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Recovering the time-variable gravitational field using satellite gradiometry: requirements and gradiometer concept

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The successful GRACE mission and its far-reaching benefits have highlighted the interest to continue and extend the mapping of the Earth's time-variable gravitational field with follow-on missions and ideally a higher spatiotemporal resolution.

Here, we would like to put forward satellite gravitational gradiometry as an alternative solution to satellite-to-satellite tracking for future missions. Besides the higher sensitivity to smaller scales compared to GRACE-like missions, a gradiometry mission would only require one satellite and would provide a direct estimation of a functional of the gravitational field. GOCE, the only gradiometry mission launched so far, was not sensitive enough to map the time-variable part of the gravity field. However, the unprecedented precision of the state-of-the-art optical metrology system on-board the LISA PATHFINDER satellite has opened the way to more performant space inertial sensors.

We will therefore examine whether it is technically possible to go beyond GOCE performances and to quantify to what extent the time-variable gravitational field could be determined. First, we derive the requirements on the knowledge of the attitude and the position of the satellite and on the measured gradients in terms of sensitivity and calibration accuracy for a typical repeat low-orbit. We conclude in particular that a noise level smaller than $0.1\ mE/\sqrt{Hz}$ is required in the measurement bandwidth [5x10^{-4} ; 10^{-2}]Hz so as to be sensitive to the time-variable gravity signal. We introduce then the design and characteristics of the new gradiometer concept and give an assessment of its noise budget. Contrary to the GOCE electrostatic gradiometer, the position of the test-mass in the accelerometer is measured here by laser interferometry rather than by a capacitive readout system, which improves the overall measurement chain. Finally, the first results of a performance analysis carried out thanks to an end-to-end simulator are discussed and compared to the previously defined requirements.