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Contents:

Summary

In offered to attention of the readers Report on scientific works on a geodesy the results of researches on topics of the sections of the International Association of Geodesy carried out in Russian Federation from a beginning 1995 till the end of 1998 are reflected. Despite of dramatical decrease of financing in the considered period, the scientific researches on a geodesy were carried out practically on all directions.
The significant results are received in the field of study of a gravitational field and geoid using satellite altimetry; improving of accuracy of tidal gravimeters and studying earth tides. Works considerably have advanced in the field of satellite geodynamics, including developments of methods of mathematical processing of measurements and its common interpretation with use of the geodetic, geophysical and geomorphological data.
Articles of the Report are written by the members of section of a geodesy of National Geophysical Committee of Russian Academy of Sciences. Editors have carried out the managing and general editing of the manuscript only, trying to minimize the corrections of the original papers submitted by authors.

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Physical Geodesy: An Overview

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1. Reference geodetic networks

(Pleshakov I.Ya., Makarenko N.L., Demyanov G.V., et al, 1998) have described a status and prospects of development of system of geodetic maintenance of the country in conditions of transition on satellite methods.

Now uniform systems of coordinates and heights on territory of Russia are set accordingly by state geodetic network (SGN) and state levelling network (SNN). SGN includes about 164 thousand stations of 1 and 2 classes of astro-geodetic network.

Total number of stations of filling networks of 3 and 4 classes is of the order of 300 thousand for all the territory of former USSR. SGN includes also 20 stations of a space geodetic network, created by Topographical service of the armed forces of Russian Federation, and 136 stations of Doppler geodetic network.

As a result of joint adjustment of all of above mentioned networks in 1995-1996 the reference system of geodetic coordinates SK-95 has been developed with approximately identical accuracy widespread on all territory of the country coordinated with geocentric system of coordinates PZ-90.

The accuracy of stations coordinates in SK-95 is about 2-4 cm on mutual distances of 10-15 km, 10-20 cmon distances up to 100-200 kms and 0,5-0,8 m at distances in one thousand and more than kilometers.

In new planned structure of a state geodetic network based on use of satellite navigation systems GPS/GLONASS the construction of a fundamental astro-geodetic network (FAGS), precise geodetic network (PGS) and satellite geodetic network of 1 class (SGS-1) is planned.

The necessity of integration of FAGS in a world geodetic network of permanent observations of GPS and GLONASS is discussed on the basis of the international projects and programs.

(Drazhnyuk, Lazarev, , Makarenko, et al 1998) have devoted article to the basic results of joint adjustment of a astro-geodetic network (AGS), space geodetic network (SGS) and Doppler geodetic network (DGS) 1995, and also to subsequent final adjustment of AGS in 1996.

The number of the measured elements included in adjustment, exceeded one million, including 3500 Laplace azimuths and 2700 bases. Volume of the measuring information used in creation of system of coordinates of 1942 (SK-42), is less than 10 % from total amount of measurements at creation of system of coordinates of 1995 (SK-95). Received increase in accuracy of SK-95 relatively to SK-42 is more, than one order.

The connection between reference geocentric systems of coordinates PZ-90 and geodetic SK-95 is characterized by three linear elements of transformation ΔX =25,90 m, ΔY=130,94 m, ΔZ =-81,76 m.

The structure of organizational deals for operative introduction ÑÊ-95 in practice of topographyc-geodetic works in territory of Russian Federation is formulated.

Gravimetry and satellite geodesy.
The solution of a geodetic boundary value problems
Calculation of quazigeoid heights and plumb-line deflections

(Zhalkovsky, Demyanov, Brovar, et al, 1998) have described parameters of planetary model of a gravitational field and geocentric system of coordinates (PZ-90).

The new planned structure of a Geodetic network of Russia created on the basis of satellite systems GPS and GLONASS, makes possible with use of gravimetric data to combine plane and height coordinate systems into uniform reference system.

The highest level of system of coordinate maintenance is the fundamental astro-geodetic network (FAGS). The spatial position of its stations is determined in global reference system of coordinates with an error relatively to the centre of mass of no more $(2\text{-}3)\cdot 10^{-8}$-R, where R- radius of the Earth.

Use of quazigeoid heights, received on gravimetric data, makes possible to coordinate satellite definitions of geodetic heights with normal heights received from the data of geometrical levelling.

By results of researches of ZNIIGAIK the method of interpolation of quazigeoid heights with use of detailed maps provides determination of normal heights with a method of satellite levelling with an average quadratic error 3-5 cm at distance between stations of precise levelling of 400-500 kms.

The wide distribution of the GPS equipment has rendered last years the basic influence on development of a technique of definition of external gravitational potential of the Earth and elements of a terrestrial gravitational field. Before occurrence of the mentioned equipment the basic task of geodetic gravimetry was the definition of plumb line deflections from gravimetric data, now main task became calculation of quazigeoid height with centimetric accuracy.

The solution of this task is connected first of all with taking into account for ellipticity of the Earth and with the strict account of influence of topographical masses as basic way of increase of accuracy of interpolation of gravity between gravimetric stations.

The tasks of definition of a surface of the Earth and its external gravitational field due to systems GPS and GLONASS were as though divided, but it is not necessary to forget, that the necessary basis of new space techniques is exact definition of satellite orbits, impossible without knowledge of an external gravitational field.
Moreover, the system of coordinates established on gravity data, is strictly connected to the centre of masses of the Earth, therefore such data can be used for the control geocentricity of system of coordinates established by satellite methods.
Thus, the main task of a theoretical geodesy consists in increase of accuracy of definition of disturbing potential. The influence of terrestrial ellipticity is kept in the basic equations of the Molodenski theory. They can be solved by standard process consecutive iterations.
On ellipsoidal reference field is necessary to distribute all arsenal of methods developed for reference spherical field. Meaning mainly decision of this task, the group of the experts of ZNIIGAIK and SAI MSU during 1993-1995 has executed a complex of works with financial support of the Russian fund of basic researches (RFBR) under the project 93-05-9945.
Articles prepared within the framework of this project, are published in the collection «Physical geodesy » in 1996, issued also with financial support of RFBR.
For definition of disturbing potential of the Earth with a relative error of $5 \cdot 10^{-5}$ the integrated equation concerning auxiliary density on a boundary surface is made.
The square of a kernel of this equation does not exceed the established limiting error, that at the decision results in the minimal number of iterations. Disturbing potential is expressed by absolutely converging integral, and its horizontal derivative does not depend on an inclination of a boundary surface. The stated principles are realized in article of Brovara, Kopeikina, Pavlova (1996) for ellipsoidal Earth and in article of Brovara (1996)- for the real Earth.
In article of Brovar, Brovar (1996) the expediency of application of mathematical models is marked as test for evaluation of influence of methodical errors of working techniques of account of the characteristics of an abnormal gravitational field of the Earth. The tested working techniques generally can be various, therefore test model of a surface and gravitational field of the Earth should respond the general requirements of the theory of potential.
The test model of a surface of the Earth should describe a relief on all Earth as a continuous surface concluding in all attracting masses and satisfying to Lyapunov conditions.
The dependences of the various characteristics of normal and abnormal gravitational fields described by exact expressions, providing gravity and heights with accuracy 1 mcGal and 1 mm accordingly are investigated.
The formulas for calculation of the mixed anomalies and other characteristics on test models of a surface and gravitational field of the Earth of the increased accuracy as the appropriate sums of potentials of point masses in spherical and geodetic coordinates are received. For the same purposes Brovar (1996) has received the formulas for definition of harmonic coefficients of potential of point masses in a series of ellipsoidal functions.
Brovar, Mayorov (1996) have estimated methodical errors of a working technique GEOID-95, developed in ZNIIGAIK, with use of test models. The technique is intended for account of disturbing potential and quazigeoid heights by the combined gravimetric method under the integrated formula and on decomposition in a series of spherical functions, thus the results can be received in spherical approximation.
As global model the a little bit changed model of Ostach and Agaeva (1982), consisting from 137 point masses is accepted. The local model is given in 43 point masses. The complete model consists from both global and local ones. The results of calculations in particular have shown, that differences of quazigeoid height , designed on spherical functions with use harmonic coefficients up to 360 degrees are significant and reach 2,065 m.
Boyko et al (1997) have described definition of normal heights as differences of geodetic heights above ellipsoid, determined by GPS, and anomalies of heights. The various methods of interpolation of anomalies of heights are investigated, the ratings of accuracy and economic efficiency of new methods compared with traditional are executed.
Mayorov (1995, 1996) has considered calculations of quazigeoid heights using the Stokes formula at use of the integral formula in a near zone and decomposition of anomalies of gravity in a series of spherical functions in a distant zone.
(Rudenya, 1998) investigated dependence of the contribution of a distant zone in quazigeoid height at calculation under the transformed Stockes formula from the geometrical form of a near zone. Such question arises, as the anomalies of gravityare set on cells limited to lines of equal breadthes and longitudes.
The decision of the basic task of a geodesy - definition of a surface of the Earth and its external gravitational field essentially becomes simpler by use reference ellipsoid and its field.
Stockes in the basic work of 1849 already used such reception. There is a unique requirement to reference field: the elements of an abnormal field should be so small, that their squares and products could be neglected. Simplicity and invariance of a reference field guarantee convenience of calculation of normal heights and anomalies of gravity.
Yurkina 1997 aspired to show what to complicate reference field does not follow, and the listed influences can be taken into account by the special terms, having allocated the appropriate influences in disturbing potential.
The same approach to influence of topographical weights allows to make topographical reductions of gravity so correct, as a reduction in free air.

Ostach (1994) has described a history, principles, change in practical realization astro-gravimetric levelling - developed in 1935 by Molodenski method of definition of quazigeoid heights above the reference ellipsoid.
The basic idea of a method consists in use local of local gravimetric survey for the account of nonlinearity of change of plumbline deflections between astronomical items. The method is used for drawing up of maps of quazigeoid heights (1980, 1987, 1993 г.г.) on all territory former USSR. The work is carried out within the framework of general adjustment of a state geodetic network.
The average quadratic errors for all territory relatively to Pulkovo do not exceed 1 m, except for east Tchukotka and Kamchatka, where the error has increased up to 1,5 m. The excess of quazigeoid for points within the limits of one sheet of a map 1:1000 000 has an average quadratic error no more than 0,2 m. As modern direct continuation of a method it is possible to consider(count) construction of a detailed quazigeoid map on the data of measurements GPS and geometrical levelling.
Byvshev (1995) has described bi-linear interpolation of quazigeoid heights and plumb-line deflections, calculated in sites of a regular grid.
Dronin (1995) has described air gradiometry data processing in spectral area.
Brovar and Yurkina (1996) have described the biographic items of information on the founder of the theory of a modern geodesy Molodenski, have described a status modern to it(him) of a astro-geodetic network and study of a gravitational field in USSR, and also arising then tasks. The bibliography of the publications Molodenski is enclosed to article.
By Yurkina (1996) two reviews of the publications are published: 1) about an establishment общеземной of system of heights and sea surface as the beginning of the account, 2) about works on the theory of a figure of the Earth executed with preservation of relative accuracy about terrestrial compression.
The brief sketch of development of geodetic gravimetry is published by Borodko, Lukashuk, Neberov (1995).
Having taken advantage of Green function, Yurkina 1996 has expressed disturbing potential on a surface of terrestrial ellipsoid and outside of it through distribution of the mixed anomalies of gravity on a surface of ellipsoid, given in function of given breadth and longitude.
Nepoklonov and Orlov (1997) have described use of spline-functions at averaging parameters of a terrestrial gravitational field.
Nepoklonov, Tchugunov and Yakovenko 1998 have described opportunities of increase of accuracy of quazigeoid heights in the Moscow urban geodetic network for sharing with relative satellite coordinate definitions. The developed technique provides transfer of normal heights with accuracy levelling of 3-rd class.
In article Yurkina and Serebryakova (1998) the utility of repeated definitions of is considered gravity and second derivative of geopotential for division of vertical movements terrestrial crust and changes of a gravitational field.
Brovar and Yurkina (1997) have published the review of development of a theoretical geodesy.

Definition of fundamental constants

In article of B.Brovar (1996) (2) the basic opportunity of determination of the various geodetic information by a new method - cascade -is shown. The theory of a cascade method of definition of a vector of gravity, orientation and coordinates of driven object is stated.
The measurements of components of gravity, carried out with the help of cascade systems on various objects, including satellites, can be used for the decision of scientific and applied tasks of specification of the fundamental constant Earth.
Brovar, Pavlova, Stroev (1995) have discussed an opportunity of definition gravitational constant G on gravimetric the data. This article is connected to a theoretical opportunity of existence of the fifth interaction. Having used the equation Poisson for Newton potential and Gauss formula, connecting integrals on volume and regional surface, the authors have received the formula for definition constant G by a geophysical method.
· This formula have applied to a underwater mountain Erimo, investigated earlier in the french-Japanese project. Gravitational constant has appeared in a limit (6,665-6,721) 10^{-11}. The large casual disorder of values G is caused by a error of the account of a relief regularly overestimated result of calculation by G-errors in density of breeds. At density known more precisely of 3 %, the accuracy of a geophysical method of definition constant G would be comparable to results of modern laboratory measurements.
Brovar (1995) has considered definition of normal terrestrial ellipsoid without a support on geoid. The best mechanical model of the real Earth (commo) terrestrial ellipsoid) should minimize gradients of disturbing potential T in all external concerning the Earth space
Bursa (Czechia), Demyanov, Yurkina 1997 have described practical realization of the offer of Brovar (1995), believing, that three parameters determining terrestrial ellipsoid: geocentric gravitational constant, difference of the main central moments of inertia, polar and average of equatorial, and average angular speed of rotation of the Earth are known from space or astronomical observations and on the geodetic data it is necessary to establish large semi-axes of ellipsoid or not dependent from having flown influences potential U_0 on a surface ellipsoid.
If potential U_0 is determined, it is logical to define geoid as equipotential surface of potential of gravity of the real Earth, on which potential is equal U_0. The heights counted from this reference surface, will be optimum, especially for common World (global) system.

Models of terrestrial gravity field

Article of Demyanov, Kryukova, et al (1996) is devoted to construction of planetary model of a terrestrial gravitational field - GAO-95A. The authors have refused a conclusion of factors of decomposition of geopotential on spherical functions and have received result as adjusted anomalies of gravity on 1^o trapezes of territory of globe.

Because of lack of the measuring data there was an instability of the decision overcome regularisation in two variants: 1) additional conditional equations for harmonics of high degrees, which are not present in only satellite model, thus the average anomalies of gravityon trapezes $3^0 * 3^0$ were used; 2) the harmonics of the high order are determined on gravimetric the data.

The first variant has resulted to smoothing of harmonics of high degrees, second - in a priority of gravity the data. Initial гравиметрические the data are taken in 1^o gravity the catalogue of ZNIIGAiK. The data of SEASAT and GEOSAT are used at calculation of anomalies of gravity on altimetric by the data. For the unexplored trapezes average 1^o anomaly of gravity are deduced on a method of a collocation with use of dependence of anomalies of gravity from a relief.

In addition, compared with former conclusions, are used gravity data given for territory of China and separate regions of Pacific and Indian oceans. The comparison of the received factors to factors of models OSU-91A both GFZ-93A and B has resulted in an average quadratic error of factors of model GAO-95 $m_{a_{nk}b_{nk}} = \pm 0{,}04 - 0{,}05$ мГал.

As the second criterion the accuracy of calculations of quazigeoid heights in the well investigated areas has served: in the European part of Russia, central Siberia, on Far East, Okhotsk sea and island and in territory of USA and Canada. For the listed areas on detailed gravity data calculated quazigeoid heights with a step 10' * 15'.

For same grid the quazigeoid heights were calculated. The rating, executed by various criteria, of accuracy has shown, that the received model of a terrestrial gravitational field does not concede on accuracy to modern foreign models for all regions of globe, and for territory former USSR much more surpasses them.

The model has adequate system of harmonic coefficients of decomposition of anomalies of gravityin a number(line) on spherical functions. The factors up to 60-th degree are published in article, the complete system up to 180 degree is stored(kept) on magnetic carriers. The complete catalogue of adjusted average anomalies of gravityon trapezes 10' * 10' is in the same way stored.

On the basis of the same principles of joint adjustment ground gravity, orbital and satellite altimetric data in ZNIIGAiK in 1997 and 1998 the planetary gravitational models GAO-97 and GAO-98 on a level of detail appropriate to decomposition of geopotential in a series of spherical functions up to 360 degree are constructed.

Altimetric data used at construction of these models, are received on the data of measurements by TOPEX and ERS1 and 2, besides large volume of sea gravity data is in addition used. The works on construction of model GAO-98 were carried out within the framework of the project INTAS 93-1779. The results of these works are submitted in the form of the report on Workshop « Aiborne Gravity and the Polar Gravity Field » Grennland, June 1998.

Dronin (1995) has described model of a terrestrial gravitational field represented by point masses according to Balmino.

Nepoklonov (1995) has considered questions of classification, comparative analysis both realization of various ways and forms of performance of models of a terrestrial gravitational field in information databases.

The questions of a rating of accuracy of digital models of a terrestrial gravitational field have been considered by Nepoklonov and Orlov (1995).

Yashkin (1998) has described principles of definition of factors of decomposition of geopotential on spherical functions on the basis of the data satellite gradiometry and systems «satellite-satellite».

Kashaev (1998) has characterized planetary model of a terrestrial gravitational field GAO-97, received on decomposition of anomalies of gravity in a series of spherical functions up to 360-th degree, study of quazigeoid heights, drawing up of its maps in scale 1:12 000 000 with accuracy of 0,5-1,0 m.

Attraction field of spherically asymmetrical heavenly bodies

The theory of Newton potential of an attraction the question for the first time put by Euler in several works and till now directly concerns not investigated with necessary completeness. Namely, considering movements of Jupiter and Saturn, Euler (1749) has paid attention to the large compression of these planets, possible displacement of resulting forces from their centres of weights and influence of this circumstance on movement.

Doubts in connection with application of the laws of movement of bodies in a field of constant weight to definition of movement of heavenly bodies Euler has expressed also in the known book 1765. The review of these works is given in Yurkina (1996) (also Yurkina 1995). For example, the resulting force of an attraction of the Earth and Sun can be displaced from the centre of weights of the Earth on size up to 30 cm, Earth and Moon - up to 140 m, Earth and ИСЗ- up to 10 kms and more, depending on height of movement of the satellite.

The application of an Keplerian orbit as intermediate at displacement of resulting force from the centre of weights is connected to infringement of the third law of Newton: to action always there is an equal and opposite counteraction, differently - the interactions of two bodies against each other are among themselves equal and are directed to the opposite parties.

Having used for the description of movement of a drawn point of the equation Hamilton-Jakoby and having applied the theory of perturbations of Jakoby, it is possible to be convinced, that the quite possible(probable)

deviations(rejections) in structure of the Sun from spherical symmetry in view of Euler effect can explain movement of Mercury perihelium (Yurkina 1997). Unfortunately, the structure of the Sun is known still unsufficiently precisely for real accounts.

The influence of the members of decomposition of potential of an attraction of the Sun and Mercury, before taken into account in such accounts, is connected to harmonics of the second degree, their influence decreases as size, opposite to distance from the Sun, in the fifth degree; the influence of harmonics of the first degree decreases as the mentioned size in the third degree.

There are bases to believe, that the Euler effect can matter at account of influence of the Moon and Sun on rotation of the Earth and its orientation in space.

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Satellite Altimetry and Space Geodesy

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The space geodesy studies in Russia for last 4 years were connected with reprocessing of GEOIK geodetic satellites data and use of space geodesy methods for solution many scientific and applicational problems.
The first geodetic results of the processing measurements with GEOIK satellites (coordinates of tracking stations, parameters of the Earth gravitational field) described in the "National report to the IAG and IUGG 1991 – 1994," Moscow, 1995. The reprocessing of tracking and altimetry GEOIK satellite data are continued now with use of the advanced processing methods, force models of satellites motion and tides models.
To make easy for research to use satellite altymetry data obtained with different satellites, the integrated satellite altimetry database (ISADB) was created in the Geophysical Center of Russian Academy of Sciences. The problem oriented database management system help users to work with different satellite data (GEOIK, GEOSAT, TOPEX/POSEIDON). ISADB include GEOIK altymetry data during the period starting from 1985 until 1996. ISADB available in "on-line" mode for express analyses data distribution and 'off-line" mode for request data. For easy use ISADB by Russian scientists, data base include "public-domain" GEOSAT and TOPEX/POSEIDON data also [22,26,27]. These research was undertaken with support from the Russian Basic Research Foundation (Project 96-07-89315).
Now continue development of the GEOIK-2 satellite with precision altimeter and tracking systems for accuracy orbit determination with use of GLONASS measurements [11].
The improvement parameters of the PZ-90 and WGS-84 coordinate system transformation was obtained [2,10].

dXî = -1.08m ± 0.2m; βX = 0
dYî = -0.27m ± 0.2m; βY = 0
dZî = -0.90m ± 0.3m βZ = - 0.16" ± 0.01.

Parameters of the of the Russian coordinate system 1942 transformation with PZ-90 was improvement also:

dXî = + 25m ± 2m; βX = 0.00" ± 0.01"
dYî = - 141m ± 2m; βY = - 0.35" ± 0.01"
dZî = - 80m ± 3m; βZ = - 0.66" ± 0.01".

The conception of the topography and geodetic works in Russia transition to GLONASS/GPS technology was development [8,15].

Satellite Laser Ranging stations of the Russian network (Komsomolsk/Amur, Mendeleevo, Maidanak/Uzbekistan, Katsiveli and Simeis/Ukraina) carried out observations according to the International scientific programs DOSE (Dynamic of the Solid Earth) and the International Earth Rotation Service (IERS), as well as for the orbital support of the satellites (ERS 1-2, Topex/Poseidon, Zeya, etc.). Russian Space Agency supports SLR network and funds a development of the 4-th generation station in the area of Altay mountains (South Siberia).
/3-5,23,28,42,43,45,50/.
Testing program of the first radiotelescope of the QUASAR system in Svetloe (IAA RAS) is completed. /16,29,32/. VLBI station consists of the radio-antenna of 32 m (diameter), equipped with the low noise receivers in S/X diapasons and radiometers for measurements of the atmosphere electric parameters. An accuracy of the antenna pointing is 10 arcsec. Four H-masers secure the time registration accuracy at the level of 3.10 (-15). The Time

system is controlled by the GPS/GLONASS navigation satellites. There are an automatic meteostation and VLBI registration system S2 as well. The first observations of the quasars at the frequency 1665 MHz have been carried out with good results. A special programming complex is developed for the geodetic VLBI data analysis. /12,13,14,16,24,32/.

In 1996-1998 a network of 15 reference points equally distributed along the longitude and equipped with receivers of the Global Positioning System is developed over the Russian territory and adjacent republics, eight of them (Krasnoyarsk, Irkutsk, Kitab, Alma-ata, Yakutsk, Tiksi, Magadan, Bishkek) are located at the Asian tectonic plate, that is extremely important for the rigid geodetic basement and for the connection of local geodynamic networks with the global geocentric coordinate system. All these sites are established in the frames of the international agreements and are included in the global network of the International GPS Service for Geodynamic, three of these stations simultaneously are working in the seismic network IRIS. /36,39,42,18/. Two sites Zwenigorod and Krasnoyarsk with the automatic meteostations are included in the experimental meteorological GPS network for the control of the atmosphere parameters and climate changes.

In the frame of the International experiment IGEX98 (October 1998 - April 1999), which was organized with the goal to combine two satellite navigation systems GPS and GLONASS for the precise positioning, 9 stations has been established along the territory of Russia (Zwenigorod, Mendeleevo, Irkutsk, Khabarovsk, Petropavlowsk, Magadan, Ekaterinburg, Yakutsk, Svetloe). These stations were equipped with the GPS/GLONASS receivers Z-24 and Z-18. All the data were transmitted via INTERNET to the Analysis centers in JPL/Pasadena and in IGN/France for the joint and comparative processing and scientific analysis.

The Pamir-Tien Shan mountain region, which is a part of the Alpen-Himalayan orogen belt, is particularly interesting, as a zone of an ongoing active mountain building, that was started 40-50 millions years ago. Up to now two overlapping GPS networks (in total about 200 points) are established in this region: CAT, managed by the GeoForschungsZentrum (Potsdam) and the network, developed by the expedition of the Institute of High Temperatures of the RAS together with the MIT (USA). Measurements are repeated yearly beginning from 1992 in order to determine the horizontal and vertical motions of the network points and to develop the crustal deformation field of the region. /53,54/.

This network spans about 2/3 broad of the West Tien Shan and will be extended up to China territory in the Xnjiang Province, an area with a substantial seismic activity. An important result for seismic hazard assessment is the determination of extremely rapid strain accumulation across the eastern Issyk Kul basin, where a velocity step of about 7 mm/yr occurs over a distance of less than 20 km. A similar step in velocity in the Ventura basin region of southern California was recognized before the Northridge earthquake. Estimated by the GPS measurements and by earthquakes data the field of deformations of the Central and South-east Asia shows that 75 percents of the north-south shortening between India and Eurasia is absorbed by crustal thickening. Many of the deformational features in Asia, such as strike slip motion on the Altyn Tagh fault, east Kunlun fault, and extension in Baikal rift appear to be more a consequence of the counterclockwise rotation of the south Asia relative to Siberia than of the collision between India and Asia. These investigations of crustal deformations in Asia have already led to the new kinematic model, that predict the spatial and temporal evolution of deformations in the region. Testing and improvement of this model should be continued with the use of GPS technology and satellite geodesy methods.

The features of the measured velocities and deformations in the Black Sea basin is also slightly different from the existing geological model, even though there are not so many geodetic measurements in this area. The first geodetic traverse of 8 fiducial GPS points along the Black sea cost have been installed in 1994-1997 by the joint expeditions of the Russian, German and Ukrainian specialists in the frame of the international projects SELF-1 and SELF-2.

During the last decade an attention of geologists, geophysicists and ecologists was addressed to the studies of the Caspian sea phenomena. On the background of a complexity and ineffectual predictability of the Caspian sea level variations and their correlation with periodic variations of the recent tectonic deformations field of the Central and South Caucasus and with different appearances of the seismic and geodynamic activity, it was shown that understanding of the mechanisms of sea-level changes could be achieved only as a result of a simultaneous analysis of all observable variations of the geophysical and hydrological effects. Some cosmic, planetary factors (solar activity, tides, etc.) should be also taken into account as potential sources of the Caspian sea variations. The precise and prolonged GPS measurements of the recent horizontal and vertical movements in this area and at the sea-level posts will provide with the unique information for the complex studies of the geodynamic and tectonic effects. /17,19,43,44,47/.

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Geodetic VLBI in Russia

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1. Introduction

During the last five years Russian radiotelescopes conducted VLBI observations regularly in accordance with national and international projects. The experiments had both tecnical and scientific aspects. One of the main purpose of activiy was the equipment upgradeing and examination.

2. Projects

There are two geodetic VLBI projects realised in Russia: QUAZAR and RADIOASTRON.

QUAZAR is intended to solve geodetic problems and to determine Earth Rotation Parameters (ERP). Fore VLBI dedicated radiotelescopes (RT20 and RT22) participate in QUAZAR [30]: Symeiz, Svetloye, Zelenchuk and Badary. The QUAZAR Control Center [16] includes data correlation Mark III processor, VAX6340 system for secondary (geodetic) processing of correlated data and integrated into Internet telecommunication system. The program packages CULTECH, AFRA, ERA, and VORIN are used.

RADIOASTRON is intended to solve problems of astrometry, geodesy, geodinamics and space navigation. Five large RT64 and RT70 take part in RADIOASTRON [30,36,62]: Eupatoriya, Puschino, Ussuriysk and Bear Lakes. These radiotelescopes form Russian Deep Space Tracking Network (RDSTN) analogous to DSN. Launching of orbiting RT is planned as a new stage of RADIOASTRON, the mode is called Space VLBI - SVLBI [23.26,62,63]. Russian RT cooperate with RT of other countries [62-64].

3. Hardware

Accuracy of VLBI measurements depends on frequency - temporal synchronisation system. The system of QUAZAR consists of three parts [15]: standard time and frequency base; a set of signal coherent transformation heterodynes; means of receiving - transforming channels phase delays control. Standard base forms 5 MGz standard frequency and connects local oscillators to the State Standard with 20-30 ns error. The base includes transportable H-maser ×1-76 for local oscillators comparison with 10 ns error during 2 days. The synchronisation system ensures subsantimeter VLBI accuracy.

VLBI processor Mark III TISS-1 have been made in the Institute of Applied Astronomy - IAA, Russian Academy of Science [8,47]. It was tested on Eupatoriya and Ussuriysk RTs. All of large RT64 and RT70 have been upgraded [5,6,63]. The following improvements have been done [62,63]. The PCs were mounted to control the RT system.

New multi-frequencies feeds were installed. The panels of mane mirror were adjusted. A new Canadian playback system S2 was tested. Bear Lakes, Ussuriysk and Puschino RTs participated in international projects with DSS43, HartRAO, NOTO, EVN, Parkes, Hobart and Tidbinbilla RTs in 1995-96. The QUAZAR network RTs have been upgraded and Simeiz RT22 was included into CDP project [5,6]. To reach the santimeter accuracy on large antennas it is necessary to take phase delays in signal paths into account [46].

4. Software, data bases

A new package VORIN (Secondary Processing of VLBI observations) have been worked out in IAA [13,35,58]. The package is used to fix the global terrestrial coordinate system, to determine geodetic control points displacements, to fix the celestial coordinate system, to determine ERP and Love numbers. VORIN is a part of QUAZAR software. It uses AFRA data base [4,18,19] as a source of information. AFRA is available by e.m. and contains data on observed (and observable) radiosources and RT used in VLBI observations. A Steel Breeze package and collocation method were used to process the observation results [20,37]. Software of RT control have been developed [10].

5. Terrestrial coordinate system, Earth rotation parameters, Earth crust deformations

Baseline vector coordinates are determined by VLBI. To determine geocentric coordinates of RTs SLR is used. The data of VLBI and SLR are combined in processing. The model NUVEL takes tectonic plates movements into account. Any baseline vector changes in time and it is advisable to analyse vectors differences from one epoch to another. Minimising the vector differences squares sum permits the global terrestrial coordinate system to be fixed and ERP to be determined [2]. This approach helped the systematic rotation on mas level of CDP coordinate system to be detected. The rotation is probably caused by NUVEL parameters errors. It is reasonable to process the results of VLBI and SLR separately to minimise the mathematical correlation of the results.

The IAA VLBI Analysis Service determines the ERP with 0,2 mas errors [44]. IERS uses the results [53]. The Earth crust deformations caused by polar tide have been discovered during IRIS dada analysis [61]. The Love numbers hp=0.65, lp=0.11 agree with theoretical values. The long period 6.40 and 42.67 years polar motions were analysed [32,33]. The baselines lengths change with 1 year period. The longer the base, the larger the amplitude of periodical change [40].

The VLBI observables have random components due to tropospheric delay fluctuations and atomic time scale fluctuations. That is why it is reasonable to determine ERP by collocation method [57]. Fluctuations of radiosources coordinates influence the accuracy of ERP determination [7,54]. Combination of VLBI, SLR and astrometry will reduce errors in ERP [1].

6. Time scale realisation

Main Metrology Center of Time and Frequency State Service unites the efforts of UT realisation and polar motion determination in Russia. VNIIFTRI publishes the data in Bulletin E [3]. A precise time scale can be realised by observing pulsars [31].

7. Atmosphere influence

Regular and stochastic variations in signal tropospheric delay influence the results of VLBI [38]. Regular seasonal variations are associated with wet component of troposphere only. Dry component course regular variations [49]. Results of VLBI observations were used to evaluate zenith tropospheric delay in Westford, Wettzell and GILCREEK [60] Package OCCAM was used for correlation of daily stochastic tropospheric delay variations. The correlation function proved to be stable. This property can be used in stochastic modelling of VLBI observations.

8. Earth satellites and space missions observations

IAA have made and is upgrading SIRIUS complex for VLBI observations of navigation satellites GLONASS and GPS [42,51]. The complex functions on the baseline Svetloye - Pulkovo. A new playback system BARS using control package ANGARA [17] and new heterodyne system [48] have been made. Navigation satellites, geostationar [50] satellites as well as quazars can be observed in real time mode [34]. Spectral analysis of RT correlation response on satellite and space mission signals can raise the accuracy of observations [41,55].

9. Radiotelescope connection to the geodetic network

Any RT is to be tied to the local geodetic network consisting of 3-5 main benchmarks and 5-10 additional benchmarks [21]. The local network is to be connected to the state geodetic network. Terrestrial and satellite methods can be used to do the connections on 1 sm accuracy level [52].

10. Conclusion

The hardware and the software of VLBI in Russia are well developed. Russian scientists have solved a lot of VLBI problems. So VLBI of Russia is an important part of the global VLBI and it is advisable to include Russian Rts into global VLBI network on a regular status.

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Precise gravimetry

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Abstract
Absolute gravity studies made by different organisations during the period 1995-1999 were concentrated mainly on metrological investigations and stationary observations of local gravity changes connected with hydrogeological effects. Two new quartz tide gravimeters for regional studies in Russia have been manufactured in Sternberg Astronomical Institute, one of it has been successfully tested at the ORB, Brussels.

Absolute gravimetry
Status and perspectives of absolute gravity studies in Russia are briefly discussed in **(Kopaev, 1995**). There are four organisations now in Russia that possess and use absolute gravimeters of GABL type - 1) Institute of Authomatics and Electrometry (IAE) of Siberian Branch of RAN (Novosibirsk); 2) Central Research Institute of Geodesy, Cartography and Air Survey (ZNIIGAiK, Moscow); 3) Institute for Physics of the Earth (IPE) of RAN (Moscow) and 4) Siberian Branch of "Engeneering Geodesy" (Novosibirsk) - however, mainly for stationary measurements.
So, almost 20-years long record of absolute gravity variations and underground water level variations has been obtained using GABL and GABL-M devices in Novosibirsk for the period 1979-1996. Long period as well as seasonal changes in gravity are well correlated with hydrogeological effects, whereas the reason for short-term gravity variations is not fully clear at the moment (**Arnautov, Kalish, Stus**, **1996)**.
Similar studies are being carried out in Moscow (Bezboshny fundamental gravity station) using different GBL absolute gravimeters of ZNIIGAiK. The 10-years long series of absolute gravity (starting from 1989) has been obtained, absolute gravity correlate with hydrogeological effects but the data are still not published unfortunately.
Absolute gravity studies in Institute for Physics of the Earth are mainly concentrated on important metrological studies with special emphasize on seismic disturbancies. Absolute gravity value precision of 2-3 mcGal under quiet conditions during the night time is obtained (**Boyarskii, Afanasyeva et al**, **1998).** Monochromatic components with frequencies of 36, 49, 56 and 86 Hz have been obtained from spectral analysis of residual after parabolic fitting of absolute gravity data for each drop using 480 levels **(Fomin, Afanasyeva et al, 1997).** Its origin is discussed as well as the techniques for its taking into account during detailed data processing.
Further aim of this studies is to search for possible global gravity variations due to the global geodynamical processes like inner core motions etc, so, simultaneous stationary investigations using similar GABL-M devices of IPE and IAE in Moscow and Novosibirsk are planned, interesting tests are described in (**Avsyuk, Arnautov et al**, **1997**).
First results of absolute gravity measurements with GBL device belonging to Siberian Branch of "Engineering Geodesy" are reported in (**Chistoedov, 1996)**, its repeatability is better than 10 mcGal.

Relative gravimetry and gravity gradiometry

Various questions connected with application of relative gravimetry at oil and gas fields are reflected in (**Volgina**, **1997**). Its helpfullness for control during oil and gas prospecting and further exploitation is stressed.

Systematic errors of usual tripod measuements of vertical gravity gradients give a precison of about 3-5 mcGal for single relative gravimeter, that leads to necessity of using a large amount of gravimeters simultaneously to determine reliable values of vertical gravity gradient, as follows from detailed data analysis obtained during relative gravity observations within the framework of the Fourth Intercomparison of absolute gravimeters at BIPM, Sevres, 1994 (**Kopaev , Vitushkin, Vitushkin, 1996**). A new model approach has been developed based on approximation of local gravity field above single pillar using a set of appropriate harmonic functions. The application of least squares method for unknown coefficients determination permit to use different data (gravity differences as well as gravity gradients) and optimal planning techniques. This techniques has been tested in underground laboratory of Russian Research Institute of Metrology using Sodin gravimeters and torsion balance GRBM equipped with digital registration system based on CCD scales. Special oftware has been developed for data processing, first results demonstrate that gravity differences determination errors are less than 1 mcGal in the space volume above the pillars **(Kopaev, Yushkin, 1996).**

Various applications of vertical gravity gradient determined by relative gravimeters for geology and seismology are described in (**Antonov, Slyusarev**, **1996**).

New concept and design of autooscillational gravity torsion balance has been suggested and tested in (**Astrelin, Zubietov et al**, **1996**). Authors claim the accuracy of 1 E.U., possibilities of its improving up to 0.1 E.U. and possible applications in seismology, geodynamics and oil prospecting are discussed.

A new idea in torsion balance data processing called "intersection points" is described in **(Mokin, 1996**) that is able to reduce the full observation cicle(four azimuths) from 3-4 hours up to 20-30 min at single station.

Tide gravimetry

Quartz tide gravimeter DELTA-1/Sodin-209 equipped with digital CCD registration system and build-in absolute calibration device based on tilt method has been developed and manufactured in Sternberg Astronomical Institute of Moscow State University **(Kopaev, Yushkin, 1995**). It has been succesfully tested in 1996 at the ORB, Brussels where 110 days of record gave δ–factors and phase lags for O_1 and M_2 that agree with reference values within the error bars of 0.4 % resp. 0.2^o (**Kopaev, Yushkin, Ducarme, 1997).** Later on, in 1997 this device has been used to check the famous hypothesis concerning the correlation between the tide gravity anomalies and heat flow in tectonically active region of Central Caucasus. Tide gravity observations have been carried out at the Baksan station located 15 km apart from sleeping volcano Mt. Elbrus. 2 months of gravity data with taking into account for atmospheric pressure variations give δ-factors for M_2 and O_1 that agree with model values (Wahr-Dehant 'plus' Schwiderski) within the error bars of 0.3 % resp. 0.6 % (**Kopaev, Yushkin, 1999**). Second device of similar type called DELTA-2/Sodin-212 has been completed recently, its tests in Moscow show an extremely small and stable drift less than 1 mcGal/day.

Results of tide gravity measurements in Novosibirsk during 1991-1996 with Askania GS-11 #186 are presented in **Saritcheva et al, 1998),** there are no dicrepancies with Wahr-Dehant model at semidiurnal frequencies (M_2 wave) at the relative accuracy level of 0.5 %**.**

Detailed analysis of the influence of atmospheric pressure variations on tide gravity measurements has been carried out in (**Gridnev, Pertsev, Kovaleva**, **1997**). No dependance on the regional topography (mountainous area, flate land, sea-cost area) has been found.

Analysis of the world highest quality tide gravity data from ICET Data Bank shows a linear trend of $\delta(O_1)$ and $\delta(M_2)$ in Euro-Asia, whereas mean values fit the version of Dehant model with anelastic mantle and frequency dependant $Q=\omega^{0.2}$ that fits also the results obtained from space geodetic observations. This anomalies (suspected also for other continents) seem to be correlated with the Core-Mantle Boundary topography and, possibly, lateral viscosity anomalies **(Kopaev, Kuznetsov, 1997**).

Direct modelling of the tidal δ-factors and phase lag anomalies has been carried out for M_2, O_1 and M_f waves using the approach of S.Molodenski (1980), maps of isoanomals are obtained. Resulting lateral anomalies of δ-factors are less than 0.1 % and correlate with anomalies of high quality tidal gravity data selected from ICET Data Bank, although the latter ones are one order larger in magnitude. It may raise a question about the applicability of mantle elastic parameters deduced from seismic data to tidal frequencies and/or on possible influence of lateral viscosity anomalies. There is no correlation between the highest quality tidal gravity data and heat flow in continental areas of Euro-Asia, however the correlation with heat flow is significant for coastal stations in region with thick astenosphere (Japan) **(Kopaev, 1999)**.

A detailed analysis of all the available tide gravity data in Russia obtained during 1960s-1990s has been carried out in **(Kopaev, 1995)** with main conclusion that russian tide gravity network suffers from both bad territory coverage and low quality of data obtained with old Askania devices only.

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Sea, Inertial And Air Gravimetry

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Introduction

During the period of 1994-1998 in Russia the works proceeded in the field of sea gravimetry, including a wide spectrum of measurements of gravity on the mobile basis, theoretical development, creation, designing and improvement of the equipment, methodical preparation and metrological certification of devices, development of a technique of processing of results of measurements both skilled and industrial measurements.

Instumental studies

At the Moscow university the researches on measurements of gravity in movement, and, in particular, on inertial gravimetry have been carried out. The tasks of inertial gravimetry are considered, the variants of the basic equation are offered.

In area of air gravimetry the technique of processing of observations is developed allowing to exclude errors connected to dynamic features of device. Is shown, that the accuracy of 1 mGal at speed of flight 360 kms / hours is possible to get at time constant not exceeding 50 seconds. The method of numerical modeling is applied for research of efficiency of the numerical spectral analysis of numbers of observations. Is shown, that the accuracy of variations of gravity first of all depends on accuracy of measurement of height.

The multichannel system of data processing is considered at measurement of gravity on the mobile basis based on Viner procedure. Entrance, target and "desirable" signals are given in the spectral form; each of signals is a vector, which components are made of the indications of altimeter and gravimeter. On a numerical example the errors are shown at speeds 180, 360 and 1000 kms / hours, the heights of flight were set equal 2-10 kms. Is shown, for example, that the accuracy 1 mGal at speed at 360 kms / hours at height of 2 kms is achieved, if the accuracy of altimeter is better than 0.3 m.

The task of filtration of gravity in real time by the plane under condition of compensation of influence of variations of height is investigated. For an entrance signal the sum of variations of gravity and noise caused error of measurement of height is accepted.. Is shown, that the accuracy of measurements at the best achieves 2-5 mGal.

At the Inertial technological research centre (ITC) of the Bauman Moscow technological university together with University of Calgary (Canada) is developed air gravity system IÒÑ-2 with the precision vertical channel of registration it is executed on the basis of precision inertial plane platform of system.
The problem of air gravity measurements measurements is solved by a combination IÒÑ-2 with a differential method GPS. A series of flights for test of system IÒÑ-2 is executed above Calgary (Canada) in March - November 1994ã. The results show, that with IÒÑ-2 the accuracy 1 mGal for 1 minute can be received.
In 1960-1980-õ years Russia within the framework of the state program " World Gravity Survey "carried out measurements of gravity in various areas of World ocean. However owing to privacy the majority of these materials remains unknown for the researchers. In the near future works of such scope in Russia (and anywhere abroad) will not possibly be because of their high cost.
Russia is one of the most "rich" states in sense sea gravity the information. Therefore scientific and practical importance of the data is urgent now and will acquire and further. Besides the profound interpretation of the large file of the complex geophysical information received in result, will bring a lot of new about geology of oceans bottom.
At the Moscow university the review of gravimetric researches in Antarctic Region for last 50 years is executed. Their role in study of a structure of Southern ocean and Antarctic Continent is shown: definition of thickness terrestrial crust, construction of the geoid form of southern polar area, definition of thickness of ice, , study of tectonics and history of development of the sixth continent of the Earth.
In 'VNIIgeofizika institute' (Moscow) is developed gravity complex "Flagman" on the basis of strongly damped quartz sensitive system with the automatic compensatory measuring device. Itt is characterized by sensitivity 0,005 mGal, stable drift (0,1-0,2 mGal/day), digital registration. The complex has passed tests in Barentz and Kara seas at prospecting works on petroleum and gas. The accuracy is from 0,08 up to 0,15 mGal.
In Tula University the project on development of the theory, principles of construction and technique of designing graviinertial complex for measurement of gravity in movement with precision of some tenth mGal is carried out. The device is created on the basis of system of stabilization of new generation. It is intended for search f oil and gas structures (especially on a shelf), geodynamic researches. The theory is developed, the perspective circuit of a complex is carried out for modeling separate modes of operations.
In "NIPIokean geofizika" Institute the quartz systems of a sensitive element for sea gravimeter are made. The definitions of their transitive characteristics allow confidently to choose pairs gravity meters with the purpose of exception cross-coupling effect at sea measurements. The modeling enables on measured data to restore an initial signal on an input. The girostabilized "GRIN" platform is developed also.
In result is created gravity complex "GRIN", working in sea and plane variants. The joint operation of complexes "TCHETA-AGG", "GRIN", "FLAGMAN", "TCHEKAN", GMN-K " LCR" has shown advantages of a "GRIN" complex and its advantage before others. At accelerations more than 50 Gal steadily continued to work only complexes " GRIN " and " TCHETA-AGG".
Comparisons of results of measurements with these complexes has given a divergence of 0,12 mGal.
In TSNII "Electrodevice" (St.-Petersburg) is developed sea gravity complex "SKALOCHNIK". It consists of a complex of relative pendulum devices and computer complex. The satellite navigating equipment providing coordinates is based on GLONASS and GPS system. The sea tests have shown, that in conditions of ocean the error of measurements of gravity does not exceed 0,5 mGal.
The errors of measurement of gravity with sea gravity meter, caused by vibrations of the carrier (ship, plane), are of 0,2-0,3 mGal at excitement of the sea up to 7-9 balls. However the strong damping smooths a useful signal, the reduction of smoothing is achieved by means of filters takin into account damping properties at processing a target signal.
The researches have shown, that the level of errors of the gravity meter complex "TCHEKAN" allows at speed of a vessel 15 kms / hours to reveal gravitational anomalies by extent less than 1 km with amplitude up to 0,1 mGal. By the plane at speed 200 kms / hours with an error less than 1 mGal can be fixed anomalies by extent of 5 kms.
The researches of "Electrodevice" have shown a basic opportunity of creation of satellite gravitational gradiometer on the basis of the cryogenic circuits and technologies.
In "VNIIokeanologia" Institute are carried out theoretical, methodical and experimental researches on increase of accuracy and resolution of sea measurements of gravity. In 1994-1995ãã the analysis of errors of sea gravity meters GMN-K, connected with influence horizontal and vertical accelerations of the basis is executed. The tests on stands, and also on a vessel in sea conditions were carried out at excitement of the sea up to 9 balls.

Gravity mapping of World Ocean, Arctic Region and Antarctic Region

On the basis of executed earlier, and also modern gravity measurements in Southern ocean and Antarctic Region and Atlantic and South Oceans at the Moscow university are made new gravity maps of Antarctic Continent and adjacent seas. The maps of anomalies in free air, Bouguer, isostatic, and also geoid heights are made.

More detailed complex geophysical researches are executed on geotraverses crossing transitive zones from the Asian continent to Pacific ocean, on Angolo-Brazilian geotravers, other ocean ranges in rifts, underwater mountains.

Geological-geophysical interpretation of sea gravity data

By results of complex interpretation of gravity and other ãåîëîãî-geophysical data the parameters of density model tectonospere of South-Brazilian geotravers are specified more detailed. The minimal thicknessof litosphere is marked under axial areas of mid atlantic ridges (15-20 kms), to flanks it is increased up to 60 kms. In areas of deep-water bottoms the thicknessof litosphere makes more than 80 kms.

The complex interpretation of the gravity data in area of Canaro-Bahama geotravers, in a zone Mid-Atlantic ridge between breaks Cane and Atlantis, and also detailed surveys in zones of crossing transform faults is carried out. All initial data are interpreted on trapezes: 5 õ 5 kms and 2,5 õ 2,5 kms. Density modeling is carried out with use of residual mantle Bouguer anomalies.

The complex analysis of results detailed gravity and magnetic researches executed of joint Russian-Italian expeditions in 1994 and 1996 in area of triple a point junctionof Antarctic, South-American and African litosphere plates (Bouvet point) is executed. The results of the analysis have allowed to allocate sites of neo-volcanic zones, distribution of the youngest oceanic crust, to identify magnetic anomalies, and on this basis to construct model of oceanic crust spreading.

The researches of isostasy and deep structure of Antarctic Continent are executed. 2 variants of isostatic model of Antarctic Continent differing by the mechanism of indemnification of ice loading are constructed. The maps of isostatic anomalies are constructed and depths of a Moho surface for both variants of model. Gravity and the aeromagnetic data in Barentz and Kara seas were generalized and interprted within the framework of the joint project between collectives " Exxon Exploration C. " (USA) and "VNIIokeangeologia" Institute.

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GEOID AND MODELS OF THE EARTH'S GRAVITY FIELD

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The development of the Earth gravitation field model (EGF) GAO-98 of ZNIIGAiK is finished. The source data for it model was prepared in cooperation with Geophysical Center of Russian Academy of Sciences.The detailability level of this model corresponds to the gravity anomaly expansion into spherical harmonics up to 360^{th} - degree. [1].

As in ZNIIGAiK the attention has been mainly paid to the problems of precise determination of gravity parameters on the Earth's surface, the condition (correlat) adjustment method has been found to be more effective because it allows to reduce detail gravity and satellite altimetry data to a single level of global parameters and to considerably diminish thus the effect of systematic errors of these data on the accuracy of quasigeoidal heights determination.

Source data. The bulk of source sea gravity and altimetry data used for this model has considerably increased in comparison with former ZNIIGAiK global models with the detailability of 180 degree. The source data was prepared in cooperation with Geophysical Center of Russian Academy of Sciences.

While for the preceding ZNIIGAiK model (GAO-95), sea gravity data base ZNIIGAiK (ZKMGD) and SEASAT and GEOSAT altimetry data have been mainly used, for the models. GAO-97 and 98, sea gravity database GEODAS (about 1200 survey routes), gravity anomalies averaged for 30'*30' - blocks for the territory of foreign countries taken from terrestrial and arrial gravity surveys and used in the model EGM-96 (USA), as well as considerably greater bulk of altimetry data have been additionally used.

In the model GAO-98, gravity anomalies for 15'*15' -blocks on the territory of Europe processed under leadership of R. Forsberg and U. Schafer as part of cooperative work within the project INTAS-93 -1779-ext, have been additionally used.

Besides, an analysis of altimetry and sea gravity data in the model GAO-98 has been carried out. About 20% of GEODAS data have been rejected because of inadmissible amounts of random and systematic errors. The main obstacle for further improvement of accuracy of the gravity models remains the lock of gravity data for some non-or insufficiently gravimetrically explored areas of land and sea. To these hard accessible areas, in which gravity measurements by traditional techniques are difficult, belong, first of all, high mountain regions of South America and Central Asia as well as continental and coastal Antarctic areas.

Three types of information have used for development of GAO-98 model:

- gravity data from areal and route gravity surveys on land and in the World ocean;
- altimetry data in form of gravity anomalies for 3'*3' and 30'*30' -blocks computed from GEOSAT (geodetic mission) and ERS-1 altimetry;
- satellite orbital data in form of coefficient set up to 60^{th} degree of purely satellite EGF models derived from satellite orbit perturbation analysis.

The choice of such a high degree of EGF model resolution as 360 made it necessary to use as source data mean gravity anomalies for 30'*30' - blocks. Gravity anomalies are calculated with the free-air reduction in respect to the international normal gravity formula 1980 and reduced to the gravimetric system IGSN-71.

The source data preparation for the GAO-98 model is characterized by a great bulk of information as will as by complicated and labor consuming processing including analysis, checking, accuracy estimation, and rejection of inadequate data, especially for foreign gravity measurements in the World Ocean.

Addjustment technigue. Unlike the widely used parametric adjustment technique which is optimal for determination of only EGF model parameters that approximate in the best way measurement data, the condition adjustment technique traditionally used in ZNIIGAiK for model parameter determination turns out to be more effective for resolution of geodetic problems for which mutual concordance of gravimetric and satellite altimetry data and corrections to measurements due to measuring errors are of importance.

As gravity measurements (especially maritime ones) and altimetry are prone to systematic errors small of amount but spread over considerable areas, such a concordance of global parameters allows a significant diminishing of the effect of systematic errors on the determination of gravity field parameters, first of all, quasigeoidal heights. Now days, it is especially important due to a wide introduction of GPS/GLONASS measurements into routine (productional) geodetic operation. The combined adjustment of gravity and satellite orbital data results in a set of corrections to the initial gravity values. Presentation of the parameters in form of corrections to the initial gravity anomaly values allows to detect and reject the systematic errors of individual gravity surveys and to get information on eventual incompatibility of weights in the combined adjustment of heterogeneous information.

The accuracy of absolute quasigeoidal heights by use of the model developed is for most regions of Russia $M_\xi = \pm 20$-25 cm, and that for relative heights at the distance of $m_{\Delta\varepsilon} = \pm 3$-4 cm. These data of apriori accuracy estimation are confirmed by the results of precise GPS-measurements along the traverse Moscow-Sankt Petersbyrg on a high-precision leveling line. [1].

Nepoklonov et al. has developed high accuracy geoid models creating and application method for russian territory. The influence of different factors on accuracy of interpolation quasigeoid height for regular grid was studied.[2].

Nepoklonov, Chugunov, Yakovenko and Orlov confirmed possibility of difference satellite coordinate determinations and local quasigeoid models for expansion of height system from source leveling datum. [3].

The method of deflection vertical digital maps creating with gravimetric data using was improved. Accuracy of deflection vertical determinations for Russia is 0,5" approximately. [4].

Nepoklonov and Orlov suggested new solution for preparation of mean gravity anomalies from gravimetric survey data. [5].

The detailed gravity quasigeoid height model for Moscow region was obtained. The accuracy of difference height determinations from comparison with GPS data for 19 sites was obtained about 2cm for 10 km distance. It research is start point for creating of quasigeoid model for Russia territory with 5'x5' resolution. The conclusion this work about end of 1999. [6].

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Rotation of the Earth

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Introduction

Studies concerning pecularities of the Earth Rotation have been intensively continued in Russia during 1995-1998.
The contemporary accuracy and expedience level of determining Earth rotation parameters requires a more sophisticated theory of the rotation of the Earth by elimination of a number of simplifications and a more detailed study of such fine effects as the excitation mechanism for the Chandler motion of the pole. Presently many investigations are based on the dynamic theory of Earth rotation relative to the mass center combined with the linear movement of the Earth as a whole with the velocity of the mass center. Markov Yu.G. et al.[1, 2] present a new model of orbital evolution of a planet (solid core and elastic envelope) caused by internal dissipating forces (thermodynamic processes are not considered) while the planet performs an orbital-rotational motion. The investigation method is a synthesis of model analysis and the small parameter method. Presented are precise equations of orbital-rotational motion for the problem “a deforming planet-satellite in the field of an attracting center”. As an example are considered rotational parameters of a deforming Earth in the gravitational fields of the Sun and the Moon.
It is shown that in such a moving system appears a trend to commensurate angular velocities of rotational and orbital motions as a result of tidal evolution.

1. The Earth and the Moon represent a close binary dynamic system its motion parameters being substantially influenced by external forces. In [3] Rykhlova et al. proposed that these forces might generate non-linear oscillations influencing proper frequencies of the oscillating bodies of the Earth-Moon system. In case of a resonance an intensification of several usually imperceptible harmonics can occur. A numerical simulation of polar coordinates data from 1962 to 1992 (using a determinate exponential model) revealed two basic periodic oscillations with periods P_1=408 ± 5 days and P_2 = 82 ± 5 days. The first oscillation is approximating the free oscillation of the Earth, the second has a frequency representing one third of the Moons orbital motions frequency.
The mathematical description of the first oscillation shows a complicated evolutionary modification of amplitude and period. The component of the exponential model with a period P=434 ± 2 days appears in high-degrees models (model degree exceeding 86).
The search for correlation between polar coordinates and other geophysical and heliophysical processes was continued. The same authors analyzed thoroughly in [4] data concerning solar spots, polar coordinates, variations of day-length, integral seismic energy, and the index of southern oscillation for the period from 1900 to1989. It was shown that there exist common variations with a period of 10.4±0.3 years and also a possibility to synchronize these variations in geophysical and heliophysical processes.
A comparison of two different series of polar coordinates data (in the CIO system and in the HIPPARCOS system) for low frequencies (less than the frequency of Chandler oscillation) revealed variations with periods of 6.4 and 42.67 years. The study of six-year oscillations evolution in phase-space (Poincare reflection) suggests a quasi-periodic character of these oscillations and their relation with variations having a 42.67 years period.[5]
A most thoroughly study of polar motion was performed in [6]. Two methods were applied: analysis of the spectral power density function and the Poincare method. Using the first an identification of the quasi-periodic regime with two basic frequencies, f_1 and f_2 in the investigated time interval, from 1990 to1998 was carried out. The presence of combined frequencies in the spectrum and a widening of the pikes is similar to the quasi-periodic regime leading to chaos. According to the Poincare method a structure is formed in the phase-plane that is similar to the trajectory of a particle moving in a pair of potential pits under influence of external forces. This analogy points to the existence of a complicated evolutionary regime having a dynamics that include besides damping effects also mechanisms for maintaining the motion. Periodic external action leads to a widening of the spectrum in the domain of low frequencies.

2. Zharov V.E. (Sternberg Institute, Moscow University) was the first to show that the periods of most harmonics in the Earth rotation velocity spectrum are similar to periods of free oscillations of the atmosphere. The latter are caused by latitudinal temperature differences generating vortex motions [7, 8, 9]. The characteristic values of atmospheric free oscillations periods are about one day and one year.
On frequencies from about 0.01 to 0.1 days it is the atmospheric turbulence that mostly influences the Earth rotation.
The maximal variation in Earth rotation has a one-day period with amplitude about one microsecond.
The influence of atmospheric tides on polar motion is insignificant (substantially below the present measurement accuracy). But the IAU-corrections to the amplitudes of nutation harmonics and to the precession velocity are significant [10] The largest correction has been determined for the value of retrograde annual nutation.

3. Tidal effects of the Earth rotation evolution. As mentioned above at present there exist no theory able to describe copletely the observed characteristics of Earth rotation and Polar motion. This is partly due to the fact that the description of tidal effects is based on the classic scheme of Laplace and accordingly on the two-bodies problem by Kepler. In reality the motion of the structural inhomogenic Earth is influenced by the Sun, the Moon and other planets, so that the Laplace approach should be considered only as a zero-approximations (the tidal force being assumed to be a sum of pair-interactions, the rotational and translational moverments of the deformed bodies, in a system line Earth-Moon are described independently, and tidal effects are considered by introducing additional hypotheses).
The studies of tidal effects of the Earth rotation evolution for a basic model system (Sun-Earth-Moon) have been applied to tidal effects for a N-body system (Sun-Earth-Moon-Planets).
Considering the influence of N external bodies on the Earth motion disturbances in a non-inertial coordinate system, the author obtained a non-contradictory interpretation of astrometrical observations of the polar motions [11-14].
The results obtained are based on a quite new approach and allow to avoid several shortages of the present theory.
Most important results obtained are:
it is shown that the model of free nutation is implacable to explain latitude variations; and that the Chandler periodicity has an equivalent in tidal force variations and should not be considered as exclusive;
a new expression is derived for the tidal potential for the N-body system;
an analytical expression is proposed for the resulting tidal force acting on the internal core of the Earth (in the frame of the forced nutation model and the Sun-Earth-Moon system);
an universal method for calculation of the perturbation function is proposed that let to solve the problem of the Solar System large planet motion in the analytical theory;
displacement values less than one decimeter caused by tidal evolution of the Sun-Earth-Moon system are determined for the internal core of the Earth and for the origin of the mobile coordinate system;
it is shown that considering the present accuracy of angular coordinates determination the classic precession and nutation theory is not requiring angular corrections for the displacement of the internal core.

4. A series of papers by N.S. Sidorenkov is devoted to oscillations of the atmosphere-ocean-earth system. He was able to show that the spectrum of the El-Nino southern oscillations (implicating mechanical and termic oscillations of the tropical atmosphere and the ocean on a planetary level) with a period 2 to 10 years contain also components multiples of the Chandler period (1.2 years).
Presently investigations are carried out to construct oscillation models of the atmosphere-ocean-earth system that could predict the phase and the appearance of the El-Nino oscillations.

5. Finally, in the Institute of Applied Astronomy (St-Petersburg) parameters of the Earth rotation are determined efficiently from the satellite LAGEOS laser ranging data of the global IERS network. Dayly to the operating center of IERS are forvarded values of X_p, Y_p, LOD, UT.
Also weekly performed solutions of parameters X_p, Y_p, dP_{sci}, dE_{ps} using data of global VLBI are forwarded to IERS. The solution of VLBI measurements for the period from 1993 to 1999 is included in the yearly report of IERS.
At the Institute for Astronomy (Moscow) a yearly solution for X_p, Y_p, LOD on laser ranging data of the LAGEOS satellite and observing station coordinates has been obtained for the period from 1995 to 1997.

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Tides and nutation of the Earth

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Introduction

The improvement of the modern VLBI-and gravimetric tidal measurements accuracy requires an adequate improvement of the Earth's tides and nutation theory. Few years ago the accuracy of the principal tidal waves measurements was of the order of 0.1-0.2% and the accuracy of astrometric measurements (in the optical range) was about 30 milliseconds of arc; the internal consistency of the same values measurements by using of superconducting gravimeters is of the order of 10^{-3} %;. the accuracy of the modern nutational amplitudes VLBI-measurements is about 20 microseconds of arc.

The comparison of the modern VLBI- measurements data and the data of modern gravimetric tidal measurements results in some contradictions; it seems, its analysis is one of the most important problem of the modern theory of the Earth tides and nutation. In particular, (1) it is necessary to explain the large difference of the free core nutation quality factor Q which is estimated by using of VLBI- and tidal measurements; (2) to find the possible limits of the lower mantle quality factors, of the liquid core viscosity, and of electrically-magnetic coupling between liquid core and elastic mantle; (3) to get an exact estimation of the core-mantle boundary flattening, and (4) to construct the models of the Earth tides which are in the best agreement with the modern VLBI- and tidal data

To solve these problems, in 1995-1998 the following investigations were performed by us.

1. As is known, up to most recent time, the theory of the Earth's tides and nutation was considered on the ground of Wahr's theory (J. Wahr, 1981), where the equations of the liquid core diurnal oscillations were integrated by means of the expansions of the displacements field into the series of toroidal and spheroidal vectorial harmonics with the reduction of the higher harmonics. As it was pointed out earlier., (see, for example, Smith, 1974), in such an approach, the process of the infnite systems of ordinary differential equations truncation and the replacement of the infinite system by the finite one results in some errors; their estimation is connected with the great difficulties. The main difficulty is that the boundary problem under consideration belongs to the class of ill-posed (in Hadamard's sense) of hyperbolic boundary problems with only one boundary condition which is given on the closed core-mantle boundary, and that this problem does not contain any small parameters. To get its solution, in (Molodensky, Sasao, 1995, a,b; S. Molodensky, E. Groten, 1996, 1998) a new approach was used which is based on the expansion of the solutions in series of the small parameter powers; this parameter is equal to the ratio of the nutational angular frequency in space to the angular frequency of the Earth diurnal rotation. Using this approach, the numerical integration of the problem under consideration was performed, and the real accuracy of the results was estimated. It was shown, that the errors of our numerical results are very small in comparison of the errors of modern VLBI-measurements.

2. Up to most recent time, in the theory of the Earth's nutation, the effects of the thermal tides were not taken into account. In (Molodensky, Groten, 1997 the theory and numerical calculations of the problem of global nearly diurnal atmospheric oscillations were constructed. Numerical calculations of the effects of atmospheric thermal tides on the Earth's rotation shows, that the observed prograde out-of-phase nutational component may be totally explained by the atmospheric effects. At the same time, the retrograde out-of-phase annual component is not explained by atmospheric effects, and its geophysical interpretation needs consideration of the Earth's model with the anelastic mantle and with the viscous liquid core. The Earth's model with an anelastic mantle, viscous liquid core, with the atmosphere and ocean was constructed which is in the best agreement with the modern VLBI-data of

the Earth's nutational amplitudes. Taking into account, that values of the liquid core flattening and parameters of the mantle quality are not sufficiently learned up to now, these parameters were fitted with the help of the condition that the discrepancies between theoretical and observed nutational amplitudes are minimal. As was shown in (Molodensky, 1999), in the nearly diurnal range of the periods the optimal values of the quality factors of the mantle are situated between their values for the periods of the Earth's free oscillations (about one hour and shorter) and for the Chandler's period (about 14 months).

For this model, the effects of the liquid core resonance in the range of the nearly-diurnal periods were calculated. The comparison of theoretical and observed values of Love numbers and gravimetric factors was performed both for the modern data which were obtained with the help of superconducting gravimeter in Bruxelles in 1974-1998 and for the data which were obtained by Askania gravimeter.

10-year series of observations in Talgar were analysed with the aim to get more exact form of the dependence of Love numbers upon the frequency. After the comparison of theoretical and observed values of Love numbers in the diurnal range of periods, very good agreement between theoretical and observed data was obtained (most significant deviation between theoretical and observed values was obtained for the minor wave ψ_1 which is situated in the vicinities of the nearly-diurnal resonance; nevertheless, this deviation is about 0.5 % of the amplitude of this wave only).

To get more exact estimation of the effects of the ocean tides, in (Pertzev, 1997a,b) the modern cotidal charts FES95.2 and CSR3 were used.

For these charts the tidal oscillations of the plumb-line in space and tidal isplacements of the Earth' center of mass (which are caused by the tidal redistribution of the masses in the ocean) were calculated. It was shown, that for the principal tidal components these displacements are of the order of 1.5 cm. This value exceeds significantly the errors of the modern satellite altimetric measurements, and, consequently, it should be taken into account in the analysis of these data.

The theory of nutation of the axially symmetrical planet was generalized for the case of the planet with the tri-axial inertia ellipsoid. The results were applied for the several Mars' models with the different values of the liquid core moments of inertia, and for the different distribution of the seismic velocities in the mantle. As was shown in (Groten, Molodensky, Zharkov, 1996), the accuracy of the measurements of the Mars forced nutation (which is proposed in NASA program) is sufficient to get a solution of the problem about existence or absence of the Mars' liquid core and to get a reliable estimations of its moments of inertia.

In the field of the improvement of the tidal equipment, the analysis of the main errors of the tidal measurements was performed. The new tidal short-base deformometer and new z-magnitometer were constructed which contain an improved system of the calibration.

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Application of GPS technology for regional geodynamical studies

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Abstract

The paper describe the investigation in GPS regional geodynamics carried out by different russian institutions mainly on joint projects with foreign teams.The main propose of researches was to obtain the data for deformometric field of tectonicaly active regions. The joint projects are dealing with some regions, important and interesting from geological-geophysical point of view Among them: Caucasus and Tien-Shan regions were the tectonic setting by interaction of Eurasian, Arabian and Indian plates almost are determined; Baical rifting zone - unic and enigmatic from point of view of origin and development, region of Eurasian continent; Kamchatka - Sakhalin subduction zone, most seismicaly active region were reveals very complicated interaction of Eurasia, North American and Pacific

litospheric plates together with Okhotsk and Amurian and minor plates. Some results of GPS study the postseismic deformations Racha (1991, M 7.2) and Neftegorsk (1995, M 7.0) earthquake are given and development of concept for using the GPS networks for earthquake prediction also is discribed in the report.

Introduction

The use of GPS technology in the regional geodynamics study on the territories of former Soviet Union begun in the frame of "Agreement between Soviet Union and United States on Cooperation in the Field of Enviromental Protection (Area IX - Earthquake Prediction). First Epoch of GPS measurements were carried out at Caucasus after Racha earthquake (1991) and in 1992 at Tien Shan [Prilepin et.al, 1997, Relinger 1997, Abdrakhmatov 1996]. In this project russian, american, georgian and armenian institutions were involved. Approximately at the same tame in Caucasus and Tien-Shan german institutions (ZPI and IFAG) begin to work on GPS projects with russian and local institutions [Michel, 1998]. From 1995 started many cooperation projects at Kamchatka, Sakhalin, Baikal, and another regions of Russia, in which involved more then 30 institutions. Due to short period of GPS measurements in projects have begun in 1995 the results need to be treated as preliminary.

Russian organizations engaged in GPS regional projects are: Institute of Applied Geophysics (RAS) Russian Academy of Sciences (Vladivostok), Institute of Applied Astronomy (Sant Petersburg), Main Astronomical Observatory (Pulkovo, Sanct Petersburg), Institute of Astronomy RAS (Moscow), Institute of High Temperatures RAS (Electromagnetic Field Expedition - Bishkek), North Caucasus Geological Expedition (Essentuki), Moscow University of Geodesy and Cartography (Moscow), Institute of Marine Geology and Geophysics RAS (Yuzhno-Sakhalinsk), Institute of Tectonics and Geophysics RAS (Khabarovsk), United Institute of Physics of the Earth (Moscow), Moscow State University (Shtenberg's Institute, Moscow), Institute of Volcanology RAS (Petropavlovsk-Kamchatskiy). In regional GPS projects receivers are used most offen the TRIMBLE 4000 SSE,I,Ashtech Z-12, the duration of observation usualy no less than 3 days (10-24 hours per day) for field sites and 24 hours per day duiring the whole compaign for feducial sites. Sample rate is 30s, cut of angle 10 - 15^b. For processing the data most often are used GAMIT/GLOBK, BERNISS and GIPSY software packages are used. As a coordinate reference system the ITRF is used in all projects. Usualy the parameters of GPS satellite orbits are derived from IGS data, but in some cases additionaly also used the monthly averages global solutions performed by Scripps Orbit Center [Bock et.al, 1997]. In those regions were there are at least 3 epoches of GPS measurements during 5-6 years the RMS of displasement vectors can be evaluated as ± 1-1,5 mm/j (1 d).

The Caucasus Region

Accordingly of the geological evidences the recent structure of Caucasus Mountain System was formed mainly by collision of Arabian and Eurasion global tectonic plates. The interaction of the plates is belived to have begun in the Middle Pleocene and is continuing now [Burtman, 1990; Khain et.al, 1995].

The study of regional geodinamics using GPS technology starts in Caucasus region in summer of 1991 after strongest earthquake in Georgia (Racha 29.04.91 M 7.2) as joint project of Russian, American, Georgian and Armenian Institutions.

The main task of research - the study of postseismic deformation and the estimation of horisontal and vertical rates of deformation in the regions of Greter and Lesser Caucasus. This data would play the important role for seismic zonning.

In this first investigations were developed two kinds of GPS network:

local network covered of the epicentral area of Racha earthquake. The network include 5 sites with the distances 15-30 km between points;

regional - romb sharped network covered the main geological provinces of Caucasus. The large diagonal of the romb ~ 500 km connected the sites situated on Skifts platform (north) and Armenian plateau (south). The small diagonal (~200 km) connects Rioni and Khura bassins. In 1994 the observations on both this networks were repeated and a few new stations were established. Then the repetition of observations and enlargement of the networks continued in 1996 and 1998 years. Now the Caucasian network include more than 20 sites.

The results of GPS investigations carried out at Caucasus during 1991-98 shows that the deformation field, as a whole, reflects the collision feature of the region. The south part of Caucasus, Armenian plateau the Lesser Caucasus and the regions to south slope of Greater Caucasus, have the vectors of sites movements with stable NNE direction. Their magnitude change gradually from 14-12 mm/y to 8-6 mm/y. The vectors of the sites, located at North Caucasus have the amplitudes 4-6mm/y but with significant changing of the directions from NNE to NNW. One can interpret the situation as if the collision potention is exhausted on the south part of Caucasian region.

Detailed geophysical interpretation of the present day Caucasus deformation field using GPS data together with seismical and geological evidence see in [Shevchenko et.al, 1998].

For study of the vertical movements we used the repeated surveys completed in 1994, 1996 and 1998. The analysis of these observations show that the the one-sigma uncertainties for vertical rates for regional sites relative to a reference station on the Skifs platform(100-500 km distance) are about 2-3 mm/year, quite comparable with the errors for levelling in mountainous terrains, especialy if we take into account the sistematic errors due to refraction in the levelling. Inspite of short time interval covered, GPS derived vertical motions support some earlier inferences made from repeated leveling surveys, particularly that movements vary substantially between different parts of the

Caucasus: the Greater Caucasus experience uplift but the Lesser Caucasus do not reveal any significant vertical movements. Also GPS sites in the Greater Caucasus show larger variations in rates compared to sites in the Lesser Caucasus. The average rates in the Greater Caucasus are about6-8 mm/year, reaching are maximum of 22 mm/year, while sites in the Lesser Caucasus are characterized by average rates of 3-5 mm/year and a maximum of 8 mm/year. Sites in the easten and western parts of the GPS network suggest that vertical motions in Caucasus can discribe by stepped model. Four out of five GPS sites in a local network situated in the epicentral area of the Racha (1991, M=7.3). Earthquake indicate postseismic (from 3 months after the earthquake to 1996) relative uplift at rates of 2-11 mm/year and only one, .most distant from the epicenter, shows subsiden0ce at a rate of 2 mm/year.

Tien Shan region In 1992 joint team consist of american, russian, kazakh and kirgizian scientist began to study the regional geodinamics of former Soviet Central Asia [Abdrakhmatov et.al., 1996].

The active orogens of this regions represent a unique setting for examining the dynamics of crustal deformation associated with continental collision. The region is a complex mosaic of geologic terranes, and presently is situated within the active collisional boundary between the Indian and Eurasian plates. [Bazhenov, Burtman, 1990] The region forms a broad northern extension of the Himalayan suture, as evidenced by the continuity of crustal seismicity northward from the Himalayan front and the similarity of compressional earthquake focal mechanisms to the orientation of predicted plate convergence.

The primary scientific goals of GPS monitoring of this region are: (1) measurement of present-day relative movements of the Indian and Eurasian Plates; (2) monitoring of strain accumulation and release along the major fault systems of Central Asia (Gissar-Kokshal, Darvas-Karakul, Talas-Fergana); (3) measurement of internal deformation within the major crustal blocks of the region; (4) evaluation of coseismic crustal deformation associated with major crustal earthquakes in the region.

To measure the present-day kinematics, 86-station GPS network in the Republics of Kyrgyzstan and Kazakhstan we established. The network shares sites with a regional-scale network established by a collaboration of German scientists from the GeoForschung Zentrum [Reigber et.al, 1993] The observed velocity field documents strain across the belt from the Kazakh Platform, north of the belt, to the segment near the border with China Rates range from near zero, in the north, to a maximum at the southern edge of the network of 13±2 mm/y and directions are essentially parallel to the convergence between the Indian and Eurasian plates. The uniform variation in north-south speed across the Tien Shan implies a roughly homogeneous strain field. The small variation in northward speeds across the network suggests that rates across individual faults within the Tien Shan do not exceed a few mm/y. Thus the distribution of strain accumulation concurs with the geological and seismological observations of active deformation throughout the Tien Shan.

The shortening rate of ~20 mm/y across the Tien Shan exceeds previous estimates by 50-100%. Seismic moments of earthquakes suggest shortening at an average rate of 10 (±3) mm/y in this century. The high rate of convergence therefore implies either a significant proportion of aseismic strain in the Tien Shan or a deficit in the seismic slip this century, which might indicate a heightened risk of a major earthquake occurring somewhere in the Tien Shan. The apparently uniform strain accumulation across the Tien Shan implies that the risk of such an event is not restricted to the northern or southern margins of the belt, but could occur on virtually any of the major thrust faults within the belt.

Baikal Rifting Zone

The origin of Baikal rifting zone steel remain one of most intrigueing geological phenomenon and a classical example of intracontinental Cenozoic rift zones actively developing at the present time [San'kov et.al.1999] A chain of rift valleys about 1800 km long runs the southeastern edge of the Siberian Shield, and the conditions of pure tension in the central rift zone give way to the conditions of shearing at its flanks. Outside the Baikal Rift zone, almost over the whole Asian continent, the present-day compressive stresses prevail. The fact that the Baical Rift is isolated from the world rift system has aroused many discussions concerning the rifting source and influence of deformation at the plate boundaries on the intraplate tectonic processes and phenomena of fundamental importance for testing different geodinamic hypotheses on the origin of the Baikal Rift zone are the estimates of horisontal movement rates and their relation to the vertical movement rates by GPS.

The recent movements in the southern Baikal Rift zone are of interest for many reasons. Its rift structures are most clearly pronounced. The amplitude of vertical movement on faults for a period of the Baikal basin formation has reached about 8 km, at the thickness of Cenozoic sediments of about 7 km. This is the oldest part of the Baikal Rift zone, its core.

The creation of GPS geodetic network of the Baical geodinamic research area has started in 1994, in the framework of the Russian-French joint project. This observation grid consisted originally of 11 geodetic control points and covered the southern and central Baical basin. In 1995, the research area was enlarged in the northeastern direction at the expense of installing two new sites, one on the Siberian Platform and another at the northern edge of the Ol'khon island. In 1997, the network was enlarged in the southwestern direction to the eastern Sayan and Prisayan'e area.

In 1996, the repeated measurements were carried out at 11 sites of the Baikal geodinamic research area, which were set in 1994. The data obtained were processed by the GAMIT/GLOBK program at the Institute of Geodinamics (Sofia-Antipolis, France).

The data obtained from the experiment are completely consistent with the neotectonic situation in the examined part of the Baikal Rift zone.
It was found that the displacements within the Siberian Platform are absent, and all the sites located in the western Transbaikalia move consistently in the SE direction. The main characteristics of the vectors are consistent with the displasements predicted from structurial-geological and seismological data. It was first established that the direction of opening of the Baikal Rift is 130^Ь to 140^Ь SE, and the estimated openig rate is 12.0 ± 5.0 mm/yr.[San'kov et.al., 1999]

Kamchatka Region
Kamchatka is placed in the region were the Pacific, North-America and Euro-Asia tectonic plates are connected. There is the zone of subduction to the East of Kamchatka, which emphasizes and terminates the unique tectonic position of the peninsula. It is very important to study tense-deformed condition within the whole region as a local field for understanding modern tectonics of Kamchatka [V.Bakhtiarov et.al.,1998].
On Kamchatka, begining from 1996 permanent GPS array consists of 8 sites were developed. As a receivers Astech Z12 are used The processing of the data curried out by PNAV and GAMIT packages The repeatability of daily results are about of 2-3 mm for lines of 20 km and 7=10 mm for 400 km.
No signs of singularities concerning of the ionosphere influence, as expected All information from this network in Petropavlovsk-Kamchatsky is collected, processed and represented for current prediction of seismic situation. There was one strong (Kronotski, 05.12.97, M=7.8) earthquake in Kamchatsky Bay during 1.5 year of GPS operation. It was accompanied by a precursor as the bayshape deformation with life-time 1 month and amplitude 20-30 mm. The relative displacements of points, located in several hundred kilometers, do not exeed 20 mm [V.Bakhtiarov, 1999, Private communication].

GPS Study of the Postseismic Deformation
The GPS studing of postseismic deformation after Racha earthquake carried out on the local network described erlier indicate significant (up to 45 mm) north south shortening roughly coincident with direction of coseismic faultship in the period 3-years period following the main shock of Racha earthquake. The large change in directions and amplitudes over the small area 30x40 km with respect to the observed regional strain pattern support the conclusion that the motions of local network sites reflect transient, postseismic deformations [Reilinger et.al, 1997].
The North Sakhalin (Neftegorsk 27.05.1995, M 7.0) the earthquake ravialed, a right-lateral seismic fault with the maximum strike slip on the epicentral region observed by geological survey about 8 m [Kozhurin and Strel'tsov, 1995].
To investigate the coseismic crustal deformation around the seismic fault, we carried out the first epoch GPS observation on July, 1995, just after the earthquake. We made GPS observation at 13 triangulation points around the northern part of the surface fault.The differences between GPS our triangulation can be explained with a dislocation model that includes buried oblique slip on a rupture surface extending 35 km along the strike of surface rupture. Assuming uniform slip on a rectangular surface, the mean values are 5.3 m right lateral strike-slip and 1.4 m reverse slip.
The secondary and third epoch of GPS observation on august, 1996 and the third one on August 1997 were carried out around the whole part of the surface fault respectively in August 1996 and August 1997. But this new data is not available at the moment of preparing the report.

GPS Measurements for Earthquake Prediction
GPS technology has already been extensively used for and for postseismic deformation research. But we must admit however that there is no positive results now for detection of short-term (days-hours) deformation forrunners by GPS [Prilepin, 1999].
One of the reasons why the problem of earthquake prediction is far away from the solution stipulated is the lack of real international cooperation on experimental study and evaluation of significance different forerunners.Many scientists today share the opinion that the deformation forerunners are primary and their study can help understanding the processes of preparation of earthquakes and prediction of the event. Properly established from the point of view the of spatiel and temporal resolution.GPS networks can provide valiable information for earthquake prediction. Study of the temporal and spatial deformation field changing on a seismically prone area help to determine the epicenter position and the magnitude of earthquake in preparation. The analysis of anomalous events of deformation rate in epicentral area can provide the data, together with ather precursors, for short-term (operative) prediction.
One of the urgent needs to improve the situation with earthquake prediction is to establish a few international polygons where the expirience of different scientific school,using modern technology for detection of different kinds of forrunners, will be accumulited. One of the suitable regions is the Caucasus, the active part of Alpine-Himalayan belt.
The general requirements for establishing GPS-networks for detection of the deformation precusors are as follows:
- the seismicaly prone area needs to be covered by a GPS-network with dimension of the order n.100 km x k.100 km, where n, k=1,2,3, the values of n, k depends on seismic zonning of the region;

- the density of a network on the last stage must be of the order 1 site for 20-40 km, if our task is to predict earthquakes with a magnitude M5 and more;
- the last stage for operative prediction the deformometric parameters (main deformation,shear deformation and dilatation) must be estimated in a quasi-real scale of time from a properly disigned monitoring network.

To fulfil these requirements it is reasonable from an economic point of view to establish GPS networks for many seismicaly dangerous area step by step.

First of all the territory to be covered with type A networks; where distances between sites of order of 100 km. At least 3 sites of this network need to be situated on every geological province, which may have specific features of deformations.

The type B of the GPS-network with distances of 15-25 km should be set up to fit a special pattern of the region: strike-slip foult, thrust foult, collision and subduction zones different scale and so on.

The A and B type networks should be remeasured every year; but after two-three years the repetition rate for remeasurement of type B networks might be increased for the whole region or part of it. This depends on the activity of the region during the previos period.

The study of the change of the patterns for the deformation field reveiled by A,B - networks, taking into acount seismological and other data for region under study, gives us the possibility to locate the most dangerous area. In this area it is nessesary to develop a C-type monitoring network with the distances between points of about 5-7 km.

The measurements of sites, the gathering and processing of data from all C-sites should be organized in such manner that the deformometric parameters will be obtain every 15-30 minutes for operative prediction.

The most difficult task for the establishment of C-type networks is to provide the accuracy of measurements on the level of 2-3 10`(-7) for short distances (5-7 km) and short spans of time (15-30 minutes).

Conclusion

The discribed projects will continued at least during next 3-5 years with the repetition rate of measurement every one-two years.

In near future is planned to start a new project "Geodinamics of Kamchatka-Kuril-Sakhalin region" This project the seismic, geomagnetic and GPS measurements is considered for 5 years in initial period.

GPS project discussed now is dealing with entlargement of GPS networks at North Caucasus with aim of using the deformation field for more accurate seismical zonning. Soon will start joint Russian-Finnish project concerning the study of Fennoscandian uplift simultaneously on territories of Kareliya and Finland.

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Recent Crustal Movements

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Introduction.
As well as in previous four years, in connection with insufficiency of money resources, on an extent of period 1995-1998 the researches on crustal crustal movements in Russia were concentrated, mainly, on the analysis and generalization of results of geodetic observations made during last century. In comparison with the previous period (Kaftan, Lilienberg, 1995) the general scope of researches of modern crustal crustal movements by geodetic methods was a little reduced.
Nevertheless, these years in territory of Russia a number of field campaigns on observations over crustal movements in frameworks not only international, but also national scientific projects was carried out. The continuation of researches on fundamental directions has allowed to receive the new essentially important sources of information mechanisms of modern crustal movements, especially in mountain belts.
The works on cartography of modern vertical crustal movements of a terrestrial surface proceeded. More profound development was received by researches of geodynamics of oil areas and rating of geodynamic risk by geodetic methods at operation of deposits.

The national projects for the known reasons, as a rule, differed by locality of researches. So, for example, within the framework of realization of the Federal target program of seismological observations and forecast of earthquakes the repeated observations with use of GPS in local geodetic networks on Caucasus, in area of the Caucasian Mineral Waters (Kurshakov, 1996) are carried out, and Far East, on Sakhalins (Vasilenko, et al., 1995, Takahasy, et al., 1995), Shikotan (Filippov, 1995).
Last works were caused by destructive earthquakes of last years Shikotan (1994) and Neftegorsk (1995). They were carried out together with the foreign experts. As a result of these works the information on local deformations of a terrestrial surface having the large value for understanding of geophysical processes proceeding in the centers of strong earthquakes is received.
The assumptions of leading Russian seismologists about an opportunity of strong earthquake on Kamchatka have served as the reason for realization of several cycles GPS observations on Petropavlovsk geodynamic range (Kirienko). One of most interesting and significant results of work, in light of events of last years, are the data of repeated linear - angular measurements on geodynamic ranges of Kamchatka, located in areas of active volcanos Karym and Tolbachik.
The geodetic measurements have allowed to reveal the patterns of large-scale deformations of a stretching and, on all probability, raising of a terrestrial surface before eruptions of volcanos. It is established, that almost 10 years prior to one of strongest eruptions of a Karym volcano in 1996-1997 . In a place again of formed crater which is not showing of activity in historical time, there were intensive deformations of a stretchings reaching 10^{-5}.
It means that geodetic methods make possible to observe the process of filling magma chambers centers.

Geodeformation networks on Caucasus (Prilepin, et al., 1997, Guseva, et al., 1998) created in the framework for **the international projects**, have put a basis of study of the spatial characteristics of crustal movements of regional scale, that also is extremely important for forecasting seismic activity in this area. The interesting results are received during realization of the international project on study of a level of the Baltic sea Baltic Sea Level Project (BSL), in which the active participation was accepted by the Russian researchers (Malkin, 1996, Demianov et al, 1998)
Within the framework of the international cooperation the works on research of modern crustal movements of foreign territories - mountain regions of Southern Europe, Transcaucasia, Central Asia and Cuba (Enman et al, 1997, Lilienberg et al., 1995, 1996, Lilienberg, 1995a, b, Ustinov, 1996).
The development and improvements of methods of processing and interpretation geodeformational observations proceed also. An effective method of definition of the global characteristics of spatial - temporary changes of a terrestrial surface in particular is offered on the basis of mathematical processing radio-interferometric measurements with simultaneous revealing quazistable stations (Gerasimenko, 1996).

Study of mechanisms of mountaneous formation processes actively proceeds. Caucasus and Transcaucasia traditionally represent modelling area for checking various geotectonic, geophysical, geodynamic ideas.
Dense network of lines of repeated levelling, presence of a plenty tide gauges at coasts of the Black, Azov and Caspian seas have allowed for the first time in the world for so extensive mountain territory to make maps of modern vertical crustal movements for three epoch of 20 century: 1930±11 – 1946±10, 1947±8 – 1971±5, 1964±11 – 1985±7, which have reflected complex system of spatial - temporary variations of modern crustal movements (Kaftan, 1996a, Kaftan, et al., 1995,1997, 1998).
High intensity of modern crustal movements with amplitudes of 1-2 cm/year. In character of modern crustal movements are clearly shown sign variability and spatially temporary variations.

Orogens and the intermountain hollows represent typical morphostructural zones of a collision of Euro-Asian and Arabian plates. By results of GPS measurements the speed of horizontal movings of the Arabian ledge achieves several cm/year, that, apparently, results in spreading in west and east of Anatolian and Iranian microplates, and also hollows of the Black sea and Southern Caspian Sea.
On this background of a regional field of pressure the own individual style allocates crustal movements all basic longitudinal and cross morphostructures, showing thus sign changing wave character.
So in the second quarter of 20th century Northern Caucasus shows weak subsidence (till -3 mm / year) or raising (till +4 mm / years); the Large Caucasus - maximal uplift till 1-1.5 cm/year; the Transcaucasian intermountain area - differential small moderate subsidence till -6 mm / years or raising till +6 mm / years, and Small Caucasus, as opposed to the Large Caucasus, is characterized by inversion of crustal movements - subsidence till 1 cm/year.
In epoch of the third quarter of our century there is a general change of an orientation of crustal movements: Northern Caucasus begins to test prevailing subsidence till -6 mm / years; the large Caucasus shows inversion of own crustal movements - weak subsidence till -2.5 mm / year; the Transcaucasian depression - the moderate subsidence till -1 cm/year, and Small Caucasus and Armenian plato are involved in the maximal uplift till 1-1.5 cm/year.
The next change of intensity and orientation of vertical crustal movements takes place in last quarter of 20th century: for Northern Caucasus the prevailing small uplift till 4-6 mm / years are characteristic; on the Large Caucasus renew intensive uplift till 1-2 ñì/years; the Transcaucasian depression tests uplift till 4-8 mm / years, and the Small Caucasus again enters a phase of subsidence with speed till -1.5 mm / years.
The revealed character of variations of modern vertical crustal movements, apparently, reflects the general mechanism of geodynamic activity of the Caucasian region consisting in alternation and change of epoch of general uplift and general subsidence of mountain systems, which can be interpreted as change the epoch of homogeneous regional compression and stretching. The duration of the periods of changes the epoch is estimated by Lilienberg by values 10-15 and 25-30 years.
The similar mechanism takes place and for some other mountain systems, for example for territories of Balkan, Ural, Transbaikalia, Tyan-Shan, Cuba, Japan, that is can be global law (Lilienberg D.A., 1996a, b, 1998b).
In this connection represents the certain interest the statistical analysis executed by Kaftan with use of large volume of the data repeated levelling and observations on tide gauges. He carried out revealing the latent periodicity and comparison of frequencies of distributions of dominant harmonics of the various periods of fluctuations of differences yearly means of of sea levels on various pairs of tide gauges of the Baltic, Black and Caspian seas.
Remarkable fact is, that the greatest amplitude, both for tide gauges data, and for levelling there is a harmonic with the period 53-58 years, for those cases, where it was showed. For differences of levels of the Baltic sea the dominant harmonic has the period 101 years, and for height changes of Kronstadt tide gauge - 43.6 years. On seen, fluctuation with the periods 44-58 years play one of the main roles in character of changes of vertical crustal movements of a terrestrial surface, that does not contradict result received from the analysis height changes repeated levelling of Caucasus region.
So, for 44 height changes on lines of levelling of I and II classes in Caucasus determined from 1889 to 1990 with intervals of recurrence about 10-15 years, the fluctuation period value height changes is 63+28 years. Others most significant components were the harmonics with the periods 101, 147 and 19-27 years.
Other temporary changes noticed by Lilienberg, was similar with described the above alternating character of a compression - stretching as well for cross morphostructures.
The Large and Small Caucasus show compression and stretching not only in cross, but also in the longitudinal plan, that, apparently, results in alternate lengthening or shortening of mountain systems and requires the special analysis from positions of the geomechanics of geological environment.
Lilienberg marked spatial patterns of fields of modern crustal movements and deformations as their precise interrelation with morphostructure of faulting differentiated terrestrial crust. Dividing morphostructure blocks of a different type and rank fracture of a zone are allocated with high gradients of displacement up to several cm/year/km.
In works (Lilienberg, 1996a, 1996c, 1998a, 1998c) the rhythm ratings of modern crustal movements in results of levelling with the periods about 100-120, 80, 50-60, 35-40, 20-25, 10-15, 5-7,3-4 and 1 year are resulted which, in opinion of the author, is fixed for various geodynamic phenomena, such as vertical and horizontal crustal movements, seismicity, magmatic and mud volcanizm, etc.
The oscillatory components of higher frequencies with the periods 4, 2 and 1 year are revealed on Garm geodynamic range from results of repeated levelling and laser measurements (Rastvorova, Enman, 1997). On the data of tilt and strain observations in the same area the fluctuations with the periods 2, 1 year and 15 day (*Atlas ...,* 1998) are revealed.

The natural attention of the Russian researchers is directed to last years on **study of the regional tendencies of vertical crustal movements of a terrestrial surface and their connections with seismic activity**. The repeated geodetic measurements have allowed in a new fashion to approach to a rating and forecast of geodynamic risk, study kinematics of seismogenic mechanisms. These questions serve a subject of numerous discussions (Lilienberg D.A., 1998a, 1998c).

Last years in Russia the purposeful researches were successfully carried out according to opportunities of use of geodetic methods for the forecast of a place and time of occurrence of strong earthquakes.
The strategy and technique of the control of accumulation of elastic seismogenic deformations (Pevnev, 1997,1998) is developed.
The special attention at study of processes of preparation of strong earthquakes was given to abnormal rises of a terrestrial surface in areas of high seismic activity observable in our century in different regions of a planet.
In territories of the states of former USSR there are cases of abnormal rises of a terrestrial surface before strong earthquakes (Kaftan, Ostach et al., 1996, Kaftan, 1996a, 1997, Kaftan et al., 1998).
It is three sequences occurring in the Caucasian region, two - in territory of the Large Caucasus and one - in area of tragical Spitak earthquake. The retrospective analysis of the information about speeds of vertical crustal movements and seismic in the Carpaty-Balkan region (Kaftan, 1997), has shown, that before strongest seismic events of our century - Vranchea earthquakes - abnormal uplift of a terrestrial surface also took place
Interesting and showing for the benefit of a reality of existence of connection between abnormal rises of a terrestrial surface and strong earthquakes is the fact of their arrangement in limits and in immediate proximity (in high gradient zones) from territories of abnormal uplift registered on maps of vertical crustal movements. In too time there are territories of abnormal uplift, which earthquakes has not followed (or has not followed yet).
Such area is the Stavropol raising registered on maps of modern vertical crustal movements of a terrestrial surface (Kaftan, et al., 1998). Pays on itself attention that fact, that right at the beginning of our century within the limits of this area there was a strong earthquake with Ì=6.0. These circumstances force to consider the specified area seismically dangerous.
The analysis of the available data has allowed to reveal both similarity, and difference of course geodeformational and seismic processes on Caucasus and in Carpathians in relation to similar cases in other regions of the world.
In addition to principles submitted earlier by the Chinese researchers, on the basis of the analysis of new data about vertical crustal movements of a terrestrial surface of Carpathians and Caucasus, for the given regions it is possible to formulate the following value principles:
(1) territories subject to abnormal uplift, which speeds more than twice exceed background values, and also the zones, limiting them, of high gradient changes of speeds can be considered as territories of the increased seismic danger.
(2) Average interval of time from the moment of registration of an abnormal raising before occurrence of strong earthquake within the limits of territory of the raised(increased) seismic danger 16 ±7years.
(3) the duration of dangerous interval from the moment of registration of an abnormal raising makes 2-30 years.
(4) The average repeatability of strong earthquakes with M> 5.9 within the limits of territory of the increased seismic danger and during dangerous interval is 6 years.
The specified principles have the generalized and qualitative character, but, nevertheless, they allow to allocate territories of the increased danger and to estimate the tendencies of change of seismic activity of these territories. For their specification it is necessary to carry out regular and often enough observations over vertical crustal movements of a terrestrial surface in seismo-active areas.
The spatial - temporary analysis of distribution of epicenters of the strong earthquakes executed with a specially developed technique, has shown, that as the most probable area of occurrence of strong earthquakes in the Caucasian region the coming years it is necessary to consider its southeast end, subsequent seismic events, by one of which was the earthquake in Dagestan (1999) have confirmed this forecast.

The attempts of a rating of the contribution of modern crustal movements and deformations of a terrestrial surface in changes of levels of the seas and internal reservoirs do not stop. This problem are especially urgent for Russia in connection with catastrophic rise of a level of the Caspian sea in 1978-1995 almost on 3 m, that was by the reason of ecological and socio economic disasters, and also in connection with construction and operation of mountain reservoirs.
Traditionally reasons of fluctuations of a level of Caspii for short intervals of time contacted to climatic changes and volumes of a river drain. These considerations were based on meteorological network. However they were not justified for separate years and have appeared insolvent for the forecast of changes of a sea level till 2000, when instead of expected significant downturn of a level in 1978 there has come its sharp rise. It was by the reason of activization of search others not of the hydroclimatic reasons of changes of a sea level.
The behaviour of repeated geodetic measurements in Caspian region has allowed to analyse an opportunity of influence tectonic of crustal movements and deformations on changes of a Caspian level. In opinion of Lilienberg, by essential were revealing tectonic structure of the Caspian hollow and adjacent with it areas, and also dominant value for formation of a relief of strong horizontal crustal movements and deformations and its pulsational character.
The periodicity of fluctuations of vertical crustal movements considered above, in many respects is close to known cyclicity of hydroclimatic processes, that speaks about their close interrelation within the framework of the global mechanism.
In opinion of Lilienberg the long-term tendencies of endo- and exogenic processes in many respects coincide: for example, abnormal changes of a sea level in 1929-1940 (sharp fall) and in 1978-1995 (sharp increase) coincide on

time with activization of large-scale geodynamic processes (seismicity) in adjacent areas accordingly northern and average orogens of a regional segment of the Alpine belt.
In Northern Caspian region some tens underground nuclear explosions in the economic purposes for creation of underground storehouses of petroleum were made.
The activization mud volcanizm also is connected to phases of subsidence and stretchings of the earth crust (Lilienberg, 1996d, 1997a, 1998b, c). Thus he marks migration of activity of mud of volcanos from a southwest on northeast and their activization with periodicity 10-22, 25-30 and 50-60 years, depending on pulsations of the mechanism of progress of a ledge of the Arabian plate.
In the main zone of subduction depending on intensity of pressure of the Arabian ledge there is a migration of the centers of strong earthquakes to speed from 6 till 20-30 km / year.
Believing established the essential contribution of the tectonic factors in fluctuations of a sea level, Lilienberg puts forward complex tectono-hydro-climatic concept of changes of a level of the Caspian sea (Lilienberg, 1996c, 1997a, 1998b).
The important contribution to a problem of interrelation of dynamics of external geospheres became also generalization of results of geodetic observations around reservoirs and hydraulic engineering structures in mountains of Central Asia (Nurek, Toctogul, Rogun, Tcharvak reservoirs) and Caucasus (Inguri, Sulak cascade of hydroelectric power stations).
In papers (Ustinov, 1996,1999) the background characteristics of crustal movements of a terrestrial surface and their changes are revealed at filling and operation of reservoirs, activization of displacement on breaks, differential movements of blocks, exited seismicity.

The researches of interrelation of global and large-scale geodynamic processes proceeded, such as a level of the Caspian sea, change of speed of rotation of the Earth and solar activity, on the basis of the analysis of long temporary series of observations (Kaftan, 1996b, Kaftan, Tatevian, 1996). The statistical analysis of the latent periodicity in yearly means series of values of heights of a Caspian level, speed of rotation of the Earth and Wolf numbers is executed.
The comparison of the periods and phases of the revealed harmonics has shown, that solar activity and rotational mode of the Earth have both general and own harmonics conterminous to fluctuations of a Caspian level. Received polyharmonical model has ensured the forecast, justified till the present time, of the termination of rise and downturn of a Caspian level. The statistical substantiations of hypotheses about interrelation of the specified processes are received.
The researches of periodicity in changes of solar activity on qualitatively more high level are continued. Is carried out harmonical analysis of two hundred fifty years' series of monthly average values of the international Wolf numbers Ri. Kaftan developed three variants of the forecast current of 23 cycle of solar activity. Is shown, that the next epoch of a maximum of activity will continue from the end of 1999 on 2003, thus the average amplitude of values Ri will make 90-100 units.
This forecast sharply differs from the majority of the published forecasts promising very high activity in epoch of a maximum - up to 160 Ri. Nevertheless, last months have shown, that the forecast of low activity began to receive the increasing confirmation in comparison with the high forecast. The received results are supposed to be used for revealing interrelation of solar activity with dynamic characteristics (Demianov, Kaftan, Zubinsky, 1998) and planning of the international GPS field campaigns of observations.

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