COST-G

Combination Service for Time-variable Gravity Models

COST-G models of time-variable gravity for precise orbit determination

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EGU 2023

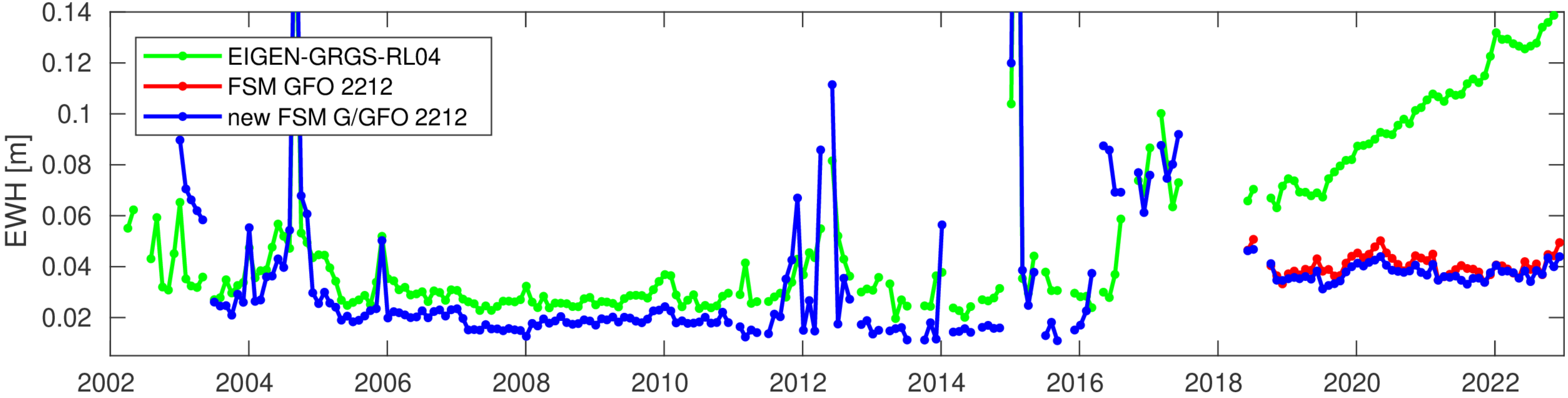
G2.1 Precise Orbit Determinatin for Geodesy and Earth Science

UNIVERSITÄT BERN

POSITIM

Time-variable gravity field models

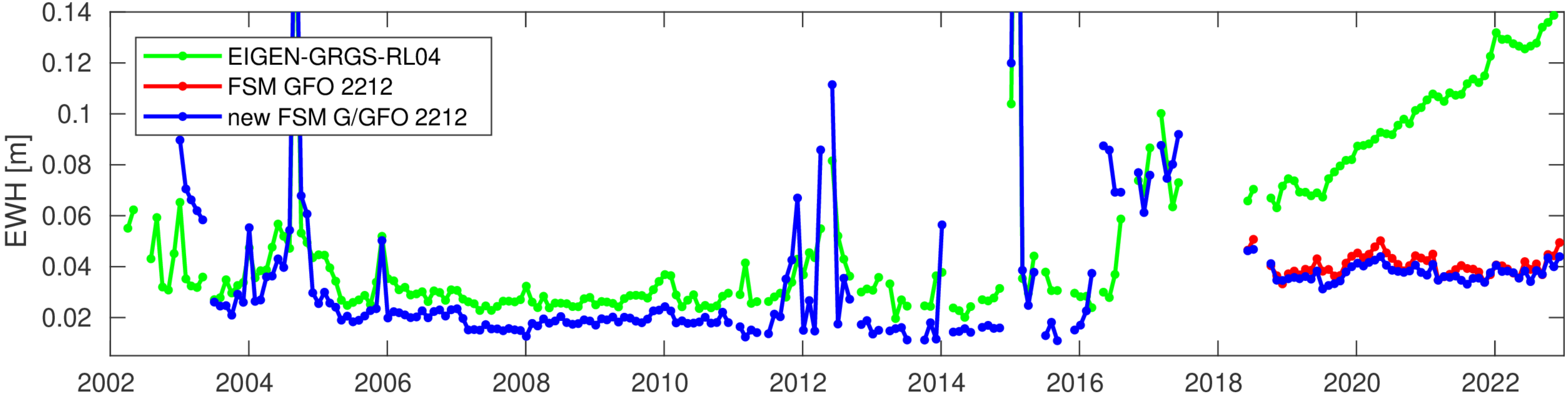
EIGEN-GRGS-RL04: High-resolution static gravity field model with additional time-variations at low- to medium resolution (bias, trends, and periodic annual/semi-annual variations, fitted to monthly GRGS GRACE gravity fields).



FSM GFO 2212: Fitted signal model (bias, trends, and periodic annual/semi-annual variations) based on the COST-G combined monthly gravity fields of GRACE-FO (until June, 2021); one set of coefficients for the whole period.

Time-variable gravity field models

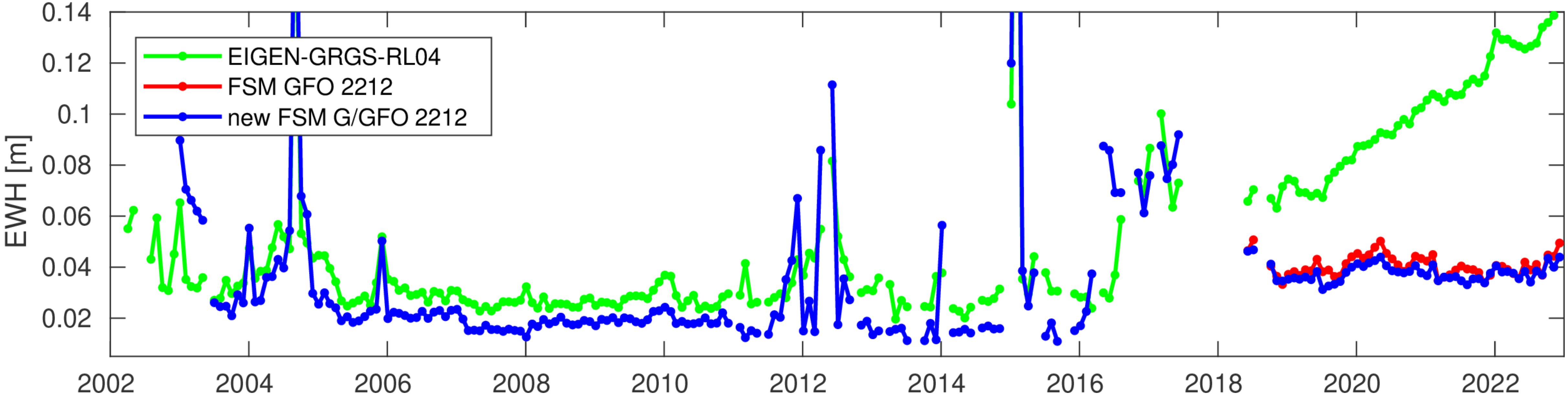
new FSM G/GFO 2212: Fitted signal model (bias, trends, and periodic annual/semi-annual variations) based on the COST-G combined monthly gravity fields of GRACE and GRACE-FO (until June, 2021).



GRACE: several sets of time-variable coefficients fitted to approx. annual sub-periods.
GRACE-FO: one set of time-variable coefficients fitted to whole GRACE-FO period.
Continuity conditions at boundaries.

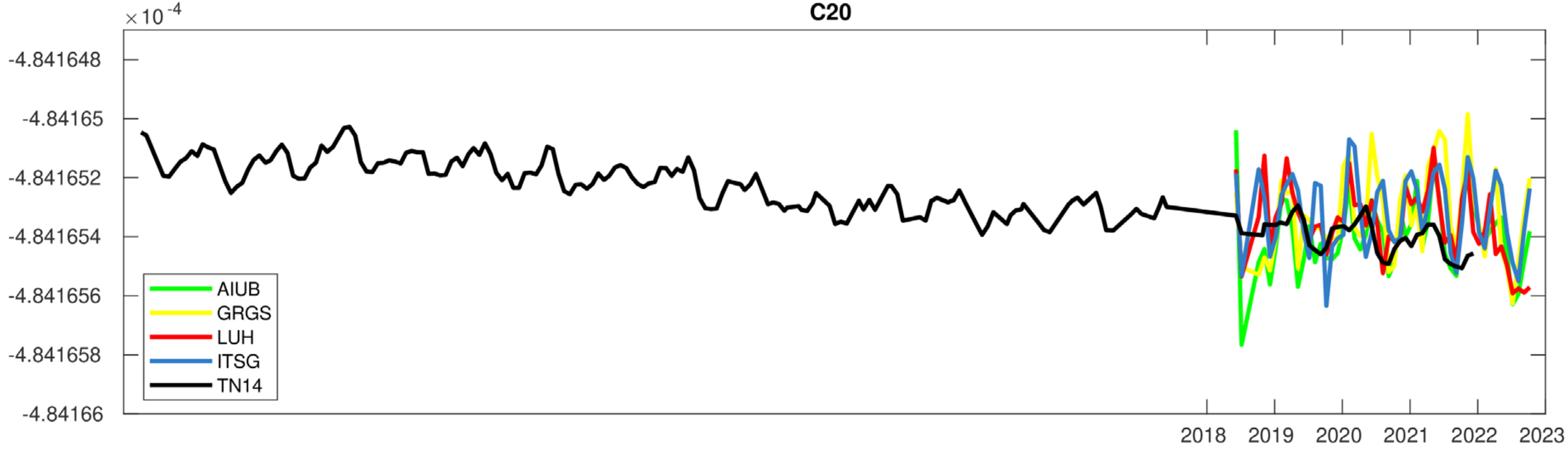
Time-variable gravity field models

new FSM G/GFO 2212: Fitted signal model (bias, trends, and periodic annual/semi-annual variations) based on the COST-G combined monthly gravity fields of GRACE and GRACE-FO (until June, 2021).



The monthly GRACE gravity fields were screened prior to the fit of the extended COST-G FSM => outliers indicate monthly solutions of inferior quality.

GRACE-FO C_{20} (IfG ACT only) is still not usable



GOCE orbit fit

3D-RMS values [cm] of the orbit fit residuals (mean values from all involved arcs)
Parametrization: 6 orbital elements, accelerometer biases 1/arc (3 directions)

	March			April			June			December		
Model/Month	2019	2020	2021	2019	2020	2021	2019	2020	2021	2019	2020	2021
COST-G FSM	5,53	5,77	6,30	5,37	5,72	6,39	5,39	5,86	6,63	5,48	6,05	7,78
COST-G monthly	6,42	7,10	7,27	6,36	7,06	7,84	6,40	7,36	7,62	6,94	7,51	7,57

- COST-G fitted signal models (FSM), augmented by high-degree coefficients from a static field (GOCO06S), show significant improvement w.r.t. the monthly models of COST-G in almost all cases!
- The cause is most probably a reduction of noise in the high-d/o gravity field coefficients by the model fit (model error < noise reduction).

Setup of SLR validation

- weekly LAGEOS-only solutions: 01.01.2015 - 31.12.2015
- Parametrization:
  - seven-day arcs
  - 5 empirical parameters per arc: one bias along-track, 1/rev sin/cos in along- (and cross-) track
  - Station coordinates (NNR/NNT datum definition based on ILRS reference stations)
  - Range biases for selected stations (ILRS recommendations)
  - ERPs: piecewise linear, pole X and Y loosely constrained (1m); dUT fixed to C04 at midnight epochs
  - Geo-center-motion (one set of offsets in x/y/z per 7 days), loosely constrained (1m)
- Background model:
  - GGM05S (max. d/o 90); C_{21}/S_{21} according to linear mean pole model
  - ILRS: apriori model as provided for ITRF2020-Repro
  - COSTG FSM: fitted signal model
  - Ocean tides: FES2014 (max. d/o 30) incl. shallow tides (admittances)
  - Atmosphere tides: S1, S2
  - Non-tidal atmosphere- and ocean-dealiasing (AOD, max. d/o 30)
  - Earth tides: IERS2010
  - Subdaily Pole: Desai

ERP-differences with respect to C04

No 1/rev. cross-track par.	X-pole: bias [µas]	RMS [µas]	Y-pole: bias [µas]	RMS [µas]
GGM05S (static)	66.3	261.1	86.5	245.8
ILRS (time-var.)	54.3	219.4	88.0	201.1
COST-G FSM (time-var.)	51.0	215.6	80.6	196.7

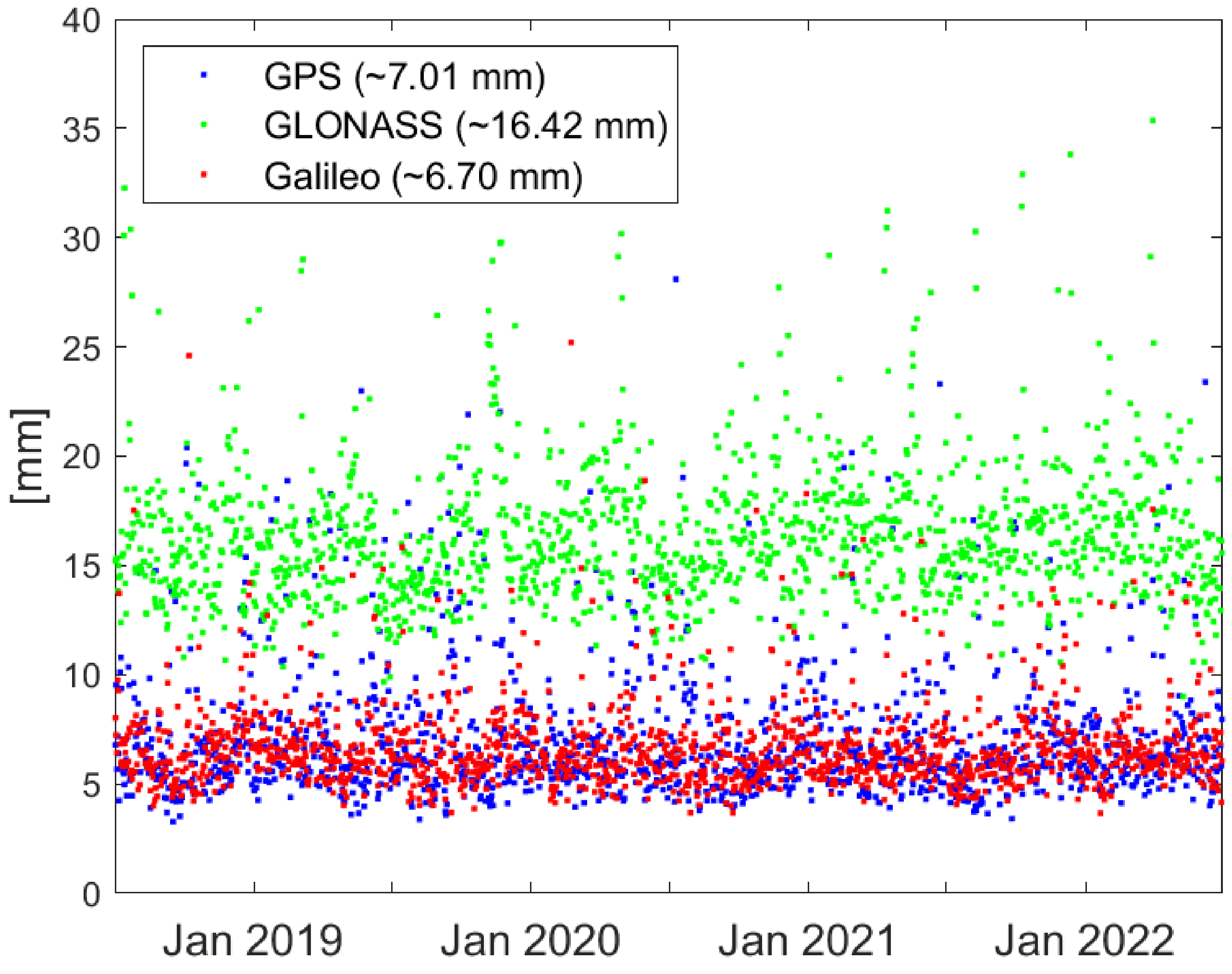
+ periodic cross-track	X-pole: bias [µas]	RMS [µas]	Y-pole: bias [µas]	RMS [µas]
GGM05S (static)	91.4	148.1	68.4	119.8
ILRS (time-var.)	73.7	142.3	75.9	126.2
COST-G FSM (time-var.)	68.8	132.8	66.0	117.8

+ C20	X-pole: bias [µas]	RMS [µas]	Y-pole: bias [µas]	RMS [µas]
GGM05S (static)	68.8	175.9	72.2	156.1
ILRS (time-var.)				
COST-G FSM (time-var.)	49.3	164.5	65.5	157.2

Setup of GNSS orbit validation

- solutions containing GPS, GLONASS and Galileo
- 4 years: 01.07.2018 - 30.06.2022
- background models and parameterization in agreement with the ITRF20 and CODE processing standards:
  - three-day arcs
  - ECOM2 (empirical force model) + orbit midnight pulses
  - DESAI2016 subdaily pole
- REF solution: EGM2008 + C_{20}, C_{30}, C_{40} bias and drift;
  C_{21}, S_{21} according to linear mean pole model
- COSTG: fitted signal model (FSM)

Orbit overlaps (midnight misclosures): REF

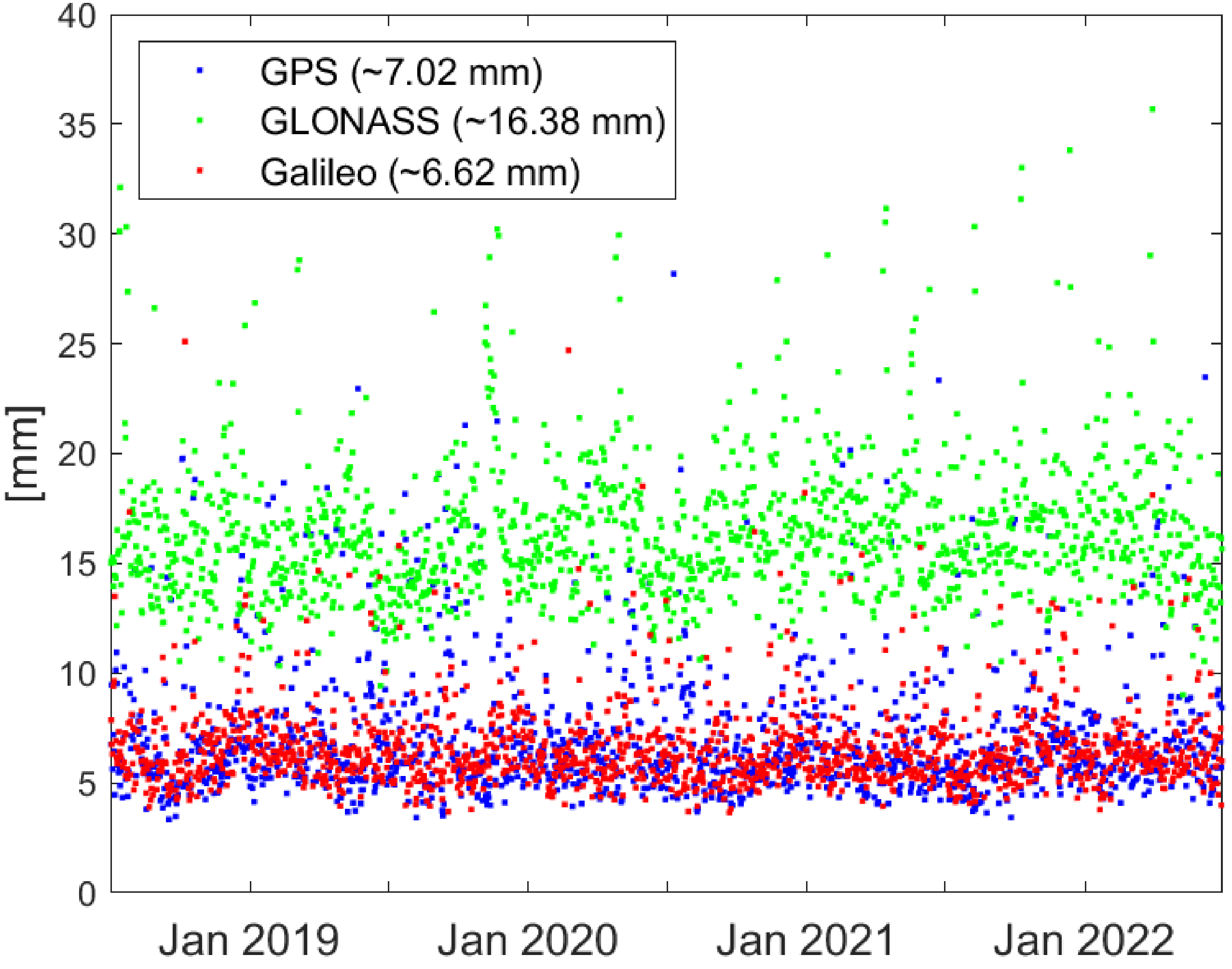


From subsequent 3 day arcs the middle days are extracted which overlap at exactly one epoch :

end of first orbit at midnight
= start of second orbit

The averaged midnight misclosures per satellite system are provided in the legend.

Orbit overlaps (midnight misclosures): COSTG



From subsequent 3 day arcs the middle days are extracted which overlap at exactly one epoch :

end of first orbit at midnight

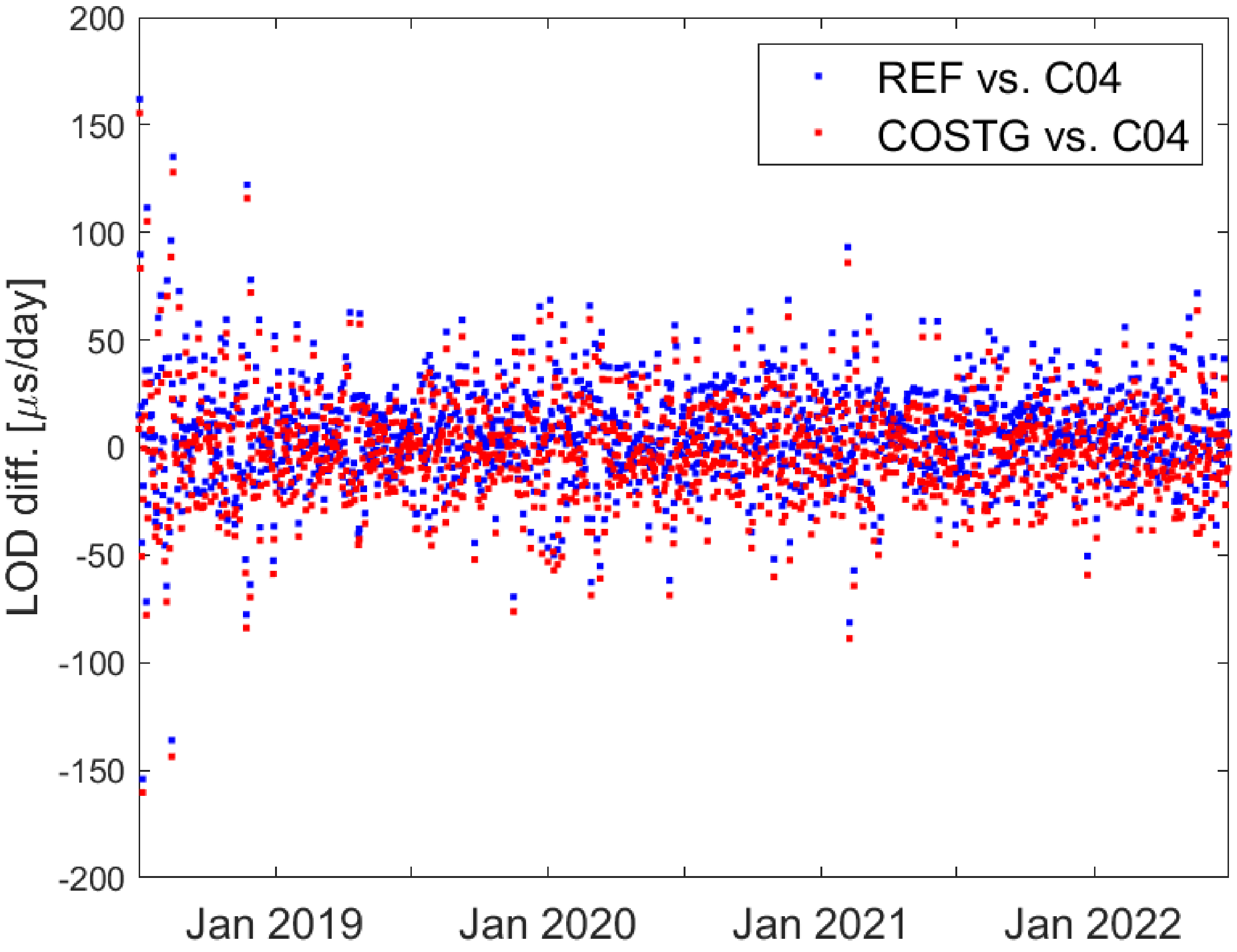
= start of second orbit

The averaged midnight misclosures per satellite system are provided in the legend.

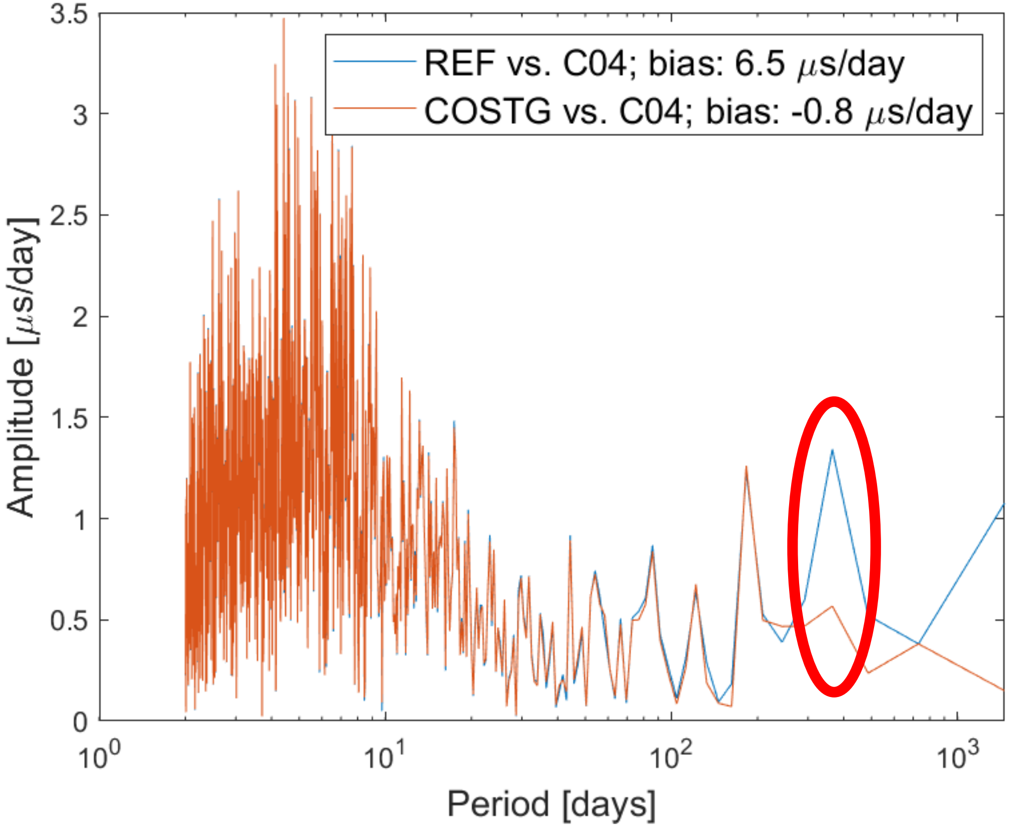
SLR-validation:

	GLONASS	Galileo
REF	0.70+-3.44 cm	0.39+-2.11 cm
COSTG	0.70+-3.44 cm	0.34+-2.11 cm

Length Of Day (LOD) estimates



The bias and the amplitude of the annual variations of LOD with respect to C04 are significantly reduced!

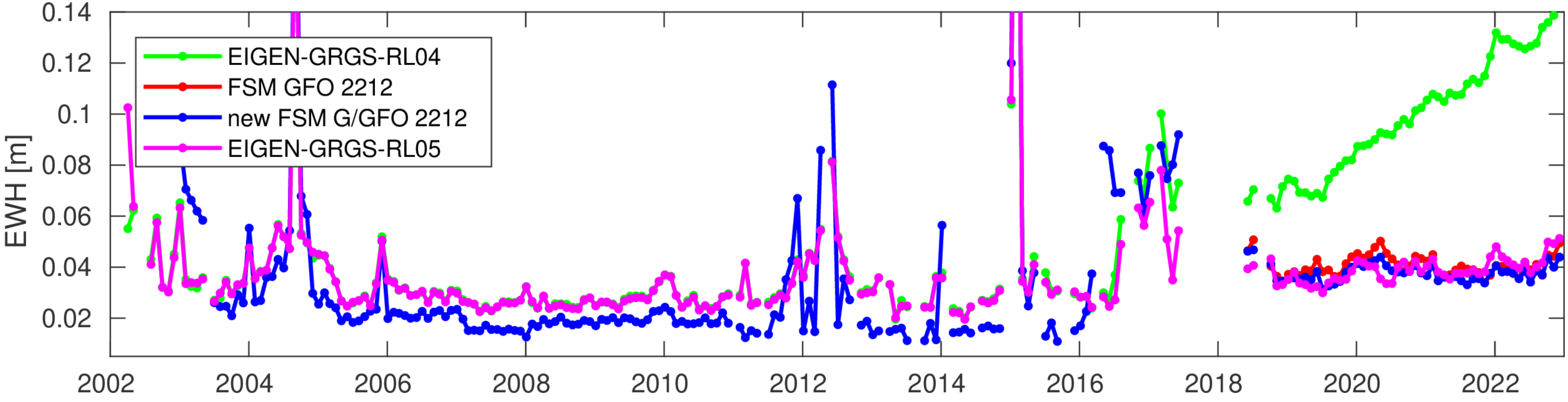


Conclusions

- LEO-POD clearly profits from a time-variable gravity model; the lower, the more … in case of GOCE (250 km) the FSM even outperforms the monthly gravity fields.
- In case of SLR (LAGEOS, 5900 km) small improvements over a static or the ILRS apriori time-variable gravity model are visible, attenuated by empirical periodic 1/rev-parameters.
- In case of GNSS the main impact is on LOD, where artifact with annual period are drastically reduced.

Spoiler

EIGEN-GRGS-RL05: High-resolution static gravity field model with additional time-variations at low- to medium resolution (bias, trends, and periodic annual/semi-annual variations, fitted to monthly GRGS GRACE/GRACE-FO gravity fields).



Several sets of time-variable coefficients fitted to approx. annual sub-periods.
Extrapolation based on whole GRACE/GRACE-FO period.