. Inclined straight lines indicating the inertial corridor of increments can be drawn through the vertexes of angles (points) of these diagrams. The characteristic parameter of the outset of the inertial structure is a change of sign of the increment of the order (k + 1) relative to the order k. The necessary parameter of the outset of inertial structure is a nodal point at which the half–wave sign in the increment forms changes (see Fig. 1). This nodal point and the sign below it will be called the lower sign of the nodal point D_1. The forecasting rule of the lower sign of the diagnostic nodal point from the data obtained in the year preceding the forecast suggests that condition (4) is satisfied in general case and at the present stage is formulated in the following way: *The sign of the trend Δ_{i+1}^{1} and sign of the anomaly A_{i+1} of the subsequent year are determined by the lower sign of the diagnostic nodal point in the form of increments of the preceding year.* In Table I, for convenience of judgement on correctness of the rule, the plus sign denotes coincidence of signs of the real increments Δ_{i+1}^{1} of the mean January temperature of air in Moscow during 1948–1953.

When applying this rule, difficulties connected with the presence of several diagnostic nodal points (see 1952) or their lacking because of insufficient increment order (in our paper k = 1–14) can emerge. When the nodal diagnostic point is lacking (because of insufficient order k), its sign is assumed to be a sign opposite to that of anomalies in the year preceding the forecast; in the case of two diagnostic points, it is assumed to be that of the point nearest to the anomaly.

Moreover, situations arise (see Fig. 1, 1948, 1951, and 1953) in which in the forecast year the prognostic nodal point P_1 can appear in the interval Δ^k between the anomaly A_{i+1} and the prognostic maximum $\Delta_{i+1,\max}^{k}$ nearest to this point. In this case, the rule of the lower sign in the year preceding the forecast is supplemented and refined by the rule of signs of the prognostic maximum $\Delta_{i+1,\max}^{k}$ and prognostic nodal point P_1 stipulating that inequalities (3) and (4) are satisfied, respectively.

Qualitative rule of the trend estimation allowing for the prognostic data obtained in the forecast year. This rule applies interconnection of the position of the nodal points and prognostic maximums of the absolute values of Δ/σ in half–waves in increment forms in the interval of observations between the neighboring reference forms Φ_p–$\Phi_{p+\theta}$, in which $A_p \gg \sigma_{A_{p-\theta}}$, $A_{p+\theta} \gg \sigma_{A_{p+\theta}}$.

Let us formulate the following qualitative preliminary rule of trend determination from the data on the expected position of the nodal points in the preceding year and year of forecast. *The sign of trend and sign of process anomaly of the subsequent year are determined by the sign of prognostic maximum. In this case, in the presence of the prognostic nodal point, on the sign* change type it will be opposite to the prognostic maximum sign; in the lack of this point** and otherwise, it will be equal to the prognostic maximum sign.*

As follows from the formulation of this rule, when forecasting, it is necessary to implement the following procedures (by the method of linear extrapolation at this stage): determination of prognostic maximum and position of the prognostic nodal point and identification of its type. Arrangement of the prognostic and diagnostic nodal points and maximums is shown for the observation period between the reference forms $\Phi_p(1949)$–$\Phi_{p+\theta}(1952)$, where $\theta = 3$ is the number of years between the reference forms (see Fig. 1).

Upper prognostic nodal points of the sign change type P_1 practically always appear in a year relative to the reference form. The question of the presence of the upper nodal point P_1 in the year following the reference one requires thorough analysis because it is not always unambiguous and depends on the strength of response of oscillations of the first increment Δ_{i+1}^{1} after the oscillation A_p of the reference year. To identify maximums $\Delta_{i+1,\max}^{k+1}$ in years $(i + 1)$ relative to i it is reasonable to use the following approximate relations for the absolute values Δ_i^k in columns of Table I:

$$\text{if} \quad A_i + \sum_1^k \Delta_i^k < \Delta_i^{k+1}, \quad \text{then} \quad \Delta_{i+1}^{k+2} \ \max , \tag{11}$$

$$\text{if} \quad A_i + \sum_1^k \Delta_i^k \ge \Delta_i^{k+1}, \quad \text{then} \quad \Delta_{i+1}^{k+1} \simeq \max , \tag{12}$$

$$\text{and if} \quad A_i + \sum_1^k \Delta_i^k > \Delta_i^{k+1}, \quad \text{then} \quad \Delta_{i+1}^{k+2} \equiv \max . \tag{13}$$

Maximums from the sets of the adjacent normalized estimations Δ_{i+1}^{k-1}, Δ_{i+1}^{k}, ... , Δ_{i+1}^{k+c}, as a rule, fall on that Δ_{i+1}^{k} at which the maximum difference is observed between the sums of the absolute values $A_i + \Delta_i^k$, ..., $A_i + \Delta_i^{k+1}$ and the subsequent values of Δ_i^{k+1}, Δ_i^{k+2}, ..., Δ_i^{k+c}. Positions of the upper prognostic nodal points in the 2th, 3th, etc. years after the reference form are best determined on the basis of the following empirical approach called the subrule for determination of the position of the prognostic nodal point P_1:

Position of the prognostic nodal point is determined by the number of increments in the interval of prognostic half–wave in the coordinates Δ_i^k after the prognostic maximum increasing quantitatively compared with the preceding year by one or two (very rare case) serial numbers k. Application of this subrule is most effective in the classical case in which the upper nodal point appears immediately after the reference form year. So, for example, if the number of increments in the interval of the prognostic half–wave of the reference form extending from the normalized maximum to the upper nodal point equals to unity then in the subsequent year the number of increments of the same sign in the interval to the upper nodal point will be equal to two, in the second year after the reference form it will be equal to three, etc. More accurately the increment number is estimated with allowance for the increments over the prehistory period from the year preceding the reference form to the year preceding the forecast.

We note that the application of the above–considered subrule for determination of prognostic nodal point position consists in drawing the straight lines connecting the prognostic and diagnostic nodal points and the straight lines connecting the prognostic maximums in the adjacent increment forms and extrapolation of their position from the diagnosis year to the forecast year (see Fig. 1). In this case, the position of maximum in neighboring half–waves with opposite signs is taken to be that of the mirror image of the real maximum. We note that the nodal points (apart from the points of the type of sign change) in the diagnosis interval also include the prognostic nodal points of the type of sign maintenance. The position of the prognostic nodal

* The sign of the sets $A_i - \Delta_i^k$ changes in all years except 1948 (see Fig. 1 and Table I). In 1948, the nodal point of the type of sign maintenance ($D_1 = 0.286$) was observed, i.e., the axis $y \equiv \Delta^k$ was not crossed.

** See Fig. 1. In 1948, P_1 was between $\Delta^1 - \Delta^3$.

points is specified by the point of crossing of the extrapolation lines with the ordinate axis.

Examination of the rules and estimation of the correctness of forecasts on the coefficient ρ. Results of examination of the rules for different observation periods were used for estimation of the trend of the forthcoming period on the coefficient of signs ρ and against the background of the inertial forecast

$$\rho = \frac{[n(+) - n(-)]}{N}, \qquad (14)$$

where $n(+)$ and $n(-)$ are the numbers of years (points) with coincidence (+) and incoincidence (–) of predicted and actual signs of anomalies, N is the number of years (points). The inertial forecast is considered to mean a sign of the first increment extrapolated from the preceding year to the subsequent one. It is clear from Table III that in the case of application of the rule (when the obvious diagnostic parameters are taken into account), we receive high estimations $0.4 < \rho < 0.9$ with critical $\rho_{cr} = 0.2$, whereas for the inertial forecast, $\rho = 0.05$.

Spatial analysis of estimations ρ (see Table III) shows that the application of this rule is less effective in Western regions where cyclonic activity (noise component) is more intensive. A high degree of correctness of the main rule for the forecast of the drought indexes (humidification) at the Center of the European territory of the Soviet Union (ETSU) (st. Fatezh, Kursk region) should be recognized as most positive fact.

TABLE III. Obtained estimation of correctness (+/–) of forecast of anomalies signs of the air temperature and drought index s_i on the coefficient ρ, %, from the forecasts transmitted in advance to the Center on Hydrometeorology of the USSR in 1983–1984 for recommended list of stations.

Station, region	Air temperature anomaly								Drought index s_i	
	1983			1984					1984	
	I–III	V	VI	I–III	IV	V	VI	VII	V	VI
Number of stations, + / –	30/0	30/0	14/15	30/0	23/7	22/8	12/17	17/12	10/1	6/1
ETSU, ρ, %	100	100	48	100	77	73	41	58	91	85
Number of stations, + / –	9/0	9/0	8/0	9/0	6/3	6/3	7/2	9/0	1/2	3/4
Western Siberia, ρ, %	100	100	100	100	67	67	78	100	33	42
Number of stations, + / –	19/0	19/0	12/7	12/7	14/5	18/1	19/0	19/0	5/0	5/0
Middle Asia, Kazakhstan, ρ, %	100	100	63	63	74	95	100	100	100	100
Number of stations, + / –	58/0	58/0	34/22	51/8	43/15	46/12	38/19	45/12	16/3	14/5
Throughout the territory, ρ, %	100	100	61	86	74	79	67	79	84	74

Note: For temperature anomaly, mean $\bar{\rho}$ is 81%, with its critical value $\bar{\rho}_{cr}$ = 60%.

Experimental forecast by the above–considered rules had been transmitted to the Center on Hydrometeorology of the USSR and to the Main Geophysical Observatory since 1981. The results of the forecast of anomaly of individual elements were examined for recommended list of stations in the territory of Western USSR extended to the Enisei. As the data in Table III show, the average estimations ρ are sufficiently high, suggesting that it is expedient to develop the proposed method.

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