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GURN (GNSS Upper Rhine Graben Network) Status and First Results

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1. Introduction

In September 2008 the Institut de Physique du Globe de Strasbourg (Ecole et Observatoire des Sciences de la Terre, EOST) and the Geodetic Institute (GIK) of Karlsruhe University (TH) established a transnational cooperation called GURN (GNSS Upper Rhine Graben Network). Within the GURN initiative these institutions are cooperating in order to carry out geo-scientific research in the framework of the transnational project TOPO-WECEP (Western and Central European Platform; http://www.topo-wecep.eu/), which succeeded the former project URGENT (Upper Rhine Graben Evolution and NeoTectonics; http://comp1.geol.unibas.ch/) of the EUCOR universities (European Confederation of Upper Rhine Universities). The research is actually based on GNSS (Global Navigation Satellite Systems) in order to establish a highly precise and highly sensitive network of permanently operating GNSS sites for the detection of recent crustal movements in the Upper Rhine Graben (URG) region.

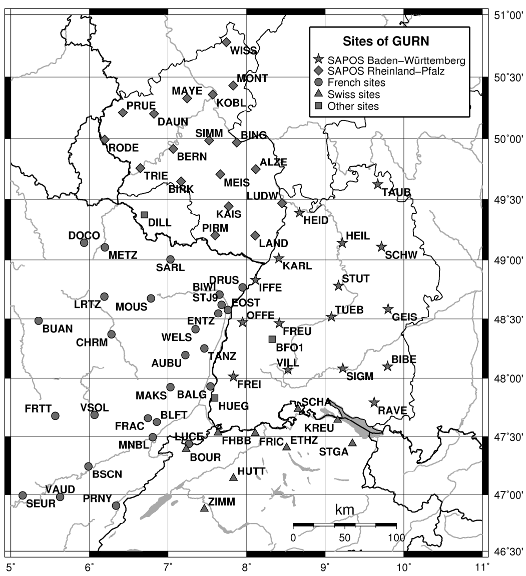

Fig. 1: Status of GURN

At the beginning of the GURN initiative, GURN consisted mostly of permanent operating sites of SA*POS*® Baden-Württemberg and different data providers in France (e.g. EOST, Teria, RGP). In July 2009, the network was extended to the South when swisstopo (Switzerland) and to the North when SA*POS*® Rheinland-Pfalz joined GURN. Therefore, actually the GNSS network consists of approx. 80 permanently operating reference sites, see Fig. 1.

The paper presents the actual status of GURN, main research goals, and first results concerning the data quality as well as time series of a preliminary processing of all available data since 2002 using GAMIT/GLOBK (EOST) and the Bernese GPS Software (GIK).

2. Geological background

The Rhine Graben is the central, most prominent segment of the European Cenozoic rift system which extends from the North Sea through Germany and France to the Mediterranean sea over a distance of some 1000 km (ZIEGLER 1992; BOURGEOIS ET AL. 2007). Within GURN the focus will be on the region of the URG. The URG is a 300 km long and 40 km wide SSW-NNE trending rift, extending from Basel (Switzerland) to Frankfurt (Germany). It is bounded to the west by the Vosges mountains and to the east by the Black Forest. The graben is bounded to the north by the uplifted area of the Rhenish Massif. To the south, the Leymen, Ferrette, and Vendlincourt folds represent the northern-most structural front of the Jura fold and thrust belt. This thin-skinned compressive deformation front would propagate 30 km further to the north up to Mulhouse (France). Preceded by late Cretaceous volcanism, the rifting was initiated during Late Eocene to early Miocene (42-31 Ma) starting with broadly E-W or ENE-WSW extension and lasted until Aquitanian time (20 Ma).
The URG is considered to be the most seismically active region of northwest Europe with significant probability for the occurrence of large earthquakes (MEGHRAOUI ET AL. 2001). For a better understanding of the processes that lead to seismic activity in the URG, it is necessary to study not only the location of the fault itself but also its kinematics. Seismic hazard assessment in the URG is hindered especially by a lack of information on the time-dependent behaviour of active structures. GURN will contribute to remedy this regional defect.

3. Site quality check

The main goal of the long-term GURN initiative is to improve the geodesy-related data base on recent crustal motion in the URG significantly, in order to verify and improve existing geo-scientific models. Before starting with the processing of all available GNSS data, several checks of the quality of the sites and their data have to be performed aiming for accurate results.

3.1 Case study: Monitoring of GNSS sites using tiltmeters

The first performed check was a monitoring of two selected SA*POS*® GNSS sites (KARL, IFFE) using precise two axes tiltmeters (type: Kern Nivel20). It is important to verify the behaviour of the sites (e.g. building, monumentation), due to the fact that the main goal of GURN is to determine recent crustal movements. The general assumption within GNSS-based geodynamic studies is: GNSS-derived movements are identical to ground-related movements. Therefore, the site resp. antenna environment of each non-pillar GURN site has to be verified.
The first selected site was KARL, which is established by a steel construction on the roof top of a massive old building. A precise two-axis tiltmeter and, in addition, a precise thermometer – installed in order to check the quality of the temperature measurements of the tiltmeter – were mounted on the steel construction. The equipment

was protected against weather by a plastic cover. The measurements were performed for several weeks. In Fig. 2 the relative signals of the tiltmeter in N-S and E-W direction as well as the temperature variations are shown. Some peaks especially in N-S direction are clearly visible, which are strongly correlated with the measured temperature. If the measured tilts (max-tilt value - min-tilt value) are assumed to represent movements of the building, horizontal movements of ± 1.8 mm have to be expected.

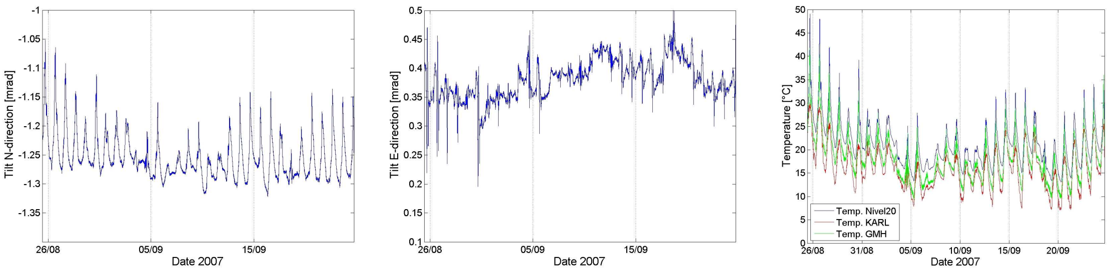

Fig. 2: Relative tiltmeter signals in N-S (left) and E-W direction (middle) and temperature variations (right); site: KARL

As second GNSS site, IFFE was selected. IFFE is located on a control tower at the lock of Iffezheim at the river Rhine. The control tower is situated between the two lock chambers, which have a length of 240 m, a width of 24 m and a height of around 15 m. The tiltmeter was installed directly below the antenna at the steel tube of the monumentation and protected against weather by a plastic cover and isolation. The x-axis (y-axis) was oriented across (along) the river. In addition, a temperature sensor was installed. The measurements have been performed for one month. In Fig. 3 the measurements of one representative calm day (little temperature variations) are shown. Especially in x-direction (across-river), a stair-function behaviour is clearly visible. The behaviour is caused by the operation of the lock chambers. Taking the height of the control tower, the height of the lock and the difference of min- and max-tilt into account, an apparent horizontal movement of ± 1.8 mm can be calculated.

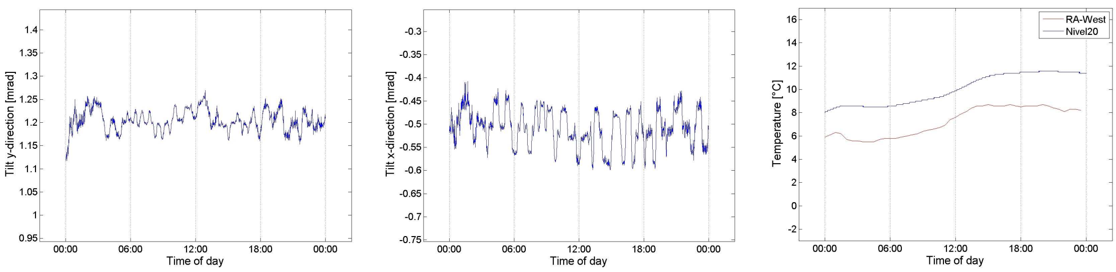

Fig. 3: Relative tiltmeter signals in along-river (left) and across-river direction (middle) and temperature variations (right); site: IFFE

The two experiments show clearly, that there are movements of the sites caused by different sources. Further investigations (e.g. using more tiltmeters on different floors of buildings, additional terrestrial antenna monitoring using a precise tachymeter) are planned in order to distinguish e.g. between movements of the building and movements caused by the antenna monumentation. This will lead to more representative recent crustal movement rates derived from GNSS data, separating apparent, environment-induced motions from GNSS-based movement rates.

3.2 Check of the multipath environment

Within the tiltmeter case study no GNSS data were taken into account, so improved checks were carried out at the GIK in order to get an impression of the GNSS data quality. An important GNSS error source are so called multipath effects. The interference of the direct signal and the reflected signal (e.g. walls) can cause significant position errors.

The multipath checks were performed using the Software WaSoft/Multipath (WANNINGER AND WILDT 1997). Within this software, phase-related site-specific multipath effects are calculated within small networks (expansion: 100-150 km). Therefore, GURN is separated into small overlapping sub-networks.

Based on the results of the multipath check, a classification of the GURN sites concerning multipath affection was carried out, see Tab. 1. The sites are separated in good (low multipath impact), medium (medium multipath impact) and bad (high multipath impact) sites. Examples for sites of each class are given in Fig. 4. On the right axis, the azimuth from 0° to 360° and on the vertical axis, the elevation of 0° to 50° is given. All signals above an elevation of 50° are assumed to be not affected by multipath.

Tab. 1: Classification of the GURN sites using multipath affection as criterion in percentage of all sites

Multipath affection	good	medium	bad
Number of GURN sites [%]	65 %	20 %	15 %

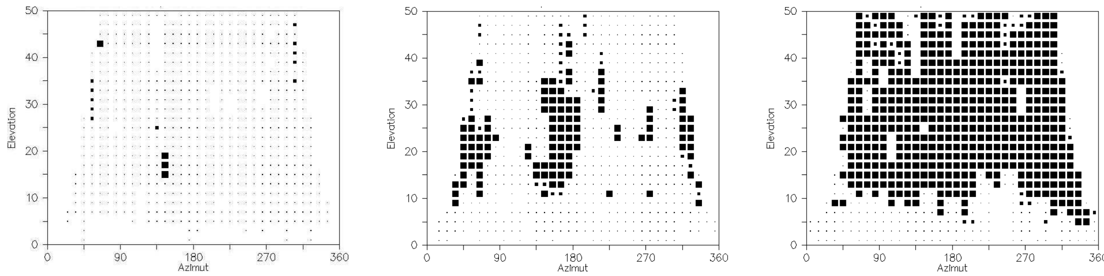

Fig. 4: Multipath maps, good/medium/bad site (low/medium/high multipath impact detected, left/middle/right), small/medium/large dots in the plot represent observations not/little/heavily affected by multipath

Starting as a cooperation with SA*POS*® Baden-Württemberg in 2004, yearly multipath analyses are carried out at the GIK. This enables – besides quantifying the multipath affection of sites – to realize modifications which affect GNSS results (e.g. constructional modifications in the vicinity of the site), in order to avoid pseudo-deformations due to propagation of the modifications into coordinate time series. In addition, an extended SNR-based stochastic model will be used in the future, in order to reduce the effect of standard GNSS observation weighting on coordinate determination of multipath affected sites (LUO ET AL. 2008).

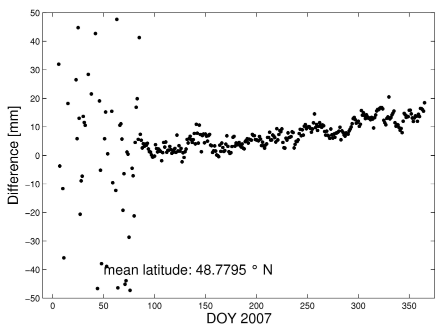

Fig. 5 Time series of the northing component of site STUT

3.3 Checks of the scattering of the time series

As an additional data quality test, so-called PPP (Precise Point Positioning) solutions for every GURN site using GPS data of the year 2007 were calculated at the GIK using the Bernese GPS Software (DACH ET AL. 2007). Within this case

study, coordinate time series of each single site were calculated and analysed separately based on a non-differential data processing strategy. The combined analysis of these coordinate time series and the multipath maps is very useful in order to gain a realistic impression of the data quality.
As an example, Fig. 5 shows the resulting time series for site STUT. At the beginning of the year 2007, a large variability of the northing component is clearly visible, which ends abruptly at doy 086, when an equipment exchange was performed.

4. Preliminary results

Based on the results of various data quality checks, differential data processing strategies were applied. The processing of the data is carried out by EOST and GIK using different software and different modeling approaches (MAYER ET AL. 2009). In this way, an independent control and quality verification of each processing is possible. In order to avoid jumps in coordinate time series and to guarantee continuous time series, the GIK working group uses reprocessed orbit data within one consistent reference frame (STEIGENBERGER ET AL. 2007). Two examples representing preliminary results of the GIK working group are shown in Fig. 6. They represent the time series of the sites RAVE and KARL. Within both time series the Eurasian trend is eliminated.

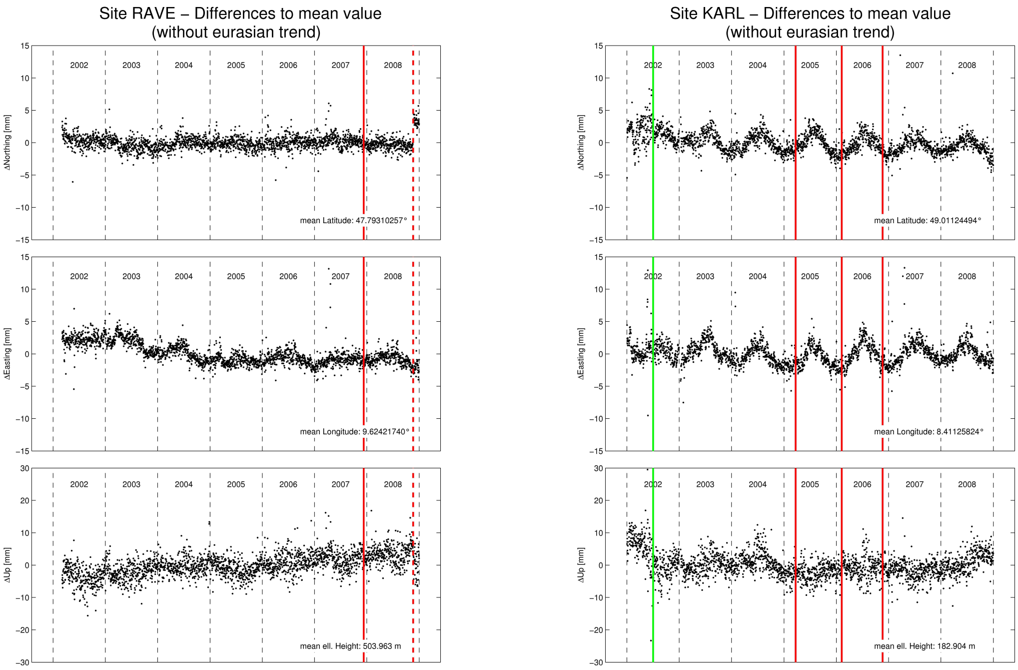

Fig. 6: Preliminary coordinate time series of GURN sites RAVE (left) and KARL (right)

Site RAVE shows a quite calm behaviour with low scattering of the data. At the end of 2008 a jump in the northing component occurs, which is caused by an equipment change. Hard- and software changes on sites, especially replacements of the antennas, can cause severe jumps in time series. In the case of site RAVE the equipment was changed in order to be capable of receiving GPS and GLONASS signals. The site KARL shows no jumps but a strong seasonal signal which is probably not caused by movements of the ground, but by the behaviour of the monumentation.

5. Summary and outlook

The next steps within GURN are the proper estimation of site velocities together with a cleaning of the time series (e.g. steps, seasonal signals). Furthermore, the preliminary results of the two working groups (EOST, GIK) will be compared in order to validate the results. The first milestone of GURN is to create a new well-founded model of recent geokinematics for the Upper Rhine Graben. Long-term goals are (i) generation of water vapour fields with a high temporal and spatial resolution and (ii) combination of different geodetic techniques (GNSS, levelling, InSAR) in order to perform a hybrid deformation analysis.

Acknowledgements
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