EUREF Action for the Densification of the EUVN Network

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Abstract

Following the successful completion of the EUVN project and responding to the resolutions of the EUREF2000 and '2001 symposia the EUREF Technical Working Group (TWG) has decided to initiate an action for the densification of the EUVN (D_EUVN) network.

The EUVN densification and the related D_EUVN database will serve as a base for

– geoid improvement on the continental and national levels

– better information on the national height datum differences,

– outlier and bias identification in the present EUVN database,

– sea level and vertical land movement monitoring.

– an improved continental reference for GPS-heighting activities,

After thorough discussions a Working Group has been formed from TWG members and external experts to prepare and manage the project. By the end of 2005 a standardized, continental scale GPS/leveling database will be created and used for scientific and practical purposes. This paper summarizes the aims, standards and expected results of the project.

Introduction

In 2001, following 6 years of activity the EUVN project has been completed successfully. The well established EUVN network consists of almost 200 GPS/levelling sites – including tide gauges – fairly covering the European continent.

The realized high quality but sparse EUVN network was designed to

– contribute to a unified European height datum with supporting the unification of the different European height systems,

– connect European tide gauge benchmarks for monitoring absolute sea level variations,

– make preparations for a European Vertical Kinematic Network,

– establish fiducial points for the European geoid.

The ellipsoidal station coordinates were derived from a coordinated 9-day campaign. The GPS markers were connected to the nearest UELN benchmarks with 1st order levelling. Gravimetric measurements were also performed for the derivation of geopotential numbers. Thanks to the careful preparation, standardization, data collection and the best known processing techniques the accuracy of both the derived ellipsoidal and levelled heights is kept better than 1 cm. Detailed description of the project and the results can be found in [IHDE et al, 2000].

One of the most important product of the EUVN project is the pointwise availability of high accuracy geoid values at the network sites. The so-called EUVN geoidal heights – derived as difference of the GPS ellipsoidal and levelled (UELN) heights – were compared to the currently available continental gravimetric geoid EGG97 [DENKER; TORGE, 1997]. The differences, depicted in Figure 1 are showing different sort of discrepancies. Generally the EGG97 and EUVN geoids agree within 2 dm and mostly the variation of their difference – within a certain limit – seems to be *random*. There are only few regions (Alps, SE-Europe, Baltic, Central Scandinavia, Atlantic coastline), where *systematic, large scale trends and/or biases* are clearly present. Among them the most significant is the Alpine region, where the discrepancies are go up to –40 cm. The Anatolian part of Turkey also show significant variation of the differences. At this stage it is impossible to identify the sources of the long wave differences; they may be caused by either the geoid or leveling problems.

There are also *large outliers* most likely caused by gross errors in the leveling information. The most obvious example can be found in Central Poland, where two nearby points have 69 cm difference.

In order to distinguish, identify and eliminate the inconsistencies in the present EUVN database a more accurate continental geoid solution and a denser GPS/levelling network would be inevitable.

The need for the EUVN densification

In contrary to the most careful preparation and execution of the network establishment outliers and biases are still present in the database as indicated by the above comparison with EGG97. Therefore the planned EUVN function of being fiducial network for the European geoid could be only partially fulfilled. However at the present stage the clear separation of the biases in the gravimetric geoid and the large

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scale levelling is not possible, both quantities have to be improved.

During the next years fundamental improvement of the European geoid is expected. The existing (GRACE, CHAMP) and planned (GOCE) satellite missions will improve the global knowledge of the long wavelength geopotential down to the sub-dm level. The IAG IGGC (International Gravity and Geoid Commission) European Subcommission therefore has initiated to start the preparations for the computation

of a new European gravimetric geoid benefiting from the improved geopotential models and updated terrestrial gravimetric databases. The production of the new EGG solution is expected around 2005 as earliest. Its accuracy should be few cm at the largest part of Europe. This improved continental geoid will be considered as a fundamental contribution to the analysis of the unified continental (UELN) and national levelling networks. Those future analysis may focus on specific areas indicated by the present comparison of EGG97 and EUVN.
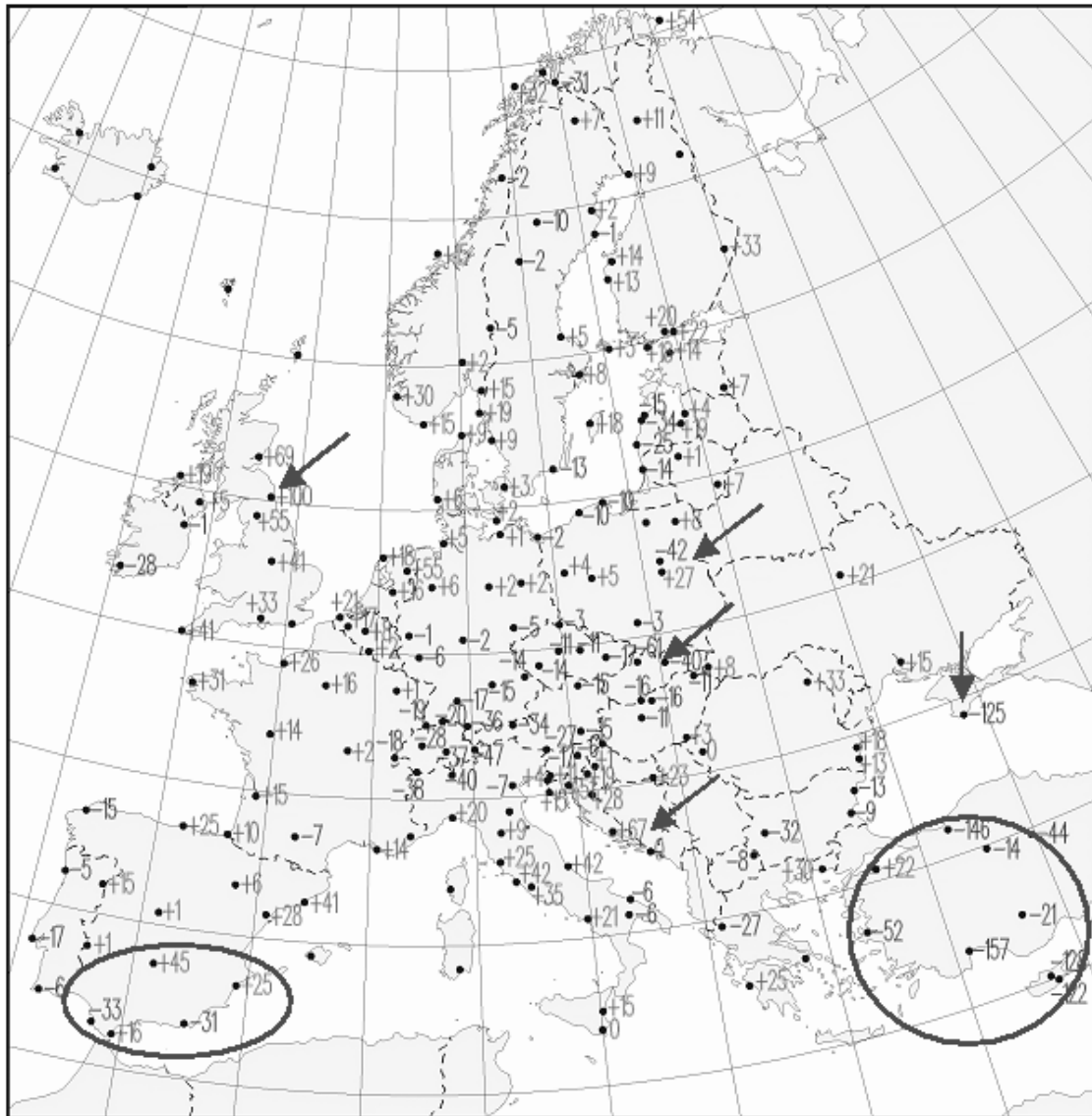

Fig.1 . Differences between the EGG97 (z^{EGG97}) and the EUVN/UELN ($h^{EUVN} – H^{UELN}$) geoids [cm] [Ihde et al. (2000)].

On the other hand the improvement of the levelling networks (re-measurements or re-adjustments using homogenized standards and reductions) on national and continental scales would be also necessary. However, due to the high cost and manpower demands of levelling this work cannot be done within a reasonable time frame. Instead of a regional activity, coordinated local/national actions should be done to clarify the causes of the discrepancies observed in the current solution.

The pointwise EUVN/UELN and EGG97 differences may be categorized into (medium to long wave) biases and outliers. The denser is the network the easier is the separation between outliers and long wave trends. Having this, currently sparse network only the gross errors can be easily identified (see red arrows in Fig.1.). However the differences may be an excellent indicator also for small outliers. A good example is the Hungarian EUVN subnetwork, where PENC had a higher difference (-16 cm) than the two adjacent sites (-11 cm). Following further problem indications PENC was re-

levelled in 2001 and we found 4 cm levelling error. Applying the new height information PENC fits better now (-12 cm).

Therefore a careful re-analysis of the datasets related to the suspected points or the establishment of (local) densification networks would be helpful to confirm and quantify discrepancies.

In case of the already clearly detected long wave biases (e.g. Alpine region) the network densification is not so vital. There is no reason to invest money into the detection and densification of known information. Unfortunately that category represents the smaller part of the network.

Beyond the above specified scientific reasons there are at least two practical arguments supporting the importance of the EUVN densification:

1. Based on the D_EUVN network and the new EGG continental geoid – to be completed by 2005 – we shall have in hand a unique tool to analyze the national and continental levelling networks. Benefiting from the improved gravimetric geoid and the D_EUVN database the detection of the long wave levelling biases (if there are any) will be possible. This control dataset would support the elaboration and check of the future levellings and standardized reductions.

2. The proper combination of the improved gravimetric geoid and the dense D_EUVN database will allow the production of a high accuracy (in absolute and relative sense) height reference surface. This combined geoid, consistent with ETRS89 and EVRS may serve as a tool for future GPS-heighting works. The use of the standardized GPS/levelling database allows the elimination of the medium to long wave discrepancies from the geoid. The mean separation of the GPS/levelling sites determines the minimum wavelength to be corrected. Using the continental or even better a national solution the cm-accuracy height reference surface could be produced.

The EUVN densification action

Based on the above scientific and practical arguments the EUREF TWG discussed and agreed on the initiation of a coordinated action to go further on the densification of the existing EUVN network. We must note here that the planned D_EUVN is not considered as a direct continuation of the EUVN project. The D_EUVN activities are more practice-oriented, the tasks, already successfully treated in EUVN (levelling network connections, height datum establishment, tide gauge investigations) are out of our scope.

The main task is the creation and maintenance of a standardized, densified continental GPS/levelling database and then – in close cooperation with the IGGC – the creation of an accurate continental height reference surface, consistent with ETRS89 and the EVRS. These aims are in full agreement with the EUREF resolutions, displayed in the Appendix.

In ideal case the establishment of a densification network with evenly distributed sites would be desirable. Additional scientific constraint would be the spectral harmonization of the gravimetric geoid (its long wave component computed from a geopotential model) and the GPS/levelling network. The optimal case would be the 50 km mean site separation

to cover the 100 km (1 degree) wavelength of the geopotential models. However this would lead to an enormously large network (several thousands of new points), which is impossible to finance, measure and handle. Therefore the densification should only focus on critical areas, where the current comparison of the EGG97 and EUVN/UELN shows high variation. However appropriate (existing and/or newly measured) GPS/levelling data is also highly welcome from the entire continent.

The selected, most critical and most interesting regions are the following:

– SE-Europe (Greece, Bulgaria, Turkey)
– Southern Spain
– Great-Britain
– Scandinavia
– Baltic countries

There are additional local areas, single points (indicated with red arrows in Fig.1), where focused studies would be desirable.

The NMA's, responsible for the specific regions will be informed and kindly requested to support the densification action with high quality GPS/levelling data.

Schedule, data content

A Call for Participation will be sent out by March 2003. The Call will include a project introductory and a detailed description of the requested data.

a) The maximum site separation should be less than 100 km (50 km would be optimal) corresponding to at least one point per 10000 km^2

b) The GPS-derived spatial coordinates should be derived according to relaxed EUVN standards:
   – n*24 hours measurements (n>=1),
   – the coordinates should refer to an ITRF frame, expressed in the epoch of observation,
   – processing with a scientific software package (e.g. Bernese) according to the EUREF standards

c) The GPS markers should be linked to the nearest UELN nodal point,

d) Gravimetric measurements should be also performed to derive geopotential numbers

The action is planned to carry out in 2 overlapping phases. *Phase_1* refers to each country and includes the creation of an inventory and the collection of the existing and eligible D_EUVN GPS/levelling information. There are several countries, where existing data is already eligible for our purposes. The deadline for data submission is 31 October 2003.

Phase_II is devoted to the establishment and measurement of new sites. This phase may only refer to countries, regions listed above. Phase_II may also start in spring 2003 and the work should be finished in 2005.

The deadline for the completion of the D_EUVN database is 31 May 2005.

The GPS and levelling data should be transferred to the EUREF/UELN Data Centre (BKG Frankfurt), where the

data will be submitted to a detailed check and analysis. The checked and corrected (if necessary) data will be sent back to the data providers. The compiled database should be freely used for scientific studies (testing different combination techniques the gravimetric geoid and GPS/levelling data) and practical applications concerning GPS-heighting. The studies should be done in close cooperation with the gravimetric community.

The produced continental scale combined gravimetric+GPS/levelling geoid will be provided to the agencies that submitted data and supported the activities.

Summary

The comparison of the EUVN/UELN GPS/levelling data with the EGG97 geoid revealed dm-level inconsistencies between the two datasets. While at the present stage we are not able to distinguish between the different error sources a coordinated improvement of all related quantities has been initiated. The IGGC European Subcommission has started the preparations for the production of a new continental gravimetric geoid solution; its completion is envisaged around 2005.

Parallel with the geoid computation the improvement and densification of the EUVN database has been decided. The planned D_EUVN (densified EUVN) action focuses on the check of the current database (outlier elimination) and additionaly asks the NMA's for densification at the suspected areas (e.g. SE-Europe, Fennoscandia). An inventory of the available high quality GPS/levelling datasets will be prepared first. The existing data and the new measurements should be prepared in a standardized way. The data will be collected and analyzed at the EUVN/UELN Data Centre at BKG.

The D_EUVN action starts in 2003 and will be completed by 2005. The improved EGG gravimetric geoid and the D_EUVN database will allow the analysis of the national/continental levelling networks and the production of a sub-decimeter accuracy height reference surface (a combined gravimetric – GPS/levelling geoid) – consistent with ETRS89 and the EVRS – for GPS-heighting works.

The products of D_EUVN will be freely available for scientific purposes.

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ANNEX: Related EUREF Resolutions

Resolution No. 3
of the EUREF Symposium in Tromsø 22 –24 June 2000

The IAG Subcommission for Europe (EUREF)

noting Resolution No.3 of the EUREF Symposium 1998 in Bad Neuenahr-Ahrweiler,

recognizing the completion of the EUVN height solution, which includes GPS/leveling geoid heights,

thanks the National Mapping Agencies for their support in supplying data,

recommends that the GPS/leveling heights of the EUVN solution should be used as fiducial control for the future European geoid determinations,

asks the relevant authorities

- to provide the necessary information for tide gauge connections,
- to densify the network of EUVN GPS/leveling geoid heights,
- to complete and extend the EUVN project.

Resolution No. 4
of the EUREF Symposium in Dubrovnik, 16-18 May 2001

The IAG Subcommission for Europe (EUREF)

recognizing

- the European Vertical GPS Reference Network (EUVN) with its GPS-derived ellipsoidal heights and leveled connections to UELN,
- the definition of the European Vertical Reference System EVRS with its first realization UELN 95/98, called EVRF2000,

considering

- this implicit pointwise realization of a European geoid consistent with both ETRS89 and EVRS,
- the existence of a large number of regional and local geoids in Europe,
- the urgent need by the navigation community for a height reference surface,

asks its Technical Working Group and the European Subcommission of the IAG IGGC (International Gravity and Geoid Commission) to take all necessary steps to generate a European geoid model of decimetre accuracy consistent with ETRS89 and EVRS.