Genetic-algorithm based search strategy for optimal scenarios of future dual-pair gravity satellite missions


IGIS General Assembly, Shanghai, China, 30 June – 6 July 2014

(1) GIS, Institute of Geodesy, University of Stuttgart, Germany [author correspondence: siavash@gis.uni-stuttgart.de]; (2) ULUX, Faculté des Sciences, de la Technologie et de la Communication, Université du Luxembourg; (3) IAPG, Institute of Astronomical and Physical Geodesy, Technische Universität München, Germany; (4) DEMOS Space S.L.U., Madrid, Spain

Introduction

Research into time-variable gravity field recovery for future satellite missions is focusing on the use of double satellite pairs (Figure 1) in a Bender constellation. The primary objective is to achieve higher temporal and spatial resolutions. However, the search space for finding optimal scenarios of double pair is vast as the performance of the mission scenarios is a function of the orbital parameters of both pairs. The inclinations of each pair, the evolution of ground-track pattern distribution of the missions within time, missions’ altitudes, relative ascending node angles of the pairs and inter-satellite distances within each pair have important impacts on the gravity recovery quality of the mission scenarios.

This work employs genetic algorithms on top of the expertise from previous studies to find optimal scenarios for retrieving the geophysical signals. In fact, the genetic algorithm approach is used as the main search strategy tool of this research, where restrictions from our previous experiences

Science and Mission Requirements

Within the ESA SC4MGV project “Assessment of Satellite Constellations for Monitoring the Variations in Earth’s Gravity Field”, the consolidated science and mission requirements for a future gravity mission have been defined. The anticipated impact of the identified science and missions requirements on applications in geosciences is summarized in Figure 2 as well as the gain compared to state-of-the-art GRACE solutions.

Figure 2: Anticipated performance in terms of spatial vs. cumulative geoid error (right).

Mission Requirements

1) The NGGM mission shall deliver global observations between +60° and -60° latitude where small deviations within 1° are allowed
2) The NGGM mission shall deliver observations for at least 11 years covering one solar cycle such that related effects can be observed for a complete cycle.
3) The NGGM shall observe the geoid with 1 mm accuracy at 3 days intervals with 500 km spatial resolution and at 10 days intervals with 150 km spatial resolution.

Figure 3: repeat mode selection from figure of merit based on homogeneity of ground-track gap evolution.

Gap-filling optimization

In order to reduce the enormous search space of orbit and satellite constellation (SC) parameters a dedicated search strategy is applied. In the first step the search space is reduced based on (i) experience from previous studies and (ii) Quick-Look/Reduced-Scale Tool (QLT/RST) simulations.

The second step a genetic algorithm (GA) is applied to the remaining search space. In the GA (Figure 4), for maximum SH degree/order 100, indicates a high stability of the results from genetic algorithm

Figure 4: result from genetic algorithm (left) and dependence of solution on $\Delta$Ω and $\Delta$M (right); results based on 10 day solutions up to maximum degree $L_{\text{max}} = 100$

The result of the GA (Figure 4), for maximum SH degree/order 100, indicates a high stability of the results from genetic algorithm

In the first iteration, five best SCs (Table 1) have been selected from the GA results and are thoroughly validated using a number of criteria, among them various spectral criteria (e.g. degree-RMS, isotropy, ... ) and spatial benchmarks (e.g. basin average RMS) and geophysical time series analysis (total water storage changes ...). They are applied in order to scrutinize the SCs. Figure 5 presents an excerpt of the validation. Besides the mean degree RMS and the spread around the mean, the total water storage change RMS of the recovered minus the simulated fields for 251 basins is shown. Both type as well as other performance criteria allowed to identify our fifth scenario as the best performing.

Table 1: Selected optimal scenarios based on GA results and technical considerations (please note that in order to have better coverage of the higher latitudes, the inclinations of scenarios 2 and 4 have been tuned to higher angles).

In addition to the GA, the homogeneity of the ground-track gap evolution can be used as criteria for optimum repeat mode selection (Figure 3). In order to have better coverage of the Earth and higher spatial resolution, repeat orbits with a homogeneous gap evolution should be favoured and large unobserved gaps should be avoided.

Acknowledgement

This study was a part of ESA SC4MGV project “Assessment of Satellite Constellations for Monitoring the Variations in Earth’s Gravity Field”. ESA-ESTEC is gratefully acknowledged for funding the project under ESA Contract No. 4601086317/15/NL/NV.