Paper Nr. 38

Impact of non-gravitational force model deficiencies for Genesis orbit and geodetic parameter estimation based on GNSS

9th International Colloquium
on Scientific and Fundamental
Aspects of GNSS
25-27 September, Wrocław, Poland

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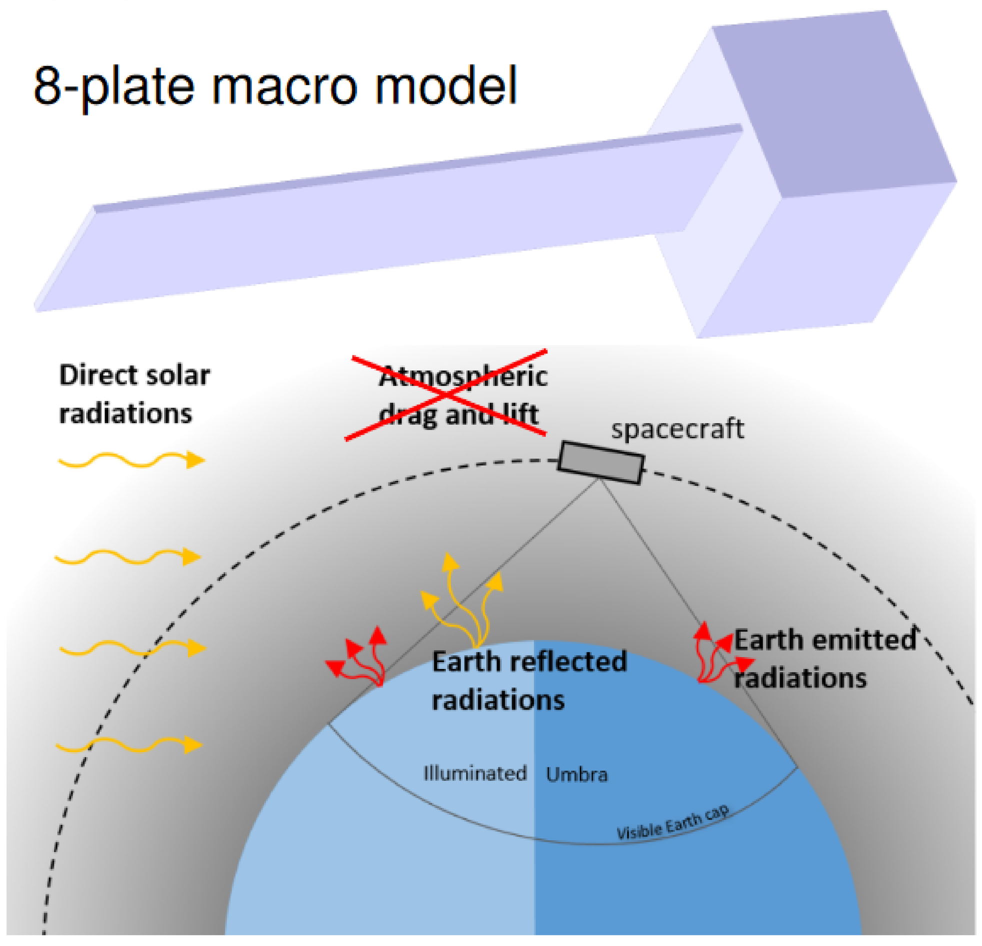
Introduction

The ESA Genesis mission, which is set to launch in 2028, aims to **improve the accuracy and stability of the Terrestrial Reference Frame (TRF)**. The satellite will orbit the Earth at an altitude of about 6000 km and will be equipped with a nadir and zenith antenna to help with the poor tracking geometry. The spacecraft will act as a space-tie using all four space-geodetic techniques, i.e., Very Long Baseline Interferometry (VLBI), Satellite Laser Ranging (SLR), Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS), and Global Navigation Satellite Systems (GNSS).

This research aims to investigate the importance of **dynamic orbit modeling**, focusing on the spacecraft's geometry and its optical properties. We perform a **closed-loop simulation using simulated GNSS pseudo-range and carrier phase data for Genesis** and various ground stations over 37 days in 2023 to assess mismodelings of the non-gravitational forces.

Modeling and Constraining

The Solar Radiation Pressure (SRP) and the emitted and reflected Earth Radiation Pressure (ERP) were modeled, while atmospheric effects were not included for orbit modeling. The spacecraft geometry and optical properties were introduced **using a macro model (MAC)**, approximating the satellite using a boxwing model with **8 plates**. Model deficiencies were created by changing the optical properties of these plates.



To absorb orbit modeling errors, **Piecewise Constant Accelerations (PCAs)** were set up. The orbit modeling is more dynamic when the PCA time intervals are longer and their magnitude is constrained by a smaller a-priori standard deviation σ_{abs}. Two options for PCA constraining will be explored here:

Option	Length [min]	σ_{abs} [m/s^2]
Relaxed	6	$5 \cdot 10^{-09}$
Strict	15	$1 \cdot 10^{-10}$

Acknowledgements

The simulated data used in this research was generated by O. Montenbruck and P. Steigenberger at the German Aerospace Center (DLR). Calculations were performed on UBELIX, the HPC cluster at the University of Bern (http://www.id.unibe.ch/hpc).

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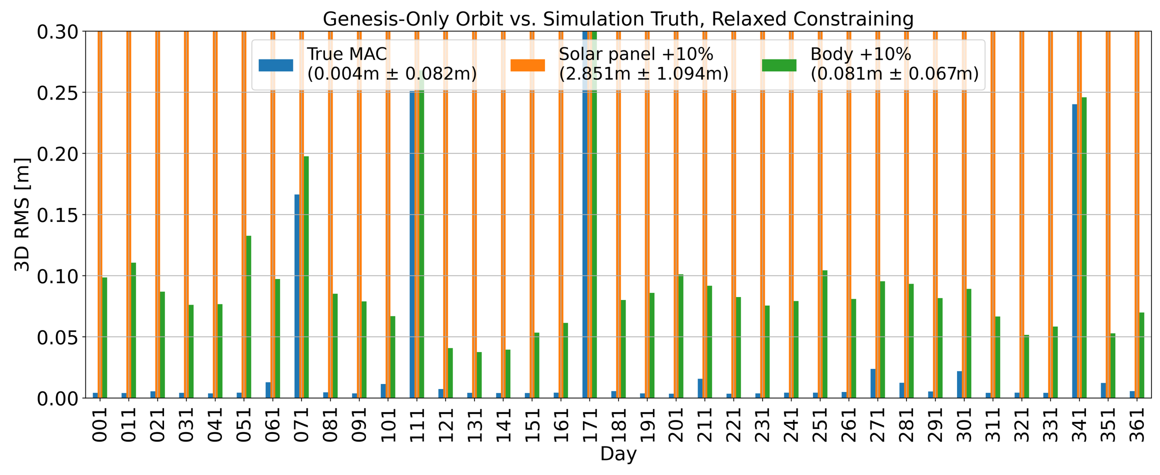
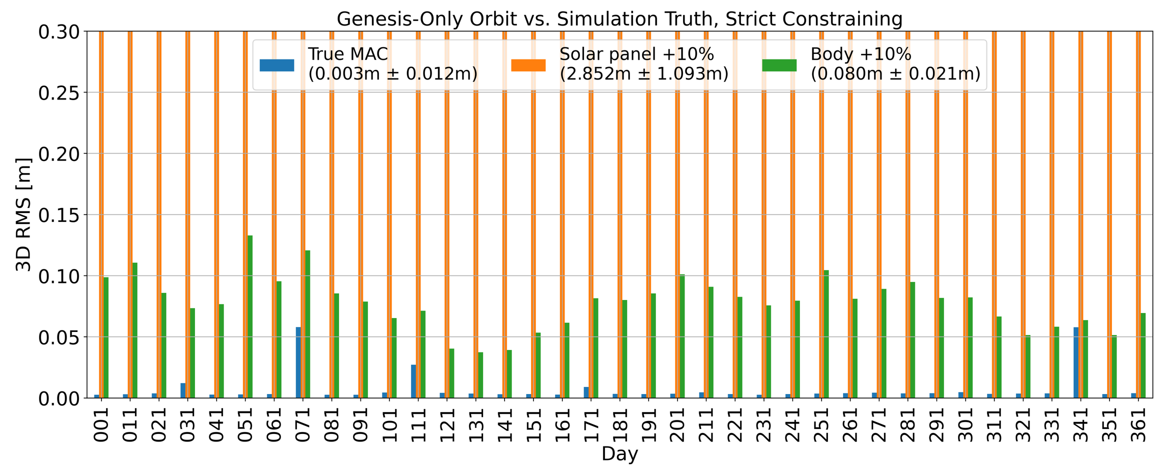
Genesis-Only Orbit Determination

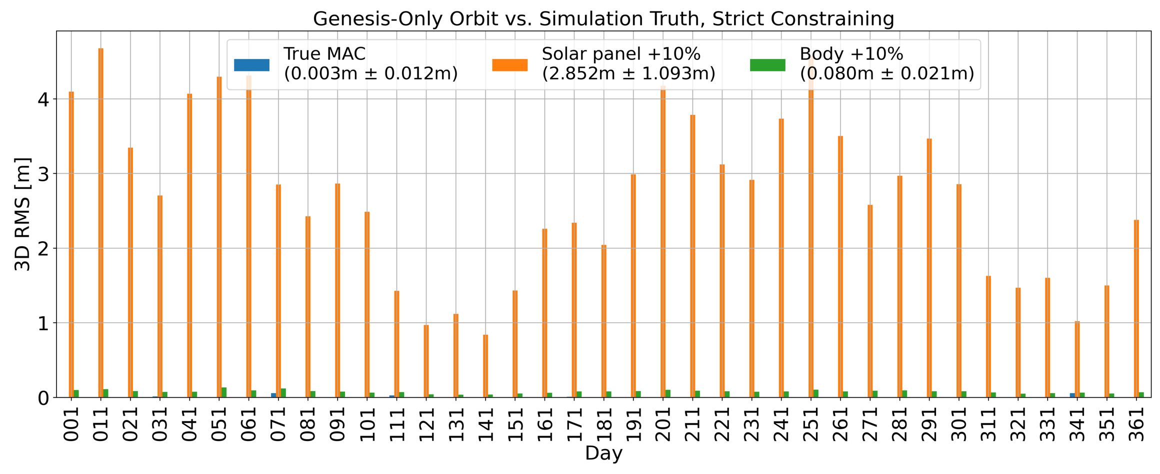
The influence of MAC errors on the Genesis orbit determination using the simulated data from both the **zenith and nadir antenna** were explored by using fixed station coordinates and geodetic parameters. The tested models were the true MAC, an error of +10% on the body surfaces, and +10% on solar panel surfaces.

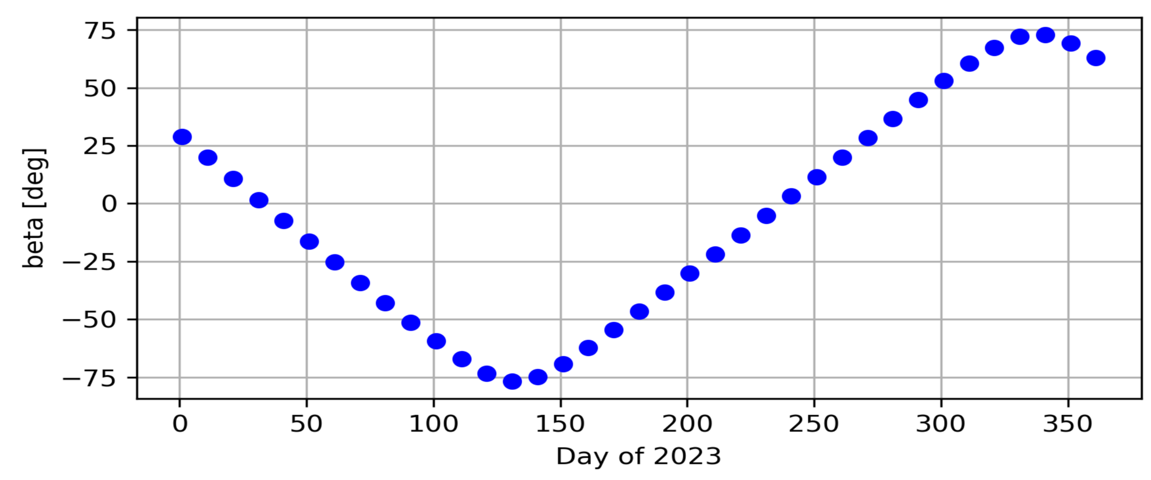
Proper constraining seems to play a large role, as even when using the true model, days 071, 111, 171 and 341 show a significant degradation of the orbit. These deviations from the true orbit are not as prominent when stricter constraining is applied.





Body surface errors lead to RMS values of orbit errors in the cm range, while **errors of solar panel properties have a severe negative impact** on the calculated orbit due to the assumed yaw-steering. The pattern of these RMS values is related to the Sun β-angle, with low elevations of the Sun above or below the orbital plane corresponding to larger RMS values.

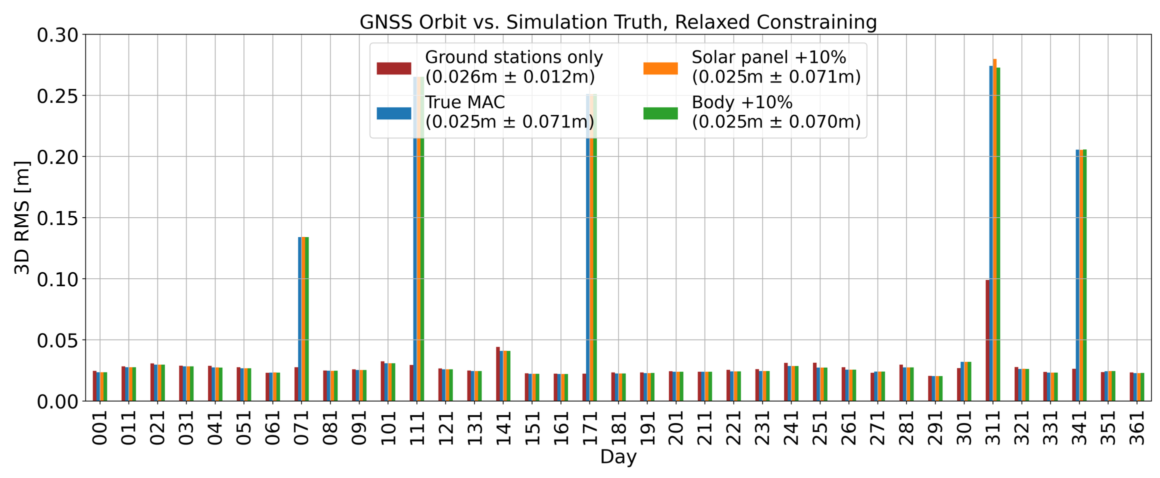


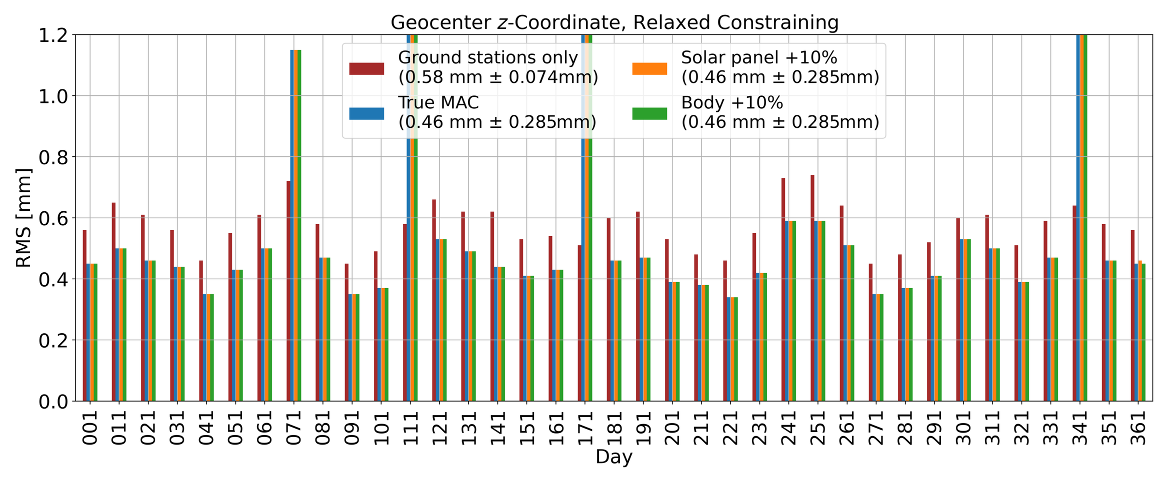


Combined Solution and Geocenter Coordinates

In the combined solution, the ground station coordinates, GNSS orbits and clocks and geodetic parameters were estimated together with the Genesis satellite orbit. The 3D RMS of the GNSS orbit differences and the formal error of the z-coordinate of the geocenter are exemplarily shown here.

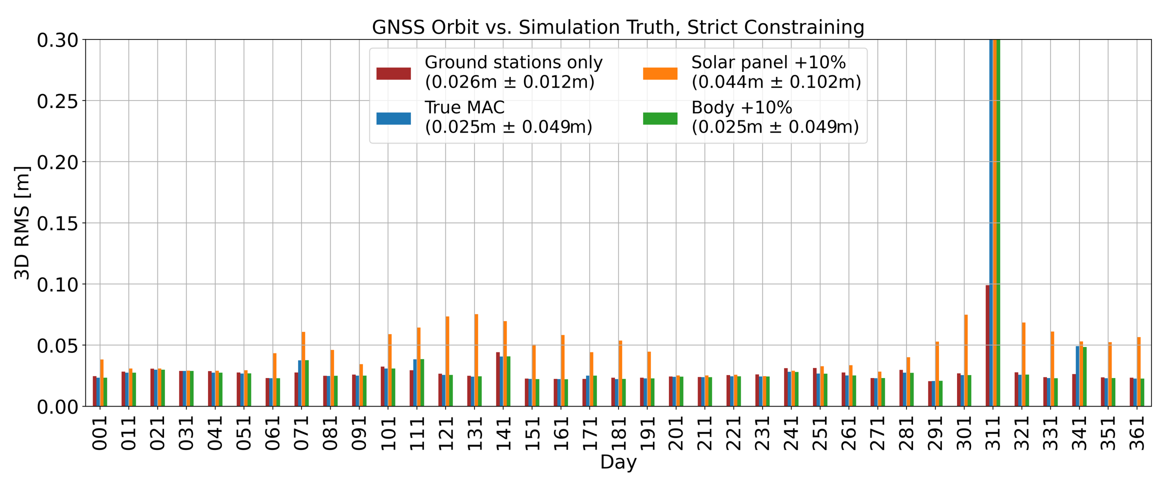
When PCA constraints for Genesis are more relaxed, GNSS orbit and geocenter coordinate RMS' are independent of the type of error applied to the MAC. This implies that relaxed constraining helps with the orbit degradation introduced by MAC errors. However, for **problem days** on which the Genesis orbit cannot be accurately calculated, the combined solution and the determined **geodetic parameters** are also **negatively influenced**.

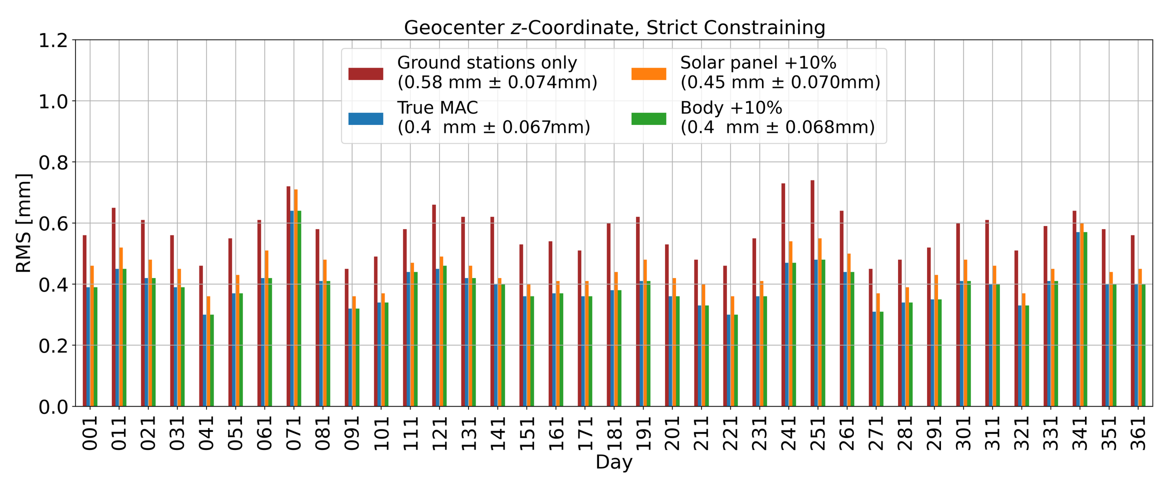




As expected, **stricter constraining** leads to a **smaller formal error of the geocenter coordinates** and helps to overall minimize the effects of these problematic days. However, day 311 still stands out for the GNSS orbits, and days 071 and 341 show a larger RMS for the the geocenter even for the true MAC.

With a more dynamic Genesis orbit solution, the effects of the different **modeling errors are visible** again, especially when changing solar panel properties. When looking at the GNSS orbit RMS, the pattern corresponding to the β angle is now seemingly reversed, with larger RMS values for larger angles. The differences between models for the formal errors of the geocenter coordinates do not show such a pronounced pattern.





Conclusion

It seems the **parametrization for the modeling** of the Genesis orbit needs to be **carefully chosen** and the optical properties, especially for the **solar panel**, should be known as accurately as possible. The **problem days** like 071 and 341 illustrate that the Genesis GNSS data processing is far from trivial. A possible reason could be issues with processing the data from the zenith antenna, which often has far fewer observations than the nadir antenna. Such days need to be carefully handled in order to not let Genesis deteriorate the estimation of geodetic parameters.