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What is required to map the Earth's time-variable gravitational field with satellite gradiometry?

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While GRACE-like missions are widely considered to continue the monitoring of mass variations and transport in the Earth system, the possibility to observe the time-variable gravitational field by using satellite gradiometry also seems to be within reach in the near future. New technologies developed for the LISA pathfinder mission open the way to even more performant space inertial sensing, in particular thanks to state-of-the-art optical metrology sensors. Such technologies can easily be adapted to a gradiometer configuration which could potentially outperform GOCE's gradiometer sensitivity by up to 2 orders of magnitude.

Here, we examine what are the benefits and the remaining challenges of a future gravity gradiometry mission with respect to science and user needs. More specifically, two aspects are addressed. First, the definition of requirements: estimating gravitational gradients on a moving platform requires to measure several quantities: satellite position and attitude, acceleration gradients, angular velocity and acceleration. In order to map a signal as tiny as the time-variable part of the gravitational field, stringent requirements have to be defined for the different sensors involved in the measurement process. To derive these requirements, we have run end-to-end simulations for different levels of total noise degrading the measured gradients. Then, the error of the recovered gravity field solutions has been quantified. Based on these results, an error budget has been allocated to each error or noise source. In particular, we show that, to be sufficiently sensitive to temporal gravity field variations, the gradiometer noise must be below 0.1 $mE/\sqrt{Hz}$ in the measurement bandwidth $[5 \times 10^{-4}; 10^{-2}]$ Hz, which is 200 times better than GOCE's gradiometer. Just as much challenging is the error on the attitude angle determination which must not exceed 0.1 arcsec/$\sqrt{Hz}$ for the rotation about the cross-track axis.

Second, as the gradiometer performance is one of the most critical issues, particular attention is paid to its feasibility. A concept of an optical gradiometer inheriting from GOCE and LISA Pathfinder technology is put forward and a first assessment of its noise budget is described. By optimizing the gradiometer design and its physical parameters, we have been able to estimate a preliminary noise budget that almost meets the accuracy requirement of 0.1 $mE/\sqrt{Hz}$ for the gradients.