

# NEAR REAL-TIME DEFORMATION IN GERMANY - A CONTRIBUTION TO THE GERMAN RESEARCH NETWORK NATURAL DISASTERS (DFNK)

**Sibylle Goebell, Gero W. Michel, Roman Galas, Christoph Reigber**

GeoForschungsZentrum Potsdam, Division 1.: Kinematics & Dynamics of the Earth,  
Telegrafenberg A17, 14473 Potsdam, Germany

## **Abstract**

Deformation of plate interiors has become a new and promising study field for modern space geodetic techniques. This is owing to 1) the increasing need in an improved assessment of seismic hazard and risk in intraplate settings where major earthquakes are rare and unexpected while the vulnerability is steadily growing and 2) the increasing accuracy of the methods that enable monitoring of transient and secular deformations at very low rates. Here we present monitoring strategies and preliminary results from the German Research Network Natural Disasters (DFNK) program that aims at linking experts, and health organizations with social authorities and the public in order to increase awareness and reduce seismic risk. The main objective of the part of the program presented here is a) to prepare and model precise deformation data in near real-time using a steadily increasing network of permanent GPS-receivers, b) evaluate operational aspects such as the development of dedicated hardware subsystems, data communication and processing strategies, c) determine rates and distributions of long-term deformation, d) study the nature of short-term transient motion, e) create tectonic fault/block models and assess how much of the current deformation is released seismically, and f) evaluate strategies for a quasi-online detection of e.g. tectonic target signals.

## **1. Introduction**

The vulnerability of today's societies is steadily growing and each natural disaster leads to new unprecedented damage records. This is especially true for intraplate settings such as Germany, where e.g. recurrence rates of large seismic events are low and the society tends to be unprepared. As opposed to the low occurrence probabilities of large to major events, high population density and concentration of property cause significant exposure and create a huge level of risk. Little has been done in Germany to date, in order to conduct new integrated studies on the evaluation of hazard and risk. The DFNK-program provides the first synergetic approach that aims at linking scientists from different disciplines, from the industry, and the public for a better assessment towards an improved evaluation of risk and risk management.

This project contributes to this approach with continuous monitoring of deformation using a steadily growing network of permanent GPS-stations in Germany. This network covers the tectonically most active areas such as the Upper and Lower Rhine-Graben, the lower Rhine Embayment, the Swabian Alb, the Alpine foreland, as well as the area of Vogtland, that has frequently and recently been prone by earthquake swarms. In addition, the network is deemed capable of monitoring large-scale ground deformation induced by activities of the industry including mining or large scale water extraction.

Overall tectonic deformation is expected to be low in Germany and NNW-SSE directed shortening and ENE-WSW directed extension rates are assumed to be between 1 and 3 mm per year. However, little is known about the processes that accommodate this deformation and whether deformation and strains are highly distributed and/or localized along faults is a matter of ongoing discussions. Measurements in a dense GPS-network might have the possibility of evaluating this process. Results are expected to contribute to a better understanding of the seismogenic loading process and/or the influence man-induced effects, such as water extraction, might have on the deformation signal.

## Structure and partners of DFNK

The DFNK is divided into five clusters, that investigate four groups of natural hazards. These clusters are devoted to:

- Earthquake Risk Assessment,
- Flood Risk Assessment,
- Storm Risk Assessment,
- Forest Fire Simulation System and
- Data Bases and Information Systems.

Different institutions and universities participate in the different clusters and assorted subprojects have been defined. Along with the studies introduced herein, that have been conducted at the GFZ Potsdam, the following institutions and universities are involved in the earthquake cluster: Technical University of Berlin, GeoForschungsZentrum Potsdam, Bauhaus-University of Weimar, Munich Reinsurance Group, University of Karlsruhe and the Federal Institute of Geosciences Hannover (BGR, see fig. 1).

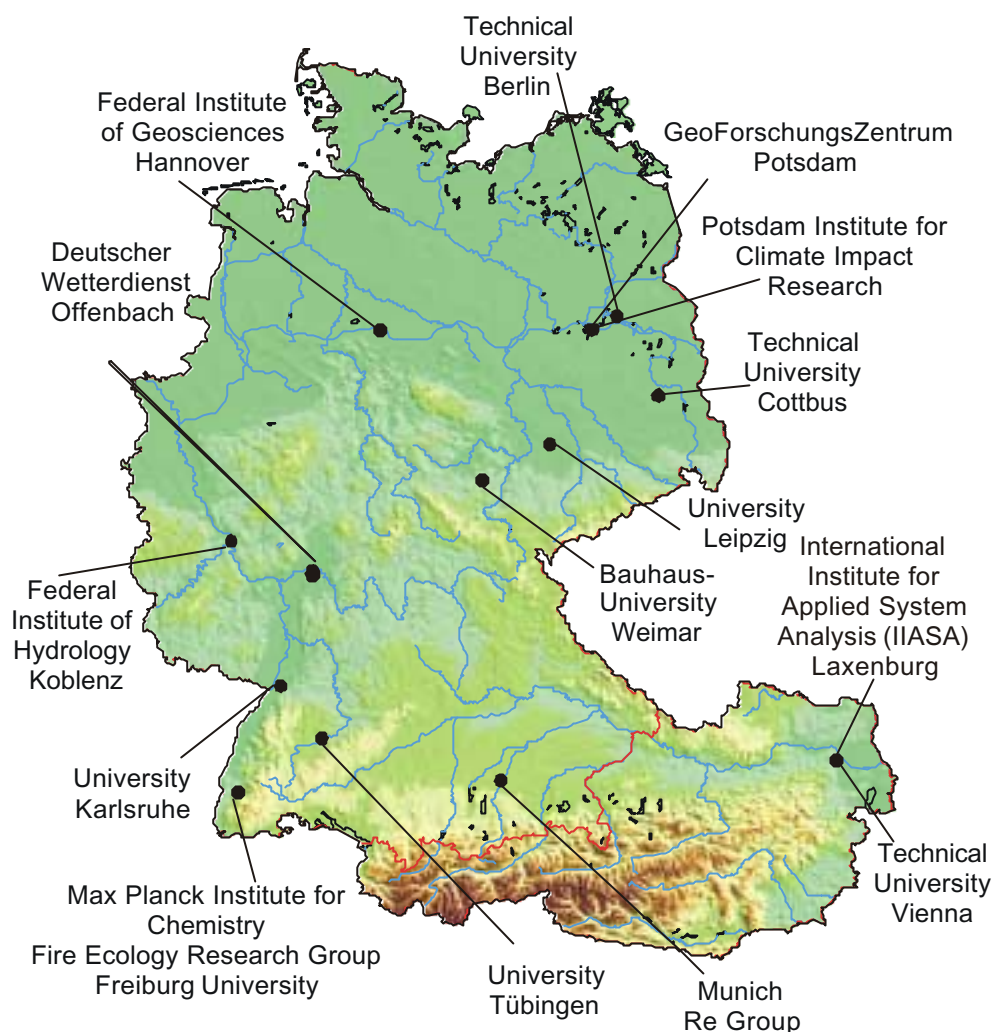


Fig. 1: Partners of the DFNK.

## 2.1 Objectives

Objectives of this study comprise:

- Unified recording and continuous processing of GPS-data throughout Germany,
- preparation of results of a dense permanent GPS-network for precise deformation monitoring and
- interpretation of the results taking into account modern neotectonic approaches, including techniques such as remote sensing for a better assessment of seismically active structures, seismic deformation rates, seismic and anthropogenically induced hazard and for a better understanding of causative geologic processes.

## 3. GPS-research networks in Germany

The following GPS-networks are used in this study:

- A permanent and steadily growing network of the Satellite-Positioning-Service (SAPOS) of the German land surveying agencies.
- A GFZ-network that has been operated in cooperation with the 'German Weather Service' (DWD).

Presently, the SAPOS-network consists of about 250 GPS-stations, the number being increased by a few each year (Hankemeier, 1996). In the project discussed herein, 27 of these stations as well as 23 stations of the GFZ-DWD network have been used so far for test reasons (see fig.3). Included are also three IGS-stations of the global GPS-network of the International GPS Service (IGS), namely Potsdam, Oberpfaffenhofen and Wettzell. The global network is being processed and analyzed, besides other centers, at the IGS analysis center at GFZ (Gendt, 1995). Generally, the GPS-data are transferred online to GFZ and then processed and analyzed using the GFZ software EPOS. The current version, EPOS.P.V2, has been updated by some necessary modules recently and is going to improve further in order to guarantee continuous deformation monitoring on a high precision level. Considering the very low rates of deformation expected (strain rates of  $< 10^{-8}/a$ ), long-term monitoring and processing is anticipated if active faults displaying full seismogenic coupling are estimated. Transient effects that might be induced by temporal strain release due to faults that display 'creep', as has been suggested by different geologists, may lead to signals with a higher chance of being identified by our measurements.

### 3.1 Assessment of Earthquake hazards

Up to now, seismic hazard assessment studies in Germany have concentrated on seismic and seismotectonic information with little or no input from geology or from geodesy. The integrated approach presented here has the major advantage of including neotectonic and space geodetic information as well as simulations of different scenarios into the program. Fig. 2 shows the change in baseline length derived using weekly determined GPS-station coordinates between Westerbork (the Netherlands) and Potsdam from summer 1997 to spring 2000. The resolving gradient revealed a yearly elongation of this baseline by  $1.3 \text{ mm} \pm 1 \text{ mm}$ . On the left of Fig. 3 vectors indicate site motions of the European Reference Network (EUREF), supplied by the Federal Agency for Cartography and Geodesy (BKG). These site motions were calculated with respect to 'stable' Eurasia as defined by the data of 30 IGS-stations in the area. Results suggest that the area east of the Rhine-Graben is currently drifting roughly to the east with respect to the Potsdam station with a rate similar to that suggested by the change in baseline length of the stations Potsdam and Westerbork, as mentioned above. Owing to a historical earthquake record of 600 years, as provided by Grünthal (GFZ), moment rates were derived by integration over a

truncated Gutenberg-Richter approach. This was done assuming that deformation is largely accommodated by normal faulting along the Rhine-Graben. These rates depend heavily on the maximum earthquake. The right side of Fig. 3 denotes approximated slip rates, as a function of the maximum earthquake, on an estimated ‘Rhine-Graben fault’ segment. This segment was assumed to strike perpendicular to the extension direction approximated by the EUREF solution (i.e. roughly N-S) and depicts a length of 40 km. Rates of seismic vs. geodetic moment and slip tend not to merge until an upper bound earthquake with a magnitude of above 8 is introduced into the calculations. Further studies are necessary to evaluate these numbers in more detail.

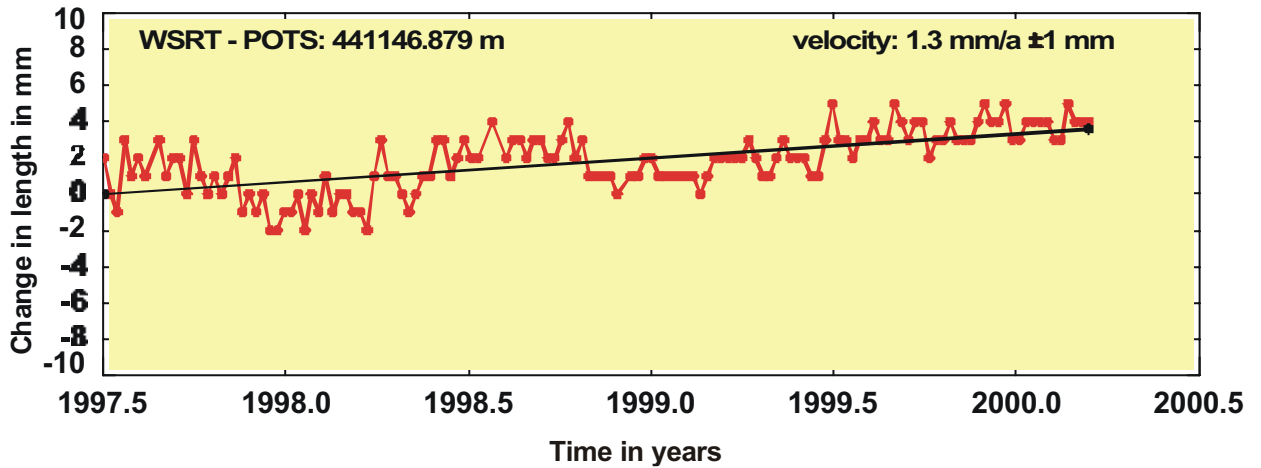


Fig. 2: Change in baseline length out of weekly determined GPS-station coordinates.

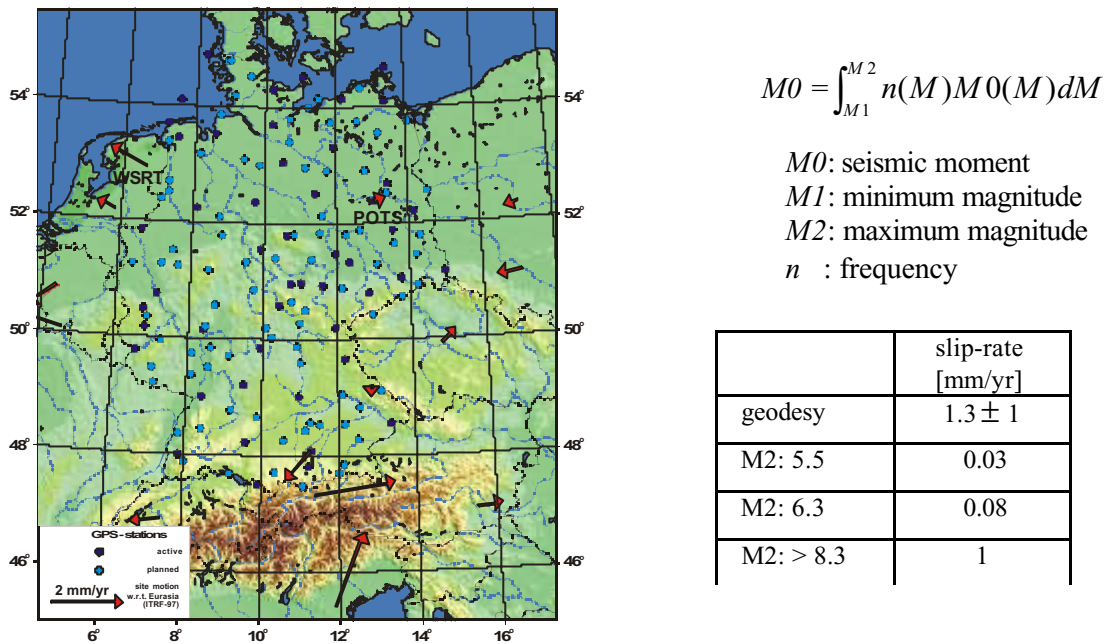


Fig. 3: Site motions of the European Reference Network (EUREF).

### 3.2 Interpretation of deformation and deformation monitoring in Germany

Interpretation of deformation results include modeling approaches with input data from geology, seismotectonics and seismology. Prerequisite are discussions of possibilities the data might provide for quasi-online detection of tectonic target signals and separation of different causative processes influencing this signal. Analyzing data from local networks in addition to the permanent GPS-network presented above, is expected to further aid in detecting signals due to e.g. changes in water table induced by mining and/or drinking-water extraction. Implementation of additional mobile stations that might help to localize transient effects has also been envisaged.

### Conclusions

The permanent GPS-network project presented here, that is part of an initiative of different institutions and universities to link information related to different natural hazards, aims to contribute to the assessment of hazards and risks in Germany. In the sub-project presented, existing networks have been used and further extended. A variety of data analysis strategies have been tested. The aim is to provide continuous and near real-time information of current deformation in Germany for a better understanding of ongoing tectonic, and environmental processes related to current surface deformation.

### References

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