National Report of Germany on EUREF

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GPS Reference Network GREF

The coordinates for the GPS reference network GREF, which are derived from daily evaluations and published weekly as mean values, form the national contribution of Germany to a European overall solution. It is combined with a EUREF combination solution at BKG together with the inclusion of 14 further national partial solutions of other European states. In parallel with the coordinate determination tropospheric signal path delays are estimated from the GPS observations. The Europe-wide combination of these troposphere parameters constitutes a new task that has been performed since June 2001. Through a financial support of the "Centre for Orbit Determination in Europe" (CODE) BKG participates in the supply of the necessary precise GPS satellite orbits by the "International GPS Service (IGS)". Precise orbits of the Russian GLONASS satellites are independently determined within the scope of the "International GLONASS Service" (IGLOS). The nationwide activities are regionally spatially supported by the quarterly integration of the SAPOS reference stations of the German States *(Länder)* into the networks GREF, EUREF and IGS. Connected to the evaluation processes is a GPS/GLONASS database which receives the observations of the projects GREF (including SAPOS data of the States), EUREF (function as EUREF Data Centre), IGS and IGLOS (function as Regional IGS Data Centre for Europe).

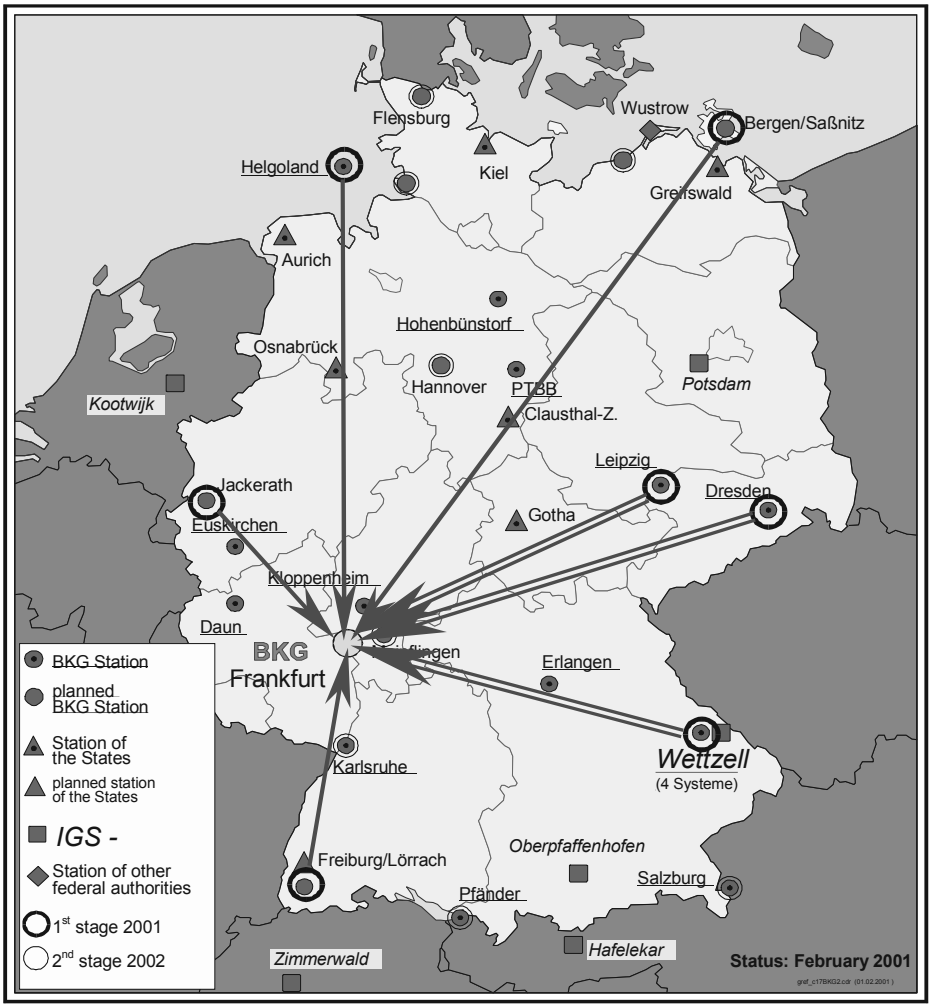

Fig. 1: Status of real-time networking of GREF

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The work carried out for integrating the SAPOS stations of the German States into the networks of GREF, EUREF and IGS started in 1999. Today, 13 States participate, on the basis of bilateral agreements, in this service which was established by BKG and which is performed on a quarterly basis. Besides the derivation of station displacements for realizing a high-precision nationwide uniform system the objective consists in monitoring the SAPOS stations within the scope of a quality management. The stability of single stations is checked by a time series presentation of the coordinates of the SAPOS stations for all available measurement epochs. For the future it is planned to perform a simultaneous nationwide evaluation of all available SAPOS stations "as a whole" instead of a State-wise evaluation.

The German GPS/GLONASS real-time network constitutes the result of a technological modernization and further development of the existing GREF network. The reference stations are starshaped connected to the Central station at the BKG Frankfurt. Modernisation and further development/ upgrading is realized in the partial components

- GPS/GLONASS receivers and meteorological stations in the reference stations
- GPS/GLONASS networking software in the central station
- data communication via dedicated lines (Internet, ISDN)

The data supply for users (RTCM), RINEX, coordinates) is realized via Internet, ISDN dedicated lines and long wave. The data are marketed according to the regulations on user charges/fees for SAPOS.

Satellite Positioning Service of the German National Survey SA*POS*®

Establishment of the Satellite Positioning Service SA*POS*® of the German National Survey has almost been completed. A network of multifunctional permanently operated GPS reference stations delivers data for Differential GPS (DGPS) which makes positioning for various application fields possible for the respective user. Depending on the used equipment, accuracies from the meter range up to centimeter-accurate results can be reached, for which purpose various service areas with different characteristics are established.

Figure 2 gives an overview of the status of set-up of the SA*POS*® reference stations for the Federal Republic of Germany. Presently (May 2002), 95 % of the planned SA*POS*® reference stations are in operation.

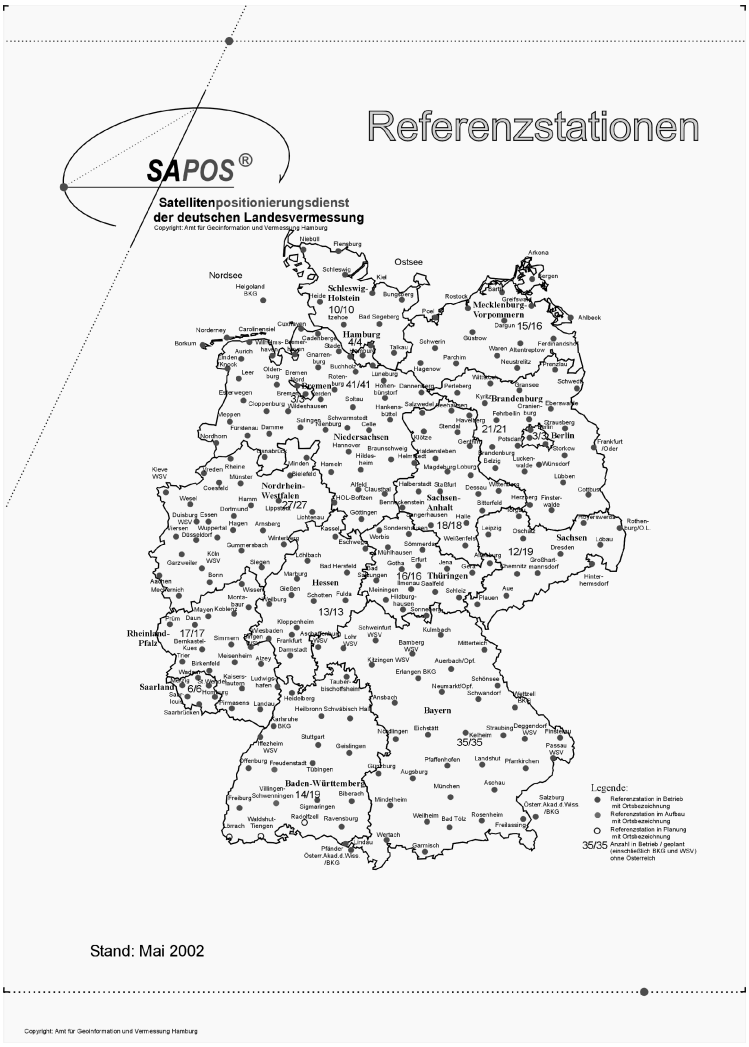


Fig. 2: Overview of the SAPOS® reference stations in the Federal Republic of Germany

In most countries an online networking of the reference stations is established. With the place- and time-dependent correction data, which can be individually calculated from that basis, the accuracy and reliability of positionings has further increased. The status of setup of the networking is about 89 % in May 2002. By the end of 2002 the networking shall be established for the whole of Germany all over the country. At present, SA*POS*® is probably the worldwide largest area with networked DGPS data for real-time solutions.

The concept for the uniform networked high-precision real-time positioning service SA*POS*®-HEPS was finalized. Mobile radio serves as medium for transmitting the correction data to the user (SA*POS*® standard duty). SA*POS*® standard option is the transmission via 2 m band. The data format for the user interface is RTCM Version 2.3 for SA*POS*® standard duty is the data type 20/21, SA*POS*® standard option are RTCM-AdV and RTCM Version 2.3, data type 18/19. The SA*POS*® duty standards shall be introduced in the Federal States by 30th June 2002.

Furthermore, the online networking of the reference stations will be introduced as SA*POS*® standard duty, in fact also beyond the State boundaries. The technique of Area Correction Parameters (FKP) is SA*POS*® standard duty, the technique of Virtual Reference Station (VRS) is SA*POS*® standard option. The networking shall be realized in the Federal States by 31st December 2002.

In the Technical Committee SA*POS*® the cooperation of representatives of AdV with the manufacturers of GPS hardware and software and communication technology was continued. Format definitions were agreed and arrangements were made concerning SA*POS*®-compatible products.

Uniform Height System for Germany

After the unification of Germany in 1990 it was necessary to introduce a uniform height system for the whole of Germany. In the old West German States normal orthometric heights with the name "heights above sea level (NN, German reference surface)" were used; in the newly formed German states normal heights in the level of the gauge Kronstadt (near St. Petersburg) were valid. With the name "German Primary Levelling network 1992 (DHHN 92)" a uniform height system on the basis of the latest precise levelling was established in each of the old and newly formed German States. The heights were calculated as normal heights according to the theory of Molodensky with the normal gravity formula of the Geodetic Reference System 1980 (GRS 80) in the level of the former gauge Amsterdam. The heights, which were calculated in the system of the DHHN 92, are named "heights above Normalhöhennull (NHN, level datum of DHHN 92)". The differences between the previous height systems and the DHHN 92 may reach values of several decimeters.

Since 1st January 2002 the system of normal heights in the system of the DHHN 92 has been completely realized in the newly formed German states. The state of work in the old German states is varying. For about one third of all vertical control points located in Germany heights about NHN are all in all already available.

The determination of the quasigeoid, which was started in 1993, is being performed as joint work with the survey authorities of the States.

Concerning the quasigeoid of the Federal Republic of Germany the foundations have been laid for the transition between ellipsoidal heights in the ETRS89 and normal heights in the DHHN92 with an accuracy of 1 ... 2 cm.

It holds the equation:

$$H^{DHHN} = h^{ETRS} - \zeta^{ETRS}_{DHHN}$$

The conversion is possible nationwide without local corrections.

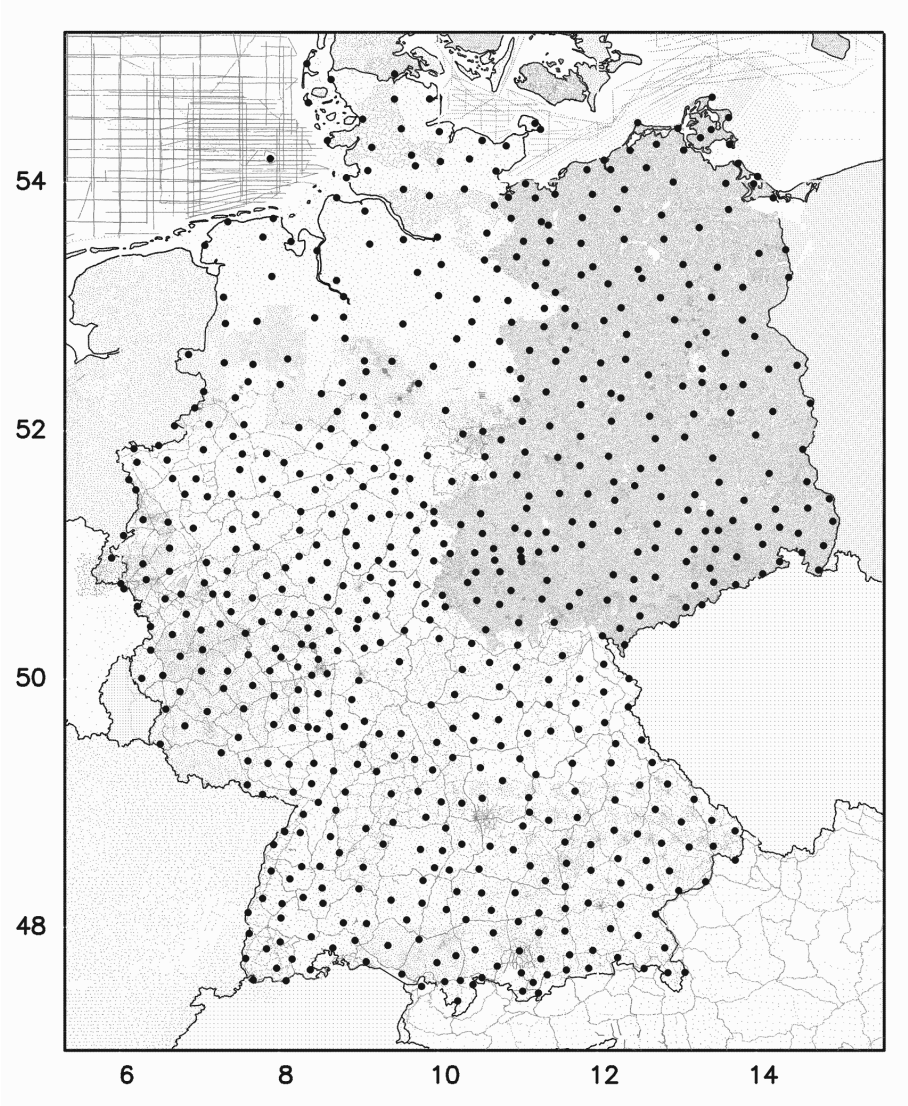
Using SAPOS, normal heights can be derived in the DHHN92 in real-time. For the determination of the quasigeoid the following data were used:

- 650 satellite geodetic levelling quasigeoidal heights (ζ_{SN}) derived from GPS heights (2 x 24 h measuring time) in ETRS89 and normal heights in the DHHN92 (σ = 1,5 cm)
- Mean gravity anomalies (Δg_F) derived from 250 000 point gravity values (σ = 1 mGal)
- Digital terrain model, basic resolution 30 m x 30 m
- Geopotential model EGM96.

The technique is based on the adjustment of point masses in connection with a Remove-Restore technique. A spherical function development of the disturbance potential first reduces the gravity anomalies and quasigeoidal heights:

- quasigeoidal heights fit the reference systems ETRS89 and DHHN92

The accuracy of the geoid model is (standarddeviation): in plains 1 cm, in highlands 2 cm, in high mountains 4 cm.



Satellite geodetic levelling quasigeoidal heights and point gravity values