Methods and Tools for Interactive Adaptation of Digital Fields Using the System GeoBazaDannych

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Abstract. *Examples of interactive formation of digital models of geological objects in computational experiments that meet the intuitive requirements of the expert are given and discussed. Methodological and algorithmic solutions, special tools of the system GeoBazaDannych are noted, and the results of comparison with reference solutions in the complex The Generator of the geological model of the deposit (GGMD) are presented. The results of several methods of approximation and reproduction of the digital field, its interactive adaptation by means of the system GeoBazaDannych are considered and explained.*

Keywords: *digital geological model, system GeoBazaDannych, intelligent graphical visualization, interactive adaptation of digital fields, smart methods of computer model adaptation.*

1 Introduction

Geological modeling is an independent direction that includes the improvement of mathematical methods and algorithms, development of computer programs that provide a cycle of model construction, forming, filling and maintenance of databases [1], [2]. The corresponding software includes the loading from different sources and data preprocessing, correlation, creation of digital cubes of reservoir properties, interactive data analysis, visualization with the help of any type graphics, mapping. The data used in geological and geoecological models are a representative part of the geodata, which classify, summarize information about processes and phenomena on the earth's surface [3]. Methods and tools for developing, modifying of permanently operating computer-based geological models with built-in self-tuning tools are priority [2]. Herewith, an important component is the task of evaluating the adequacy and accuracy of the proposed digital models [4], [5]. The key issues are automation of adaptation of models taking into account continuously incoming additional data, as well as a revision of the results of processing the initial information using new interpretation methods [3], [6].

Possible options, methodological solutions, and software tools that allow you to confirm the validity of interpretations, visualize and obtain numerical values of errors calculated by different methods of intellectual data processing results included and used in computer geological models are discussed below. For illustrations, the key task of forming and processing digital fields used in computer models is selected. In particular, we discuss the proposed methods that have been tested for solving different applied problems, as well as implemented in the interactive computer system GeoBazaDannych [7] specialized algorithms for calculating approximating digital fields.

The interactive computer system GeoBazaDannych is the complex of intelligent computer subsystems, mathematical, algorithmic and software for filling, maintaining and visualizing databases, input data for simulation and mathematical models, tools for conducting computational experiments, algorithmic tools and software for creating continuously updated computer models. The software packages implemented on the system GeoBazaDannych platform can be found in the publications [8] – [14]. By means of the system GeoBazaDannych, it is possible to generate and visualize digital descriptions of spatial distributions of data on sources of contamination, on the geological structure of the studied objects; graphically illustrate solutions to problems describing the dynamic processes of multiphase filtration, fluid migration, heat transfer, moisture, and mineral water-soluble compounds in rock strata; design and implement interactive scenarios for visualization and processing the results of computational experiments. GeoBazaDannych subsystems allow you to calculate and perform expert assessments of local and integral characteristics of geological objects and ecosystems in different approximations, calculate distributions of concentrations and mass balances of pollutants; create permanent models of oil production facilities; generate and display thematic maps on hard copies.

The main components of the system GeoBazaDannych [7], [8]:

- the data generator Gen_DATv;
- the generator and editor of thematic maps and digital fields

Gen_MAPw;

- modules for organizing the operation of geographic information systems in interactive or batch modes;
- the software package Geo_MDL – mathematical, algorithmic and software tools for creation of geological models of soil layers, multilayer reservoirs;
- modules for three-dimensional visualization of dynamic processes of distribution of water-soluble pollutants in active soil layers;
- software and algorithmic support for the formation and maintenance of permanent hydrodynamic models of multiphase filtration in porous, fractured media;
- the integrated software complex of the composer of digital geological and geoecological models (GGMD).

Integration of the capabilities of various geographic information systems (GIS) and GeoBazaDannych is provided by a wide range of tools of the system for importing and exporting data, images, and functions. Several non-standard solutions that are recognized as difficult for all geodata processing packages are discussed below. The examples of approximation and reconstruction of the digital field, its interactive adaptation by means of the system GeoBazaDannych and evaluation of the accuracy of results using the tools of the GGMD complex illustrate the unique capabilities of the developed methods and software. Using the tools of the GGMD complex ([15], [16], [17]), estimates of the accuracy of digital field reconstruction are obtained and illustrated with graphics.

2 Examples of Interactive Adaptation of Digital Fields

The specific capabilities of the algorithms implemented in the system GeoBazaDannych for interactive preparation and adaptation of digital parameter distributions in relation to the tasks of composing computer models of geological objects are illustrated by examples using the results of [15]. At the same time, we will not consider typical graphic objects (pyramids, parallelepipeds, cylinders, cones). The reason is that three-dimensional geometric patterns can be processed separately in the system GeoBazaDannych. A special module of the system can be used to restore surfaces when the digital field is not calculated using the approximation method on the selected sections, but is filled in with the calculated values of functions from the template library (by the generator of defining functions) [7].

Also, to demonstrate the special capabilities of the system GeoBaza-Dannych, in addition to the perturbations of the type (2) considered in [15], perturbations simulating a plateau and a split are introduced. They are set by expressions (1) – (3):

$$fH(x\_, y\_) := cos(\pi x/2) + cos(\pi y/2),$$

$$fHill2(x,y) = \begin{cases} fH(x,y), -1 \leq x \leq 1 \cap -1 \leq y \leq 1 \cap fH(x,y) \leq 0.6, \\ 0.6, -1 \leq x \leq 1 \cap -1 \leq y \leq 1 \cap fH(x,y) > 0.6, \end{cases} \tag{1}$$

$$fHill5(x,y) = \begin{cases} fH(x,y), -1 \leq x \leq 1 \cap -1 \leq y \leq 0, \\ 0, \end{cases} \tag{2}$$

$$fHill6(x,y) = \begin{cases} fH(x,y), -1 \leq x \leq 1 \cap -1 \leq y \leq 0 \cap \\ \qquad -1 \leq x+y \cap x+y > 0, \\ 0. \end{cases} \tag{3}$$

The specific expression of the analytic description of the reference function and its graphical visualization is given below.

The task of reconstruction of the grid function involves calculating the values of the approximating function at regular grid points from the values of randomly located experimental data points (observations), i.e. creating a regular array of Z values of node points from an irregular array of (X,Y,Z) values. The term irregular array of values means that the X, Y coordinates of data points are distributed irregularly across the function definition area.

The procedure for constructing a regular network of level values and restoring the grid function is an interpolation or extrapolation of values from a collection of scattered sets of source points and values of surface levels in them to uniformly distributed nodes in the study area. Methods for restoring grid functions and the corresponding algorithms are implemented in several specialized computer graphics and GIS packages. They can be divided into two classes: exact and smoothing interpolators [18], [19]. In fact, the method falls into a particular class depending on the user-defined settings when performing value calculations. Most methods for restoring the function and constructing a digital field are based on calculating weighted coefficients that are used to weigh the values of the measurement data at the nearest points. This means that, all other things being equal, the closer the data point is to a network node, the more weight it has in determining the value of the function being restored at that node.

It should be understood that restoring a grid function does not imply finding a single solution to a certain mathematical problem. Subjective opinion and expert qualifications are factors that are always present in such activities [4]. Therefore, for constructing digital models, it is important to have tools for interactive data processing, simulation of possible situations for obtaining and correcting input information, and modules for mathematical processing and statistical analysis ([18], computer algebra system, for example Wolfram *Mathematica*). The multi-format data exchange tools mentioned above is required for simultaneous work in multiple software environments. It is important for the user to have tools that allow them to play with the source data and compare the results with the prepared reference models. How this is implemented in the system GeoBazaDannych is described below, the corresponding preparatory actions in the GGMD complex are described in detail in [15], [16].

To illustrate the techniques of interactive work in GeoBazaDannych subsystems, the surface is used below, the analytical description of which is as follows

$$
\begin{gathered}
fOriginA(x,y) = zBasic(x),\\
zSurf7n(x,y) = fOriginA(x,y) + 2.5+\\
+3.5\cdot fHill6(0.02\cdot(x-100), 0.03\cdot(y-115))+\\
+3.5\cdot fHill2(0.04\cdot(x-80), 0.03\cdot(y-40))+\\
+2\cdot fHill5(0.04\cdot(x-145), 0.05\cdot(y-40))-\\
+1.5\cdot fHill(0.05\cdot(x-225), 0.02\cdot(y-145))-\\
-3\cdot fHill(0.04\cdot(x-220), 0.03\cdot(y-40)).
\end{gathered}
\tag{4}
$$

As noted above, in contrast to models (5) and (6) [15], forms with simulated plateau (fHill2) and splits (fHill5, fHill6) have been added. The splits are oriented in the plan (projection on the horizontal plane) as follows: one along the 0X axis, the second in the diagonal direction. The scale and dimensions in the plan (the boundaries of the area on the X0Y plane) are preserved. Moreover, the same observation profiles and points with measurements on the profiles are used below. The illustrations are shown on figure 1. Shown on figure images of surface zSurf7n(x,y) give an aggregate vision of this surface. Individual details can be studied on the contour map with density map (color filling of intervals) on figure 2. We emphasize attention on fragments of the zSurf7n surface, namely, perturbations fHill2, fHill5, fHill6. Such fragments cannot be reproduced using standard methods for restoring digital fields.

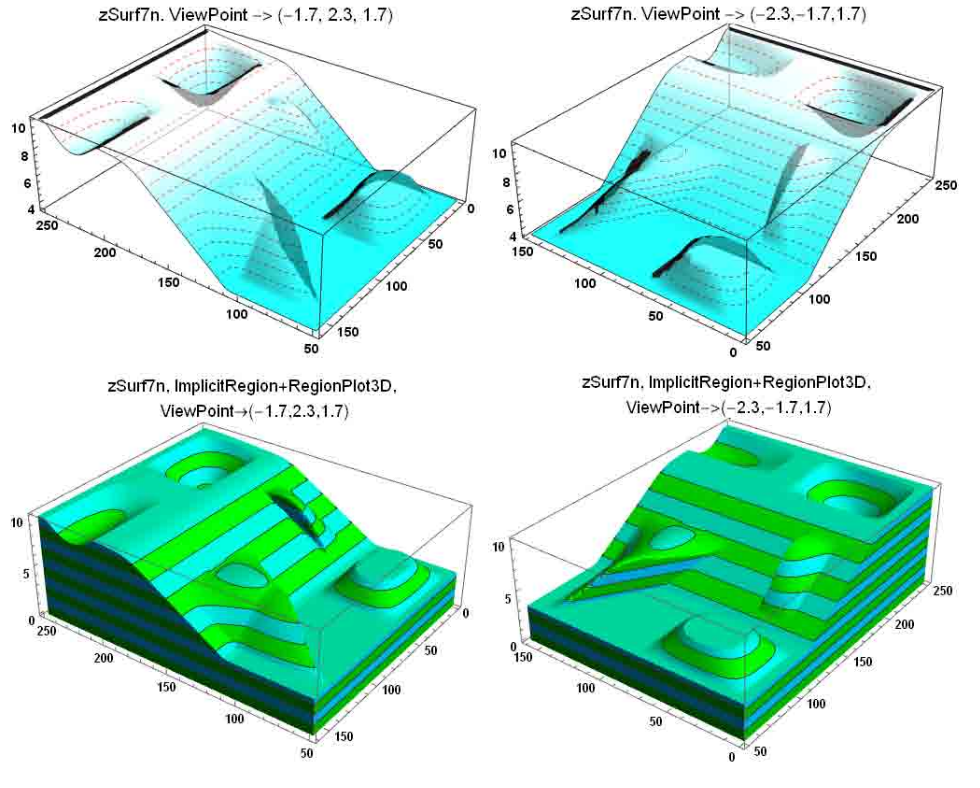

Figure 1: Zsurf7n surface and volume graphs

Illustrations on figures 3 – 8 show examples of possible solutions using the methods of adjustment distributions in the system GeoBazaDannych, and for this purpose, the steps of simulating observations and restoring the distribution over a scattered set of points with measurements are performed. The corresponding results obtained in the GGMD complex are shown on the isolines map on figure 3. The measurement points are shown as on the figures of [15], they are given for different observation profiles by different primitives, and the centers of the perturbation forms

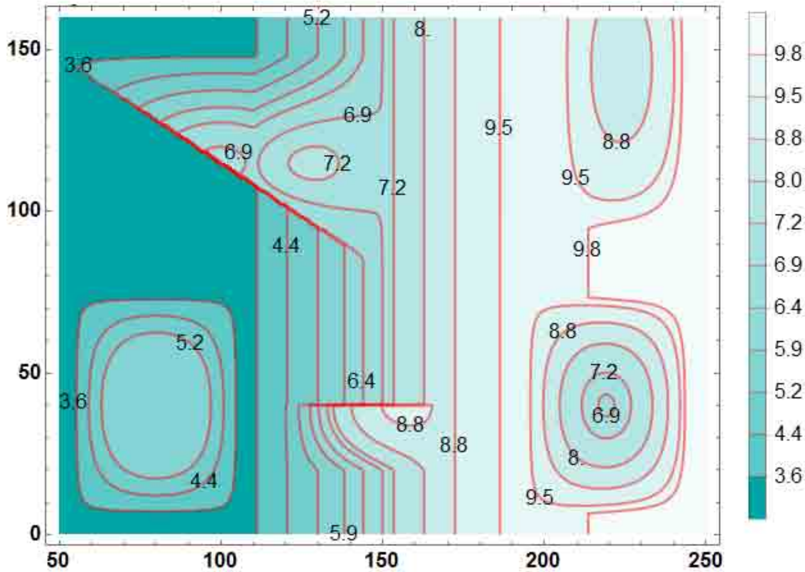

Figure 2: Isolines and density map of digital field of zSurf7n function

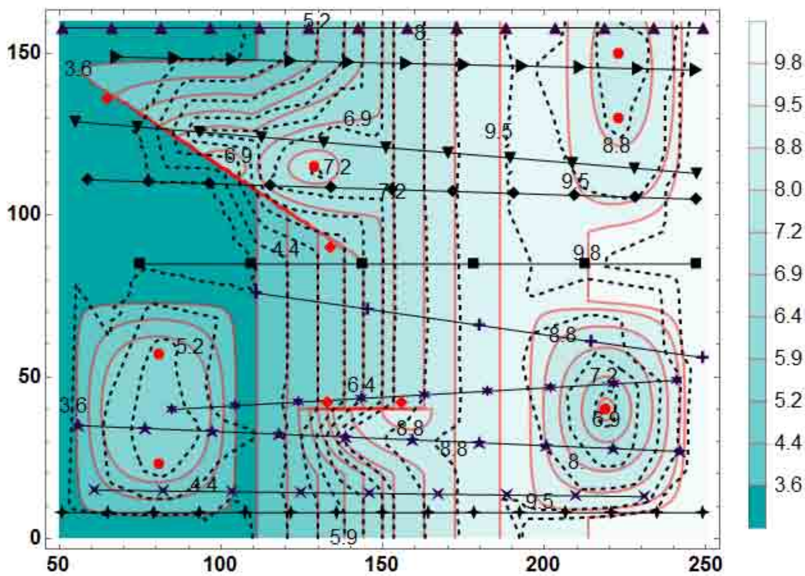

Figure 3: Isolines of the digital fields of the reference and restored distributions

are marked with circles. On maps, the isolines of the reference field are given as solid red lines; to the restored field, they are dashed black lines. There was no goal to choose a good system of profiles, they are formed sketchily, about how often designers do this. The reconstructed field is obtained by the 2nd-order interpolation method in Wolfram *Mathematica*. The implementation features are described in [5], note that in *Mathematica*, when working with irregularly placed data points, interpolation can only be performed using the 1st order method.

How to understand the illustrations shown on figures 4 – 8? In this case, the task is to correct the digital fields obtained via the approximation algorithm by using such GeoBazaDannych elements as subdomain, selected, split, and boundary conditions [7]. In fact, it is an interactive intellectual adaptation. To get results in the system GeoBazaDannych, the data of measurements on profiles and control points in the GGMD are exported to an Xls file that is imported into the Gen_MAPw. The corresponding illustration is given on figure 4, where the profiles, points of observation are shown; the values of measurements are displayed near their primitives. In the database, values are stored with machine precision, for brevity, the output of the map is made in the format of a single significant number after a decimal point.

Using the mentioned initial data, in Gen_MAPw obtained the results of digital field reconstruction by spline approximation of standard GeoBazaDannych's method. The results are shown on figures 5, 6. These results (the use of standard mathematical methods) should not be commented on, because in the practice of creating computer models, they are often such, although in fact they are not suitable for use.

The possibilities of adapting digital fields in Gen_MAPw are illustrated in figures 7, 8. The boundary of the area, the calculated grid is not changed (the same as above), the boundaries of sub-domain, inclusion, and the contour-split are entered. The concepts of subdomain, inclusion, and contour-split in the system GeoBazaDannych assume the implementation of the corresponding modules for processing source data, which are described in [7]. Here, only a few examples of their use are shown. Selected section provides autonomous calculation in nodes within these sub-domains. Points that belong to these regions with measurements outside the Selected sections are not taken into account. Plots (marked with horizontal hatching) have attributes that identify the areas bounded by them as inclusions. Sections (marked with horizontal hatching) has attributes that identify the area bounded by them as inclusion. In inclu-

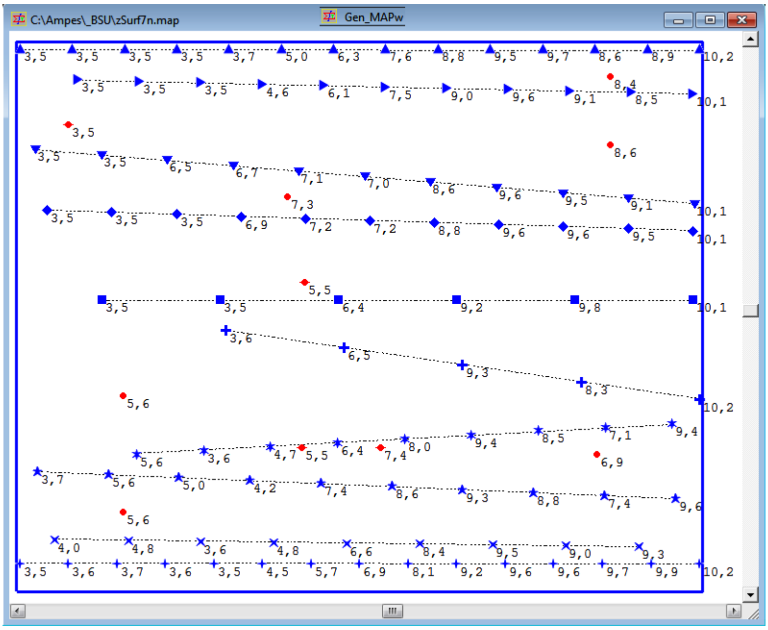

Figure 4: Results of exporting points with measurements from the GGMD to the Gen_MAPw

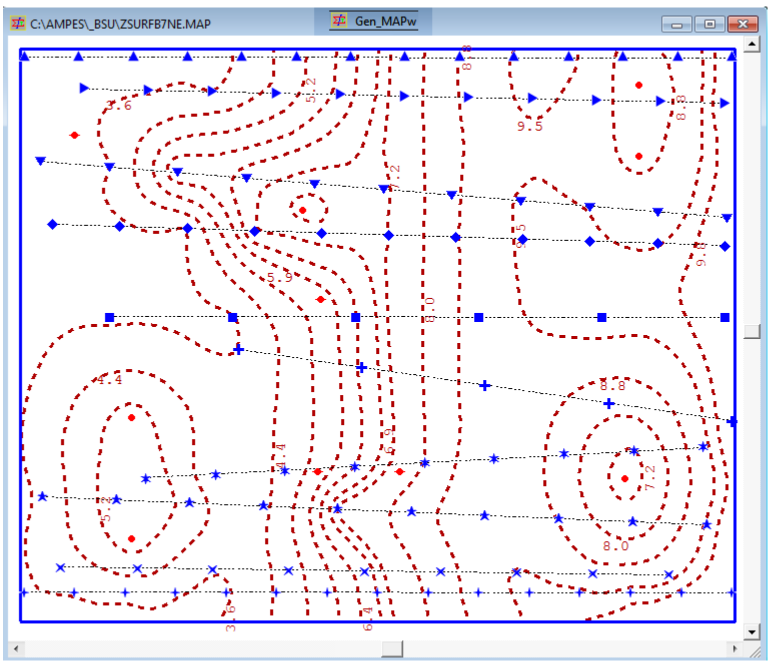

Figure 5: Isolines of the restored field in the Gen_MAPw

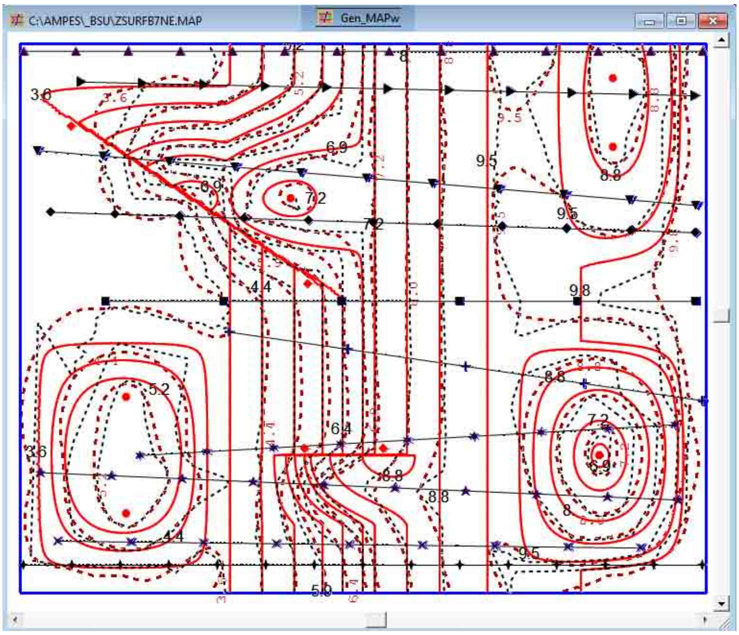

Figure 6: Comparison of the GGMD and Gen_MAPw fields isolines

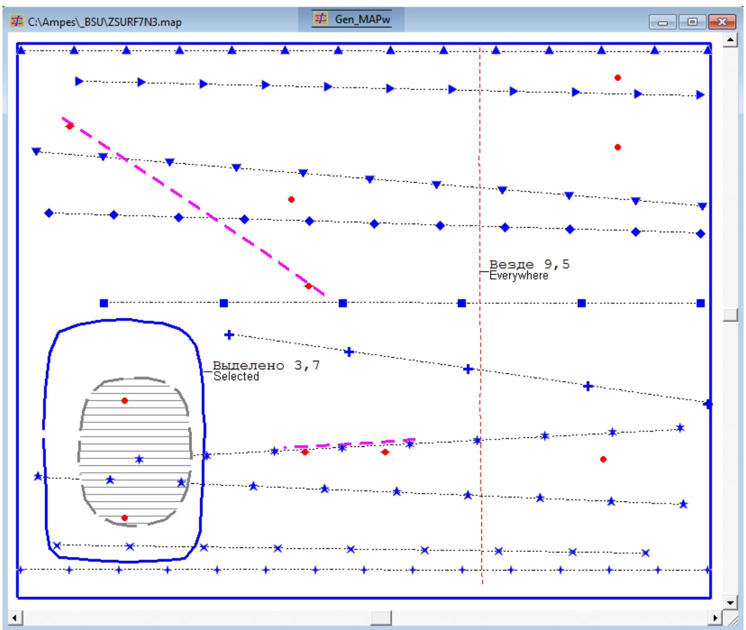

Figure 7: Comparison of the GGMD and Gen_MAPw fields isolines

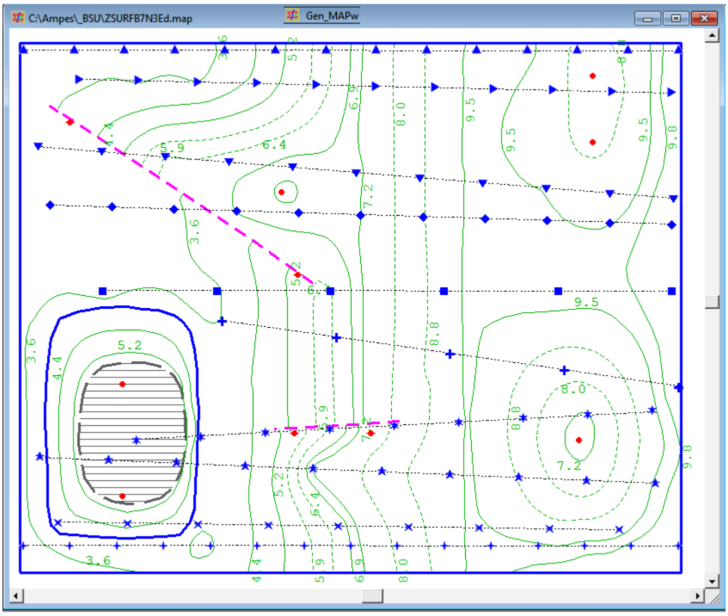

Figure 8: Comparison of the GGMD and Gen_MAPw fields isolines

sions, an autonomous calculation of the digital field is also performed, and points with measurements that get inside give their values to the border, and they are taken into account in the external part.

The input map for Gen_MAPw: subdomains, inclusions, splits, conditions is shown on figure 7. The corresponding results of restoring the digital field and isolines of the resulting distribution are shown on figure 8. The effects are obvious, and the accuracy of the reference increases significantly.

It should be noted that the initial capabilities of the system GeoBaza-Dannych have been significantly expanded in recent years. This was achieved by integrating and addition the system with the tools of the GGMD complex and the functions of the computer algebra system. In the current state, the system GeoBazaDannych provides users not only with the means to solve specific industrial tasks, but also with the possibility of scientific research on new methods of analysis and processing of initial data and used computer models. In particular, for the above problem, error estimates are obtained using the method described in [5]. We do not give specific digits here, because the errors of the so-calculated adapted field are comparable to the accuracy of obtaining grid functions, and these errors are an order of magnitude lower than in the unadapted field.

3 Conclusion

The article discusses the questions of instrumental filling and use of the interactive computer system GeoBazaDannych. The results of intellectual processing of data included and used in computer geological models are presented and discussed.

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