

Gravity Anomaly Enhancement for Geothermal Prospect Characterization: A Comparative Application of First Horizontal Derivative, Second Vertical Derivative, and Regional-Residual Separation Using Surfer and Oasis Montaj

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ABSTRACT

Gravity surveys help delineate structures controlling geothermal systems, but the Complete Bouguer Anomaly (CBA) mixes regional trends, residual signals, and noise. This study applies an anomaly enhancement workflow to CBA data (145–155.5 mGal) from a geothermal prospect of about 1.1×1.0 km and compares Surfer and Oasis montaj. After kriging and shaded-relief rendering, First Horizontal Derivative and Second Vertical Derivative filters were computed. Radial spectrum analysis yielded cut-off wavenumbers of 1.90 cycles/km ($\lambda \approx 525$ m) and 7.54 cycles/km ($\lambda \approx 133$ m) separating regional, residual, and noise components. The platforms differed in shading, SVD implementation, and separation domains; only Surfer supported spatial-domain separation. The workflow offers practical guidance for software selection in geothermal gravity exploration.

INTRODUCTION

Geothermal energy is increasingly recognized as a reliable, low-carbon source of baseload power and direct heat, and its development has expanded across volcanic and tectonically active regions worldwide. Global installed direct-use capacity, for example, was estimated at 107,727 MW by the end of 2019, an increase of 52% over the 2015 figure (Lund & Toth, 2021). Indonesia, located along the Pacific Ring of Fire, holds some of the largest geothermal resource potential on Earth. Indonesia has approximately 23.2 GW (23,202.77 MW) of geothermal potential, making geothermal energy an important resource for the country's energy transition (ESDM, 2026). Realizing this potential, however, depends on the ability to locate and characterize productive reservoirs before costly exploratory drilling is undertaken. Surface geophysical methods therefore play a central role in the early stages of exploration, where they help to constrain the geometry of the heat source, the reservoir, and the structural pathways through which hydrothermal fluids circulate.

Among these methods, gravity surveying is one of the most widely used because of its relatively low cost, rapid field deployment, and sensitivity to lateral variations in subsurface density (Telford et al., 1990; Blakely, 1995). In geothermal settings, density contrasts commonly arise from faults and fracture zones, intrusive bodies, hydrothermal alteration, and variations in basement topography, all of which may control the permeability and thermal structure of a prospect. Gravity data are typically reduced to the Complete Bouguer Anomaly (CBA), which removes the effects of latitude, elevation, and terrain from the observed field. The CBA is thus the primary input for subsequent qualitative and quantitative interpretation.

Despite its utility, the CBA is not directly interpretable in terms of individual geological structures. The measured field is the integrated response of all density heterogeneities, from deep and broad sources to shallow and localized ones, and is further contaminated by observational and processing noise. Consequently, subtle anomalies related to shallow geothermal structures may be masked by dominant long-wavelength trends. This limitation motivates the use of anomaly enhancement techniques, which emphasize specific spatial wavelengths or edge characteristics of the field and thereby improve the interpretability of the data (Hinze et al., 2013).

Two derivative-based filters are especially common for this purpose. The First Horizontal Derivative (FHD) expresses the rate at which the gravity anomaly changes in the horizontal plane, and its maxima tend to lie above steep density boundaries, making it effective for delineating faults and lithological contacts (Cordell & Grauch, 1985; Fedi & Florio, 2001). It is computed as

$$FHD = \sqrt{\left(\frac{\partial g}{\partial x}\right)^2 + \left(\frac{\partial g}{\partial y}\right)^2} \dots\dots\dots (1)$$

Where g denotes the gravity anomaly. The Second Vertical Derivative (SVD), in contrast, accentuates shallow, short-wavelength features and sharpens the expression of structural boundaries, with its zero contour often used as an approximation of the edges of causative bodies (Henderson & Zietz,

1949; Elkins, 1951). Because gravity is a harmonic function in source-free space, the SVD can be obtained in the spatial domain from horizontal derivatives through Laplace's equation:

$$\frac{\partial^2 g_z}{\partial z^2} = -\left(\frac{\partial^2 g_z}{\partial x^2} + \frac{\partial^2 g_z}{\partial y^2}\right) \dots\dots\dots (2)$$

In practice, the sign convention and the manner in which this relationship is implemented may differ between software packages, which can affect the resulting anomaly maps.

A second and equally important step is the separation of regional and residual anomalies. The regional component reflects deep, broad sources, whereas the residual component carries the signature of shallower targets that are most relevant to geothermal exploration. Spectral analysis offers an objective approach to this problem: the radial spectrum of the gridded field is plotted on a logarithmic scale, and distinct linear segments are interpreted as contributions from sources at different depth ranges, so that the intersections between segments define cut-off wavenumbers (Spector & Grant, 1970; Syberg, 1972). Alternatively, spatial-domain methods such as moving-average filtering estimate the regional trend by smoothing the data with a defined window, and the residual is subsequently derived from the difference between filtered fields. The choice between these approaches has direct consequences for which structures are retained in the interpreted map.

The practical implementation of these procedures relies on commercial or semi-commercial software. Surfer is widely used for gridding, contouring, and spatial-domain operations, whereas Oasis montaj, here used in its Viewer edition, provides dedicated tools for potential-field processing. Although both platforms are routinely used in geophysical practice, their outputs are rarely compared in a systematic way, and differences in gridding display, shading, derivative implementation, and the domains in which regional-residual separation can be performed are seldom documented. Such differences may influence the efficiency of the workflow and, potentially, the interpretation derived from it. A transparent comparison is therefore valuable for practitioners and students who must select tools for gravity-based geothermal studies.

Accordingly, this study aims to (i) apply an anomaly enhancement workflow to a sample CBA dataset for testing purposes, comprising kriging-based gridding, shaded-relief visualization, FHD, and SVD, (ii) determine the regional-residual and residual-noise cut-off wavenumbers through radial spectrum analysis, (iii) estimate the regional and residual anomalies in the spatial domain using moving-average filters and (iv) compare the capabilities and outputs of Surfer and Oasis montaj throughout the workflow. The remainder of this paper is organized as follows. Section 2 describes the data and processing methodology, Section 3 presents the results of the enhancement and separation procedures, Section 4 discusses their implications for geothermal interpretation and software selection, and Section 5 concludes the study.

LITERATURE REVIEW

Gridding and Shaded-Relief Visualization

The irregularly distributed CBA observations were interpolated onto a regular grid using kriging, a geostatistical estimator that provides the best linear unbiased prediction at unsampled locations and honors the spatial correlation structure of the data (Cressie, 1993). A grid spacing of 50 m and an exponential variogram were applied. The same grid was used in both software packages to ensure that subsequent differences originate from the software itself and not from the interpolation.

Contour maps were rendered with a shaded-relief effect to emphasize the morphology of the anomaly field. In both programs, the illumination was defined by a horizontal light position of 45° and a vertical light position of 45°. The two renderings were then compared qualitatively with respect to contour smoothness, color-scale handling, and the visibility of local anomalies.

First Horizontal Derivative (FHD)

The FHD was calculated from the gridded CBA data according to Equation (1). The same CBA grid was used as the input in both Surfer and Oasis montaj. In Surfer, the first derivatives were calculated separately in the x and y directions using the First Derivative function, producing the $\partial g/\partial x$ and $\partial g/\partial y$ grids. In Oasis montaj, the corresponding derivative components were obtained using the Grid Spatial Filtering procedure. The resulting derivative components were combined according to Equation (1) to obtain the FHD magnitude grid. This approach ensured that the FHD calculation was based on the same mathematical definition in both software packages, while allowing their respective processing implementations to be compared. High FHD amplitudes were interpreted as lateral density contrasts and, therefore, as potential structural boundaries (Cordell & Grauch, 1985). The directional derivative maps were also examined individually, because each emphasizes structures perpendicular to its direction of differentiation.

Second Vertical Derivative (SVD)

The SVD was calculated in the spatial domain using Laplace's relation (Equation 2), which expresses the second vertical derivative as the negative sum of the second horizontal derivatives. Two implementations were compared. In Surfer, the second derivatives in the x and y directions were calculated and summed in the Grid Math module with the expression $-(A + B)$, thereby satisfying Equation (2). In Oasis montaj, only the node-by-node summation of the two second-derivative grids was applied, and no multiplication by -1 was performed. The resulting maps were compared with regard to sign convention and the expression of anomaly polarity, since this directly influences how the zero contour is used as a structural boundary indicator (Elkins, 1951).

Radial Spectrum Analysis and Cut-Off Determination

To establish an objective basis for separating regional and residual components, the radial spectrum of the CBA grid was calculated, and the

natural logarithm of the spectral value ($\ln A$) was plotted against the radial wavenumber k (cycles/km). On such a plot, sources at different depth levels tend to form distinct linear segments (Spector & Grant, 1970; Syberg, 1972). Three segments, interpreted as regional, residual, and noise components, were identified from the lowest to the highest wavenumbers, and a least-squares linear regression of the form

$$\ln A = m k + c \dots\dots\dots (3)$$

Was fitted to each segment, where m is the gradient and c the intercept. The cut-off wavenumber between two adjacent segments i and j was determined from the intersection of their regression lines:

$$k_c = \frac{c_i - c_j}{m_j - m_i} \dots\dots\dots (4)$$

The corresponding cut-off wavelength was then calculated as

$$\lambda_c = \frac{1}{k_c} \dots\dots\dots (5)$$

And converted to meters. The radial spectrum was generated in Oasis montaj through the matched-filtering initialization routine, with the CBA grid as input, a first-order initializing polynomial, 100 minimum-curvature iterations for grid plugging, and a 10% grid expansion. The routine yielded the Fourier-transformed grid, the radial spectrum file, and the residual spectrum grid. The regression and cut-off computation were performed in a spreadsheet environment.

METHODOLOGY

The data were processed in four consecutive stages: (1) gridding and shaded-relief visualization of the CBA; (2) computation of the FHD and SVD derivative filters; (3) determination of cut-off wavenumbers through radial spectrum analysis; and (4) separation of regional and residual anomalies (Figure 1). Stages 1, 2, and 4 were carried out in two software environments, namely Surfer and Oasis montaj, the latter used in its Viewer edition, so that the output and operational capability of each platform could be compared under identical input data and parameters. The functional differences identified across the workflow are summarized in Table 3 in Section 3.

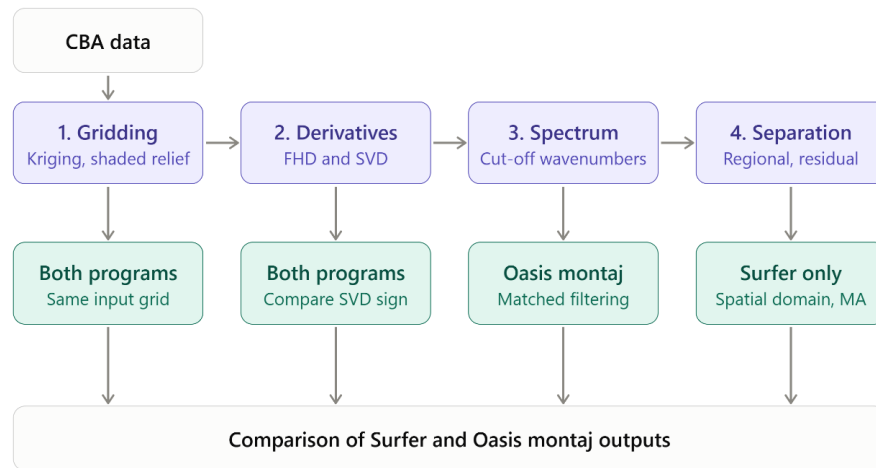


Figure 1. Flowchart of the anomaly enhancement workflow.

Regional-Residual separation was attempted in both the frequency and spatial domains. In the frequency domain, the cut-off wavenumbers obtained in Section 2.5 were intended to define the filter parameters. However, the frequency-domain filter application could not be implemented in the software configurations used in this study: the required filtering functionality was not accessible in the edition of Oasis montaj available for the analysis and was not available in Surfer. Therefore, the cut-off wavenumbers were used as interpretive references, while the actual regional-residual separation was performed only in the spatial domain using Surfer.

In the spatial domain, the regional anomaly was estimated by applying a 41×41 -cell moving-average low-pass filter to the CBA grid. The residual anomaly was then computed by grid subtraction of the 41-cell and 11-cell moving-average grids. The resulting regional and residual maps were evaluated according to how well they isolated broad trends and localized anomalies in the study area.

RESEARCH RESULT

Gridding and Shaded-Relief Visualization

The kriged CBA grid produced a smooth and spatially continuous anomaly field in both software packages (Figure 2). The field is dominated by a north-south elongated zone of relatively high values in the central part of the study area, flanked by lower values along the western and eastern margins. In Surfer, the highest values (approximately 154–155.5 mGal) occur in the northern part of the area, around 354,200–354,400 mE, while a second high of approximately 153–154 mGal occurs in the south, around 354,100–354,400 mE. These two highs are connected by a narrower neck of intermediate values (approximately 151–152 mGal). The lowest values (approximately 145–147 mGal) are found along the western margin, with a secondary low along the eastern margin.

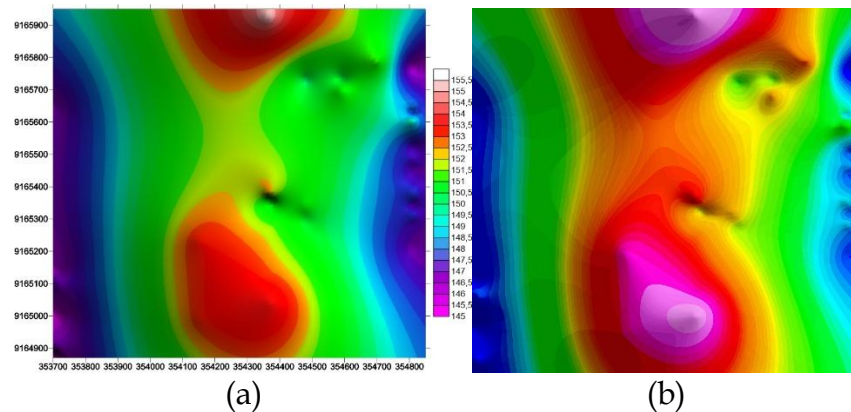


Figure 2. Shaded-relief map of the CBA gridded by kriging: (a) Surfer and (b) Oasis montaj.

The same configuration of highs and lows was reproduced by Oasis montaj, indicating that both programs preserved the large-scale structure of the CBA field. The visual character of the two maps nevertheless differed. The Surfer map displayed fewer, broader color intervals with a labeled legend at 0.5 mGal increments, whereas the Oasis montaj map displayed a finer color gradation and a more pronounced shading effect, which accentuated small-scale undulations of the surface. Because the two programs applied different default color tables (Figure 2), the same anomaly appears in different hues, and visual comparison of the two maps was therefore possible only in terms of pattern and not of color.

First Horizontal Derivative

The first derivatives of the CBA grid in the x and y directions were obtained in Surfer through the First Derivative function and in Oasis montaj through the horizontal gradient routine. In Surfer, the resulting x- and y-derivative grids were combined using Grid Math according to Equation (1) to obtain the FHD magnitude grid. In Oasis montaj, the horizontal gradient routine directly outputs the x- and y-derivative grids together with the horizontal gradient magnitude grid. The resulting maps are presented in Figure 3 and Figure 4.

The x-derivative ($\partial g/\partial x$) map from Surfer exhibits values from approximately -3.4 to $+1.6$ mGal/m. A broad, positive zone occupies the entire western half of the area up to approximately 354,300 mE, and the maximum values are concentrated in the southwest. This zone is separated from the predominantly negative eastern half by a relatively narrow transition at approximately 354,300–354,400 mE, which runs in an approximately north-south direction and marks the steepest eastward decline of the CBA. In the eastern part, several localized dipole-like anomalies are visible, notably at approximately 354,450–354,550 mE, 9,165,700 mN, and along the eastern margin at 354,800 mE. The y-derivative ($\partial g/\partial y$) map, by comparison, is characterized by values near zero across most of the area, with a range of approximately -3.5 to $+3.5$, and shows isolated anomalies in the north, the eastern margin, and at a few points in the south and center. The weakness of the y-derivative over much

of the area is consistent with the predominantly north-south elongation of the anomaly field noted in section above.

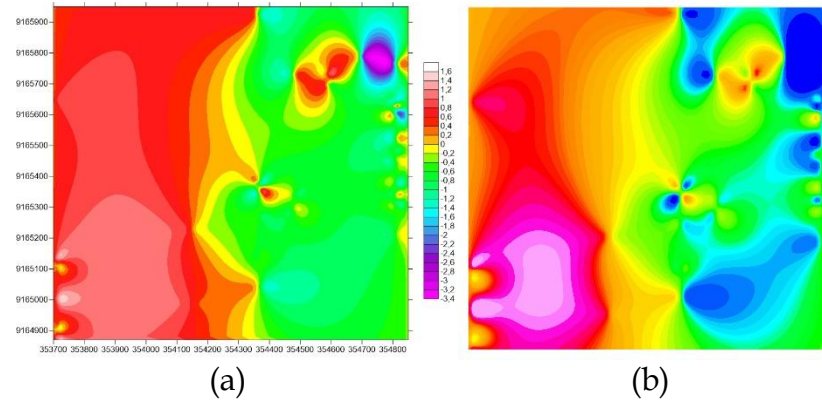


Figure 3. First derivative of the CBA in the x direction ($\partial g/\partial x$): (a) Surfer and (b) Oasis montaj.

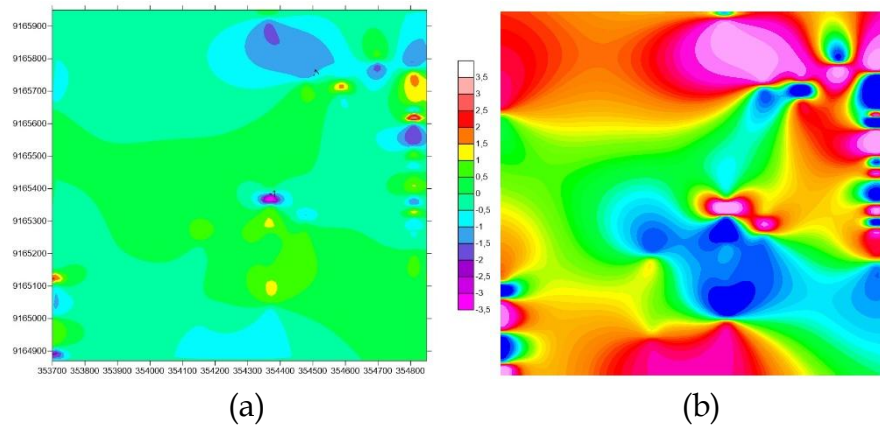


Figure 4. First derivative of the CBA in the y direction ($\partial g/\partial y$): (a) Surfer and (b) Oasis montaj.

The Oasis montaj derivative maps reproduced the same spatial pattern, including the west-east transition in the x-derivative and the isolated anomalies along the eastern margin. As with the shaded-relief maps, the Oasis montaj output appeared more detailed, with a finer color classification, particularly in the y-derivative, in which more internal structure is visible than in the corresponding Surfer map.

Second Vertical Derivative

The SVD maps are shown in Figure 5. In Surfer, the SVD was computed in the Grid Math module with the expression $-(A + B)$, where A and B are the second derivatives in the x and y directions, respectively. In Oasis montaj, the same two grids were added using the node-by-node algebraic operation, without a sign change, and the output grid was accordingly named a “positive” SVD.

The Surfer SVD map is dominated by values close to zero over most of the area, with a range of approximately -16 to $+18$ mGal/m², and short-wavelength anomalies are restricted to small isolated sites. Positive anomalies

are found in the north (approximately 354,400 mE, 9,165,900 mN), at the northeastern margin, and at several locations along the eastern margin, while negative anomalies are distributed at similar sites, including north of the center around 354,350–354,500 mE and near 9,165,700 mN. The Oasis montaj SVD map exhibits the same set of isolated anomalies, but it appears much more heterogeneous, with alternating high and low zones across the entire area. This visual difference is attributable at least in part to the different color scale, which stretches small amplitude variations over the full color range, and the polarity of the anomalies is reversed relative to Surfer because no sign inversion was applied.

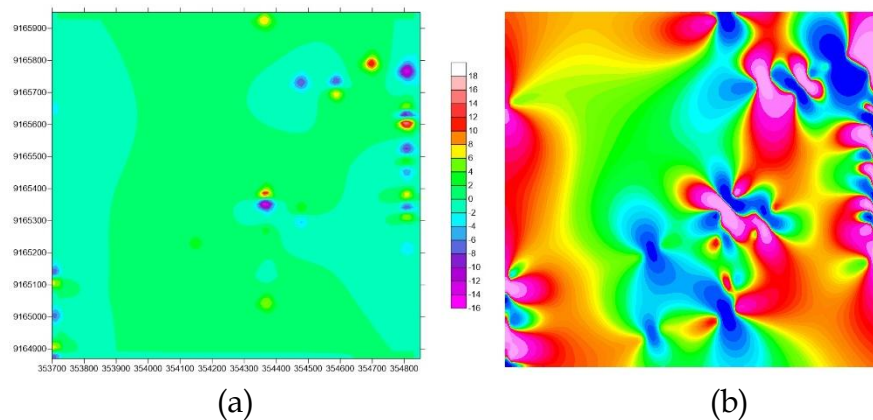


Figure 5. Second vertical derivative (SVD) of the CBA: (a) Surfer, computed as $-(\partial^2 g / \partial x^2 + \partial^2 g / \partial y^2)$, and (b) Oasis montaj, computed as $\partial^2 g / \partial x^2 + \partial^2 g / \partial y^2$ without sign inversion.

Radial Spectrum and Cut-Off Wavenumbers

The radial spectrum of the CBA grid was plotted as $\ln A$ versus wavenumber k (Figure 6), and linear regressions were fitted to the three spectral segments. The regression parameters are summarized in Table 1. The gradient decreases in magnitude from the regional segment (-0.4565) through the residual segment (-0.3037) to the noise segment (-0.0490), with intercepts of 3.718, 3.427, and 1.507, respectively.

Table 1. Linear regression parameters of the radial spectrum segments.

Zone	Gradient (m)	Intercept (c)
Regional	-0.4565	3.71818
Residual	-0.3037	3.42701
Noise	-0.0490	1.50658

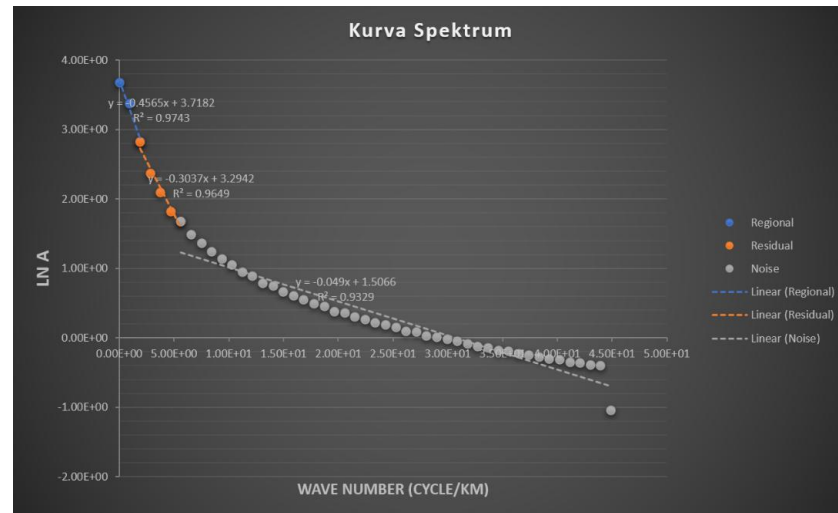


Figure 6. Radial spectrum of the CBA ($\ln A$ versus wavenumber k) with linear regression of the regional, residual, and noise segments.

The intersection between the regional and residual regression lines defined a cut-off wavenumber of 1.90 cycles/km, corresponding to a wavelength of approximately 525 m. The intersection between the residual and noise lines defined a second cut-off at 7.54 cycles/km, corresponding to a wavelength of approximately 133 m (Table 2). Accordingly, spatial features with wavelengths longer than approximately 525 m were classified as regional, those between approximately 133 and 525 m as residual, and those shorter than approximately 133 m as noise.

Table 2. Cut-off wavenumbers and wavelengths.

Cut-off	k (cycles/km)	λ (m)
Regional – Residual	1.90473	525.0
Residual – Noise	7.54104	132.6

Regional and Residual Anomalies

The regional anomaly obtained with the 41×41 moving average (Figure 7) is a strongly smoothed version of the CBA, with a range similar to that of the original field (approximately 145–155.5 mGal). Its principal feature is a pronounced high in the south, centered at approximately 354,200–354,400 mE and 9,165,000–9,165,200 mN, with values around 154 mGal, accompanied by a weaker high of approximately 151–152 mGal in the north. The western and eastern margins are characterized by low values of approximately 146–147 mGal. The shorter-wavelength anomalies visible in the CBA, including the isolated sites noted in Sections 3.2 and 3.3, were largely removed.

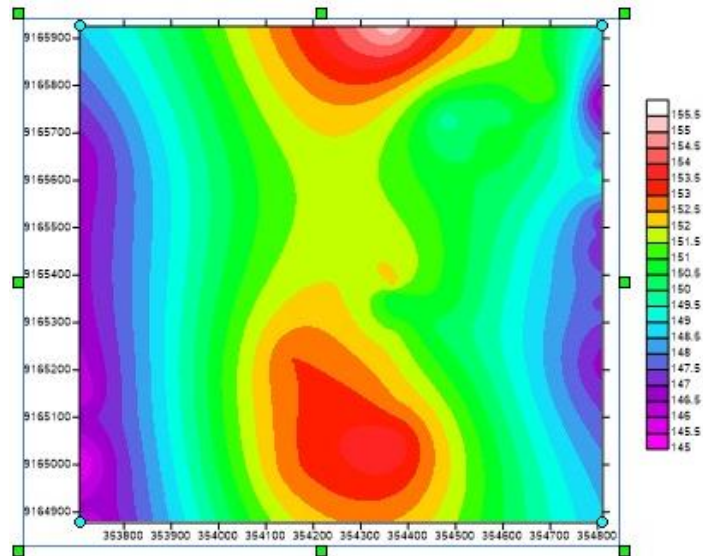


Figure 7. Regional anomaly estimated in the spatial domain using a 41-cell moving average (Surfer).

The residual anomaly (Figure 8) has a much smaller amplitude, ranging from approximately -2.2 to $+1.4$ mGal. Positive residuals are concentrated in two zones: a northern zone near 354,300–354,400 mE and 9,165,900 mN (up to approximately $+1.4$ mGal), and a southern zone, elongated in a northwest–southeast direction, at approximately 354,200–354,500 mE and 9,165,000–9,165,250 mN (approximately $+0.9$ mGal). Negative residuals appear as smaller closed anomalies at the western margin (approximately 9,165,600 mN), in the northeast (approximately 354,600 mE, 9,165,700 mN), and along the eastern margin, reaching approximately -1.3 mGal.

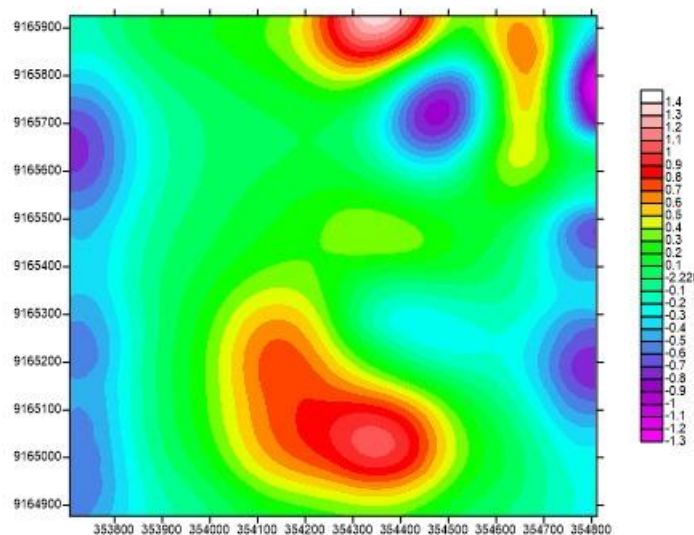


Figure 8. Residual anomaly obtained in the spatial domain from the difference between the 41-cell and 11-cell moving-average grids (Surfer).

Summary of Software Comparison

The differences identified across the workflow are summarized in Table 3.

Table 3. Comparison of Surfer and Oasis montaj for each processing stage.

Stage	Surfer	Oasis montaj (Viewer edition)
Shaded-relief rendering	Broader color intervals; labeled legend	Finer color gradation; stronger relief effect
First derivatives (x, y) SVD	Directional derivative (0°, 90°) – (A + B) applied through Grid Math	Horizontal gradient routine; also, outputs magnitude grid Summation only; no sign inversion
Radial spectrum	-	Matched-filtering initialization
Frequency-domain separation	Not achieved	Not achieved
Spatial-domain separation	Achieved (moving average, grid math)	Not achieved

DISCUSSION*Structural Implications of the Enhanced Anomaly Field*

The CBA map shows that the study area is dominated by a north–south elongated density high flanked by lower values on both margins (Section 3.1). The first derivative maps refine this picture. The pronounced west–east transition in $\partial g/\partial x$ at approximately 354,300–354,400 mE represents the steepest lateral gradient in the dataset, and its near-linear, north–south trend is characteristic of a steeply dipping density boundary such as a fault or a lithological contact (Cordell & Grauch, 1985; Fedi & Florio, 2001). In geothermal exploration, structures of this kind may be of particular interest because structural discontinuities can influence hydrothermal fluid circulation. The weak $\partial g/\partial y$ response over most of the sample area is consistent with a predominantly north–south-oriented gradient pattern, although this interpretation is based solely on the geophysical characteristics of the sample CBA dataset. Because the dataset is used for methodological testing rather than for a specific geothermal site, no direct comparison with mapped faults, lineaments, or surface manifestations is made.

However, the density contrast alone does not identify the nature of the source. A gravity high may reflect an uplifted dense basement, an intrusive body, or zones of hydrothermal silicification and mineral deposition, whereas gravity lows may reflect fractured and porous rock, argillic alteration, or thick low-density volcanoclastic cover (Blakely, 1995; Nishijima & Naritomi, 2017). Resolving this ambiguity requires independent constraints, such as geological mapping, resistivity data, or well information, which were not available in this study. The structural interpretation above is therefore preliminary.

The isolated, dipole-like anomalies observed along the eastern margin and near 9,165,700 mN in the derivative maps deserve a cautious treatment. Their dimensions are on the order of the shortest wavelengths in the dataset, and

many are likely to fall within or near the noise band defined by the 133 m cut-off (Section 3.4). Such features may result from near-surface density heterogeneity, but they may equally originate from sparse station coverage during kriging, from terrain-correction errors, or from edge effects of the derivative operators at the grid boundary. Their interpretation as geological structures should be avoided unless supported by additional observations.

Spectral Separation and the Residual Anomaly

The spectral analysis provides an objective basis for the scale separation applied in this study. A cut-off wavelength of approximately 525 m separates the regional from the residual components, while a second cut-off at approximately 133 m separates the residual component from the higher-wavenumber noise. The residual map is consistent with this spectral partition, as its anomalies have lateral dimensions of a few hundred meters and amplitudes of approximately $\pm 1\text{--}2$ mGal, in contrast to the regional field, which spans more than 10 mGal. These results indicate that the spectral analysis provides a useful basis for selecting spatial scales for the subsequent regional-residual separation.

The spatial relationship between the regional and residual fields is also informative. The positive residual anomalies in the north and south coincide with the regional highs, indicating that shallower dense material is superimposed on a deeper, broader density structure. In geothermal settings, positive residual gravity anomalies have been associated with dense intrusive bodies and with zones of hydrothermal sealing, whereas negative residuals may indicate fractured or altered, lower-density rock (Nishijima & Naritomi, 2017). The small negative residuals along the margins may therefore be of interest as potential permeable zones, but, as discussed above, this remains a hypothesis to be tested against geological data.

Comparison of Surfer and Oasis montaj

The most important finding of the software comparison is that, with identical input grids, both programs reproduced the same large-scale anomaly pattern and the same derivative structure. The differences between them lie in the rendering of the maps, the implementation of specific operations, and the processing domains available, not in the fundamental results.

The treatment of the SVD is the clearest example of a difference with potential interpretive consequences. Surfer required an explicit sign inversion to satisfy Laplace's relation (Equation 2), whereas the Oasis montaj workflow used here returned the unsigned sum. The location of the zero contour, which is commonly used to approximate source edges (Elkins, 1951), is not affected by this difference, but the polarity of the anomalies is. An interpreter who compares maps produced by the two programs without checking the sign convention could therefore confuse density highs and lows. This confirms the concern raised in the Introduction and argues for documenting the sign convention explicitly in any published workflow. Part of the visual difference

between the SVD maps may also arise from the differing color tables rather than from the data.

The domains available for regional-residual separation also differ. Spatial-domain filtering was feasible only in Surfer, while the radial spectrum was generated only in Oasis montaj. In practice, the two programs are thus complementary: Oasis montaj supports spectral characterization, while Surfer provides spatial filtering and grid arithmetic capabilities. In the present study, the frequency-domain filtering stage could not be implemented using the available software configurations. This limitation is associated with the Viewer edition of Oasis montaj used in this study and should not be interpreted as an intrinsic limitation of the Oasis montaj software family. Likewise, the required frequency-domain filtering workflow was not implemented in Surfer. A fully licensed configuration with the appropriate Fourier-domain filtering functionality would allow the cut-off wavenumbers determined from the radial spectrum analysis to be applied directly as filter parameters, providing a more rigorous frequency-domain separation of the regional, residual, and higher-wavenumber components.

Limitations and Recommendations

Several limitations should be noted. First, the comparison between programs was qualitative. No quantitative similarity measure, such as a difference grid or root-mean-square error between corresponding outputs, was computed, and the use of different color tables further limits visual comparison. Second, the moving-average filter is a crude low-pass operator whose response contains side lobes, and the large 41-cell window is sensitive to edge effects in a grid of this extent. Third, the interpretations offered are not validated by independent geological or geophysical data. Fourth, the results depend on the kriging parameters and on the station density, which were not varied here.

Future work should therefore (i) compute difference grids between corresponding Surfer and Oasis montaj outputs on a common color scale; (ii) apply frequency-domain filters using the cut-off wavenumbers derived here; (iii) complement the derivative filters with other edge detectors, such as the tilt derivative or the theta map, to test the robustness of the structural boundaries; and (iv) integrate the results with geological, geochemical, and resistivity data to constrain the geothermal model.

CONCLUSIONS AND RECOMMENDATIONS

This study applied an anomaly enhancement workflow to the CBA data of a geothermal prospect and compared the outputs of Surfer and Oasis montaj. The main conclusions are as follows.

1. The kriged CBA field (≈ 145 – 155.5 mGal) is dominated by a north-south elongated high flanked by lower values on the western and eastern margins. Both programs reproduced this pattern.
2. The first horizontal derivative revealed a steep west-east gradient at approximately 354,300–354,400 mE, interpreted tentatively as a north-south trending density boundary of potential structural significance. The SVD

highlighted only localized, short-wavelength anomalies, which should be treated cautiously.

3. Radial spectrum analysis yielded cut-off wavenumbers of 1.90 cycles/km ($\lambda \approx 525$ m) for the regional-residual boundary and 7.54 cycles/km ($\lambda \approx 133$ m) for the residual-noise boundary. The spatially filtered residual anomaly, with amplitudes of approximately -2.2 to $+1.4$ mGal, showed positive anomalies in the northern and southern parts of the area.
4. The two programs differ mainly in map rendering, SVD sign convention, and the available separation domains. Only Surfer allowed spatial-domain separation, and only Oasis montaj generated the radial spectrum. Neither allowed frequency-domain separation in the configuration used.
5. The programs are complementary, and a combined workflow with an explicit statement of sign conventions is recommended.

These results provide a reproducible basis for anomaly enhancement in gravity-based geothermal exploration, and they should be confirmed with independent geological and geophysical data.

ADVANCED RESEARCH

This study has three main limitations. First, the Surfer and Oasis montaj outputs were compared only visually, without a quantitative measure such as a difference grid. Second, the geological interpretation is preliminary because no independent geological or resistivity data were available. Third, frequency-domain separation could not be completed in either program, so the moving-average filters, which are sensitive to edge effects, were used instead.

Future research should (i) compute difference grids between the two programs on a common color scale, (ii) apply frequency-domain filters using the cut-off wavenumbers obtained here, (iii) test the structural boundaries with other edge detectors such as the tilt derivative, and (iv) integrate the gravity results with geological, geochemical, and resistivity data.

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