

QUAKE-G: Integrating Quantum Gravimetry and Satellite Models for Multiscale Analysis of Earth's Gravity Field Variations

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Abstract: The QUAKE-G project integrates quantum gravimeters, satellite gravity missions and GNSS observations to investigate multiscale gravity variations. Advanced processing algorithms enable separation of signals, improving geophysical interpretation and supporting future network-based quantum gravimetry applications.

Quantum gravimetry represents a major technological advancement for observing temporal variations of the Earth's gravity field. Modern quantum gravimeters exploit atom interferometry to provide absolute measurements with sensitivities of $\sim 1 \mu\text{Gal}$ (10^{-8} m/s^2), enabling stable monitoring of mass redistribution processes. This precision supports geophysical applications such as groundwater monitoring, volcanic surveillance and crustal deformation studies.

The QUAKE-G project (Quantum Utilization for Advanced Knowledge in Earth Gravity), funded within the NQSTI framework, develops an integrated approach for the analysis of gravity field variations by combining terrestrial quantum gravimeters with satellite gravity missions such as GRACE and GRACE-FO. A comprehensive database including gravimetric satellite models (2002–2025), ground observations and co-located GNSS data has been assembled, together with dedicated tools for data ingestion, processing, and long-term analysis. Advanced algorithms have been developed to reduce observations for solid Earth tides, ocean loading, and atmospheric effects, and to separate local and regional signals. The workflow supports multi-station analysis, enabling the estimation of key geophysical parameters such as the gravimetric factor and the temporal delay between gravity variations and GNSS-derived vertical deformation. Their spatial distribution shows correlation with geological structures, providing insight into crustal density and viscosity.

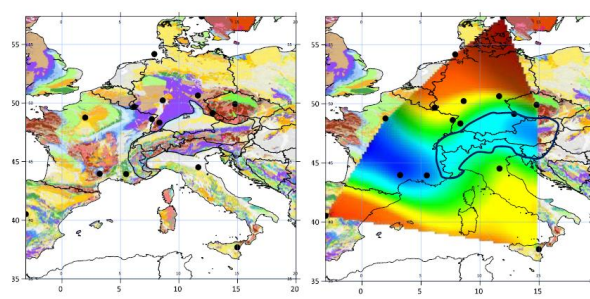


Fig. 1 Multi gravity stations analysis

The integration of ground-based quantum measurements with satellite observations improves the spatial and temporal resolution of gravity monitoring, bridging local and global scales. This approach supports the transition toward network-based gravimetry and represents a step toward operational applications in geophysics and natural hazard monitoring.

At the end of the QUAKE-G project, several analysis tools and processing workflows have been developed in synergy with INGV to support the study of temporal variations of the Earth's gravity field. These developments are particularly relevant in the context of the growing network of permanent quantum gravimeters currently being deployed in Italy and across Europe. The integration of advanced processing algorithms with a network of high-precision quantum instruments represents a promising step toward operational monitoring of gravity field variations, enabling improved investigation of geophysical processes such as crustal deformation, volcanic activity, and hydrological changes.

References

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