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Cold Atom Interferometer activities for measuring the Earth's gravity field

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In the past decade, it has been shown that atomic quantum sensors are a newly emerging technology that can be used for measuring the Earth's gravity field. Whereas classical accelerometers, based e.g. on capacitive sensing and electrostatic actuation, are limited by relatively high noise at low frequencies, Cold Atom Interferometers (CAI) can be highly accurate over the entire frequency range, which also has the benefit that they do not need any calibration phase. Several studies related to these new sensor concepts were initiated at ESA, mainly focusing on technology development for different instrument configurations (gravity gradiometers and satellite-to-satellite ranging systems) and including validation activities, e.g. two successful airborne surveys with a CAI gravimeter. We will present the first conclusions of these different mission and instrument studies:

- The first airborne gravity survey during the ESA Cryovex/KAREN 2017 campaign using this technology was conducted by DTU and ONERA. The measurements did not show any drift and the accuracy was found to be less than 4 mGal at 11 km resolution. A second campaign has been conducted by ONERA and CNES in 2019 in the South of France and improved the accuracy by a factor 4, reaching classical airborne survey state-of the art performance.
- A first space quantum gravity mission concept is based on a gravity gradiometer that delivers a very high common mode rejection, greatly relaxing the drag-compensation requirements.
- The second concept is based on quantum accelerometers for correcting low frequency errors of electrostatic accelerometers that are used in a low-low satellite-to-satellite ranging concept in order to measure non-gravitational accelerations.

For both concepts we will present the expected improvement in measurement accuracy and in the derived Earth gravity field models, taking into account the different types of measurement (e.g. single axis vs. three axis, integration time, etc.) and different mission parameters (e.g. attitude control, altitude of the satellite, lifetime of the mission, etc.). A technology roadmap will be outlined for potential implementation of a quantum inertial sensor geodesy mission within 10-15 years.