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Relativistic geodesy and gravimetry with quantum sensors: current developments and geodetic perspectives

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The recent breakthroughs in long-distance frequency comparisons of Strontium optical atomic clocks through phase-stabilized optical fibers open a new field for geodesy. The results obtained are already consistent with the expected gravitational frequency redshift between the involved stations at a level that corresponds to an inaccuracy of less than 1 m in height difference, and an improvement towards the cm accuracy level is expected rather soon. Particularly interesting is the fundamentally new perspective of tying potential differences and height differences to an atomic reference. Potential applications include regional geoid determination and the connection of height systems and tide gauges. In a broader view, quantum metrology offers many options for gravity related measurements. For optical clocks, relevant levels of precision and accuracy are obtained from a rather large variety of atomic species, both for clocks interrogating many neutral atoms in optical lattices, and for single-ion clocks using quantum logic that enables accessing particularly favorable atomic transitions. To assess the advantages of the different options and to choose specific setups is a challenge both for the re-definition of the SI second and for geodetic applications. Similarly, and closely related, atom interferometry offers many options for gravity related measurements. Different species in a variety of setups are being used successfully to determine gravity accelerations and its spatial derivatives.