Geodetic Integration of Europe: Practical Problems

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Summary

All EUREF communities use ETRS-89 coordinate system simultaneously with national coordinate systems which serve as national datums. ETRS-89 is transformable to the national systems by unique way. Existence of the ETRS-89 and national systems is satisfactory for geodetic unification of the Europe. The article is continuation of the paper (Cimbịlnḳk, 1998), but some of the old definitions are mentioned once more.

Initial state

1. In Europe, there is 46 states, 5 various reference ellipsoids and at least two cartographic projections (GROTHENN, 1994).
2. Just in CZ (and Slovak Republic), there are 2 ellipsoids (Bessel, Krasovski), accounting only those more recent, 2 cartographic projections (Krovak and Gauss) and we make use of 4 coordinate systems in total: S-JTSK, S-52, S-42 and S-42/83; further will be added: 2 ellipsoids (GRS80 and WGS84) and 2 coordinate systems (S-JTSK/95 and an army system).
3. An increasing number of geodetic points is available in Europe in ETRF-89 system; these points are spread over the whole territory of Europe in perfectly homogeneous way and are so accurately determined that it would be needless to increase their number and acccuracy further on. This is true for applications on coordinate systems, but not for geodynamic studies (however, considerations about geodynamics are out of scope of this presentation).
4. Nearly all points in the ETRF-89 system are identical with those in traditional geodetic networks of the respective state geodetic datum.

Projections, sheet line system

For GIS - as for a perspective database of all data including geodetic and cartographic data - problems of sheet line system, of map content, etc. are in fact subsidiary. The choice is dictated by other circumstancies, not by the coordinate frame or ellipsoid used.

Trying to explain options of coordinate system and the relevant projections: we start with describing conditions in Czech Republic, where is obvious that two systems will exist simultaneously (one civil and one military), both specifically Czech, but both closely connected with the European system.

Civil parts of the national economy will probably use the S-JTSK/95 for a long time. Also users out of Czech Office of Surveying and Cadastre, and especially on places where numerical operatus will be connencted with a graphical output, will use this system. The S-JTSK/95 will have a planar version (Y, X, H_{niv}) and a geocentric version $(\varphi, \lambda, H_{el})$ or an equivalent (X, Y, Z) identical with ETRF89 on the territory of the Czech Republic.

The old system S-JTSK will be replaced by the new S-JTSK/95 soon. The older S-JTSK is still in use but it has a lower accuracy in scale and in orientation (see CIMBÁLNÍK and KOSTELECKÝ, 1994).

As for the Europe as a whole, the international cooperation in the frame of subcommission IAG EUREF takes shape to conclusions similar to those above, those formulated in CZ. In any case the individual european states will have their own national coordinate systems plus ETRF89, and a unique transformation between them.

Suggestion

The present-day heterogenity in transforming the national systems to or from ETRF-89 leads the authors of this contribution to the following suggestion and to a call for an unique transformation illustrated on the case of the Czech Republic.

The seven-parameter transformation between ETRF-89 (1989.0) and the Czech national system S-JTSK, including the additional "transformation" (so called Jung's transformation or transformation by means of quadratic polynomials, or matrix of coordinate differencies) ***AT*** between orthogonal coordinates, should be used. The method is shown by following equations. The symbols are selected to permit easy e-mail communication.

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Transformation model:

$$\begin{pmatrix} X2 \\ Y2 \\ Z2 \end{pmatrix} = (1 + p4 \times 10^{-6}) \times \begin{pmatrix} 1 & p5 & -p6 \\ -p5 & 1 & p7 \\ p6 & -p7 & 1 \end{pmatrix} \times \begin{pmatrix} X1 \\ Y1 \\ Z1 \end{pmatrix} + \begin{pmatrix} p1 \\ p2 \\ p3 \end{pmatrix} + AT(X1, Y1, Z1)$$

ETRF-89 to S-JTSK:

$p1$ = -570.828 m, $p2$ = -85.677 m, $p3$ = -462.842 m,

$p4$ = -3.5623,

$p5$ = 5.261"/r ", $p6$ = 1.587"/r ", $p7$ = 4.998"/r "

where r " is 206264.8"

Transformation S-JTSK to ETRF-89:

$p1$ = 570.838 m, $p2$ = 85.683 m, $p3$ = 462.847 m,

$p4$ = 3.5610,

$p5$ = -5.261"/r ", $p6$ = -1.587"/r ", $p7$ = -4.998"/r "

where $p1$, $p2$, $p3$ are shifts, $p4$ is scale factor, and $p5$, $p6$, $p7$ are rotations.

If ***AT* is "zero" identically**, mean quadratic value of residuals after 7 parameter transformation are in the W-E direction 0.17 m, in the N-S direction 0.15 m and in the position 0.23 m - see also Figure 1. Mean value of residuals in heights is 0.57 m, see Figure 2.

If we use the **additional cubic-conformal transformation as *AT***, for transformation of position and determined quasigeoid (eg. EGG97) for transformation of the heights, we obtain mean quadratic value of residuals in position 0.10 m, and 0.04 m in heights.

As is visible from this example for the Czech Republic, the 7 parameter transformation will be satisfactory for most, namely GIS, transformations.

Althought literature describes different ways how to derive the national coordinate systems, we add a short explanation also to this table (which ellipsoid was used, type of projection, orientation, amount and density of identical points, mean quadratic value of residuals, etc), together with some references. For more details concerning Czech Republic see i.e. (CIMBÁLNÍK and KOSTELECKÝ, 1994).

Conclusion

Our suggestion for a unique transformation between the local national coordinate systems and the european coordinate system is fully practical and is intended to serve for geodetic work beyond boarders of neighbouring states. Presented method of transformation has accuracy high enough for GIS/LIS applications.

It is recommended to include this topic on the programme of the relevant working group of EUREF because - after the realization of our suggestion - there would be a duty for each cooperating state to provide needed data (and information) to others. An EUREF workshop should define the final form of the data for exchange, the way of their exchange and method of the documentation. The Czech colleagues offer to derive relevant parameters for all EUREF participating countries, if the set of identical points from individual countries would be to disposal.

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Differences in horizontal position between Czech national coordinate system S-JTSK
and seven parameter transformation of ETRF89 to S-JTSK (cm)
(number near the point means difference in cm)
rms value is 23 cm

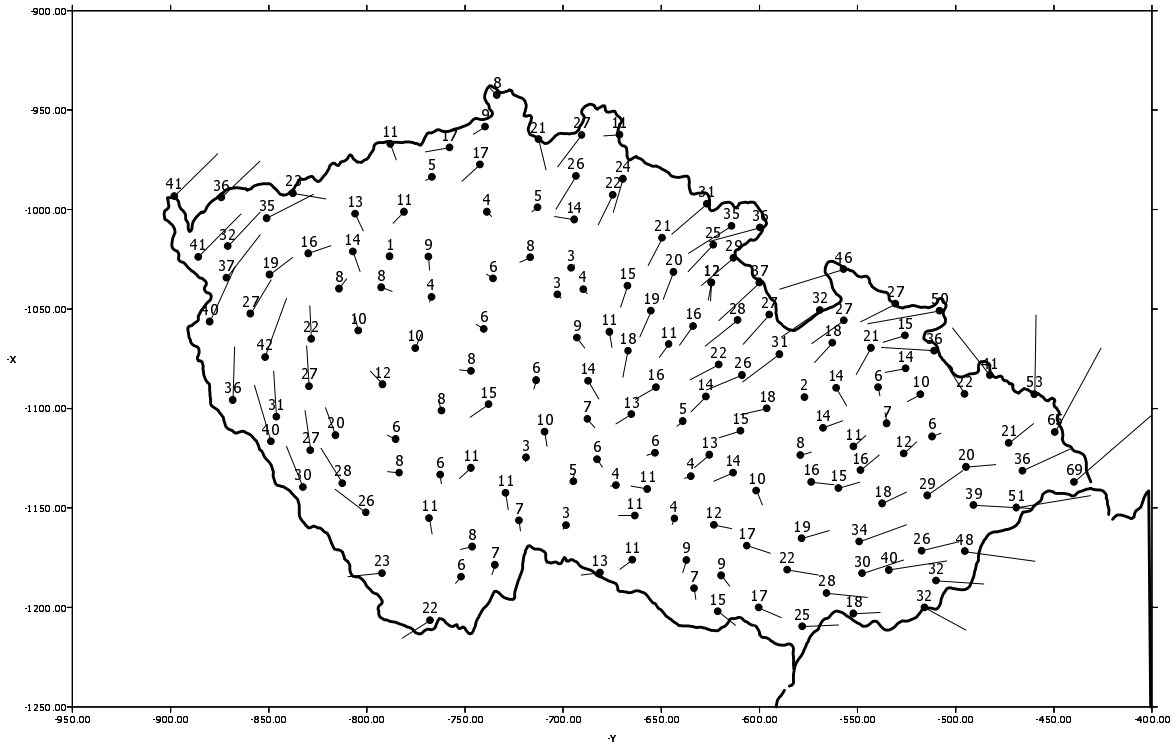

Fig. 1

Differences between levelling heights and heights determined
on the basis of seven-parameter transformation of ETRF89 ellipsoidal heights
(without using of the quasigeoid) for the territory of Czech Republic.
Contour interval 0.2 m, rms value is 0.57 m

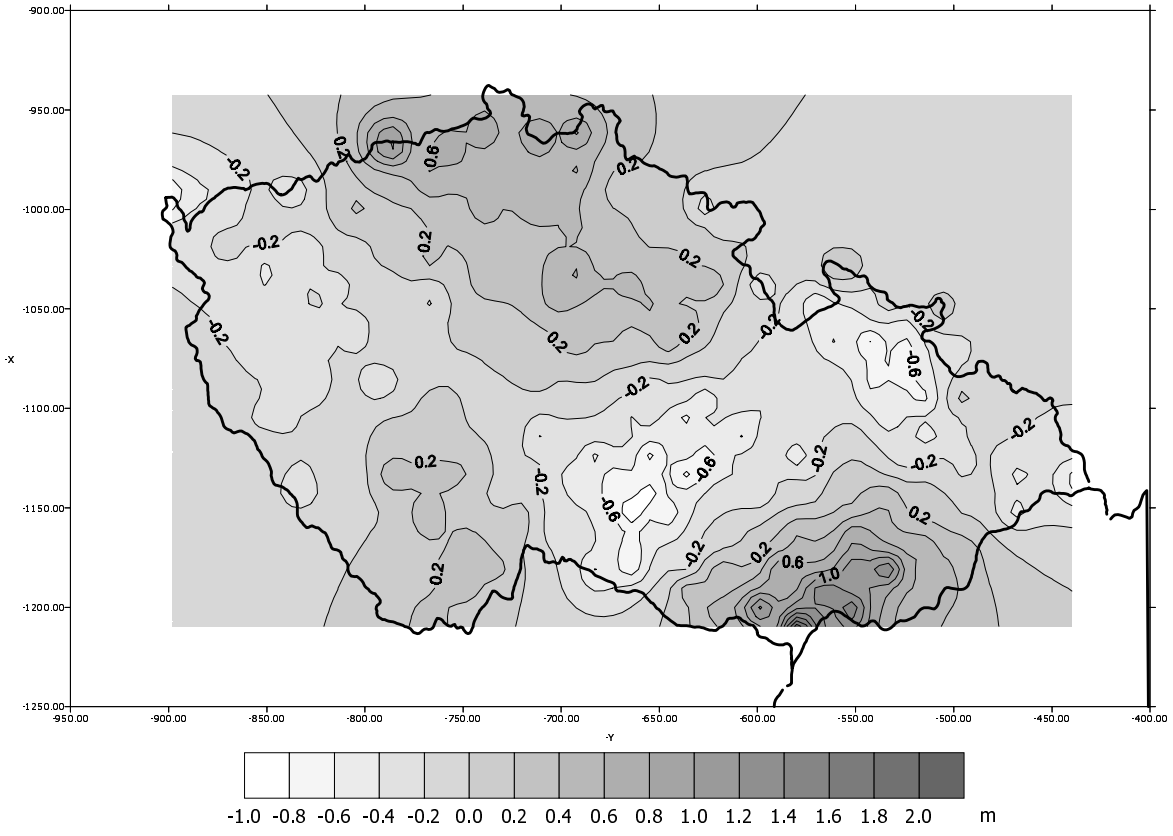

Fig. 2