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EPN Analysis Coordinator Report

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Abstract

This report includes the activities related to EPN analysis since the past EUREF symposium in 2008. The 6th EPN Local Analysis Centres (LACs) Workshop was hold on October 2008 in Frankfurt Main, Germany and representatives of the LACs attended this workshop beside other interested parties. Recommendations for EPN re-processing, usage of GNSS derived ZTD parameters, improved feedback to LACs and for other items have been arranged there. EPN analysis products that are available with a delay of shorter than one day since the end of observations hold the potential to serve as warning for the case of a station equipment failure or a local event that affects the station marker, e.g., tectonic movements. The EUREF TWG proposed to investigate the ability of the so-called “rapid daily combination” solution for establishing an alert system. First experiences deal with the identification of relevant signals. The IGS combines and compares several regional networks, e.g., EPN or SIRGAS. The resulting “MIT T2 RNAAC” solution file allows proofing the fit of the EPN into a global network. EPN analysis perspective includes establishing a multi-year solution that is continuously updated. The Analysis Coordinator uses the new FODITS tool of the Bernese GPS Software for developing this new product.

1 Introduction

The main task of the EPN AC is to manage all items related to the analysis of the EPN GNSS data and to combine EPN sub-network solutions as calculated by currently 16 LACs. The combined solutions become official EPN products. This paper will not report on the complete series of products, but will highlight a few recently happened events and actions that are related to EPN analysis.

2 EPN LAC Workshop 2008

The 6th EPN LAC Workshop was held on October 22-23, 2008 in Frankfurt am Main, Germany, hosted by the Federal Agency for Cartography and Geodesy (BKG). 33 registered workshop participants from 15 European countries visited the workshop and followed the 24 oral presentations. The workshop was organized in 6 working sessions, each with presentations and time for discussion, which was used intensively.

A new EPN re-processing initiative has been launched during the workshop and Christof Völksen was elected responsible person to further push all related activities, e.g., establishing a working group and drafting a charter for EPN-reprocessing. The workshop plenum agreed to improve the feedback to LACs, e.g., through visualization of LAC-specific issues at the EPN-CB, and to better show the LAC’s efforts in public, e.g., at the EPN-CB websites and official papers. The collaboration between EPN, EUMETNET and EGVAP will be increased by comparing GNSS derived ZTD parameters with radiosonde data. The workshop presentations and minutes are available at the EPN-CB website [Habrich 2008].

3 IGS Global Combination of Regional Networks

The Massachusetts Institute of Technology, Cambridge, USA is an IGS Analysis and Associate Analysis Centre and calculates a combination of regional permanent networks on weekly basis that is named "MIT T2 RNAAC" solution. It also generates the global "MIT T2" solution that is a combination of actually 8 IGS ACs [Herring 2008]. Three regional solutions (EPN, SIRGAS and GSI) and 1 global solution (GRG CNES, Toulouse) will be added to the MIT T2 solution to build the regional MIT T2 RNAAC combination. All solution files are available at the CDDIS IGS data centre. The delay of the publication of the mentioned two products is 8 weeks after the end of observations and it requires publishing the weekly EPN combination explicitly earlier that 8 weeks delayed.

The Map in Figure 1shows the stations of the global MIT T2 solution as black dots and the additional stations from the MIT T2 RNAAC in red dots. GRG is the global solution from CNES, which is nearly invisible in this map, because the sites belong mostly to the MIT T2 solution and are consequently printed in black. The EPN, SIRGAS and GSI solutions densify the regions in Europe, South America and Japan. The coordinate comparison between the EPN and the MIT T2 solutions for week 1520 results into a mean RMS of 3.5 mm. This number may be interpreted as a measure of the global alignment of the EPN network. The computation of such RMS numbers for 9 additional weeks (week 1511 to 1519) confirm the global alignment in the range from 2 to 4 mm. The further usage of the MIT T2 RNAAC solution for EUREF is going to be evaluated.

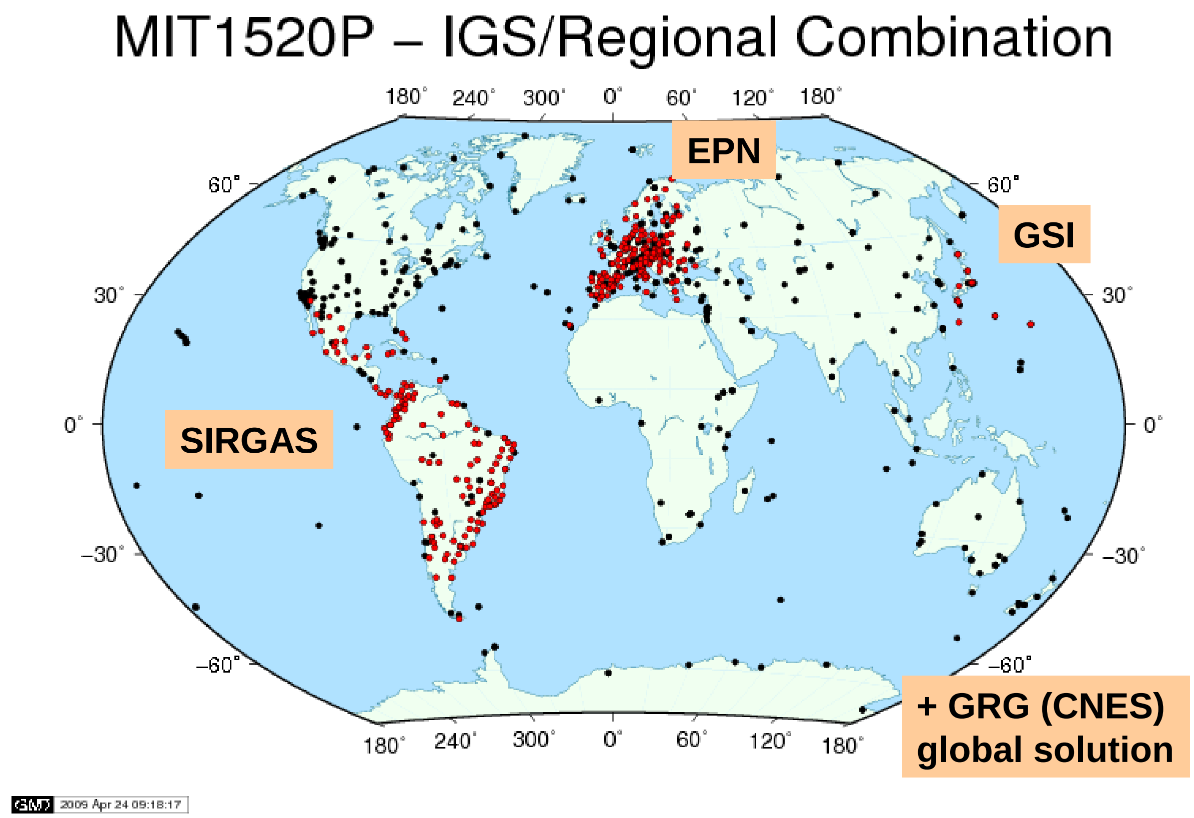


Figure 1: MIT T2 RNAAC Solution for Week 1520

4 Rapid Daily Combination

EPN analysis products that are available with a delay of shorter than one day since the end of observations hold the potential to serve a warning message in the case of a station equipment failure or a local event that affects the station marker, e.g., tectonic movements. The EUREF TWG proposed to investigate the ability of the so-called “rapid daily combination” solution for establishing an alert system. First experiences deal with the identification of relevant signals and will be explained in the following.

The LACs apply IGS rapid satellite orbits and EOPs in the rapid daily processing. There remains a processing window of 6 hours for the LACs between the availability of IGS rapid products at 5 p.m. and the combination of LAC contributions at 11 p.m.. Recently 9 LACs announced to contribute to the rapid daily product, but mostly between 4 and 6 LACs submit a solution as shown in Figure 2.

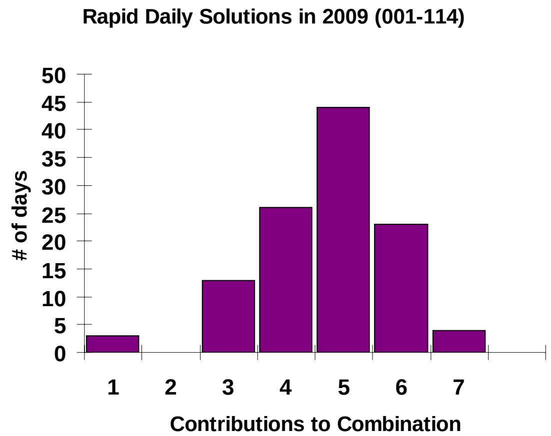


Figure 2: LAC Rapid Daily Submissions

The LAC submissions provide a rapid daily solution for currently 164 stations (see Figure 4) and approximately half of them will be processed redundantly, i.e., by more than 1 LAC (see Figure 3). Red dots in Figure 4 indicate EPN stations that are analysed in the “weekly” LAC processing.

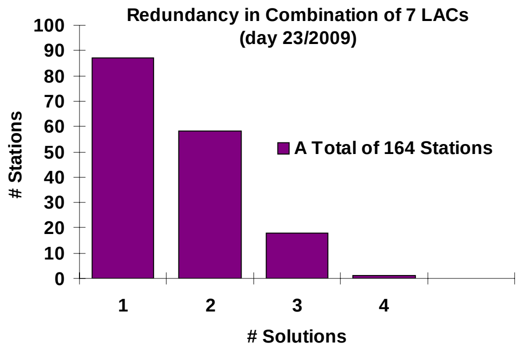


Figure 3: Redundancy in Rapid Daily Solution

The identification of a relevant quantity is an important step to use the rapid daily solutions for event detection. This section shows first experiences of a simple approach that compares the rapid daily solution with the most recent final weekly solution for purpose of event detection. The weekly solutions are delayed by 5 weeks. An outlier rejection criterion of 2 cm for horizontal and 3 cm for height components has been applied. This comparison has been carried out for the days 1 to 58 of year 2009 and the number of accepted/rejected stations is given in Figure 5.

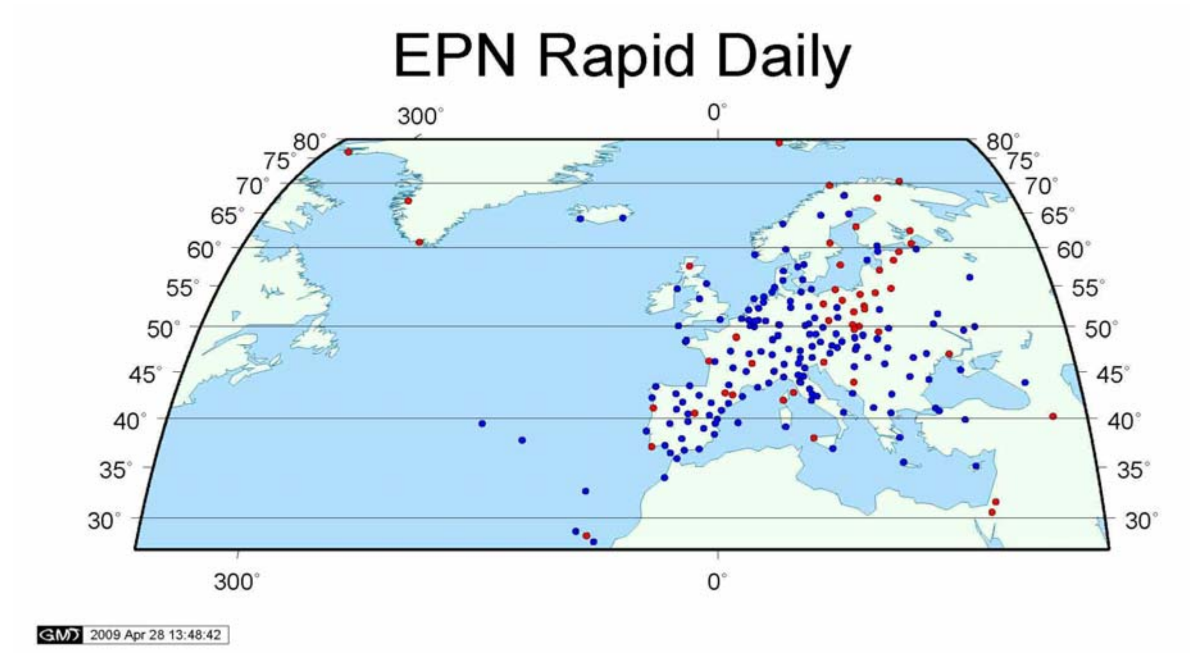


Figure 4: EPN Stations with Rapid Daily Solutions (in blue)

It occurred in 25 days that a single station has been rejected as we could read in more details from Figure 6.

A rejection of 8, 9 and more sites happened for some days of week 1515 as visible in Figure 5. For one day of that week there is a low number of only 40 accepted stations, which leads to the assumption that the comparison for that day is not reliable and shouldn't be used. The ratio between accepted and rejected stations has been computed to consider the idea of ignoring particular poorly tested days in more general. The corresponding ratios are given in Figure 7.

This figure confirms a significant bad performance of the station comparison for 3 days in week 1515 and 1 day in week 1517. We filtered the daily comparisons for days fulfilling "accepted/rejected ratio < 0.05" and the remaining stations are given in Figure 8. There are now no days with 8 or more rejected sites. For further investigations we use only the filtered days, where 42 of the 58 days remain in the series.

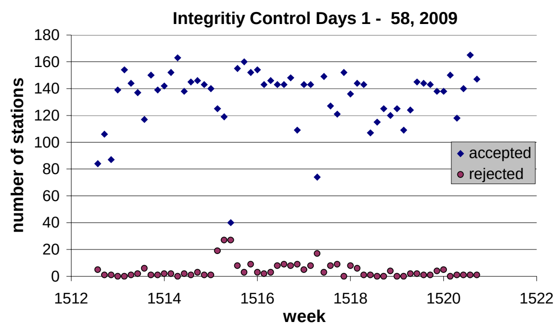


Figure 5: Comparison of Rapid Daily and Weekly solution - Accepted/Rejected Stations

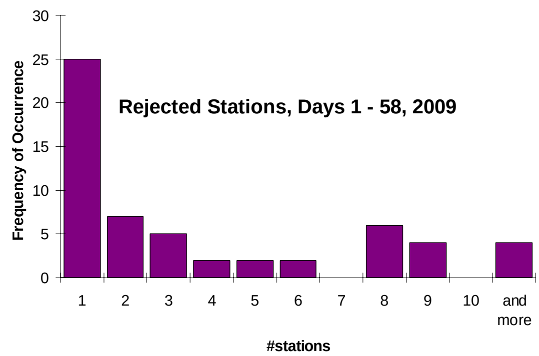


Figure 6: Comparison of Rapid Daily and Weekly solution - Frequency of Rejections

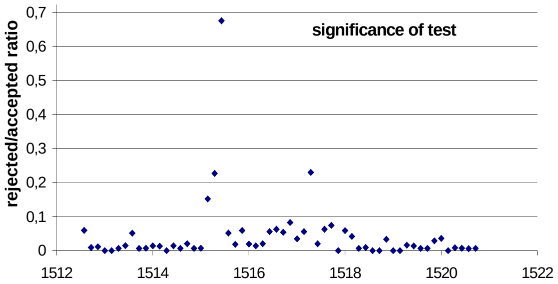


Figure 7: Accepted/rejected Stations Ratio

The next step inspects each rejected stations individually. Figure 9 shows the 21 affected stations and the corresponding number of rejections, and Figure 10 the rejections per day and station. The station MDVJ has been rejected for 3 successive days in week 1516. Figure 11 shows the weekly solutions for MDVJ to validate any event during that period. The weekly solutions confirm a significant change in the height component for week 1516. Note, the rapid daily comparison scheme applied the weekly solution of week 1511 (5 weeks delayed) as reference for outlier detection. A sub-group of the 16 EPN LACs submit final daily solutions at the same time as the weekly solutions. Such daily solutions are based on final IGS products and are available with a delay of 5 weeks. Also the so-called "final daily solutions" are shown in Figure 11 for the periods of weeks 1514 to 1517 and confirm the outstanding behaviour of MDVJ for week 1516. There is no information about any event for MDVJ during the week 1516 from the EPN-CB.

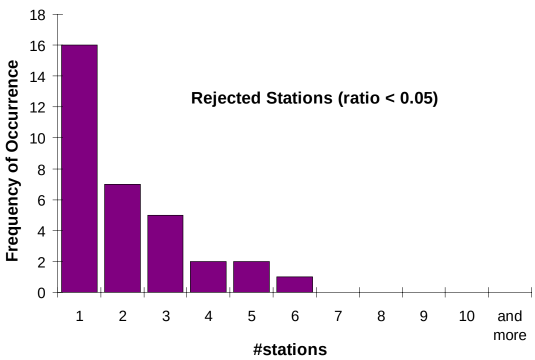


Figure 8: Filtered Rejected Stations

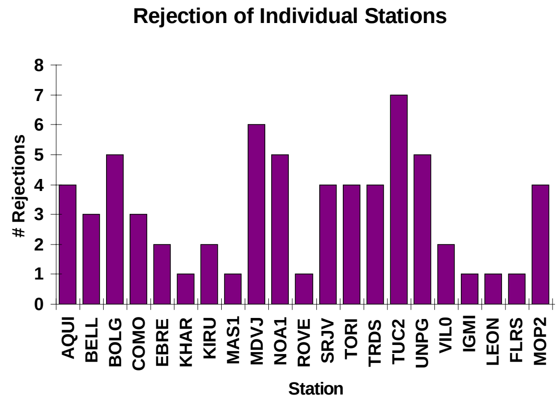


Figure 9: Individual Stations Rejected

We conclude from the example of the station MDVJ that the rapid daily solution may provide a meaningful warning. The confirmation of other rejected stations and the usage of the warnings for practise is going to be investigated.

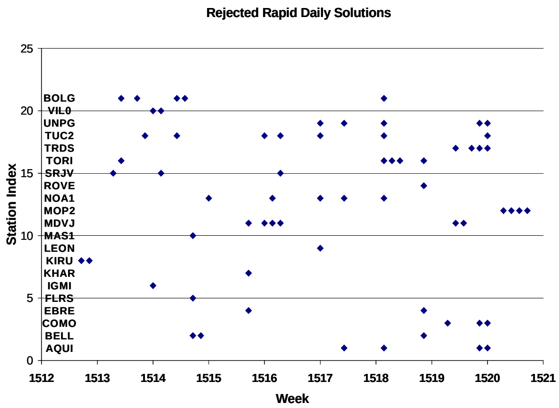


Figure 10: Rejections per Day and Station

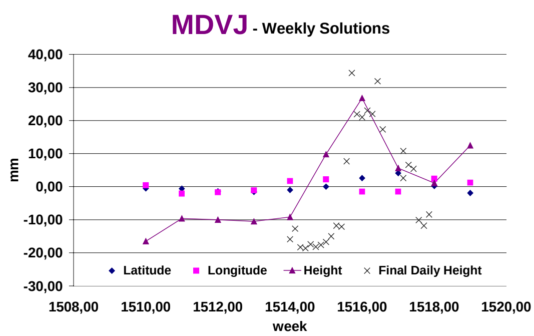


Figure 11: Weekly Solution for MDVJ

5 Multi-Year Combination

The long term goal of the multi-year combination as generated by the EPN AC is to continuously combine the weekly and possibly daily EPN solutions. This combination will be compared to the solutions of the EPN Time Series Project and ITRF. LAC-specific time series are going to be investigated for purpose of LAC validation. This action will be implemented by applying the ADDNEQ2 and FODITS tools of the Bernese GNSS software. New tools for comparison of results, e.g., from other than Bernese software, will be developed. A test of the methodology for the weeks 1400 - 1525 will be presented in the following.

Outlier and discontinuity detection for the mentioned data interval has been carried out by usage of the FODITS tool [Ostini 2008]. The programme options of FODITS have been set to model the time series with the estimation of velocity parameters (linear part) and the set up of periodic parameters (non-linear part). The minimum interval length for velocity parameters has been set to 1 year. For shorter data periods no velocity has been estimated. For this first investigation of the applied method only an annual period has been introduced. Obviously even this period has no meaning for the short interval of 2.4 years that is analysed here. A detection level for discontinuities of 10 mm for horizontal and vertical components and for outliers of 10 mm/20 mm for horizontal/vertical components was used.

Statistics for outlier and discontinuity detection are summarized in Table 1. Note that the solutions from DEO has been withdrawn from Table 1, because discrepancies between a-priori and estimated solution coordinates up to the extent of 1 m has been found. A significant difference for the number of detected outliers and jumps for the various LAC-specific combinations becomes visible. This may be explained by the different subset of stations that build the individual LAC networks and by the individual efforts invested on the LAC's side to minimize any remaining outliers in the submitted solutions.

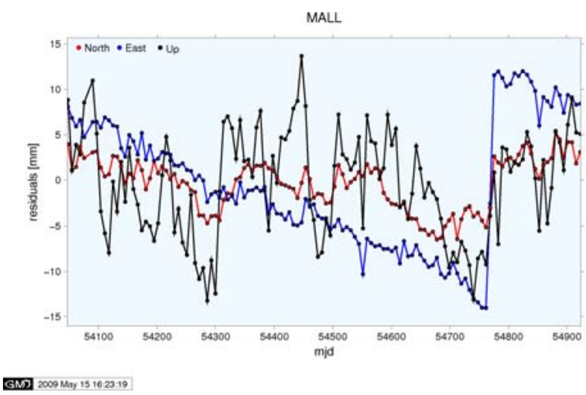
The identified jumps are expected to be equivalent for all LACs. Therefore the huge number of 29 jumps found for SUT needs to be investigated. The final RMS of unit weight is computed after considering the outliers and jumps for all solutions and it remains equal or even gets smaller, which confirms the success of the method applied. The computed index "jumps/station/year" is an interesting quantity in case the index will be computed for a re-processed time series again as soon as it will become available in the future. It is expected that such quantity will be significant smaller after re-processing.

LAC	Initial No. of Stations	Initial RMS Unit Weight [m]	No. of Detected Outlier	No. of Jumps	Final No. of Stations	Final RMS Unit Weight [m]	Diff. RMS Unit Weight [m]	Jumps /station /year
ASI	37	0,010	51	8	45	0,009	0,000	0,09
BEK	79	0,011	21	7	86	0,010	-0,001	0,04
BKG	87	0,016	72	14	101	0,009	-0,008	0,07
COE	45	0,011	29	3	48	0,010	-0,001	0,03
GOP	49	0,015	28	13	62	0,008	-0,006	0,11
IGE	51	0,011	2	*2*	53	0,009	-0,002	0,02
IGN	51	0,010	5	7	58	0,008	-0,002	0,06
LPT	45	0,009	*0*	*1*	46	0,009	0,000	0,01
NKG	49	0,011	20	6	55	0,009	-0,002	0,05
OLG	82	0,014	53	10	92	0,009	-0,005	0,05
ROB	56	0,010	*2*	4	60	0,009	0,000	0,03
SGO	37	0,011	7	3	40	0,010	-0,001	0,03
SUT	49	0,020	114	*29*	78	0,012	-0,007	*0,25*
UPA	46	0,013	63	*1*	47	0,008	-0,004	0,01
WUT	73	0,018	70	19	92	0,010	-0,008	0,11
EUR	234	0,007	128	22	256	0,004	-0,002	0,04

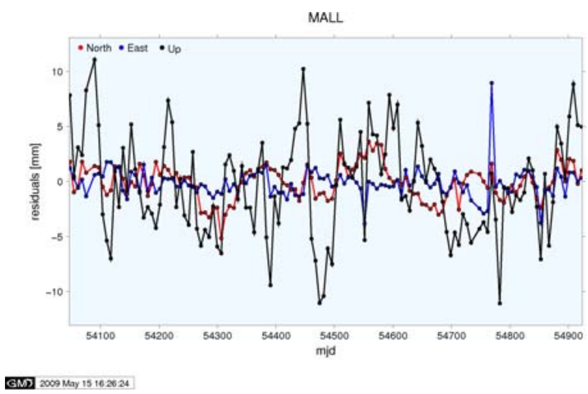
Table 1: Outlier and Discontinuity Detection Statistics

The station MALL has been selected to show an example for discontinuity detection with FODITS. Figure 12 shows time series residuals from 4 LACs that analyse that particular station and also the residuals for the EPN combined series (named EUR). Each time series is given for the initial combination and for the final combination that considers discontinuities as accepted by FODITS.

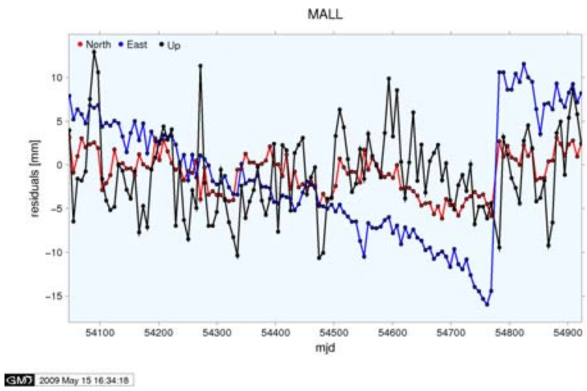
There was a receiver and antenna change in week 1503 for the station MALL that caused a discontinuity in the longitude component of coordinate time series. This jumps has been detected in all individual time series. The jump is obviously amplified in the EUR combination. The week 1503 has been marked as an outlier in the EUR solution and the identified jump has been moved to week 1502. We explain this jump in week 1502 by the event in week 1503 as well. That jump results in the mean to 22.6 mm with 0.8 mm standard deviation. Two additional jumps in the height component have been found in the BKG time series, but were not recovered in EUR combination. This phenomenon could not yet be explained.



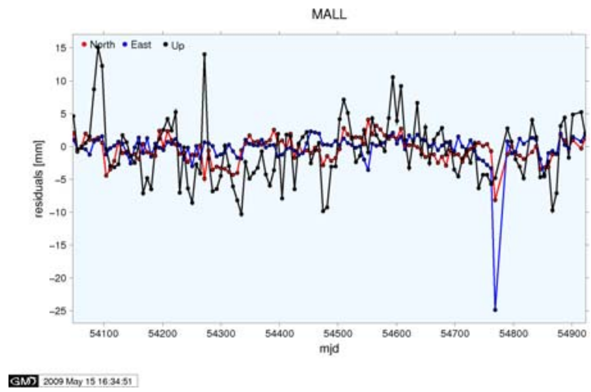
BKG initial combination



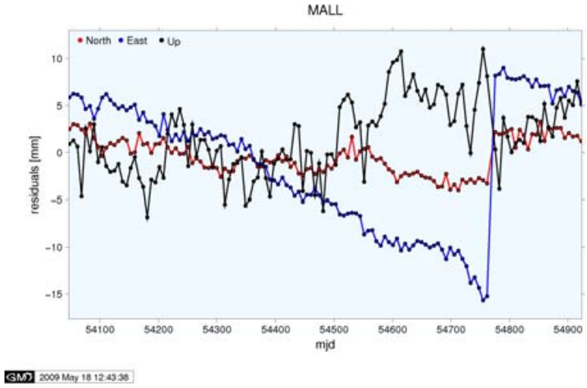
BKG final combination



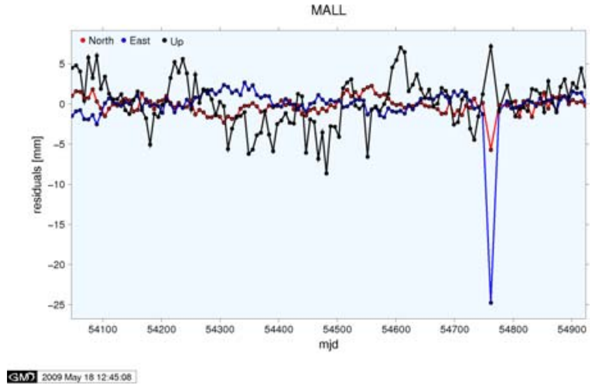
GOP initial combination



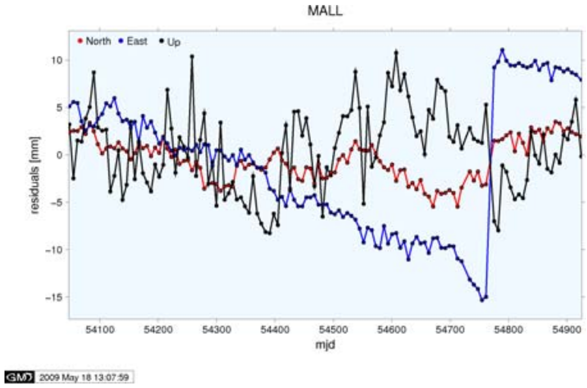
GOP final combination



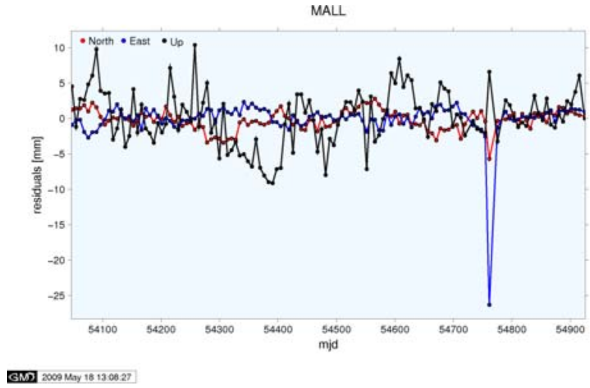
IGE initial combination



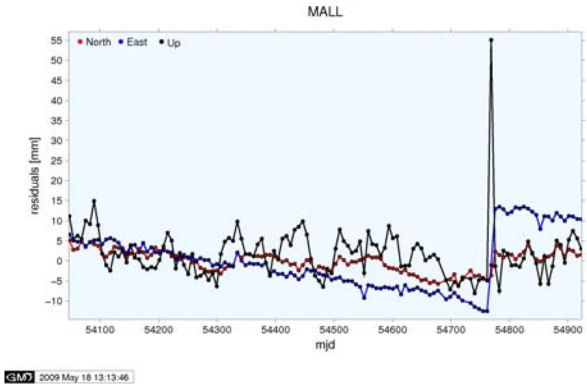
IGE final combination



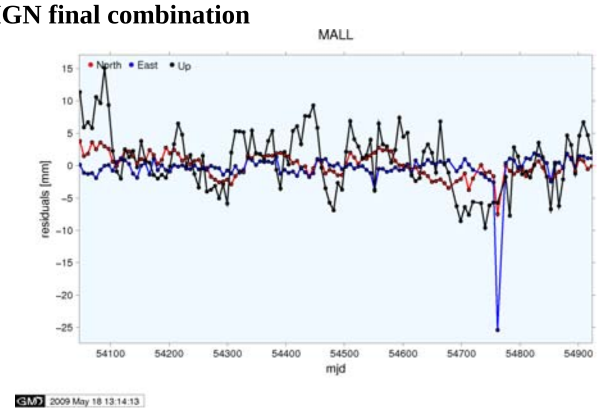
IGN initial combination



IGN final combination



EUR initial combination



EUR final combination

Figure 12: Discontinuity Validation for MALL

Station Velocity

Velocities have been estimated for all stations, and relative constraints in the order of 0.01 mm between subsequent solution numbers have been applied. Estimated velocities for the station MALL are exemplary summarized in Table 2. It has be mentioned that the velocities here are only suitable to study the methodology of the new approach and not for any geophysical interpretation, because of the too short data interval used. Note, the time series has been tested for annual periods by FODITS, but none has been accepted.

LAC		X mm/year	Y mm/year	Z mm/year
BKG	MALL 13444M001	-13,6	20	10,6
BKG	MALL 13444M001AA	-13,6	20	10,6
BKG	MALL 13444M001AB	-13,6	20	10,6
EUR	MALL 13444M001	-8,8	19,1	18,6
EUR	MALL 13444M001AA	-8,8	19,1	18,6
GOP	MALL 13444M001	-10,2	18,8	15,2
GOP	MALL 13444M001AA	-10,2	18,8	15,2
IGE	MALL 13444M001	-13,3	18,2	12
IGE	MALL 13444M001AA	-13,3	18,2	12
IGN	MALL 13444M001	-10,4	18	14
IGN	MALL 13444M001AA	-10,4	18	14

Table 2: Estimated Velocities for Station MALL

Lessons Learned form Methodology Test

The LAC-specific combination discovered a significant huge number of jumps for one particular LAC and 2 additional jumps compared to all other solutions for another LAC. Therefore LAC-specific multi-year solutions are needed. We also detected some inconsistency in the data blocks of a few LAC SINEX files. Consequently such files have been excluded on the LAC level. Obviously such errors remain undetected during the weekly combination procedure and may bias the weekly EPN solutions. Two LAC-specific jumps are not visible in the weekly EPN combination, but will bias the combination if not considered. FODITS detected meaningful discontinuities in individual LAC and the EPN combined time series reliable.

6 Perspective

The establishment of a warning system may supplement the quality management of EPN products. The EPN AC is going to develop such a warning system based on rapid daily solutions in the first step. Additional LACs are kindly asked to contribute to the rapid daily product through submission of particular SINEX files in order to complete such solutions for all EPN sites.

It is planned to generate continuously multi-year combinations for weekly and possible daily solutions for purpose of comparison to results of the EPN Time Series project and to ITRF. Additional LAC-specific time series will be added. They give a feedback to the LACs and allow detection of inconsistencies on the individual LAC level. Tools for comparison of multi-year solutions from various software packages will be developed.

Within the scope the EPN re-processing initiative the new LAC solutions will be combined [Völksen 2009]. An update of EPN processing options is in preparation.

7 References

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C.Völksen [2009]: *Draft Charter for the*

EUREF Working Group on Reprocessing of the EPN, http://epn-repro.bek.badw.de