UDC 910:550.3
Оригинални научни рад
Original Scientific Paper

Владимир ЛОБАНОВ
Х. Б. ЛОБАНОВА
С. Р. СТЕПАНЕНКО
В. Е. ЛЕОНОВ
АМФОНП, Санк-Петербург

Development of Non-homogeneous - Non- stationary Processes Theory for Investigation in Geophysical Sciences to and After 2000

Background: Modern geography is the same as the philosophy in the end of the Greek Ages. In the period of the great Geographical Discoveries the geography was as a common geophisical science about new continents, areas and lands, about their geology, botanic, hydrometeotology, ethnography and other aspects, which are distributed over the space. In that times, all naturel sciences were as the descriptional sciences and a naturalist was a multi-subjects specialist, as a geographist. The same situation took place with philosophy in Ancient World, when all other sciences have been explained from the position of only one science. However, to the Middle Ages there as the separation of main sciences such as chemistry, physics for example, in independent sciences becouse every of them accumulated a lot of knowledges about particular subject. The same situation was in natural sciences about one century ago and as a result, the geography today has the name of the "spatial box" for many other natural or geophysical sciences. Other and more important problem today is the understanding between different geographycal scinces because, the distance between them becomemore and more in every decade owing to stable scientific schools and traditions. However, the modern period is the time for the unification of main progress in every of them for a development of new more effective sciences. This is a cyclic process in the development of the science on the Earth.

The extention of modern impact of many factors on natural processes increases the significance of these processes for manking and turns the scientists to the investigations of their detailed and dynamic features over the area. In the end of XX and the beginning of XXI will be "teh great transition" in geophysical sciences from the investigation of generalized parameters to the modelling of dynamic properties of complex processes. This change must give the same progress in natural sciences as the quantum mechanics in comparison with Newton's ones in physics in the beginning of XXth century.

Key words: geography, spatial box, geographical sciences, non-homogeneus, non-stationary, process.

Necessity of changes

Today model for the analysis of temporal-spatial properties of geophysical process is the stationary sample with intra-year correlation from homogeneous "general totality". There are tree main reasons for a change of the existing model:

- information reason, as the stationary model takes into account the most common "statical" parameters of time series (mean value, variation, non-symmetry of the distribution and inter-year relationship), that is not enough for investigations in geophysical sciences today;

- compositional reason, as the existing model does not take into account the changes in geophysical characteristics under the imapct of enviromental changes (climate, antropogenic impacts, etc.)

- extrapolation reason, as the mehodoloy of existing methoda of time series modelling and computations differs from the methodology of super-long-term forecasting through booth two these methodologies are used for the same time series.

In according of three main reasons, the model does not take into account three main properties of geophysical processes, such, as: dynamics, non-homogeneity and non-stationarity.

Specifically the existing conception fives either very common model in the form of a distribution function or generalized parameters (mean value, variance etc), which are transfered from the present to the future or very weak description (maximum 10-15% of explanation) in the form of Markov's autocorrelation and model like them. In the conditions of moder change and "close" World this conception and its metnods are not suitable for the positions both of practice (very weak description) and the taking into account all modern changes and natural dynamics (climate change, man's impacts, long-term natural fluctuations, etc.) and from the position of correct future foresight (long-term forecasting).

Main ways of investigations

Modern human civilization chose the way of nature change for its goals, that has been developed both in the construction of different kinds of mechanisms and in the creation of various abstract theories and mathematical methods for understanding of surroundings. The development of two main kind of the civilization, such as

technogenic civilization and sensoring one is in **Fig. 2.1.**, as well as the development of theoretical and empirical ways of the investigations in **Fig. 2.2.**

Unfortunaterly, the way of technogenic civilization gives one-sided view about nature and does not take into account points of view of the nature, other groups of civilization and the main Creator especially. This infinite fith in mechanisms and imagination of the particular mind leads to the antrophy of given human possibilities from one hand and to the conflict with nature, that gives the clearnes especially in the creation of ecology as a new science, from other hand.

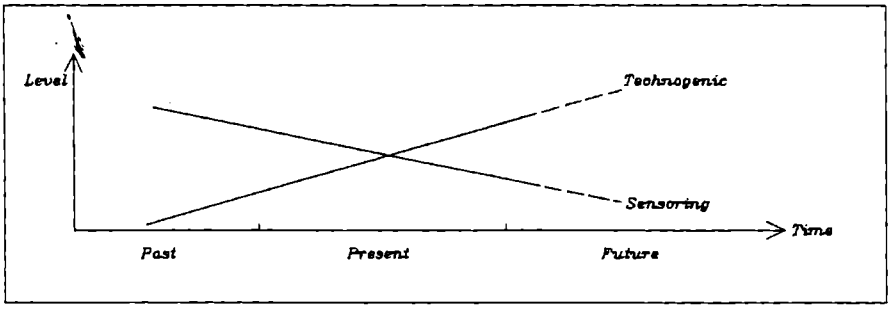


Fig. 2.1. - *Development of the civilization*

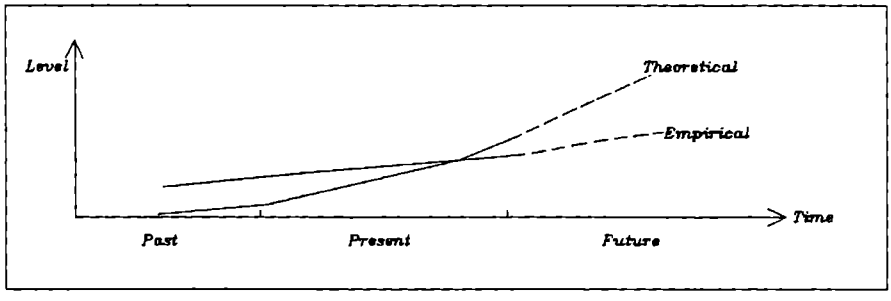


Fig. 2. 2. *Development of investigation ways*

Very often the man thinks that he investigates the nature but really he plays with devised methods on the natural background. Using this methodology, the man trusts his model on the nature and fits this model for a real condition. Anywhere this methodology works in limited conditions, as a Newtonian mechanics, but often it is very difficult to test it, as in hydrometeorological modelling, for example. The contrudiction between development of the volume of the experimental data and the complex of mathematization is given in the **Fig. 2.3.** as the crossing curves with more shape of mathema-

tization one. The example can be in the field of GCMs (Global Circulation Models), which do not provide with experimental data for verification today.

Two ways of the investigations have different views on uding of real observational data. In theoretical way real data are used for their fitting to given theory. In experimental way as ussual the real data is the basis of the empirical analysis which are fulfiled without any theory. Therefore in the 60 th of this century a new scienece as a theory of an active experiment (Nalimov, 1960) has been founded for the development of common theoretical principles which should be used in the organization of any active experiment to get the maximum new knowledge and regular properties about the particular event or object. This theory gave the mani proghress in modern physics, chemistry, biology, medicine and other branches of science where the active experiment was possible. Using the set of elementary mathematical functions, the common ideas of the theory about model structure, the main one-factor functions could be developed under fixed homgeneous and united into one complex model. The theory of experiment could not applied till now in the sciences with observations only (passive experiment), such as geography and geophysics especially. This sector of science uses the theoretical and mathematical models from other scientific branches or superficial empirical expressions from its own observations. The main problem of these sciences is to develop the theory for determination of homogeneous conditions in observed time series, which are very complex and consist of many different scale processes as well as to take into account the dynamic properties over the time and space.

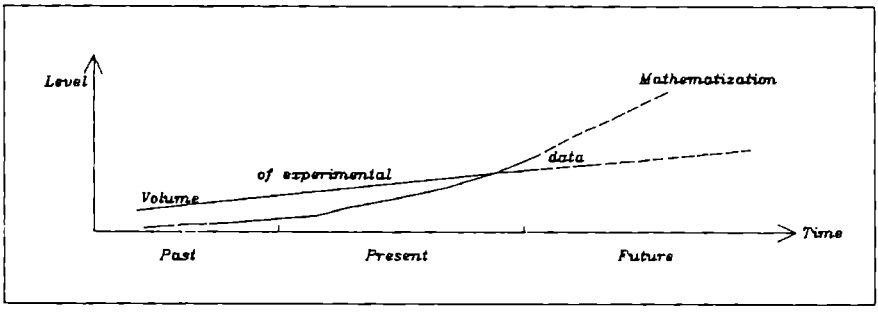
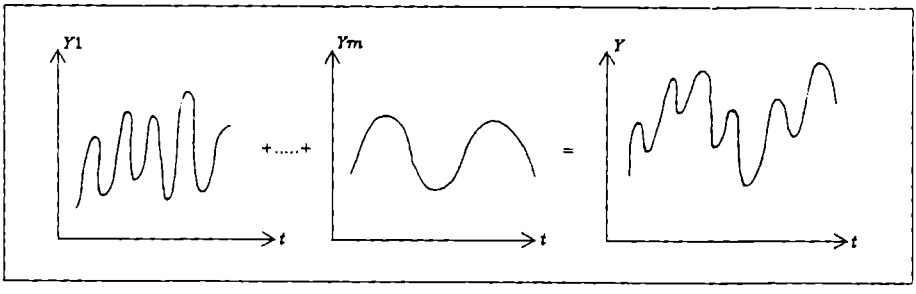


Fig. 2.3. - *Development of the possibilities*

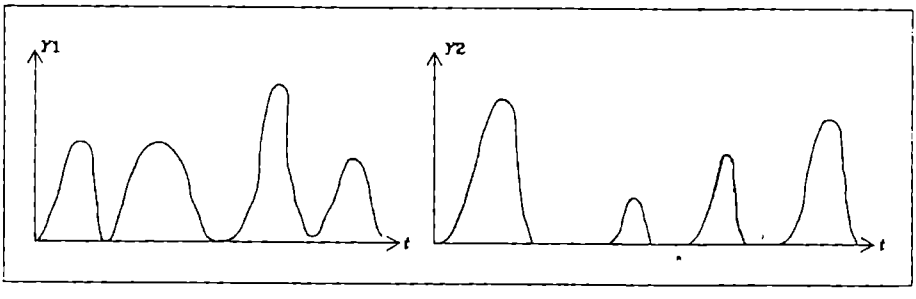
Main Grounds of the Theory of Non-homogeneous Non-stationary Processes

Postulates. - The main idea of this approach and its methodology consists in the folloving step by step the observed realizations of natural characteristics and the creation of kaws and methods from properties of natural processes only. The suggested new theory colud be considered as a theory of a passive experiment and this theory, methodology and methods could give the progress in the geophysical scieneces no less than the theory of an active experimentin physics and chemistry. The main chain of any investigation: analysis-modelling-forecasting will be developed both methodologically and filleed by particular methods for applications in hydrometeorology and other fields of geophysic sciences. Five main postulates have been developed for new theory.

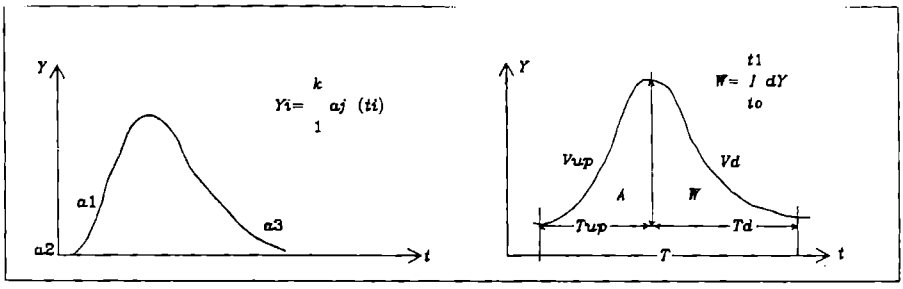
First postulate: any investigated time series of hydroometeorological observations is a sum of several "elementary" time series and every of them corresponds with the particular physical process:



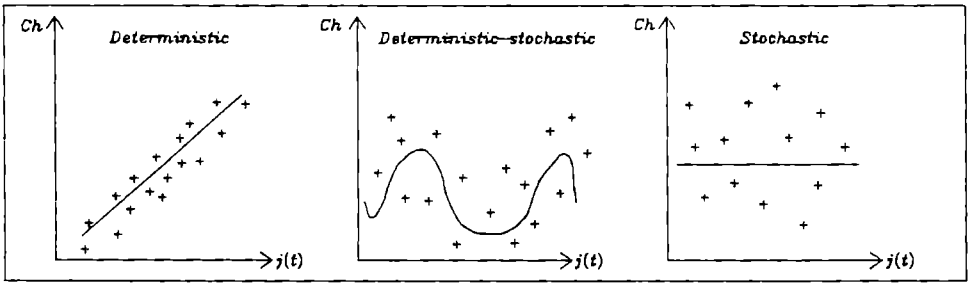
Second postulate: every elementary (homogeneous) time series is a sequence of elementary cyclic events, which follow one after another or are devided by tim intervals and every elementary time series answers the homogeneous proces of the particular scale:



Third postulate: every elementary cyclic event is described entirely by coefficients of function of the cycle or by the main informative dynamic indexes, such as: amplitude (*A*), period (*T*), average speed and duration of the raising and falling of the cycle (*Vup, Tup, Vd, Td*) and cycle volume (*W*):



Fourth postulate: dynamic property of any homogenous process is described fully, if the models over the time have been developed of one from three kinds: deterministic, stochastic or deterministic-stochastic:



Fifth postulate: the method of the compositional hydrometeorological process is determinated fully, if the models of every homogenenous process and intercommunications between them have been founded:

The theory of non-homogeneus - non-stationary processes is based on three existing theories: theory of random function, theory of the active experiment and theory of consecutive analysis.

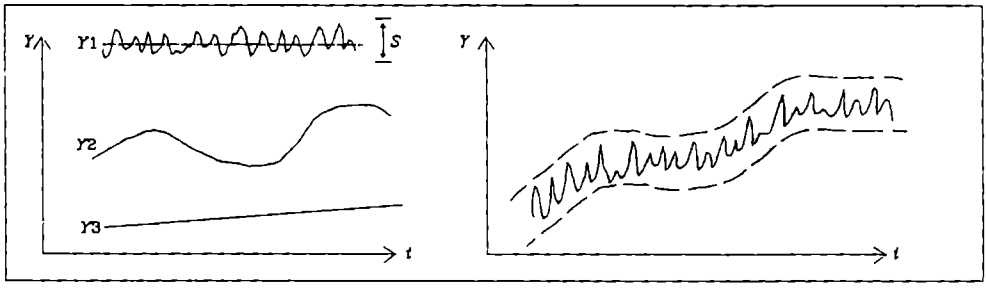
Dinamic geophysics

On the basis of main grounds of new theory of non-homogeneous - non-stationary processes it is possible to give a definition

of new modern science - dynamic geophysics. This science deals with the regular properties of dynamic indexes of geophysical events in the time series of any scale, for example, day, month, year, etc. the elementary event in the dynamic geophysics is a cycle. These elementary events become a random events in the case when the regular properties over the time do not take place and there is a stochastic process under condition:

$$S\ (Ch) > 100\% - Ey$$

where S(Ch) - standard variance of remainders in the model Ch=f(t), t - time, Ch - informative characteristic, Ey - relative error of the process (in %).



Main properties of natural processes

The conception of cyclic nature of fluctiations of natural processes (and hydrometeorological too), is the basis of the dynamic geophysics. The cyclicity is a sequence time series of phases of raising and decreasing of observed values with different periods:

$$Yl < Yl\ \ 1 < \ldots < Ym > Ym\ \ 1 > \ldots > Ym\ \ k < Ym\ \ k\ \ 1 < \ldots,$$

where m - period of raising, k - period of decreasing, m k - period of the cycle.

The cyclic nature and repeatability of earthly processes are related with the rotational monement inherent to all objects in the Universe (Galaxy, the Solar system, the Earth, the atmosphere, etc.). The following classification can be suggested for the determination of different kinds of repeatability:

Kind of repeatibility	Kind of the object
A. Strict periodicity - constant periodsand amplitudes of the cycles overthe time.	Objects of the Cosmos: galaxies, stars' and planets' systems
B. Periodicity-cyclicity - small difference from constant period and amplitudes	Processes on the enternal boundary and global Earth' processes: sun's activity, dynamic of the ocean current and wetting of the continents, etc.
C. Cyclity - average differences from constant periods and amplitudes	Processes on the large and middle areas.
D. Rhythic - big differences from constant periods and amplitudes.	Processes on them small areas.

Another reason of cyclicity is a property of inertia and entropy of the system, when after an influence of external factor, the system speeds in former state with minimum of internal energy.

The second basic property of natural processes is a composite nature of their structure, that is conditioned by influence of different scales factors, forming the runoff process as a whole. As a rule it is not known a priori how many simple bomogeneus processes participate in the formation of investigated time series, or at least how many different- scale components, each being also a composition of similar-scale processes, represent the time series.

Main methods of dynamic geography

Common. - Dynamic geography is a particular part of dynamic geophysics which deals with the changing of environmental characteristics have a different scale of fluctuations, for example mean period of cyclic event in geomorphology is several milions years, in soil changes - thousands years, etc. The main property of any geographycal process is its complex different-sclales nature. All geography processes are changing over the time, but with different speeds. there are three groups of methods of the dynamic geophysics, which is neccesary to use in the dynamic geography and they are:

- methods of spatial modelling of geographical characteristics and their generalization in some informative dynamic indexes;
- methods of the decomposition of complex time series of geographical characteristics or indexes into some homogenenous different-scale components;

- methods of super-long-term forecasting of changes in time series of these dynamic geographical indexes for estimation of their future states.

Method of poli-linear decomposition. - This method is suggested form spatial modelling of the fields of geographic characteristics and their decimposition in three main components, which are caracterized: the gradient of geographical field (B), field's level (A) and variation of all small schale components (S), for hydrometeorological processes, for example, these are the macro-synoptic variations. The ways of the applications of this method have been given for example, in (Lobanov, 1994, Stepanenko, 1995). The main common expression is:

$$Y(X_1,X_2,X_3,X_4)=Co(X_4)\ C_1(X_4)=Yp(X_1,X_2,X_3)\ E(X_1,X_2,X_3,X_4)$$

where X_1,X_2 - geographical co-ordinates, X_3 - number of the month, X_4 - number of the year, C_1, - coefficients that are obtained by least square method (LSM).

Truncation method. - The decomposition of time series of geographical characteristics or generalized indexes into different-scale components can be realized by truncation method (Lobanov, Stepanenko, 1988). It has been established that this method has the considerable advantages over the existing methods, such as spectral and correlation analysis, different methods of a moving average and a smotthing, which can be applied for conditions of constant periods and amplitudes of cycles for everu homogeneous process only, but real situations are more various. Truncation method is based on the main postulat of the theory of an active experiment, that the fluctuations are significant, if they are more than amplitude of errors, and on the superposition ptinciple about interrelationships between homogeneous components. Superposition principle of this method means, that any interaction of two adjacent scales is reflected in the coefficients of the equation of additive structure.

Methods of Super-Long Forecasting. - Newapproach of super-long forecasting includes the following stages (Lobanov, Lobanova, 1995):

- the decomposition of the complex process;
- the choice of informative predictive characteristics;
- the analysis of time series of informative indexes, their generalization and first level of interval forecast for some years to future;

- the establishment of relationships between a response and factors and the forecasting of factors;

- the correction of predictions on the basis of intercommunications between response and its factors (the third level of forecast);

- the development of common forecasted field of the cycle for every homogeneous component;

- the unification of forecasted cycles of all components to one predicted model;

- the assessment of efficiency and stability of super-long-term prediction.

The main methods of forecasting are as the follows: decomposition methods, - extrapolation methods, methods of correction, methods of formation of forecasted cycle field and methods for assessment of efficiency.

Tab. 1. *- Poli-linear regression models for common characteristics of geographical fields of temperature and H - 500*

Function	Factors	Coefficients	Explained part variance in %	Correlation coeficient
At	Bt	-0,15	44.1	0.906
	Bh	0,21	17.1	
	Ah	0,11	10.0	
	Ah*Bh	-0,23	10.8	
Bt	At	-0.01	46.4	0.906
	St	-0.01	20.7	
	At*Bh	0.02	14.9	
St	Sh	0.44	59.6	0.909
	Bt	-0.52	11.1	
	BtSh	-0.81	8.5	
	AtBtAhBd	-2.36	3.5	

Particular application

Geographical distribution of monthly mean surface temperature from 1891 to 1990 and series of 500 mb Heights (geopotential heights) from 1949 to 1990 have been considered and used for modeling. Method of poli-linear decomposition has been applied for the determination of aspatial indexes and truncation method - for assessment of lont-term climatic components in their time series. It has been established, that parameters At and Bt of temperature have a century-long trend and a correlation coeficient between them R=-0,81. The standard deviation of the process of macrosynoptical scale St has a step-trend with a sharp falling at the beginning of 1960 th. The similar result has been obtained for parameters of

H=500 mb - Ah, Bh and Sh. Models of intercommunication between the coefficients of separation form temperature and geopotential heights have been built too and the results are given in **Tab. 1.**

REFERENCES

1. **Lobanov V. A.:** *Empirical method of filtration and decomposition of natural processes into different'scale components.* - Proc. of All-Union Conference on the Modelling Complex process, USSR - Grondo, 1988, p. 104-114.

2. **Lobanov V. A.:** *Statistical decisions in changing natural conditions* Proc. of Inter. Conference on Statistical and Bayesian Methods in Hydrological Sciences, September 11-13. - Paris, 1995, p. 210-232.

3. **Lobanov V. A., Lobanova H. V., Leonov V. E.:** *Forecasting methods on the basis of cyclity and different-scale concept.* - Proc. of Intern. Conference on Modeling and Simulation, November 27-30. - Newcastle, Australia, 1995, p. 156-162.

4. **Palm V. A.:** *Principles of quantitative theory of organic reactions'* - "Chemistry". - Leningrad, 340 p.