EVS 2000 – Status and requirements

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1. Introduction

The development and realization of European height systems by the IAG Subcommission on Continental Networks for Europe (EUREF) is undertaken on several levels and in different steps. The priorities in the realization are guided by requirements of CERCO and the technical state of the art:

Static approaches

UELN 95 a physical height system based on national precise levellings with continental extension, zeropoint Amsterdam, accuracy level over Europe 0,1 m and better, latest realization UELN-95/98

EUVN 97 a ellipsoidal height system based on ITRS/ ETRS, height accuracy level 0,01 m, realized in 1997.4 by the EUVN-97 GPS Campaign over Europe, results in ITRF 96 (epoch 1997.4) and ETRS 89

Both systems are integrated in the sense of point and value-related integration and contain tide gauge stations and their sea-level information, too.

Kinematic approach

EVS 2000

With the resolution No. 4 of the EUREF Symposium 1996 in Ankara the development of a continental kinematic height reference network on the cm-level using all available height relevant kinematic observations (e.g. repeated levelling observations, GPS, gravity, tide gauges) was decided.

The Technical Working Group (TWG) was asked to form a special working group to oversee the development of the computation method and methodology. At the same time the EUREF-member countries were urged to deliver height relevant data to the International Height Data Center at BKG. This work was influenced by the need of a best possible height reference frame in the field of accuracy and maintenance on the continental level. The members of the special working group were selected from National Survey Agencies and Universities. While the first two meetings in 1999 were used for a more general survey in the field of modelling, data sources, software, testing procedures a.s.o., the third meeting in May 2000 in Paris was dominated by modelling aspects.

2. Modelling of height relevant observations

Height relevant observations and the final unknown parameters are:

		Observations		Parameters
Levelling:		DH_{ij} (t)		
GPS Coordinates:		h_i (t)		
	or	v_{hi}		H_i (t_0)
Absolute Gravity:		g_i (t)		h_i (t_0)
	or	v_{gi}		v_{hi} (t_0)
Tide Gauge Observations:		v_{TGi}		
		⇑		⇑
or		L	=	F (x)

These are non-linear functions which have to be defined. First aspects and concepts are presented here. They have to be updated especially in the area of "Absolute Gravity" and "Sea level height observations at tide gauges".

Precise Levelling

The functional model of a kinematic approach for precise levelling is well known from the determination of recent crustal movements with repeated levelling epochs:

$$Dh_{ij}\,(t_k) + e_{DHijt} = H_{j,ref} + Dt_k \cdot v_j - (H_{i,ref} + Dt_k \cdot v_{Hi})$$

with

H_i, H_j physical heights of the stations *i* and *j*

t_k observation time at epoch *k*

t_{ref} reference time (to be defined)

Dt_k $t_k - t_{ref}$

v_i velocity of station *i*

e error of the observations

An unsolved problem of levelling points is the behaviour of the monument during the observed epochs. In RCM-evaluations a stochastic modelling introducing a "point-instability" was very successful (LEONARD 1986).

The following levelling stations are automatically part of

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the adjustment:

- Nodal points of every epoch
- identical points in at least two epochs

Identical points can be reduced to "representative points", if a country have a tradition to do that (DHHN 92).

The starting model for the velocity should be linear due to the fact that in most European countries only 2 or 3 epochs are available. The unknowns for one of the velocity surface concepts, which were used in RCM in a successful way should be introduced later. The stochastic model of levelling observation is normally only a function of the length of the levelling line. Enlargements depending on the height difference, the behaviour of the instruments or the introduction of neighbourhood correlations are in use also. Nevertheless, in any case the stochastic model should be validated with variance component estimations, as done in the UELN95/98-adjustments.

Space techniques

Space techniques as Very Long Baseline Interferometry (VLBI), Satellite Laser Ranging (SLR) and especially GPS deliver three-dimensional data sets:

x_t, y_t, z_t, and the covariance matrix S of this system. The three-dimensional results can by transformed to ellipsoidal values L, B, h and separated after that step to one dimension h, v_h, $S_{h,vh}$

$$h_i(t_k) + \varepsilon_{hit} = h_{i,ref,} + \Delta t_k\, v_{hi}$$

or

$$v_{hi} + \varepsilon_{vhi} = v_{hi}$$

with the convention $v_{hi} = v_{Hi}$

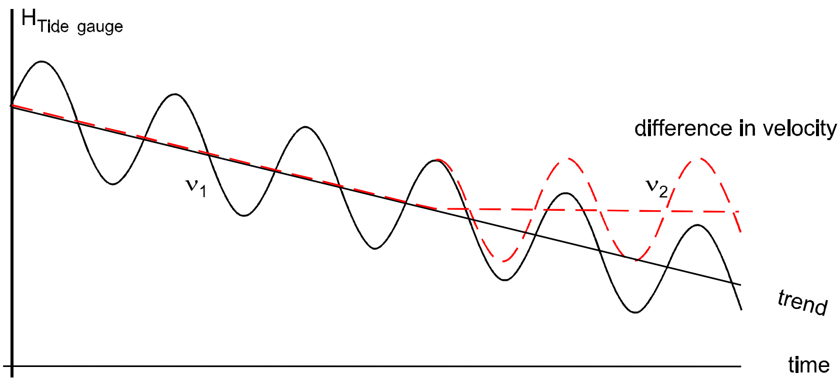
The results of space techniques are only useful, if they provide as similar accuracy as precise levelling. IHDE et al. (1999) stated that records of a certain period of data are needed. Using the time series of BKG he found out, that at present the minimum time span should contain three years of observation. The existing EUREF-Permanent-stations are the first candidates for this task. Unfortunately the required connection the levelling network is often not yet realized.

Tide gauges

Sea level heights H_{TG} measured at tide gauges and related velocities v_{TG} are depending on numerous parameters. The use for the determination of height changes must be done very carefully. E.g. some areas of the Northern Sea neighbouring tide gauges give totally different results due to unknown local effects. The used tide gauges should be collocated with permanent GPS stations.

$$v_{TGi} + e_{vTGi} = v_{TGi}$$

with the convention $v_{TGi} = v_{hi} = v_{Hi}$



Absolute Gravity

$$g_i(t_k) + e_{git} = g_{i,ref} + Dt_k \cdot k \cdot v_{gi}$$

or

$$v_{gi} + e_{vgi} = v_{gi} \cdot k = v_{hi}$$

Repeated precise gravity measurements are also sensitive to height changes. Unfortunately there are also other effects which can influence the accuracy significantly. Therefore, these stations have to be collocated with other methods too.

Requirements on EVS 2000 Software

An EVS 2000-Software working on the European level must be able to process the relevant observations with their stochastic model. The implemented testing procedures have to be drastic in all parts and the result should be on a common level. Within the adjustment and modelling part a lot of individual solutions are possible due to the added data material. In table 1 the existing observations or related values mentioned under chapter 2 are put together on the level of potential differences or numbers.

Input	→ EVS 2000 →	Results
levelling	ΔC_i	
adjusted heights	$\bar{C}_i, \Sigma_{\bar{C}\bar{C}}$	$\bar{C}, v_C$
space techniques	$h_i, v_h, \Sigma_{h,v}$	
gravity	v, Σ_{vv}	$\Sigma_{\bar{C},\bar{v}\bar{C}}$
tide records	v, Σ_{vv}	

At present (6/2000) the following software solutions are available or under construction:

- *KINEPOT* (Bundesamt für Landestopographie, Wabern, CH) → repeated levellings
- *KRUNA* (Bundesamt für Kartographie und Geodäsie, Frankfurt, D) → repeated levellings, observed velocities, Σ_{w}
- *PANDA* (Geotec, Laatzen, D), under development

4. Test Data

As already mentioned a test data set is put together (SACHER et al. 2000). The test area will contain

NL (5 epochs)

DK (3 epochs)

D (2 + 1 epochs)

Most of the data are already available at the BKG-Height Data Center. The observations of one German epoch have to be added and some connections over the borders could be strengthened with more epochs.

5. Outlook

A complete data set with epochs of repeated levellings will be available in 2001 and national as well as international computing centers are required for the experience-based development of the models. We also take the chance to ask one more time for additional national levelling data sets. The collocation of different observation techniques will be an important task for the next time. Within the EUREF permanent network this is on the way, tide records and precise gravity have to follow.

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