GRACE Follow-On orbit and gravity field determination using GPS carrier phase and SLR observations

M. Lasser, L. Geisser, U. Meyer, D. Arnold, and A. Jäggi
from University of Bern, Astronomical Institute, Switzerland

IAG Scientific Assembly 2025, Rimini, Sept. 1-5, 2025

Introduction

LEO (Low-Earth Orbiter) satellites equipped both with GNSS (Global Navigation Satellite System) antennas and laser retroreflectors enable the combination of these two space geodetic techniques, and thus, can serve as so-called **space ties**.

Taking the example of the two **GRACE Follow-On** LEO satellites (Landerer et al., 2020), which are dedicated to the determination of the Earth's gravity field, **GPS code and carrier phase** observations and **SLR** observations can be **combined** to derive **reduced-dynamic orbits** together **with Earth's gravity field parameters**. In this case, the two satellites act as a space tie connecting the SLR and GPS observations techniques, and the Earth's gravity field serves as a global tie.

Methodology

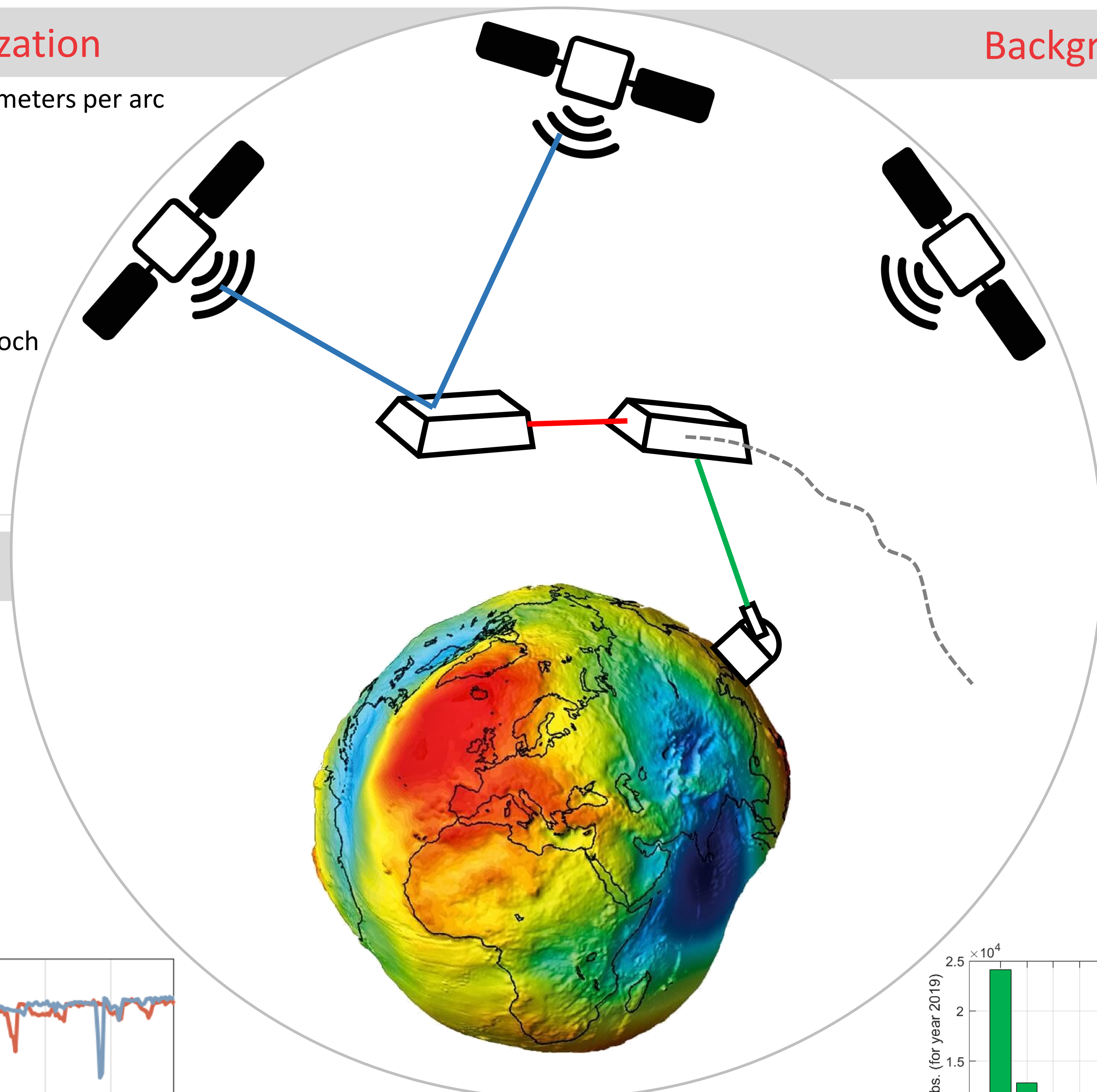
Satellite **orbit parameters** of both GRACE Follow-On satellites (GF1 and GF2) and **Earth's gravity field** parameters are **simultaneously** estimated using the Celestial Mechanics Approach (Beutler et al., 2010), which is implemented in the Bernese GNSS Software (Dach et al., 2015).

Daily reduced-dynamic orbits are estimated using **pseudo-stochastic** orbit parameters to absorb unknown deficiencies in the modelling. The jointly estimated **Earth's gravity field** parameters are set up to **degree and order 70** and solved for **monthly snapshots**. The time-variable gravity field recovery **relies on a set of a priori force models**, which account for forces perturbing the satellites trajectories.

The parameter estimation is based on 10 s sampled GPS carrier phase observations to the two GRACE Follow-On satellites and SLR two-way range observations (for the **year 2019**).

Parametrization

Orbit parameters for GRACE Follow-On:	# parameters per arc
Initial conditions:	2x [6]
Constant accelerations:	2x [3]
15 min pulses in	
radial direction	2x[96]
along-track direction	2x[96]
cross-track direction	2x[96]
satellite clock correction	per epoch
carrier phase ambiguities	
Gravity field parameters:	
degree/order 2 .. 70	



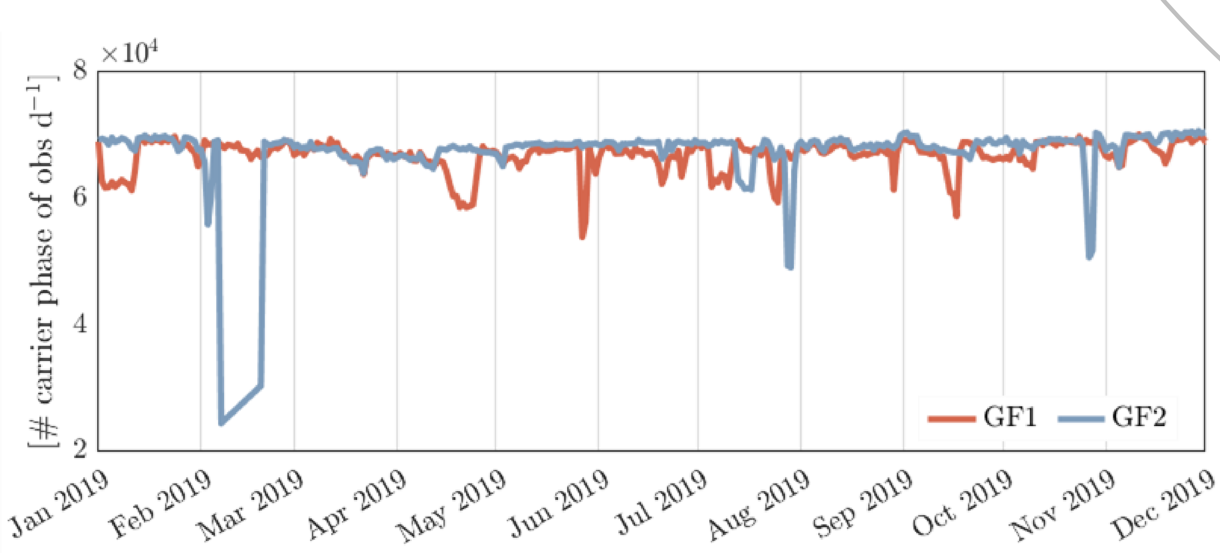
Background Models

Gravity field	EIGEN-GRGS RL05
Astronomic bodies	JPL DE405
Mean pole	Linear
Solid Earth tides	IERS2010
Solid Earth pole tides	IERS2010
Ocean tides	FES2014b
Ocean pole tides	IERS2010
Atmospheric tides	AOD RL06
De-aliasing	AOD RL06
Relativistic effects	IERS2010
Reference frame	ITRF/SLRF 14
ERP	IERS-14-C04

GPS Observations

Total number of GPS observations in use to:
GF1: ~2 M per month
GF2: ~2 M per month

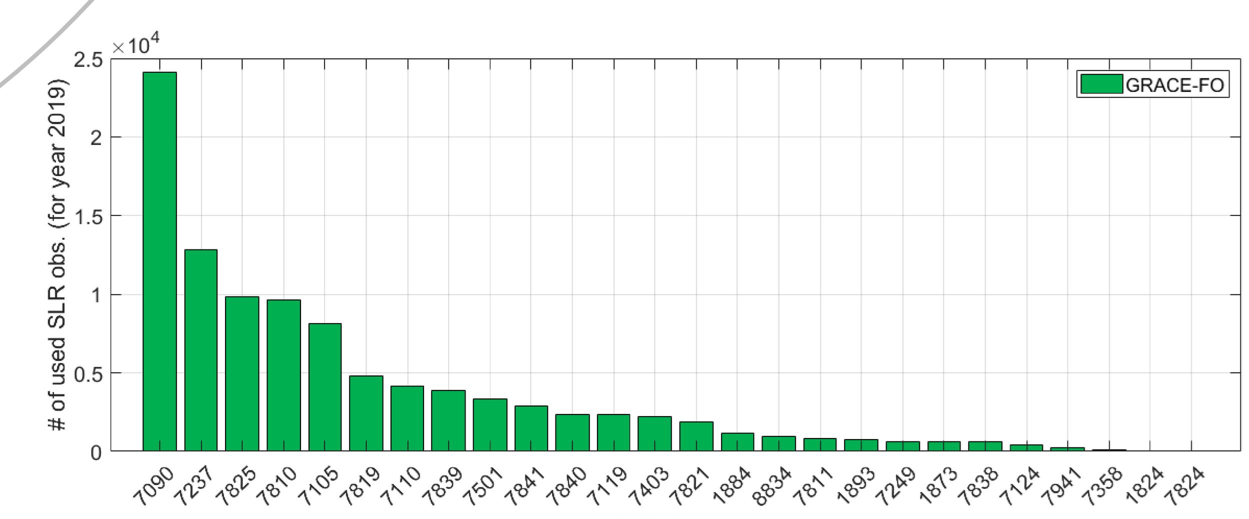
Elevation mask: 10°



SLR Observations

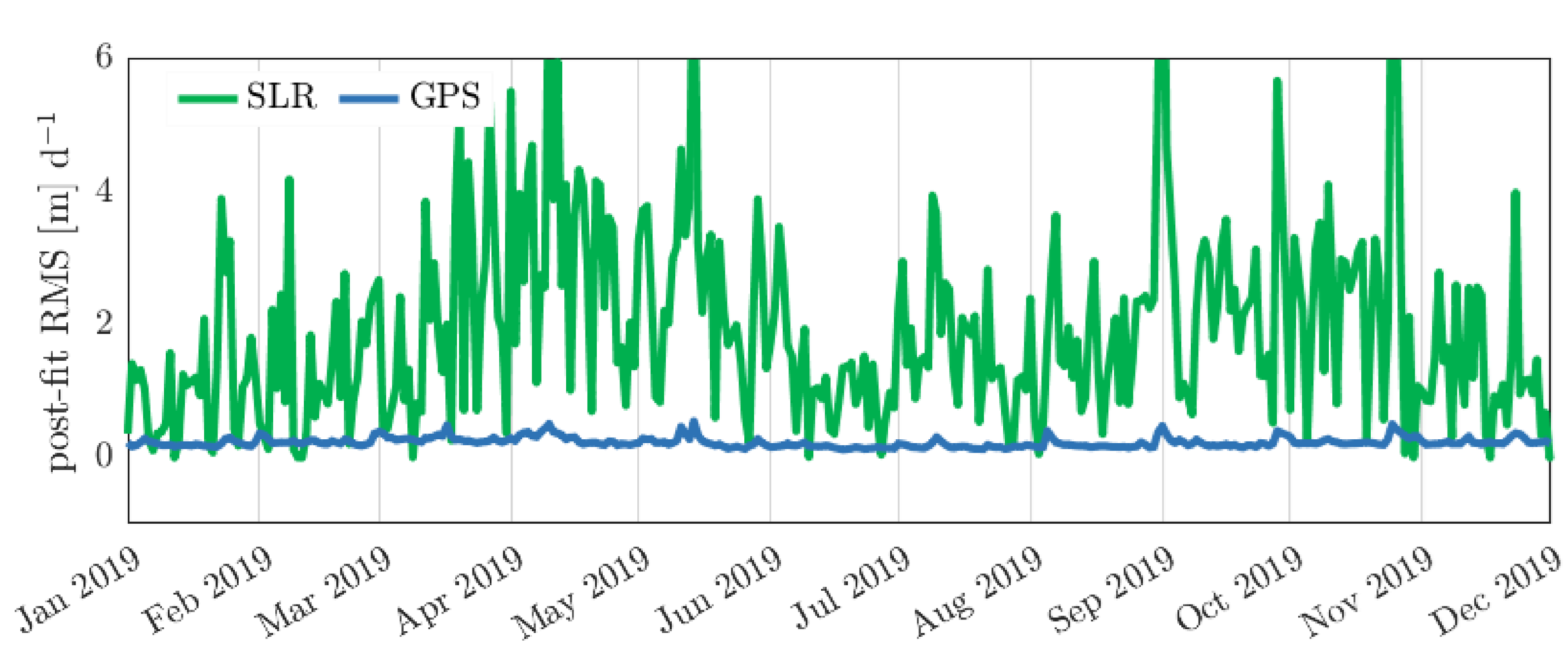
Total number of SLR normal point observations to:
GF1: ~4'000 per month
GF2: ~4'000 per month
Tracked by 26 SLR stations

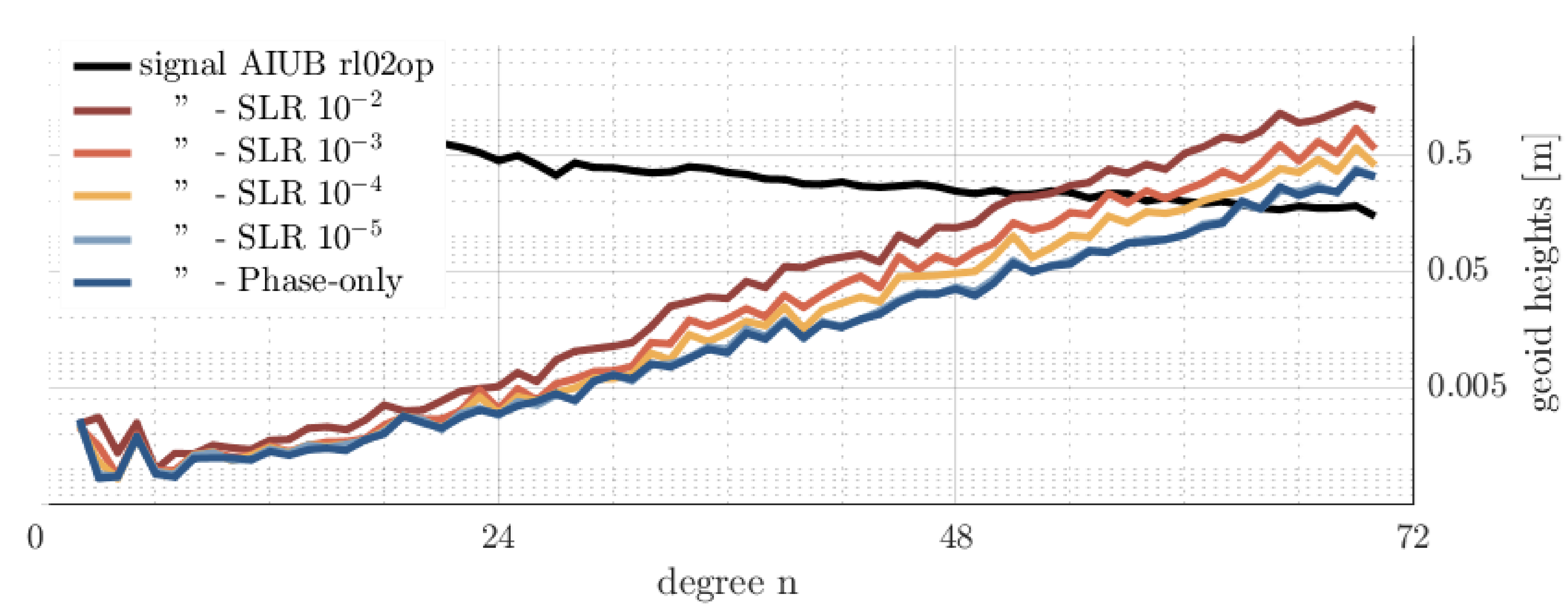
Elevation mask: 3°



Results

The daily dynamic orbit estimation, i.e., 6 initial conditions for each GRACE-FO satellite, results in **post-fit RMS** values of on average **20 cm** using only GPS observations and **2 m** with only SLR observations. In the **combination of GPS and SLR** observations to GRACE-FO, the **two different space geodetic techniques have to be weighted** relative to each other. In this study a weight according to **the ratio of these post-fit RMS values squared** is introduced (case SLR 10^{-2}) and besides, additional weighting schemes are investigated, where SLR is further down-weighted. For the gravity field estimation, the **SLR contribution** to the estimation of the **pseudo-stochastic parameters is neglected** due to the low number of observations. The relative weighting scheme plays a crucial role in determining the gravity field solution.





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Contact

Poster compiled by M. Lasser & L. Geisser, August 2025
Astronomical Institute, University of Bern
martin.lasser@unibe.ch
linda.geisser@unibe.ch