Revista Minelor – Mining Revue
ISSN-L 1220-2053 / ISSN 2247-8590
vol. 31, issue 3, pp. 104-111, selected paper from the First International EnviroMining Virtual Conference 2025

METHODS OF EVALUATING THE DEPTH AND DIMENSIONALITY OF GEOLOGICAL STRUCTURES BASED ON GEOPHYSICAL PARAMETERS MEASURED AT THE LAND SURFACE

Laurențiu ASIMOPOLOS[1], Natalia-Silvia ASIMOPOLOS[2], Adrian-Aristide ASIMOPOLOS[3]*

[1]Geological Institute of Romania, Bucharest, Romania, asimopolos@gmail.com
[2]Geological Institute of Romania, Bucharest, Romania, asi_nata@yahoo.com
[3]Polytechnic University of Bucharest, Faculty of Transportation, Romania adrian.asimopolos@gmail.com

DOI: 10.2478/minrv-2025-0033
received – 23.01.2025 / revised – 10.02.2025
accepted – 18.02.2025 / published – 22.09.2025

Abstract: *The depth and size of the geological structures, affected by tectonic elements (faults, fractures, cracks), can be determined by various methods. In the paper we present applications of moving averaging with variable window, polynomial trend surfaces and hypersurfaces, the variation of the generalized Pearson coefficient as well as their combinations for the 2D and 3D cases. The geophysical parameters measured at the ground surface are transposed into a rectangular grid, using interpolation formulas and software programs. The values in the grid nodes, together with latitude and longitude, represent the input data for the programs performed by authors and presented in the paper. If we also have data of geophysical parameters measured at different depths, we can also introduce the depth into the input data. Thus, we will have three independent parameters and a dependent geophysical parameter. By running specific programs we obtain the equations of trend surfaces or hypersurfaces, for different degrees, chosen according to the depth of the geological sources investigated. Thus, we obtain 2D, residual and trend maps for different degrees of the polynomials that are equivalent to different investigation depths. Similarly for 3D space, if we have geophysical data measured in depth.*

Keywords: *geophysical parameters, polynomial trend surfaces*, *hypersurfaces, moving averaging, Pearson coefficient, tectonic elements*

1. Introduction

There are various methods for achieving this separation of gravimetric anomalies. This paper presents some examples of the use of the moving average method and the polynomial trend surfaces. In particular, we presented the results of the mobile mediation with different windows compared to the trend surfaces with different degrees, for a case study in Vrancea seismogenic area. Polynomial trend surfaces analysis contributes to the recognition, isolation and measurement of trends that can be calculated and represented by analytical equations, thus achieving a separation in regional and local variations. The analytical expressions of the polynomial trends based on the least squares method were calculated, highlighting the regional trend caused by the deep structures.

Calculating the residual values resulting from the difference between the initial values and the trend values from the network nodes used, we highlighted the superficial local effects. We also obtained information about the regional trend caused by geological structures at medium and large depths, by calculating the difference between gravity parameters, obtained with different moving average windows or tendency surfaces with different degrees, interpolated in same network. In the bibliographic references [1] - [11] are found the theoretical premises of the methodology used in this work, which guided us in the development of the related software programs, which we applied for WGM 84 gravimetric data, from the International Gravimetric Bureau [https://bgi.obs-mip.fr/].

[*] Corresponding author: Adrian-Aristide Asimopolos, Associate Professor PhD, Polytechnic University of Bucharest, Faculty of Transportation, Romania, contact details: Splaiul Independenței 313, București 060042, 0727345113

Revista Minelor – Mining Revue
ISSN-L 1220-2053 / ISSN 2247-8590 vol. 31, issue 3 / 2025
pp. 104-111

2. Methodology for filtering of geophysical data

2.1. The variation of the correlation factor

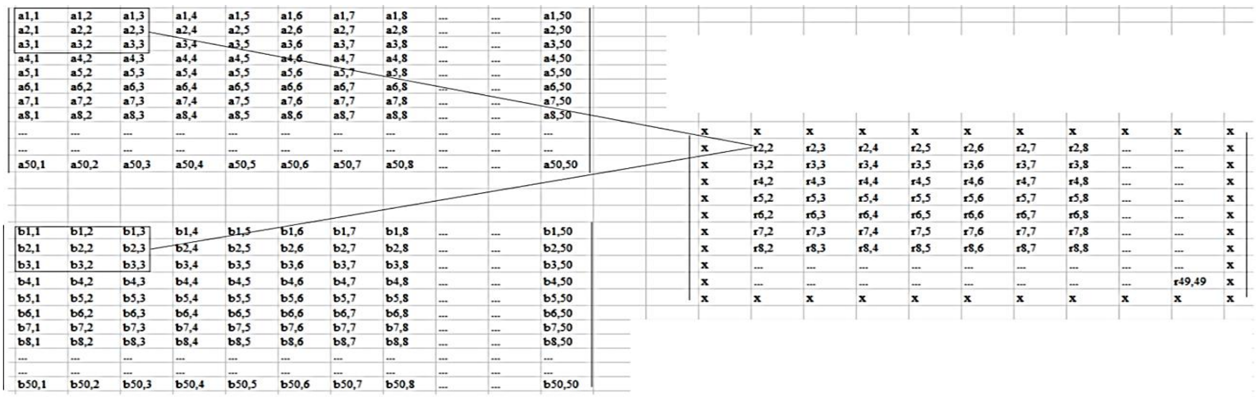
The variation of the correlation factor between two or more sets of parameters brings information for geophysical, geological and tectonic assumptions. This correlation factor can be calculated, similarly as in mobile averages with windows of different sizes, passing through the entire network of points, bringing information from depths.

The correlation factors may be good indicators for parameters that are related on common causes.

In this paper we have developed computational programs for the generalized correlation factor Pearson between two variables disposed in the surface (2D) or Euclidean 3D space. In the first case we used squares of different sizes and in the second case we used cubic windows. We scrolled these windows with a point until the entire parameter space passed. The values calculated successively for the correlation factor we reported in the centre of the used mobile window, thus obtaining sets of 1D, 2D or 3D values for it.

$$r_{z/w} = \frac{n\sum z_i w_i - (\sum z_i)(\sum w_i)}{\sqrt{\left[n\sum z_i^2 - (\sum z_i)^2\right]\cdot\left[n\sum w_i^2 - (\sum w_i)^2\right]}}$$

To study the variation of correlation we chose a rectangular window 9 values sides with 3 values on the X axis (East West) 3 values on the Y axis (North-South). This variation correlation factor we studied in 4 cases: from initial values of both parameters and between moving average calculated with 3 windows (with: 9, 25 or 49 values) of both parameters. To calculate the index variation of correlation between two parameters, which are determined in the same grid, I used a mobile window of 3 x 3 values, and the index is represented in the central node.



We calculated the index variation correlation between two parameters representing mobile mediations with different square windows (9, 25 or 49 values) of input geophysical parameters.

For 2D case we calculated in surface (latitude, longitude) the correlation factor variation between geophysical parameters (Bouguer anomaly, Free Air anomaly, Magnetic Anomaly, Geoid high, Ellipsoidal high, etc.). Also, for 3D case we calculated in space (latitude, longitude, depth) the correlation factor variation between geophysical parameters.

The functional links between the more sets of geophysical data are realized between the more cause phenomenon, represented by geological structures and a phenomenon-effect for each response function of the Earth. This information's can be integrated in 3D GeoModeler software together with all geological and geophysical parameters, obtaining a 3D model with scientific and economic importance.

The analysis with polynomial trends surface is a filtering method that helps to recognize, isolate and measure trends, by separating large variations from local variation trends. This separation is accomplished by adjusting the trend function to different values. We calculated the rezidual Bouguer anomaly after removed the trend plan and than the trend surfaces of degree 6, from data WGM2012 (from Bureau Gravimétrique International).

2.2. The analysis of polynomials trends surfaces

The analysis of polynomials trends surfaces are the old methods, based on the smallest squares method used for the smoothing of geological data, which many authors have dealt with: Vistelius (1961), Unwin

(1978), etc. Tendency analysis is part of the field of regression analysis satisfying the smallest square criterion. The difference between the calculated value of the trend surface at a certain point and the value observed at that point is the residual value. The sum of the squares of these residual values must be minimal according to the smallest square criterion. If the trend area is considered to be a regional or large-scale component, then the residual value should be considered as the local or small-scale component. Removing the regional trend has the effect of highlighting local components represented by residual values. The principles of surface trend analysis and surface hyperspace are applicable to surfaces and hyperspace in any number of dimensions. The simplest example of trend surface plan is the equation: z_{tend} = A + Bx + Cy, wherein x and y are independent variables and the dependent variable z is constants A, B and C is calculated as the sum of the deviations to a minimum. The deviation of a given point is the difference between the observed and calculated and can be expressed by: deviation = z_{obs} - z_{tend}. It follows that: deviation = z_{obs} - A - Bx – Cy

Expressing the sum of squared deviation's function Φ (A, B, C) we get:

$$\boldsymbol{\Phi(A,B,C) = \sum_{i=1}^{n}\left(z_i - A - Bx_i - Cy_i\right)^2}$$

where z_i are observed values at each point of coordinates (xi, yi) and n is the number of observation points.

If Φ (A, B, C) should be minimized, it is necessary that: $\boldsymbol{\frac{\delta\Phi}{\delta A} = \frac{\delta\Phi}{\delta B} = \frac{\delta\Phi}{\delta C} = 0}$

$$\frac{\delta F}{\delta A} = \sum_{i=1}^{n} 2\left(z_i - A - Bx_i - Cy_i\right)(-1) = 0 \qquad -\sum_{i=1}^{n} z_i + A\cdot n + B\sum_{i=1}^{n} x_i + C\sum_{i=1}^{n} y_i = 0$$

$$\frac{\delta F}{\delta B} = \sum_{i=1}^{n} 2\left(z_i - A - Bx_i - Cy_i\right)(-x) = 0 \qquad -\sum_{i=1}^{n} z_i x_i + A\sum_{i=1}^{n} x_i + B\sum_{i=1}^{n} x_i^2 + C\sum_{i=1}^{n} x_i y_i = 0$$

$$\frac{\delta F}{\delta C} = \sum_{i=1}^{n} 2\left(z_i - A - Bx_i - Cy_i\right)(-y) = 0 \qquad -\sum_{i=1}^{n} z_i y_i + A\sum_{i=1}^{n} y_i + B\sum_{i=1}^{n} x_i y_i + C\sum_{i=1}^{n} y_i^2 = 0$$

$$\begin{bmatrix} A \\ B \\ C \end{bmatrix} = \begin{bmatrix} n & \sum x & \sum y \\ \sum x & \sum x^2 & \sum xy \\ \sum y & \sum xy & \sum y^2 \end{bmatrix}^{-1} \times \begin{bmatrix} \sum z \\ \sum zx \\ \sum zy \end{bmatrix}$$

The quadratic trend surfaces or higher degree is calculated similarly. Following the same procedure, we conducted programs for the following trend surfaces (of 3nd degree and 6th degree):

For tendency cubic surface:

$$Z=A+BX+CY+DX^2+EXY+FY^2+GX^3+HX^2Y+IXY^2+JY^3$$

$$\Phi(A,B,C,D,E,F,G,H,I,J)=SUM(Z- A-BX-CY-DX^2-EXY-FY^2-GX^3-HX^2Y-IXY^2-JY^3)^2$$

$$\frac{\partial\Phi}{\partial A} = \sum\left(-2\left(Z - \mathrm{A - BX - CY - DX^2 - EXY - FY^2 - GX^3 - HX^2Y - IXY^2 - JY^3}\right)\right) = 0$$

$$\frac{\partial\Phi}{\partial B} = \sum\left(-2X\left(\mathrm{Z - A - BX - CY - DX^2 - EXY - FY^2 - GX^3 - HX^2Y - IXY^2 - JY^3}\right)\right) = 0$$

....

$$\frac{\partial\Phi}{\partial J} = \sum\left(-2\mathrm{Y}^3\left(\mathrm{Z - A - BX - CY - DX^2 - EXY - FY^2 - GX^3 - HX^2Y - IXY^2 - JY^3}\right)\right) = 0$$

It results:

$$An + B\sum X + C\sum Y + D\sum X^2 + E\sum XY + F\sum Y^2 + G\sum X^3 + H\sum X^2Y + I\sum XY^2 + J\sum Y^3 = \sum Z$$

$$A\sum X + B\sum X^2 + C\sum XY + D\sum X^3 + E\sum X^2Y + F\sum XY^2 + G\sum X^4 + H\sum X^3Y + I\sum X^2Y^2 + J\sum XY^3 = \sum XZ$$

....

$$A\sum Y^3 + B\sum XY^3 + C\sum Y^4 + D\sum X^2Y^3 + E\sum XY^4 + F\sum Y^5 + G\sum X^3Y^3 + H\sum X^2Y^4 + I\sum XY^5 + J\sum Y^6 = \sum Y^3Z$$

For tendency bi-cubic surface:

$$Z=A+BX+CX^2+DX^3+EY+FXY+GX^2Y+HX^3Y+IY^2+JXY^2+KX^2Y^2+LX^3Y^2+MY^3+NXY^3+OX^2Y^3+PX^3Y^3$$

we obtain:

$$\begin{vmatrix}
n & \Sigma X & \Sigma X^2 & \Sigma X^3 & \Sigma Y & \Sigma XY & \Sigma X^2Y & \Sigma X^3Y & \Sigma Y^2 & \Sigma XY^2 & \Sigma X^2Y^2 & \Sigma X^3Y^2 & \Sigma Y^3 & \Sigma XY^3 & \Sigma X^2Y^3 & \Sigma X^3Y^3 \\
\Sigma X & \Sigma X^2 & \Sigma X^3 & \Sigma X^4 & \Sigma XY & \Sigma X^2Y & \Sigma X^3Y & \Sigma X^4Y & \Sigma XY^2 & \Sigma X^2Y^2 & \Sigma X^3Y^2 & \Sigma X^4Y^2 & \Sigma XY^3 & \Sigma X^2Y^3 & \Sigma X^3Y^3 & \Sigma X^4Y^3 \\
\Sigma X^2 & \Sigma X^3 & \Sigma X^4 & \Sigma X^5 & \Sigma X^2Y & \Sigma X^3Y & \Sigma X^4Y & \Sigma X^5Y & \Sigma X^2Y^2 & \Sigma X^3Y^2 & \Sigma X^4Y^2 & \Sigma X^5Y^2 & \Sigma X^2Y^3 & \Sigma X^3Y^3 & \Sigma X^4Y^3 & \Sigma X^5Y^3 \\
\Sigma X^3 & \Sigma X^4 & \Sigma X^5 & \Sigma X^6 & \Sigma X^3Y & \Sigma X^4Y & \Sigma X^5Y & \Sigma X^6Y & \Sigma X^3Y^2 & \Sigma X^4Y^2 & \Sigma X^5Y^2 & \Sigma X^6Y^2 & \Sigma X^3Y^3 & \Sigma X^4Y^3 & \Sigma X^5Y^3 & \Sigma X^6Y^3 \\
\Sigma Y & \Sigma XY & \Sigma X^2Y & \Sigma X^3Y & \Sigma Y^2 & \Sigma XY^2 & \Sigma X^2Y^2 & \Sigma X^3Y^2 & \Sigma Y^3 & \Sigma XY^3 & \Sigma X^2Y^3 & \Sigma X^3Y^3 & \Sigma Y^4 & \Sigma XY^4 & \Sigma X^2Y^4 & \Sigma X^3Y^4 \\
\Sigma XY & \Sigma X^2Y & \Sigma X^3Y & \Sigma X^4Y & \Sigma XY^2 & \Sigma X^2Y^2 & \Sigma X^3Y^2 & \Sigma X^4Y^2 & \Sigma XY^3 & \Sigma X^2Y^3 & \Sigma X^3Y^3 & \Sigma X^4Y^3 & \Sigma XY^4 & \Sigma X^2Y^4 & \Sigma X^3Y^4 & \Sigma X^4Y^4 \\
\Sigma X^2Y & \Sigma X^3Y & \Sigma X^4Y & \Sigma X^5Y & \Sigma X^2Y^2 & \Sigma X^3Y^2 & \Sigma X^4Y^2 & \Sigma X^5Y^2 & \Sigma X^2Y^3 & \Sigma X^3Y^3 & \Sigma X^4Y^3 & \Sigma X^5Y^3 & \Sigma X^2Y^4 & \Sigma X^3Y^4 & \Sigma X^4Y^4 & \Sigma X^5Y^4 \\
\Sigma X^3Y & \Sigma X^4Y & \Sigma X^5Y & \Sigma X^6Y & \Sigma X^3Y^2 & \Sigma X^4Y^2 & \Sigma X^5Y^2 & \Sigma X^6Y^2 & \Sigma X^3Y^3 & \Sigma X^4Y^3 & \Sigma X^5Y^3 & \Sigma X^6Y^3 & \Sigma X^3Y^4 & \Sigma X^4Y^4 & \Sigma X^5Y^4 & \Sigma X^6Y^4 \\
\Sigma Y^2 & \Sigma XY^2 & \Sigma X^2Y^2 & \Sigma X^3Y^2 & \Sigma Y^3 & \Sigma XY^3 & \Sigma X^2Y^3 & \Sigma X^3Y^3 & \Sigma Y^4 & \Sigma XY^4 & \Sigma X^2Y^4 & \Sigma X^3Y^4 & \Sigma Y^5 & \Sigma XY^5 & \Sigma X^2Y^5 & \Sigma X^3Y^5 \\
\Sigma XY^2 & \Sigma X^2Y^2 & \Sigma X^3Y^2 & \Sigma X^4Y^2 & \Sigma XY^3 & \Sigma X^2Y^3 & \Sigma X^3Y^3 & \Sigma X^4Y^3 & \Sigma XY^4 & \Sigma X^2Y^4 & \Sigma X^3Y^4 & \Sigma X^4Y^4 & \Sigma XY^5 & \Sigma X^2Y^5 & \Sigma X^3Y^5 & \Sigma X^4Y^5 \\
\Sigma X^2Y^2 & \Sigma X^3Y^2 & \Sigma X^4Y^2 & \Sigma X^5Y^2 & \Sigma X^2Y^3 & \Sigma X^3Y^3 & \Sigma X^4Y^3 & \Sigma X^5Y^3 & \Sigma X^2Y^4 & \Sigma X^3Y^4 & \Sigma X^4Y^4 & \Sigma X^5Y^4 & \Sigma X^2Y^5 & \Sigma X^3Y^5 & \Sigma X^4Y^5 & \Sigma X^5Y^5 \\
\Sigma X^3Y^2 & \Sigma X^4Y^2 & \Sigma X^5Y^2 & \Sigma X^6Y^2 & \Sigma X^3Y^3 & \Sigma X^4Y^3 & \Sigma X^5Y^3 & \Sigma X^6Y^3 & \Sigma X^3Y^4 & \Sigma X^4Y^4 & \Sigma X^5Y^4 & \Sigma X^6Y^4 & \Sigma X^3Y^5 & \Sigma X^4Y^5 & \Sigma X^5Y^5 & \Sigma X^6Y^5 \\
\Sigma Y^3 & \Sigma XY^3 & \Sigma X^2Y^3 & \Sigma X^3Y^3 & \Sigma Y^4 & \Sigma XY^4 & \Sigma X^2Y^4 & \Sigma X^3Y^4 & \Sigma Y^5 & \Sigma XY^5 & \Sigma X^2Y^5 & \Sigma X^3Y^5 & \Sigma Y^6 & \Sigma XY^6 & \Sigma X^2Y^6 & \Sigma X^3Y^6 \\
\Sigma XY^3 & \Sigma X^2Y^3 & \Sigma X^3Y^3 & \Sigma X^4Y^3 & \Sigma XY^4 & \Sigma X^2Y^4 & \Sigma X^3Y^4 & \Sigma X^4Y^4 & \Sigma XY^5 & \Sigma X^2Y^5 & \Sigma X^3Y^5 & \Sigma X^4Y^5 & \Sigma XY^6 & \Sigma X^2Y^6 & \Sigma X^3Y^6 & \Sigma X^4Y^6 \\
\Sigma X^2Y^3 & \Sigma X^3Y^3 & \Sigma X^4Y^3 & \Sigma X^5Y^3 & \Sigma X^2Y^4 & \Sigma X^3Y^4 & \Sigma X^4Y^4 & \Sigma X^5Y^4 & \Sigma X^2Y^5 & \Sigma X^3Y^5 & \Sigma X^4Y^5 & \Sigma X^5Y^5 & \Sigma X^2Y^6 & \Sigma X^3Y^6 & \Sigma X^4Y^6 & \Sigma X^5Y^6 \\
\Sigma X^3Y^3 & \Sigma X^4Y^3 & \Sigma X^5Y^3 & \Sigma X^6Y^3 & \Sigma X^3Y^4 & \Sigma X^4Y^4 & \Sigma X^5Y^4 & \Sigma X^6Y^4 & \Sigma X^3Y^5 & \Sigma X^4Y^5 & \Sigma X^5Y^5 & \Sigma X^6Y^5 & \Sigma X^3Y^6 & \Sigma X^4Y^6 & \Sigma X^5Y^6 & \Sigma X^6Y^6
\end{vmatrix}
*
\begin{vmatrix} A \\ B \\ C \\ D \\ E \\ F \\ G \\ H \\ I \\ J \\ K \\ L \\ M \\ N \\ O \\ P \end{vmatrix}
=
\begin{vmatrix} \Sigma Z \\ \Sigma XZ \\ \Sigma X^2Z \\ \Sigma X^3Z \\ \Sigma YZ \\ \Sigma XYZ \\ \Sigma X^2YZ \\ \Sigma X^3YZ \\ \Sigma Y^2Z \\ \Sigma XY^2Z \\ \Sigma X^2Y^2Z \\ \Sigma X^3Y^2Z \\ \Sigma Y^3Z \\ \Sigma XY^3Z \\ \Sigma X^2Y^3Z \\ \Sigma X^3Y^3Z \end{vmatrix}$$

2.3. The analysis of polynomials trends hypersurfaces

In R^4 space z=f(x,y,w) = $\sum_{i=0}^{m}\sum_{j=0}^{n}\sum_{k=0}^{p} a_{ijk}x^i y^j w^k$, Grid ($x_i$, y_l, w_k)

Order1 Z=A+BW+CX+DY

Order2 $Z=A+BW+CX+DY+EX^2+FWY+GXY+HWX+IW^2+JY^2$

Order3 $Z=A+BW+CX+DY+EX^2+FWY+GXY+HWX+IW^2+JY^2+KX^3+LW^3+MY^3+NX^2Y+$
$+OXY^2+PY^2W+QYW^2+RW^2X+SWX^2+TWXY$

Calculation procedure for order 1 of the hypersurface (hyperplane) Z=A+BW+CX+DY

$$-\sum_{i=1}^{n} z_i + A\cdot n + B\sum_{i=1}^{n} x_i + C\sum_{i=1}^{n} y_i + D\sum_{i=1}^{n} w_i = 0$$

$$-\sum_{i=1}^{n} z_i x_i + A\sum_{i=1}^{n} x_i + B\sum_{i=1}^{n} x_i^2 + C\sum_{i=1}^{n} x_i y_i + D\sum_{i=1}^{n} x_i w_i = 0$$

$$-\sum_{i=1}^{n} z_i y_i + A\sum_{i=1}^{n} y_i + B\sum_{i=1}^{n} x_i y_i + C\sum_{i=1}^{n} y_i^2 + D\sum_{i=1}^{n} y_i w_i = 0$$

$$-\sum_{i=1}^{n} z_i w_i + A\sum_{i=1}^{n} w_i + B\sum_{i=1}^{n} x_i w_i + C\sum_{i=1}^{n} y_i w_i + D\sum_{i=1}^{n} w_i^2 = 0$$

$$\begin{bmatrix} A \\ B \\ C \\ D \end{bmatrix} = \begin{bmatrix} n & \sum x & \sum y & \sum w \\ \sum x & \sum x^2 & \sum xy & \sum xw \\ \sum y & \sum xy & \sum y^2 & \sum yw \\ \sum w & \sum xw & \sum yw & \sum w^2 \end{bmatrix}^{-1} \times \begin{bmatrix} \sum z \\ \sum zx \\ \sum zy \\ \sum zw \end{bmatrix}$$

Calculation procedure for order 2 of the hypersurface (hyperplane)

$$Z=A+BW+CX+DY+EX^2+FWY+GXY+HWX+IW^2+JY^2$$

$$\Phi(A,B,C,D,E,F,G,H,I,J)=SUM(Z-A-BW-CX-DY-EX^2-FWY-GXY-HWX-IW^2-JY^2)^2$$

$$\frac{\partial\Phi}{\partial A} = \sum(-2(Z-A-BW-CX-DY-EX2-FWY-GXY-HWX-IW2-JY2)) = 0$$

$$\frac{\partial\Phi}{\partial B} = \sum(-2W(Z-A-BW-CX-DY-EX2-FWY-GXY-HWX-IW2-JY2)) = 0$$

$$\frac{\partial\Phi}{\partial C} = \sum(-2X(Z-A-BW-CX-DY-EX2-FWY-GXY-HWX-IW2-JY2)) = 0$$

$$\frac{\partial\Phi}{\partial D} = \sum(-2Y(Z-A-BW-CX-DY-EX2-FWY-GXY-HWX-IW2-JY2)) = 0$$

$$\frac{\partial\Phi}{\partial E} = \sum(-2XY(Z-A-BW-CX-DY-EX2-FWY-GXY-HWX-IW2-JY2)) = 0$$

vol. 31, issue 3 / 2025
pp. 104-111

$$\frac{\partial \Phi}{\partial F} = \sum \left(-2WY\left(Z - A - BW - CX - DY - EX2 - FWY - GXY - HWX - IW2 - JY2\right)\right) = 0$$

$$\frac{\partial \Phi}{\partial G} = \sum \left(-2XY\left(Z - A - BW - CX - DY - EX2 - FWY - GXY - HWX - IW2 - JY2\right)\right) = 0$$

$$\frac{\partial \Phi}{\partial H} = \sum \left(-2WX\left(Z - A - BW - CX - DY - EX2 - FWY - GXY - HWX - IW2 - JY2\right)\right) = 0$$

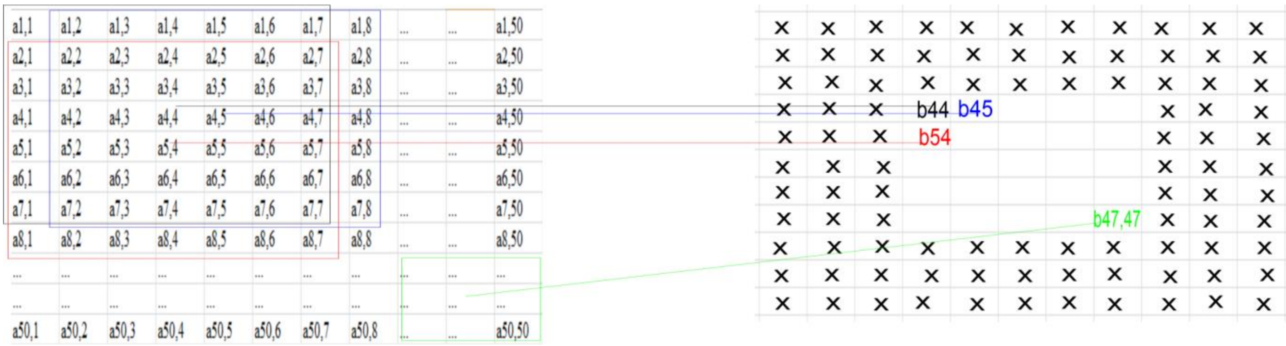
$$\frac{\partial \Phi}{\partial I} = \sum \left(-2WW\left(Z - A - BW - CX - DY - EX2 - FWY - GXY - HWX - IW2 - JY2\right)\right) = 0$$

$$\frac{\partial \Phi}{\partial J} = \sum \left(-2YY\left(Z - A - BW - CX - DY - EX2 - FWY - GXY - HWX - IW2 - JY2\right)\right) = 0$$

2.4. The analysis with mobile average method for 1D, 2D and 3D

For mobile average method we have developed programs based on the following algorithms: We note with a(i, j) the values of the mediated parameter z in the node of the network (i, j), where i and j take integer values within the ranges [1; 100] used by the mobile window used. To illustrate the algorithm, with the 7x7 floating window, we compiled the following sketch:

$$\overline{a_{i,j}} = \sum_{i=-3}^{i=3} \sum_{j=-3}^{j=3} a_{ij}\,,$$



3. Case study in Vrancea zone

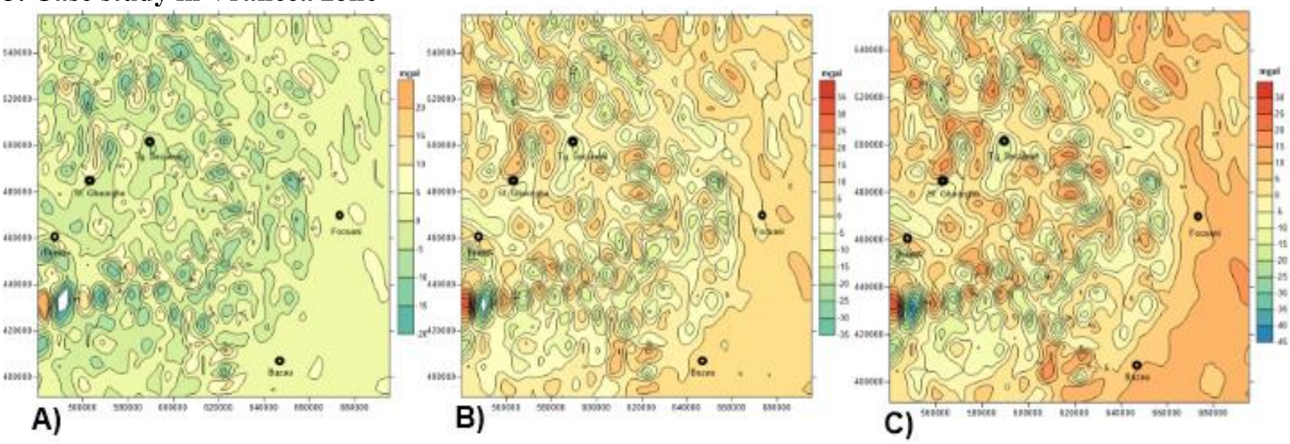


Figure 1. Residual Bouguer anomaly calculated with the mobile averages of 3 different square windows:
A) Residual Bouguer anomaly calculated with the mobile averages of 9 values;
B) Residual Bouguer anomaly calculated with the mobile averages of 25 values;
C) Residual Bouguer anomaly calculated with the mobile averages of 49 values.

For tendency surfaces, we have developed programs for calculating analytical expressions for the following types of surfaces: plan (first degree): $Z_{tend}=A+Bx+Cy$, 2nd degree: $Z_{tend}=A+BX+CY+DX^2+EXY+ +FY^2$, 3rd degree: $Z_{tend}=A+BX+CY+DX^2+EXY+FY^2+GX^3+HX^2Y+IXY^2+JY^3$, 6th degree: $Z_{tend}=A+BX+ CX^2+DX^3+EY+FXY+GX^2Y+HX^3Y+IY^2+ JXY^2+KX^2Y^2+LX^3Y^2+MY^3+NXY^3+ OX^2Y^3+PX^3Y^3$, where X and Y represent the independent variables (in the coordinates system STEREO 70 in the directions W-E, respectively N-S) and Z represents the variable dependent on X and Y.

The residual value is $Z_{rez} = Z_{obs} - Z_{tend}$ highlights the local aspects of anomalies.

vol. 31, issue 3 / 2025
pp. 104-111

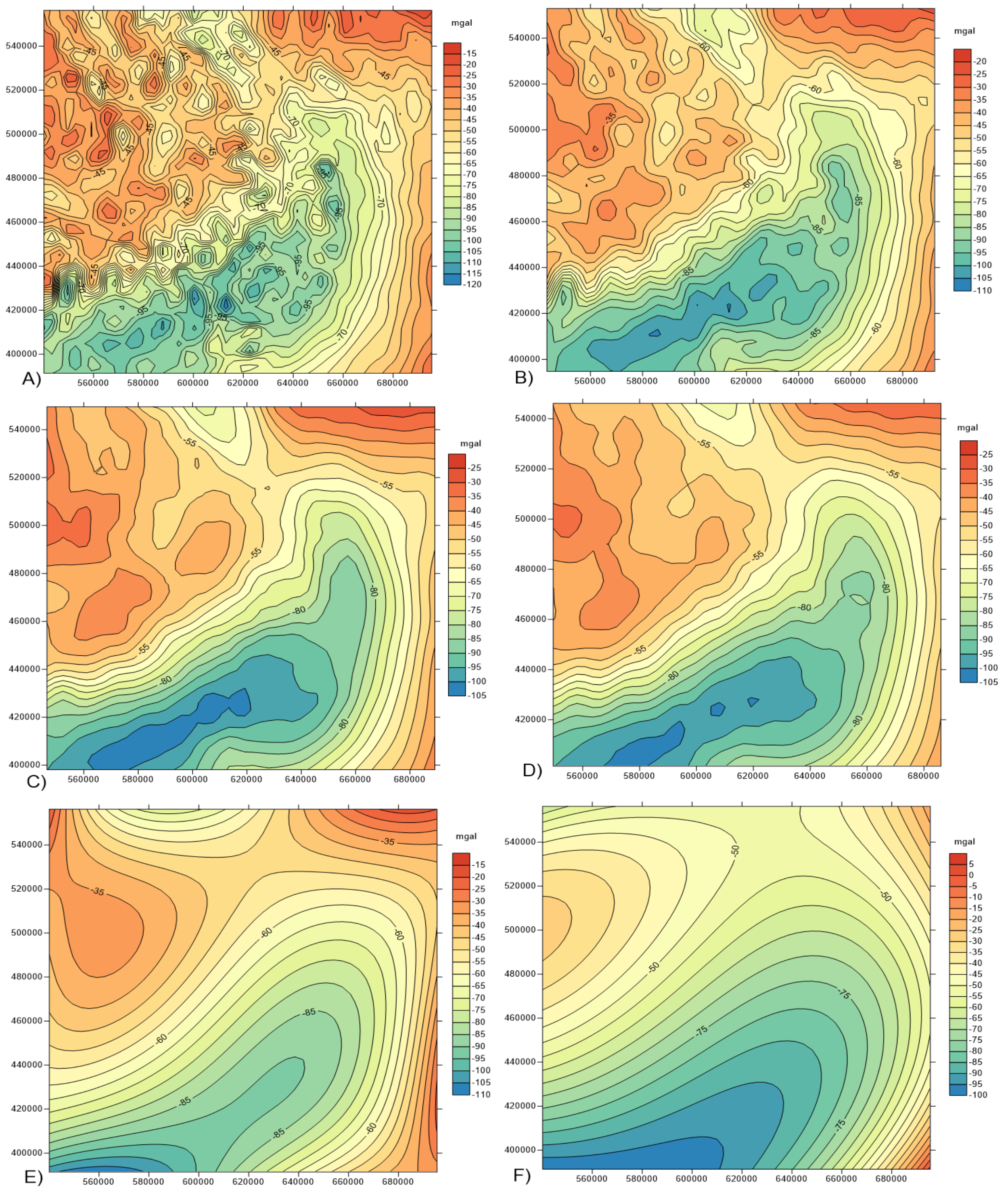


*Fig.2. Bouguer Anomaly in the studied area from BGI data; A) The representation of unfiltered data; B) Representation of the data averaged in moving windows of 9 values (3 lines * 3 columns); C) Representation of the data averaged in moving windows of 25 values (5 lines * 5 columns); D) Representation of the data averaged in moving windows of 49 values (7 lines * 7 columns); E) The tendency surface with 6th order; F) The tendency surface with 3rd order.*

In fig.2E, it is the tendency surface with 6th order,

$$Z_{tend}=A+BX+CX^2+DX^3+EY+FXY+GX^2Y+HX^3Y+IY^2+JXY^2+KX^2Y^2+LX^3Y^2+MY^3+NXY^3+OX^2Y^3+PX^3Y^3$$

the coefficients being: A=499438.5000000000; B=-373202.3671875000; C=81600.5175781250; D=-5520.4898071289; E=-19053.6718750000; F=91387.8554687500; G=-28282.2333984375; H=2245.9517211914; I=-63199.0019531250; J=13665.5058593750; K=619.8403320313; L=-186.4072189331; M=9255.7174072266; N=-3328.0280761719; O=342.1310119629; P=-7.7146945000.

In fig. 2F, it is the tendency surface with 3rd order,

$$Z_{tend}=A+BX+CY+DX^2+EXY+FY^2+GX^3+HX^2Y+IXY^2+JY^3$$

the coefficients being: A=-11938.42251006; B=4797.3673020601; C=1487.1852331124; D=-652.9127963639; E=-438.9016750949; F=0.0000125275; G=45.8620878794; H=-31.7580106317; I=85.5197506216; J=-37.4263031660.

The tendency plan of Bouguer anomaly has the following equation:

$$Z=-188.707147163*X-0.1554708098*Y+27.0513680505.$$

4. Conclusions

In the present paper we presented as filtering methods only the mobile mediation with windows of different dimensions and polynomial tendencies of different degrees. These types of filters were compared with the results of other types of filtrations that I did not present in this paper (Fourier 2D analysis, Wavelet analysis with different window types, analytical continuation up and down), given the volume, both theoretical-and methodological, the programs used and the results of the processes, as well as their geological significance.

The results of all types of filtering can be matched with 2D models (for which we have developed the data profiles and sketched the structure in depth based on the results obtained by various methods and various authors).

Also, the variation of the correlation factor between two sets of parameters brings information for geological and tectonic assumptions. This correlation factor between two sets of data can be calculated, similarly as in mobile averages with windows of different sizes, passing through the entire network of points, bringing information from different depths. The correlation between two sets of parameters may be some indicators that they are dependent on common causes. Contrast of densities juxtaposed in areas with different petrophysical properties at suture zones, usually cause gravimetric anomalies. However, some of the anomalies of gravity that have deep causes may be masked by the presence of geological formations of a very different density compared to deep formations. Anomalies of gravity caused by small-scale formations can be easily recognized in residual maps after regional trends are eliminated.

The anomaly separation operation consists in determining the number of sources, the characteristics of each (depth, density, shape, and dimensions) so as to result in cumulative total anomaly, measured at the Earth's surface.

This separation has to be done in the context of the fundamental ambiguity of gravimetric information, based on the cause-effect ratio.

In conclusion, referring only to the types of filters presented in the paper, we can say that they provide us with information with different degrees of regionality and from different depths, which of course cannot be quantified until all the geological and geophysical information has been corroborated. These filters can bring both information about local and surface effects (residual maps, through "high pass" filters), mid-depth structures (through "band pass" filters), and deep structure (tendency maps, through "low pass" filter).

Acknowledgements

This research was funded by ERA-MIN & contract no 305/2022 with UEFISCDI Romania, project: AI-COSTSQO-Artificial Intelligence and Combined Survey Techniques for Stone Quarries.

We address our thanks for scientific publications, reports and gravity data, to: Bureau Gravimétrique International (BGI), International Association of Geodesy (IAG) and International Centre for Global Earth Models (ICGEM).

References

[1] **Barthelmes F., Köhler W.,** 2016
Journal of Geodesy. The Geodesists Handbook 2016. International Association of Geodesy. 90(10): 907-1205.
doi: 10.1007/s00190-016-0948-z. (accessed February 12, 2017)

[2] **Farhang-Boroujeny B.** 2013
Adaptive Filters: Theory and Applications. John Wiley & Sons, Ltd. West Sussex, 529 pp.

[3] **Harbaugh J.** 1972
Aplicaţiile calculatoarelor în geologie (in romanian). Ed. Tehnică. Bucureşti. 328 pp.

vol. 31, issue 3 / 2025
pp. 104-111

[4] **Heiskanen W.A., Moritz H.,** 1967
Physical Geodesy. Ed. W. H. Freeman & Co. San Francisco. 364 pp.

[5] **Karakus D., Safak S., Onur A.H.,** 2011
A new aproximation method for the trend hypersurface analysis for elevation of drilhole data. Archives of Mining Sciences. Institut Mechaniki Górotvoru. Krakow. 56(1): 47-58.

[6] **Knapp J.H., Knapp C., Răileanu V. Matenco L., Mocanu V., Dinu C.** 2005
Crustal constraints on the origin of mantle seismicity in the Vrancea Zone, Romania: The case for active continental lithospheric delamination. Tectonophysics. Elsevier. 410: 311-323.

[7] **Pavlis N.K., Holmes S.A., Kenyon S.C., Factor J.K.,** 2008
An Earth Gravitational Model to degree 2160: EGM2008. General Assembly of the European Geosciences Union. Vienna, Austria. April 13-18. 33 pp.

[8] **Unwin D.,** 1978.
An introduction to trend surface analysis – Concept and Techniques in Modern Geography, CAT MOG 5, ISSN 0305-6142

[9] **Poularikas D., Ramadan Z.M.,** 2006
Adaptive filtering primer with MatLab. Edit. CRC/Taylor & Francis Group. Boca Raton. 240 pp.

[10] **Zadeh I., Mueller B., Schubert G.,** 2005
Three-dimensional numerical modeling of contemporary mantle flow and tectonics stresses beneath the earthquake-prone southeastern Carpathians based on integrated analysis of seismic, heat flow and gravity data. Physics of the Earth and Planetary Interiors. Elsevier. 149: 81-98.

[11] **Vajda P., Vanicek P., Meurers B**. 2004
On the removal of the effect of topography on gravity disturbance in gravity data inversion or interpretation. Contributions to Geophysics and Geodesy. Geophysical Institute of Slovak Academy of Sciences. Bratislava. 34(4): 339-369