Simulating and Analysing VGOS Observations for Genesis Orbits and EOP Determination

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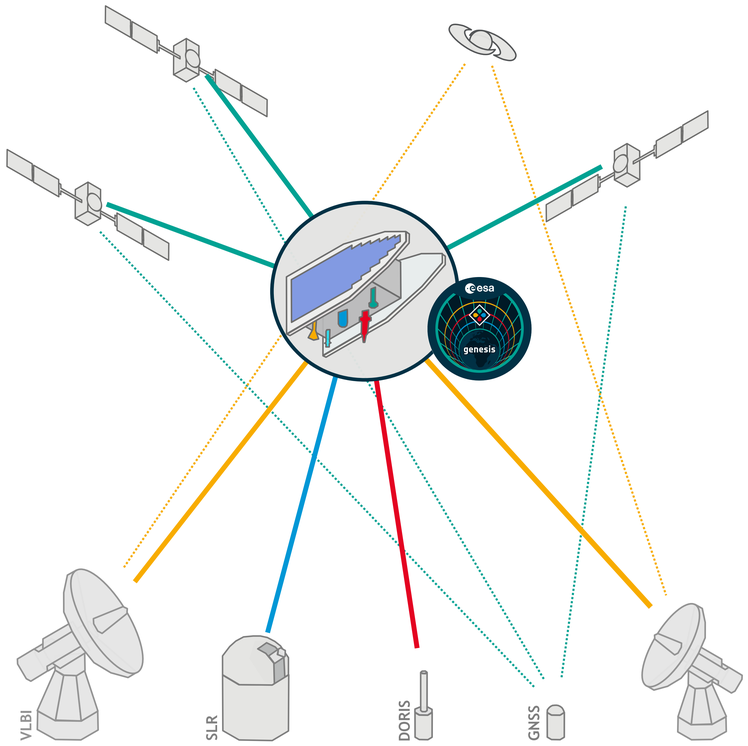

Fig 1. The ESA Genesis mission schematic concept. Genesis logo: ©ESA.

Introduction

The upcoming Genesis mission [Delva et al., 2023] of the European Space Agency (ESA) aims at combining 4 space geodetic techniques: GNSS (Global Navigation Satellite Systems), SLR (Satellite Laser Ranging), DORIS (Doppler Orbitography and Radiopositioning Integrated by Satellite), and VLBI (Very Long Baseline Interferometry). This promises progress for an improvement of the international terrestrial reference frame (ITRF) [Altamimi et al., 2023] to an accuracy of 1 mm and stability of 0.1 mm/yr, and the determination of inherent biases of each space geodetic technique. In this work we assess precise orbit determination (POD) for different Genesis orbits using 24 h VLBI sessions.

Method

Software: C5++ (simulation & analysis), VieSched++ (scheduling), Orekit (TLE gen).

Simulation and POD method as in [Klopotek et al., 2020].

Station network: 14 VGOS (VLBI Global Observing System) stations.
Day: 21 March 2025 for 24 h.

Satellite observations minimum-repeat-time (MRT) of 4 minutes [Schunck et al. 2024]. Scan length of 30 s for both quasars and satellite. POD initial orbit is the true orbit random perturbed in position by σ=30 m.

We estimate the orbit (1-day arc), station positions, and ERPs (UT1-UTC, XPO, YPO), using quasar and satellite observations.

We investigate 6 orbit types:

- SA: inc: 60°, alt: 5850 km, ecc: 1e-4
- SB: inc: 60°, alt: 6000 km, ecc: 1e-4
- SC: inc: 60°, alt: 6000 km, ecc: 1e-3
- SD: inc: 60°, alt: 6000 km, ecc: 1e-2
- SE: inc: 60°, alt: 6150 km, ecc: 1e-4
- SF: inc: 95°, alt: 6000 km, ecc: 1e-4

• Each at 8 RAANs (Right Ascension of the Ascending Node): 0°,45°, ..., 270°,315°.

• Each with 30 Monte Carlo runs using:
  ○ Observation noise 10 ps (~3 mm)
  ○ Clock noise (random walk, n=1e-14)
  ○ Atmospheric turbulence (Cn = 1.5e-7)

Thus each orbit type has 240 runs. Each run the orbit is sampled every 5 minutes (288 epochs in 24 h).

Results: Orbits

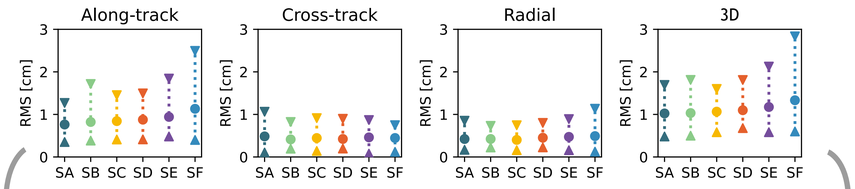

Fig 2. Minimal, maximum and average RMS of all orbit solutions (8 RAANs x 30 Monte Carlo runs) w.r.t. input unperturbed orbit per Genesis orbit type.

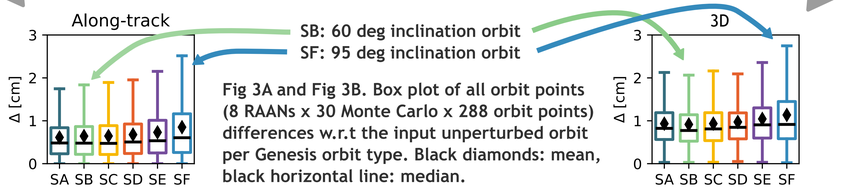

Fig 3A and Fig 3B. Box plot of all orbit points (8 RAANs x 30 Monte Carlo x 288 orbit points) differences w.r.t the input unperturbed orbit per Genesis orbit type. Black diamonds: mean, black horizontal line: median.

Results: ERP

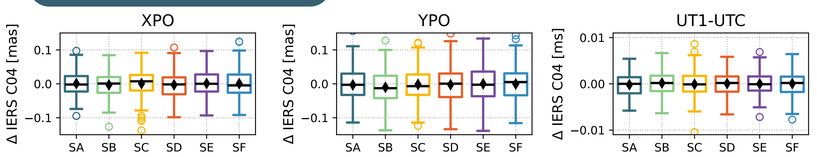

Fig 8. Estimated Earth Rotation Parameter (ERP) w.r.t. IERS C04 for each orbit type. Black diamonds: mean, black horizontal line: median.

Results: Stations

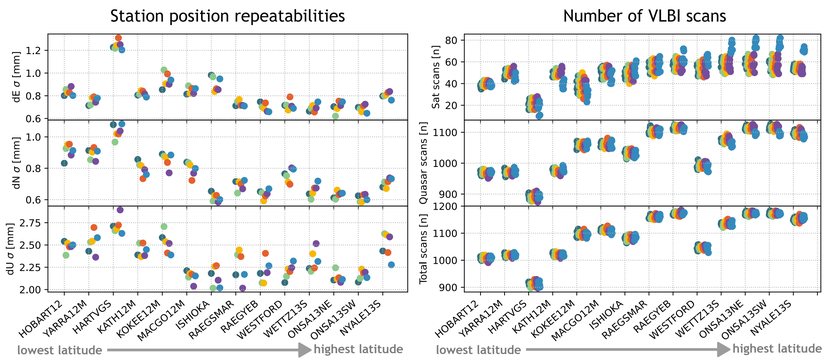

Fig 9. Station position repeatabilities as standard deviation per station and orbit type.

Fig 10. Number of VLBI scans per station for each RAAN and orbit type.

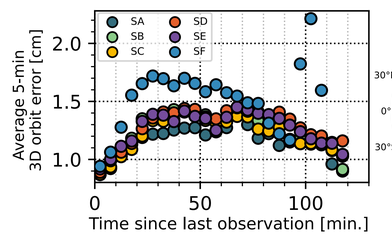

Fig 4. Time since observation versus orbit error. Data grouped epochwise per orbit type.

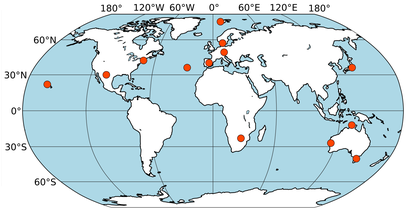

Fig 5. The station network used.

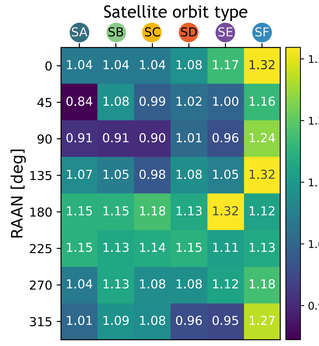

Fig 6. 24 h orbit arc 3D RMS for Satellite orbit type versus RAAN.

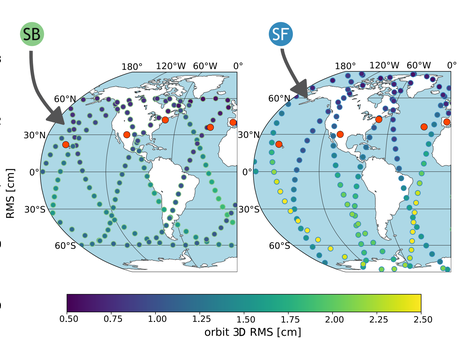

Fig 7. Epoch wise 3D orbit RMS per orbit type at 0 deg RAAN. Left: SB orbit type, right: SF orbit type.

Conclusions

Orbit From a POD perspective the low inclination orbit type results in a more accurate and precise estimation of the orbit compared to the higher inclination orbit type. An increase in eccentricity leads to a slightly worse POD performance per orbit point and mean RMS per 1-day orbit arc. A lower altitude performs slightly better in 3D 1-day orbit arc RMS, while a higher altitude performs worse across all assessed POD metrics. The actual RAAN of each orbit type also impacts the 3D RMS of the 1-day orbit arc solutions by up till 15-27 %.

Earth Rotation Parameters There seems to be no significant difference between the estimation of the 3 ERP parameters per orbit type, though a larger mean offset for the YPO can be observed for the lower inclination orbit type over the higher inclination orbit type.

Station position repeatability A higher inclination orbit allows for more scans of Genesis for the high latitude VGOS stations. Only for NYALE13S with a latitude higher than the 60° inclination the extra satellite scans have a direct positive effect for the up component. Stations that are relatively isolated in a network, such as KOKEE12M, benefit from having less satellite scans, since those are observed at relatively low elevations.

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