# Ground truth for the NGGM MAGIC

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Ground truth of the time-variable gravity field derived from space missions can be obtained from the time series of gravity data acquired at a particular location or selected sites on the Earth surface. This might turn being pivotal for simulation of the expected gravity signal in the preparatory stage of the NGGM (*Next Generation Gravity Mission*) such as MAGIC, as well as in the initial supervised "classification" of a satellite image and calibration, in amplitude and phase, of satellite data. In principle, the most suitable ground instrumentation for this task would be an array of superconducting gravimeters (SGs). In fact, when dealing with time-variable gravity, both ground-based measurements and satellite observations require sensitivities at the level of a few tens of $nm/s^2$, nearly $10^3$ times smaller than those required for the definition of the static gravity field. Also, a good time stability is required. Spring gravimeters cannot be used for this comparison because of their irregular drift and absolute gravity measurements are sampled infrequently and at widely separated locations.

Of course, it is not possible to collect ground truth data everywhere on the Earth. We propose to carry out a realistic simulation of the expected gravity signature at the Earth's surface obtained from the NGGM MAGIC mission. To do so, we need to consider a ground area with sides of at least a few hundred km, where gravity records from multiple SG stations can be combined to provide a comparable average to the MAGIC footprint. This is possible only in Western Europe, where a dozen or so of SGs are currently operating fairly close together.

The Earth is a coupled dynamic system with a climate component, which includes the atmosphere, the oceans, the cryosphere and the continental hydrology. The state of art has demonstrated that separation of the couplings is possible, from the joint analysis of multiple geodetic measurements and/or of the climate and hydrology models. However, continental hydrology is expected to be the major contributor to the observed non-tidal gravity changes, representing the "full loading effect", namely Newtonian and elastic effect, of near-surface water variations. Global or regional hydrological models derive mass changes on the ground, namely snow, soil-moisture and groundwater, balancing precipitation, evapotranspiration and runoff. In Western Europe, all these components of the water cycle are rather well monitored and quantified thanks to gauges, satellite measurements and atmospheric modelling. Time-variable gravity variations can then be computed accurately from the continental water storage estimates. In spite of continuous progresses, modelling of the hydrological effects (in magnitude and phase) on terrestrial and space gravity measurements still remain challenging, as subsurface water dynamics is very difficult to assess, both at local and larger scales. Furthermore, there also remains an inconsistency of scale between single station values and smoothed satellite data. But the availability of a dense cluster of SGs and the improved spatial and time resolution of the NGGM-MAGIC, could be a breakthrough in overcoming this limiting factor.

The "ground truth" in past and ongoing satellite missions, like GRACE and GRACE-FO, has been realized through a "downward continuation" of the satellite field. Gravity variations at a SG location is usually reconstructed from the spherical harmonics (SH) Stokes coefficients provided by different analysis centres, with the help of appropriate combination of load Love numbers, describing the Earth's response to surface loads. Compared to SG instruments, satellites are sensitive to larger-scale phenomena; therefore, any satellite/SG comparison relies on common variability among the SG timeseries on a regional scale. Empirical orthogonal function (EOF) analysis has proven to be an efficient method for seeking common variability in SG time-series, which can then be compared with gravity variations derived from satellite measurements.

We propose to form a working group, bringing together scientists from different European groups with recognized experience in the following fields, which we consider fundamental for developing the proposed research theme

- SG data analysis
- Comparison of terrestrial and satellite gravity data
- EOF and other data mining techniques
- Global and local hydrology modelling