# National Report of Germany

J. Ihde<sup>1</sup>, U. Faulhaber<sup>2</sup>, M. Sacher<sup>1</sup>, G. Weber<sup>1</sup>, H. Wilmes<sup>1</sup>

<sup>1</sup>Bundesamt für Kartographie und Geodäsie, BKG, Frankfurt

<sup>2</sup>Arbeitsgemeinschaft der Vermessungsverwaltungen der Länder der Bundesrepublik Deutschland, AdV

### **GPS Reference Network GREF**

The main objective of the German GPS reference network GREF is still to serve the establishment and maintenance of one unique nation-wide geodetic reference system. In addition to its existing function, GREF's capabilities are extended to provide an Internetbased positioning and navigation service with accuracies of ± 0.5 m. 20 GREF stations are gradually connected by dedicated leased communication lines with a central computer at BKG in Frankfurt. New GPS-GLONASS receivers replace old GPS receivers used Real-time data transmitted before. via telephone or Internet feed the GPSNet networking software of Trimble/Terrasat. So far 12 of the new GPS-GLONASS stations were interlaced. Differential GNSS corrections in RTCM 2.0 format are derived for about 15 virtual reference stations covering the entire area of the Federal Republic of Germany. The work is part of the "EUREF-IP"

GREF Realtime extension ONSA



Planned Realtime Connection (until Juli 2003)
Status: May 2003

Status of real-time networking of GREF

project for delivering DGNSS corrections via Internet, where accuracies in the order of  $\pm 1$  m are expected. Institutions from six European states currently take part in the project.

Subnetworks of the German States are integrated by the BKG into the national GREF network as well as into the European EUREF and the global IGS net. This work is periodically carried out to contribute to the definition of the official coordinates of the States as well as for control and monitoring purposes.

# Satellite Positioning Service of the German National Survey, SAPOS

SAPOS is operated by the Working Committee of the Surveying Authorities of the States of the Federal Republic of Germany (AdV) as a joint project. The objective is to make available - by modern methods - a uniform, homogeneous spatial reference system for all fields of application in surveying and cadastre, as well as for other navigation and positioning purposes. The basis of SAPOS is an nationwide network of about 250 continuously operated GPS reference stations, which are determined as fixed points of the national survey in the European Terrestrial Reference System 1989 (ETRS89). Since the beginning of 2003 all 250 reference stations are in operation.

SAPOS offers its customers four service areas with different accuracies. The area in greatest demand is HEPS, a real time positioning service with centimeter accuracy. Due to its importance, the AdV adapted mandatory operation regulations for this service in 2001.

When building up the total network, the States of the Federal Republic included their SAPOS sub-networks into already existing hierarchically ETRS89 reference structured networks (EUREF, DREF, and State reference networks). However, the first determination of coordinates for these networks was based on various observation times which resulted in an inhomogeneous accuracy. Thus. the coordinates of the SAPOS stations needed to be improved in order to meet today's requirements for



Overview of the SAPOS<sup>®</sup> reference stations in the Federal Republic of Germany

real-time networking software. With a new adjustment, based on one week of observations in October 2002 and covering all existing stations, improved coordinates could be derived for the complete network with a homogeneous overall accuracy of  $\pm 1$  cm. The new network adjustment was done by the BKG.

To increase the efficiency and acceptance of SAPOS services, the AdV tackled several projects. A Central Unit has been installed at the LGN in Hanover. Its task consists in

- Nation-wide joining of the data of the State centers;
- Nation-wide provision of data for users;
- Nation-wide management of user authentication/authorization;
- Nation-wide regulation concerning user fees.

This Central Unit furthermore coordinates other nation-wide activities. It shall be the contact partner and negotiator for all users and in addition support the internal exchange of data between States on their demand.

For the further opening of the geodata-market, the AdV wants to establish partnerships with private service providers. The intention is to extend and spread the use of public investments. Following this idea, the AdV and ascos, an affiliate of the Ruhrgas AG, have singned a co-operation for a German-wide purchase of SAPOS data. Thus, existing private potential for operation and marketing can be used mutually. From the synergies, both partners expect an accelerated introduction and intensified applications in the DGNSS market.

To be able to determine heights in the authoritative system with an accuracy of up to one centimeter a) online, b) without control points, and c) on the basis of GNSS, two methods are in use in Germany: The satellite-geodetic leveling Quasi-Geoid, presented in the National Report 2002, and the Digital Finite Element Height Reference Surface (DFHBF).

As well known, the use of dedicated leased telecommunication lines for the transmission of real-time data is expensive. Within the framework of EUREF and under participation of the BKG for SAPOS, a new technique has been developed for the dissemination of GNSS real-time data over the Internet. The "Networked Transport of RTCM via Internet Protocol" (Ntrip) enables streaming GNSS data over wired as well as wireless Mobile IP Networks. The RTCM SC-104 has established a new Working Group under participation of the GNSS industry in order to help in the development of an international standard for Internet-based RTCM data dissemination.

## Height and Gravity System

The work of the data and analysis center for the European height networks at the BKG was directed toward the extension of the data base by further measuring epochs. Up to 2001, two epochs of first order levelling networks of Germany were available in the data base:

- 1953-1959 (SNN56) and 1974-1978 (SNN76) in the Eastern part;
- 1934-1964 (DHHN60) and 1980-1985 (DHHN85) in the Western part.

During the last year the data of the second order levelling network of the epoch 1953-1959 (SNN56) in the former GDR were digitized and stored in the BKG height data base. Thus, two complete epochs of the first and second order levelling network of the Eastern part of Germany are available now for a kinematic adjustment.

For the direct transition between GPS heights in the ETRS89 and levelling heights in the DHHN92, a Quasi-Geoid was derived from approx. 700 GPS/levelling points and approx. 250000 point gravity values in cooperation between the BKG and the States. The accuracy of the Quasi-Geoid with reference to the systems ETRS89 and DHHN92 modeled with point masses is  $\pm 1 - 2$  cm.

To secure the gravity reference system in level and scale in the long run, the BKG regularly performs absolute gravity measurements in combination with continuous registrations of the superconducting gravimeters in Wettzell, Bad Homburg and Moxa.

The integration of the gravity measurements into the international reference system is realized via the careful monitoring of the physical standards of the measuring instruments, the participation in international comparison campaigns at the BIPM, as well as via bilateral comparative measurements with other absolute gravimeters on selected stations.

Absolute gravity measurements with highest accuracy serve to independently monitor the height component on selected GPS permanent stations and in coastal gauge points.

### Link to Global Reference Systems

Within the scope of the Research Group Satellite Geodesy (FGS), the BKG operates together with the Research Institution Satellite Geodesy (FESG) of the Technical University of Munich - the Fundamental Station Wettzell. Through these efforts, Germany contributes considerable to the international services of the International Association for Geodesy (IAG), predominantly with the goal to realize global reference systems. In particular, IAGcoordinated. observations regular are performed.

Apart from observations on the Fundamental Station Wettzell, since May 2002 the BKG operates - together with a Chilean consortium -Transportable Integrated Geodetic the Observatory (TIGO) in Concepción, Chile. TIGO, developed in Wettzell, is equipped with VLBI, SLR, and GPS-GLONASS receivers as well as local sensors, like gravimeter and seismometer. On the Antarctic station O'Higgins, which is operated commonly by the BKG and the German Aerospace Center (DLR), **GPS/GLONASS** observation VLBI and campaigns are performed.

Within the FGS framework, the BKG futhermore contributes to international IAG services through data gathering, holding, and analysis. Through its participation in IGS activities, the BKG maintains various continuously operating GPS stations which are included in national, continental, and global networks as well as a regional data center, which administers the European IGS stations in the main focus. Following the ILRS scope - apart from the analysis of the global observations - laser ranging data of the Fundamental Station Wettzell and of TIGO are examined.

Within the IVS, the BKG provides observations from the Fundamental Station Wettzell, from TIGO, and from O'Higgins. It runs one of the three global IVS data centers and is one of the six IVS analysis centers operating world-wide.

Since 2001 the Central Bureau of the International Earth Rotation Service (IERS) is located in Frankfurt. This IERS CB operates a data and information center which conveys IERS product information as derived through complex observation and evaluation procedures. The new IERS CB information center aims to serve its international user community reliable and always in time. Apart from editing and providing information in digital printed form, the IERS CB has and responsibility for various periodic reports and Workshops and meetings minutes. are organized to practically realize scientific insights, new definitions of standards and resolutions for the IERS product and research centers as well as other IAG services.

At the Center for Orbit Determination in Europe (CODE) the BKG participates in the determination of precise GPS orbits. The determination of weekly precise GLONASS orbits is carried out in Frankfurt within the context of the International GLONASS Experiment (IGLOS).

As EUREF Analysis Center for the European Permanent Network EPN, the BKG contributes to the maintenance of the uniform European reference system ETRS89, the system recommended by the European Commission. Coordinates and troposphere parameters, as estimated from national subnetworks, are combined into one uniform continental EUREF solution. While coordinating the data analysis, the BKG has the responsibility to continuously maintain and improve the already reached high level in product accuracy and reliability.