

Status of the EPN Analysis Centres and Combined Solutions

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The EPN Analysis Centres Coordinator (ACC) combines and analyses GNSS coordinate solutions computed by the EPN Analysis Centres (AC).

This presentation examines solutions provided by the 12 EPN ACs for the EPN Repro3 project and the combined solutions derived from them.

- Status of the EPN AC solutions in EPN Repro3 project
- Methodology for analysis and combination of AC solutions
- Results from analysis of individual AC Repro3 solutions
- Results from combination of AC Repro3 solutions
- Summary and outlook

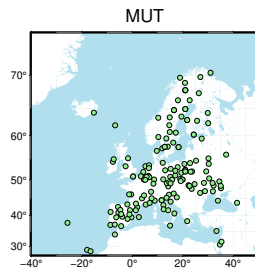
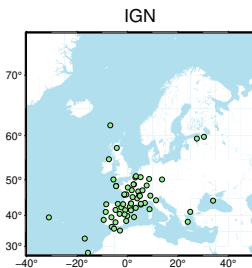
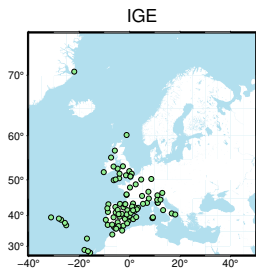
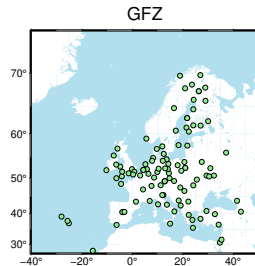
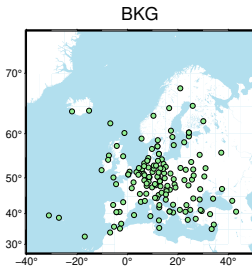
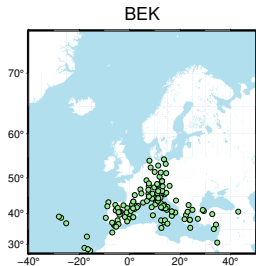
EPN Analysis Centres participating in EPN Repro3 project

AC	Agency
BEK	Bavarian Academy of Sciences and Humanities, Germany
BKG	Bundesamt für Kartographie und Geodäsie, Germany
GFZ	GeoForschungsZentrum, Potsdam, Germany
IGE	Instituto Geográfico Nacional, Spain
IGN	L'Institut national de l'information géographique et forestière, France
MUT	Military University of Technology, Poland
NKG	Nordic Geodetic Commision, Lantmäteriet, Sweden
ROB	Royal Observatory of Belgium, Belgium
SGO	Lechner Knowledge Center, Hungary
SUT	Slovak University of Technology, Slovakia
UPA	University of Padova, Italy
WUT	Warsaw University of Technology, Poland

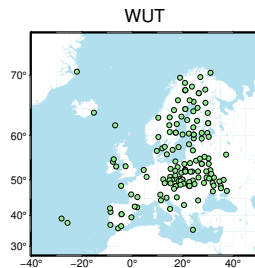
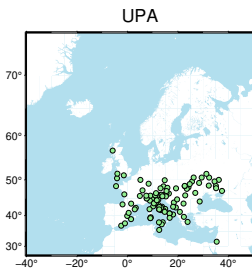
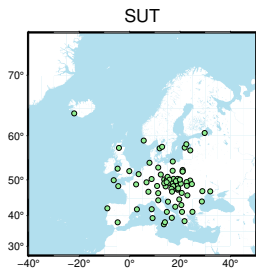
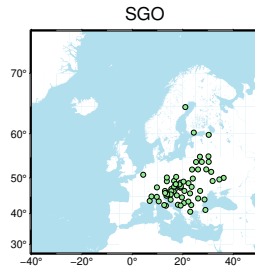
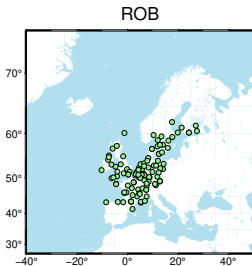
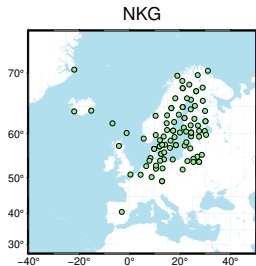
EPN Repro3 – available AC solutions (as of 9.06.2025)

AC	Software	No. of sites	Provided solutions	No. of. daily SNX files
BEK	Bernese 5.4	156	1996-2022	9827
BKG	Bernese 5.4	189	1996-2022	9827
GFZ	EPOS.P8	134	1996-2022	9827
IGE	Bernese 5.4	118	1996-2022	9827
IGN	Bernese 5.4	76	1996-2022	9827
MUT	GAMIT 10.71	180	1996-2022	9827
NKG	Bernese 5.4	125	1996-2022	9827
ROB	Bernese 5.4	142	1996-2022	9827
SGO	Bernese 5.4	76	1996-2022	9804
SUT	Bernese 5.4	109	1996-2022	9827
UPA	Bernese 5.4	126	1996-2022	8857
WUT	Bernese 5.4	191	1996-2022	9827

AC subnetworks of EPN stations (1/2)



AC subnetworks of EPN stations (2/2)



The basic steps of combination procedure:

- 1 Check AC SINEX files (station metadata, included/missing stations, file format)
- 2 Stack individual daily AC solutions into long-term solutions (CATREF software)
 - check the quality of AC solutions, detect potential issues
- 3 Combine cleaned AC daily solutions (Bernese GNSS Software)
- 4 Stack combined daily solutions into long-term solutions (CATREF software)
 - examine the quality of combined solutions

Checking of metadata in AC daily SINEX files (step 1)

The following information was checked in each AC SINEX file:

- station metadata: (1) receiver and antenna types, (2) antenna phase center offsets (PCOs), (3) antenna eccentricities, and (4) antenna azimuths
- included/missing stations
- SINEX format (limited)

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Detected inconsistencies in AC solutions:

BKG: antenna azimuths (187 cases, 3 stations)

GFZ: antenna type (8 cases), receiver type (19 cases), antenna eccentricity (3 cases), PCOs (7 cases)

IGE: antenna azimuths (2 cases), PCOs (5 cases)

MUT: antenna azimuths (20 cases), PCOs (9973 cases)

UPA: problem with SINEX format (5 daily solutions)

Checking of included stations in AC daily SINEX files (step 1)

- Most of the ACs processed all available data for stations in their subnetworks (i.e., not taking into account official EPN inclusion dates)
 - BKG processed data for official periods of station inclusions in EPN
- Several former stations processed by only one or two ACs
- Several stations missing in UPA solutions
- Stations that were officially included into EPN after GPS week 2237 (27 Nov. 2022) were usually not processed by the ACs
 - several such stations included in SUT, UPA, WUT solutions

Stacking of daily AC solutions into long-term solutions (step 2)

The next step (2) involved combining daily solutions from individual ACs into long-term solutions. This step enabled the evaluation of the quality of daily AC solutions and the detection of potential issues.

The AC daily solutions were stacked into long-term solutions using CATREF software:

- the resulting residual position time series were checked for outliers
 - stations for which position outliers were detected were excluded iteratively from daily AC solutions
 - the thresholds for position outliers were: 15 mm for horizontal residuals; 30 mm for vertical residuals; 10 for normalized residuals
 - lists with detected position outliers were provided to the ACs
- discontinuity list was based on
https://www.epncb.eu/pub/station/coord/EPN/EPN_discontinuities.snx

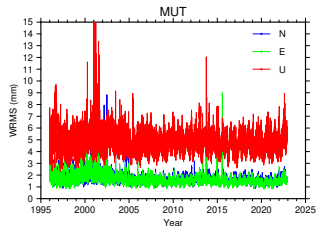
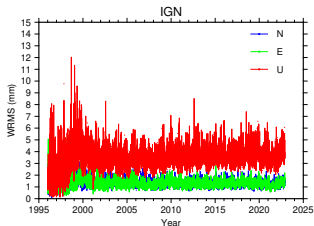
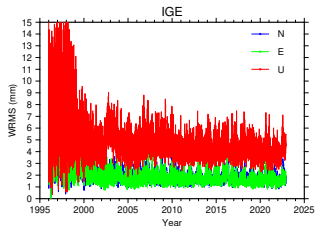
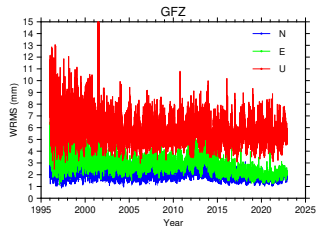
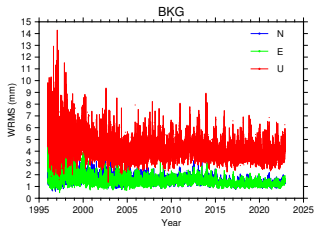
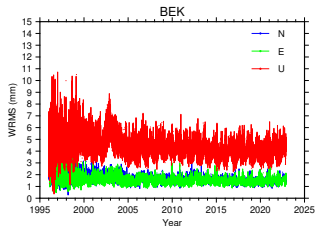
Stacking of AC daily solutions into AC long-term solutions

AC	Used solutions ¹	No. of used daily solutions	No. of sites	Mean WRMS			Remarks
				N (mm)	E (mm)	U (mm)	
BEK	0834-2237	9827	156	1.59	1.50	4.33	
BKG	0834-2237	9827	189	1.55	1.46	4.23	
GFZ	0834-2237	9827	134	2.05	2.83	5.79	
IGE	0834-2237	9827	118	2.05	1.94	4.72	
IGN	0834-2237	9827	76	1.30	1.25	3.51	
MUT	0834-2237	9826	180	1.64	1.59	4.80	1 solution excluded
NKG	0834-2237	9827	125	1.40	1.39	4.03	
ROB	0834-2237	9827	142	1.17	1.08	3.11	
SGO	0834-2237	9803	76	1.52	1.46	3.60	1 solution excluded, 23 missing
SUT	0834-2237	9827	109	1.41	1.29	3.89	
UPA	1200-2237	6509	126	1.93	1.78	5.52	225 sols. excluded, 532 missing
WUT	0834-2237	9827	191	1.77	1.58	4.85	

¹ GPS weeks

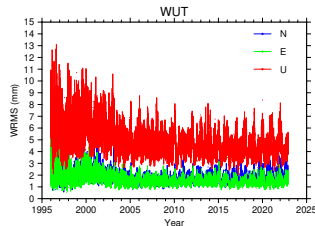
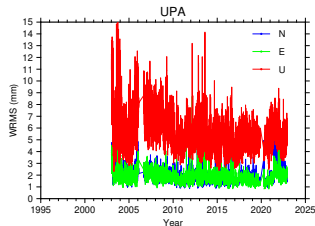
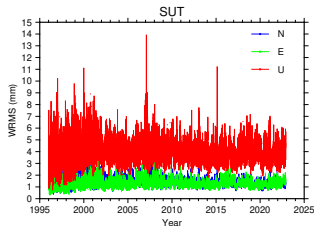
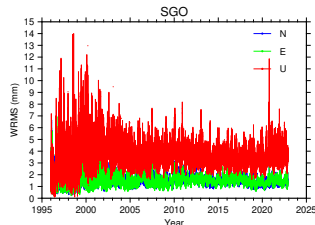
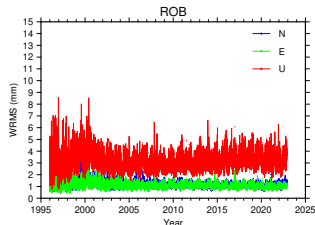
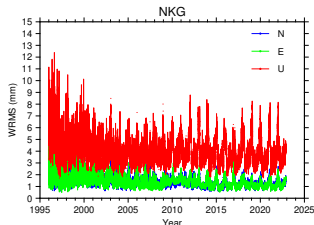
WRMS of AC solutions

- WRMS of station position residuals between AC daily solutions and AC long-term solution

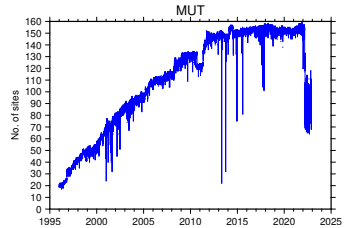
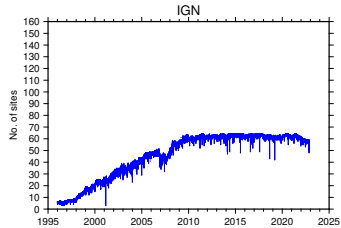
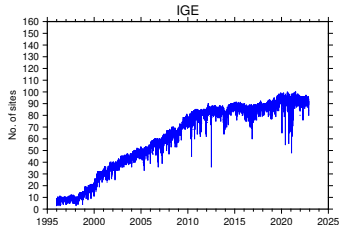
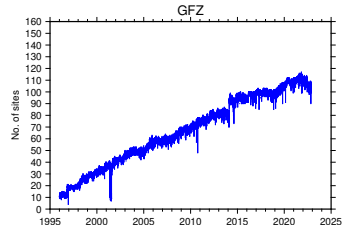
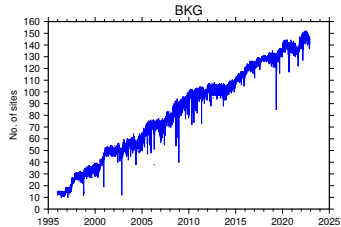
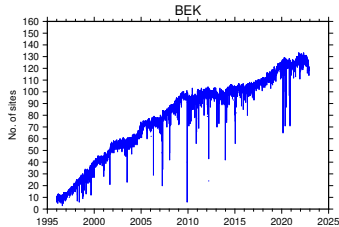


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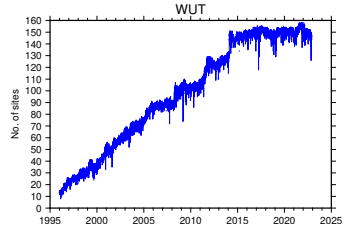
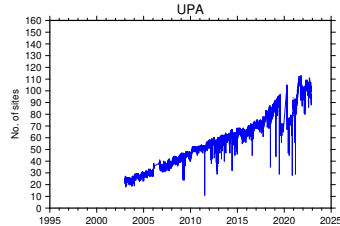
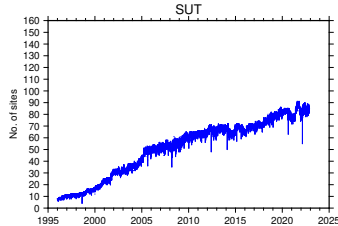
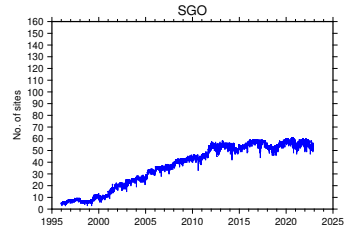
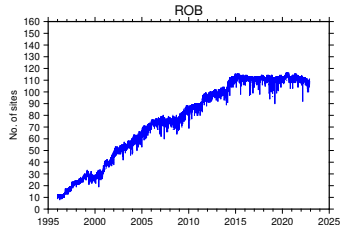
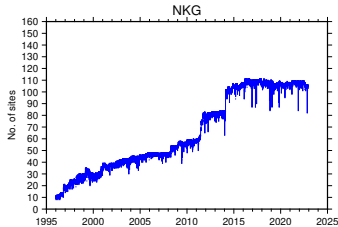
- WRMS of station position residuals between AC daily solutions and AC long-term solution



Number of stations in AC solutions



Number of stations in AC solutions



Combination of AC solutions (step 3)

Step 3 involved the creation of daily combined solutions on the basis of AC solutions that were cleaned in step 2.

The daily combined solutions were created using Bernese GNSS Software:

- the combined solutions were aligned to IGS20
- each AC solution was compared with the combined solution to evaluate its quality
 - stations were eliminated from a particular AC solution if their coordinate differences wrt. the combined solution exceeded assumed thresholds (6 mm in the horizontal and 12 mm in the vertical component)

The present (preliminary) combined solutions were derived from:

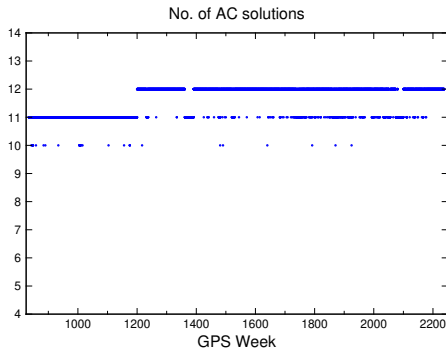
- 11 AC solutions for GPS weeks 0834-1199 (1996.0-2003.0)
 - UPA solutions not used yet
- 12 AC solutions for GPS weeks 1200-2237 (2003.0-2022.9)

Exclusion of EPN AC daily solutions

- Some AC daily solutions were excluded from combination due to (1) small number of stations, (2) problems with inversion of normal equations, or (3) being identified as problematic during long-term stacking (step 2)
- The following AC solutions were excluded (week/day of week):
 - IGE: 0929/1
 - IGN: 0846/1, 0846/4, 0847/2, 0847/6, 0890/0, 0933/5, 0846/2, 0847/1, 0848/2, 1103/3, 1217/0, 1924/6, 1927/4, 1929/0, 2036/2, 2049/1
 - GFZ: 0842/4, 0883/6
 - MUT: 1156/0, 1217/0, 1791/6, 1843/6, 1850/6, 1867/1, 1870/4
 - SGO: 2175/3
 - UPA: 220 solutions (219 excluded in step 2)

AC solutions in combined solutions

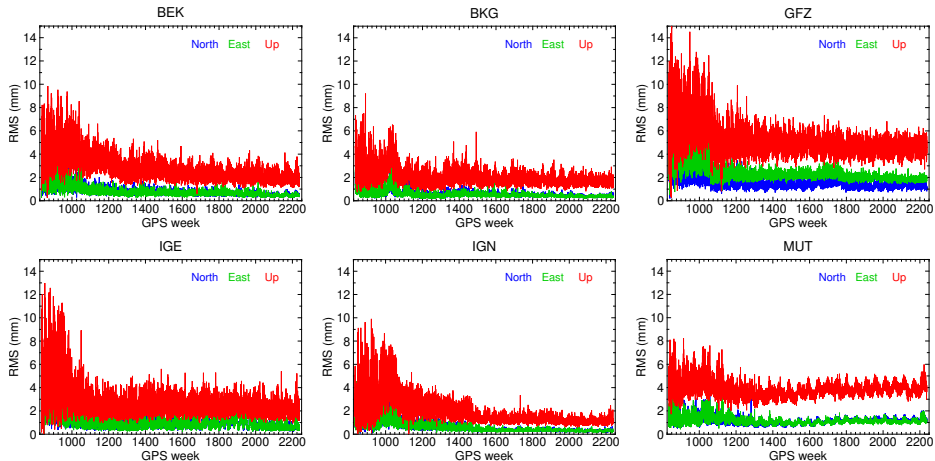
- Number of AC solutions included in daily combined solutions



- ~10% of combined solutions for period 1200-2238 based on 10 or 11 AC solutions

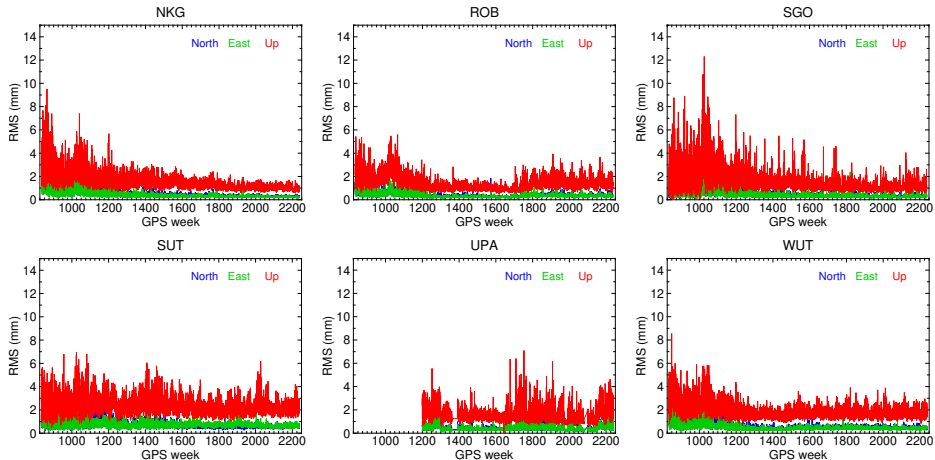
RMS of AC residuals

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WRMS of AC solutions

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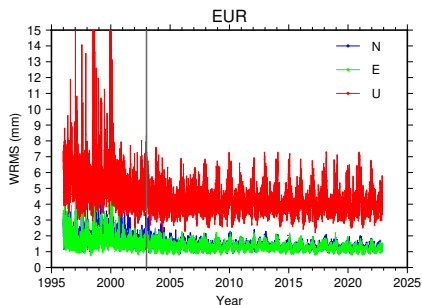
Checking the daily combined solutions (step 4)

In the last step the position time series of daily combined solutions were checked:

- daily combined solutions were stacked into a long-term solution using CATREF software
- the resulting residual position time series were examined
 - detected position outliers will be excluded from final daily combined solutions

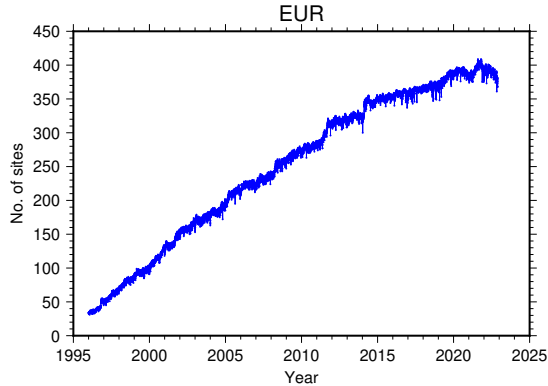
WRMS of combined solutions

- WRMS of station position residuals between combined daily solutions and the long-term solution



- Solutions after GPS week 1200 (grey line) already checked for position outliers and cleaned

Number of stations in daily combined solutions



Summary and outlook (1/2)

- Status of AC repro3 solutions
 - 11 ACs (of 12) provided solutions for the entire period 1996-2022
 - 1 AC (UPA) provided ~90% of daily solutions
- The quality of AC solutions was examined individually for each AC
 - the station position time series were analyzed and outliers were excluded
- The preliminary combination of AC daily solutions done
 - for period 2003-2022 90% of combined solutions based on all 12 AC solutions
 - no significant issues detected in the combined solutions for that period

Summary and outlook (2/2)

- Noticed issues with AC solutions
 - significant problems with UPA daily solutions during creation of long-term solution
 - 219 solutions excluded for period 2003-2022 (similar problems occur for period 1994-2002 as well)
 - A few minor issues concern solutions from IGN, MUT, GFZ, IGE, SGO, UPA ACs which had to be excluded from daily combinations (due to small number of stations, increased number of position outliers, or problems with matrix inversion)
 - Several solutions (especially IGE and GFZ) with significantly larger noise during early years

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- We recommended refining AC solutions, especially those which cause problems during combinations, so that they can be used for combinations and enhance their quality and redundancy

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- We recommended refining AC solutions, especially those which cause problems during combinations, so that they can be used for combinations and enhance their quality and redundancy
- We thank all ACs participating to the Repro3 project for their great effort!