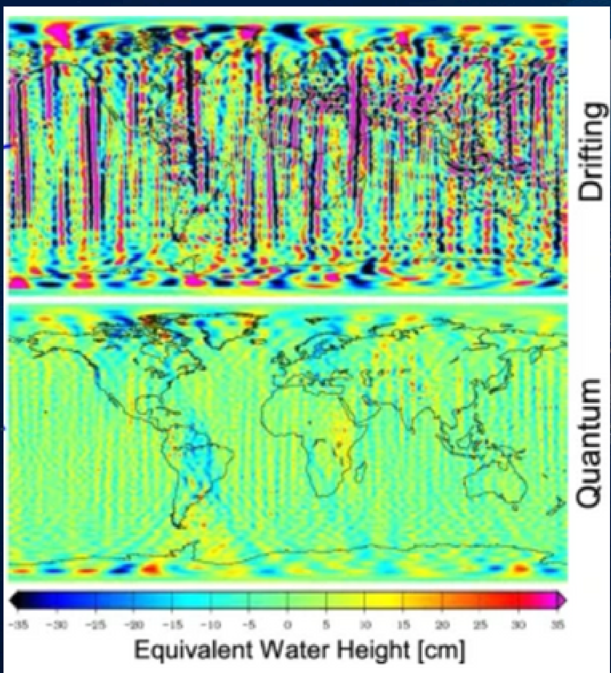
CARIOQA-PMP

Quantum Technologies in Space: Advancing Gravity Measurements and Fundamental Physics

Factsheet 7: June 2025

Quantum accelerometers provide absolute, stable measurements of acceleration that do not drift over time. Unlike classical devices, these sensors leverage the intrinsic properties of atoms, enabling precise and stable acceleration measurements.



Spectra of gravity field recovery in equivalent water height considering quantum or drifting accelerometers in a GRACE-like mission'

source : Lévèque et al., Gravity Field Mapping Using Laser Coupled Quantum Accelerometers in Space, arXiv:2011.03382, 2020.

Indeed, classical electrostatic accelerometers in gravimetry missions struggle with noise at low frequencies, which contributes to the characteristic "striping" pattern in gravity field data, particularly in the GRACE mission. This issue, along with other factors like atmospheric and ocean variability and a one-dimensional observation direction, limits the ability to measure long-wavelength gravity fields accurately. High sensitive quantum sensors providing more stable, drift-free measurements can eliminate the striping due to low frequency noise and contribute to a better understanding of mass transport and climate change.

On the other hand quantum accelerometers provide absolute measurements with errors that can be studied and mitigated through metrology, making them more reliable for scientific missions. Their error margins can be accurately accounted for and managed, and missions like CARIOQA will further advance the technological readiness of these instruments to achieve higher sensitivity in space.

In addition, quantum sensors also open new possibilities for testing fundamental physics. The proposed STE-QUEST mission aims to test the universality of free fall using cold atoms as test masses. This will enable tests of general relativity that are two orders of magnitude more precise with respect to the state of the art, advancing our understanding of gravity and space-time, and potentially offering insights into the unification of quantum mechanics and gravity.

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