GURN (GNSS Upper Rhine Graben Network) Status and Research Goals

Karlsruhe Institute of Technology

A. Knöpfler (1), M. Mayer (1), F. Masson (2), G. Ferhat (2,3), P. Ulrich (2), and B. Heck (1)

(1) Geodetic Institute, Karlsruhe University (TH), Germany
(2) IPGS/EOST, Strasbourg University, France
(3) INSA de Strasbourg Strasbourg, France

Abstract

In April 2008 the Institut de Physique du Globe de Strasbourg (Ecole et Observatoire des Sciences de la Terre) and the Geodetic Institute of the Karlsruhe University (TH) established an international joint venture 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 (West and Central European Platform), which succeeds the former project EUCOR-URGENT (Upper Rhine Graben Evolution and NeoTectonics). The proposed research is based on GNSS (Global Navigation Satellite Systems) in order to detect recent crustal movements.

Geophysical Context

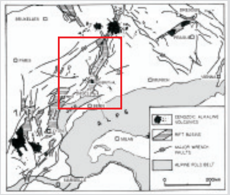

Figure 1: The European Cenozoic Rift System. The red square indicates the GURN region. Image modified from Ziegler (1992).

The Rhine Graben is the central, most prominent segment of the European Cenozoic rift system (fig. 1) of Oligocene age which extends from the North Sea through Germany and France to the Mediterranean Sea over a distance of some 1000 km. Within GURN the focus will be on the Upper Rhine Graben (URG). The URG is a 300 km long and 40 km wide SSW-NNE trending rift, extending from Basel (Switzerland) to Frankfurt aM (Germany), see fig. 2. 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 east-west or ENE-WSW extension and lasted until Aquitanian time (fig. 3). Today, the southern end of the Rhine Graben is characterized by small uplift and subsidence rates (ZIPPELT & MÄLZER 1987) and by a quasi-compressive, left-lateral strike-slip tectonic regime (fig. 3), with a maximum stress-axis oriented NW-SE (fig. 4).

The URG is considered to be the most seismically active region of northwest Europe with significant probability for the occurrence of large earthquakes. 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 faults but also their kinematics. Seismic hazard assessment in the region is hindered by a lack of information on the movements of the active structures.

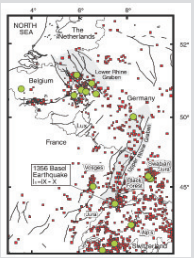

Figure 2: Seismotectonic framework of the Lower and Upper Rhine Graben. Red squares depict the instrumental seismicity from 1910 to 1990 (1<M<5.5). Green circles correspond to the historical seismicity (MEGHRAOUI ET AL. 2001). It is obvious that the URG is a seismotectonical highly active area, which has to be monitored, in order to verify the risk potential.

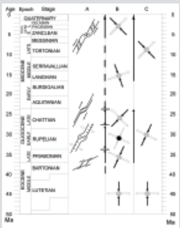

Figure 3: Time scale for the development of the Upper Rhine Graben rift system. Column A - Kinematics of faults for the different phases of the graben development (SCHUMACHER 2002). Column B - Stress conditions for the different phases as described by SCHUMACHER (2002). Column C - Development of the stress field as described by MICHON ET AL. (2003). The Figure is taken from LOPES-CARDOZO (2004).

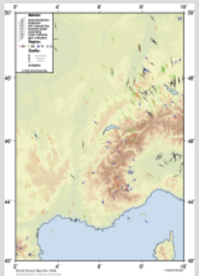

Figure 4: Map of the directions of maximum horizontal compression in the western Alpine foreland. Figure is taken from LOPES-CARDOZO (2004) and obtained from the website of the World Stress Map project (Link: www.world-stress-map.org) maintained at the Karlsruhe University (TH).

Satellite Geodetic History in the Upper Rhine Graben

Geodetic Measurements using satellite techniques have a long tradition in the URG. In the framework of EUCOR the project URGENT (Upper Rhine Graben Evolution and NeoTectonics) took place in the years 1999-2003. EUCOR (EUropean COnfederation of Universities on the Upper Rhine) is the union of the seven universities of the Upper Rhine Graben: Basel (CH, University of Basel), Freiburg (D, Albert-Ludwigs-University), Karlsruhe (D, Karlsruhe University), Mulhouse (F, Université de Haute Alsace Mulhouse/Colmar), Strasbourg (F, Université Louis Pasteur, Université Marc Bloch, Université Robert Schumann). EUCOR was established in 1989.

Within this project GPS campaigns have been carried out in 1999, 2000, and 2003. These campaigns were suffering from the small number of occupied sites (approx. 30) as well as from poor and inhomogeneous spatial resolution and from the poor amount of GPS data (2 x 24h), especially. But the results and experiences gained within this interdisciplinary and transnational project were quiet promising. Therefore, in order to continue and intensify the work of this project, GURN was established in April 2008 as a geo-scientific cooperation.

GURN: GNSS Upper Rhine Graben Network

GURN actually (April 2009) includes German, French and Swiss continuously operating GNSS sites.

Most data of the German sites are provided from SAPOS®-Baden-Württemberg. Most sites were recently enabled to track GLONASS data.

The data of the French sites have several origins: RENAG (Universities and research institutes), RGP (network of IGN), Teria, Orpheon, EOST. Thus, the sites were established for scientific or business purposes.

Additionally, two IGS sites (HUEG, ZIMM) and the sites DILL and BFO1 are included.

For the further extension of the network, oral agreements for the sites of SAPOS®-Rheinland-Pfalz and the permanent sites from Switzerland (Swisstopo, ETH Zürich) have been made, the written agreements are in process.

The resulting network will cover the whole URG region homogeneously. The mean distance between the network sites will be 40-60km.

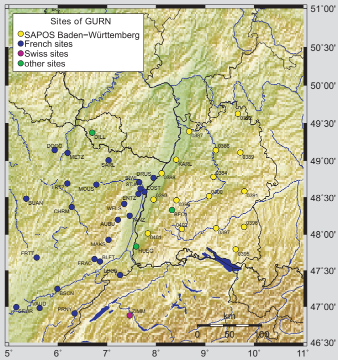

Figure 5: Map of GURN in the actual configuration (April 2009) with sites in Germany, France and Switzerland

Goals of GURN

The primary goal of the GURN project as a long term project is to obtain precise and realiable estimates of horizontal and vertical movements of the area under research. In the beginning of this project all available data of permanently observing GNSS sites have to be checked, in order to evaluate the data quality and to be able to select suitable sites and data processing strategies. This is due to the fact that especially the SAPOS® sites were established for cadastral purposes (no pillar monumentation).

The GNSS-related research aims within GURN are:

- short term: Generation of highly precise daily GURN solutions
- short term: Automated web-based presentation of results in near real-time
- short term: Carrying out investigations in order to achieve an improved stochastic GNSS modeling
- long term: Automated generation of extended water vapor fields
- long term: Revised geodynamic model of the URG area

Acknowledgments

We thank all of our data providers for supplying data of their permanently operating GNSS networks: RENAG (France), RGP (France), Teria (France), Orpheon (France), SAPOS®-Baden-Württemberg (Germany) and IGS.

Verification of Data Quality - Methods and preliminary Results

Preliminary check of the quality of the GNSS sites using TEQC
Using TEQC (UNAVCO) (ESTEY & MEERTENS 1999) code-related multipath effects as well as the percentages of missing data of each site are quantified. This enables a preliminary quality classification of the GURN sites (fig. 6).

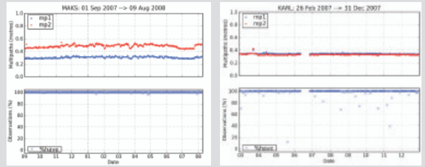

Figure 6: Check of code-related multipath and availability of observations using TEQC (UNAVCO) for two sites of GURN. MP1 and MP2 are the multipath effects on L1 and L2

Preliminary check of the quality of the GNSS sites using WaSoft/Multipath
Analyzing the L3 residual time series of phase observations WaSoft/Multipath (WANNINGER & WILDT 1997) detects – under several assumptions – multipath effects of observation sites in order to improve the code-based quality classification of the GURN sites (fig. 7).

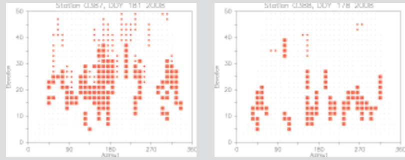

Figure 7:
Check of phase-related multipath using WaSoft/Multipath
Legend: dot = observations; no dot = no observations; small rectangles = few multipath effects; large rectangles = large multipath effects.

Improved quality check
Using the PPP module of the Bernese GPS Software (DACH ET AL. 2007) preliminary time series of all GURN sites were derived within the ITRF2005 (ALTAMIMI ET AL. 2007), which is introduced in the PPP processing using the final CODE orbits. Therefore the Eurasian trend of the horizontal, local topocentric coordinates is clearly visible. Analyzing the time series (e. g. scattering) the quality classification could be improved (e.g. fig. 8).

In contrast to the French sites, SAPOS® sites are equipped with absolute calibrated antennas.

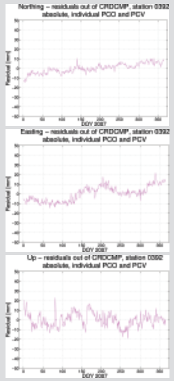

Figure 8:
Residuals of the coordinate components (Northing, Easting, Up) out of the PPP processing using the Bernese GPS Software for site 0392 for the year 2007

Preliminary time series
The GPS data were analyzed using the GAMIT/GLOBK (HERRING ET AL. 2006) 10.33 version at Strasbourg IPGS. Figure 9 presents one of the longest time series of our GPS network: STJ9 is located in the Rhine Graben at about 10 km of Strasbourg, France.

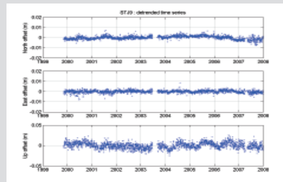

Figure 9:
Time series for Northing, Easting and Up of the site STJ9 between the years 1999 and 2008, processed using GAMIT/GLOBK 10.33

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Geodetic Institute, Karlsruhe University (TH)
Englerstr. 7, D-76131 Karlsruhe, Germany
gurn@gik.uni-karlsruhe.de

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