EUREF 14: National Report of Austria

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1. Permanent Networks

Over parts of Africa, Asia and Europe five networks of permanent GNSS stations are monitored in post-processing mode by the Federal Office of Metrology and Surveying (BEV) and the Austrian Academy of Sciences. EUREF (sub-network of the EPN, 95 stations, started 1996) and AMON (East Alpine Region, including APOS stations, 85 stations, started 2001, year 2006 reprocessed) are designed to realize the reference system ETRS89 whereas CERGOP (Central European Geodynamics, 85 stations, started 1999), GREECE (95 stations, started 2013) and MON (Plate Boundaries in the Eastern Mediterranean, 70 stations, started 2000) focus on geokinematics. At least once a year the cumulated time series of all networks except EUREF are analysed. The main product of the analysis is the file of station velocities. All networks are processed on a weekly basis according to the EPN guidelines by the OLG group. GREECE is too new to deliver reliable station velocities. The three earthquakes in January 2014 around Kephallinia show up in the time series of one station (Fig. 1) at GREECE and at MON as well. Because the national reference frame relies still on the EUREF campaign of 2002 and was only transformed to a version of 2008 to include absolute calibration values, the corresponding velocity residuals with respect to the Eurasian Plate are also transformed to ETRF2000 (Fig. 2, horizontal and vertical components).

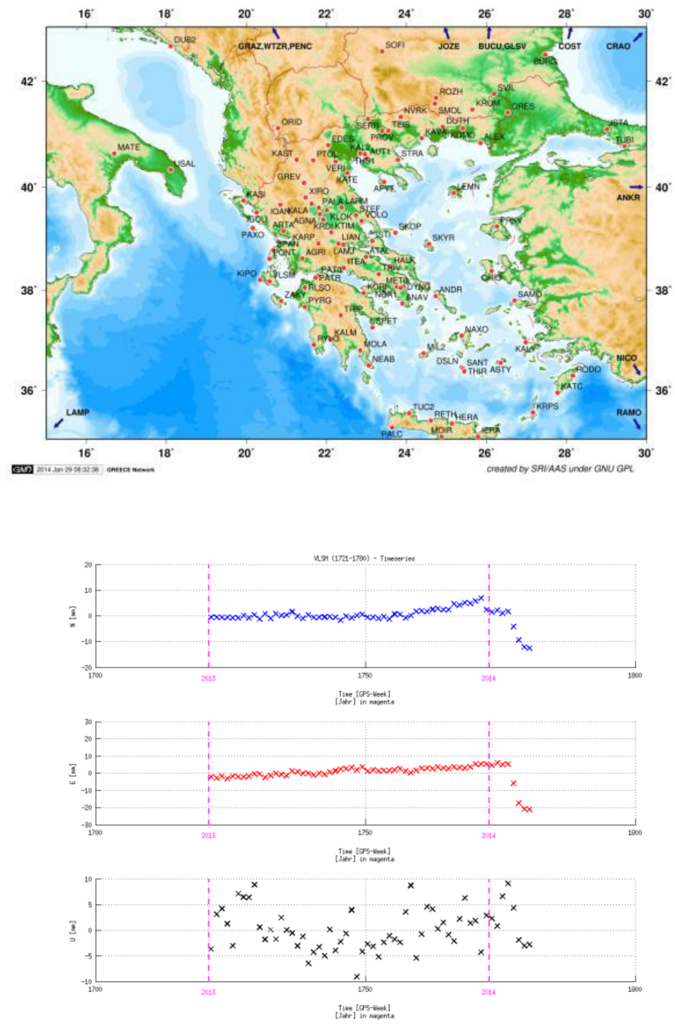

Fig. 1: Map of the network GREECE 2014 and the jump at VLSM after the earthquakes of January 2014

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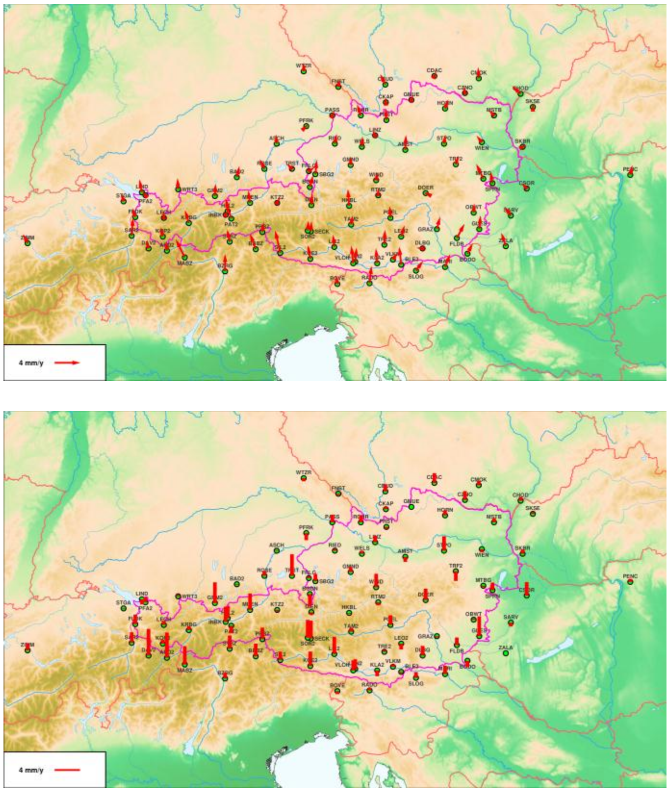

Fig. 2: Map of the network AMON with horizontal (above) and vertical (below) velocities of the cumulated time series 2000-2014

2. APOS - Austrian Positioning Service

2.1 APOS - Production System

The APOS reference station network uses raw data from about 70 stations operated by national and international associate partners (Fig. 3). By the end of 2013 national associate APOS partner KELAG (Kärntner Elektrizitäts - Aktiengesellschaft) had replaced the station Sonnblick by the new station Schareck which is situated within of a few kilometres from the first site. An on-the-roof repositioning of the station Sillian was necessary due to the installation of solar panels by the local municipality. The upgrading of the central software from Trimble® VRS³net to the new Trimble® Pivot Platform (TPP) was completed at the beginning of 2014. Further tasks for 2014 will include the migration to a virtualized APOS IT-infrastructure.

2.2 APOS - Monitoring Aspects

Three permanent APOS RTK monitoring stations in different topographic areas of Austria are operating now.

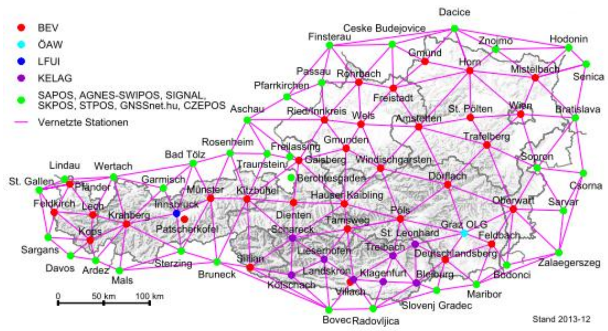

Fig. 3: APOS - reference station network (status 2013-12)

These stations are not part of the productive real-time system and work like customers' mobile roving equipment. Once per minute the receivers connect to APOS in VRS mode and calculate individual RTK positions which are then compared to the well known post-processing position results. The comparisons show a ± 0.5 – 0.7 cm mean RMS of the horizontal components and ± 2.0 – 2.5 cm of the vertical component. The TPP 2.5.9 software update leads to more accurate results compared to the former VRS³Net 1.4.8 solutions. Nevertheless in the mountainous areas in the western part of Austria the systematic height effects can amount to dm height deviations, which are caused by the enormous height differences (> 1500 m) between reference stations and typical rover measurements. To improve future RTK height measurements APOS started in May 2014 to cooperate with the German colleagues of SAPOS Bavaria and Trimble to take part in the development and testing of advanced 3D height interpolation methods for mountain areas.

2.3 APOS - Commercial Aspects

Up to now about 700 customers (Fig. 4), respectively more than 1600 accounts of "APOS Real Time" in all kinds of working fields have registered, i.e. a growth rate of 21% compared with 2013. By August 2013 nearly 8700 online hours had been reached. The demand for access to "APOS Real Time" via GSM/CSD decreases steadily and the biggest of the Austrian mobile communication providers announced to terminate this service by the end of 2015.

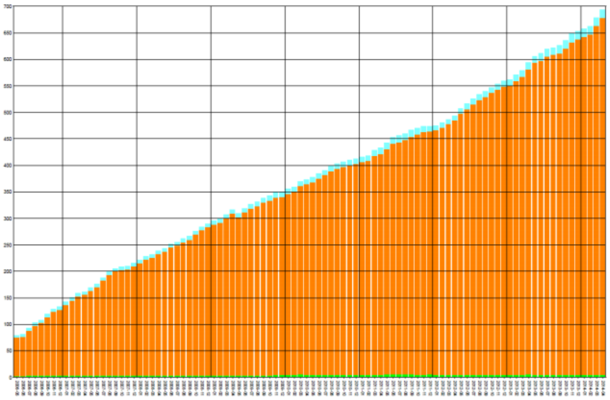

Fig. 4: APOS - customer accounts over the period 2006-06 to 2014-04: blue - external/free of charge, orange – external, green (bottom-line) - internal

3. Gravimetry

In 2013 absolute gravity observations were continued at the stations Obergurgl and the ECGN[4] stations Graz and Trafelberg (TRFB). The ECGN station Pfaender (PFAN) could not be used in 2013. The BEV also took part in the second international key comparison in Walferdange / Luxemburg with its absolute gravimeter FG5/242. Further the results of the European Comparisons of Absolute Gravimeters 2011 were published in Metrologia 50.

3.1 Station Obergurgl

Since 1987 the BEV has operated the absolute gravimeter JILAg-6 at Obergurgl/Tyrol. Since 2010 the absolute gravity measurements in Obergurgl have been continued with the new absolute gravimeter FG5/242. The 27 years of gravity monitoring show an increasing absolute gravity, which is mainly caused by glacier ablation in the Alps (global warming)[5]. The difference between spring and autumn measurements on an average is 5 microgal, which shows the influence of the snow load signal on gravity. The offset between JILAg-6 and FG5-242 is around 15 microGals, but both gravimeters show the same trend concerning increasing gravity and the seasonal signals.

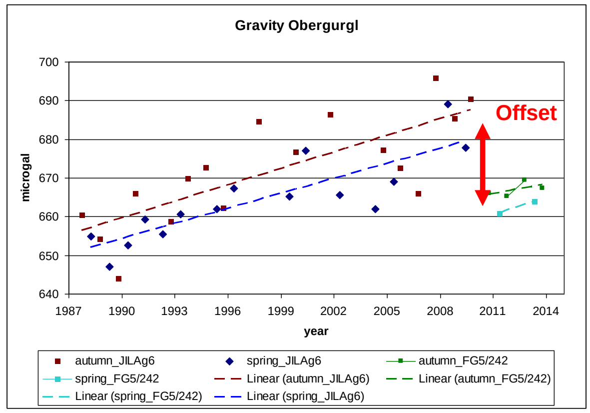

Fig. 5: Gravity data series at Obergurgl/Tyrol at an elevation of 1935 m ASL

Fig. 6: Situation of the absolute gravimeter station Obergurgl/Tyrol

[4] **E**uropean **C**ombined **G**eodetic **N**etwork (http://www.bkg.bund.de/geodIS/ECGN/EN/Home/homepage__node.html__nnn=true)

[5] P. Arneitz, B. Meurers, D. Ruess, C. Ullrich, J. Abermann, M. Kuhn: Gravity effect of glacial ablation in the Eastern Alps – observation and modelling. The Cryosphere 03/2013; 7: 491–498.

3.2 European Comparison of Absolute Gravimeters

The BEV maintains the Austrian standard for gravimetry, which is submitted to international comparisons. All these applications require high accuracy and a precise description of the measurement uncertainty. Such campaigns have been organised eight times at an interval of approximately 4 years at the BIPM in Sévres/Paris since 1981. Since 1989 the Austrian absolute gravimeter JILAg6 has participated six times in the ICAG at the BIPM in Paris and two times in the ECAG in Luxemburg. Since 2003 the Luxembourg European Center for Geodynamics has organized the European Comparisons of Absolute Gravimeters (ECAGs) three times. Since 2010 the absolute gravity measurements in Austria have been continued with the new absolute gravimeter FG5/242. The FG5 of the BEV participated already in the ECAG 2011[6] and the ICAG 2013 in Luxemburg.

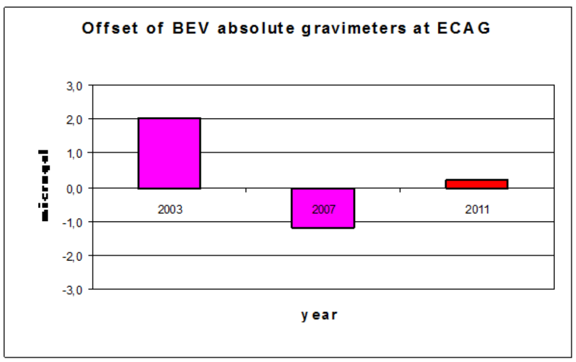

Fig. 7: Offset of absolute Gravimeters of BEV at ECAG: JILAg-6 (2003 and 2007); FG5-242 (2011)

4. Precise Levelling

In 2013 repeated precise levelling could be continued just for a section of 60 km due to limited capabilities / capacities (Fig.8). Additionally a new precise levelling line of 17 km length at the Austrian – Hungarian boundary along the Hanság channel (Einserkanal) could be prepared, which will be levelled in 2014. The aim is to establish a new GPS-levelling point at the south-east edge of the Austrian "Seewinkel" to fix the Geoid there. The BEV supports the project "GeNeSEE", a new geodetic survey of the Lake Fertő – Hanság-canal system[7]" which is a common project of Austria and Hungary and supported by the EU to improve the knowledge of the hydrological situation of Neusiedlersee region. The existing precise levelling lines around the lake provide the background for investigations using modern media like airborne laser scanning (Fig. 9).

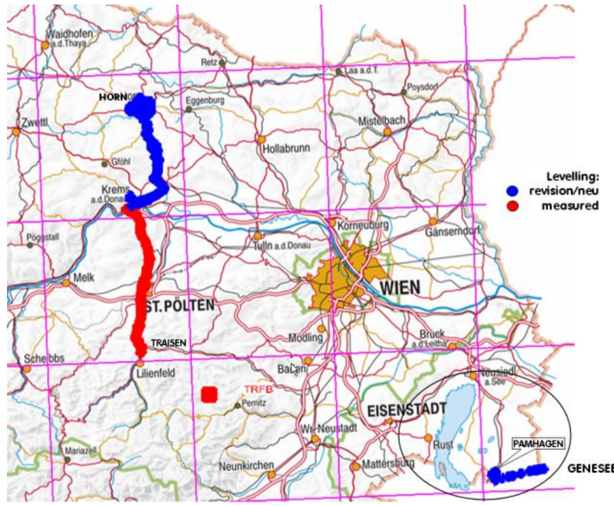

Fig. 8: Precise levelling activity in Austria 2013

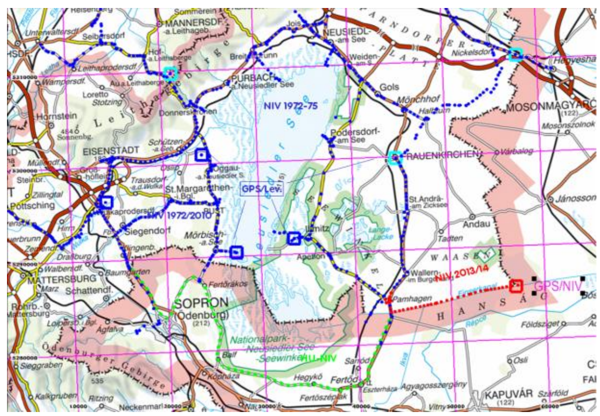

Fig. 9: Background of the project GeNeSEE

5. Kinematic Height Adjustment

The Federal Office of Metrology and Surveying (BEV) and its predecessor institutions have been levelling for more than 100 years. It all started with the European arc measurement in 1871. The average water surface elevation at Molo Sartorio became the datum valid for the whole Austro-Hungarian monarchy, for Austria the 1875 gauge is used as the datum. The system

6 Olivier Francis, et.al.: The European Comparison of Absolute Gravimeters 2011 (ECAG-2011) in Walferdange, Luxemburg: Results and Recommendations. *Metrologia* 50 (06/2013) 1–12)

7 http://www.at-hu.net/at-hu/en/projects.php?we_objectID=412

was based on spheroidal heights. Up to now there has been no free adjustment. Local and regional changes in time caused by physical processes (plate tectonics, landslides), could almost not be detected. The former adjustments were strictly fixed at the node points.

The project uses all survey data to check the quality of the node points which will also be handled as free variables. The method of levelling hardly changed during the last 150 years. Therefore the data can be combined easily and are comparable. The precision of the instruments has improved considerably, therefore the observations before 1939 will not be considered at the first stage. Of the remaining data 40 % still have to be digitized as shown in Fig. 10.

The adjustment is based on the observations from 1939 to 2014. All points which are observed in more than one epoch are used. Most of these points have two to three epochs, the maximum is eleven. To combine these observations the Dijkstra's algorithm is used to find the shortest distances for a common epoch. The redundancy of the observations allows to estimate individual velocities and to reference all points to a common epoch. From that orthometric heights can be computed by using gravity data. Thus the levelling data can be directly compared with geometrical heights derived by GNSS.

The adjusted heights will refer to EVRS 2007. For that the connection to the neighbouring countries and to UELN will be used. The results will then be available at the BEV. At a later stage of the project the results will be analysed if they can be compared to the movements derived from GNSS time series. Presently the first results demonstrate that the method and the data are promising. The first analysis will be done in 2014.

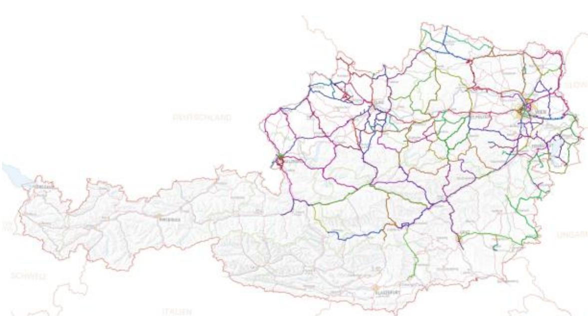

Fig. 10: Overview of the already digitized levelling data

6. Precise Geodetic and Astronomic Measurements at the Geomagnetic Observatory (GMO) of ZAMG

The knowledge of astronomical orientation is necessary for geomagnetic observations. Also the stability of the observatory building has to be checked by using geodetic methods. That’s the reason for stabilizing a network of geodetic benchmarks in and above the gallery of the GMO. The heights of the benchmarks are determined by precise levelling, the positions above using GPS and inside using a precise theodolite. The astronomical orientation is fixed by target boards (in German “Mire”).

The Conrad Observatory at Trafelberg is situated about 50 km south-east of Vienna close to Pernitz. As a second step after the seismic-gravimetric observatory the construction of the geomagnetic observatory started in 2010 and was finished in 2013. The complex consists of a 400 m long tunnel orientated North-South. Geomagnetic sensors were installed in several additional tunnels and cross connections to monitor long- and short-term variations (= “space weather”) of the geomagnetic field. At the northern intersection point there are 16 pillars which will be then used for orientation, calibration and international comparisons of magnetometers. The tunnels are all together 1000 m long.

Thanks to the close collaboration between ZAMG (Central Institute for Meteorology and Geodynamics) and the BEV (Federal Office of Metrology and Surveying) the geodetic survey was made by the Department Control Survey of the BEV.

6.1 Topics

- Determination of the azimuth for the orientation of the magnetometers
- Determination of the azimuths to target boards (“Miren“) inside and outside the gallery
- Primary fixing of benchmarks to verify the stability of position und height

6.2 Procedure

As the whole area has to be magnetically neutral, all stabilisation material has to be non-magnetic. Vertical benchmarks of fillister headed aluminium were used inside the gallery, outside there were stabilized brass benchmarks. The long - distance target ("Fernmire" at "Bettelmannkreuz") is made of a 2 m metallic rod in a concrete base about 2.4 km north of the gallery, it is used for periodic surveys of the orientations in the tunnel. The target boards in the tunnel were built based on the type used by the BEV.

6.3 Heights

The heights were determined using the digital levelling equipment Trimble-DiNi03. The levelling network is linked with the levelling benchmarks of the Seismic-Gravimetric-Observatory (SGO) and with the precise levelling network of the BEV. 52 new benchmarks were stabilized (42 inside, 10 outside). The levelling length of the loop through the gallery and back above is about 1600 m.

6.4 Positioning

The global position was measured twice at two points by GPS measurements over 24 hours on top of the south entrance and at the Bettelmannkreuz. Due to the duration of the measurement and the proximity to the EPN-Station Trafelberg (TRFB) the estimated inaccuracy of the ETRS - Coordinates is less than 2mm. The network was optimized using the program system PANDA (**P**rogram for **A**djustment of geodetic **N**etworks and **D**eformation **A**nalysis) for simulation. We did not only put emphasis on the accuracy to be reached, but also on the reliability, to discover measurement errors. The measurements were carried out using the precise total station Trimble S8 with two sets in both circle plains. All distances were measured by using target boards as well as reflectors. To minimize the uncontrollable influence of refraction, the points were put close to the axis and the measurements were taken at a time when outside and inside (all year about 7° C) temperature were quite similar.

6.5 Azimuth

The determination of the azimuth is done by astronomical observation of the Polaris on three benchmarks: southern portal, northern portal and a distant objective ("Bettelmannkreuz"). That makes two bidirectionally measured azimuths: gallery axis → long-term objective and northern portal → long-term objective. These measurements were carried out using the theodolite Kern-DKM3A.

Fig. 11: Pillars for geo-magnetic observations

Fig 12: Simultaneous observation 24h-GPS and terrestrial

6.6 Results

Heights: 52 benchmarks, levelling length ~ 1,600 m, loop error 0.15 mm.
Survey network: 33 network points + 29 detail points; Observations: Distances: ~230, Angles: horizontal ~250, vertical ~250.

Reached accuracy:

The semi major axis of error ellipse of network points is between 0.3 and 0.7 mm. The result reflects the expectations created by a previous simulation.

The accuracy of the azimuth from the southern to the northern portal is ± 1.3”. The observation of two survey points (northern portal and Bettelmannkreuz) is still not finished. The result will be improved.

This task was a very interesting challenge and enabled us to test the technical feasibility under laboratory conditions.

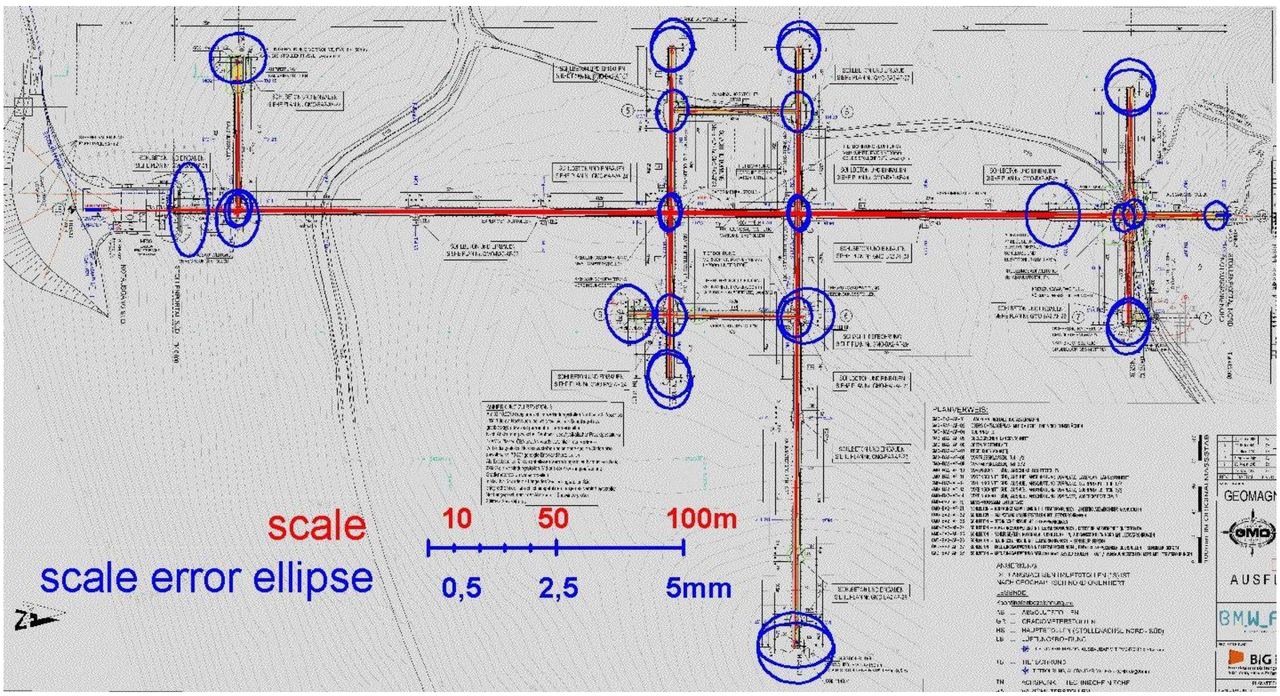

Fig. 13: Survey network and error ellipses