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MONITORING OF DISPLACEMENTS OF OBJECTS OF TERRESTRIAL SURFACES BY INTERFEROMETRY METHOD

Abstract. Geomechanical monitoring is a system of observations of the state of the geological environment, the processes of displacement of rocks and the earth's surface, geomechanical and hydrodynamic processes in a rock mass, interpretation of the results of observations, the formation of judgments about the state of the rock mass as a whole and the forecast of parameters of stable slopes.

To determine the displacement of the earth's crust of the Akbakay field, the technology of terrestrial radar interferometry was used. Which is used by only a few research institutes and organizations in the world.

In satellite radar interferometry, the promptness to obtain an actual spatial information about the Earth's surface is an important requirement for modern Earth remote sensing data, along with high spatial resolution, as well as geometric accuracy. The operational efficiency is one of the main advantages of radar systems for remote sensing of the Earth or a system of instruments synthesized by radar.

Geomechanical monitoring and research on geodynamic polygons reveal wide opportunities for studying vertical movements of the earth's crust.

In this work, the most important point is the scanning of the terrain and objects around the scanner standing point, i.e. Scanning special marks with the maximum resolution, which allows you to get a cloud of points.

Key words: Geomechanical monitoring, Space monitoring, geodynamic polygon, crustal movements, remote sensing of the Earth, interferometry, artificial earth satellite, rapper, digital model.

Introduction. On the territory of the Republic of Kazakhstan, developed and further developing industry sufficient number of such man-made systems and ties with this in parallel, the question of man-made disasters is raised. The increase in various risks are given a lot of attention everywhere, as evidenced by the increased number of risks. publications on the subject, including in mining countries. [1].

President Of The Republic Of Kazakhstan N. A. Nazarbayev in the missive to the people "The way of Kazakhstan-2050" within the framework of the program of industrial-innovative development set a task to create a leading school in the field of effective deposits development in The Nazarbayev University and signed convention. This vision of the head of State shows the importance of the mining industry in the further development of the country. With increasing depth of mining safe mining operations have the influence of the movement of rocks and the earth's surface, mountain pressure and mountain shocks.

Besides, at reconstruction of old mines development of temporarily left Tselikov, especially during transition from open to underground methods of working out, questions of movement rocks and protection facilities are becoming important for many mining enterprises'. The complexity of these issues lies in the fact that many of them is necessary to solve during the design and construction of mining enterprises, when there are often no reliable data on the deposits nature and the parameters of the process of moving rocks. It was during this period set the borders project of threat zones of displacement, choose the Foundation place of the mine shafts,construction of industrial facilities and residential settlements, expect safety pillars or provide other measures for the protection of buildings and mountain productions'.

At present, has formed two main areas, which are under being a study of this issue: mining pressure and the actual displacement of the mountain rocks and the earth's surface. In the first direction are studied mainly conditions stability, deformation and displacement of rocks surrounding In the second direction, the earth's surface and intermediate displacement are studied the strata of rocks with the aim of establishing the measures for the protection of buildings and in e workings from the harmful effects of underground mining. Studies in this case are carried out mainly by setting instrumental observations of the earth's surface displacement.

The results of observations on the gold deposits of Kazakhstan has repeatedly were used at drawing up Instructions on protection of constructions for fields with unexplored nature of the movement of rocks. Later in Kazakhstan was held a monitoring of the displacement of KazNTU – on ore deposits as a result of which a number of Instructions on protection were made facilities for various mines. In this regard, the scientific works of the above-mentioned scientists re analyzed, taken into account the results of large-scale studies on the problem of studying the process of development of ore deposits, including the open-underground method of development. One of them is the research carried out at the mine Akbakay [2].

Initial data and research methods. The rapid development of science and technology the past 10-15 years, led to the birth a new method for determining the coordinates in geodesy and surveying - satellite system. The use of the satellite system for geomechanical monitoring is based on three the main directions. The first direction is connected with the construction and reconstruction of support structures surveying networks on the earth's surface and areas of open mining. The second direction-the implementation of surveying surveys surface and communications in the fields of downhole production of hydrocarbons, open mine excavations, dumps, tailings, as well as filming engineering constructions'.

Conducting geodetic observations is based on a system of constant base stations.

They collect GPS information- receivers or GNSS receivers and the Rover in RTK mode (the actual time) is introduced amendments. Geodetic works on supervision are carried out by means of mobile (temporary) base and permanent base stations [1].

Results of the study and discussion. Based on the GPS measurements surveying service to the mine Abai were provided with reference points (earlier and new) whose coordinates are determined with high accuracy [Sultanguzin U.M., Aubakirov T.O., Musabaev T.A i dr. Kosmicheskie issledovanija v Kazahstane, Almaty: ROND, 2002]. The scheme of location of strong points and shooting on the field "." is shown in figure 1 and coordinates in table 1.

1. Using the results of satellite definitions in the field of geodesy is not ends, because with each passing day, improved technology and equipment, accordingly, the scope of their use is expanding. [11]

The emergence in recent times of surveying and geodetic practice of modern devices, in the form of 3D scanners, allows you to study in detail the elements of occurrence surfaces of attenuations and inaccessible locations. In the conduct of geomechanical monitoring, the study of vertical and horizontal the earth surface displacement finds wide applicable scope radar interferometry method. Currently, there are two methods of radar interferometry: satellite and ground. In satellite radar interferometry, the efficiency of obtaining the actual spatial information about the earth's surface is an important requirement, applied to modern data of remote sensing of the Earth (remote sensing), along with high spatial resolution as well as geometric accuracy. Exactly efficiency is one of the main advantages of radar systems of remote sensing or synthesized radar equipment (SAR) systems [4]. Thanks to the microwave radio band used in radar, the data serve as a unique source information about the earth's surface. Space radar monitoring of subsidence, caused by the development of deposits, successfully carried out abroad and in Kazakhstan.

In the fields of geodetic observations are carried out twice a year (spring and in autumn) and additional seismological measurements are carried out. For obtaining reliable data must be carried out simultaneously with geodetic observations in monitoring mode space radar interferometric survey areas of deposits, which allows to regularly receive the field of displacement of the earth surfaces with high precision [21].

The main methods of carrying out geomechanical observations on the Akbakay field were:

1. Geomechanical monitoring;
2. Space interferometric monitoring;
3. Instrumental monitoring.

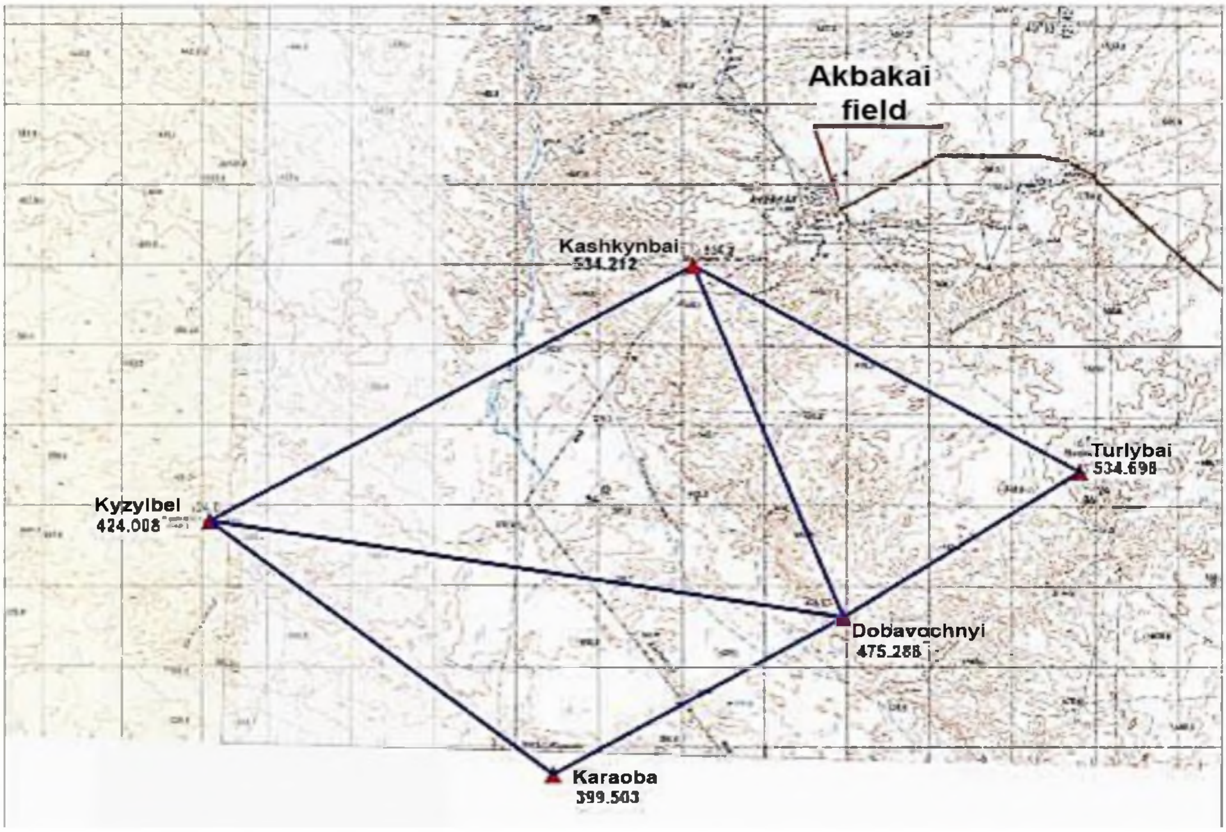

Figure 1 – Location outline of geodetic network points and survey points

The Catalogue of coordinates points

Points	Coordinates		
	X	Y	H
Turlybai	4993455,446	323687,609	534,698
Kashkynbai	4998214,446	314456,909	534,212
Kyzylbel	4991708,246	302559,769	424,008
Karaoba	4985882,546	310687,379	399,503
Dobavochnyi	4989490,346	317564,379	475,288

Recently the increasing distribution for determination of vertical and horizontal displacements of the land surface is received by methods of the space radar interferometry (SRI) in which amplitude and a phase, the radio signal reflected from a surface is fixed.

The basic advantage of a space radar interferometry before other methods of vertical and planned deformations monitoring of the land surface consists in direct measurement of the diversity in a relief which occurred for the period between two (three, four) space shootings occurring at different times.

The file of shifts received as a result of interferometric processing displays the happened changes of the studied land surface relief resulted from various natural and technogenic processes.

The interferometric technique of land surface motions monitoring assumes existence of couple of SAR the images removed from two relatives, but the parallel orbits of the spacecraft carried on time, locally.

Each radar image of interferometric couple (or chain) contains an amplitude and phase layer. The amplitude layer is more suitable for the visual analysis. The resulting phase F, received during interferometric processing of phase layers images of interferometric couple, consists of the following components [10]:

$$F = F_{topo} + F_{def} + F_{atm} + F_n$$

where: F_{topo} – phase incursion due to survey of a topography under two different corners; F_{def} – phase incursion due to surface shift during the period between shootings; F_{atm} – phase incursion due to lengths distinction of optical paths because of refraction in the environment of a signal distribution; F_n – phase variations as a result of electromagnetic noise.

For interferofram creation on couple of radar space pictures the license software products (Gamma, D-InSAR (ERDAS), PhotomodRadar, SARscape (Envi), etc) allowing to create high-precision and multi-scale digital models of a relief and also a number of the specialized maps displaying the quantitative and qualitative information about stability of the land surface.

As a result of the carried-out surveys there was created a shifts map of the land surface of the Akbakaysky mine territory on which there was registrated shifts of soils and grounds in a sag trough up to 5 cm (figure 2).

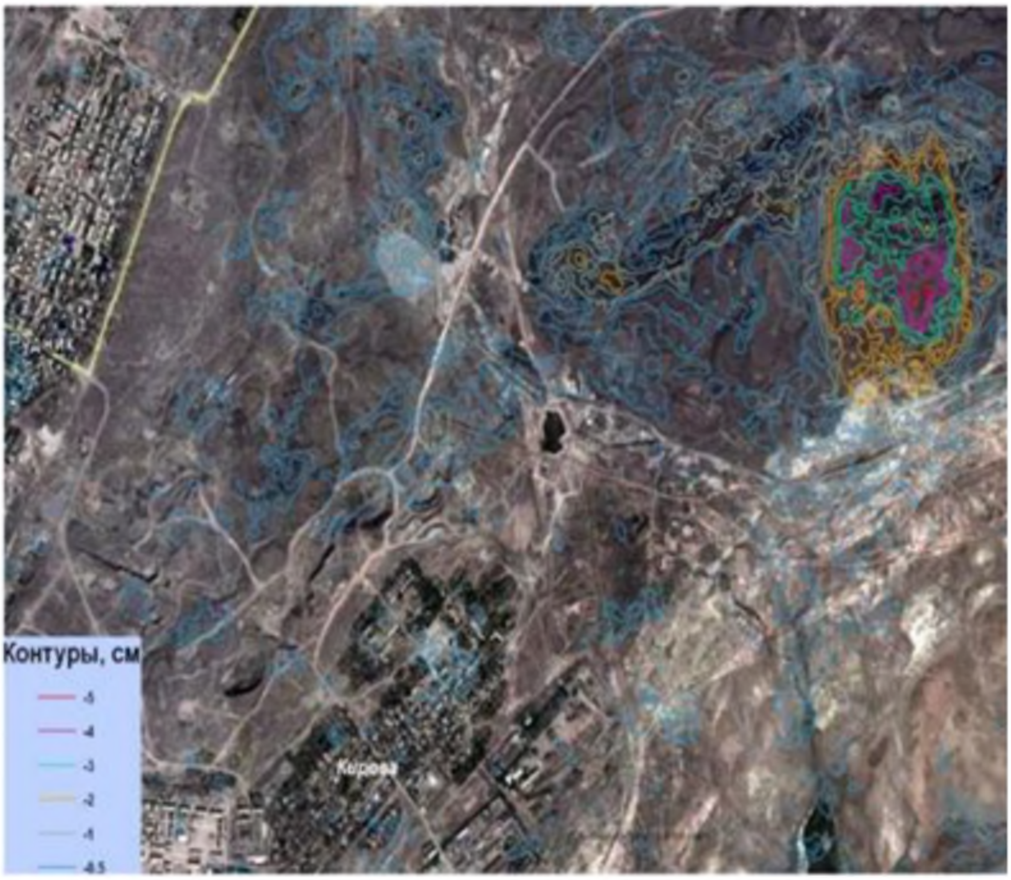

Figure 2 – Map of the land surface of the Akbakay mine territory
on which there was registrated

Based on the processing of radar images obtained by the space Agency from artificial earth satellites (ISZ), defined vertical movement of the territory the object and the assessment of its state (figure 3).

Figure 3 – Space the field "Akbakay" used in interferometry

Radar interferometry makes it possible to work with data obtained by remote sensing, creation of three-dimensional models, sections and profiles of terrain According to the results of space radar observations, a number of local foci were established sedimentation of the earth's surface over areas of underground mining. Currently on this areas of land being land-based observations. Such geomechanical observations and researches on geodynamic polygons opens wide opportunities to study the vertical movements of the earth's crust. The advantages of space monitoring are, first of all, its greater productivity compared with traditional geodetic survey. Cosmic monitoring shows in advance of settling of a surface over the developed space (coverage area up to 3000 sq.km). The method does not require large economic costs, no need for field surveying work. Radar images obtained from ISS depending on the type of spacecraft change within 11 to 45 days (figure 4).

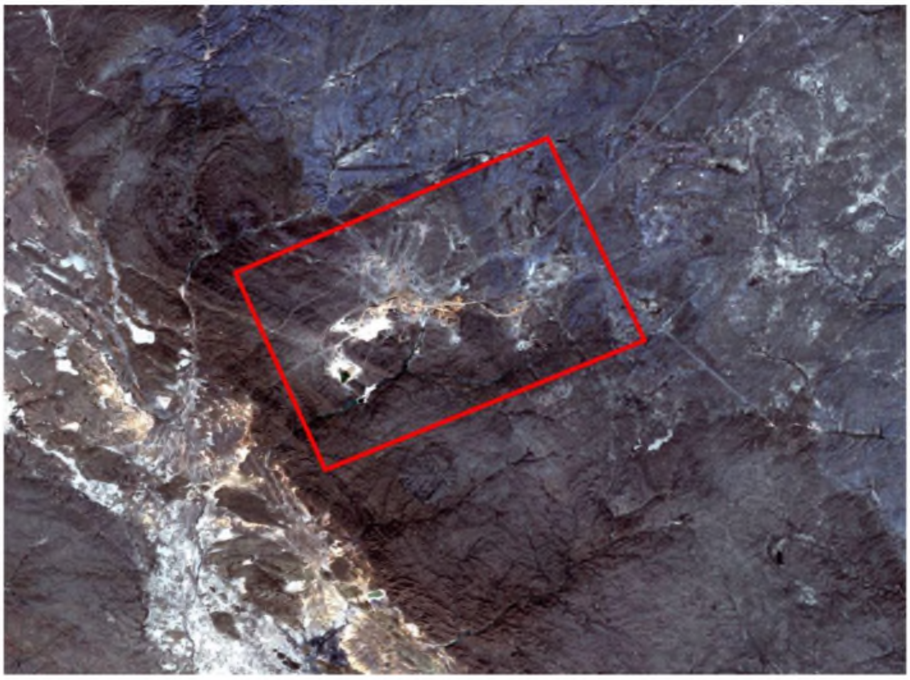

Figure 4 – Space image of "Akbakay" field received from LandSat satellite

There are two types (seismic and cosmic) of monitioring Seismic monitoring can provide information that is short-term harbinger of the impending destruction of rocks in local areas. Space monitoring provides information on long-term processes, flowing both in the local areas of observation and in a large area. The that way, they complement each other [3].

The shift (sag) zone of the land surface received on the technology using data of the radar spacecraft TerraSAR-X having high spatial resolution has more detailed parts and more precisely displays trough contours

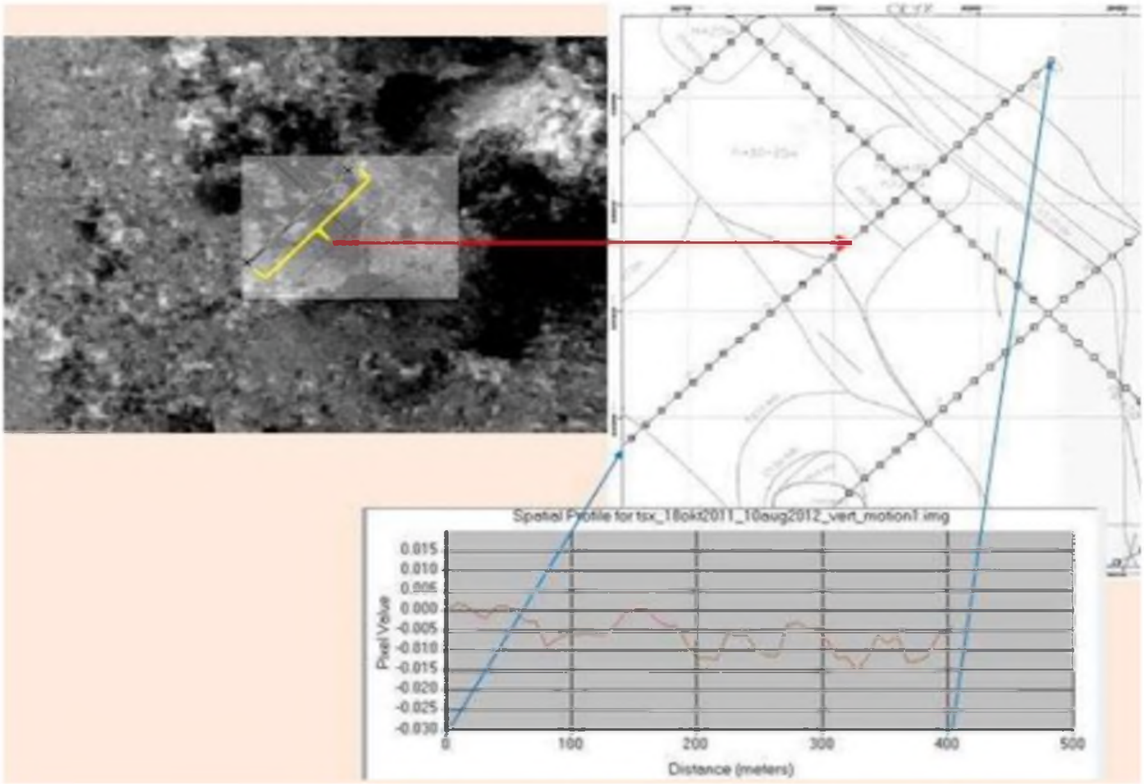

Figure 5 – Comparison of results lifting of the land surface, received by method of a differential interferometry and land measurements

The comparative analysis of differential interferometry results and comparison of the results of the land surface lifting received by a differential interferometry method with data of surveying measurements during 2011-2016 on a profile showed rather high correlation. There is a arrangement scheme of a profile on the resulting map of shifts received from interferometric measurements and size of shifts along this profile in the (Figure 5).

According to interferometric measurements in a reference point point 27, absolute value of the land surface sag was 0.8 cm since October, 2014 till August, 2015, and on land measurements this value is equal to 1 cm.

Summary. The third direction is the implementation of a systematic surveying observations of the earth's surface displacement and deformations of building elements and constructions'. Currently, GPS-monitoring is successfully conducted on a number of large enterprises of mining complex of the Republic of Kazakhstan. In General, in the process of the providing the region with basic stations and adjustment of "permanent" strong points call out a number of difficulties. Therefore, the geodynamic polygons and mines to conduct geomechanical monitoring using modern surveying instruments, new technologies and software product.

Cooperation with geodetic observations is also useful when identified the areas vulnerable to subsidence of the ground surface, and required more precision observations with real-time results, since space data monitoring require longer processing times. The main advantage is the possibility space-based monitoring coverage of significant areas. At the field Aqbaqay observation station is about 500 frames. Shooting is carried out one once a year at every point where the rapper is laid. In the best case manage to hold 2 measurements per year on all lines and thus obtain information on offsets from interval 1 year 6 months. During this time, the collapse may develop, and it is impossible predict. According to the results of space radar surveys, data on the earth's displacements the surfaces are delivered to us every month.

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ЖЕР БЕТІНДЕГІ ОБЪЕКТІНІҢ ЖЫЛЖУЫН ИНТЕРФЕРОМЕТРИЯЛЫҚ ӘДІСПЕН МОНИТОРИНГТЕУ

Аннотация. Геомеханикалық мониторинг жүргізу – геологиялық орта жағдайын бақылау жүйесі, тау жынысы мен жер бетінің жылжу үдерістері, тау жыныстары массивіндегі геомеханикалық және геодинамикалық үдерістер, орындалған бақылау интерпретациясы, жалпы массив жағдайын топтастыру және берік кемер параметрлерін болжау.

Ақбақай кен орнындағы жер қыртысының жылжу жағдайын анықтау үшін жердегі радар интерферометриясы қолданылады. Бұл технологиясы әлемдегі бірнеше ғылыми-зерттеу институттары мен ұйымдары ғана қолданады.

Спутниктік радарлы интерферометрияда ағымдағы жердің беті жайлы кеңістіктік ақпарат алудың жылдамдығы, сонымен қатар кеңістіктік ажыратымдылық мен геометриялық дәлдік – жерді қашықтықтан зондтауға қойылатын маңызды талап. Жерді қашықтықтан зондтау немесе синтезделген радарлы аппараттық жүйедегі радиолокациялық жүйе артықшылықтарының бірі жылдамдық болып саналады.

Геомеханикалық мониторинг және геодинамикалық полигондар жөніндегі зерттеулер жер қыртысының тік қозғалысын зерттеу үшін мол мүмкіндік береді.

Жұмыстың маңызды қыры – сканер айналасында тұрған жер мен объектілерді сканерлеу. Арнайы маркаларды жоғары дәлдікпен сканерлеу нүкте бұлтын алуға мүмкіндік береді. Жер қыртысының жылжу жағдайын анықтау үшін жердегі радарлы интерферометрия қолдану технологиясын әлемдегі бірнеше ғылыми-зерттеу институттары мен ұйымдары ғана қолданады.

Жерсеріктік радарлы интерферометрияда жербеті туралы өзекті кеңістіктік ақпаратты алу жеделдігі жоғары кеңістіктік ажыратымдықпен, сондай-ақ геометриялық дәлдікпен қатар жерді қашықтықтан зондтаудың қазіргі заманғы деректеріне қойылатын маңызды талап болып саналады. Дәл осы шапшаңдық жерді қашықтан зондтаудың радиолокациялық жүйесінің немесе жүйенің синтезделген радар аппаратурасының негізгі артықшылықтарының бірі болып саналады.

Геомеханикалық мониторинг және геодинамикалық полигондардағы зерттеулер жер қыртысының тік қозғалысын зерттеуге мол мүмкіндік береді. Радиолокацияда қолданылатын микротолқынды радиодиапазон арқасында деректер жер беті туралы бірегей ақпарат көзі болып саналады. Кен орындарын игеруден туған отырыстардың ғарыштық радиолокациялық мониторингі шетелде және Қазақстанда табысты жүзеге асырылады.

Кен орындарында геодезиялық бақылау жылына екі рет (көктемде және күзде) жүргізіледі және қосымша сейсмологиялық өлшемдер жүргізіледі. Сенімді деректерді алу үшін геодезиялық бақылаумен бір уақытта жоғары дәлдікпен жер бетінің жылжу алаңын тұрақты алуға мүмкіндік беретін кен орындары аумағының ғарыштық радиолокациялы интерферометриялық түсірілімін мониторингтік режимде жүргізу қажет.

Жердің жасанды серіктерінен (ЖҚЗ) ғарыш агенттігі арқылы алынған радарлық суреттерді өңдеу негізінде объект аумағының тік жылжығаны анықталды және оның жай-күйіне баға берілді.

Радарлық интерферометрия ЖҚЗ алынған мәліметтермен жұмыс істеуге, үшөлшемді модельдерді, тіліктер мен жергілікті жер профильдерін құруға мүмкіндік береді. Ғарыштық радарлы бақылау нәтижелері бойынша жер беті жерасты өндіру учаскелерінің үстінен бірқатар шөккен жергілікті ошағы белгіленген. Қазіргі уақытта осы учаскеде жер бетіне бақылау жүргізілуде. Геодинамикалық полигондардағы мұндай геомеханикалық бақылау мен зерттеулер жер қыртысының тік қозғалысын зерттеуге жағдай тудырады.

Ғарыштық мониторинг артықшылықтары, ең алдымен, дәстүрлі геодезиялық түсіріліммен салыстырғанда өнімді болып келеді. Ғарыш мониторингі игерілген кеңістік үстінде (аумақты 3000 шаршы метрге дейін қамту) жердің алдын ала шөккенін көрсетеді. Әдіс үлкен экономикалық шығынды талап етпейді, далалық геодезиялық жұмыстарға қажеттілік жоқ.

Түйін сөздер: геомеханикалық мониторинг, ғарыштық мониторинг, геодинамикалық полигон, жер қыртысының қозғалысы, жерді қашықтықтан зондтау, интерферометрия, жердің жасанды серігі, репер, сандық модель.

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МОНИТОРИНГ СДВИЖЕНИЙ ОБЪЕКТОВ ЗЕМНОЙ ПОВЕРХНОСТИ ИНТЕРФЕРОМЕТРИЧЕСКИМ МЕТОДОМ

Аннотация. Геомеханический мониторинг – это система наблюдений состояния геологической среды, процессов сдвижения горных пород и земной поверхности, геомеханических и гидродинамических процессов в массиве горных пород, интерпретация результатов наблюдений, формирование суждения о состоянии массива в целом и прогноз параметров устойчивых откосов.

Для определения сдвижения земной коры месторождения Акбакай применялась технология наземной радарной интерферометрии, которая применяется только несколькими научно-исследовательскими институтами и организациями в мире.

В спутниковой радарной интерферометрии оперативность получения актуальной пространственной информации о земной поверхности является важным требованием, предъявляемым к современным данным дистанционного зондирования Земли, наряду с высоким пространственным разрешением, а также геометрической точностью. Именно оперативность является одним из основных преимуществ радиолокационных систем дистанционного зондирования Земли или синтезированный радар системой аппаратур.

Геомеханические мониторинги и исследования на геодинамических полигонах раскрывают широкие возможности изучения вертикальных движений земной коры.

В этой работе самым ключевым моментом является сканирование местности и объектов вокруг точки стояния сканера, т.е. сканирование специальных марок с максимальным разрешением, что позволяет получить облака точек. Технология применения наземной радарной интерферометрии для определения сдвижения земной коры применяется только несколькими научно-исследовательскими институтами и организациями в мире.

В спутниковой радарной интерферометрии оперативность получения актуальной пространственной информации о земной поверхности является важным требованием, предъявляемым к современным данным дистанционного зондирования Земли, наряду с высоким пространственным разрешением, а также геометрической точностью. Именно оперативность является одним из основных преимуществ радиолокационных систем дистанционного зондирования Земли или синтезированной радар аппаратурой систем.

Геомеханические мониторинги и исследования на геодинамических полигонах раскрывает широкие возможности изучению вертикальных движений земной коры. Благодаря микроволновому радиодиапазону, используемому в радиолокации, данные служат источником уникальной информации о земной поверхности. Космический радиолокационный мониторинг просадок, вызванных разработкой месторождений, успешно осуществляется за рубежом и в Казахстане.

На месторождениях геодезические наблюдения ведутся два раза в год (весной и осенью) и проводятся дополнительные сейсмологические измерения. Для получения надежных данных необходимо одновременно с геодезическими наблюдениями вести в мониторинговом режиме космическую радиолокационную интерферометрическую съемку территорий месторождений, позволяющую регулярно получать поле смещений земной поверхности с высокой точностью.

На основе обработки радарных снимков, полученных космическим агентством из искусственных спутников Земли (ИСЗ), определены вертикальные сдвижения территории объекта и дана оценка ее состоянию.

Радарная интерферометрия создает возможность работать данными, полученных ДЗЗ, создания трехмерных моделей, разрезов и профилей местности. По результатам космических радарных наблюдений

установлен ряд локальных очагов оседаний земной поверхности над участками подземной добычи. В настоящее время на этом участке местности ведутся наземные наблюдения. Такие геомеханические наблюдения и исследования на геодинамических полигонах раскрывает широкие возможности изучению вертикальных движений земной коры.

Преимущества космического мониторинга состоят, прежде всего, в его большей производительности по сравнению с традиционной геодезической съёмкой. Космический мониторинг показывает заблаговременно оседания поверхности над выработанным пространством (охват территории до 3000 кв.м.). Метод не требует больших экономических затрат, нет необходимости в полевых геодезических работах.

Ключевые слова: геомеханический мониторинг, космический мониторинг, геодинамический полигон, движения земной коры, дистанционного зондирования Земли, интерферометрия, искусственный спутник Земли, репер, цифровой модель.

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