Homogenisation of the Austrian field of control points – preparatory work for a higher absolute accuracy in cadastre

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Abstract

Based on the points of EUREF all Austrian national control points will be calculated in the ETRS89 system using all measurements since 1920. The results will be used mostly to present the cadastre and other products in an international system best possible.

Through the common recalculation of all measurements of one point from different epochs we get information about any ground motion within time.

In the Western Austrian Provinces homogenisation is on the way and we do already have results. By means of APOS (Austrian Positioning Service) some points are controlled randomly to see whether the intended absolute accuracy of ±3cm (1σ) was reached. To homogenise the Austrian control points as a basis for the homogenisation of the cadastre and other GIS products will presumably take 2-3 years.

1. Present situation

In Austria the realisation of the European Reference System is used for the renewal of the field of control points as preparatory work for a higher absolute accuracy in cadastre. The following description shows how this work is done.

In Austria the history of the control points and the cadastre is more than 100 years old. In both fields the development finds its expression in the different qualities of the co-ordinates in the national system MGI (Ellipsoid of Bessel and the projection "Gauß Krüger").

We can state, that the quality of the official co-ordinates of the control points as well as of the boundary points is much lower than today with the new measuring techniques can be obtained. Today all the inhomogenities can be detected very accurately.

The inhomogenities in the co-ordinates are caused by different systematic errors. As control points are the base for all measurements (laid down in the Austrian Survey Act) their quality has a big influence on the quality of the cadastre. First I will try to describe these systematic errors and then the methods to eliminate them.

The "Austrian Survey Act 1969" (Vermessungsgesetz 1969) says, 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 network of control points (330.000) with a mean density of 4 points per km^2 has been established by the Federal Office of Metrology of Surveying (BEV) during the last 40 years.

Homogenisation means for us to eliminate systematic errors in the co-ordinates best possible. Thereby the relative accuracy among the control points as well as the absolute accuracy in a world-wide system is of great interest. In some other countries the expression PAI (Positional Accuracy Improvement) is used for this procedure.

2. Concept of homogenisation

Homogenisation is done in 4 phases.

The first step is to increase the absolute and relative accuracy of all control points based on the results of EUREF. This step will be described below.

The second step is to increase the absolute and relative accuracy of the cadastral map - since 2004 available digitally for the whole territory of Austria – and other derived products. For this step the results of step one will be used. A software-product to transform the whole content of the map is tested.

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The third step is to establish an RTK-system with permanent GPS-stations (APOS) to represent the future reference system in Austria. By 2006 the whole territory of Austria will be finished.

The last step - when the homogenisation is finished with almost the same absolute and relative accuracy and APOS is established - will be an essential reduction of the number of control points to about 10% of the present number. The reduction will depend on

- the need in urban regions, forests and in regions with landslides
- the further development of satellite based space techniques

3. Connection between ETRS89 and MGI

The task is to establish a reversible connection between both systems MGI and ETRS89.

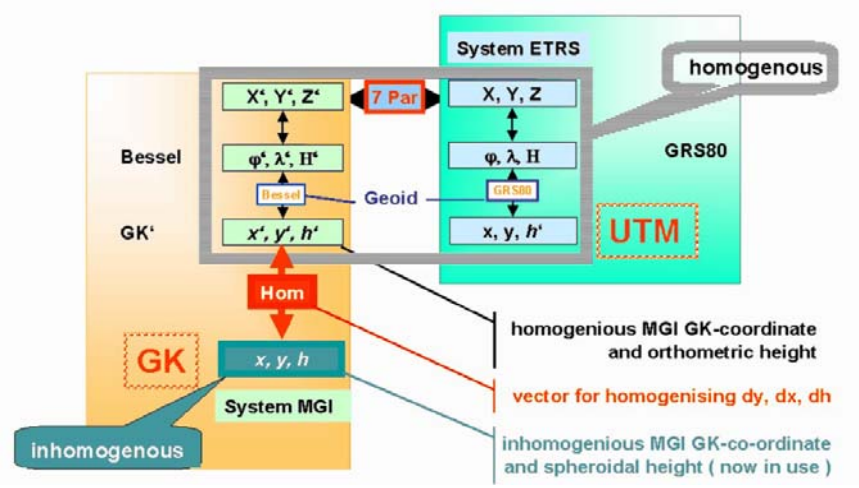

Fig. 1. Reversible connection between ETRS89 and MGI

Both systems have different accuracies.

Gelöscht: in realisation

The realisation of the system MGI contains a lot of systematic effects (inhomogenities) and therefore is inaccurate compared to ETRS89.

By transforming the co-ordinates to MGI using 7 parameters we get co-ordinates (x', y', h') of the same accuracy. The difference to the inhomogeneous co-ordinates in use we call "vector for homogenising". This vector contains all the systematic effects of the present national system MGI. The task is to determine this vector for all control points and to use them in an interpolation model for determining (homogenizing) the boundary points of the cadastre.

One set of 7 parameters is used for the whole territory of Austria.

4. Categories of control points

In Austria the field of control points is very dense. In many regions the distance between control points is less than 300 metres. Besides the 60.000 1st to 5th order points with distances of less than 1.5 km we have 6th order points with different qualities, there are about 230.000 points measured by terrestrial and about 40.000 measured by photogrammetric methods.

For these 3 different types of points we use different procedures for homogenisation.

- 1st to 5th order points are determined exclusively by the adjustments of GPS-baselines (40% of the points) and terrestrial measurements (60%)
- terrestrial 6th order points are determined by GPS (20%) or by interpolation (80%)

- photogrammetric 6th order points are determined exclusively by GPS (100%)

5. Systematic errors in the co-ordinates of the control points

The control points of 1st to 3rd order have another characteristic in systematic errors than the 4th to 6th order points.

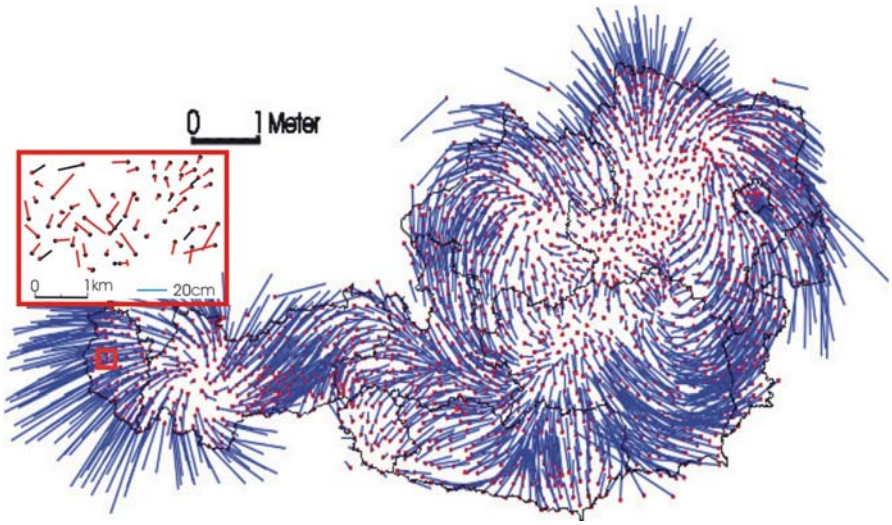

Fig. 2. Inhomogenities in the control points

Adjusting the observations of the 1st to 3rd order points on the base of ED87 and transforming the co-ordinates (one set of 7 parameters for Austria) to the system MGI leads to differences up to 1.5 meters 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 we use the differences in a mathematical model ETRS89 co-ordinates of the 4th to 6th order control points can be determined with an accuracy of ± 10 cm. This is accurate enough for most GIS applications.

For the 4th to 6th order points the differences are not as systematic as for the 1st to 3rd order. Differences between neighbouring points up to 20 cm and more can occur. There are different reasons for this. One reason is that in the past only small blocks have been 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 we have values up to 10 mgon. In some cases the identity of the point isn't secured because of landslides or subsidence or problems with the stabilization. Furthermore in the past photogrammetric methods (aero-triangulation) have been used for the determination of co-ordinates.

About 20000 changes in the last 50 years show that a lot of approaches were needed to gain the present (not sufficient) quality in the co-ordinates. Nevertheless today we know, that new adjustments in an inhomogeneous system are not the right way to solve the problem. It was about time to apply a new strategy for homogenization.

6. The new Austrian fiducial network

Since 1990 different campaigns for different purposes have been done, so today we have about 400 points with 24 hours GPS-measurements. Besides IGS and EUREF stations we have the points of the Austrian Geodynamic Reference Frame (AGREF), the Austrian Reference Frame (AREF) and the reference stations of the Austrian Positioning Service (APOS). The latter will be established till the end of 2006.

All these points have co-ordinates in ETRS89 and represent the new Austrian fiducial network. Starting from these co-ordinates all control points and cadastral points will be determined in the new system.

7. Calculation procedure

Since 1989 more than 100.000 GPS-baselines (mean length 1,5 km) on 38.000 points of 1st to 5th order have been observed and stored in an observation database. In a first step these baselines will be adjusted within the fiducial network.

In 1988 on the other hand we started to capture the terrestrial measurements (distances, horizontal and vertical angle) made since 1920 and put them into an observation database. In a second step with these measurements the ETRS89-coordinates of the control points, not observed by GPS, are being computed. In the first half of 2006, when all measurements will be available in the database a project of about 120 man-years will be finished.

Gelöscht: with

Gelöscht: not measured by GPS

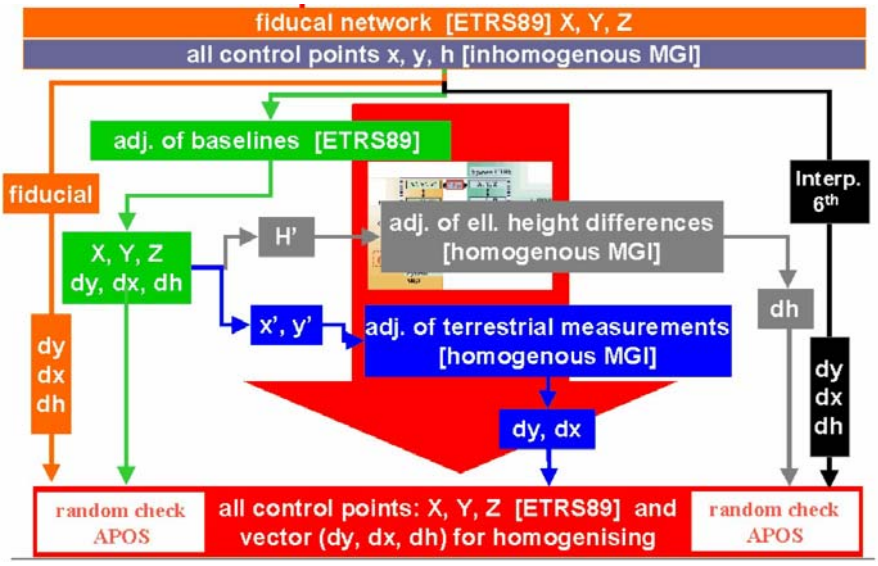

Fig. 3. Calculation procedure

The initial situation is: All control points have inhomogeneous MGI-coordinates and there are about 400 points of the fiducial network with high accuracy.

The goal is to get ETRS89 co-ordinates of all control points respectively the vector for homogenising for interpolations.

- The vector for homogenising for the fiducial points can be determined by the 7-parameter transformation.
- The adjustment of the GPS-baselines leads to their ETRS89 values respectively the vectors for homogenising.
- The adjustment of the terrestrial measurements is split into two parts. At first the vertical component is determined and then the horizontal position.
- The ellipsoidal heights are the initial values for the adjustment of ellipsoidal height differences and after the adjustment the component dh is established.
- The homogenous MGI-co-ordinates are the input for the adjustment of the horizontal component and after the adjustment the components dx and dy are established.
- All the established vectors for homogenising then can be used for the interpolation of 6^{th} order points and further for cadastral boundary points.
- APOS is used to control randomly some new co-ordinates.

8. First results

In a small part of Austria, the Province of Vorarlberg, the calculation procedure has been applied. 17 fiducial points (1 EUREF, 3 AGREF, 11 AREF, 1 from Switzerland and 1 from Liechtenstein) have been used for the

adjustment of 2500 points observed from 1990-2001 (42 GPS campaigns). Afterwards the terrestrial measurements of 1500 further points have been adjusted (89 campaigns).

After all co-ordinates of the control points of Vorarlberg had been determined, we made random checks with APOS at some points in the years 2003-2005. The differences in the horizontal component between the adjusted co-ordinates and the APOS co-ordinates you can see below:

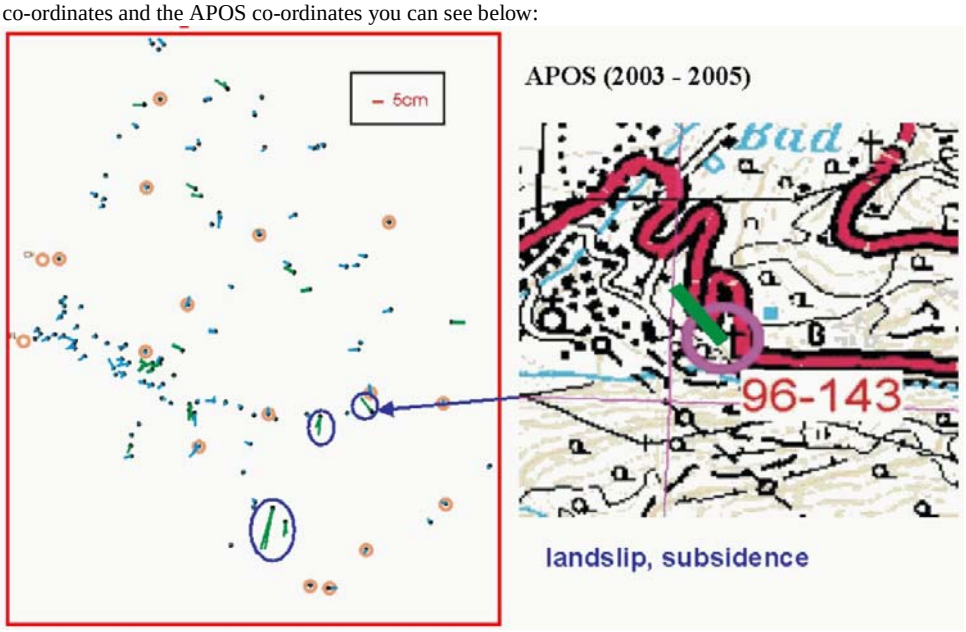

Fig. 4. Random checks with APOS

The mean difference at the fiducial points (24 hours measurements) is 0.015 meters with a standard deviation of 0.014. In general APOS fits very well with the co-ordinates of the fiducial network. Only at two points we have differences of 5 and 6 cm. At both points we have APOS observations from 3 different epochs and only two epochs fit very well.

The differences at the points with GPS-baselines measured from 1990 to 2001 (in blue) are similar. The mean difference is 0.019 meters with a standard deviation of 0.012.

The differences are larger on the points with only terrestrial measurement. The mean difference is 0.072 meters with a standard deviation of 0.039 and without the three tagged points 0.041 ± 0.023. On the one hand the terrestrial measurements are not as accurate as the GPS-baselines and on the other hand there were up to 50 years (1954 to 2005) between the measurements.

The three tagged points with terrestrial observations and observations from APOS on different epochs were detected as sliding. In Vorarlberg at 6% of the 1^{st} to 5^{th} order points movements were detected. We found horizontal movements up to 0.5 cm/year (30 cm from 1933 to 1995) and vertical movements up to 1cm/year (50 cm from 1946 to 2001).

Conclusion

The activities for the renewal of the field of control points and the cadastre are in progress. Capturing terrestrial observations is almost finished. The adjustment of GPS- and terrestrial observations for producing homogenous ETRS89 co-ordinates for all control points are at the beginning and will probably be finished 2007/2008. APOS, completed by the end of 2006, will be used for random checks of the new co-ordinates. The procedure for transforming / interpolating the cadastral content to ETRS89/UTM is tested by the colleagues at the cadastral offices. After finishing the homogenization of the cadastre the number of control points will be reduced essentially. Many more points are moving in nature than we know about. It will be a task for the future to analyse regions with land sliding more closely.