CARIOQA-PMP

CARIOQA RESEARCH SPOTLIGHT #1:

Translating scientific publications into accessible knowledge

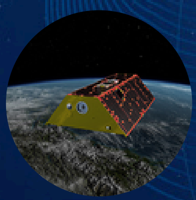
Benefit of MAGIC and multipair quantum satellite gravity missions in Earth science applications, *Jürgen Kusche, Christina Strohmenger, Helena Gerdener, Bernd Uebbing, Anne Springer, Yorck Ewerdwalbesloh, Annette Eicker, Carla Braitenberg, Alberto Pastorutti, Roland Pail, Philipp Zingerle, Marius Schlaak, Mirko Reguzzoni, Lorenzo Rossi, Federica Migliaccio, Ilias Daras, Geophysical Journal International, Volume 242, Issue 2, August 2025*.

Abstract

Satellite gravity missions such as GRACE and GRACE-FO have greatly advanced our understanding of the Earth system by monitoring changes in mass distribution, including water movement, ice loss, and ocean circulation. However, their spatial and temporal resolution remains limited, which constrains applications like regional water management and early hazard detection. To overcome these limitations, new mission concepts are being developed, including MAGIC and next-generation approaches based on quantum sensor technologies. These future missions aim to provide more precise, higher-resolution measurements, and this paper evaluates this hypothesis.

Methodology

The study uses numerical simulations to compare the performance of four satellite mission scenarios:



A GRACE-FO-like mission (current reference)

The MAGIC mission (next-generation dual-pair system)

A three-pair quantum satellite configuration (CAI3)

A six-pair quantum satellite configuration (CAI6)

These scenarios were tested under realistic conditions, including measurement noise and modelling uncertainties. The simulated data were then applied to key Earth science use cases:

- *Monitoring terrestrial water storage*
- *Detection of geophysical events*
- *Estimation of ocean mass and sea level changes*

Key Results

The study demonstrates that next-generation satellite gravity missions—particularly those combining multiple satellite pairs and quantum sensors—have the potential to significantly advance Earth observation capabilities. These improvements could support more accurate and timely monitoring of water resources, climate change and geophysical hazards, although their full impact will depend on parallel progress in modelling and data integration.

Link with the CARIOQA Mission: *The CARIOQA mission is a first step towards quantum-based satellite gravimetry. By demonstrating quantum accelerometer in orbit, it will pave the way for future quantum gravity missions capable of improving observations of mass transport within the Earth system and supporting the Earth science use cases identified in this scientific publication.*

Funded by the European Union

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