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Sink-hole modeling at a power plant site using microgravity data

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Abstract

A microgravity survey was conducted for detecting the sink-holes at site of a power plant.

Pits, man-made tunnels and canals were considered as topographical effects and were corrected. To show the capability of the method two sites in a power plant have been surveyed for existing areas which can be affected by sink-holes overnight.

Ground shakes due to the running facilities were also preventing us from taking a calm measurement.

Despite all unwanted factors at site, we could delineate the sink holes quite accurately. The depth of and the shape of these anomalies have been modeled by 3-D inversion of micro-gravity data.

Key words: Microgravity, Sink-holes, Topographical effects, 3-D modeling

مدل‌سازی فروچاله در نیروگاه برق با داده‌های میکروگرانی‌سنجی

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چکیده

یک پروژه میکروگرانی‌سنجی برای آشکارسازی فروچاله‌ها در یک نیروگاه برق اجرا شده است.

اثر تونل‌های کم‌عمق زیرزمینی و تأسیسات سطحی نیروگاه در داده‌ها تصحیح شده‌اند. این تأسیسات شامل مخازن سوخت برج‌های خنک‌کننده و غیره‌اند.

عملیات برداشت داده‌ها در دو سایت واقع در نیروگاه که خطر ایجاد فروچاله‌ها در آنها وجود داشته است صورت گرفت.

با وجود نوفه‌های فراوان حاصل از تأسیسات، برداشت داده‌ها با دقت قابل قبولی و با استفاده از گرانی‌سنج‌های سینترکس صورت گرفت. بعد از به‌دست آوردن اطلاعات لازم نظیر عمق و شکل این حفره‌ها با اعمال فیلترهای متفاوت نظیر فراسو، فروسو و اویلر روی نقشه‌های بی‌هنجاری بوگه، شکل نهایی و عمق این بی‌هنجاری‌ها با مدل‌سازی سه‌بعدی تعیین شده‌اند.

از آنجاکه اطلاعات مربوط به محل و عمق بی‌هنجاری‌ها (فروچاله‌ها) در زیر تأسیسات حساس نیروگاه بسیار حیاتی است، این اطلاعات می‌تواند برای مهندسان عمران و تأسیسات بسیار باارزش باشد.

واژه‌های کلیدی: میکروگرانی‌سنجی، فروچاله، اثرات توپوگرافی، مدل‌سازی سه‌بعدی

1 INTEODUCTION

Natural cavities in limestone bedrock (Karst regions) cause sink holes in upper deposits.

Detection of cavities is one of the most frequently cited applications of

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microgravimetry.

Microgravity is a valuable complement to the other geophysical, geologic, and direct methods for site investigation in such areas.

The first attempt to detect caves by made gravity measurements was made by Coolley (1962) where symmetrical geometric forms were used to the approximate different types of caves.

Fajklewicz, (1983) has a vital role in the application of microgravity, in mines and urban areas.

Butler (1980 and 1984), Arzi (1975) and Neumann (1977) used microgravity in Karst detection and engineering applications.

Sink-holes are seen very frequently in many parts of Iran. They are mainly produced due to a substantial decrease in the underground water table. They are vital and risky problems particularly when they exist in urban and industrial areas. We aim to detect and model the sink-holes which generate from Karstic holes in the basement.

2 FIELD PROCEDURES

The location of the sink-holes are detected at the sites for infrastructures.

The study area is located inside an electrical power plant in the vicinity of a city in Iran (the name of the city is not given for security reasons). The site is located in a smooth area of Quaternery deposits and a Karstic limestone as the basement.

The area of investigation is 1km by 2 km.

The measurement stations are located mostly in the part of the area which contains man made facilities such as under ground canals, cooling towers, boilers, gas oil reservoirs etc. Two separate grids consisting of 1552 and 957 points were selected.

A basic grid dimension of 10 meters was used. The measurement points locations are shown in figure (1). Data were collected with a CG3-m gravity meter with a sensitivity of approximately 1μGal.

3 GRAVITY CORRECTIONS

The data are corrected for the effects caused by the variations in elevation, topography, earth tides and instrument drift.

Drifts of the gravimeter were removed using a base station close to the site.

Free-air and Bouguer corrections are computed through related equations.

The terrain correction is the most sensitive stage in reductions which was due to substantial man-made facilities in the power plant. The effects of these facilities are computed through related equations for computing the gravity effects of cylinder and rectangular prism equations (1) and (2) follows (Banerjee and Gupta 1977),

$$g_{cyl} = f\sigma\pi a^2 \sum_{n=0}^{\infty} \frac{\left(\frac{1}{4}\right)_n \left(\frac{3}{4}\right)_n}{(1)_n (2)_n} \left[\phi_n(z-1) - \phi_n(z+1)\right] \quad (1)$$

where

$$\phi_n = \frac{1}{\sqrt{z^2+\rho^2+\alpha^2}} \left[\frac{4\alpha^2+\rho^2}{\left(z^2+\rho^2+\alpha^2\right)^2}\right]^n \sum_{K=0}^{\infty} \frac{\left(2n+\frac{1}{2}\right)_k}{(n+2)_k} \left(\frac{a^2}{z^2+\rho^2+\alpha^2}\right)^k$$

g_{cyl} : The vertical gravitational attraction of a vertical cylinder.

$$(x)_n = x(x+1)(x+2)(x+3)...(x+n-1)$$

f : universal gravitational constant

σ : density of the cylinder

α : radius of the cylinder

ρ : horizontal distance between the center of the cylinder and measurement point .

z : vertical distance between the center of the cylinder and measurement point.

2l : height of the cylinder

$$g_{par} = f\sigma \left|\left|\left| x\ln(y+r) + y\ln(x+r) - z\arctan \frac{xy}{zr} \right|_{x2}^{x1} \right|_{y2}^{y1} \right|_{z2}^{z1} \quad (2)$$

where

g_{par} : the vertical gravitational attraction, of the prism bounded by the planes X=x1, X=x2; Y=y1, Y=y2 and Z=z1, Z=z2,
σ : density of the prism,
f : universal gravitational constant and

$$r = \sqrt{x^2 + y^2 + z^2}.$$

Using equations (1) and (2) the topographical effects could be calculated.

Then considering these corrections, Bouguer gravity anomalies are computed.

4 INVERSION TECHNIQUES

The 3-D inversion method described by Last and Kubik (1983) was applied to model the low density zones.

To determine the geometry of the anomalous bodies, the neighboring subsurface volume was demonstrated into a 3-Dgrid of m contagious cells j, j=1,….,m.

The attraction of each cell at the survey point Pi(i=1,…,n) is presented by equation (2).

With these basic elements the inversion tries to determine the anomalous bodies by an expansion or growth process. An interesting advantage of this method is the possibility of considering both positive and negative density contrasts.

This method was applied to the data considering a contrast density of ±500 kgm^{-3} based on the existing geological information.

The geometry of negative and positive anomalies can be are determined through the inversion technique. These anomalies are completely critical in construction of the dam and should be avoided or stabilized somehow.

5 INTERPRETATION

The Bouguer gravity anomalies of the site are depicted in figure 1.

Negative anomalies of the lower contrast densities are demonstrated with numbers 1 to 13 (figure 1)

Using the polynomial fitting, the residual gravity anomalies are computed and shown in figure 2.

The residual gravity anomalies also show some areas of negative anomalies of lower density and particularly around the anomaly number 1.

For an area around this anomaly which has been determined on the map of the residual gravity figure 2, the inversion method considering the contrast density of ±500 kgm^{-3} is used and the results are demonstrated in figures 3-9 for different depths and coordinates.

As the figures demonstrate the geometry of negative and positive anomalies are quite determined.

Inspecting the figures the following results are obtained:

- Negative anomalies are concentrated in the borders at coordinates x=50 m and x=300 m from 1637 m to 1617 m height (figures 3-5 and figure 8).
- Small negative anomalies are detected in different coordinates from 1607 m to 1602m height (figures 6, 7 and 9).

Considering the depth expansion of these two branches of anomalies the linear concentration of anomalies (figures 3-5) seems to be more important which has to be investigated on site.

6 CONCLUSIONS

The near-surface anomalies such as sink holes and cavities can be detected through micro-gravity data even in industrial and urban areas where a variety of noises exist. The inversion of gravity anomalies can provide valuable information about the geometry of these anomalies.

In the site the main negative zones in x=50 m and y=50 to 250 m and x=300 m and y=50 to 250 m have to be carefully investigated (excavated).

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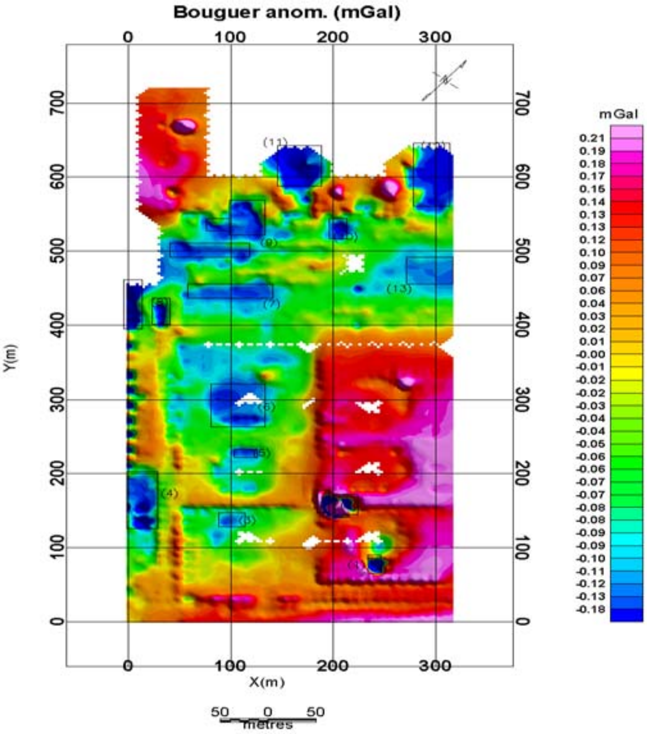

Figure 1. Bouguer Gravity Anomalies.

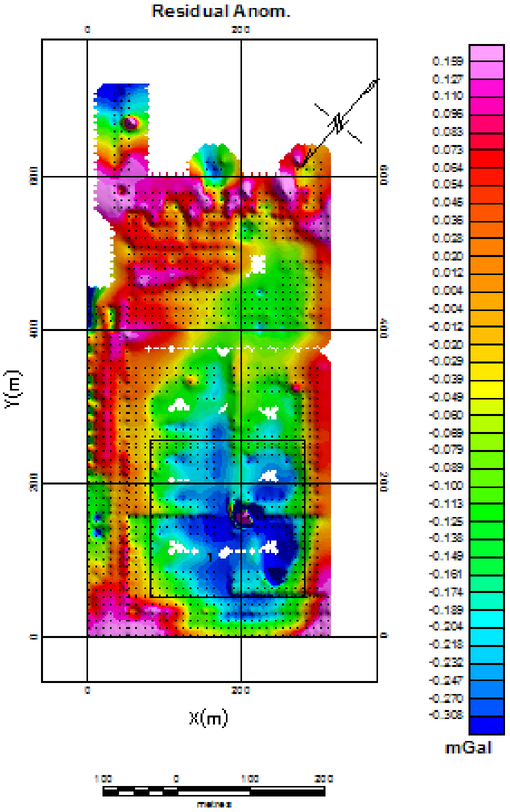

Figure 2. Residual gravity anomalies.

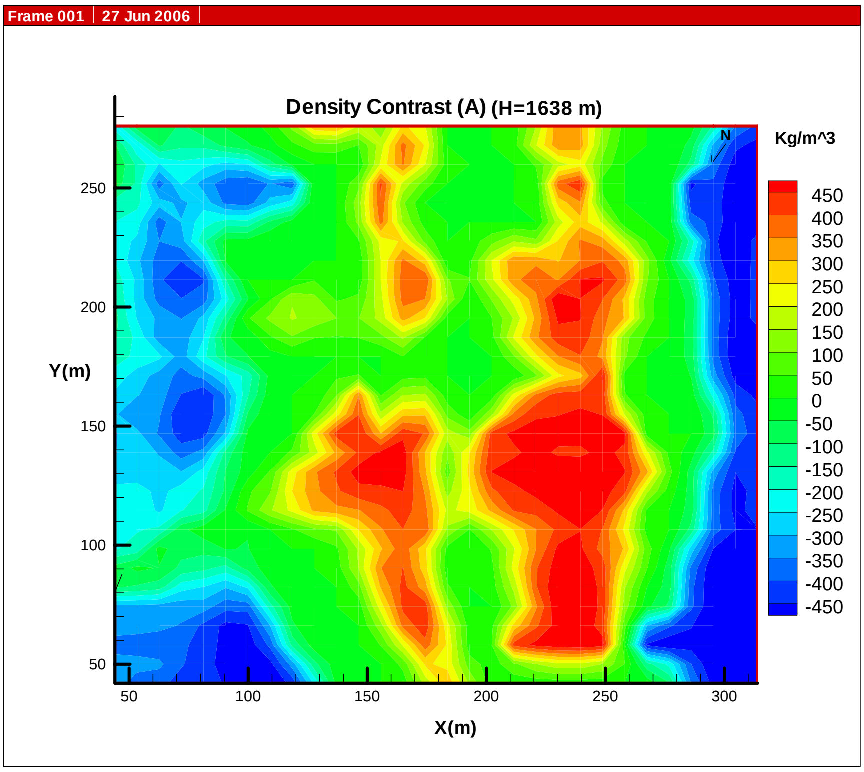

Figure 3. Density contrasts in 1638 m.

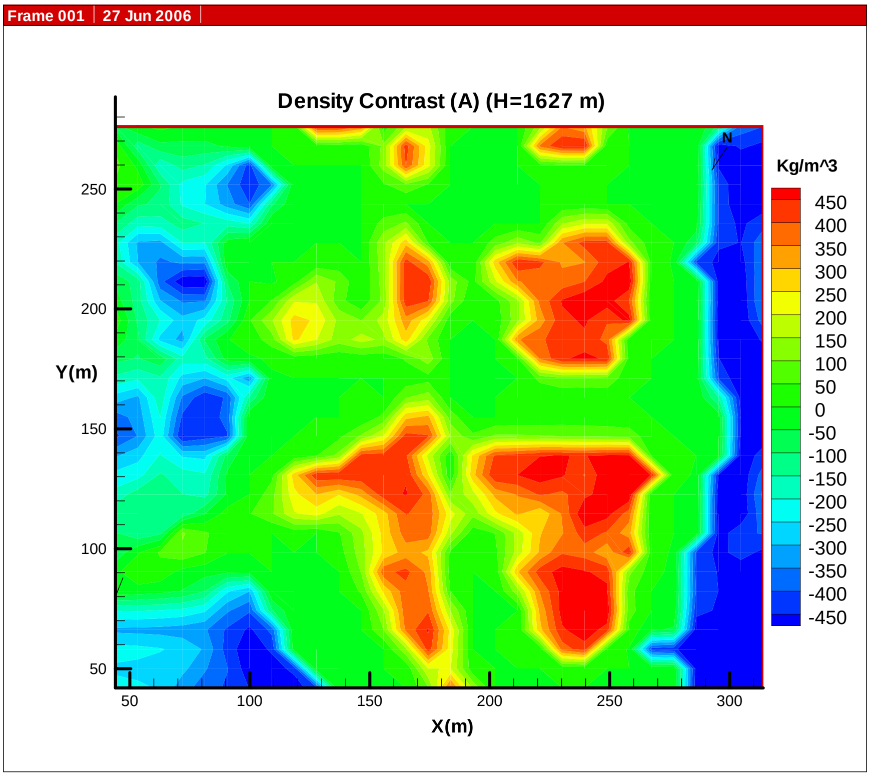

Figure 4. Density contrasts in 1627 m.

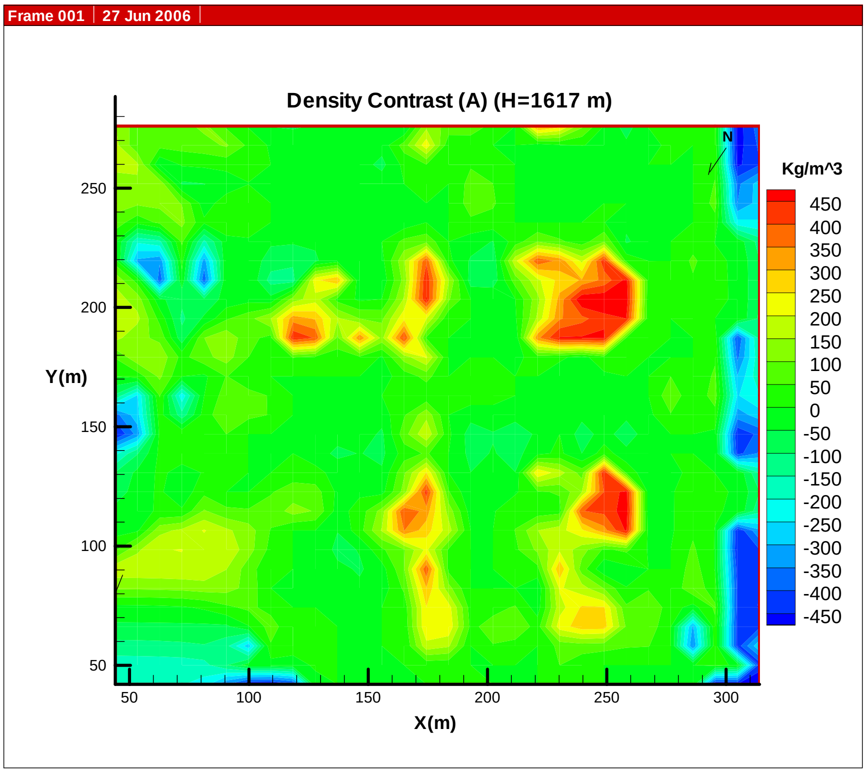

Figure 5. Density contrasts in 1617 m.

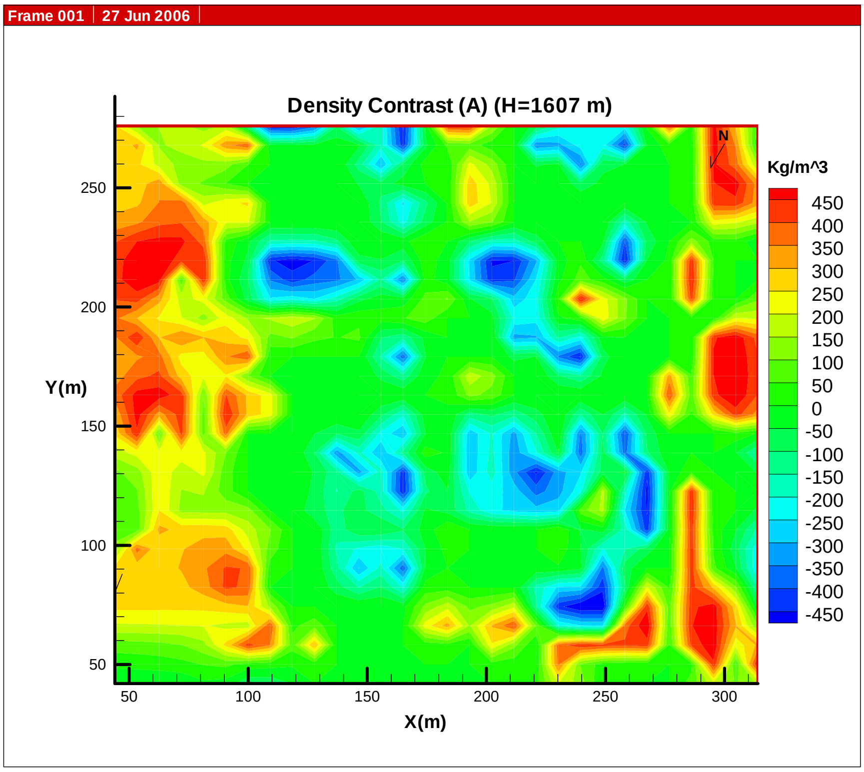

Figure 6. Density contrasts in 1607 m.

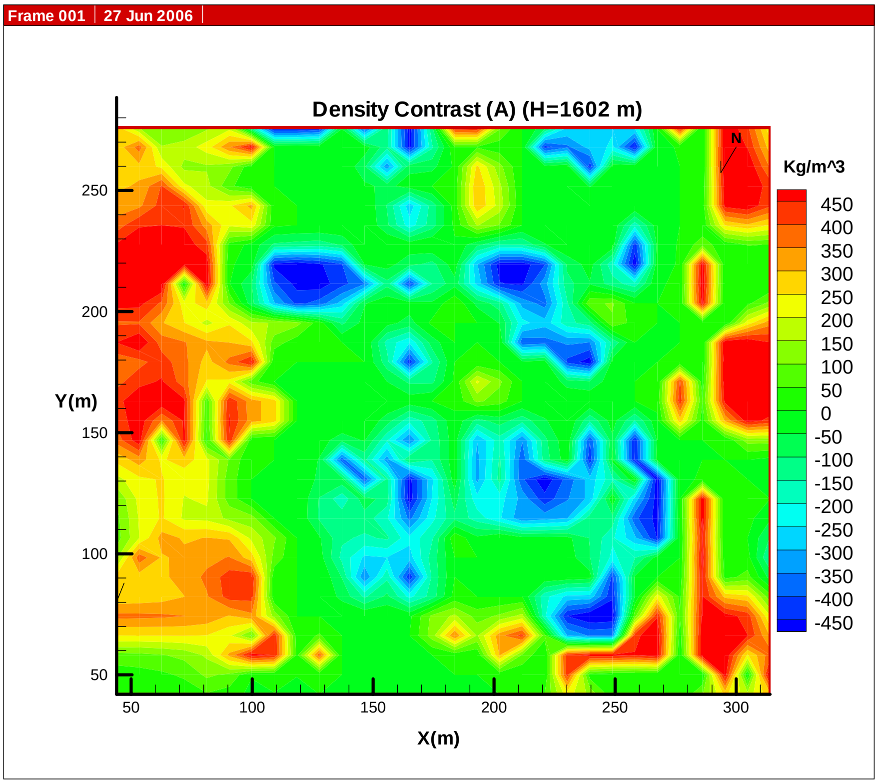

Figure 7. Density contrasts in 1602 m.

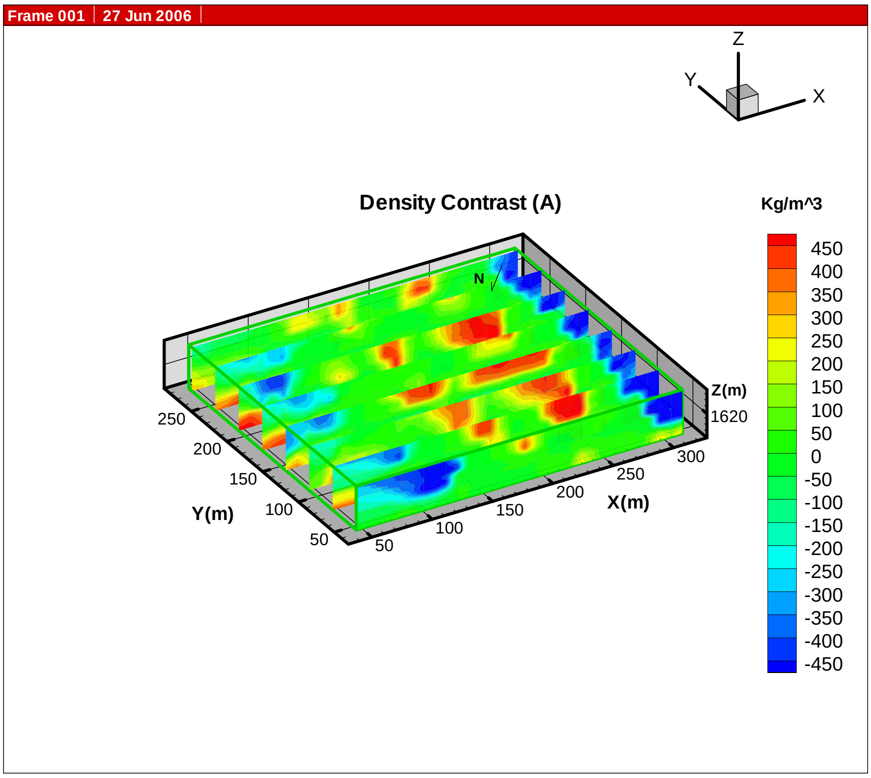

Figure 8. 3-D view of density contrasts.

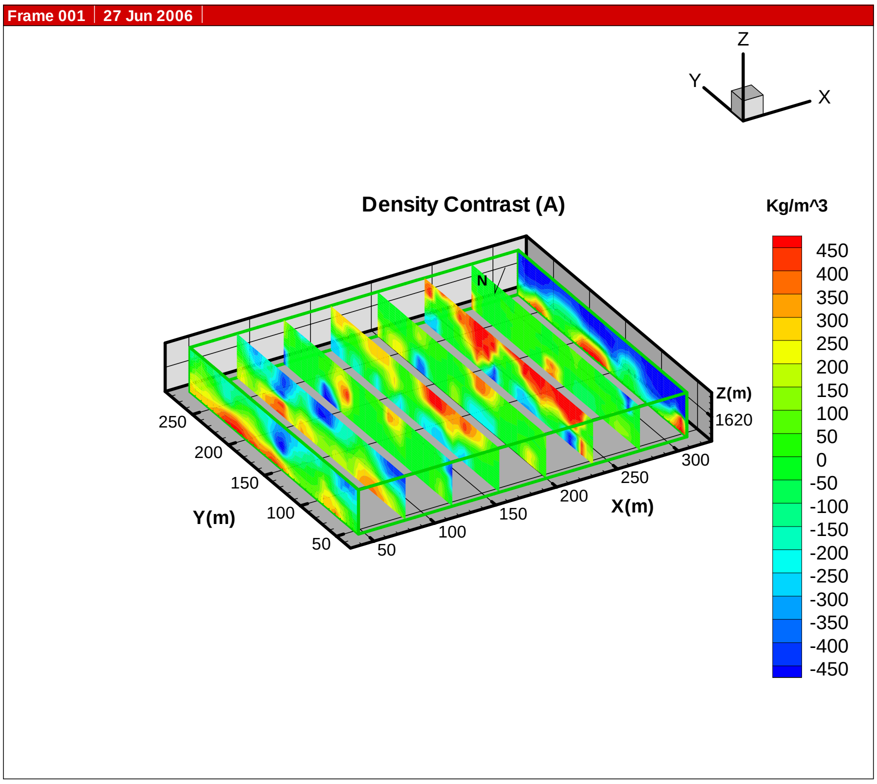

Figure 9. 3-D view of density contrasts.

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