The QUAKE-G project: quantum gravimeters revolutionize gravity data analysis and geophysical investigations

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Abstract

Quantum gravimeters are revolutionizing gravity data analysis with accurate absolute measurements. The QUAKE-G project aims to design algorithms to distinguish local and regional geophysical signals, integrating satellite data, to advance Earth's hydrological and geodynamical research.

Quantum gravimeters, among the few quantum-based technologies currently available on the market, represent European excellence and cutting-edge technology that are transforming the field of gravity data analysis by enabling highly precise, continuous absolute measurements of the gravitational field (10^{-8} m/s^2 or 1 μGal) [1]. The analysis of these precise continuous gravity measurements in geophysical applications offers numerous advantages: in groundwater monitoring, gravitational variations can indicate changes in the water table level, enabling more efficient management of water resources; in volcano surveillance, gravitational changes can detect magma movements and other precursor phenomena to volcanic eruptions [2]; in crustal studies, the analysis of regional gravitational variations give precious insights into the dynamics of the Earth's crust, contributing to our understanding of seismic processes.

The "Quantum Utilization for Advanced Knowledge in Earth Gravity (QUAKE-G)" project aims to develop algorithms for the analysis of gravitational data from a network of permanent absolute quantum gravimeters. This algorithm will enable the separation of local geophysical signals from regional ones, integrating observations from permanent stations with satellite data. In doing so, it will enhance the temporal and spatial resolution of gravitational measurements, providing more accurate and timely information for natural resource management and geophysical risk mitigation. The project involves collaboration between Geomatics Research & Development srl (GReD), a technology company, and Istituto Nazionale di Geofisica e Vulcanologia (INGV), a research center to leverage quantum gravimeter technology for geophysical applications. The INGV, currently operates a network of permanent gravimeters, including two quantum gravimeters across Italy, with plans to expand the number of quantum instruments. The densification of permanent stations for gravitational field observation, enabled by quantum sensors, will pave the way for a shift from single-station analysis to a network-based approach. This will facilitate the separation of high-frequency, high-resolution local signals from deeper, regional effects characterized by longer wavelengths and periods. The QUAKE-G project will develop tools for analyzing geophysical signals within this network, with the potential for future expansion to include a comprehensive investigation of geophysical signals and phenomena at other permanent gravimetric stations across Europe. Additionally, improved characterization of regional signals will enable the validation and integration of ground-based observations with satellite mission data (e.g., GRACE-FO or the European Space Agency's NGGM mission). This integration will homogenize the data and enhance the spatial resolution of satellite-derived results.

The project marks a significant advancement in the use of quantum gravimeters for geophysical applications, combining cutting-edge technology with scientific collaboration to create powerful and precise monitoring tools. A key innovation lies in the integration of terrestrial data collected by quantum gravimeters with satellite observations. This synergy will refine geophysical models, making them more accurate and comprehensive by combining the high spatial and temporal resolution of ground-based measurements with the global and continuous coverage provided by satellites.

References

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