LEO activities at AIUB

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Introduction

GNSS data of spaceborne receivers on board different Low Earth Orbiting (LEO) satellites (scientific missions and CubeSats) are regularly processed at the Astronomical Institute of the University of Bern (AIUB) for (reduced-)dynamic and kinematic Precise Orbit Determination (POD) of these satellites. Usually, in-house computed final GNSS orbit, clock and bias products of the Center for Orbit Determination in Europe (CODE) and the Bernese GNSS Software are employed. This poster gives an overview on a selection of currently ongoing activities in the domain of LEO data processing.

Copernicus POD Service

Copernicus is the European Union's Earth observation program (copernicus.eu) with the **Sentinel satellites** constituting its space segment.

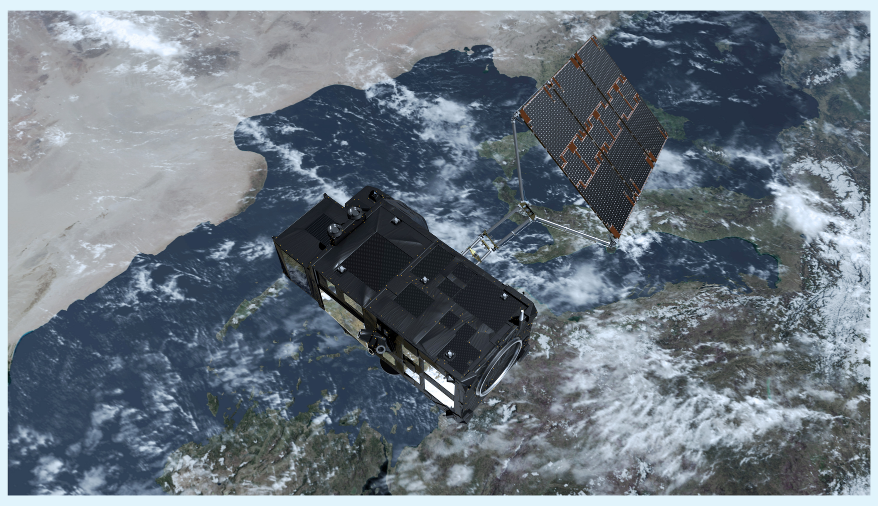


Figure 1: A Copernicus Sentinel-3 satellite for high-accuracy optical, radar and altimetry measurements for marine and land services. The official, non-time-critical Sentinel-3 orbit solutions need to fulfill an **accuracy requirement of 2 cm** in radial direction. ©ESA/ATG

AIUB is part of the **Copernicus Precise Orbit Determination (CPOD) Quality Working Group (QWG)** and operationally computes orbits for all Sentinel-1, -2, -3 and -6 satellites for the purpose of orbit comparison and validation.

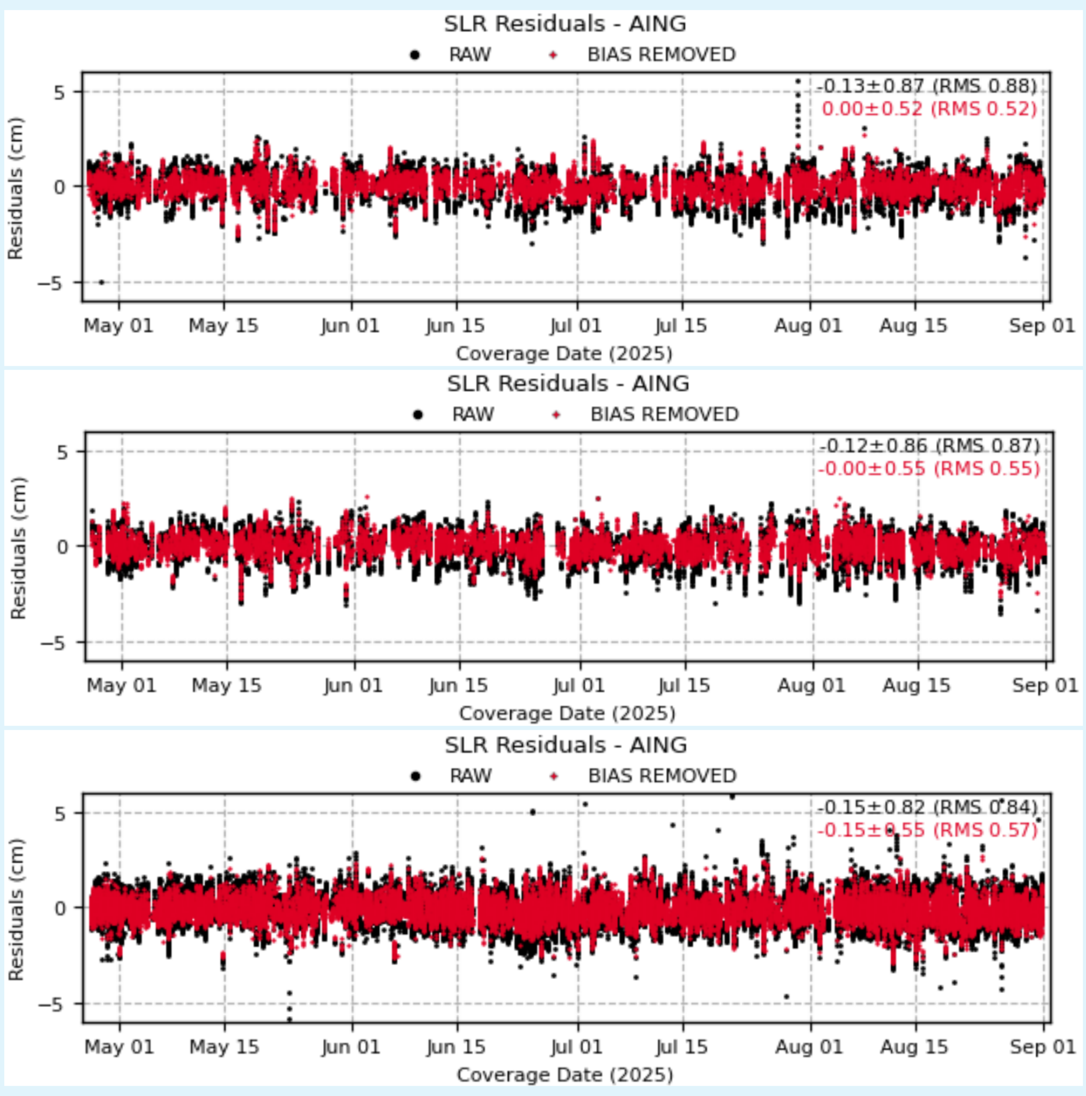


Figure 2: Satellite Laser Ranging (SLR) residuals for the AIUB Sentinel-3A (top), 3B (middle), and 6A (bottom) orbit solutions for CPOD Regular Service Review #35. SLR allows for an independent orbit validation and demonstrates that the AIUB solutions are among the best in the CPOD QWG.

For the Sentinel POD, AIUB makes use of the latest **COST-G Fitted Signal Models (FSM)**, see right column.

GRACE Follow-On

Mass variations in the Earth's gravity field are nowadays primarily observed with the GRACE Follow-On satellite mission through GPS, accelerometers and an ultra precise inter-satellite link (KBR and LRI) between the two satellites flying ~200 km apart.

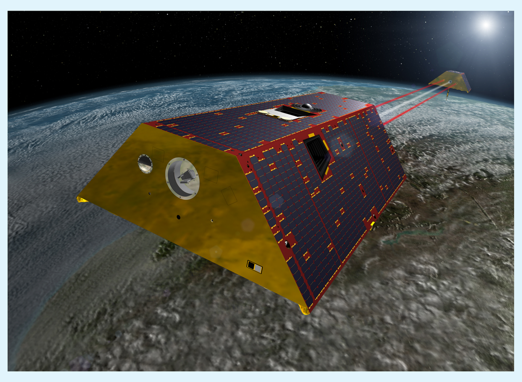


Figure 4: Gravity Recovery and Climate Experiment (GRACE) Follow-On (Credits: NASA)

GRACE Follow-On data is operationally processed at AIUB to **estimate monthly snapshots of the Earth's gravity field**. In the newest release (AIUB-GRACE-FO_rl03op) the modelling strategy has been revised to also include uncertainty information of short-term mass variations (AOerr) and the background force modelling has been updated to most recent models (atmosphere and ocean de-aliasing AOD RL07, MIXED2025 ocean tide model, TiME2022 atmospheric tide model). We make use of Variance Component Estimation (VCE) for automated data screening and to determine variance components for pseudo-stochastic orbit parameters (PCAs, see Fig. 5), and introduce noise covariance estimation from post-fit residuals to treat the stochastic nature of the observations more accurately (*emp cov* in Fig. 5).

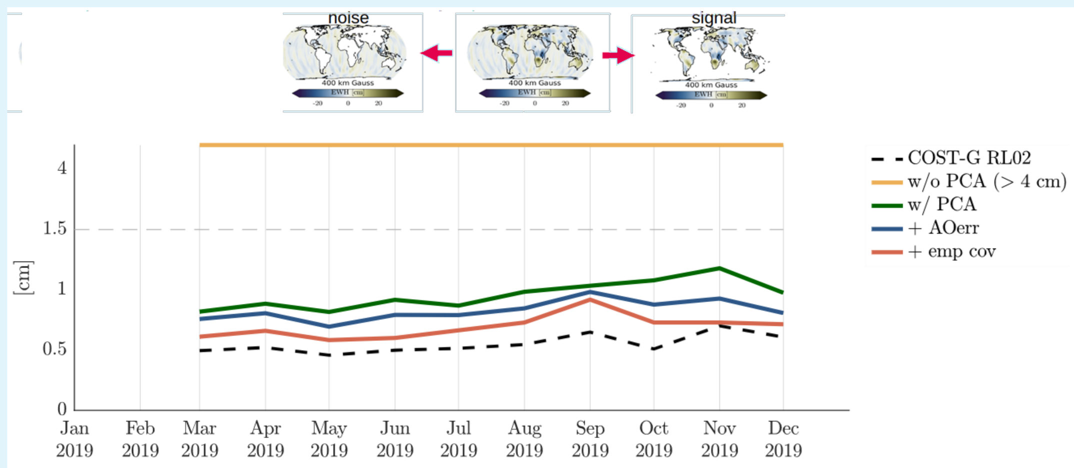


Figure 5: RMS over the open oceans w.r.t. a mean model where trend and seasonal signals where removed. Each line shows a specific feature of the noise modeling strategy (piece-wise constant accelerations, introducing AOD uncertainty information, empirical covariances derived from post-fit residuals).

Ongoing research features the combination of GRACE Follow-On data and SLR to geodetic satellites, and in future of SLR range observations to GRACE Follow-On as well, for an improved recovery of very low degree spherical harmonics coefficients, namely C_{20} and C_{30} (see Fig. 6).

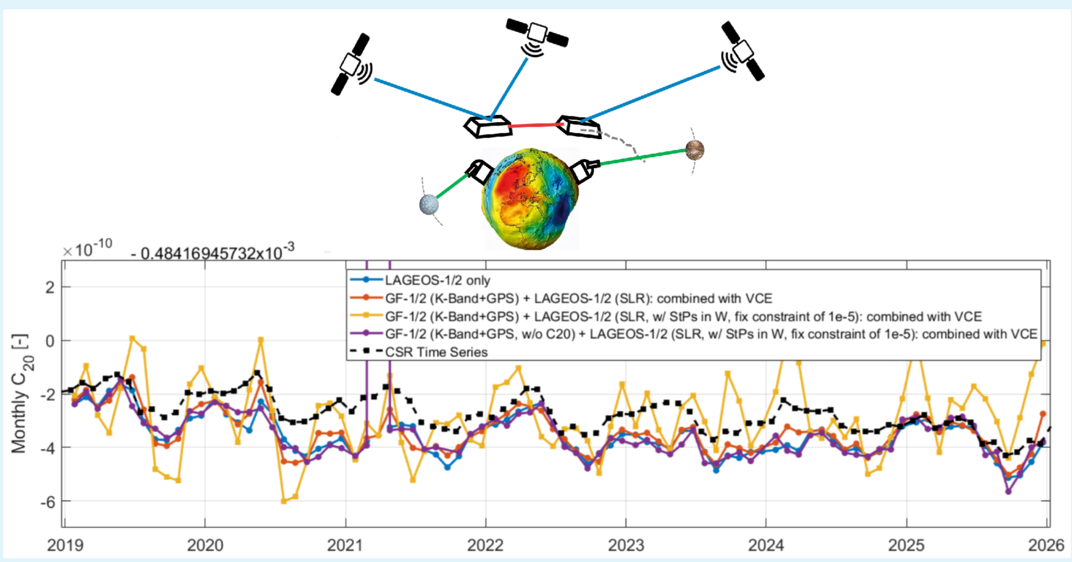


Figure 6: Estimation of the C_{20} coefficient from SLR-only and in combination with GRACE Follow-On data for different combination techniques and pseudo-stochastic orbit parametrisations.

COST-G

In the frame of the **IAG Combination Service for Time-Variable Gravity Fields** (COST-G, cost-g.org), AIUB is performing the combinations of the monthly GRACE, GRACE-FO and Swarm gravity fields. For the COST-G RL02 GRACE combination, nine COST-G Analysis Centers (ACs) and two partner Analysis Centers (PCs) were providing their monthly gravity field solutions, while for the operational GRACE-FO combination still nine ACs/PCs are routinely generating their contributions with latencies of 1-3 months. The numer of COST-G ACs is thus on the same level as for IGS.

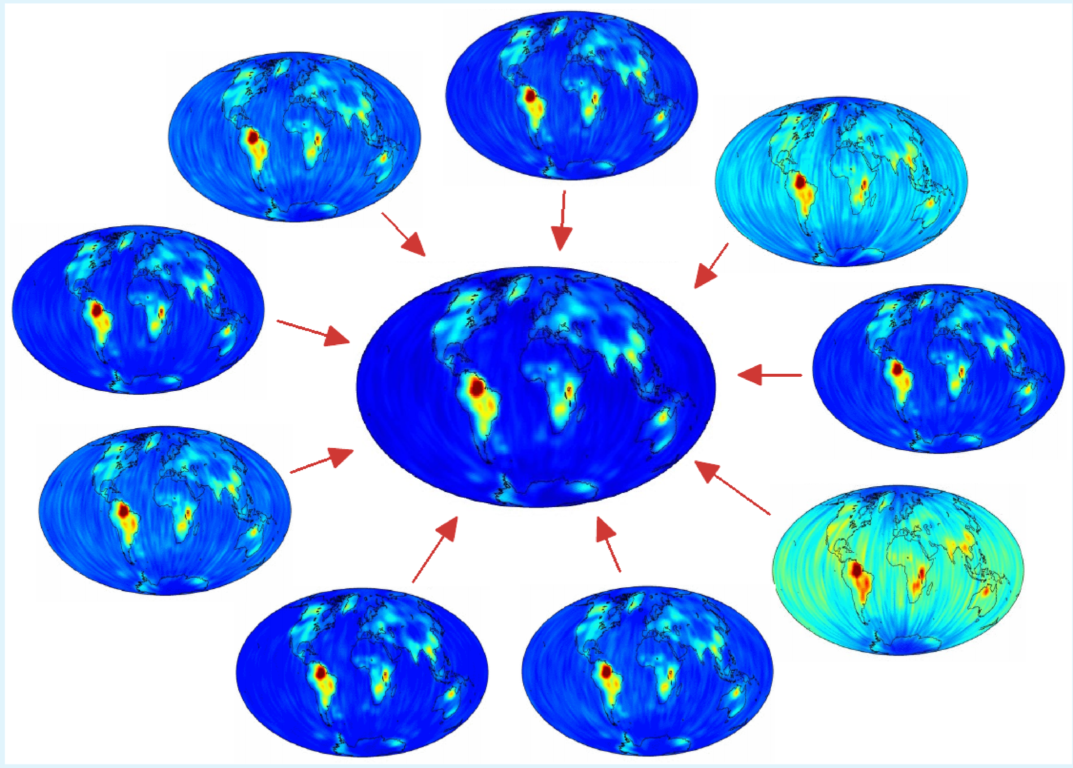
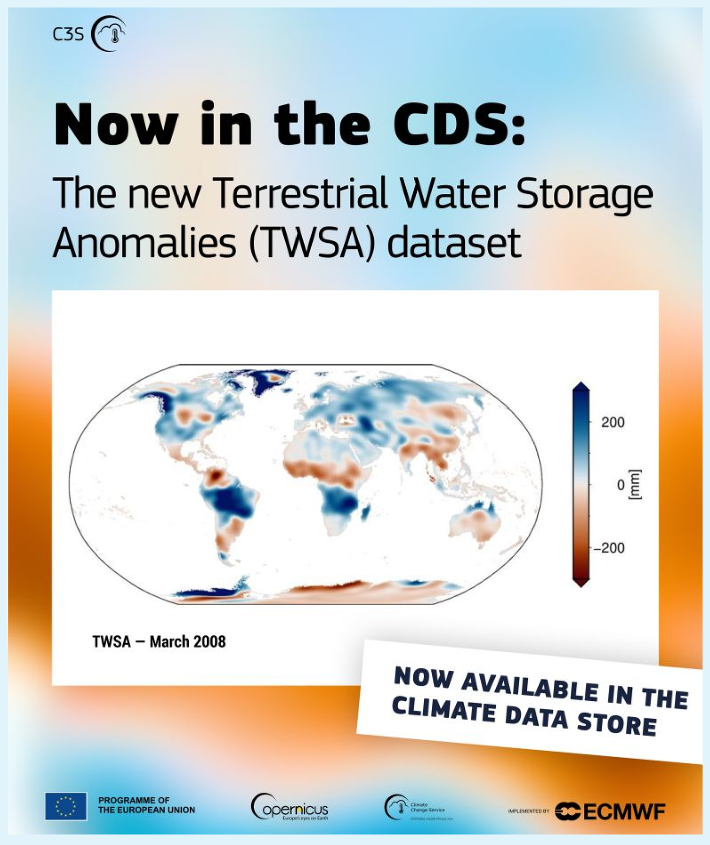


Figure 7: Non-seasonal variability of the individual GRACE-FO time-series and the COST-G combination (center), which over quiet ocean areas serves as a proxy for the noise assessment of the gravity field solutions.

The signal content of all contributing gravity fields is subject to the COST-G quality control, while the different noise levels are taken into account in the combination by relative weights, determined by VCE. The combined COST-G gravity fields stand out by their **favorable signal-to-noise ratio**, as is demonstrated in Fig. 7 by the reduced variability over quiet ocean areas. The combined COST-G gravity fields are available as Level-2 products (spherical harmonic coefficients) from the International Center for Global Earth Models (ICGEM, icgem.gfz.de). Level-3 products, i.e., post-processed global grids of specific mass variations (e.g., Terrestrial Water Storage (TWS) or polar ice mass change) and mass change time-series for specific areas (e.g., river or glacial basins) are generated by the COST-G Level-3 Product Center at the German Research Center for Geosciences (GFZ) and are distributed via the Gravity Information Service (GravIS, gravis.gfz.de).



The new Essential Climate Variable (ECVs) TWS anomalies was adopted in the implementation plan of the Global Climate Observing System (GCOS) in 2022. **On April 7, 2026 the Copernicus Climate Change Service (C3S) started the operational provision of a TWS anomalies dataset based on the COST-G RL02 GRACE/GRACE-FO Level-2 products** (Meyer et al., 2025, doi: 10.5880/COST-G.ICGEM_02_L2):

TWSA Data

GPS L1/L5 Signals

First LEO satellites (e.g., EPS-SG) **track GPS L5 instead of L2** for POD. Currently, CODE develops GNSS product chains (including in particular GNSS satellite clock corrections and biases) allowing for the processing of L5 observations. The following shows results of tests with these products for Sentinel-6A POD for a day when both L2 and L5 was tracked:

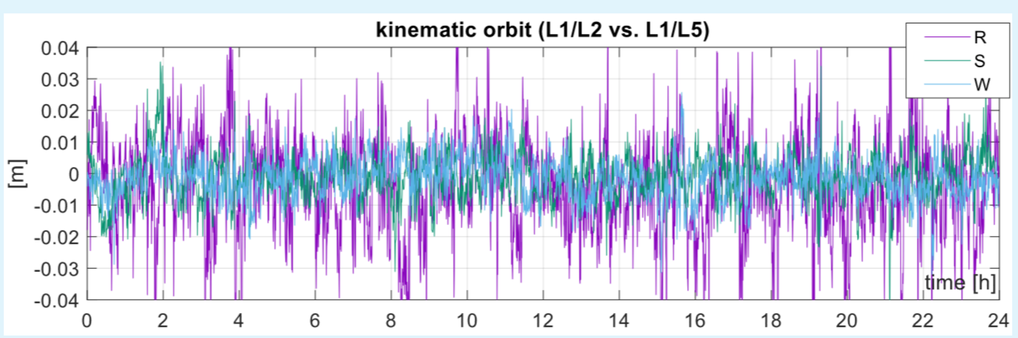


Figure 3: Differences of Sentinel-6A kinematic orbits in radial (R), along-track (S) and cross-track (W) for day 21/062 (when GPS L5 tracking was switched on), once computed with L1/L2 and once with L1/L5.

Ambiguity resolution rate [%]

	GPS(L1/L2) GAL (E1/E5)		GPS(L1/L5) GAL (E1/E5)	
GNSS	WL	NL	WL	NL
GPS	81.1	79.4	97.6	93.4
Galileo	96.9	96.5	98.5	98.1
TOTAL	90.8	89.9	98.1	96.3

Table 1: Success rates for Sentinel-6A wide-lane (WL) and narrow-lane (NL) ambiguity resolution. The values are higher when using L1/L5.

See also oral presentation S2 01 "Experimental CODE products based on GPS L1/L5 signals" by M. Kalarus.

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