Recent advances in the determination of a high spatial resolution geopotential model using chronometric geodesy

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This work aims to evaluate the contribution of optical atomic clocks in the determination of the geopotential at high spatial resolution. The quality of the geopotential reconstruction is evaluated by comparing solutions computed from synthetic gravimetric data, combined or not with synthetic clock data. Our synthetic tests are performed in a French area with a moderate relief, which leads to variations of the gravitational field over a range of spatial scales. We show that adding few clock data into a gravimetric network permits to reduce the reconstruction bias significantly and to improve the standard deviation by a factor 3. Optimization of a clock data network with a genetic algorithm is also investigated.

1 Introduction

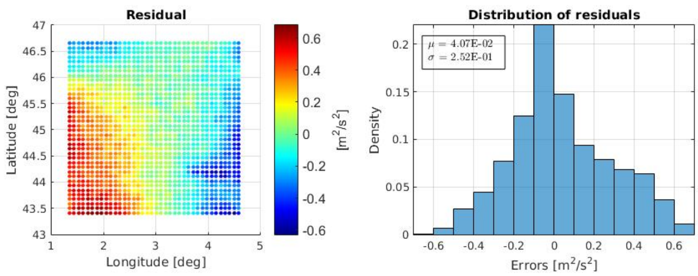
Comparisons between highly precise optical clocks are opening new perspectives for the direct determination of geopotential at a centimeter-level accuracy in geoid height [1,5]. Indeed, two clocks with an accuracy of 10^{-18} in terms of relative frequency shift would detect a 1-cm geoid height variation between them, corresponding to a geopotential variation ΔW of about 0.1 $\mathrm{m}^2\,\mathrm{s}^{-2}$(see e.g. [3]). However, so far detailed quantitative estimates of the possible improvement in geoid determination when adding such clock measurements to existing data are lacking.

In this context, the present work aims at evaluating the contribution of this new kind of direct measurements in determining the geopotential at high spatial resolution (10 km). We investigate to what extent clocks could contribute to filling the gap between the satellite and near-surface gravity spectral, and spatial coverages, in order to improve our knowledge of the geopotential and gravity field at all wavelengths. We consider the Massif Central area, marked by smooth, moderate altitude mountains and volcanic plateaus leading to variations of the gravitational field over a range of spatial scales. This type of region is interesting because the scarcity of gravity data is a limitation in deriving accurate high resolution geopotential models.

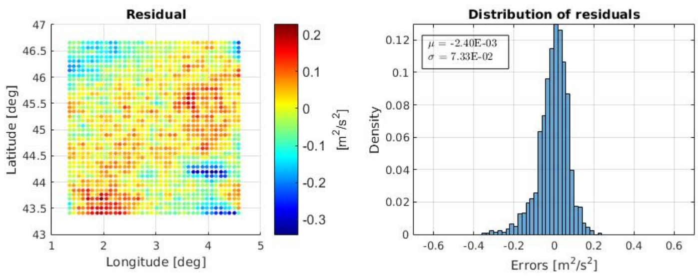
2 Methodology and results

Our study is based on synthetic noised data. The gravity anomalies δg and the disturbing potential T are generated with GEOPOT [6], allowing to compute the gravity field related quantities at given locations. The synthetic data are sampled from a spherical harmonics geopotential model, and a topography model, up to 10 km resolution. The long wavelengths of the gravity field covered by the satellites and longer than the extent of the local area are removed, providing centered data for the determination of local covariance function. A white noise is added to the simulated data, and we estimate the disturbing potential by least-squares collocation from the gravimetric data with and without the clock data. Their locations are chosen to reproduce a realistic distribution of measurements. Finally, we assess the quality of the reconstructed potential by comparing residuals of these solutions to that of the control grid.

We demonstrate in Figure 1 that adding the clock-based potential values to the existing gravimetric data set can notably improve the final gravity field solution. In Figure 1a, the estimation is realized from the 4374 gravimetric data only, and in Figure 1b by adding 33 potential data to the gravity data. The noise level is respectively 1 mGal and 0.1 $m^2 s^{-2}$. We show that adding clock data reduces the reconstruction bias significantly and improves the standard deviation by a factor 3. Another important conclusion stemming from our simulations is that in solving the problem of gravity field recovery it is not required to have a dense clock network, only a very few percent of clock measurements compared to the number of needed gravity data is sufficient. More details about the methodology and results can be found in Lion et al. [4]. We are also investigating ways to optimize clock networks in order to find an optimal design and to improve further the determination of the gravity field. First simulations using genetic algorithms such as ϵ-MOEA [2] give promising results. Several distributions of clock data obtained with the genetic algorithm give better residual than those presented here with about 20 potential data.



(a) Without clock data.



(b) With clock data.

Figure 1: Accuracy of the disturbing potential T reconstruction on a regular 10-km step grid in Massif Central, obtained by comparing the reference model and the reconstructed one.

Acknowledgments

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