LOCAL GEOMETRIC AND GRAVIMETRIC DATUM AND ITS RELATION TO THE GLOBAL TERRESTRIAL REFERENCE SYSTEM

R. Kelm
Deutsches Geodätisches Forschungsinstitut, Abt. I
Marstallplatz 8, D-8000 München 22

ABSTRACT

In active tectonic zones relative earth surface displacements of mm-order and relative gravity disturbances of 0.1 mgal size may be expected between two survey epochs. To monitor and separate these small effects significantly special local free networks have to be designed which are measured by relative observations of highest accuracy (mm- and µgal-level). For the connection of the local nets to a global terrestrial reference system a suitable local datum for point coordinates (geometric datum) and gravity field parameters (gravimetric datum) has to be defined within the terrestrial reference system.

The definition of the local datum is given and its dependency on the relative observation type discussed. For the datum realisation mainly satellite techniques are proposed. The tolerance interval of the datum parameters with respect to the global terrestrial system are analysed. Adjustment results referred to the local datum can directly be transformed into the terrestrial system without loss of significance, if the datum does not exceed the tolerance intervals. As a consequence requirements for the fundamental stations establishing the terrestrial reference system are discussed.

1. INTRODUCTION

Each geodetic observable quantity depends on physical fields which are of dynamical nature with periodical and nonperiodical frequencies, as there are the gravity field, the atmospheric field and the strain field of the earth. Especially the strain and the gravity field are strongly correlated, because they are mainly excited by the same sources, e.g. by the change of mass distribution in the earth crust or by tidal effects. The more accurately the geodetic observations can be measured, the more sensitive they react on the frequency band of the physical fields and the more difficult it is to separate the systematic effects from each other by suitable estimation models. On the search for a separation tool

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the fact among others is to be considered that physical fields behave in local areas of the earth surface differently than in the global frame. This is a problem of relating suitable estimates of local observations to coordinate estimates in a global terrestrial reference system. The paper aims at characterising this problem in order to give some impulses for further research. Therefore it is sufficient to treat a very simplified case: We only introduce two characteristical types of observations. For the determination of horizontal strain rates multi-wave distance measurements with a priori accuracy up to 1 cm for that distance, and for the vertical direction levelling-combined with relative gravity measurements leading to a distance accuracy up to 1 cm. The task here is to analyse the possibility of connecting suitable three-dimensional estimates of functions of distance, levelling and relative gravity parameters related to a local reference system with coordinate estimates of a global terrestrial reference system.

2. DEFINITIONS AND PROBLEMS

A Conventional Terrestrial reference System (CTS) is supposed to be available as defined e.g., by H. Moritz (1979), with the mean rotation axis Z and a Y-axis perpendicular to it and therefore situated in the mean equatorial plane - only this two - dimensional case is regarded further on in the simulation studies.

Some definitions are useful for the description of the task and resulting problems:
The geometric geodetic datum defines the relation between a local reference system and CTS and is given by geometric datum parameters (GDP): GDP are not significantly estimable by any kind of local observations and are therfore not dependent on estimable functions in the local reference system. In general, translation, rotation and scale parameters belong to GDP. When e.g., only distances are observed, not more than a scale parameter is determined by this observation type, and as GDP remain the translation and rotation parameters.

In the same way a gravimetric geodetic datum can be defined: It relates a local gravity field to a global one within CTS, and its parameters (here generally functions) cannot be determined by gravimetric-sensitive local observations. Because the task here is mainly of geometrical nature, this datum will not be dealt with further on in this paper.

In the CTS it is possible to estimate unbiased Cartesian coordinates e.g., by dynamical satellite techniques. This is not possible in a local reference frame when only local observations are available. Nevertheless it is useful to define coordinate estimations: Estimable coordinates are Cartesian coordinates within a local reference system which are estimated by local observation quantities with consideration of minimal constraints, the kind and number of which are given by the GDP. For instance in the Y, Z-plane GDP are only two translation parameters to a certain network point. Then there are two minimal constraints which have to be chosen well-defined , but can be distributed arbitrarely; e.g., the two coordinates of a point are taken as errorless in the estimation procedure.

The datum realization is regarded as the procedure which delivers the GDP by special observation techniques independent of the local observations.

With these definitions the problem here is described in four topics:
TOP 1: Which kind of GDP has to be defined in the local reference frame?
TOP 2: Which tolerance intervals for the GDP before the datum realization are allowed in order to transform the estimate coordinates into CTS after datum realization without significant systematical error influences?
TOP 3: Which observation techniques are suitable for the datum realization?
TOP 4: Vice versa - which requirements can be proposed for the establishment of CTS?

3. ANALYSIS AND RESULTS

TOP 1: By local observations translation parameters to CTS cannot significantly be determined. Distance observations only give information about the scale in the local network. An open question is if the indirect observation type of geopotential difference ΔV - derived from levelling and relative gravity results - significantly fixes the rotation parameter. For the analysis ΔV is linearised around approximate coordinates and gravity field functions given by geometric and gravimetric datum parameters based on a mass point model for the local gravity field. The resulting observation equation is in the Y, Z-plane

$$\Delta V = (b + \delta b)\ \delta y + (c + \delta c)\ \delta z \qquad (1)$$

with

ΔV: observed minus approximate potential difference

δy, δz: unknown differentials of the coordinate differences of two points

b, δb: sensitivity matrix elements

δb is only effected by local gravity field disturbancies and is negligible for this analysis. b and c are functions of the geocentric radius vector and do not differ much from each other. When (1) is transformed by infinitesimal rotation, the rotation part of ΔV - $\delta\Delta V$ - as a function of the infinitesimal rotation parameter $\delta\varphi$ is

$$\delta\Delta \sim (y\Delta z - z\Delta y)\ \delta\varphi \qquad (2)$$

with

y, z : coordinates of a point in Y, Z-plane

Δy, Δz : coordinate differences between two points.

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An analysis of (2) shows that

$$\text{sign } y\Delta z = - \text{ sign } z\Delta y$$

so that the rotational parameter is estimable in fact. So in this problem only translation parameters are GDP.
TOP 2: For the analysis the results of a numerical simulation study in the Y, Z-plane, as described in the primary task, is interpreted. Presumed that errorless observations are available and the local gravity field is estimated with significant accuracy the true potential difference is disturbed by about 0.01 m^2/sec^2 when the GDP (here only translation parameters) differ from the true values by 1 m. This means that a systematical error of 1 mm in the vertical direction occurs - that can be tolerated. So tolerance intervals of the GDP up to 1 m are allowed.
TOP 3: For the transformation of estimable coordinates of a local net to CTS the exact values of GDP (here the coordinates of the points to which the translation parameters are related) have to be determined by observation types which connect fundamental stations of CTS to that point. In near future this could be realized by laser satellite techniques expecting an accuracy on cm-level.
TOP 4: Only one idea should be given here: Let us review the initial idea presented in the introduction. For comparison of local and global effects - both sensitive to cm level - the accuracy of the estimated coordinates must reach this level, too. But the coordinates of CTS - fundamental stations are mean values - averaged over the time. For a sensitivity analysis it is required that all local and global estimated coordinates relate to the same epoch -. Therefore it is proposed that for each fundamental station motions as a function of t with respect to CTS have to be determined.

4. CONCLUSIONS

For the analysis of the local and global behaviour of the figure and the gravity field of the earth globally and locally observed geodetic quantities are to be used both consistently transformed into CTS. Besides further advantages it helps to separate highly correlated systematic effects caused by physical fields from each other. It is a problem of relating estimable coordinates of local areas - each independently surveyed and estimated in arbitrary epochs - to the CTS. The analysis and results given here - though only being preliminary and restricted to simplified case - nourish the hope that the problems can be solved to a significant accuracy in near future. But nevertheless much research work has to be done for the establishment of CTS and the connection theory between local networks and CTS.

REFERENCE

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