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An update of GFZ's contribution to EPN-Repro3

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Overview

In a collaborative effort, the EPN Reprocessing Working Group undertakes the significant task of reprocessing all GNSS data accumulated in the EPN from 1996 until the end of 2022. As an EUREF Analysis Center, GFZ joins this effort by processing an EPN subnetwork of about 122 stations. Like the operational efforts, the reprocessing is performed using GFZ's processing software EPOS.P8. This contribution discusses station selection, processing scheme, and first results covering 2000 to 2024.

Station network

As agreed upon within the EPN Reprocessing Working Group, GFZ is processing the same station network as in the operational configuration (Fig. 1). T. Liwosz recommended this station selection based on the number of EPN analysis centers processing each EPN station in operational solutions and in the reprocessing effort. Additional considerations were made about stations included in the IGS20 and the GFZ's IGS solution, and stations operated by GFZ.

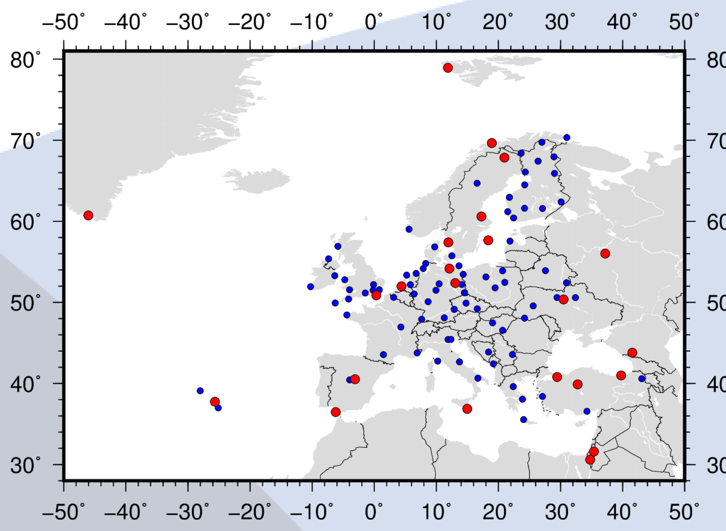


Fig. 1: The station network used for the GFZ EPN repro3 solution; IGS20 stations are marked in red (station THU2 at Thule Airbase in Greenland is not shown but processed).

Processing statistics

Fig. 2 shows the number of processed stations and satellites. The network increased from about 25 stations in 2000 to more than 115 stations in 2021 and 2022. The number of processed satellites reflects the added constellations. The ratio of resolved ambiguities is around 95% and 90% for GPS and Galileo, respectively (Fig. 3). The decreased fixing ratio for Galileo needs further investigation.

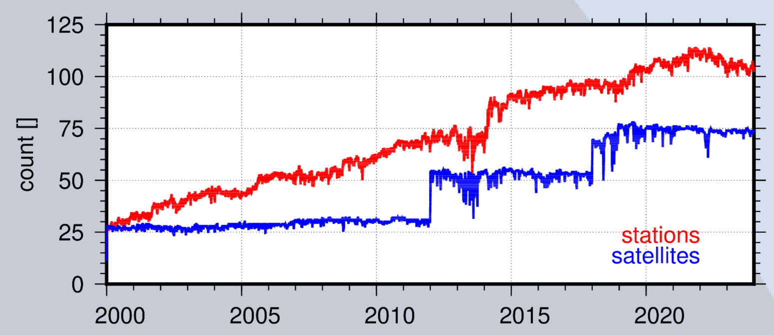


Fig. 2: Stations (red) and satellites (blue) contained in the daily solutions.

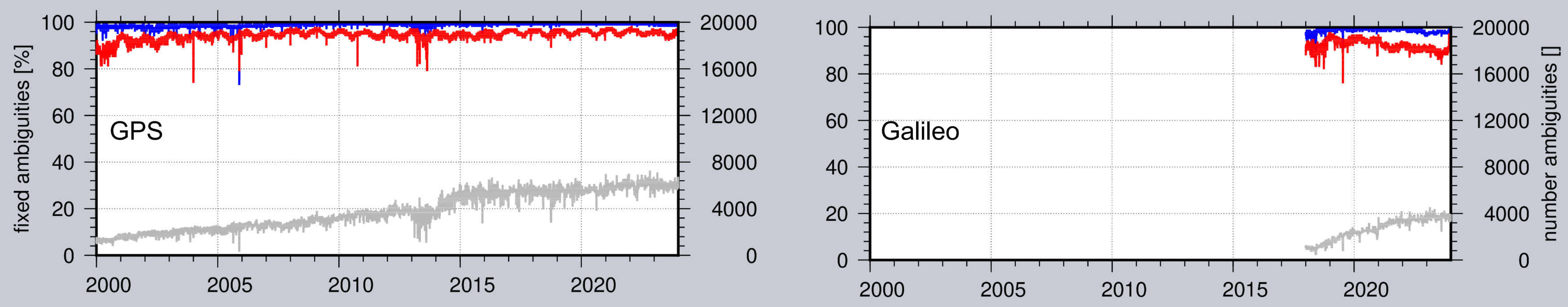


Fig. 3: Ambiguities (grey) and ratio of fixed widelane (blue) and narrowlane (red) ambiguities.

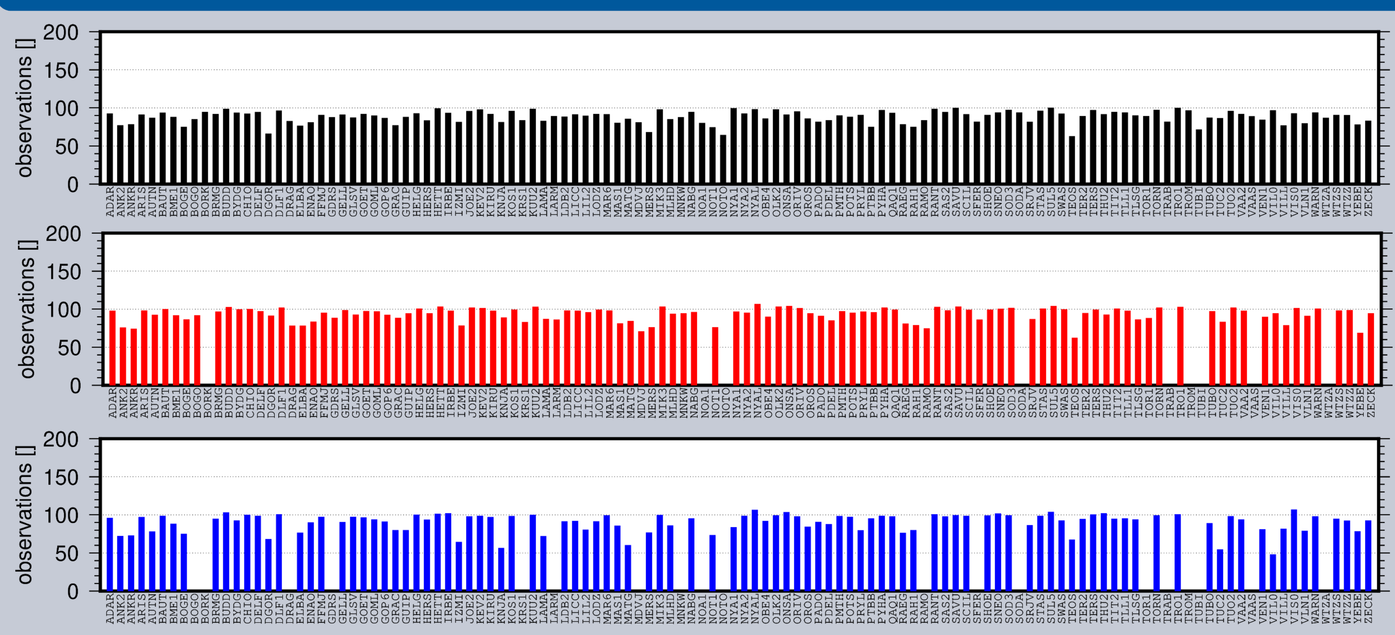
Processing strategy

GNSS observations were processed with the GFZ software package EPOS.P8. The processing follows the Guidelines for the EPN Analysis Centres with minor differences (i.e., 300s sampling rate, GPT2 meteo values, and no re-computation of the troposphere for the weekly solutions). Details are specified in Table 1. GFZ repro3 products (Männel et al. 2021) were used for the reprocessing, while GFZ final products were used in the operational EPN processing. The processing chain comprises a daily pre-processing and pre-cleaning followed by an iterative least-squares adjustment including ambiguity fixing for GPS and Galileo. Daily solutions for coordinates and troposphere are derived from this adjustment step. Weekly solutions are computed from the derived daily normal equations.

Observations	Ionosphere-free linear combination formed by undifferenced ➢ GPS, ➢ GLONASS (since 2012 / GPS week 1669), ➢ Galileo (since 2018 / GPS week 1982) observations; 300s sampling rate (30s for pre-cleaning); 3° elevation cutoff-angle, elevation-dependent weighting applied
Modelling	➢ GFZ orbit & clock products (operational, repro3) ➢ GPT2 meteo values mapped with VMF3 (Landskron & Böhm et al. 2018) ➢ Second-order ionospheric correction applied ➢ EPN20 antex (type-mean) & IGS20 reference frame ➢ Gravity field: GOCO6s (Kvas et al., 2020) ➢ Ocean tides: FES2014b (Lyard et al. 2021) ➢ HF-EOP: Desai-Sibois model (Desai and Sibois 2016) ➢ Mean pole tide according to IERS 2018
Ambiguities	Resolved for GPS and Galileo
Parameters	➢ Station coordinates (minimum constraint w.r.t. IGS20) ➢ 1h troposphere delay (no re-computation for weekly solution) ➢ 24h gradients, receiver clocks
Software	EPOS.P8, metadata management via semisys.gfz-potsdam.de

Tab. 1: Processing summary for the GFZ EPN repro3.

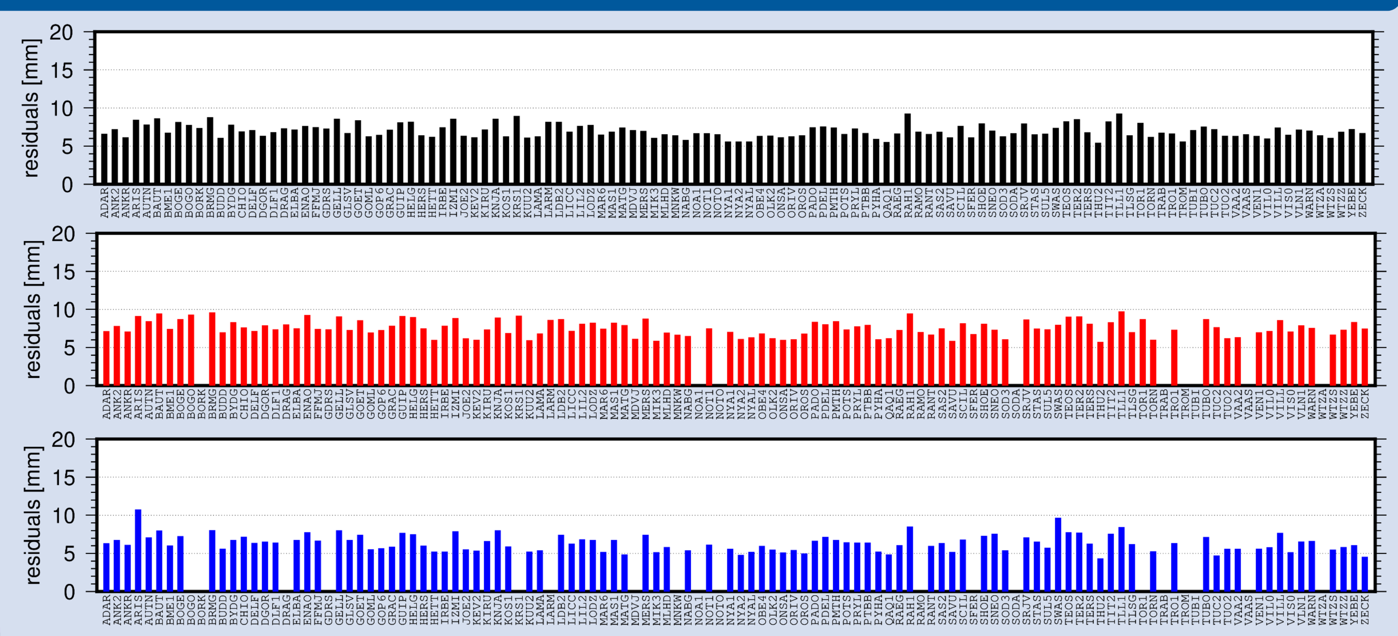
Station-specific statistics



Summary of station-wise statistical indicators: number of processed observations (Fig. 4) and phase residuals (Fig. 5).

Fig. 4: Averaged number of observations (ionosphere-free linear combination); sorted by constellation.

Fig. 5: Averaged observation residuals (observed – computed) for each station; sorted by constellation.



Weekly solutions

Fig. 6 shows averaged station coordinate repeatabilities computed with respect to the corresponding weekly solution. While North and East coordinates show overall small values of 1.1 and 1.8 mm on average, two stations (NOA1, Greece, and MERS, Turkey) show slightly larger repeatabilities in the East component (3.7 and 3.3 mm, respectively). In the up direction, repeatabilities are, on average, 4.2 mm but reach 7.6 mm for ELBA (Italy). The additional figure shows the number of daily solutions available for each station.

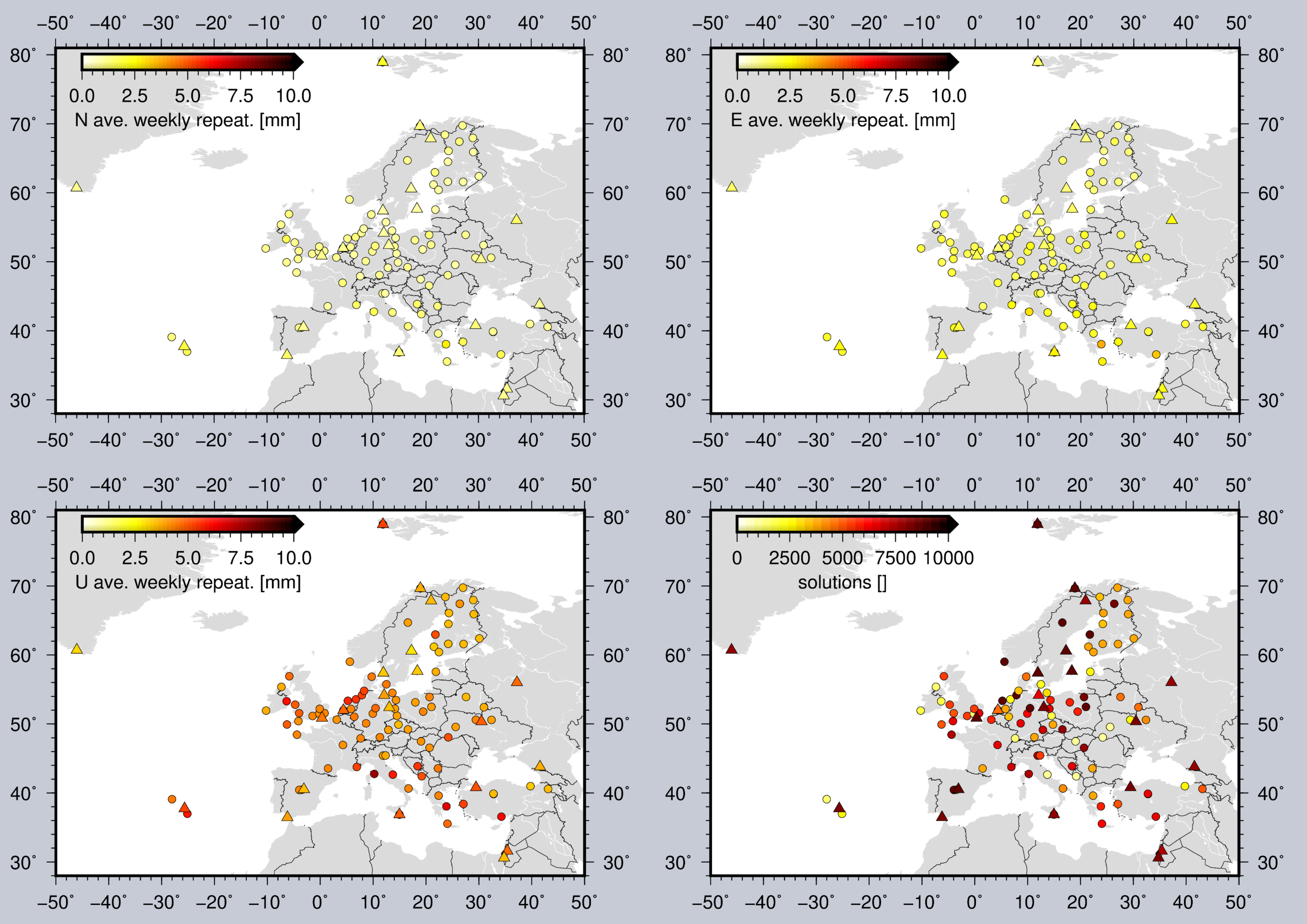


Fig. 6: Averaged weekly repeatabilities in North, East, and Up directions and number of daily solutions between 2000 and 2024.

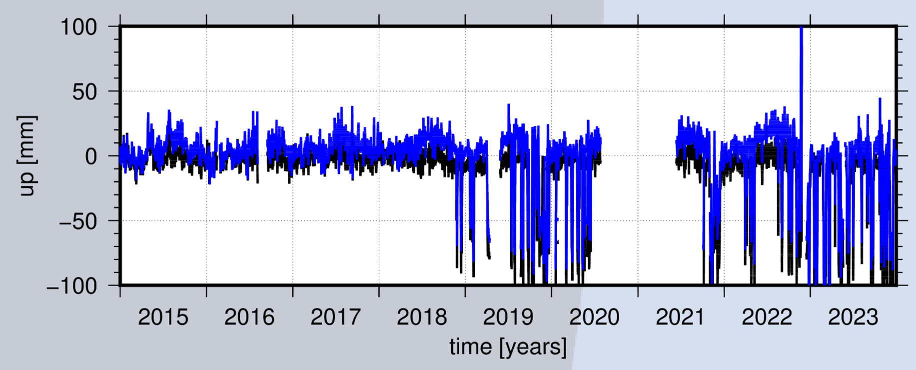


Fig. 7: Vertical coordinate for ELBA: GFZ solution (blue), PPP solution from NLG (black).

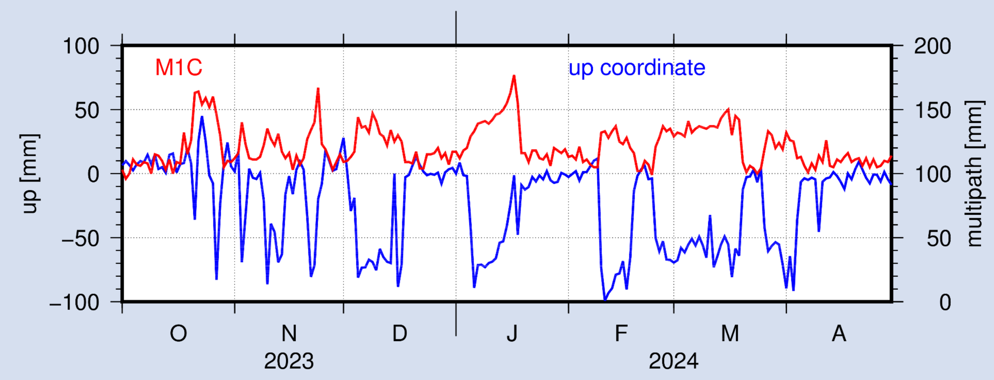


Fig. 8: Vertical coordinate for ELBA (blue), code multipath for GPS L1 frequency (red).

The coordinate results for ELBA show large corrections in the vertical direction (Fig. 7). Since 2018, coordinate corrections of up to 10 cm have been found for many but not all daily solutions. Similar corrections are visible in the NGL solutions (Blewitt et al., 2018). A detailed look into data quality indicators derived with G-Nut/Anubis reveals a correlation with larger multipath values (Fig. 8).

References

- FES2014b: Lyard et al. (2021), https://doi.org/10.5194/os-17-615-2021
- GFZ repro3 products: Männel et al. (2021), https://doi.org/10.5880/GFZ.1.1.2021.001
- G-Nut/Anubis: gnutsoftware.com/software
- GOCO6s gravity field: Kvas et al. (2019), https://doi.org/10.5194/essd-13-99-2021
- High-frequent EOP: Desai and Sibois (2016), https://doi.org/10.1002/2016JB013125
- NGL solutions: Blewitt et al. (2018), https://doi.org/10.1029/2018EO104623
- Semisys: Bradke (2021), https://doi.org/10.5880/GFZ.1.1.2020.005,
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