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Optimization of atomic clock locations for the geopotential determination from gravimetric network

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Clock comparisons with an uncertainty at the 10^{-18} in terms of relative frequency can provide a new kind of measurement to improve our knowledge of Earth's gravity field and geoid. Indeed, instead of using state-of-the-art Earth's gravitational field models to predict frequency shifts between distant clocks, they could permit to determine geopotential differences directly at a centimeter-level accuracy.

In our previous work (Lion et al., 2017) dealing with the geopotential determination at high spatial resolution in mountainous regions (e.g. the Massif Central – France), we have pointed out that clock-based geodetic observable can provide useful information at spatial scales beyond what is available from satellites and they could be used to fill areas not covered by the gravity data on the ground. Our synthetic simulations have shown that adding few clock-based potential data to a gravimetric data set can significantly improve the quality of reconstruction of the geopotential. Therefore, it turns out there is a large variety of possible clock distribution allowing to reduce the reconstruction residuals (bias and standard deviation), with different locations and number of clocks.

In this work, we have investigated ways to optimize clock locations from a gravimetric data set in the Massif Central region in order to know where to put them to minimize the residuals and improve further the determination of the geopotential. To do that, we have used a multi-objective genetic algorithm (GA). A GA is an evolutionary algorithm inspired by the idea of natural evolution. Starting from a random initial population, with different clock distributions, the algorithm selects clock locations with good chances of reproduction and reproduces the new generation of clock locations using operations such as crossover and mutation. The process depends on some objectives we want to reach in order to solve the optimization problem, and it is repeated several times for a given number of generations or until a solution considered as optimum is found. We show how GA can help to provide optimal solutions for a problem with a fixed and variable number of clock locations. We discuss the effect of different parameters, such as the way to define the objectives and the constrains of the problem, the effect of the coverage and the quality of the gravimetric data and possible applications.

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REFERENCES: - Lion, G., Panet, I., Wolf, P., Guerlin, C., Bize, S., Delva, P. (2017). Determination of a high spatial resolution geopotential model using atomic clock comparisons. Journal of Geodesy, 91(6), 597-611.