EARTH SCIENCES

IDENTIFICATION OF LOCAL GRAVITY ANOMALIES BY TRANSFORMATION AND FILTRATION METHOD

İsgandarov E.,
Associate professor,
Department of "Geophysics" Azerbaijan State Oil and Industrial University (ASOIU), Azerbaijan, Baku
Zhang J.
Master student,
Department of "Geophysics" Azerbaijan State Oil and Industrial University (ASOIU), Azerbaijan, Baku
https://doi.org/10.5281/zenodo.17738487

Abstract

Gravity exploration, being one of the geophysical exploration methods, makes it possible to study the structure of the earth's crust and its sedimentary strata. The use of gravity exploration is based on the study of the distribution of the gravity field measured on the earth's surface, which is complex, since it consists of local and regional gravity components. These gravity components correspond to local and regional geological structures. We are mainly interested in local gravity anomalies, which can be associated with oil and gas deposits, minerals and various ore minerals. To identify local anomalies, various transformation methods are used, which are the process of transforming the observed complex in order to separate it into constituent elements. At the Department of Geophysics of the Azerbaijan State Oil and Industry University (ASOIU), the Force-Fortran program Avertrans has been developed, which allows performing transformation by the method of averaging over an area with various transformation parameters. As is known, the process of transformation of a potential field can be considered as a process of frequency filtering, various methods of which are collected in the menu of the world-famous program Surfer of the Golden Software company. However, these filters are intended mainly for suppressing signal noise and calculating derivatives and gradients of various orders and directions, and the parameters of these filters are not suitable for identifying local anomalies of the potential field, in particular, gravitational field. The article presents the results of applying the developed program Avertrans on a model gravitational field, as well as ways of using the filtering capabilities of the Surfer program to identify local anomalies of gravity using the example of a model gravitational field. The purpose of the research is to show the capabilities of the Avertrans program, as well as to develop a technique for applying the capabilities of the Surfer program to identify local anomalies of gravity.

Keywords: local anomaly, transformation, filtering, transformation radius, calculation algorithm, low-pass filter.

Introduction

Gravitational exploration is one of the methods of geophysics that currently successfully solves various geological problems for the purpose of prospecting and exploration of mineral deposits [14]. Gravitational exploration studies the structure of the earth's crust and its sedimentary strata based on the study of the nature of local and regional anomalies of the gravitational field. These components of the field are identified by transforming complex observed fields. There are various methods of transforming gravimagnetic fields, such as the graphical method, which is used in the case of a simple linear field along the profile, the method of averaging over an area or along a profile, the gradient method (or Saksov-Nigard), the method of higher derivatives, methods of analytical continuation of fields in the upper and lower half-spaces, etc. [11]. The initial data are the values of the gravity anomaly field in the Bouguer reduction, which will be further called the observed field.

The method of averaging over an area refers to statistical methods. The essence is that at each point of a uniformly quantized field, the average value of the field on the circumference of a circular palette is calculated. The radius of the circle depends on the geological task at hand, i.e. the larger the radius, the greater the depth of the study. The observed gravitational field (Bouguer anomaly) is the sum of the regional and local anomalies:

$$\Delta g_{ob} = \Delta g_{reg} + \Delta g_{loc} \quad (1)$$

From here:

$$\Delta g_{loc} = \Delta g_{ob} - \Delta g_{reg} \quad (2)$$

The regional component of the field is calculated using the following formula:

$$\Delta g_{reg} = \Delta g_{av} = \frac{\sum_{i=1}^{n} \Delta g_i}{n} \quad (3)$$

Here n is the number of points on the circumference of the circular palette; Δg_{av} is the average field value on the circumference, which is attributed to the center of the palette; Δg_i is the gravity value at the nodes of the circular palette.

Several radii can be used for averaging. Usually, this transformation method is performed on a computer using appropriate programs and algorithms [1-8, 13-14]. However, these methods are based on the palette method. To enter field values into a computer, the original field is initially quantized (discretized) by linear interpolation at the nodes of a square grid, usually 1x1 cm in size in the scale of the original map. Based on the calculation results, a regional anomaly map and a local gravity anomaly map are constructed, which are the initial data for interpretation.

Tools and methods

For the gravity field transformation on a computer, the Avertrans Force-Fortran program was developed at the Geophysics Department of the Azerbaijan State Oil and Industry University (ASOIU) [9]. This program allows transforming gravity-magnetic fields by the averaging method using two radii of a circular palette - the inner radius R_1 and the outer radius R_2. The values of the radii of the averaging palette depend on both the sizes of local anomalies and the depth of the studied anomaly-forming geological structures. According to the Avertrans program, the values of the observed gravity field and the sizes of the transformation area are first entered, which are then printed (to check the correctness of the data). According to the algorithm, the average field value is then calculated at each radius, and then the average value is calculated over two radii. The resulting average value is taken as the value of the regional field in the center of the palette. To calculate the local component of the gravitational field, the difference between the observed field value in the center of the palette and the calculated average value for the corresponding radii at each point of the discretized field is found. To obtain maps of local and regional anomalies according to the algorithm, the regional field is calculated once and the local gravity anomaly values are calculated another time. Based on the calculated and printed values of local and regional anomalies, maps of the local and regional fields are constructed using a graphical program.

At the beginning of the research, we compiled a model of the gravitational field in milligal isolines, which was discretized in the nodes of a square grid with a step of 1x1 cm in the map scale (1:100000) by linear interpolation. For visual representation, the original map was digitized in the "Digit" mode of the Surfer program to create a "grid". Based on this "grid", maps of the original gravitational field model were constructed in 2D and 3D versions in a modern interface (Fig. 1-2). As you can see, the section map is 1.0 mGal, and the gravity values increase from northwest to southeast in the range from -2 mGal to +23 mGal. The isolines, complicated by several local anomalies in the central part, are oriented mainly in the direction from southwest to northeast.

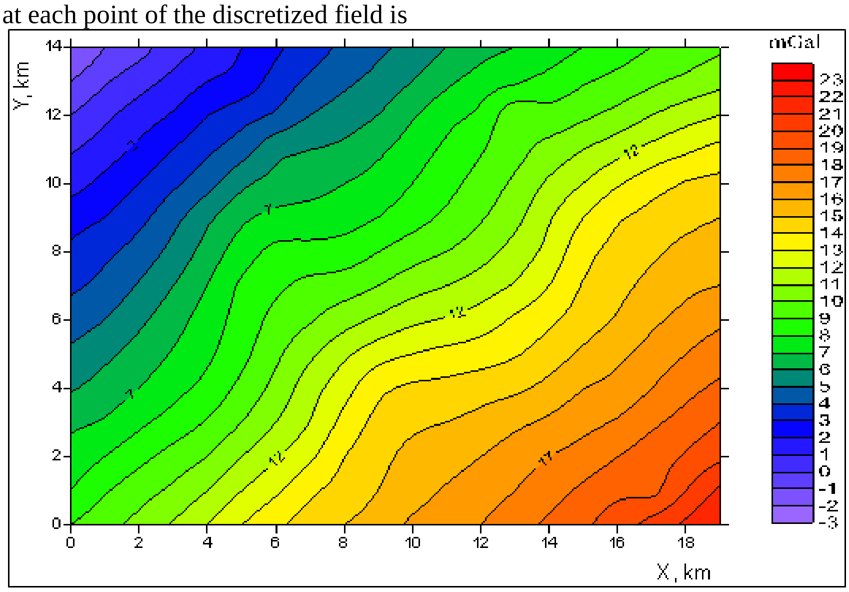

Fig. 1. Map of the digital model of the gravitational field in 2D version

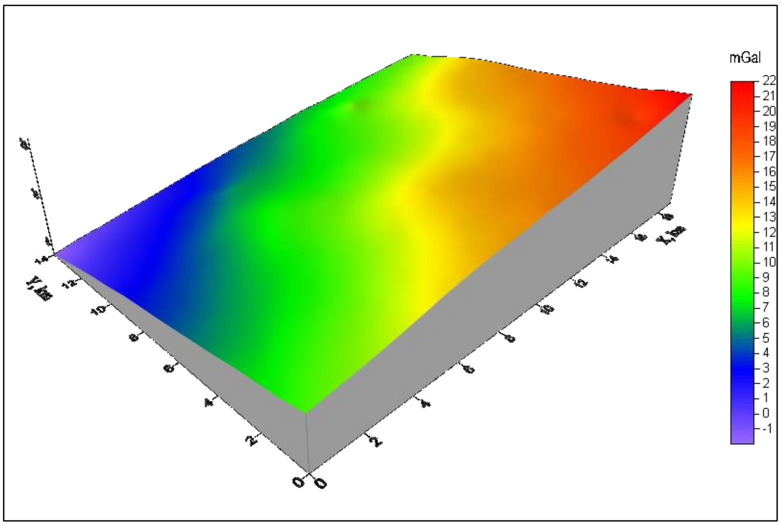

Fig.2. Map of the digital model of the gravitational field in 3D version

The discretized (quantized) values of this field (Fig. 3) were entered into the Avertrans program to calculate the values of the regional and local gravity field in the “Averaging” method (R_1= 2R and $R_2=\sqrt{R}$, R is equal to the quantization step 1km) (Fig. 4-5). Based on the calculated values of the regional gravity field, a map of the regional field was constructed in 2D and 3D versions (Fig. 6-7). As can be seen, the regional gravity anomaly smoothly increases from the northwest to the southeast, reflecting the regional structure of the proposed geological model. Below is a map of the local gravity anomaly in areal and spatial form constructed on the basis of the calculated values of the local gravity anomaly (Fig. 8-9). As can be seen, in the western, southern, northern and eastern parts of the original field, four clear positive local gravity anomalies (gravity maxima) with an intensity of approximately 0.5-0.7 mGal, oriented in different directions, are distinguished. In the rest of the original field, relative gravity minima of irregular shape with an intensity of approximately -0.2 mGal and oriented in different directions are distinguished.

As is known, the transformation of potential fields, in particular the gravitational field, can be considered as a process of frequency filtering [10], but in this case, instead of the usual signal frequency expressed in a unit of measurement in to the time unit, a spatial frequency is used, expressed in a unit of measurement inverse to the distance unit. As indicated above, we are interested in the "Averaging" transformation method. As a result of transformation by this method, the total field is divided into local and regional components. The filtering method is based on the frequency principle of signal extraction. The task is to extract a local anomaly of a given model gravity field using filtering methods. As is known, the Surfer program has a mode for performing signal filtering using various methods [12]. There are a large number of filtering methods here, which are divided into two groups: linear and nonlinear filtering methods, which consist of low- and high-frequency filters. However, as our practical analysis of these methods shows, it is impossible to extract a local anomaly of the gravity field using the existing set of filters. This is due to the fact that high-frequency filters use frequencies that are too high, which are associated with rough sections of isolines. Therefore, high-frequency filters do not allow extracting frequencies associated with local gravity anomalies. These frequencies are rather close to average frequencies, which are lower in value than noise frequencies. Low-pass filters retain frequencies that are too high and are associated with interference but not with local anomaly frequencies. It should be noted that of all the available filtering methods, only low-pass filters have the ability to manually select the averaging window size. And one filter, the "General User define filter," has the ability to change the filtering window parameters. The idea is that if you select the low-pass filter window parameters manually correctly, you can identify a regional gravity field anomaly. The local anomaly can be calculated by subtracting the regional component of the gravity field at the "grid" level from the observed field using the "Math" function of the Surfer program. The filter menu "Filtr" is used for

-2.0	-1.0	-0.4	0.5	1.2	2.0	2.8	3.5	4.2	4.8	5.3	6.0	6.7	7.0	7.5	8.0	8.5	9.0	9.5	9.8
-1.0	-0.1	0.6	1.3	2.0	2.3	3.4	4.2	4.8	5.3	6.0	6.8	7.4	7.8	8.3	8.9	9.3	9.8	10.2	10.7
0.0	0.8	1.5	2.1	3.0	3.6	4.1	5.0	5.5	6.0	6.9	7.7	8.2	9.9	9.3	9.8	10.3	11.0	11.6	12.0
0.9	1.5	2.2	3.0	3.8	4.5	5.8	6.0	6.2	6.8	7.5	8.2	8.9	9.6	10.3	11.0	11.6	12.3	12.8	13.3
1.6	2.3	3.0	3.8	4.6	5.8	6.3	6.6	7.0	7.4	8.0	8.7	9.4	10.2	11.2	12.0	12.9	13.6	14.1	14.3
2.6	3.0	3.7	4.7	5.8	6.8	7.3	7.4	7.6	8.0	8.6	9.2	9.9	10.7	11.9	13.0	13.9	14.3	14.7	15.0
3.2	3.8	4.4	5.3	6.4	7.5	8.3	8.3	8.4	9.0	9.6	10.0	10.6	11.4	12.3	13.7	14.3	14.8	15.3	15.5
3.8	4.3	5.1	6.0	7.0	8.2	8.8	9.3	9.5	10.0	10.6	11.0	11.5	12.1	13.0	14.1	14.7	15.3	15.8	16.0
4.5	5.0	5.8	6.6	7.5	8.4	9.3	9.9	10.6	11.2	11.8	12.1	12.5	13.2	13.8	14.5	15.1	15.8	16.3	16.8
5.2	5.8	6.4	7.1	7.8	8.7	9.8	10.8	11.8	12.6	13.0	13.3	13.5	13.9	14.5	15.2	15.8	16.4	17.0	17.6
5.9	6.4	7.0	7.7	8.3	9.3	10.3	11.6	12.6	13.8	14.2	14.3	14.6	14.8	15.3	16.0	16.3	17.0	17.7	18.2
6.8	7.1	7.8	8.4	9.1	10.0	11.0	12.0	13.3	14.3	14.8	15.0	15.3	15.8	16.2	16.7	17.1	17.8	18.4	19.0
7.4	8.0	8.7	9.4	10.0	11.0	11.9	12.8	14.0	14.7	15.3	15.6	16.0	16.5	17.0	17.4	18.0	18.6	19.1	19.8
8.0	8.9	9.6	10.2	11.0	12.0	12.8	13.8	14.4	15.0	15.6	16.1	16.5	17.0	17.6	18.2	18.8	18.6	20.0	21.2
9.0	9.7	10.3	11.1	12.0	13.0	13.8	14.5	15.0	15.4	16.2	16.5	17.0	17.6	18.2	18.8	19.6	20.4	21.2	22.0

Fig. 3. Initial data of the Avertrans program (values of the gravity anomaly of the models field in mGal units)

1.4	2.2	2.8	3.7	4.3	5.0	5.6	6.2	6.8	7.6	8.1	8.7	9.3	10.1	10.5	11.0
2.3	3.0	3.9	4.5	5.2	5.7	6.3	6.9	7.4	8.1	8.9	9.5	10.3	10.9	11.6	12.2
3.0	3.9	4.7	5.5	6.1	6.7	7.1	7.5	8.1	8.8	9.5	10.4	11.0	11.9	12.6	13.1
3.9	4.7	5.5	6.3	7.0	7.5	7.9	8.3	8.8	9.4	10.1	10.9	11.8	12.6	13.4	14.0
4.6	5.4	6.3	7.1	7.8	8.3	8.8	9.1	9.6	10.2	10.9	11.7	12.5	13.3	14.0	14.7
5.2	6.1	6.9	7.8	8.5	9.1	9.6	10.2	10.6	11.1	11.7	12.4	13.2	13.9	14.7	15.2
5.8	6.6	7.5	8.3	9.2	9.9	10.6	11.2	11.7	12.2	12.6	13.2	13.8	14.6	15.2	15.8
6.4	7.2	8.0	8.9	9.8	10.7	11.5	12.2	12.8	13.2	13.6	14.1	14.6	15.2	15.8	16.4
7.1	7.8	8.6	9.6	10.4	11.5	12.4	13.1	13.7	14.1	14.5	14.9	15.4	15.9	16.5	17.1
7.9	8.6	9.4	10.2	11.2	12.2	13.1	13.8	14.4	14.9	15.3	15.7	16.1	16.7	17.3	17.7
8.7	9.4	10.2	11.1	12.0	12.9	13.7	14.5	15.1	15.5	16.0	16.4	16.9	17.5	17.9	18.6

Fig. 4. Results of calculation by the Avertrans program (values of the regional gravity anomaly of the model

0.1	-0.1	0.2	-0.1	-0.2	0.0	-0.1	-0.2	0.1	0.1	0.1	1.2	-0.0	-0.3	-0.2	-0.0
-0.1	-0.0	-0.1	-0.0	0.6	0.3	-0.1	-0.1	0.1	0.1	-0.0	0.1	-0.0	0.1	0.0	0.1
-0.0	-0.1	-0.1	0.3	0.2	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.2	0.2	0.1	0.3	0.5
-0.2	0.0	0.3	0.5	0.3	-0.1	-0.3	-0.3	-0.2	-0.2	-0.2	-0.2	0.1	0.4	0.5	0.3
-0.2	-0.1	0.1	0.4	0.5	0.0	-0.4	-0.1	-0.0	-0.2	-0.3	-0.3	-0.2	0.4	0.3	0.1
-0.1	-0.1	0.1	0.4	0.3	0.2	-0.1	-0.2	-0.0	-0.1	-0.2	-0.3	-0.2	0.2	0.0	0.1
-0.0	0.0	0.0	0.1	0.1	-0.0	-0.0	-0.0	0.1	-0.1	-0.1	0.0	-0.0	-0.1	-0.1	-0.0
-0.0	-0.1	-0.2	-0.2	-0.0	0.1	0.3	0.4	0.2	0.1	-0.1	-0.2	-0.1	0.0	-0.0	-0.0
-0.1	-0.1	-0.3	-0.3	-0.1	0.1	0.2	0.7	0.5	0.2	0.1	-0.1	-0.1	0.1	-0.2	-0.1
-0.1	-0.2	-0.3	-0.2	-0.2	-0.2	0.2	0.5	0.4	0.1	0.0	0.1	0.1	-0.0	-0.2	0.1
0.0	-0.0	-0.2	-0.1	-0.1	-0.1	0.3	0.2	0.2	0.1	0.0	0.1	0.1	-0.1	0.1	-0.0

field in mGal units)

Fig. 5. Results of calculation by the Avertrans program (values of the local gravity anomaly of the model field in mGal units)

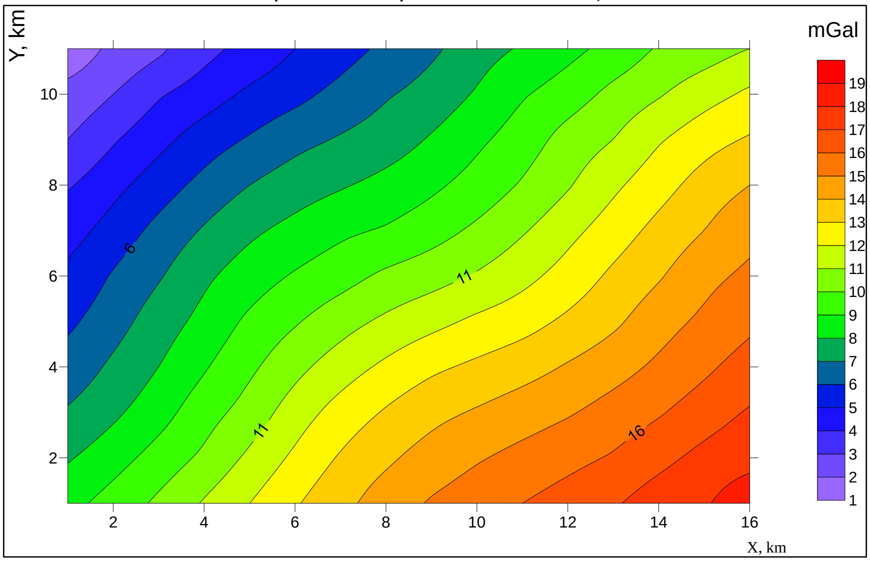

Fig. 6. Map of the digital model of the regional field in 2D version

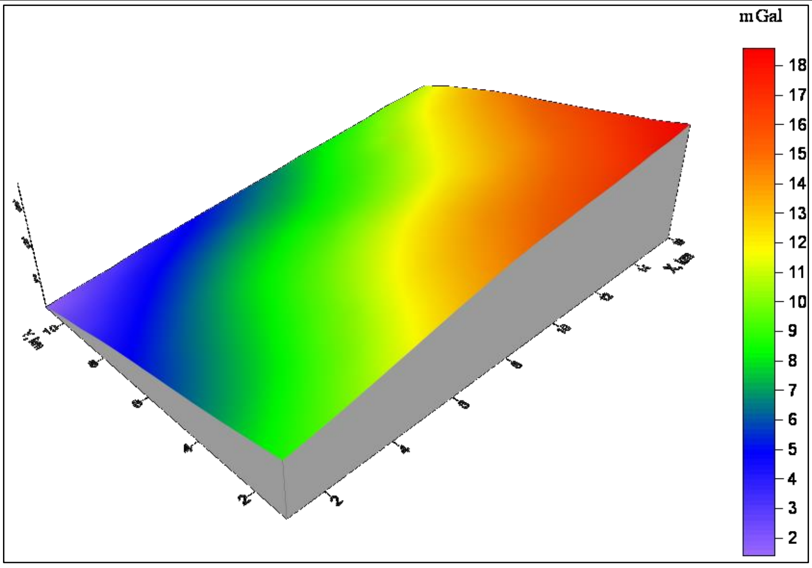

Fig. 7. Map of the digital model of the regional field in 3D version

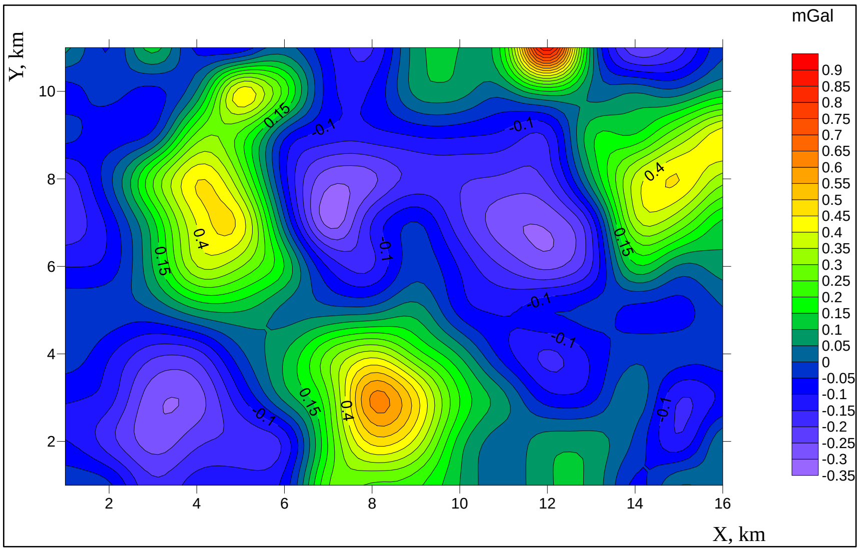

Fig. 8. Map of the digital model of the local field in 2D version

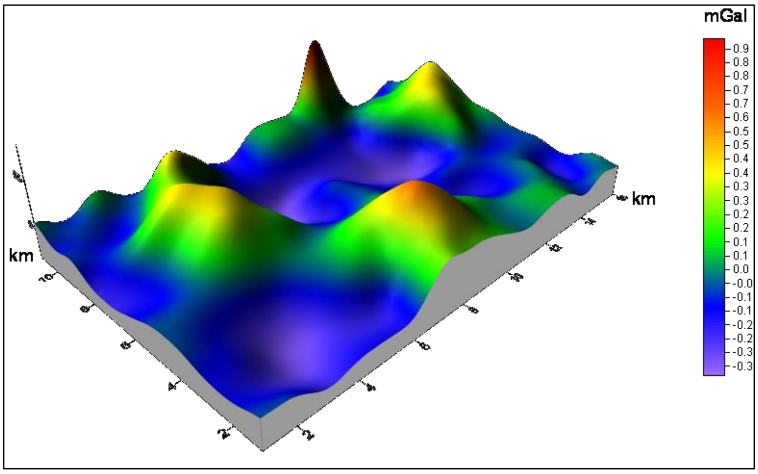

Fig. 9. Map of the digital model of the local field in 3D version

the filtering itself. It should be noted that this graphic program has a sufficient number of filters that allow you to calculate various gradients and derivatives of the potential field, which are widely used in solving various subtle geological and geophysical problems. But this article is about identifying the local gravity field anomaly itself using the filtering method. In accordance with this idea, low-pass filtering of the created “grid” of the gravity field model was performed with a window size of 21x21 pixels, corresponding to the size of the averaging palette with outer radius (Fig.10). The figure below shows the results of filtering with these parameters, i.e. map of the regional gravity component and local gravity component (obtained by subtracting the "grid" of the regional background from the "grid" of the observed gravity field) (Fig. 11-13). As can be seen, a map of the local anomaly was obtained, on which four gravity maxima with an intensity of about 0.6-0.7 mGal are clearly distinguished. Comparison of this map with the map of the local gravity anomaly obtained by the "Averaging" transformation method using the Avertrans program shows good agreement.

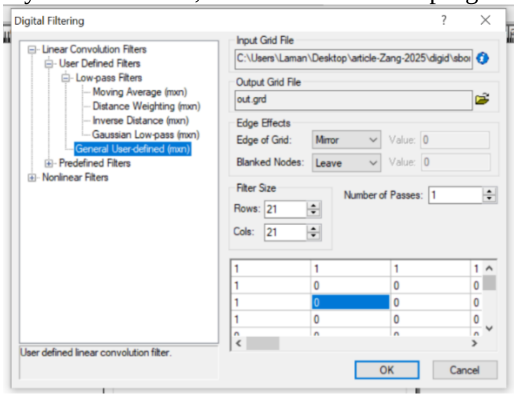

Fig.10. Selecting parameters for the filtering window

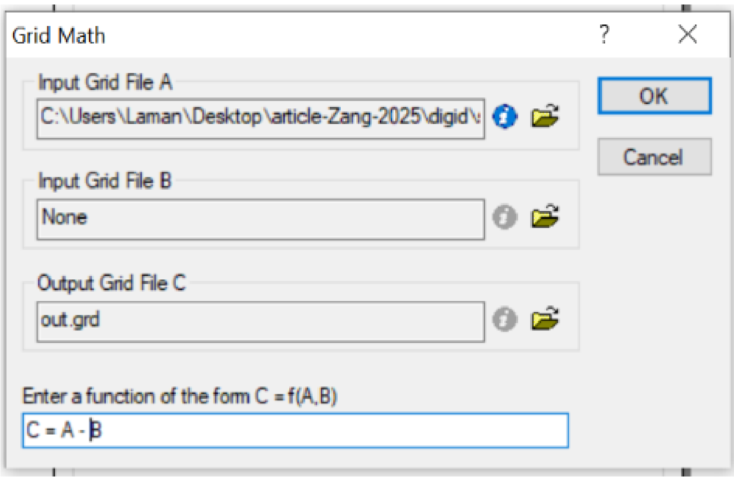

Fig.11.
Window for calculating the difference between the of the observed gravity field and grids of regional anomalies

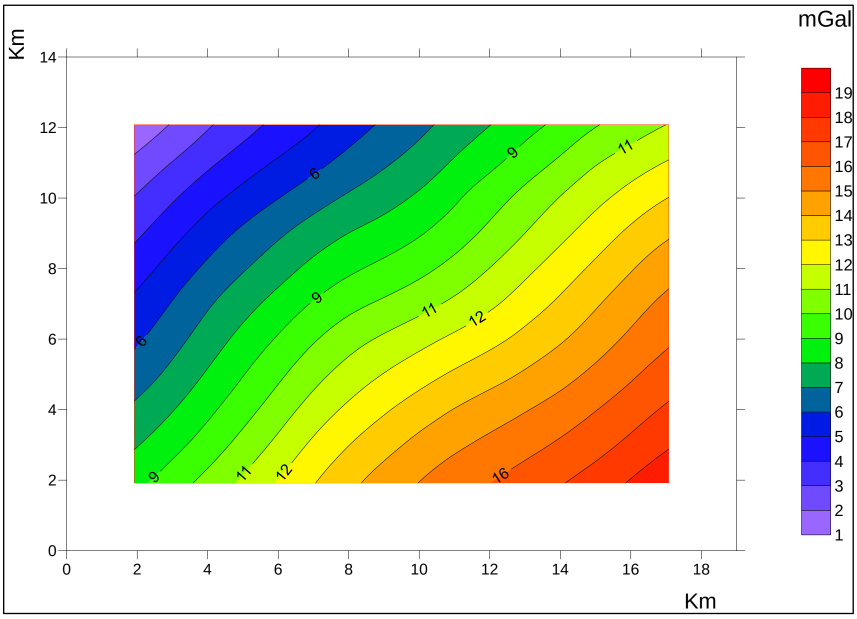

Fig. 12. Results of low-pass filtering using the Surfer program in the "User Defined Filters" group in the "General User define filter" tab (map of the regional component of the gravity field of the model).

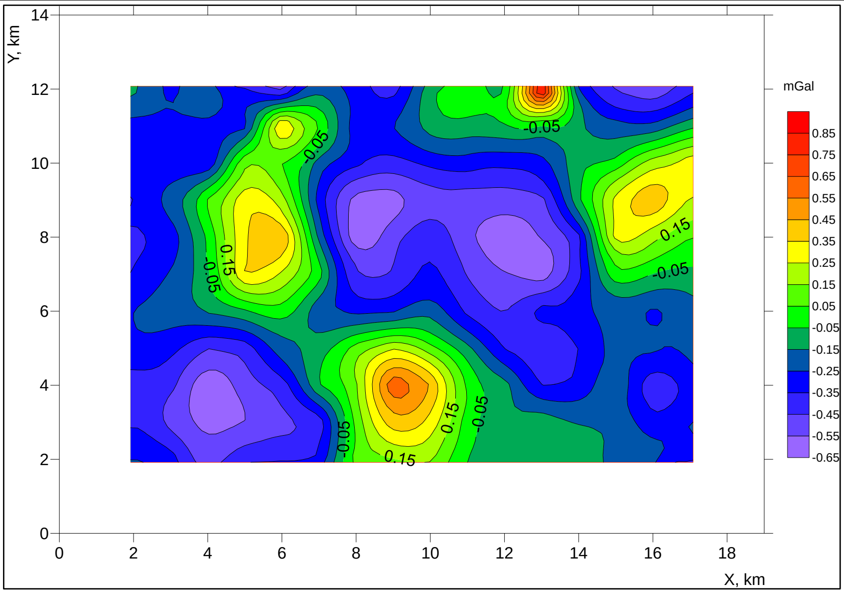

Fig.13. Map of the local component of the model's gravity field, obtained by subtracting the "grid" of the regional field (the result of low-pass filtering) from the "grid" of the observed gravity field of the model.

References:

1. Dolgal, A.S., Kostitsyn, V.I., Pugin A.V., Khokhlova, V.V. (2022). Vybor modeli Zemli dlja preobrazovanija gravitacionnyh anomalij v regional'nyh issledovanijah [Selecting an Earth Model for Transforming Gravity Anomalies in Regional Studies]. Geophysics, Mining Institute, Ural Branch of the Russian Academy of Sciences. 614007, Russia, Perm, 2-7 (in russian).

2. Dubovenko, Yu. I. (2011). On the resolution of reductions of gravity anomalies. Institute of Geophysics of the National Academy of Sciences of Ukraine, Kyiv, pp. 135-143 (in Ukrainian).

3. Iskandarov, E.H. (1998). Algoritm for effective transformation of gravitational field on the areas with complex composition. Geophisies news in Azerbaijan – bulletin, Baku, p.17-18.

4. Iskandarov, E.H. (2002). C.S.Mammadova C.S, Mahmudova V.M.. Gravity and electromaqnetik fields transformation. Azerbaijan international geophizikal conferens, Baku.

5. Iskandarov, E.H. (2010). Increasing the efficiency of transformation of gravitational fields in conditions of great depths. Abstracts. YII Azerbaijan international geophysics conference on the topic "Ways to increase the efficiency of geophysical research under active geodynamic conditions, such as the South Caspian Basin", Baku.

6. İskandarov, E.H., (2017). Digital processing of gravimagnetic data. Proceedings of Azerbaijan international geophysics conference. Management of Geophysics, Baku.

7. Iskandarov, E.H., You Yunlong You Liguo (2019). Transformation of gravitational anomalies by methods derivatives and gradients. Danish Scientific Jornal, 21, 13-16.

8. Isgandarov, E.H., (2021). Transformation of gravemagnetic anomalies. Proceedings of the International PARCECO scientific conference organized by the Azerbaijan-French University (UFAZ), operating under the Azerbaijan State Oil and Industry University, November 30 - December 1, Baku.

9. İsgandarov, E.H., Kirgizbayev, A.,Isgandarova, L.E.(2024). Transformation of gravi -magnetic anomalies on the computer. Italy's scientific journal Annali d'Italia, №53, pp.12-19, pdf, ISSN 3572-2436., https://doi.org/10.5281/zenodo.10869374

10. Mironov, V.S. (1980). Kurs gravirazvedki [Gravity Prospecting Course], Leningrad, Nedra (in russian)

11. Mudretsova, E.A., Veselova, K.E. (1990). Gravirazvedka [Gravity Prospecting], Handbook - Geophysics, 2nd edition, revised and enlarged, M. Nedra. (in russian).

12. Silkin, K.Y., (2008). Geoinformacionnaja sistema Golden Software Surfer 8 [Geographic information system Golden Software Surfer 8]. Textbook for high schools. Publishing and printing center of Voronezh state University, Surfer.pdf. 66 (in russian).

13. Tsimelzon, I.O., Amiraslanov, T.S., Sharifova, V.I. (1979). Ob jeffektivnosti ispol'zovanija transformacii gravitacionnyh polej metodom osrednenija v geoantiklinal'nyh ploshhadjah [On the efficiency of using the transformation of gravitational fields by the averaging method in geoanticlinal areas]. Scientific notes Azineftekhim, IX Series, 2, 17-21 (in russian).

14. Zhiyong, Li, Jonathan Li, Shilin, Zhou, Saied, Pirasteh (2015). Developing an algorithm for local anomaly detection based on spectral space window in hyperspectral image. Earth Science Informatics 8(4), DOI:10.1007/s12145-014-0200-4.

15. Znamensky, V.V. (1989). Obshhij kurs polevoj geofiziki [General Course in Field Geophysics], Textbook for Universities, M. Nedra. (in russian).