A new combined processing for Genesis

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Session G2.1 Precise Orbit Determination for Geodesy and Earth Science

ESA Navigation Support Office Current Capabilities

- **GNSS** products, contributing to **IGS**
  - **CHAMP** - *Consolidated High Accuracy Multi-GNSS Processing*
  - Constellation-wise processing with Normal Equation stacking
- **SLR** products:
  - SLR targets: contributing to **ILRS**
  - SLR to MEOs & LEOs for validation purposes
- **DORIS** products
  - DORIS-equipped LEOs: contributing to **IDS**
- **VLBI** products:
  - VLBI to Quasars and *soon* to contribute to **IVS**

⇨ The ESA Navigation Support Office:

- regularly processes all 4 geodetic techniques and satellites in different orbital regimes: LEOs, MEOs, GEOs and HEO
- aims to process all space geodetic observations in a single combined approach (adding one technique at a time)
- plans to include all LEOs and geodetic targets (e.g., LAGEOS, LARES)

Genesis – At the Foundation of Navigation

Session G2.2: Overview of Genesis - an ESA mission at the Foundation of Navigation by Sara Gidlund et al.
Session G1.1: Genesis: A Unique Space Geodetic Observatory by Gaia Fusco et al.

Contribute to improve ITRF accuracy and stability:

- Parameter **accuracy of 1 mm**
- Parameter **stability of 0.1 mm/year**

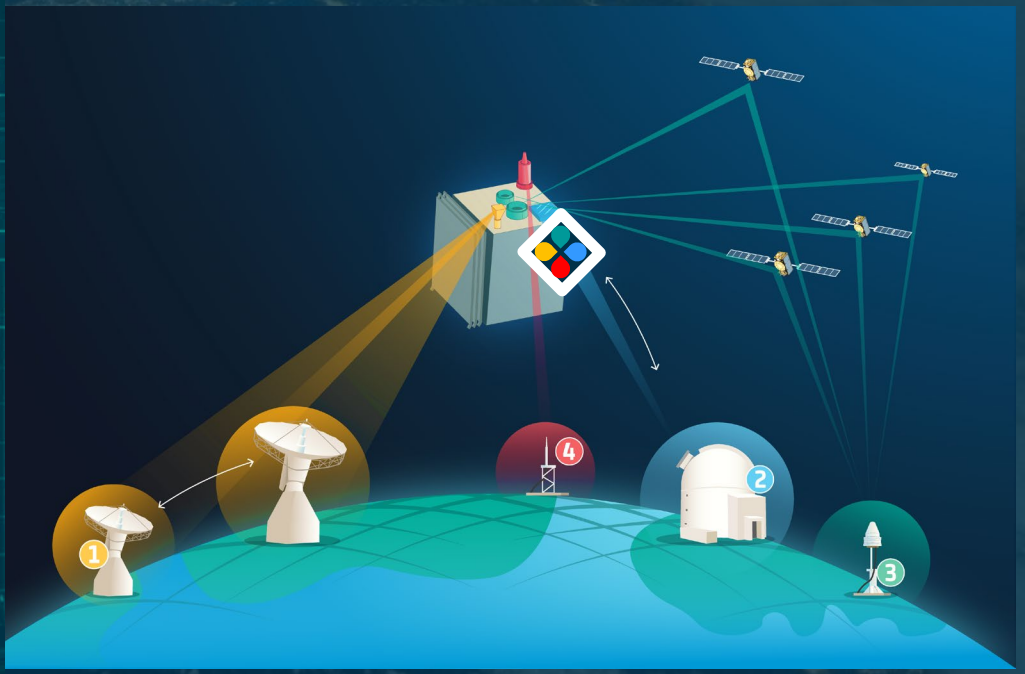
Contribute to improve the link between the ITRF and the ICRF

1 - VERY-LONG-BASELINE INTERFEROMETRY (VLBI) Transmitter

2 - SATELLITE LASER RANGING (SLR) Retroreflector

3 - GLOBAL SATELLITE NAVIGATION SYSTEMS (GNSS) Receiver (Nadir and Zenith antennas)

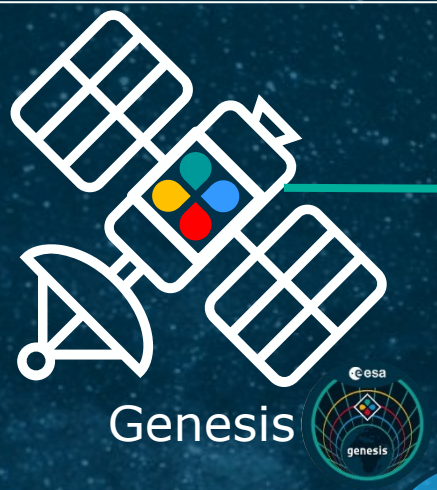
4 - DORIS Receiver



Genesis Data PROcessing, Archiving and Distribution

GNSS
Galileo & GPS

DORIS



GNSS+Doris
Measurements

OHB-Italy

GNSS Measurements
Additional Data

CNES
Doris Products and
Measurements

DORIS Ground
Segment (IDS)

International Geodetic Services
SLR (ILRS)
VLBI (IVS)
GNSS (IGS)
DORIS (IDS)

PROAD

ESAC GNSS Science
Support Centre
gssc.esa.int

ESOC Navigation
Support Office

GENESIS
POD Product
and other Data

GENESIS
Data and Products
Dessimination

ESA Combination On the Observation Level

GNSS
MEO & LEO

- **GAL + LEOs**
- **GPS + LEOs**
- **GLONASS**
- **BeiDou**
- **QZSS**

MS1

GNSS & SLR validation
MEO & LEO

- **GAL + LEOs**
- **GPS + LEOs**
- **Others**
- **SLR validation**

Current state

MS2

GNSS & SLR
MEO & LEO
& SLR targets

- GAL + LEOs **+ SLR targets**
- GPS + LEOs **+ SLR targets**
- Other GNSS **+ SLR targets**

MS3

GNSS & SLR & DORIS
MEO & LEO
& SLR targets
& DORIS satellite

- GAL + LEOs + SLR **& DORIS targets**
- GPS + LEOs + SLR **& DORIS targets**
- Others GNSS + SLR **& DORIS targets**

MS4

GNSS & SLR & DORIS & VLBI
Quasar & LEO

- **GNSS** + LEOs
- SLR
- DORIS
- **VLBI to Quasar**
- **VLBI to satellite**

⇨ Processing based on Normal Equation Stacking approach developed for CHAMP

⇨ Currently adding Sentinel-6A to Galileo (enabling combination of multi-GNSS, SLR and DORIS)

⇨ **Genesis** will be used as the common element linking all four geodetic techniques together

⇨ **As IGS AC, ESA plans to include LEOs and Genesis into its current IGS GNSS processing**

Step 1: Combined GNSS MEO-LEO processing

Comparison based on the observations for the whole year 2024:

Case	Satellite constellation	# Stations	Sampling	Information
CHAMPDAILY	Galileo	200	300s	Reference Case
GAL80sta300s	Galileo	80	300s	
GAL80sta30s	Galileo	80	30s	
COOLDAILY80	Galileo + Sentinel 6A	80	30s	
COOLDAILY200	Galileo + Sentinel 6A	200	30s	
COOLMGNSS	COOLDAILY80 + GPS/GLO/QZS/BEI	80/200	30s/300s	
CHAMPMGNSS	CHAMPDAILY + GPS/GLO/QZS/BEI	80/200	30s/300s	Current IGS AC output

Analysis of the effect on the individual and combined GNSS solutions of:

⇨ number of ground stations

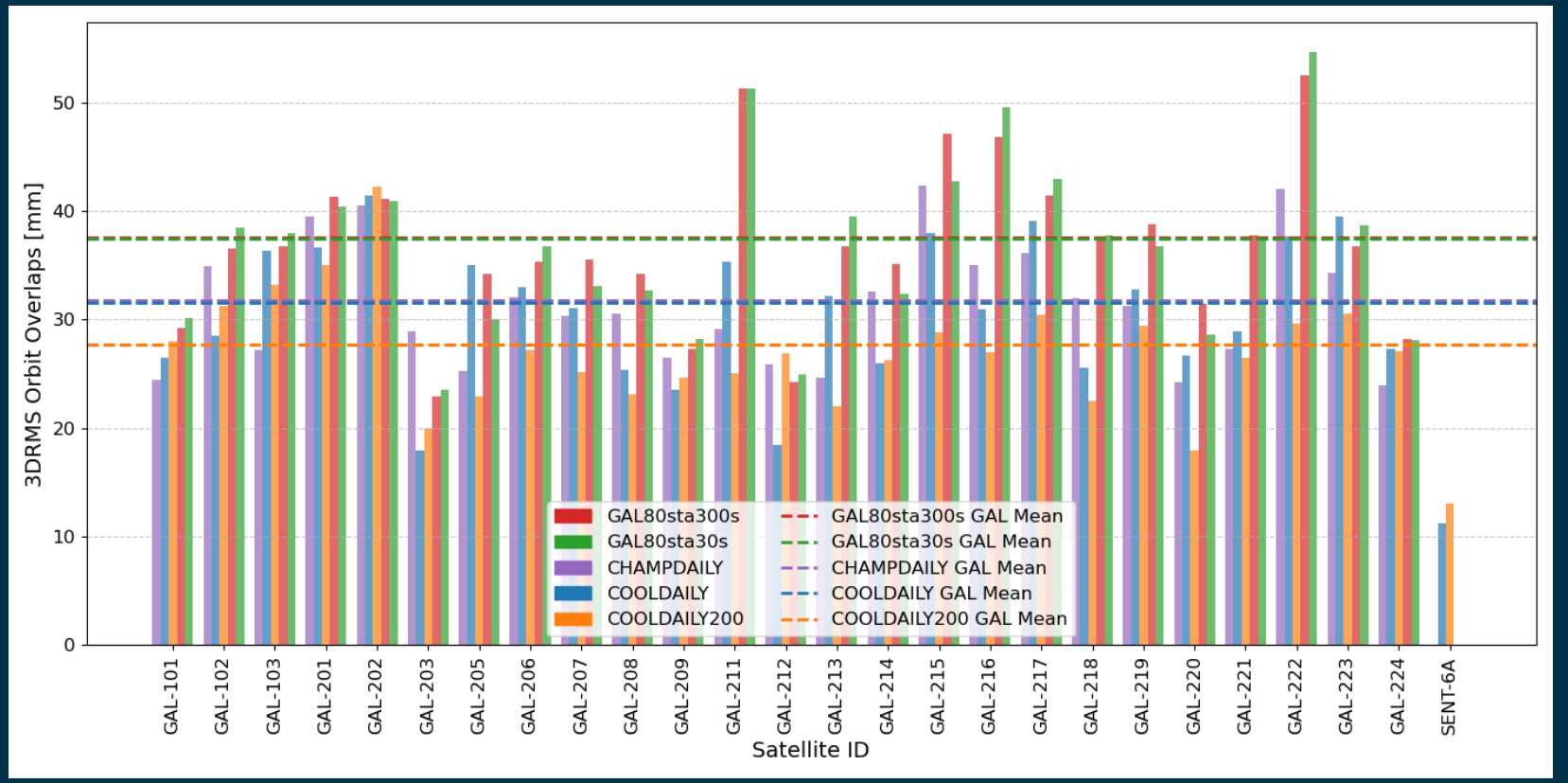
⇨ computational data sampling

⇨ adding LEO satellites (SENTINEL-6A)

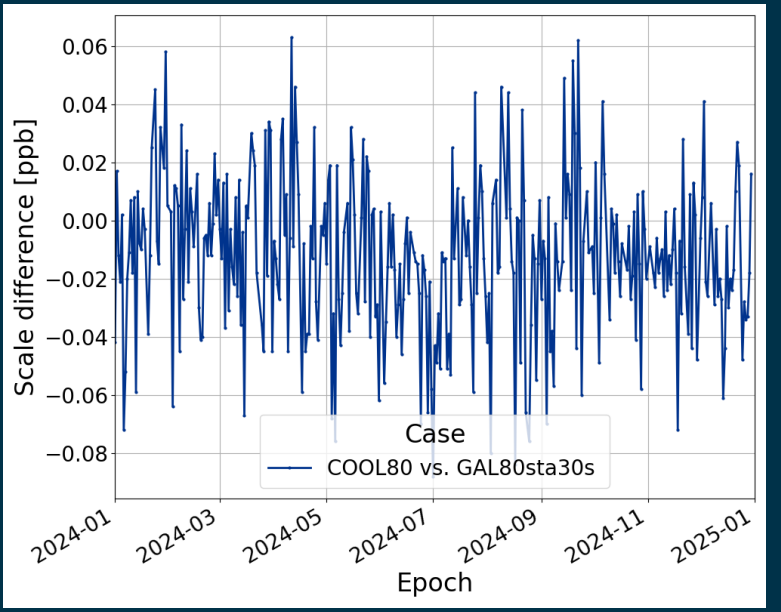
Note:

- Arc length: 24h
- ITRF2020 alignment

Effect of adding LEO satellites (SENTINEL-6A)



Future Genesis case:
Neglectable noise level differences in scale!



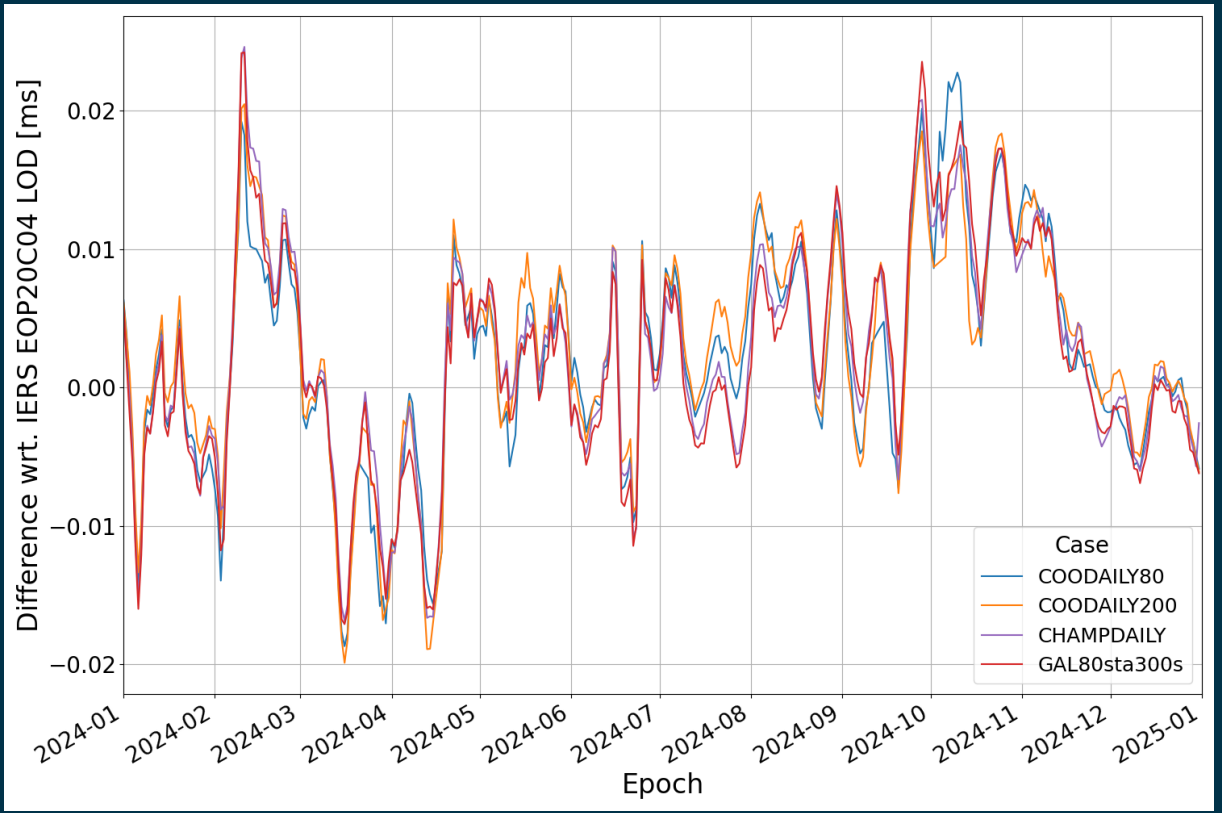
Temporal stability across 24h arcs: Satellite Orbit Overlaps

- No benefit of the data sampling reduction alone for Galileo-only solutions
- 3D RMS of 80 stations + SENTINEL-6A matches 200 stations performance
- Further 3D RMS reduction for 200 stations + SENTINEL-6A

⇨ Orbit overlaps quality with Galileo-only
⇨ Enhanced efficiency
⇨ Improved orbital consistency

Effect of adding LEO satellites (SENTINEL-6A)

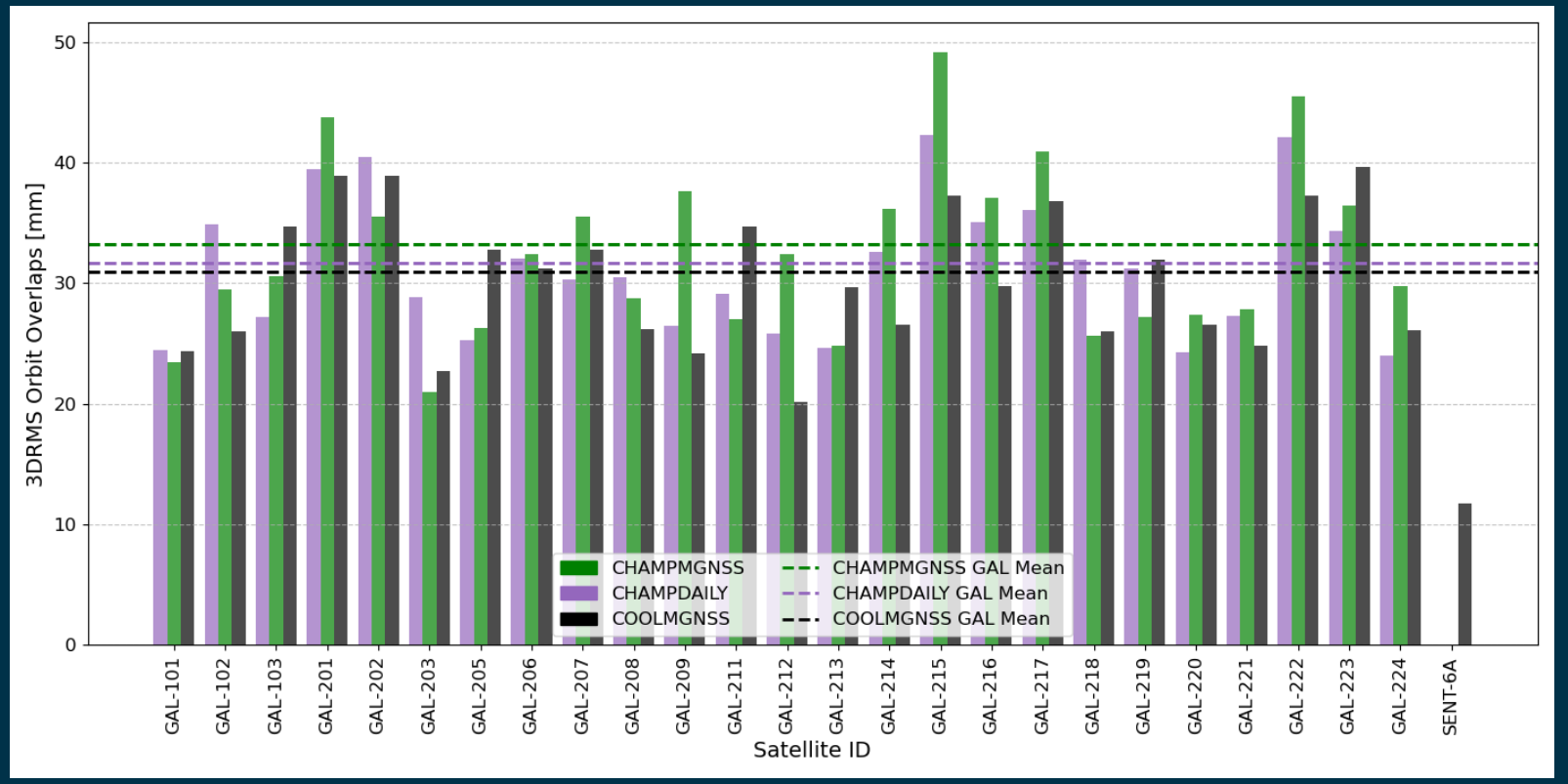
Impact on the Earth Orientation Parameter estimates with e.g. Length of Day

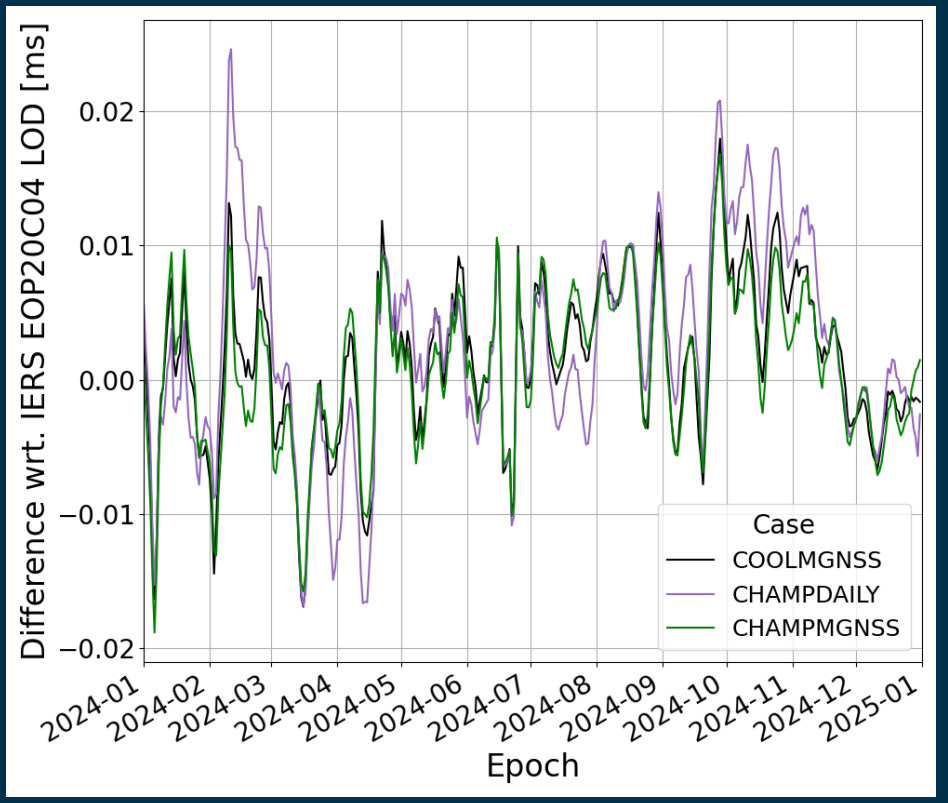


Case	Mean LOD [ms]	STD LOD [ms]	Drift LOD [ms/year]
CHAMPDAILY	0.0024	0.0077	0.0068
GAL80sta300s	0.0020	0.0080	0.0079
COOLDAILY80	0.0020	0.0077	0.0082
COOLDAILY200	0. 0026	0.0075	0.0063

- ⇨ Similar results between 200-stations vs. 80 geometrically-well-distributed station tracking network
- ⇨ The addition of Sentinel 6A does not degrade the results
- ⇨ Slight Polar Motion Rate estimates bias improvement wrt. IERS EOP20C04

Effect of adding LEOs to MGNSS on ESA IGS products





- ⇨ Slightly downgraded temporal stability of the Galileo satellites within the nominal CHAMP combination with 200 stations
- ⇨ Solved by combining COOL80 with all other GNSS 200-station solutions
- ⇨ COOLMGNSS combination potentially improves ESA IGS products

- ⇨ Earth Orientation Parameter estimates maintain the nominal CHAMP Multi-GNSS accuracy

Step 2: SLR satellite validation

Comparison based on the observations for the whole year 2024:

Case	Satellite constellation	# Stations	Sampling	Information
CHAMPDAILY	Galileo	200	300s	Reference case
COOLDAILY80	Galileo + Sentinel 6A	80	30s	Test case

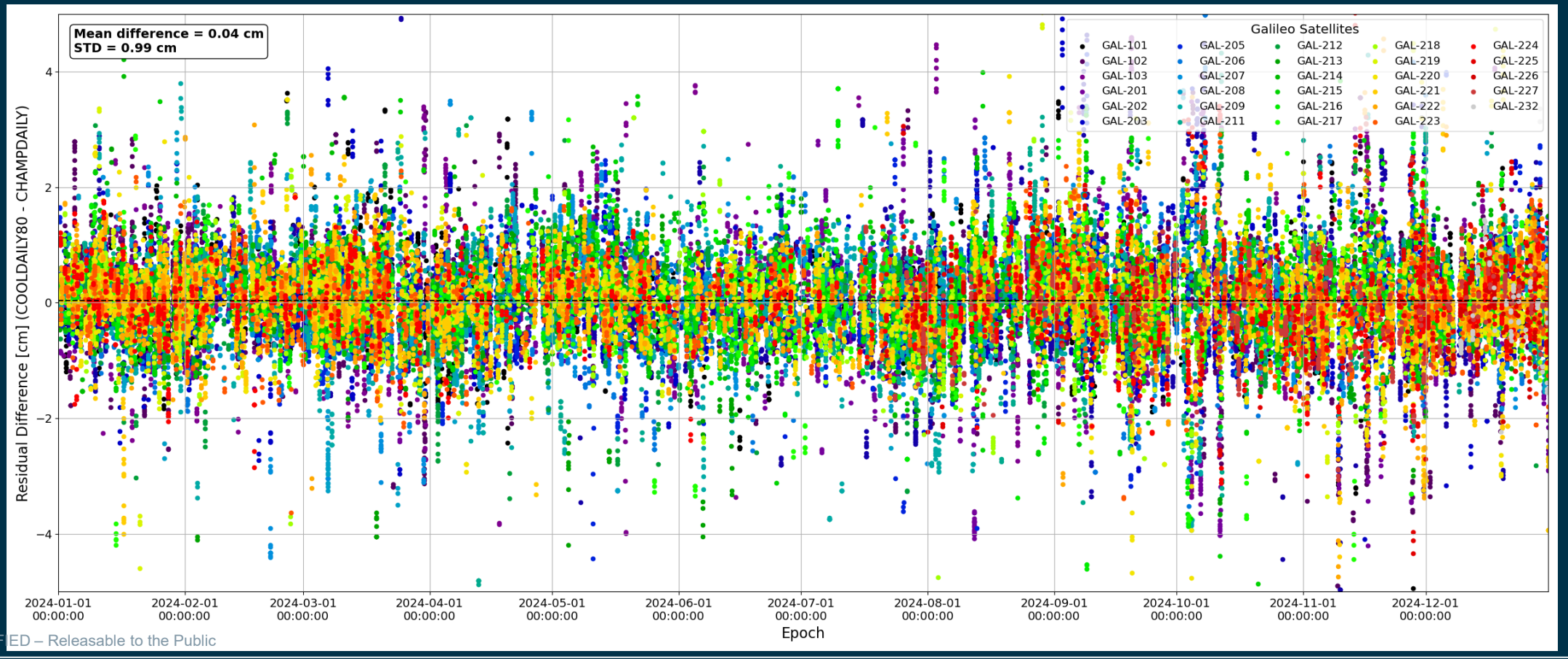
⇨ Introduction of SLR validation to GNSS orbits
- ⇨ Analysis of SLR satellite residuals
- ⇨ Helps to assess the impact of the constellation and processing strategies

Note:
- Arc length: 24h
- ITRF2020 alignment
- Maximum number of SLR stations: 17

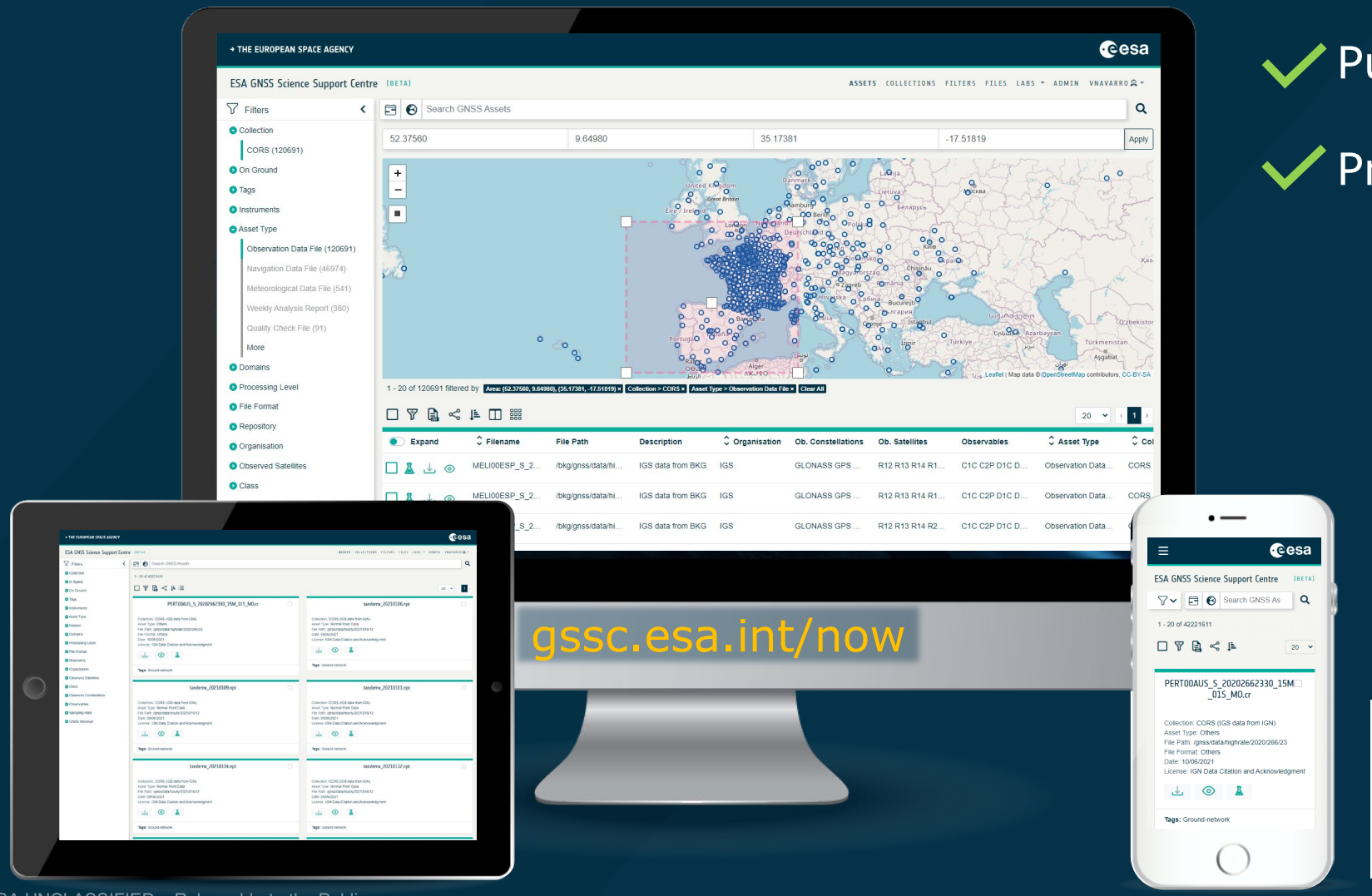
Result of SLR satellite validation

Residual differences between COOLDAY80 and CHAMPDAILY for all SLR-tracked Galileo satellites

- ⇨ Strong consistency and sub-centimetre agreement between solutions
- ⇨ Neither any significant bias nor long-term trends observed across satellites



GSSC Now – Navigation Science Digital Platform



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Thank you

Follow the next steps of the Navigation Support Office at the ENC and IAG 2025 conferences

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