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Editorial: Applications of gravity anomalies in geophysics

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Editorial on the Research Topic
Applications of gravity anomalies in geophysics

With the progress of cheap, lightweight, and efficient gravimeters (Carbone et al., 2020; Stray et al., 2022; Kim and Choi, 2023), gravity anomalies are expected to receive wider attention in the future, opening up new perspectives for increasing the capability of gravimetry to Earth sciences. Since the knowledge of the crustal density of a planet is important in determining its interior structure, gravity anomaly is widely used in Solid Earth and exploration geophysics, and also extended to the moon and Mars. In addition to the routine applications focusing on the crustal density structure, contributing to the characterization and definition of underground structures at various scales, time-varying gravity, microgravity survey, and gravity admittance are widely applied in order to supply unique information on the dynamics of underground processes. The goal of this Research Topic is to highlight the various extracted information from gravity anomalies in applications, toward an understanding of choosing appropriate methods dealing with gravity anomalies in varying study cases.

There are ten accepted papers on this Research Topic focusing on the following four research questions.

The first question is about the equivalent-layer technique (Oliveira Junior et al.) which present a comprehensive review of the computation aspects concerning the equivalent-layer technique. The equivalent-layer technique is used widely in processing gravity and magnetic anomalies, e.g., the downward continuation and the reduction to the pole at low latitudes. While such method is very inefficient for dealing with massive data sets, lots of computationally efficient methods have been proposed to reduce its computational cost. The authors from Observatório Nacional and Universidade do Estado do Rio de Janeiro (Brazil) present a comprehensive review of diverse strategies to solve the linear system of the equivalent layer in which the advantages and disadvantages for the existing strategies are described in detail.

The second question is about the time-varying gravity (Zhu et al.) which is used in monitoring the subsurface mass variation. Zhu et al., from China Earthquake Administration, have conducted numerous applications focusing on the time-varying gravity in earthquake research in the Chinese Mainland. The gravity changes before and after the earthquakes were found in several earthquakes, and thus the high-precision mobile gravity observations used to survey the gravity changes possibly induced by the earthquake had attracted people's attention. Reports show that the gravity observation network in the Chinese Mainland made a relatively successful medium-term prediction for a series of earthquakes since 2008 after the serious Wenchuan *Ms*8.0 earthquake. Zhu et al. introduce some case studies and progress using the time-varying gravity in earthquake monitoring in the Chinese Mainland which put forward the gravity applications in earthquake prediction. The time-varying gravity is also applied widely in investigating the hydrological and volcano-tectonic processes controlling the present day activity of the volcano (Pivetta et al., 2023). The present studies show that the role of time-varying gravity in earthquake prediction would become increasingly significant with the progress of cheap, lightweight and efficient gravimeter. In addition to the high precision ground time-varying gravity, the time-varying gravity from satellites has played an extremely important role in hydrology, seismology, geodesy, and geophysics (Liu and Sun, 2023).

The third question is about mapping the structural lineaments (Ganguli and Pal; Sun et al.) which is used widely in geological mapping (Altinoğlu, 2023; Ashraf and Filina, 2023; Bayou et al., 2023; Ibrahim et al., 2023; Lghoul et al., 2023; Mnasri et al., 2023; Qadir et al., 2023). Such applications are based on the qualitative interpretation of gravity anomalies in which the edge detection filters are usually applied to enhance the lineament. Sun et al. propose a modified edge detection method based on the second order spectral moment to detect edges on potential field which can enhance the weak anomalies and eliminate the false edges caused by the associated anomalies. Ganguli and Pal applied second vertical derivative and tilt derivative on the potential field data to reveal very prominent NESW trending linear gravity high and low.

The fourth question is about the quantitative interpretation of gravity anomalies. Harash et al. and Liu et al. apply the gravity inversion to obtain the Moho topography. For the Moho inversion from gravity anomalies, the Parker–Oldenburg methods in Fourier domain are powerful tools (Zhang et al., 2020; Elmas and Karsl, 2021; Borghi, 2022). The other contributions in this Research Topic are focusing on the subsurface density structures modeling using gravity anomalies (Nigussie et al.; Nigussie et al.; Moura and Marangoni; Pánisová et al.). Modeling the crustal density is very useful to reveal its composition and structure, and hence it is also significantly related to the tectonic evolution and geodynamics in Earth, Moon and Mars (Affatato, 2023; Haas et al., 2023; Smith et al., 2023).

In addition to the above-mentioned research questions, the gravity anomalies have been widely used in estimation of the elastic thickness and have been extended from Earth to other planets where gravity data is available (Broquet and Wieczorek, 2019; Genova et al., 2023). Since the routine Pratt and Airy compensation modes require a lithosphere with an unrealistic and highly anisotropic mechanical behavior, the flexure model has been extensively used to interpret short-wavelength gravity anomalies due to variations in crustal thickness. The parameter that characterizes the apparent strength of the lithosphere is the effective elastic thickness (Te) of the lithosphere, and thus the estimation of Te value is important to measure of the integrated strength of the lithosphere which can be compared from region to region and interpreted in terms of the thermal and mechanical structure of the continental lithosphere. Gravity/topography admittance is first proposed to estimate Te, and the related improvements on Te estimation are becoming the focus of attention.

We hope this Research Topic would provide a helpful source of references for those working in gravity anomalies.

Author contributions

HZ: Writing–original draft, Writing–review and editing. VS: Writing–review and editing. MG: Writing–review and editing. PL: Writing–review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Affatato, V. (2023). *Interpretation of gravitational data from past martian missions*.

Altinoğlu, F. F. (2023). Mapping of the structural lineaments and sedimentary basement relief using gravity data to guide mineral exploration in the denizli basin gravity data to guide mineral exploration in the denizli basin. *Minerals* 13 (10), 1276. doi:10.3390/min13101276

Ashraf, A., and Filina, I. (2023). Zones of weakness within the Juan de Fuca plate mapped from the integration of multiple geophysical data and their relation to observed seismicity. *Geochem. Geophys. Geosystems* 24 (10), e2023GC010943. doi:10.1029/2023gc010943

Bayou, Y., Abtout, A., Renaut, R. A., Bouyahiaoui, B., Maouche, S., Vatankhah, S., et al. (2023). The northeastern Algeria hydrothermal system: gravimetric data and structural implication. *Geotherm. Energy* 11 (1), 14–26. doi:10.1186/s40517-023-00258-2

Borghi, A. (2022). Moho depths for Antarctica Region by the inversion of ground-based gravity data. *Geophys. J. Int.* 231 (2), 1404–1420. doi:10.1093/gji/ggac249

Broquet, A., and Wieczorek, M. A. (2019). The gravitational signature of Martian volcanoes. *J. Geophys. Res. Planets* 124 (8), 2054–2086. doi:10.1029/2019je005959

Carbone, D., Antoni-Micollier, L., Hammond, G., de Zeeuw-van Dalfsen, E., Rivalta, E., Bonadonna, C., et al. (2020). The Newton-g gravity imager: toward new paradigms for terrain gravimetry. *Front. Earth Sci.* 8. doi:10.3389/feart.2020.573396

Elmas, A., and Karsl, H. (2021). Tectonic and crustal structure of Archangelsky ridge using Bouguer gravity data. *Mar. Geophys. Res.* 42 (3), 21. doi:10.1007/s11001-021-09443-z

Genova, A., Goossens, S., Del Vecchio, E., Petricca, F., Beuthe, M., Wieczorek, M., et al. (2023). Regional variations of Mercury's crustal density and porosity from MESSENGER gravity data. *Icarus* 391, 115332. doi:10.1016/j.icarus.2022.115332

Haas, P., Ebbing, J., and Szwillus, W. (2023). Cratonic crust illuminated by global gravity gradient inversion. *Gondwana Res.* 121, 276–292. doi:10.1016/j.gr.2023.04.012

Ibrahim, A., Gemail, K. S., Bedair, S., Saada, S. A., Koch, M., and Nosair, A. (2023). An integrated approach to unravel the structural controls on groundwater potentialities in hyper-arid regions using satellite and land-based geophysics: a case study in southwestern desert of Egypt. *Surv. Geophys.* 44 (3), 783–819. doi:10.1007/s10712-022-09755-8

Kim, G., and Choi, I. M. (2023). Development of SQUID detection technology for a superconducting gravimeter. *Rev. Sci. Instrum.* 94 (9), 094505. doi:10.1063/5.0163714

Lghoul, M., Abd-Elhamid, H. F., Zelenakova, M., Abdelrahman, K., Fnais, M. S., and Sbihi, K. (2023). Application of enhanced methods of gravity data analysis for mapping the subsurface structure of the Bahira basin in Morocco. *Front. Earth Sci.* 11, 1225714. doi:10.3389/feart.2023.1225714

Liu, C., and Sun, W. (2023). GRACE time-variable gravity and its application to geoscience: quantitative analysis of relevant literature. *Earth Planet. Phys.* 7 (2), 295–309. doi:10.26464/epp2023022

Mnasri, M., Amiri, A., Nasr, I. H., Belkhiria, W., and Inoubli, M. H. (2023). Integrated geophysical approach for ore exploration: case study of sidi bou aouane–khadhkhadha Pb–Zn province–northern Tunisia. *Geophys. Prospect.* 71 (9), 1772–1791. doi:10.1111/1365-2478.13338

Pivetta, T., Riccardi, U., Ricciardi, G., and Carlino, S. (2023). Hydrological and volcano-related gravity signals at Mt. Somma–Vesuvius from ~20 yr of time-lapse gravity monitoring: implications for volcano quiescence. *Geophys. J. Int.* 235 (2), 1565–1580. doi:10.1093/gji/ggad320

Qadir, H. O., Baban, E. N., Aziz, B. Q., and Koyi, H. A. (2023). Potential field survey of subsurface structures of the NW segment of the zagros fold-thrust belt, kurdistan region. *Geophys. Prospect.* 71 (8), 1673–1690. doi:10.1111/1365-2478.13401

Smith, D. E., Goossens, S., Neumann, G. A., and Zuber, M. T. (2023). Constraining the structure under lunar impact basins with gravity lunar impact basins with gravity. *Planet. Sci. J.* 4 (11), 204. doi:10.3847/psj/acfcac

Stray, B., Lamb, A., Kaushik, A., Vovrosh, J., Rodgers, A., Winch, J., et al. (2022). Quantum sensing for gravity cartography. *Nature* 602 (7898), 590–594. doi:10.1038/s41586-021-04315-3

Zhang, H. L., Ravat, D., and Lowry, A. (2020). Crustal composition and Moho variations of the central and eastern United States: improving resolution and geologic interpretation of EarthScope USArray seismic images using gravity. *J. Geophys. Res. Solid Earth* 125, e2019JB018537. doi:10.1029/2019jb018537