RECENT STEPS TOWARDS THE INTRODUCTION OF ETRS89 IN AUSTRIA

UVAJANJE ETRS89 V AVSTRIJI

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ABSTRACT

The introduction of ETRS89 in Austria is done in two steps: on the one hand homogeneous ETRS89 coordinates can be determined by using APOS – the Austrian Positioning Service. On the other hand the existing inhomogeneous coordinates of the control points are transformed by means of measurements and calculations. The current state of the work is given in the paper.

IZVLEČEK

Uvajanje ETRS89 v Avstriji poteka v dveh korakih: po eni strani se poenotene ETRS89-koordinate določa z avstrijskim državnim sistemom za zagotavljanje popravkov opazovanj (APOS). Po drugi strani pa obstoječe nehomogene koordinate kontrolnih točk transformiramo s pomočjo meritev in izračunov. Članek obravnavava trenutno stanje na tem področju.

KEY WORDS

Reference Frame, ETRS89, Austria, Homogenization, Militär Geographisches Institut (MGI), Austrian Positioning Service (APOS)

KLJUČNE BESEDE

referenčni sistem, ETRS89, Avstrija, poenotenje, avstrijski vojaško-geografski institut (MGI), avstrijski državni sistem za zagotavljanje popravkov opazovanj (APOS)

1 INTRODUCTION

The application of Global Navigation Satellite Systems (GNSS) as high-precision three-dimensional measuring systems since the middle of the eighties of the last century has brought about many changes and has had consequences in fields such as:

- set-up of reference systems in general,
- determination of coordinates,
- simplification of the international exchange of geo-referenced data,
- development of completely new business areas (precise farming, GNSS controlled machines, time services, etc.).

At the same time weak points in the existing geodetic control networks became apparent which up to now had played a minor role:

- coordinate systems, established by trigonometric measurements with bad network design and without taking into account the influence of gravity (deflections of vertical),

- height systems that were not exactly defined (without consideration of gravity).

The Bundesamt für Eich- und Vermessungswesen – BEV – stayed abreast of these developments by taking the following measures:

- realisation of a national 3-d reference system (reference frame), which is a realisation of ETRS89 and consists of active and passive stations (Höggerl, N. et al., 2002),
- development of APOS (Austrian Positioning Service),
- improvement of the existing geodetic control networks by initiating and implementing the projects „Homogenisation of the Network of Control Points", „New Height System" and „Geoid2007".

2 ETRS89 – EUROPEAN TERRESTRIAL REFERENCE SYSTEM 89

ETRS89 was defined as the European reference system by the EUREF sub-commission at the annual meeting in Florence in 1990 (Gubler, E., et al., 1992). By definition the ETRS-coordinates of the reference stations at the time 1989,0 were set equal with the coordinates of ITRS 1989,0.

For each realisation ITRFxx of ITRS exists a realisation ETRFxx of ETRS89. All these are connected by transformation parameters (Boucher, C., Altamimi, Z., 2001). The rotation of the Eurasian Plate is thus eliminated. Due to the Continental drift of Europe of approx. 2.5 cm / year, this led to a divergence of the coordinates between ITRS and ETRS89 of approx. 0.45 m. Since 1993 the realisations in ETRS89 have differed by approx. 0.02 m, if one looks at the stations on the "stable" part of the Eurasian Plate. In the year 2000 Eurogeographics, which represents the European National Mapping and Cadastral Agencies gave out the recommendation to use ETRS89 as a basis for the up-dating of the national coordinate systems (Spatial Reference Workshop, 1999). Until the year 2011 approx. 60% of the European countries will have followed this advice (Torres, J. A., Ihde, J., 2006). Austria has also decided to introduce ETRS89 as the future reference system for national mapping and surveying.

The following hierarchic order was chosen for the determination of ETRS89 reference frame in Austria (Höggerl, N., 2005), see Figure 1:

- EUREF-stations (EPN-stations and Class B-stations in Austria),
- APOS-stations (incl. the stations in the neighbouring countries),
- GPS basic network (AGREF/AREF – Austrian Geodynamic Reference Frame/Austrian Reference Frame),
- control points 1st–6th order.

The determination of EUREF/EPN- and APOS-station coordinates is routine work, which leads to weekly results. The initial coordinate values are taken from ETRF-Austria2002, which is a solution that was accepted by the EUREF sub-commission (Stangl, G., et al., 2004). There is also a final solution in ETRS89 for the GPS basic network, which refers to the EUREF- and APOS-station coordinates. Currently the remeasurement and the recalculation of the control points of 1st–6th orders is going on. The homogenized coordinates of the control points 1st–6th orders serve as a basis for the partial transformation of the cadastral points into ETRS89.

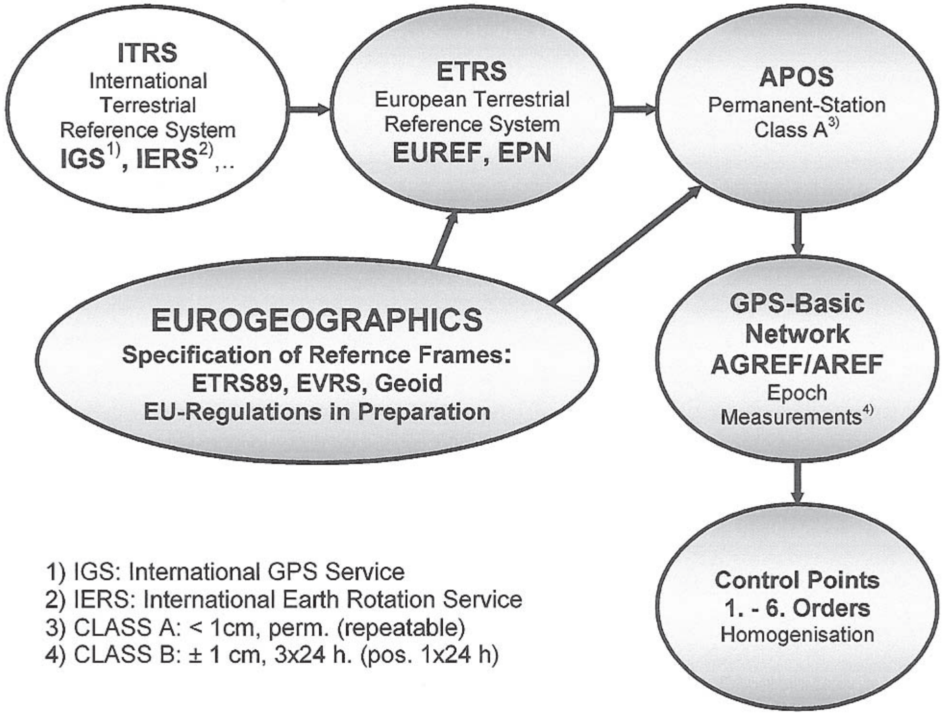

Fig. 1: *Hierarchic Schema for the Introduction of ETRS89 in Austria.*

3 APOS – AUSTRIAN POSITIONING SERVICE – FOR THE DETERMINATION OF ETRS 89 COORDINATES

3.1 Ground Segment and Data Processing

The APOS reference station network currently consists of the stations of the BEV (34), of the Austrian Academy of Sciences – ÖAW (3) and of the Carinthian Electricity Company – KELAG (8). By the end of 2007 the whole territory of Austria will be covered by APOS. To increase the redundancy of reference stations close to the Austrian borders as well as to homogeneously connect APOS with the real-time positioning systems of the neighbouring countries, the data of reference stations close to the borders are exchanged. Within the frame of the international D-A-CH Treaty signed by Germany (Baden-Württemberg and Bavaria), Austria and Switzerland it was agreed that the providers of SAPOS, SWIPOS and APOS exchange GPS-raw data. Data streams are transferred by VPN – Technology (Virtual Private Network) via internet to the central office in Vienna. In return APOS delivers data from 12 Austrian stations to SAPOS and SWIPOS. The cooperation with the Slovenian GPS service SIGNAL (5 stations), the South Tyrolean GPS Service STPOS (3 stations), as well as the Slovakian GNSS service SKPOS (2 stations) are based on similar agreements. In addition to this, there is a mutual data exchange with the Czech Republic and Hungary, which is in a testing phase at the moment (Figure 2).

The GPS raw data are prepared at the service centre of the BEV using GPSNet Software by Trimble.

The network solution for the reference stations and the different correction parameters (satellite coordinates, satellite clocks, ionosphere ...) are calculated by this software.

Fig. 2: *GNSS permanent stations, used in APOS .*

3.2 Data Providing and Users of APOS

APOS has been officially started in May 2006. At first the data were provided via GSM (mobile phone) and since 2007 they have additionally been provided via UMTS/GPRS (mobile internet). Furthermore, RINEX data are being stored for post processing applications and delivered to the customers (Höggerl, N., et al., 2007).

At the moment APOS is used by approx. 200 registered customers for real time measurements. The biggest part of the customers are from the surveying business (private and public bodies), but also a lot of electricity companies as well as operators of cable cars and university institutes use APOS. RINEX data are nearly exclusively used to geo-reference aerial pictures or laser scanning flights. In 2006, about 500 orders with a data volume of 6.4 GB were placed.

3.3 Application of ETRS89

The use of ETRS89 coordinates for the APOS reference stations was made public by the BEV in 2003 (AVerm, 2003) and started with the 1st of January, 2004. That means that all users of APOS (real time or postprocessing) receive coordinate values that already refer to ETRS89. APOS provides an efficient service for the determination of 3-d coordinates with a homogeneous absolute accuracy for Austria of ± 2cm for the position and ± 3.7 cm for the height. The comparison of coordinates of the permanent stations of the neighbouring real-time positioning services shows differences of < 1.5 cm (derived from long-term measurements).

4 REFERENCE SYSTEM OF THE »MILITÄR-GEOGRAPHISCHES INSTITUT« (MGI)

4.1 Historical Development

In Austria the control points and the cadastre have a more than 100-year-old history. The control points represent the national system MGI (Ellipsoid of Bessel, Gauß-Krüger Projection), which is still in use today (Gebrauchssystem). Due to the long time span during which coordinates have been determined, their quality differs considerably. Consequently, in former times the official coordinates of the control points as well as of the boundary points used to be less accurate than the new measuring techniques offer. Today inhomogeneities can be detected with high accuracy.

The "Survey Act" of 1969 (Vermessungsgesetz, 1969) states that all measurements for cadastral purposes have to be connected to the neighbouring control points to minimise the influence of local distortions. For this purpose a large number of control points has been established during the last 40 years:

- 60,000 1st to 5th order points
- 270,000 6th order points

That is an average density of 4 control points per km^2 in Austria.

4.2 Errors in the Coordinates of the Control Points

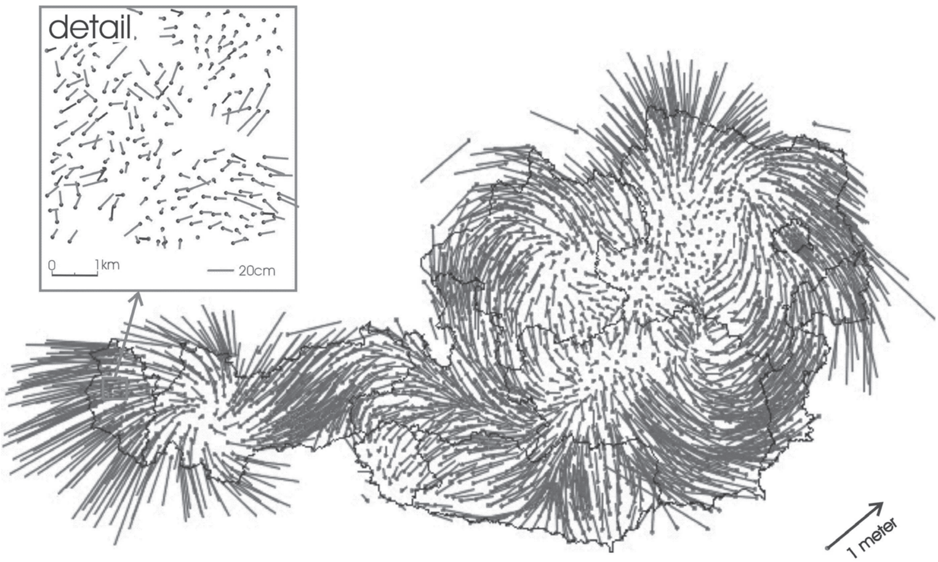

Fig. 3: *Inhomogeneities of the control points 1st to 3rd order (detail: 4th to 6th order).*

The control points 1st to 3rd order have another error characteristic than the 4th to 6th order points (Figure 3).

Adjusting the observations of the 1st to 3rd order points on the basis of ED87 and transforming the coordinates (one set of 7 parameters for Austria) to the system of MGI, leads to differences up to 1.5 metres in some regions. The main cause for it is that in the past the adjustment of the 1st order network was not done in one step. If the differences of the coordinates are used in a mathematical model, ETRS89 coordinates of 4th to 6th order control points can be determined with an accuracy of ±10 cm. This is sufficiently accurate for most GIS applications.

For the 4th to 6th order points the differences are not as systematic as for the 1st to 3rd order points. Differences between neighbouring points of up to 20 cm and more can occur. There are different reasons for this effect. One reason is that in the past only small blocks were observed and adjusted. Because of the topographical possibilities the net design was not always the best. Until 1988 deflections of the vertical were not taken into account. In Austria there are values up to 10 mgon for the deflections of the vertical. In some cases the position of the point is not stable because of landslides, subsidence or problems with demarcation. Furthermore in the past photogrammetric methods (aero-triangulation) were used for the determination of coordinates.

In addition, about 20,000 changes of coordinates during the last 50 years give evidence that a lot of experiments have been made to get coordinates of good quality. Nevertheless, today it is obvious that the adjustment of new measurements in an inhomogeneous system is not the right way to solve the problem.

5 HOMOGENIZATION OF THE CONTROL POINT NETWORK

5.1 Project Plan

To grant the user complete access to the advantages of satellite supported measurements, it is thus necessary to take into account the errors of the “Gebrauchssystem” (system in use) or to remove them. There are different possibilities to solve the problem:

- complete resurvey of the network of control points,
- partial resurvey and modelling of the errors in the remaining areas,
- partial resurvey and use of existing trigonometric and distance measurements.

Intensive analysis led to the decision to apply the last-mentioned solution. A coarse mashed network of GPS-measurements supports the rest of the network and minimizes the defects of the network. All observations from earlier triangulations are stored in an observation database and used to readjust the rest of the points. A lot of preparatory work is needed for the recalculation.

- measurement of approx. 30,000 control points 1st–5th orders,
- resurvey of control points of 6th order, which were determined by aerial photogrammetry,
- resurvey of another 50% of control points of 6th order,
- digitising the old trigonometric measuring data,

- establishing the history of points by taking into consideration different local reference points which might have been used at different epochs of measurements,
- taking into account changes in nature (landslides).

It is the aim of this work to get improved coordinate information for each single control point 1st –5th (6th) orders in the MGI system as well as in the ETRS89/UTM system. The improvement of the currently used coordinates in comparison to the homogenised coordinates will be provided as "homogeneous vectors". These homogeneous vectors offer the possibility to convert the coordinates of the system in use (Gebrauchssystem) to the new ETRS89/UTM coordinates and vice versa (see Figure 4).

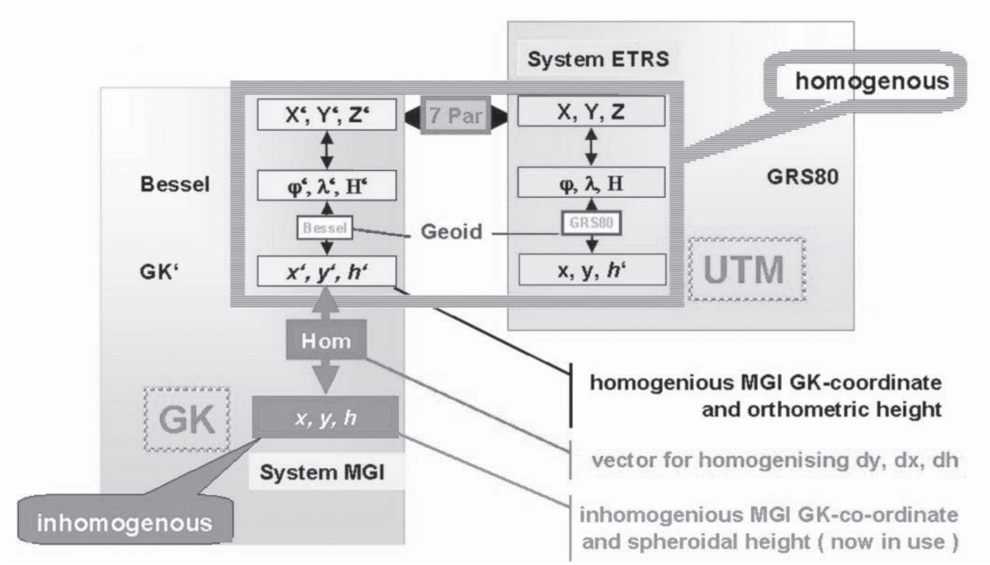

Fig. 4: *Reversible connection between ETRS89 and MGI.*

5.2 Realisation of the Homogenization of the Field of Control Points

The calculation of the improved coordinates of control points of the 1st to 5th orders is done in 2 steps:

- Adjustment of the statistic GPS vector measurements using the ETRS89 coordinates of the 65 APOS reference stations and the approx. 400 points of the GPS basic network (AGREF and AREF) as basic values;
- Adjustment of the terrestrial measurements (from the years 1920 to 1994), whereas the ETRS89 coordinates of the points determined by GPS are used as basic values.

For the control points of the 1st to 5th orders 90% of the measurements and 100% of data capturing are finished. All the data are stored in a database. The missing 10% of measurements will be finished by 2009 and the calculation procedures should be finished by 2010/11.

160,000 control points of the 6th order will get ETRS89 coordinates by measurements with APOS-RTK; by 2007 it was possible to finish 25% of the work. The control points of the 6th order that cannot be measured will be transformed.

6 HOMOGENIZATION OF THE CADASTRE

At the moment it is necessary to connect all measurements for the cadastre (done by GPS and/or classical methods) to the closest control points. These control points are used to determine the coordinates of the cadastre points in the present "system in use". But this also means that the homogeneous ETRS89 coordinates, determined by APOS, have to be put into the deformed "system in use" by constraint.

The cadastre will be homogenised by means of transformation algorithms, which have to have special properties such as rectilinearity or rectangular constancy. Additionally, the software has to be able to process varying historical point data. At the moment we are examining which software is most qualified for the transformation of the approx. 100 million cadastre points. The cadastre points are already available in digital form and build up the digital cadastral map, which is constantly up-dated.

The homogenization of the cadastre will surely take another decade and will not only require technical but also legal preparations. These preparations have already begun by implementing a simplified procedure for an overall change of coordinates for a whole cadastral unit.

7 SUMMARY

By building up APOS – Austrian Positioning Service, an infrastructure was created that facilitates the determination of three-dimensional coordinates in real-time for the whole territory of Austria with an accuracy of ± 2 cm for the position and ± 3.7 cm for the height. The APOS coordinates refer to ETRS 89 and thus facilitate the international exchange of data.

However the application of GPS/GNSS for the determination of three-dimensional coordinates shows the errors in the classically determined control points, too. For Austria these errors are 1.5 m and locally (1–3 km) still 0.1 to 0.2 m. To erase these errors extensive GPS measurements have been carried out on the control points and adjusted together with the existing terrestrial measurements. Homogeneous coordinates for the 60,000 control points of 1st to 5th orders in the ETRS89 system will be ready by 2011, for the 160,000 control points of the 6th order some years later. The cadastre coordinates will have been transformed into ETRS89/UTM by 2017.

After the homogenisation has been finished the number of control points will be reduced by 85–90%.

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