УДК 551.509.22
https://doi.org/10.17816/edgcc21202

ON THE POSSIBILITY OF LONG-TERM FORECASTING OF SEASONAL HYDROMETEOROLOGICAL PHENOMENA

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Citation: M.A. Alimpieva, S.V. Morozova 2020. On the possibility of long-term forecasting of seasonal hydrometeorological phenomena // Environmental dynamics and global climate change. V. 11. N.2. P. 73-78.
DOI: 10.17816/edgcc21202

Text of the article in Russian: https://edgccjournal.org/EDGCC/article/view/19010

In present paper the expanding application possibility of physical-statistical methods in long-term forecast are viewed. A nonparametric discriminate analyzing model has been constructed on the South-East of EPR (European part of Russia). The model is based on consideration of asynchronous bonds between the condition of circulating systems of the Atlantic-Eurasian hemisphere sector and the period of seasonal hydrotermeological events onset on South-East of EPR. This model allows distinguishing three cluster areas which associate with three phases of predicted event; commonly, only two cluster areas are distinguished. We would like to present results of predictions testing of training and control sets. The conclusion of our model region appliance effectiveness is also represented in paper.

Key words: long-term weather forecast, centers action of the atmosphere, physical-statistical model, discriminate analysis

INTRODUCTION

The scope of weather forecasting for a long term is a complicated scientific problem. The unqualified successes in this area which were accomplished in the beginning of our age are defiantly connected with a reduction to practice the global computational models (PLAV, MOZART63L25 and others). The above-mentioned models were procured by the following native and global centers: Hydrometeorological centre of Russia, North-Eurasian climate centre, Central geophysical observatory named after A.I. Voiekov, European centre of medium-term weather forecasting. However, long-term forecast success rate is still low. Within all above mentioned pattern forecasting production is usually represented by the anomalous fields of meteorological values and their characteristics averaged on different time periods (from a couple of days to month). It is generally done in statistically distributed format.

It should be noted that a necessity in predicting of not only general background of meteorological values or its abnormalities but also different hydrometeorological occurrences is kept. The examples of hydrometeorological occurrences are the following: droughts, the types of springs, the dates of daily average atmospheric temperature transition by means of definite guardrails, time frames of formation and loss of snow cover, the beginning and letup of rainy and dry periods etc. in present time the solution of analogical problems in terms of hydrodynamic modeling can't be provided [Ugrumov, 2006]. Thus for these aims the meteorological and physical-statistical methods are of higher references [Vilfand et al., 2017; Krizov, 2012; Sadokov et al., 2012]. The remarkable thing is that global computational models always are always in need of region statistical correction [Vilfand et al., 2007; Mirvis et al., 2017].

THE RESEARCH OBJECTIVES

The aim of this work was the investigation of possibility of seasonal hydrometeorological occurrences long term forecast based on consideration of distant asynchronous connections of circulating systems in Atlantic-Eurasian part of hemi-sphere with different hydrometeorological regime characteristics in the southeast of Russian European part. The targets of the research were dates of daily average atmospheric temperature transition by means of 0°C, 5°C, 10°C. In this case the possibility of exceedance (non-exceedance) of predicant numerical value the definite criterium or the occurrence of one or another phase (category) is more important than strictly numerical value of predictor. Thus the model of non-parametric discriminate analysis was used for forecast dependences building. It should be noted that with a discriminate model use the two-phase separation of predictor was used until the present time for different weather occurrences forecast [Adrianova, 1971; Baidal and Neushkin, 1978]. In the present work the discriminate analysis is based in three-phase separation of this occurrence.

We would like to show the appliance of discriminate model by an example of daily average atmospheric temperature 0°C crossing due to the fact that a technology of discriminate model using is identical for all objects of prediction.

The Saratovskaya oblast' which is an important agrarian region in Russia was the exploration area. The territory has a strongly continental climate. It leads to great variability of weather rating. The date when daily average temperature crosses zero is highly important for agrarian lands because it mainly determines conditions of snow melting and available soil moisture reserves (moisture content which is higher than wilting point and is absorbed by plants) in the beginning of spring field acquisitions. Furthermore, this date determines development of plants at the initial vegetative stages that are the most prevailing in terms of yield formation.

RESEARCH INFORMATIONAL BACKGROUND

The informational background used is data of periodic and average daily values of atmospheric temperatures from eight stations in Saratovskaya oblast'. The stations are placed in valley of river Volga (Saratov South-East, Oktibr'skiy gorodok, Marks, Vol'sk, Hvalynsk, Zolotoe, Alexandrov gai, Novouzensk). The points are characterized as the first regions where daily average temperature crosses 0°C according to climatic zonation of Saratovskaya oblast' [Atlas..., 1978]. Except northern right-bank regions at the rest regions the dates of temperature transition are coming at three days later date in terms of long term average values. In the northern regions of Right bank the stable transition comes later on six days towards the rest territory of Volga valley.

The computational model of forecast is associated with the earliest transition dates. Beside this it should be noted that definite innovation in author-developed forecasting system is an «offence» of common forecasting algorithm. Normally, the forecast is a rectification of climatic background and all forecasted characteristics (deviations) are calculated towards the long-term average value. In this case the climate has not a basic but a rectification function. Thus climatic regularities (in present paper it is zonation) afford us to adopt the forecasting model to all rest regions in Saratovskaya oblast'.

The determination of dates when the stable temperature transition occurred was proceeded by authors with sophisticated program «DATAPEREHOD» which was developed upon recommendation [Guide..., 1984]. The data about temperature were taken for 48 years time period from 1971 to 2018 from website RSRIOHIGD Russian Scientific Research Institute of Hydrometeorological Information – Global data center) [dataset..., 2017] and also from the original archive facility of agrometeorological laboratory of Southeastern research institute of agriculture.

The atmospheric centers actions of Atlantic-Eurasian part of hemisphere were the circulating structures which characteristics were used in computational pattern building. Furthermore, that particular centers actions which state is under the influence of spatial-temporal variability [Morozova, 2011]. Those are Icelandic Low and winter Asian (Siberian) high pressure area. Input data was conditioned by abnormalities which were calculated as an algebraic deviates of average long-term values. The particular characteristics of centers actions of atmosphere (latitude, longitude, pressure in center) haven't been put into primary data for model building. The data about state of centers actions of atmosphere from 1971 to 2010 were adopted from the digital application based on informational monograph [Neushkin et al., 2013]. The characteristics of atmospheric centers actions from 2011 to 2018 were recorded from medium maps which are posted in ftp-server of Hydrometeorological centre.

Forecast interaction detection was conducted with application programs package «STATISTICA». The scheme of coherent operation of predictors was used. A number of running values was determined by the statistical appraisals of parameters base (R^2, particular λ, F, p-level$_{max}$).

THE METHODOLOGY

The problem solution is based on theoretical development of teleconnection and asynchronous bonds of circulating systems with weather patterns in different geographical regions. The fact that between weather ratings and circulating indexes quite stable teleconnection bonds occur is illustrated in a great number of papers [Krizov, 2013; Sadokov et al., 2012; Randall et al., 1998; Wallace and Gutzler, 1981]. These bonds appeared either in synchronous or asynchronous forms. However, an introduction to forecast models of particular indexes which make allowance of circulating structures intensity depletes the models and restricts the availabilities of circulating objects. Thus the authors used either intensity of chosen atmospheric centers actions or a variation of their centers spatial localization in physical-statistical model.

The set of independent statistical experiments was conducted in the development of forecast instructions with the aim of determination of warning well in advance about taking a forecasting decision. The two-month period was determined as an optimal time period. That decision is based on derived estimates and with reference to practical expectations.

THE MAIN RESULTS

We considered the statistic about dates of temperature transition by means of 0°C, 5°C and 10°C. it suggested the date of 0°C crossing (σ=5.02, *C*v=0.03) has the greatest temporal variability and the date of 10°C crossing has the smallest temporal variability (σ=2.94, *C*v=0.02). The variability of date of stable daily average temperature 5°C transition is represented in the following values: σ=4.81, *C*v=0.03. Due to the fact forecast developments are shown only for the date of 0°C crossing, it should be noted that the earliest time when this date was registered was February 23rd, 2008; the latest time was April 16th, 1983 (according to Meteorological Station Saratov south-East). Thus the variability of extreme values is 53 days (two months!). All above-mentioned doubles down the importance of methodical predictions development in seasonal hydrometeorological occurrences.

The chosen characteristics of required centers actions in past autumn- winter period (except February) were investigated as prospective predictors. Whether we entrench the characteristics of atmospheric centers actions in model, the lead-time of forecast is almost zero. It leads to out-of-dateness forecast.

As a result of calculations four predictors have been selected. Their statistical estimations characteristics are represented in Table 1.

As can be seen from the table model defines about 75% of predicant varieties. Within that determination coefficient's values are quite stable. Based on value of particular lambda, which represents a contribution to objects separation of single predictor, it is accepted that a forecast determined by a group of factors is far more reliable. Physical characteristics of predictors and values of c icients of linear discriminant functions (LDF) are shown in Table 2. The above mentioned coefficients are taken from standard form of LDF:

$$L = b_0 + b_1x_1 + b_2x_2 + \ldots + b_nx_n, \quad (1)$$

where b_0 – free term of the equation,

b_n – coefficients of linear discriminant function,

x_n – (variable) predictors.

Considering the standard equations:

$$L_1 = 0.33 + 0.21x_1 + 0.01x_2 - 0.31x_3 - 0.07x_4$$

$$L_2 = -0.35 + 0.19x_1 + 0.16x_2 - 0.01x_3 + 0.06x_4$$

As can be seen from the first equation the most important are the intensity of Icelandic minimum in January and its displacement along the Meridian in November. In the second equation we can distinguish the great influence on predicant of intensity of Icelandic cyclone in January and the displacement of winter Asian anticyclone along the latitude circle in October.

The forecasting equations are created on the basis of data from 1971-2010. The values of LDF for 2011-2018 are calculated by equations obtained from data of atmospheric centers actions condition. On the picture a chart for prediction of spring transition date is represented. The date is attached to daily average air temperature transition across 0°C. A clear division of predictant phases is seen on the picture.

Table 1 **Statistical characteristics of predictors.**

Predictor	R^2	*F*-statisticsl	*p*-level	particular λ
x_1	0.694	12.230	0.0007	0.380
x_2	0.734	6.269	0.0105	0.545
x_3	0.739	7.121	0.0066	0.513
x_4	0.778	6.872	0.0076	0.522

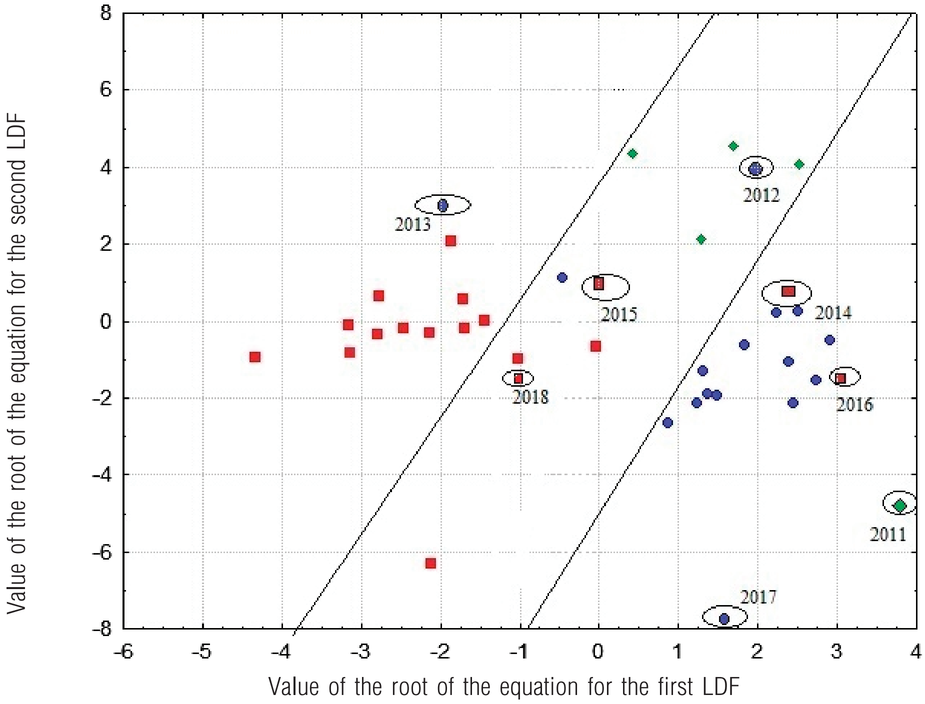
*F*кр= 3.8726

Table 2 **The values of coefficients which divide functions and characteristic of predictors**

Predictor	The values of coefficients		Physical characteristic of predictor
	L_1	L_2	
x_1	0.21	0.19	IC pressure anomaly in January
x_2	0.01	0.16	SA longitude anomaly in October
x_3	-0.31	-0.01	IC altitude anomaly in November
x_4	-0.07	0.06	IC longitude anomaly in November
Constant	0.33	-0.35	–

IC – Icelandic cyclone,

SA – winter Siberian (Asian) anticyclone



Pic 1. Visualization of model of long term forecast for spring based on daily average temperature 0°C transition dat

It is necessarily to estimate an accuracy of this specific way of forecasting weather we would like to determine a quality of proposed method. This type of long term forecasting refers to category of multiphase forecasts. The methodologies of multiphase (>2) forecasts estimating are insufficiently developed by contrast with estimation of two-phase forecasts. Some methodic holdings can be found in [Handozko, 2005; Wilks, 1995]. A contingency matrix which is adapted to three-phase transition is represented in Table 3. This matrix contains results of forecasts tests on adjective work material (numerator of a fraction) and with presenting of these tests to independent sampling (term of a fraction).

Referring to Table we can determine the number of justified forecasts and also consider differentially unjustified cases. It is possible to identify the number of early forecasts which got into a group of late forecasts, the number of late forecasts which got into a group of normal forecasts etc. For example, two forecasts from 5 unjustified cases for early dates of transition were distributed to a group of forecasts for normal dates and the other tree of them were distributed to a group of forecasts for late dates.

The P indicator is used as an approximate measure of quality of weather forecasts. This indicator reveals the percentage of justified forecasts related to the total number of forecasts. The percentage of justified forecasts was 87.5% by dependent selection and 77% subject to independent trails. The values of ϱ indicator were 0.78 and 0.54 respectively.

With a usage of contingency matrix it is possible to determine he model sensibility to rare occurrence ($\lambda^* = q_{11}/p_{01}$, where q_{11} – a percentage of justified forecasts of rare occurrence; p_{01} – a percentage of total number of forecasts of rare occurrence). We will define the model sensibility to late transition date due to the fact that this date occurs less often. Subject to dependent trails λ^* is turned out to be equal to 0.54, subject to independent trails the λ^* is equal to 0.50. It should be noted that the most complicated is the rare occurrences forecasting. The rare occurrences «capturing» by the model can be considered successful.

Table 3 **Contigency matrix of forecasted and real conditions of predicant**

Actually observed Φ_i	Forecasted Π_i			
	Early Π_1	Normal Π_2	Late Π_3	$\sum_{j=1}^{m} n_1$
Early Φ_1	12/12	-/1	-/-	12/13
Normal Φ_2	-/2	12/13	1/1	13/16
Late Φ_3	2/3	1/2	4/5	7/10
$\sum_{j=1}^{m} n_1$	14/17	13/16	5/6	32/39

$$\gamma = \frac{s - D}{s + D}$$

where S – total number of search pares, for which are simultaneously correct $i_1 > i_2$ и $j_1 > j_2$ or conversely $i_1 < i_2$ u $j_1 < j_2$, that is when ranks of search pares are equal,

D – total number of search pares, for which is correct $i_1 > i_2$ and $j_1 < j_2$ or $i_1 < i_2$ and $j_1 > j_2$, that is when ranks of search pares are not equal.

In fractions of a unit the value of this indicator according to dependent trails was equal to 0.09, subject to independent the value was equal to 0.21. It should be noted that with regard to independent trails the percentage of incorrect forecasts slightly increased which is quite usual for physical-statistical models. Nevertheless the obtained values signify about little percentage of unjustified forecasts.

As an estimation of measure of skill a comparison was conducted between the predictability of methodical forecast and the predictability of climatic forecast

$QS = Q - Q\text{cl}, \; QS = Q / Q\text{cl}$ (3)

Q – predictability of methodic forecast,

Qcl – predictability of climatic forecast

The climatic forecast was based on an assumption that all dates of transition matches with climatic normal so they are normal. The predictability either of methodical or climatic forecasts were calculated for all range of years. With regard to these hypotheses $QS = 36\%$ and the advantage of methodical approach comparing to climatic is 1.85.

CONCLUSIONS

1. The discriminant analysis technique has been applied for distinguishing three groups of objects-early, normal and late terms of date occurrence of transition across particular value. It leads to empowerment in physical-statistical direction of long term forecasting based on deeper differentiation of forecasted occurrences.

2. The asynchronous distant bonds have been reveled between the condition of atmospheric centers actions and periods of date occurrence of daily average temperature 0 crossing on the Southeast of European part of Russia. The most informative for forecasting were the intensity of Iceland minimum in January and Geographical localization of its center in November and also the displacement of winter Asian anticyclone along the latitude circle in October.

3. The forecasting developments have been obtained of further character of daily average temperature 0 crossing date for the Saratovskaya oblast'. The visualization of developments has been conducted. The estimation of forecasts which had been made on dependent selection and with a regard of independent trails has shown that reliability and good perspectives of proposed methodology for seasonal hydrometeorological occurrences forecasting.

4. As an independent conclusion an instruction can be considered for necessity of further methodic developments on estimation of tree-phase forecasts.

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