Mathematical Modeling and Identification of the Stressed-deformed State of Geodynamic Systems by Spatio-temporal Series of Combined Geodetic and Geophysical Observations in the Light of Prediction of Natural and Technogenic Catastrophes

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Key words: geodynamic systems, modeling, geodetic and geophysical observations, identification, prediction, stressed-deformed state

SUMMARY

The theory and applications of mathematical modeling methods and identification of complicated self-organizing natural and engineering geodynamic systems and, in particular, their stressed-deformed state on the basis of spatio-temporal series of combined geodetic and geophysical observations are proposed by the authors. The parametrical identification of the crustal stressed-deformed state has been carried out using GPS campaigns data in Mountain Altai (South-West Siberia) for 2001-2002 before the catastrophic earthquake of September 27, 2003.

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1. THE URGENCY OF THE PROBLEM ON IDENTIFICATION OF THE STRESSED-DEFORMED STATE OF GEODYNAMIC SYSTEMS

We consider the geodynamic objects (processes, phenomena) as the complicated and hierarchically opened (generally, nonlinear) geodynamic systems. They are classified as global (planetary), regional and local objects. The objects of engineering geodynamics, consisting of two subsystems, that is, engineering structures and geophysical environment, can be included into the last ones.

The most important results obtained for the last decades and introduction of new geosciences give evidence about a significant role of the nonlinearity in geodynamic system's behavior. The nonlinearity of processes causes rotary movements of tectonic blocks and stressed-deformed state of geoenvironments. The interpretation of geodetic (terrestrial and satellite) observations allows identifying the features of geodynamic systems. The analysis of observations for astronomical azimuths of five lines located in the Baikal region has revealed a counter-clockwise rotary of the region with a simultaneous horizontal displacement of tectonic blocks conforming to the results of stains (Yesikov, Pankrushin, 1969).

The theoretical and methodical bases for modeling and identification of the stressed-deformed state of geodynamic systems using geodetic and geophysical observations are given in work (Pankrushin, 2002). Examples for identification of movements and the stressed-deformed state of geodynamic systems by modeling and geodetic observations are represented in the book (Seredovich, Pankrushin, Kuznetsov, 2004).

In works of authors (Pankrushin, 2002, Seredovich, Pankrushin, Kuznetsov, 2004), the problem of mathematical modeling and identification of motions, as well as rotary movements and the stressed-deformed state of geodynamic systems is solved by spatio-temporal series of combined heterogeneous geodetic and geophysical observation
The problem of mathematical modeling and identification of the stressed-deformed state of geodynamic systems is solved in our formulation by spatio-temporal series of combined heterogeneous geodetic and geophysical observations in the light of prediction of natural and technogenic catastrophes.

The models of continuum mechanics within the framework of the dynamic or static theory of elasticity are widely used to solve the problems of nonlinear geomechanics, geophysics, and seismology. In particular, it is a basis for the existing systems of natural and technogenic catastrophes monitoring. They are also used in elaboration of systems for observations and computer processing of office and field observations.

These problems reflect the necessity for a comprehensive approach to investigations of various natural and technogenic geodynamic systems on the experimental basis. It, in particular, concerns a problem of mathematical modeling and identification of the stressed-deformed state of geodynamic systems.

In our formulation the problem of mathematical modeling and identification of the stressed-deformed state of geodynamic systems is solved by spatio-temporal series of combined heterogeneous geodetic and geophysical observations.

The stressed-deformed state of the earth's crust can be defined from quantitative estimations of tectonic displacement rates on the basis of geodetic data; direct measurements in rock masses (follows the method of stress dumping in cores drilled in mines, pits and tunnels, as well as the method of hydraulic breaking in mines on a depth up to several kilometers); geological data on formation of a neotectonic structure compression (folds and overlaps), tensions (rifts, disposal structures), and various faults, in particular, slips. These three approaches make possible to estimate the stressed-deformed state in the upper part of the earth's crust. They can be added by the fourth approach, which allows outlining the strains in deeper parts of the Earth’s crust and the upper mantle as well. It includes the generalization of geophysical, seismological (used to define the axes orientation of the largest and least compressing strains and a character of displacements in the center of earthquakes by studying the peculiarities of seismic wave propagation) and gravimetrical data (based on the geodynamic interpretation of a size and orientation of conjugated zones with positive and negative gravity anomalies). Such damages are, generally, appeared as a result of tectonic compression. They allow the quantitative defining of a magnitude of strains acting in the crust. Applying the methods for obtaining the motion parameters, deformations and strains from field observations, it becomes possible to increase the adequacy of analytical models and the accuracy of parameter estimations for the stressed-deformed state of geodynamic systems.

The parameters of geodynamic systems (coordinates, elevations, motion parameters, deformations and strains), in many cases, are not available to make direct measurements and they can only be determined indirectly by other observations (directions, distances, zenith angles, heights, etc.). Therefore, the problem of physical interpretation of direct observations or system identification is arisen. It is important not to separate the interpretation from the treatment of observations (adjustment or filtering), so as to impede the integrity of observations - their handling and interpretation.

Thus, the problem of methodical and algorithmic support development for information technology is a high-priority task to be solved. This technology is used for identification of motions and the stressed-deformed state of geodynamic systems by spatio-temporal series of combined heterogeneous geodetic and geophysical observations. In a broad sense, identification includes the structural identification (revealing the regularity of geodynamic system behavior) and parametrical (estimation of geodynamic system parameters). The high requirements for accuracy, completeness and estimation of the reliability of motion and deformation parameters of natural and technogenic geodynamic systems, as well as the possibility of decision-making on a character of geodynamic system behavior during investigations cause the necessity of the development of operational and optimal techniques for mathematical treatment and interpretation of spatio-temporal series of combined geodetic and geophysical observations.

These prerequisites make up a base to develop an automated information technology for identification of the stressed-deformed state of geodynamic systems. Our geoinformation technology includes a computerized process of geodynamic investigations, support for optimal solution of problems in defining the motion regularities, current and predicted estimations of the stressed-deformed state of geodynamic systems, computer visualization of various geodynamic fields and, primarily, visualization of deformation and strain fields.

2. THE MATHEMATICAL TOOLS USED FOR IDENTIFICATION OF THE STRESSED-DEFORMED STATE OF GEODYNAMIC SYSTEMS BY SPATIO-TEMPORAL SERIES OF COMBINED GEODETIC AND GEOPHYSICAL OBSERVATIONS

The identification of the stressed-deformed state of geodynamic systems is the subject for studies of geodynamic systems by field observations. The functional scheme of this problem as a result of processing and interpretation of multidimensional temporal series of combined heterogeneous geodetic and geophysical observations is shown in Fig. 1.

The construction of adequate model for an object to be studied and estimation of its physical properties obtained from the inverse problem solution using observations are the result of mathematical processing in identification. The basis for combined system modeling of spatio-temporal series of complex geodetic and geophysical measurements of the stressed-deformed state of geodynamic systems are the following concepts given below (Pankrushin, 2002).

- The geodynamic system structure consists of two main subsystems of the same hierarchical level: the Earth’s physical surface (EPS) and gravity field (EGF). More generally, geodynamic systems can include the spatio-temporal heterogeneity of geospheres such as lithosphere, atmosphere, hydrosphere, as well as, geophysical fields having interrelations with a gravitational field, electromagnetic and stressed-deformed state.

- The geodynamic systems belong to those whose distributed parameters depend on spatial coordinates $X = X(x, y, z)$ and time t. In this case the results of observations are regarded as multidimensional temporal series, processing and interpretation of which are performed by a mathematical tool for recurrent identification of dynamic systems, in particular, a Kalman-Bucy filter.

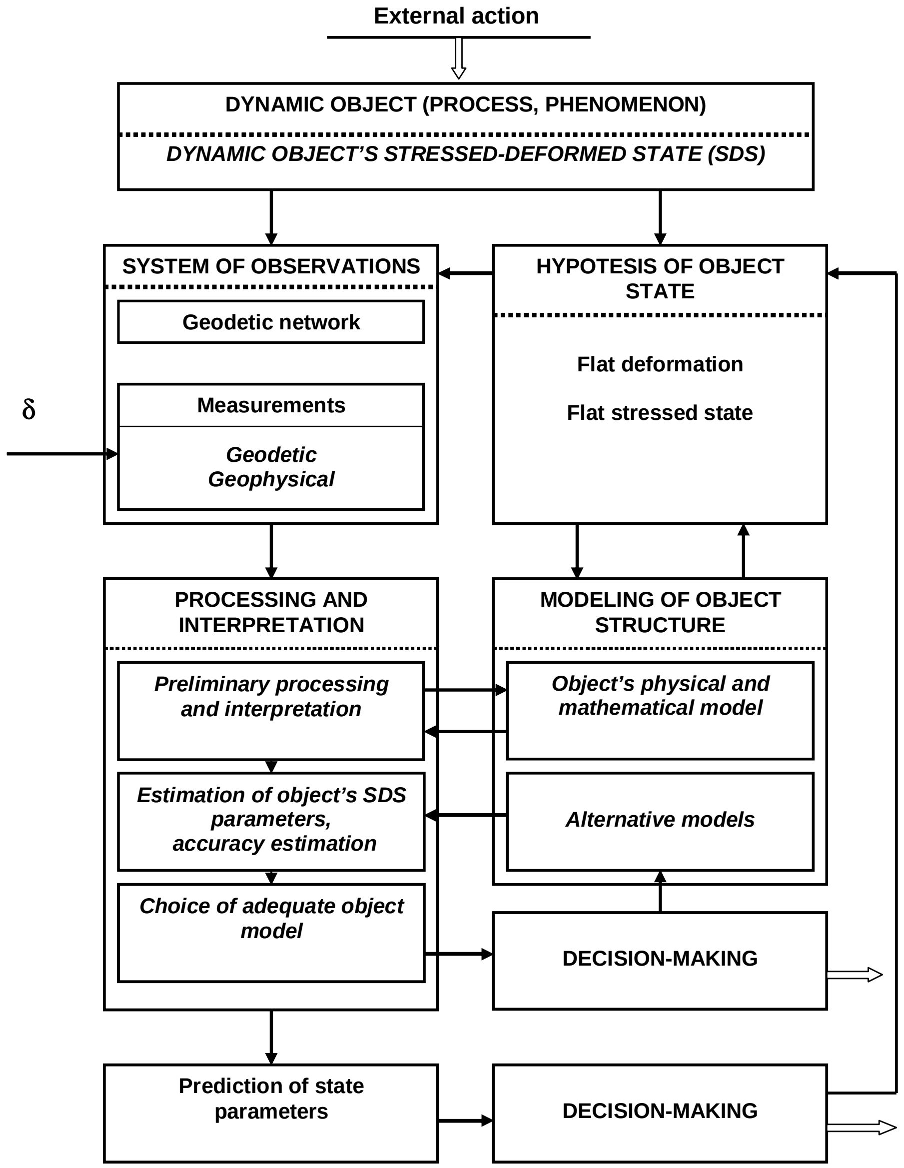


Figure 1.The functional diagram for solving a problem on identification of the stressed-deformed state of geodynamic systems

- As a rule, the interpretation of observations is carried out in terms of the incomplete apriori information on geophysical environment and external disturbing effects. Therefore, identification of geodynamic systems is considered not only as the definition of parameter estimation, but adequate and alternative spatio-temporal structures of geodynamic systems as well.

- The geodynamic system modeling is performed in state and phase spaces with a given (or identified) evolutionary operator $F(X,t)$ from the theory of dynamic systems and control.

When modeling alternative models of the regularities of geodynamic system motions and deformations of geodynamic systems along with the models of heterogeneity (blocks) of the geophysical environment, integral-and-differential operators and body models of the theory of continuous environments are used.

The structural diagram for identification of motions and the stressed-deformed state of geodynamic systems by the spatio-temporal series of combined heterogeneous geodetic and geophysical observations is shown in Figure 2.

The conceptual model of geodynamic systems is constructed as two state equations (Pankrushin, 2002). In this case a geodynamic system $\Sigma(X,t)$ is represented by the discrete points of geodetic and geophysical observations.

Let's write the first nonlinear state equation describing the regularities of geodynamic system motions (trajectories) in vector-and-difference form:
$X_R(X,t) = F(X,t)\{X_R^T(X,t-1), C_\Sigma^T(X,t), I^T(X,t), \Theta^T(X,t)\}^T + B_\Psi(X,t)\Psi(X,t)$ (1) where $F(X,t)$ is a geodynamic system revolutionary operator; $C_\Sigma(X,t)$ is a vector of specified model parameters (factors); $I(X,t)$ is a value in complex area (modeling of complex of geodynamic systems in the context of fractal approach); $\Theta(X,t)$ and $\Psi(X,t)$ are the vectors of deterministic and stochastic environmental impacts on an object (process); $B_\Psi(X,t)$ is a matrix reflecting the external stochastic impacts on an object, where T is a top index as a symbol of transposition. It should be noticed, that $\{X_R^T(X,t), C_\Sigma^T(X,t)\}^T = X_\Sigma(X,t)$; $\Theta(X,t) \in \Theta_\Sigma$, where Θ_Σ is a set of the known (observable) input of deterministic and stochastic environmental impacts on the deterministic dynamic system Σ_d as a whole, that is either an object (process, phenomenon) or a subsystem of observations Y.

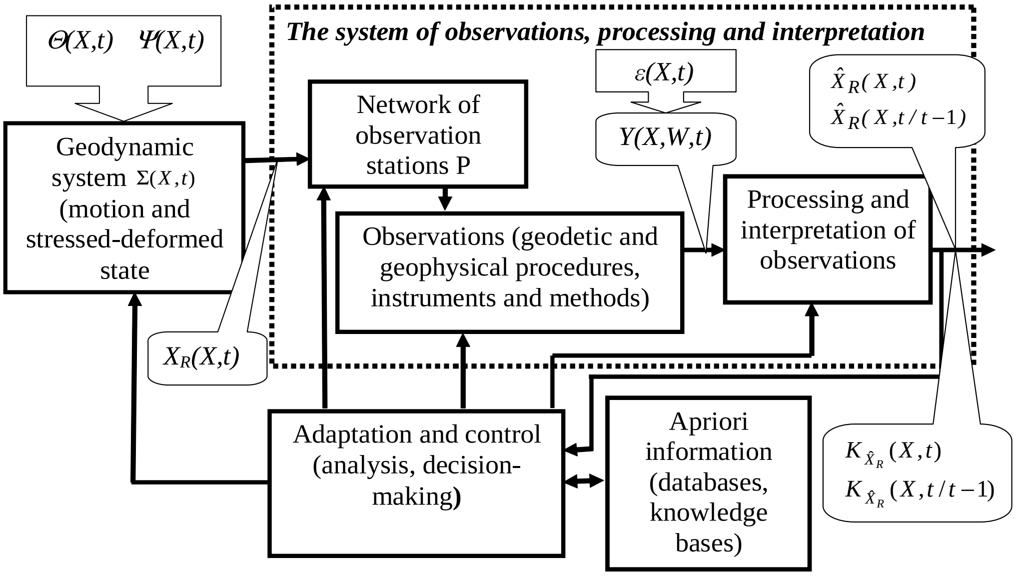


Figure 2: The structural diagram for identification of motions and the stressed-deformed state of geodynamic systems by spatio-temporal series of combined heterogeneous geodetic and geophysical observations.

The extended vector of state parameters to be defined for a geodynamic system in Eq.(1) is formed as follows: $X_R(X,t)=[X_i^T\{P_i(t)\},W_i^T\{P_i(X,t)\},X_D^T(X,t)]^T \in X_\Sigma$ or when the normal potential $U_i\{P_i(X,t)\}$ is set, $X_R(X,t)=[X_i^T\{P_i(t)\},T_i^T\{P_i(X,t)\},X_D^T(X,t)]^T$ where W is a gravity potential, $T=W-U$ is the disturbing potential. A vector of geodynamic system motion parameters $X_D(X,t)$ is formed as $X_D(X,t)=\{X_{D(EPS)}^T(X,t),X_{D(EGF)}^T(X,t)\}^T$, where $X_{D(EPS)}(X,t)$ is a vector of motion and physical surface deformation parameters or generally a vector of the crustal (rock) stressed-deformed state for the continuous environment; $X_{D(EGF)}(X,t)$ is a vector of gravitational field variations.

The second nonlinear state, which models the results of spatio-temporal series of heterogeneous combined observations (a set of a geodynamic system' output magnitudes), referring to the geodetic functions on a potential surface of gravity W can be represented as: $Y(X,W,t)=f(X,t)\{X_R^T(X,t),C_Y^T(X,t),\Theta_Y^T(X,t)\}^T+\delta_Y(X,W,t)$, (2) where $\Theta_Y(X,t)$ is a vector of external deterministic environment impacts on the system of observations; $C(X,t)$ is the known factors of this system; $\delta_Y(X,W,t)$ is a correlated sequence of accidental errors in observations with the covariant matrix $K_\delta(X,t)=K_Y(X,t)$. Adding the coordinate vector $X=X(x,y,z)$ to the function (2) as an argument, it is evident that observation rows are not only temporal but spatial. In this case the measurements of several magnitudes (output signals of a geodynamic system) can be done at each observation station.

Substitution of the gravity potential $W(X,t)$ into the expanded vector of state parameters $X_R(X,t)$ (1) leads to the construction of infinite-dimensional models of geodynamic systems describing by the state equations (1) и (2). The infinite dimensionality of models causes the necessity of their approximation by the finite models and, respectively, a complication of computational realization of the problem solution. For the purposes of construction of finite-dimensional models for geodynamic systems in state space we can go from the disturbing potential T by means of main physical geodesy's operators to its main transformers: height anomalies ζ, mixed gravitational anomaly Δg and components of gravimetrical plumb-line declination ξ,η (Pankrushin, 2002).

The multidimensional spatio-temporal series of observations $Y(X,W,t)$ are formed from the combined heterogeneous geodetic and geophysical observations reflecting a spatio-temporal structure of the stressed-deformed state of geodynamic systems. Observations should be done by the methods of geodetic astronomy, terrestrial and satellite geodesy, geophysics, etc.

Among them are the following methods of observations: horizontal directions, geometrical, water and hydrostatic leveling, alignment survey, reverse plumb-lines, acceleration of gravity, gravity variations (the second potential derivatives), geomagnetic field parameters, inclinations, deformations, crustal stains (unloading, ultrasonic, seismotomography, hydrodiscontinuties).

A Kalman-Bucy filter's adaptive recurrent algorithm is used in work (Pankrushin, 2002) to solve the problems of structural and parametrical identification of geodynamic systems. The state equations (1) and (2) are linearized to optimize their solution by a Kalman-Bucy linear filter's recurrent algorithm (Leondes, 1976).

A Kalman-Bucy filter's algorithm allows defining the optimum, in sense of criterion $\min trK_{X_R}(X,t)$ (a generalized dispersion minimum), of the current estimations of extended vector of state parameters $\hat{X}_R(X,t)$ as well as the single step predicting background estimations (a conditional mathematical expectation) of the vector: $\hat{X}_R^F(X,t/t-1) = F(X,t)\{X_R(X,t-1), C_\Sigma(X,t), \Theta(X,t)\}$ (3)
with corresponding covariant matrices $K_{X_R}(X,t), K_{X_R}(X,t/t-1)$. Here the lower case index $t/t-1$ designates the single-step predicting on an epoch t for all observations up to an epoch $t-1$.

The current and single-step predicted background estimations of a parameter vector are connected by the equation:

$$\hat{X}_R(X,t) = \hat{X}_R^F(\hat{X}^F, t/t-1) + \delta X_R^B(\hat{X}^F, t/t-1), \qquad (4)$$

where $\delta X_R^B(*)$ are the variations or anomalies $\hat{X}_R(X,t)$ on a background $\hat{X}_R^F(*)$.
In the following, we will use the designations from the work (Leondes, 1976) to reduce the records of equations. In such a manner we accept the designations with an index «t» (for

example, $Y(X,W,t)$) for the obtained magnitudes using data for the only one epoch. For the predicted background value estimations, obtained for an epoch t taking into account the results of observations up to an epoch $t-1$, we will use an index $t-1$. We are applying the following designation $\hat{X}_R^F(\hat{X}^F, t^-) = \hat{X}_R^F(\hat{X}^F, t/t-1)$ and, use the index «t^+» and designation $\hat{X}_R(X, t^+)$ to perform the estimations, which will be obtained from recurrent filtration of observations for all the epochs 1.2... t - 1, t. A Kalman-Bucy linear filter's recurrent algorithm for joint solution of state equations system (1) and (2) after their linearization, using the same designations (for the simplicity, excluding all the arguments, except for t, t^-, t^+), has the following form (Leondes, 1976):

$$\left.\begin{aligned}
&\hat{X}_R(t^+) = \hat{X}_R(t^-) + G(t^-)\Delta Y(t^-);\\
&\hat{X}_R(t^-) = F_{X_R}^F \hat{X}_R(t-1);\\
&\Delta Y(t^-) = Y(t) - \hat{Y}^F(t^-);\\
&G(t^-) = K_{X_R}(t^-)A^T(t^-)K_V^{-1}(t^-);\\
&K_{\Delta Y}(t^-) = A(t^-)K_{X_R}(t^-)A^T(t^-) + K_Y(t);\\
&K_{X_R}(t^-) = \Phi(t,t-1)K_{X_R}(t-1)\Phi^T(t,t-1) + \Gamma(t)K_{\varpi}(t)\Gamma^T(t);\\
&K_{X_R}(t^+) = [E - G(t^-)A(t^-)]K_{X_R}(t^-).
\end{aligned}\right\} \quad (5)$$

where $\Delta Y(t^-) = Y(t) - f\hat{X}_R^F(t^-) = Y(t) - \hat{Y}^F(t^-)$ are the discrepancies in observations or anomalies of geodetic functions $Y(t)$ in space of states; $K_{\Delta Y}(t^-)$, $K_{X_R}(t^-)$ and $K_{X_R}(t^+)$ are covariant estimation matrices respectively for an observation discrepancy vector, a prediction extended vector of state parameters and the current extended vector of state parameters; Φ and A are the transition matrices resulting from linearization of equations (1) and (2) accordingly; E is a unit matrix.

Applying a Kalman-Bucy filter's algorithm for the recurrent processing of observations in the form of spatio-temporal state models removes such restrictions on the system of observations as the uniformity of observation epochs and invariance of the geodetic network frame.

The recurrent character of a Kalman-Bucy filter makes it a suitable mathematical tool in automated data processing system designing and interpretation using the up-to-date computing facilities, as with our case, to develop an information technology for identification of the stressed-deformed state of geodynamic systems.

A Kalman-Bucy filter's algorithm, being itself a dynamic system, provides the data collection on object dynamics and, as a result, increases the accuracy of parameter state estimation.

It should be emphasized, that in sequence processing of observations for several epochs, the estimation of $\{\hat{\mu}(*)\}^2$ is carried out using all the measurements up to the last epoch inclusively by the recurrent formula allowing data collection during the processing:

$$\{\mu_{\sum}(t)\}^2 = \frac{\{\mu_{\sum}(t)\}^2 \nu_{\sum}(t-1) + \{\hat{V}(t/t-1)\}^T \{Q_{X_R}(t/t-1)\}^{-1} \hat{V}(t/t-1)}{\nu_{\sum}(t)}, \quad (6)$$

where $\nu_{\sum}(t) = \nu_{\sum}(t-1) + \nu(t)$, $\nu_{\sum}(t)$ и $\nu_{\sum}(t-1)$ are the degrees of freedom equal to the total number of abundant observations accordingly up to epochs t and $t-1$, inclusive; $\nu(t)$ is a number of abundant observations in epoch t.

3. IDENTIFICATION OF THE STRESSED-DEFORMED STATE OF REGIONAL GEODYNAMIC SYSTEMS (IN MOUNTAIN ALTAI)

The velocities of horizontal movements, defined for 18 GPS-stations covering the structural elements of Mountain Altai and its foothills within the Russian Federation (Fig.3), were given from the Altai GPS reference system observations (Ardjukov, 2003). The NVSK station (Novosibirsk) has been accepted as a base permanent station. The accuracy of motion velocities was limited by their errors.

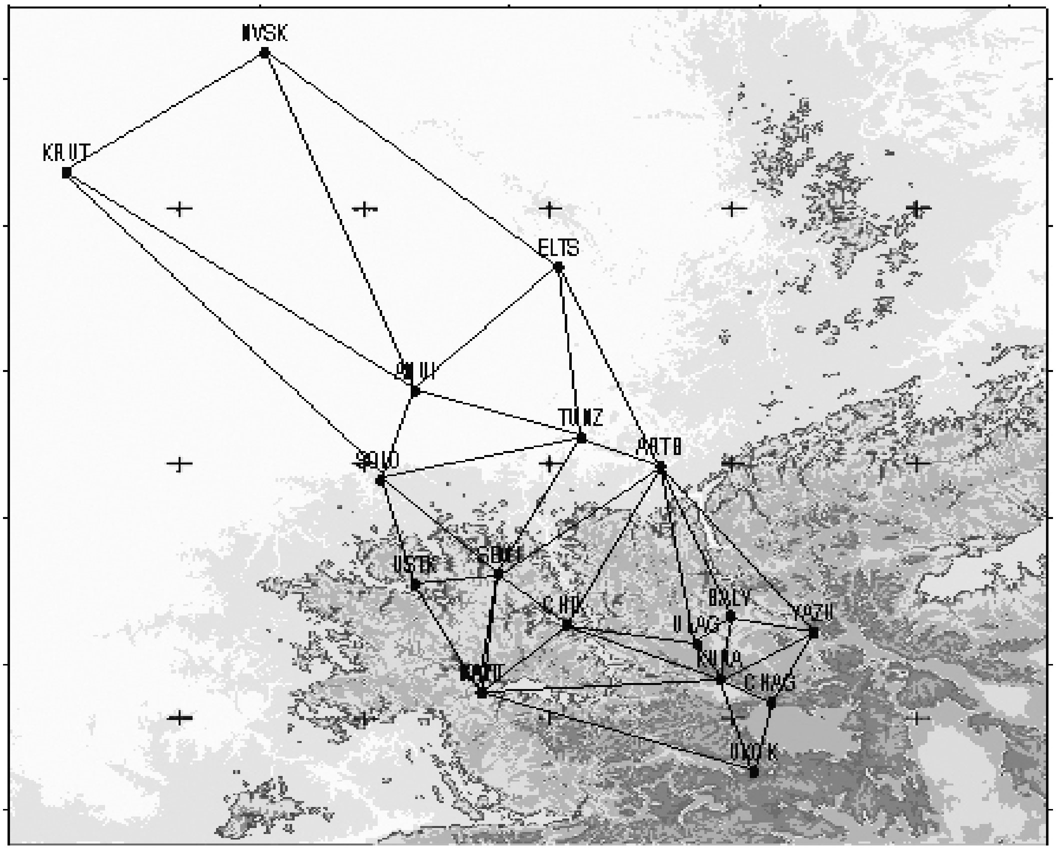


Figure 3: The map of the Altai GPS reference system. An area covered by the geodynamic system is divided into triangulated finite elements shown by the continuous lines.

The vectors of ground surface horizontal motions within the whole territory of Mountain Altai till the earthquake obtained from the interpolation have clearly pointed to their nonlinear behavior (Fig. 4).

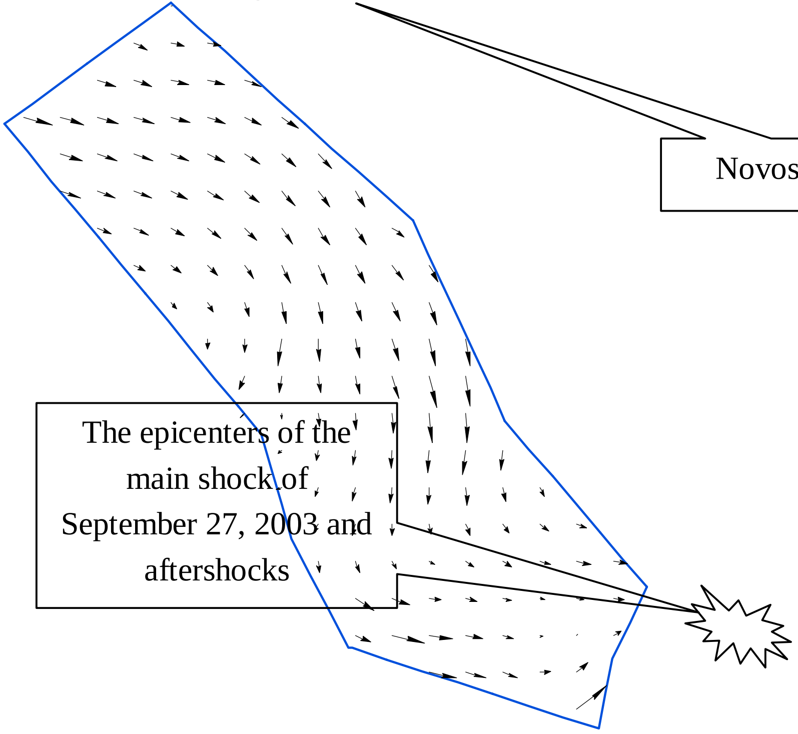


Figure 4 The directions of the geodynamic system's horizontal ground displacements in Mountain Altai before the catastrophic earthquake of September 27, 2003.

The results of field observations were processed taking into account a nonlinear character of geodynamic processes and phenomena. An area covered by the geodynamic system in Mountain Altai is divided into 22 triangulated finite elements (Fig.5). In this case the triangles with very sharp angles were eliminated. That was why the triangle SEMI-KAIT-KAYT has not been included in the processing.

The deformation vector components $\hat{\varepsilon}$ were computed. According to the geological map of the given region, we revealed that the main rocks were sandstones and limestone. Therefore, when modeling the parameters describing the object stressed state were taken the average values of the Young's module $E = 0.6 \cdot 10^{11}$ Pa and Poisson factor $\nu = 0.25$ for sandstones and limestone (Turcotte, Schubert, 1982). These values were necessary to calculate a matrix describing the elastic properties of a material. Then according to the formulas of Hooke law the values of strain vector components σ have been determined for every triangulated finite element of the Mountain Altai geodynamic system.

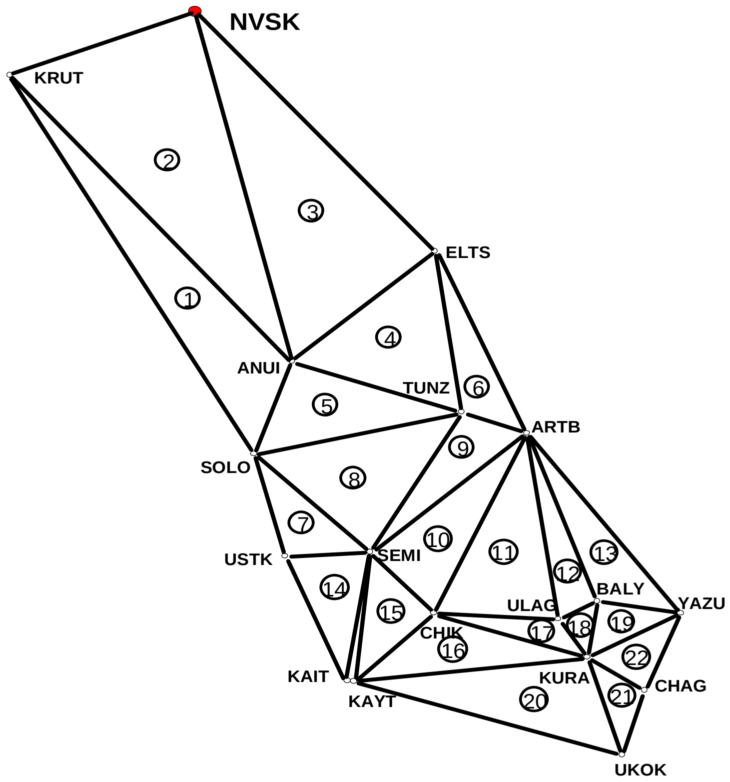
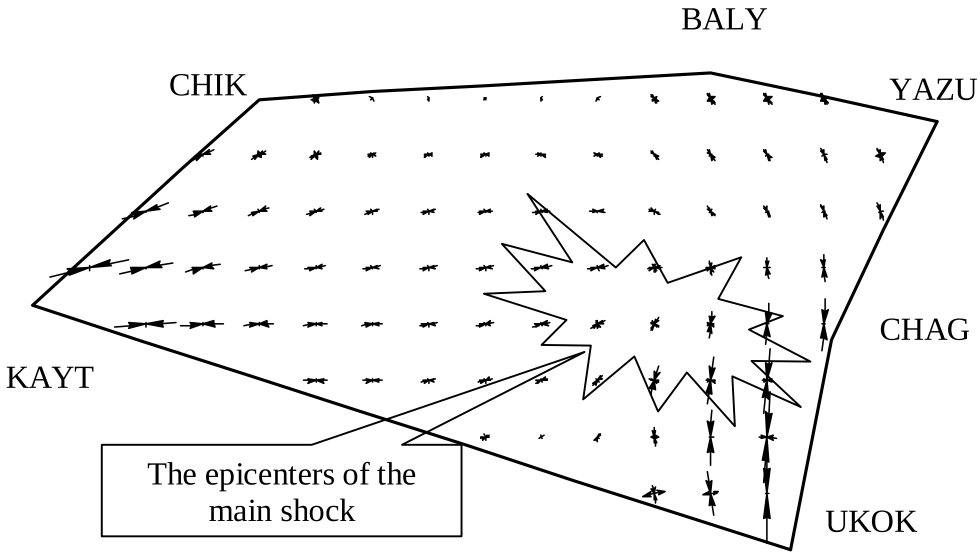


Figure 5: The geodynamic object ‘Mountain Altai’ is divided into triangulated finite elements.

The geometrical interpretation of strain tensor distribution in the southern part of the investigated territory is shown in Fig. 6. The convergent arrows point to the crustal compression. In the vicinity of the earthquake a compression was emerged in a direction of the meridian.



The epicenters of the main shock

Figure 6: The strains about a year ahead of the Chuisky earthquake.

The obtained parameters of deformation and strain fields with their subsequent computer visualization gave qualitatively new information on geodynamic processes in the region of Mountain Altai as the forerunners of earthquakes.

In work (Ardjukov, 2003) a description of horizontal movements in Mountain Altai region is included into the analysis of processing of GPS campaigns data. The authors, particularly, deal with the latitudinal displacements in the central part of region, movements to the northwest in a southern part. It should be noticed, that this method for the description of horizontal movements despite of its widespread use, has essential disadvantages. Firstly, it is the non-invariance. When any other network station is taken as a stable one (instead of NVSK), quite a different representation of horizontal movement vectors will be realized. Secondly, the description of movements by means of vectors does not allow analyzing deformation processes on the territory of a geodynamic object to be investigated. Our approach does not have such disadvantages. In our case the results of experiments are processed taking into account the nonlinear character of geodynamic processes and phenomena. The obtained deformation and strain field parameters with the subsequent computer visualization of these fields give qualitatively new information on geodynamic processes in the region of Mountain Altai

For example, the rotational movements (a counter-clockwise) and anomalous strains in a southern part of the geodynamic system in Mountain Altai were revealed. It is the region, where was the epicenter of the main shock of the Altai earthquake of September 27, 2003. The earthquake epicenters of the main shock and aftershocks for several weeks within the southern triangulated finite elements according to Fig.5 are shown in Fig. 7.

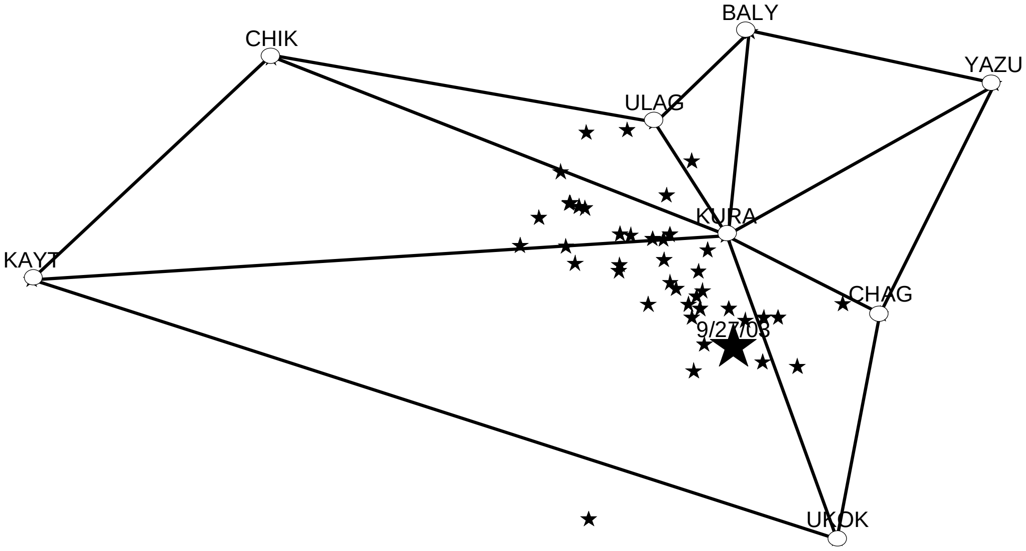


Figure 7: The earthquake epicenters of September 27, 2003 and aftershocks (from September 27, to October 17, 2003) in Mountain Altai. The main shock of September 27, 2003 with magnitude 7.3 is shown by a large star and the aftershocks by small stars.

The diagram of geodynamic system's vertical movements in Mountain Altai, modeled using GPS campaigns data, is shown in Fig. 8 (Ardjukov, 2003). The area of the earthquake of September 27, 2003 on the diagram coincides with the anomalous vertical motions. These data have been obtained as the results of GPS campaigns for the period of 2000 – 2001 – 2002.

The KURA station rising with a speed of 6.42 mm/year and its lowering as related to the nearest ULAG station with a speed of 4.66 mm/year complement the pattern of the crustal strains as a forerunner of the place of catastrophic crustal earthquake. It is the next evidence, that the large vertical motion velocity gradient and strain anomaly (Fig.6) are the important indicators to predict seismic events.

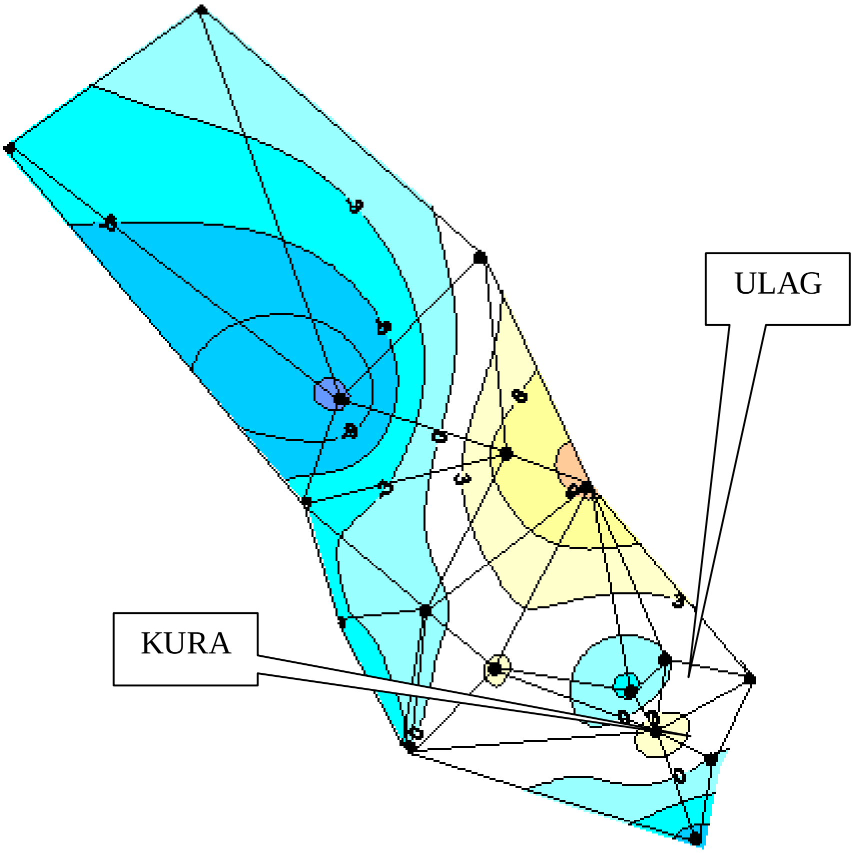


Figure 8: The diagram of geodynamic system vertical movements in Mountain Altai.

It should be emphasized, that the prediction of the exact location and probably an earthquake power might have been obtained only to strengthen the system of geodynamic system monitoring. For example, it could be done by the combined processing of geodetic and geophysical observations, adding some observation points into the network located in the southern regions of Altai (Mongolian Altai), network densification in the vicinity of the Northern Chuisky and Southern Chuisky ridges of Mountain Altai and increasing the frequency and observation composition.

4. CONCLUSION

The methodical and algorithmic support development for information technology used for motion identification and the stressed-deformed state of geodynamic systems by spatio-temporal series of combined heterogeneous geodetic and geophysical observations are considered in the paper. The geodynamic phenomena have a nonlinear character. To describe them, the models of continuum mechanics within the framework of the dynamic or static theory of elasticity are used. Taking into account the nonlinear character of motions and the stressed-deformed state of geodynamic systems, the method of finite elements is used.

The methodology proposed as well as mathematical and algorithm support for identification purposes, that is, motions and the stressed-deformed state of geodynamic systems by spatio-temporal series of combined geodetic and geophysical observations makes possible to estimate the properties of geodynamic system behavior associated with irreversible strains and stresses field heterogeneity either in two-dimensional or three-dimensional space using field surveys data. Both the estimation of a geodynamic system's point displacement and parameters of current and short-term prediction are the results of mathematical treatment of observations, which characterize the stressed-deformed state of geodynamic systems. Furthermore, the estimation of parameter accuracy is carried out. Deformation and stains fields are visualized in a convenient for the analysis form.

The numerical examples for identification of motions and the stressed-deformed state of geodynamic systems based on the field observations are given.

The parametrical identification of crustal stressed-deformed state has been carried using GPS campaigns data in Mountain Altai for 2001-2002, i.e. before the catastrophic earthquake of September 27, 2003. This geodynamic system covers the structural elements of Mountain Altai and its foothills within the Russian Federation. The results of experiments were processed taking into account the nonlinear behavior of geodynamic processes and phenomena. The obtained deformation and strain field parameters with the subsequent computer visualization of these fields gave qualitatively new information on geodynamic processes in the region of Mountain Altai. It is evident that such information can be used both for the seismic zonation, for the purposes of earthquakes prediction, and reducing the risk and hazards of natural and technogenic catastrophes.

The results of investigations testify the significant role of geodetic methods in monitoring of the slow and fast (catastrophic) crustal motions.

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BIOGRAPHICAL NOTES

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