WP10-DDSS-016: Products.EUREF.Combined.Positions

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The EUREF combined coordinate solutions are created on the basis of daily GNSS solutions generated by the 16 EPN Analysis Centres (AC)(Table 1). Each EPN AC regularly processes GNSS data from an assigned subnetwork of EPN stations and generates daily coordinate solutions in SINEX format. Each EPN station is processed by at least three ACs. Every week, the AC daily solutions are combined by the EPN Analysis Centres Coordinator in order to obtain daily and weekly combined positions for all (~320) EPN stations. The daily combined solutions are the input for the cumulative (multi-year) EUREF solution. This document describes the combination methodology used for the creation of the EPN daily and weekly combined positions.

Metadata checking

Before combining the AC daily solutions from a particular week, the metadata included in AC SINEX files are checked for a consistency with respect to information provided in station log files and in the EPN antenna calibration file (i.e., the IGS antenna calibration model augmented with individual calibrations for about 40% of EPN stations). The correctness of the following metadata is checked: receiver types, antenna types, antenna radomes, eccentricities of the antenna reference point (ARP) with respect to a station mark, and the mean antenna phase center offsets (PCO) with respect to the ARP. In addition, it is also checked if all stations for which RINEX files are available at the EPN data centers are included in AC SINEX files. In the case of detected inconsistencies an appropriate report is sent to ACs, so that ACs may correct and resubmit their solutions. To ensure the highest agreement between station positions computed by different ACs, stations for which the inconsistencies have not been corrected are excluded from the affected AC solutions. All results concerning metadata checks are reported in daily and weekly summary reports which are available at the EPN data center at BKG: ftp://bkg.bund.de/EUREF/products/WWWW/eurWWWWD.sum.Z, where WWWW is a GPS week, and D characterizes the type of the report: daily (D=0...6) or weekly (D=7). In addition, from daily AC solutions are excluded also stations for which an antenna or receiver was changed during the considered week, non-EPN stations, or EPN stations not belonging to a subnetwork of a particular AC.

Combination strategy and validation procedures

The present combination strategy is based on daily AC solutions and is used in EPN since GPS week 1925 (November 2016). Previously, the combination strategy was based on weekly AC solutions. The new approach helped to mitigate station position inconsistencies between AC solutions, which could be observed when combining AC solutions on a weekly level. The RMS values of AC daily position residuals with respect to the combined solutions have increased in relation to weekly solutions (as could be expected). Nevertheless, the increase was small and on average was about 1.3 times larger for all components.

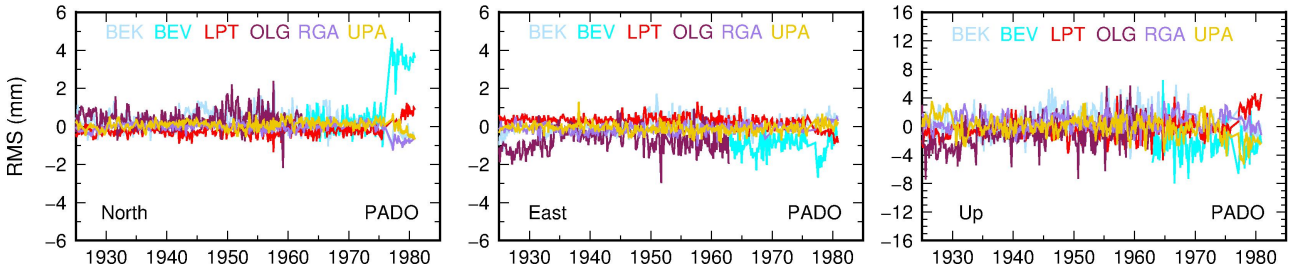
Table 1. EPN Analysis Centres characteristics

AC	Analysis Centre Description	# EPN sites
ASI	Centro di Geodesia Spaziale G. Colombo, Italy	53
BEK	Bavarian Academy of Sciences & Humanities, Germany	97
BEV	Federal Office of Metrology and Surveying, Austria	101
BKG	Bundesamt für Kartographie und Geodäsie, Germany	117
COE	Center for Orbit Determination in Europe, Switzerland	43
IGE	Instituto Geografico Nacional, Spain	86
IGN	Institut Geographique National, France	64
LPT	Federal Office of Topography swisstopo, Switzerland	60
MUT	Military University of Technology, Poland	144
NKG	Nordic Geodetic Commission, Lantmateriet, Sweden	88
OLG[1]	Austrian Academy of Science, Austria	101
RGA	Republic Geodetic Authority, Serbia	56
ROB	Royal Observatory of Belgium, Belgium	98
SGO	BFKH Satellite Geodetic Observatory, Hungary	42
SUT	Slovak University of Technology, Slovakia	59
UPA	University of Padova, Italy	57
WUT	Warsaw University of Technology, Poland	119

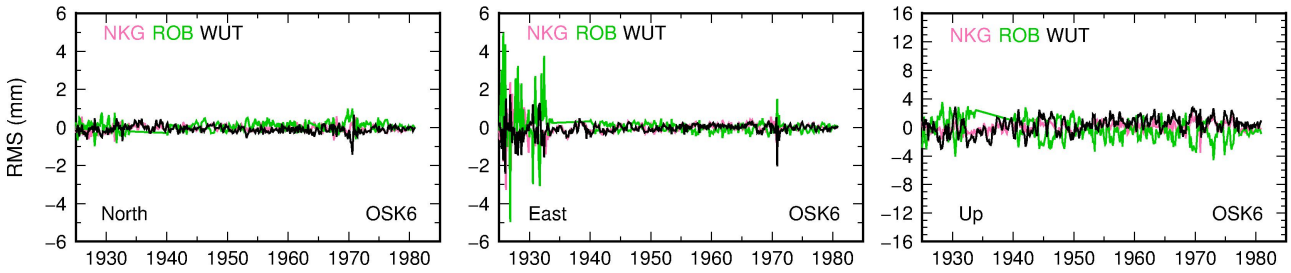
The present combination strategy consists of several steps. AC solutions are combined on a normal equation level using the Bernese GNSS Software 5.2 (Dach et al., 2015). Each AC solution is compared with the combined solution by means of a 7-parameter transformation using all stations included in AC solutions. If the coordinate residuals between AC solutions and the combined solution exceed the threshold of 8 mm in horizontal components, or 16 mm in the vertical component for some stations, then these stations are eliminated from the AC solutions and the combination process is repeated. In Figure 1 the examples of residual position time series between individual AC solutions and the combined solutions are presented. These time series may reflect the antenna change (Figure 1a), the reference frame change (Figure 1b), biases and more noisy solutions (Figure 1c-d). For each AC solution the RMS of all position residuals is also computed. These RMSs are used as indicators of the overall quality of the daily AC solutions and their values are regularly monitored. In Figure 2 the daily AC and mean RMSs are presented for a period between November, 2016 and January, 2018. The RMSs for individual ACs vary between 0.2 and 2 mm for the horizontal components, and between 1 and 6 mm for the vertical component. However, for a majority of ACs the RMS values are closer to the lower limits.

Each daily combined solution is stacked together with previous 10 weekly solutions, and compared with the resulting solution. Stations for which coordinate residuals between a daily combined solution and the stacked solution are larger than 15 mm in horizontal components, or 25 mm in the vertical component are eliminated from the daily combined solution (before exclusion, the outliers are verified visually by inspecting longer residual position time series plots). In the last step, clean daily combined solutions are stacked into a weekly solution.

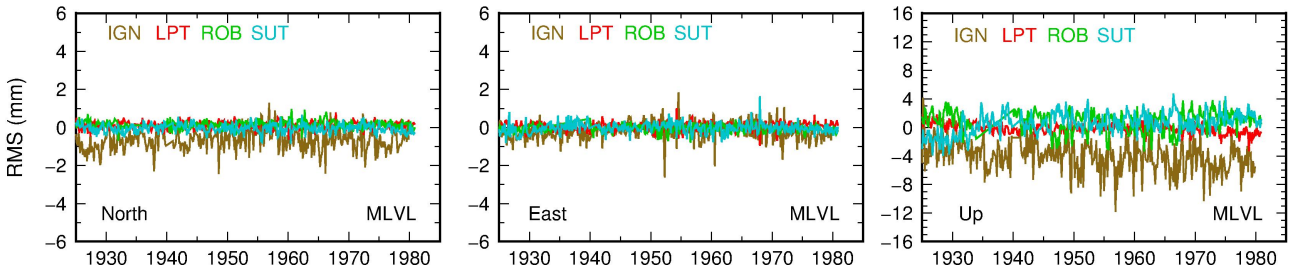
1 Former EPN analysis center. Since week 1963, the activities of OLG AC were took over by BEV AC.



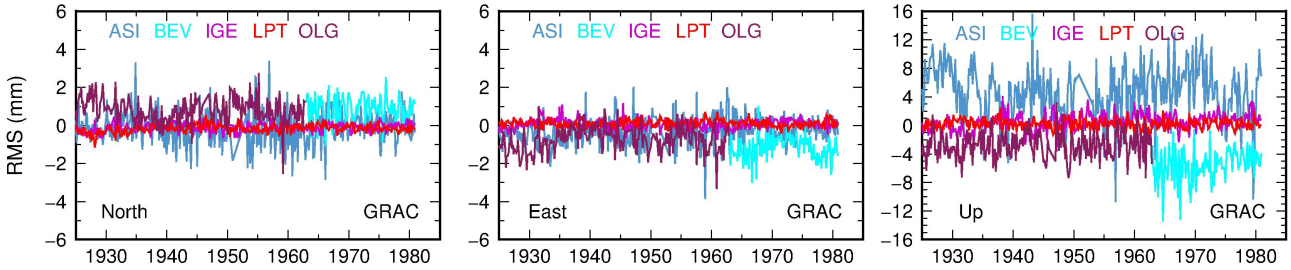
(a) station PADO00ITA (antenna change during week 1976)



(b) station OSK600SWE (IGb08 to IGS14 change on week 1934)



(c) station MLVL00FRA



(c) station GRAC00FRA

Figure 1. Time series of daily station position residuals between individual AC solutions and the combined solutions

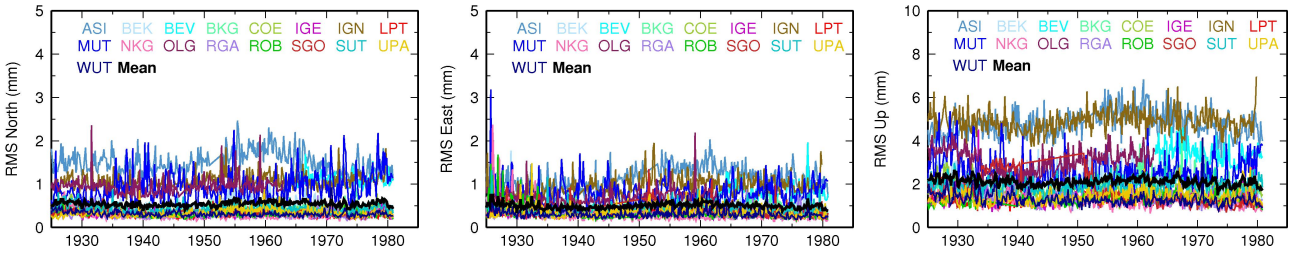


Figure 2. RMSs of AC daily position residuals wrt. the daily combined solutions for north, east and vertical components. Thick black lines denote mean RMS values

The resulting daily and weekly combined solutions are aligned to the latest realization of the IGS terrestrial reference frame (presently IGS14) using no-net-translation minimum constraint conditions. The differences between reference coordinates and the daily (weekly) combined coordinates are also inspected. Stations for which these differences exceed the threshold of 8 mm in horizontal components, or 15 mm in the vertical component are not used for the reference frame alignment. The number of stations rejected from, and used for the reference frame alignment in daily combined solutions between November, 2016 (week 1925) and December, 2017 (week 1980) is presented in Figure 2. The increased number of usable reference stations may be observed since week 1934, when the EPN combined solutions started to be aligned to the IGS14 reference frame (up to week 1934 the IGb08 reference frame was used).

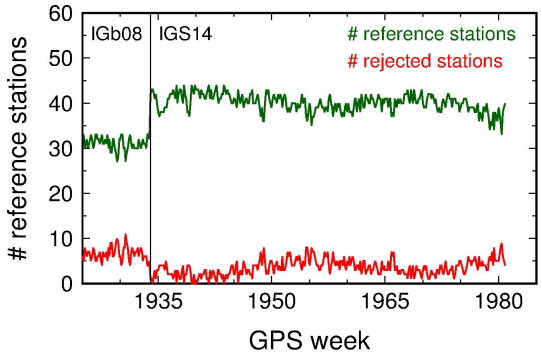


Figure 3. Number of reference stations used for, and rejected from the alignment of the EPN daily combined solutions into the IGb08 and IGS14 reference frames

Comparison with other software

In addition to routinely created combined solutions using Bernese GNSS Software, daily combined solutions are also created using CATREF software (Altamimi et al., 2012). In contrast to Bernese, in CATREF software the station positions estimated by ACs are combined, which are weighted by using the inverses of covariance matrices of AC solutions. The comparisons are useful to verify combined station positions, detected outliers, RMSs of AC solutions. The comparison of solutions generated with both software shows high agreement. The mean RMSs of daily position residuals obtained for a period of 70 weeks, were 0.2, 0.2 and 0.9 mm for the north, east and vertical component respectively.

Recent changes in GNSS data processing strategy

At the last AC workshop (held in Brussels in October, 2017) it was decided to harmonize the troposphere modelling among the ACs in order to improve the position consistency between AC solutions. Since GPS week 1980 it is mandatory that all EPN ACs use Vienna Mapping Function (VMF) for the troposphere modelling (up to week 1980 about half of ACs used Global Mapping Function). It was shown that coordinate differences between both approaches (VMF and GMF) may reach 10 mm in the height component, especially if low elevation data are used.
At present only one week (1980) of AC solutions, which were all computed with VMF was combined.

References

Altamimi, Z., P. Sillard, C. Boucher (2012), CATREF software: Combination and Analysis of Terrestrial Reference Frames. LAREG Technical, Institut Géographique National, Paris, France.

Dach, R., S. Lutz, P. Fridez, P. Walser (2015), *Bernese GNSS Software, Version 5.2*, Astronomical Institute, University of Bern.