# Orbit optimization for future gravity field mission: the influence of the choice of time variable gravity field models


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## Introduction

In the past, different studies have discussed the potential orbit configurations of future satellite gravity missions, where most of those works have targeted orbit optimization of the satellite missions of the next generation in the so-called Bender formation (Figure 1). The studies have investigated the impact of the Keplerian orbital parameters, esp. the influence of the repeat orbits and mission altitude of both satellite pairs and the inclination of the second pair in Bender formation on the satellite configurations' gravity recovery quality performance.

Obviously, the search space for the orbit optimization in the Bender formation is vast and therefore, different approaches have been suggested for the purpose of optimal orbit design. Among the aforementioned approaches, however, different assumptions for input geophysical models as well as the error models into the simulation software play a role. This study shows:

how different assumptions for input models into the simulation tool may change the orbit optimization results.

For this purpose, the genetic algorithm for orbit optimization of Bender formation is run with different input models, here by inclusion of:

- the old and updated ESA geophysical models
- error models for the ocean tide, atmosphere and ocean

We expect different results for orbit optimization by different initial conditions.

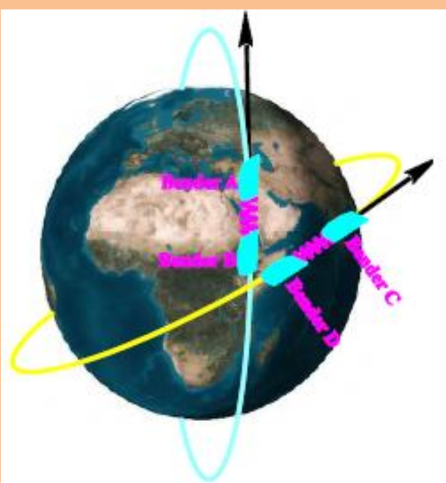

Figure 1 – Dual-pair mission in the so-called Bender configuration

## Geophysical models and simulation tool

For the simulation environment of this study, we employ the dominant mass variations of hydrology (H), ice (I) and solid Earth (S) of the Earth system by use of the time-variable gravity field generated within two different input models from:

- ESA-project "ESA Earth System Model for Gravity Mission Simulation Studies" (Dobslaw, et al., 2015), and
- previous ESA study by Gruber, et al. (2011).

The time-span applied in our study starts from 1 January 1996 for 10-day gravity recovery up to SH degree $L_{max} = 90$.
Our error models consist of:

- OT error: The difference between two ocean tide (OT) models EOT08a and GOT4.7.
- AO error: The atmosphere-ocean error product from IAPG (TU Munich), defined as two atmosphere models difference (ECMWF - NCEP) plus 10% of the ocean signal of the model OMCT.

The GA simulation runs, thereafter, are performed for the optimization of our Bender orbit configurations (Figure 2).

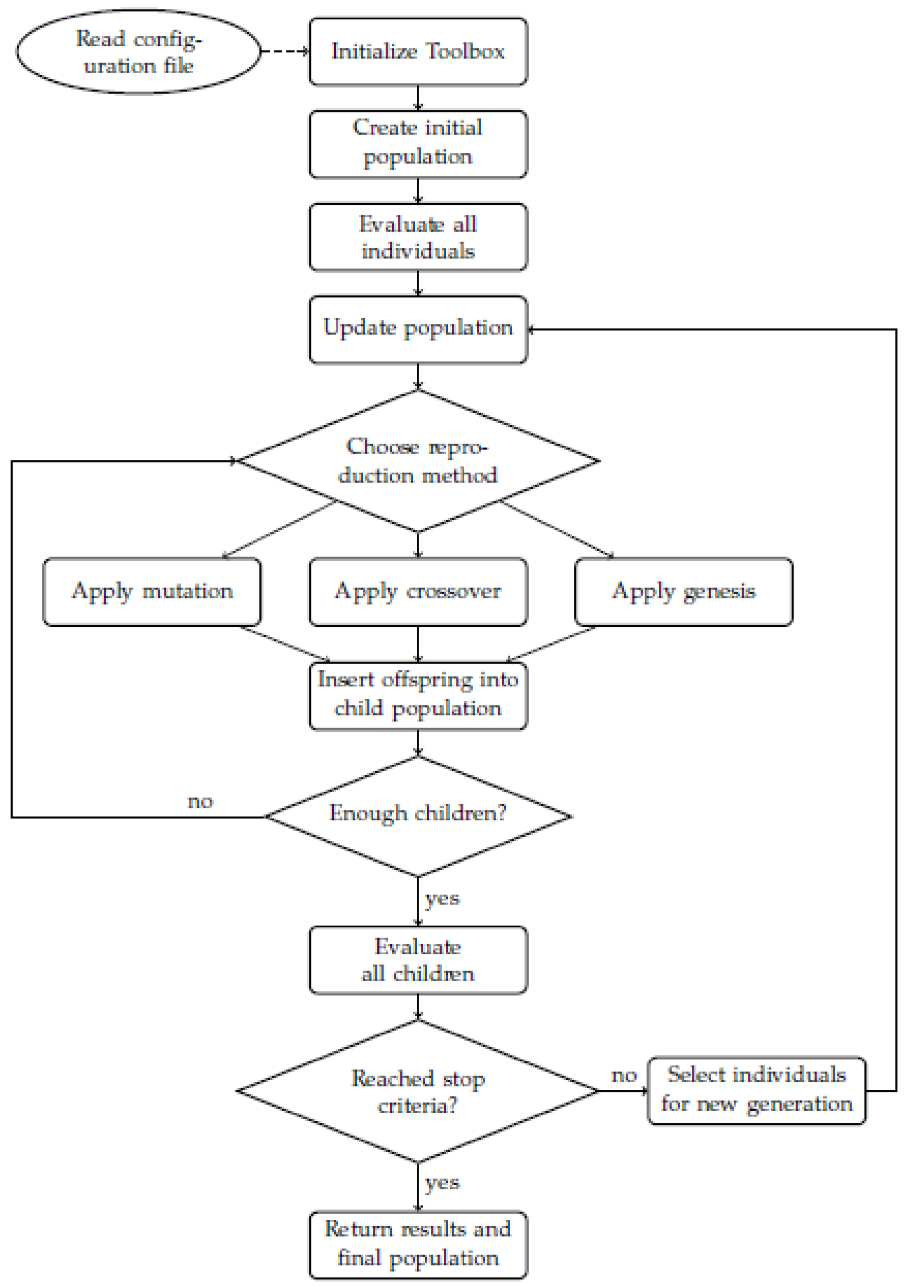


Figure 2 – Flowchart of the genetic algorithm (taken from Ellmer, 2011).

## Results

The simulations of our study include different scenarios:

- Including and excluding the relative Keplerian orbital parameters RAAN ($\Delta\Omega$) and mean anomaly ($\Delta M$) in the optimization problem
- ESA old and new models for HIS (respectively from Gruber, et al. 2011 and Dobslaw, et al., 2015).
- Including or excluding AO and OT errors in the input models

First, we start our investigation for the impact of the relative Keplerian orbital parameters RAAN ($\Delta\Omega$) and mean anomaly ($\Delta M$) in the optimization problem for the new HIS models.

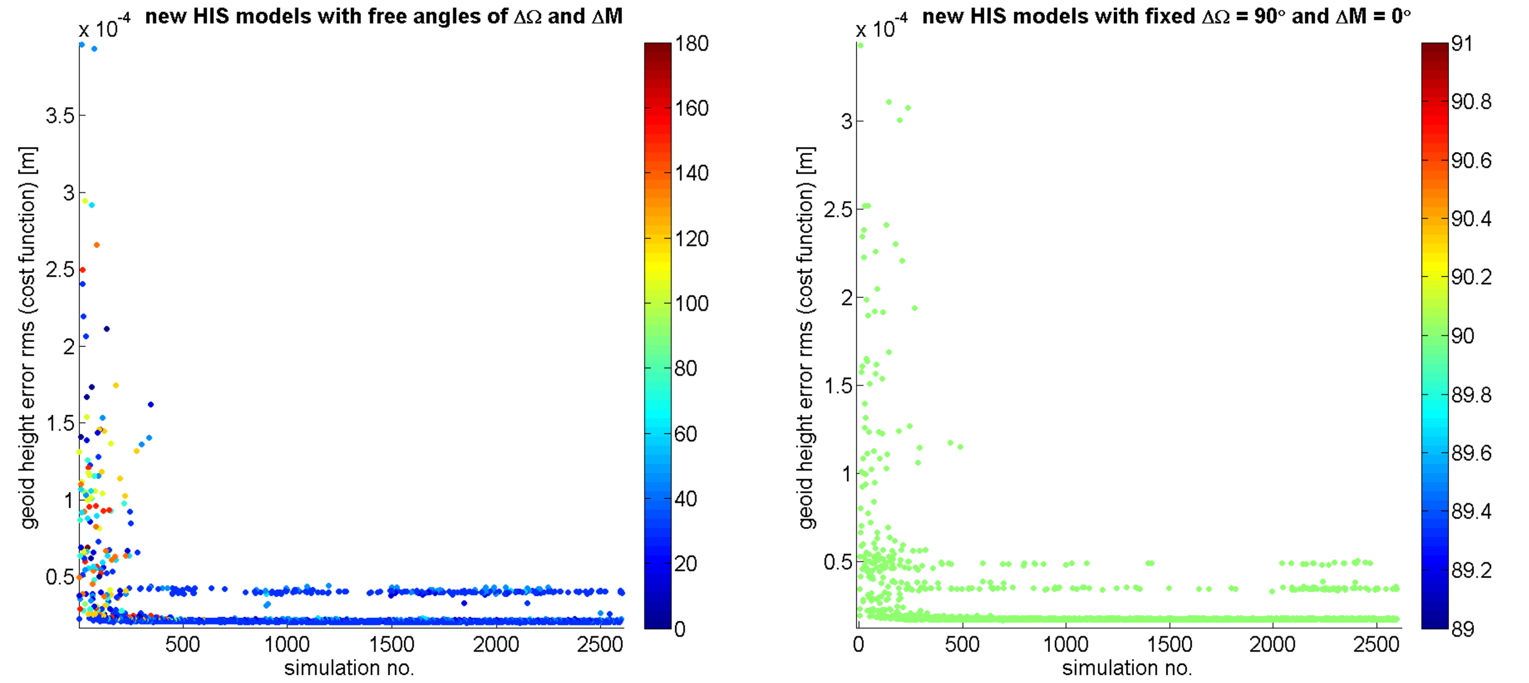


Figure 3 – Including (left panel) and excluding (right panel) of the relative Keplerian orbital parameters RAAN ($\Delta\Omega$) and mean anomaly ($\Delta M$) in the optimization problem for the new HIS models as the simulation input (only the impact of $\Delta\Omega$ is shown here).

As seen from Figure 3, when we allow the relative angles $\Delta\Omega$ and $\Delta M$ freely change (with step of 15°), the optimized $\Delta\Omega$ angle is close to zero. This is also the case for the old HIS models (Figure 4).

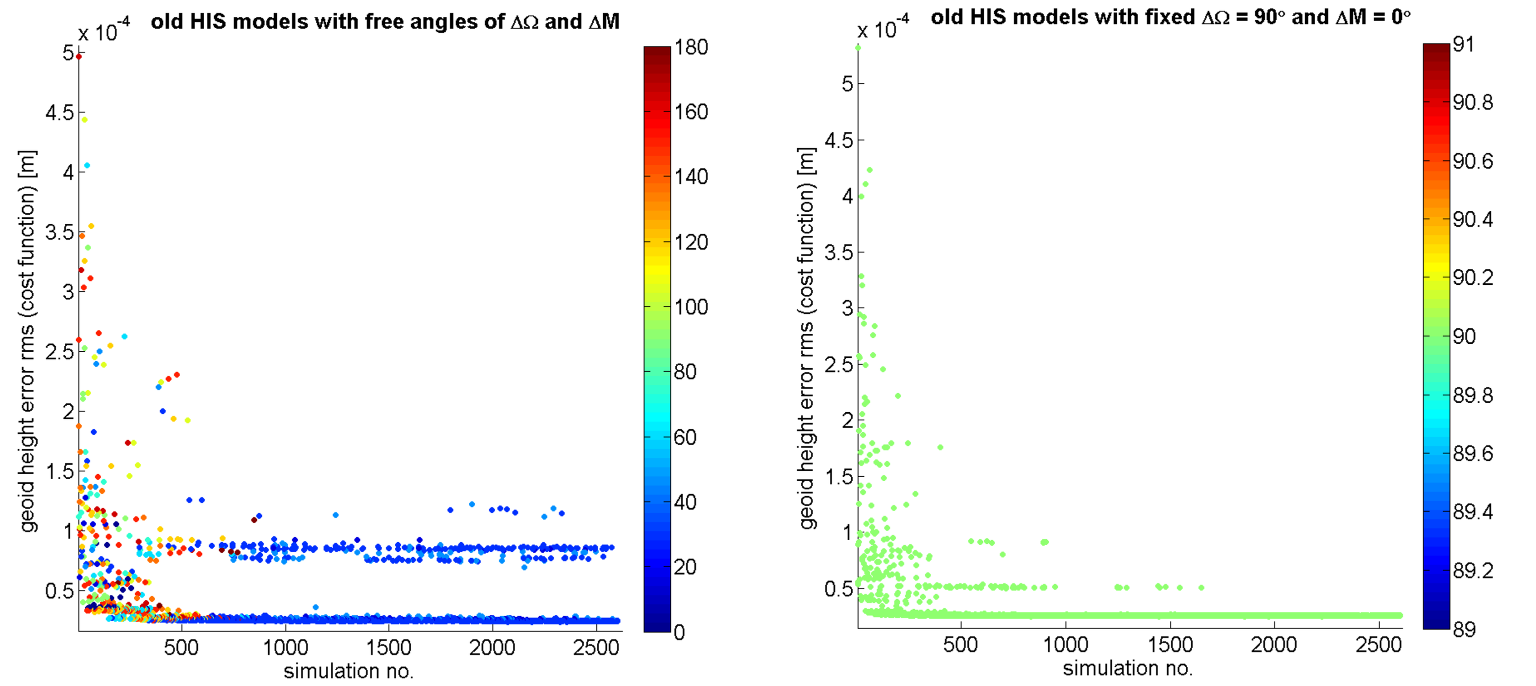


Figure 4 – As Figure 3, but for the old HIS models.

The inclusion of atmosphere-ocean (AO) and ocean tide (OT) models' errors in the input models of the GA simulation tool is also performed, and the simulation outputs are depicted in Figure 5.

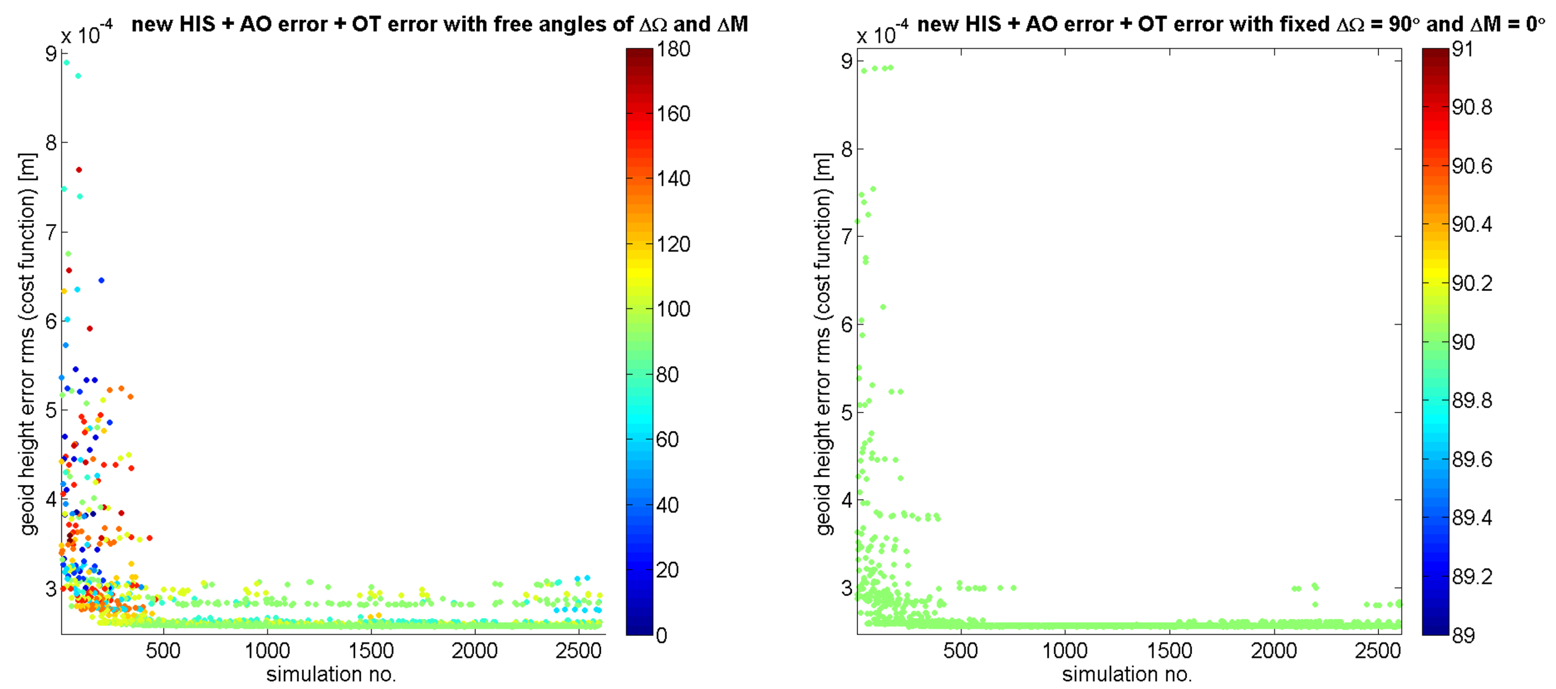


Figure 5 – As Figure 3, but for the new HIS models plus AO and OT models' errors.

As the figure illustrates, when the relative angles $\Delta\Omega$ and $\Delta M$ are allowed to freely change, the optimized $\Delta\Omega$ angle is close to 90° (or equivalently 270°). This is in contrast to where the AO and OT models' error are not included in the input models (Figures 3 and 4).

## Discussion

In this study, the GA simulation tool has been run several times, every time with different initial conditions (input models). Moreover, since the GA has basically stochastic behaviour, the simulations have been also run with the same input models, in order to reduce the uncertainty of the results. The main outcomes of the study are

- After around 300 simulations (approximately 6 generations), the first convergence happens. Afterwards, however, more than one band of results can be seen which might be considered controversial. It is possible that the algorithm should run for more generations.
- As the most important outcome of the study, the optimized values for $\Delta\Omega$ between the two satellites in the so-called Bender formation are significantly different for the case of only HIS input models inclusion ($\Delta\Omega \approx 0°$) and the case with HIS plus AO and OT models' errors ($\Delta\Omega \approx 90°$ *and 270°*).
- The performance study of individual satellite scenarios (i.e. different in their Keplerian elements) by different input models is of the interest for the future studies.
- It would also be of interest to study other different input model scenarios, where only AO model error or only OT models error or even only some finite numbers of important ocean tide components are included.

## References


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