IAG SUBCOMMISSION FOR EUROPE (EUREF)
OF THE COMMISSION X
GLOBAL AND REGIONAL NETWORKS
EUREF

IAG SUBCOMMISSION FOR EUROPE
OF THE INTERNATIONAL
GEOID AND GRAVITY COMMISSION
(IGGC)

European Combined Geodetic Network (ECGN)

1st CALL FOR PARTICIPATION

Implementation of the ECGN stations

Letter on behalf of the ECGN Working Group

March 19, 2003

Dear Colleagues,

Since the mid-nineties the IAG Subcommissions for Europe EUREF has been working on the establishment and development of the European Height System. The European height projects have been successfully developed thanks to the close cooperation between the National Mapping Agencies (NMA) and universities. The European Vertical Reference Network (EUVN) is an example for the combination of GPS, levelling, tide gauge, and gravity observations.

Since 2001 the Technical Working Group of EUREF has discussed the continuation of the work serving the realization of an integrated kinematic reference system for Europe, with which the increasing accuracy requirements for spatial and height reference systems can be met.

Following the discussions the IAG Subcommission for Europe of the Commission X Global and Regional Networks (EUREF) and of the International Geoid and Gravity Commission (IGGC) agreed to develop an integrated geodetic network ECGN for Europe.

The ECGN Project is linked with many current international geodetic projects and will contribute to them. To that belong the satellite gravity field missions CHAMP, GRACE and GOCE and the gauge projects TIGA-PP and ESEAS.

Now a proposal for the development of the European Combined Geodetic Network (ECGN) has been prepared, which was discussed at the EUREF Symposium in Ponta Delgada in July 2002 (http://www.euref-iag.org/resolutions.html#PDelgada). Representatives of 30 European countries recommended the realization of the project together with the gravity community. The EUREF TWG has been asked to establish a Working Group of interested parties of EUREF and IGGC to realize the ECGN and take it forward.

The ECGN project as a cross-commission project was also approved at the business meeting of the IGGC/Europe at the GG2002 Symposium in Thessaloniki.

The competences of EUREF and IGGC in such fields as setup and use of spatially referenced systems, acquisition of terrestrial gravity data, and gravity field modelling will be of great benefit to the overall realization of the project. The existing structures of EUREF as well as the possibilities available to the “Expert Group Geodesy“ within EuroGeographics concerning the organisation of scientific-technical projects will additionally support the activities involved with the project.

The ECGN is considered as a European contribution to the Integrated Global Geodetic Observation System (IGGOS). However, the ECGN also constitutes an independent component of its own. The primary concern of the project consists in connecting the height component with the gravity determination while allowing for measuring data that are acquired in the European coastal regions and above adjacent seas.

The project will be initialized in two steps. This 1st Call aims at establishing the necessary observation stations thus ensuring appropriate forward planning. The stations shall combine the various geodetic techniques: GPS, leveling, gravity and tide gauge observations in costal zones.

By the end of 2003 the 2nd Call for participation serving for the complex analysis of the data acquired as well as for their combination and matching with further observations will be launched. The 1st Call is addressed to scientific institutions, geodetic national mapping agencies, and also to station-operating institutions.

The activities will be organized and accompanied by a Working Group comprising the following members: Trevor Baker (Proudman Oceanographic Laboratory, Bidston Observatory, UK of Great Britain and Northern Ireland), Carine Bruyninx (Royal Observatory of Belgium), Oliver Francis (European Center for Geodynamics and Seismology, Luxembourg), Jacques Hinderer (Ecole et Observatoire des Science de la Terre/ Institut de Physique du Globe de Strasbourg, France), Johannes Ihde (Chair, Federal Agency for Cartography and Geodesy, Germany), Ambrus Kenyeres (FÖMI Satellite Geodetic Observatory, Hungary), Jaakko Makinen (Finnish Geodetic Institute, Finland), Steve Shipman (International Hydrographic Bureau, Monaco), Jaroslav Simek (Research Institute of Geodesy, Czech Republic) and Herbert Wilmes (Federal Agency for Cartography and Geodesy, Germany).

Your cooperation and participation in this project are welcome. Please contact me or any other member of the working group if you have any questions or comments regarding this call.

Sincerely Yours,

Johannes Ihde

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Summary

In 1995, EUREF took over the task of the realization and maintenance of European vertical reference systems. The work started with the UELN (Unified European Level Network) project and one year later continued with the realization of the European Vertical Reference Network (EUVN). The EUVN is a static integrated network, at all EUVN points three-dimensional coordinates and geopotential numbers are derived. In addition the corresponding normal heights as well as the gravity values are provided. In the tide-gauge stations, the connection to the sea level is realized. Finally, the EUVN represents a geometrical-physical reference frame. In 2002, the EUVN project has been closed successfully and EUREF started the preparation of a new phase.

EUREF invited the European Subcommission of the IGGC to participate in the ECGN project under the auspices of a cross-commission project. The initiative was approved at the business meeting of the IGGC/Europe at the GG2002 in Thessaloniki.

Since decades, there have been several initiatives to connect the reference frames of different geodetic techniques. For the geometrical reference, the real breakthrough was brought by the GPS technique. However, the reliable and accurate connection of this geometrical information with the physical (height) reference system is not yet solved. In this sense, the EUVN represents the successful realization of a static geometrical-physical reference frame (connection) on a continental scale. The integration of all the geometric techniques would be desirable, where gravity must play a key role. In addition, the study of the time evolution of the different reference frames and their related parameters (coordinates, gravity values etc.) would improve the knowledge about the connection itself (kinematic approach).

Within EUREF, the European Permanent Network (EPN) is in operation since 1996, experiences with tide gauges are available, and EUREF started with the adjustment of repeated levellings (EVS 2000). In 2001, EUREF promised the participation of the EPN stations in the IGS GPS Tide Gauge Benchmark Monitoring Pilot Project (TIGA-PP) and the European Sea Level Service (ESEAS).

In order to ensure the long-time stability of the terrestrial reference system with an accuracy of 10^{-9} at both the European and global scale, the interaction between the different time dependent influences of the system Earth on the terrestrial reference system and the related observations has to be considered in the evaluation models.

Major absolute gravity projects within Europe in the last 15 years have been:
- national gravity networks (e.g. German Gravity Base net 1994 (DSGN94), measured with FG5-101 and JILAg-3, Austrian gravity base net measured with JILAG-6, Netherland's gravity base net measured with JILAg-3 and FG5-101, FG5-202);
- geodynamic networks (e.g. to monitor the Fennoscandic uplift (JILAg-5, FG5—102 (NOAA), FG5-101), or to monitor the rifting of Iceland (FG5-101, JILAg-3 and JILAg-5); Ardenne and Roer graben studies (FG5-202));
- sea level changes (e.g. tide gauge stations around U.K. (FG5-103), along the Mediterranean coast (SELF-project, FG5-101 and IMGC), or along the German coast (JILAg-3 and FG5-101));
- international gravity network (campaigns of US-NIMA within Eastern Europe in the 1990's, measured with FG5-107, FG5-101 and IMGC; the UNIGRACE-project from 1997 to 2001 with JILAg-5, FG5-101, JILAg-6, FG5-206 and ZZG);
- study of temporal variations of the gravity field with super-conducting gravimeter and absolute gravimeter time series (Bad Homburg, Wettzell, Moxa, Vienna, Membach, Medicina, Strasbourg, Metsähovi, Ny-Alesund).

Today's results show clearly that, only in conjunction, absolute and super conducting gravimeters constitute a tool able to achieve the µGal-range in gravity measurements and they offer therefore a basis for research on secular gravity and height variations.

The proposal is to establish a EUROPEAN COMBINED GEODETIC NETWORK (ECGN) to combine the spatial and height reference system with Earth gravity field parameter estimation. It is in agreement with the planned IAG project of an Integrated Global Geodetic Observation System (IGGOS).

The ECGN is a European network for the integration of time series of spatial/geometric observations (GNSS - GPS/GLONASS and in the future GALILEO), gravity field related observations and parameters (gravity, tides, ocean tides), and supplementary information (meteorological parameters, surrounding information of the stations e.g. eccentricities and ground water level).

The combination serves to compare techniques, to investigate influences to the stations in particular and to the models of the reference systems.

The call for participation is, from the point of view of time, structured in two stages. The first call is directed to the implementation of the ECGN stations following the concept of the project. The ECGN stations have the standard observation techniques GNSS (GPS/GLONASS, GALILEO), gravity (super conducting gravimeter and/or absolute gravimeter), levelling connections to nodal points of UELN/EVRS, meteorological parameters.

Standard for the ECGN stations is a local network for the derivation of eccentricities at a 1 mm accuracy level in all three spatial components. The GNSS part of the observations gathered at the ECGN stations will be an integral part of the EPN (EUREF Permanent Network) and as such will have to fulfill the EPN guidelines.

In parallel to the first call, the ECGN working group will prepare the second call for the analysis and investigations. In the first step, the main action of the ECGN working group will be a pilot study of the combination of the different observations from the available stations, and this to get experiences in the combination of spatial information with gravity field related data. For super conducting gravimeter data, the GGP (Global Geodynamic Project) data centre could be used for data collection. ECGN levelling data will be collected at the UELN/EVRS data center. Local data centers for absolute gravity data and super conducting gravimeter data should be installed in the first stage by the ECGN working group.

Description of the Proposal

Background

One of the fundamental development potentials of geodesy for the present and the near future lies in the improvement of the accuracy level and the increase of availability of the Earth's gravity-field-related height component. Whereas during the past 10 years positioning made dramatic progress in accuracy and operability, there was no substantial development in the Earth's gravity-field-related height components.

Today, GPS positioning is used for referencing basic geospatial data, and in conjunction with geoinformation systems GPS, has superseded traditional terrestrial methods of positioning in both science and practical applications, including the European administrative sectors. On the other hand, precise height determination, which is an integral component of geodetic positioning, continues to be based on classical terrestrial methods, which with accuracies of 10^{-6} to 10^{-7}, falls short of three-dimensional GPS positioning by the order of two. Since the classical terrestrial methods are restricted to their respective continents, there is no standardized reference system of heights on the global level.

In Europe, the reproduction cycle of the height reference systems takes about 30 years. Consequently, the height component from levelling for GPS positioning is not available with the same accuracy and operationally. This fact not only considerably impairs the referencing of geoinformation systems through GPS as to their overall efficiency, but also the performance of scientific kinematic and dynamic studies and investigations of the geosphere.

The contradiction in accuracy and operability between GPS positioning and the height levelling can be solved by using geoid solutions with an adequate accuracy (1 cm). They are used for reducing the GPS heights to heights referenced to the Earth’s gravity field. The presently available geoid solutions are characterized by long- and medium-wave errors (> 100 km), which can be ascribed primarily to inhomogeneities of the different height systems, and also to the insufficient density and inhomogeneity of the terrestrial gravity data.

It is expected that the satellite gravity field missions CHAMP, GRACE and GOCE will bring a considerably improvement to the determination of the long- and medium-wave portion of the gravity field. The short-wave components of the Earth’s gravity field, which in the long run ensures the continuity of

1 cm accuracy level on the local scales, also will have to be acquired by means of terrestrial gravity data .
Therefore, it is necessary to combine the data derived from satellite gravity field missions with terrestrial gravity data, that have been reduced to a standardized height level. During a first phase, combinations of GPS observations and classical levelling measurements may serve to represent fiducial points for the combined solution.

The experiences within the EUVN project have shown the practical and methodological problems with the combination of different geodetic observation techniques, especially geometrical and gravity field related data. To give an idea of this, the relations between ITRS/ETRS89 and EVRS (defined as a world height system (WHS) in the components conventions, parameters, and realization) are given in table 1. For the combination of the spatial (geometrical) and Earth gravity related components a unique integrated reference system has to be defined and realized.

Table 1: Relations between ITRS and EVRS/WHS (conventions, parameters, realization)

ITRS	**WHS/EVRS**
IUGG Resolution No. 2, Vienna 1991	**IAG Subcommission for Europe, Resolution No. 5, Tromsö 2000**
Origin	
(Explicit) Geocentric, the center of mass being defined or the whole Earth, including oceans and atmosphere.	***(Implicit)***
Orientation	
Initial BIH orientation. No global residual rotation with respect to horizontal motions at the Earth´s surface.	No necessary convention
units-scale	
SI unit meter	SI units meter and seconds
The ITRS scale consistent with the Geocentric Coordinate Time (TCG)	The scale of the Earth body W_o is approximated by the normal potential of the mean Earth ellipsoid U_o which includes the masses of the oceans and the atmosphere.
Coordinates	
quasi-Cartesian system	potential of the Earth gravity field
X	$W_p = W(X) = U_p + T_p$ (GPM)
	$= W_o - C_p$ (Levelling)
system parameters	
	mean Earth ellipsoid (U_o, GM, J_2, w)
Realization	
ITRF 2000	EVRF 2000 (UELN 95/98, ETRS89, GRS 80)
tide-free	$W_p = W_{NAP} + C_p$ (Levelling) , zero tidal system

Table 2 shows the components of an integrated geodetic reference system and their dependence on the tidal systems. It shows that a unique concept for the reduction of observations and related parameters is necessary. Only the origin of both is identically defined. For a height system, a zero level surface has to be agreed on. W0 as zero level has the advantage that in regard to the semi-major axis and the flattening of the mean earth ellipsoid it is independent from the tidal system. The main difference has to be considered at the realization: The ITRS/ITRFyy coordinates are given in the non-tidal system, the EVRS heights are given in the zero tidal system.

Gravity related components are given in a zero tidal system, conform to the IAG Resolution No 16 adopted in Hamburg in 1983 and to the handling of the gravity data. Contrary to this, the ITRFyy coordinates are given in the non-tidal system, the same holds for the global geopotential model EGM96. The European geoid was reduced to the zero tidal system. The non-tidal system/crust is far off the real Earth shape - there is no justification for the non-tidal concept. The Stokes formula is not valid for the mean tidal system, but the mean sea level is reduced to the mean/zero geoid for oceanic studies.

Table 2: Components of an integrated geodetic system and their dependence from tidal systems

	gravity $g/\Delta g$	geoid W/N	levelling height ΔH	altimetry h	mean sea level msl	position X/h
Mean tidal system **Mean/zero crust** (Stokes is not valid if masses outsite the Earth surface)	Δg_m	N_m	ΔH_m	Relation to N_m for oceanographic studies	h_{msl}	
Zero tidal system **Zero/mean crust** (Recommended by IAG Res. No. 16, 1983)	Δg_z Stokes →	N_z (EGG97)	(EVRF2000) ΔH_z			
Non-tidal system **Non-tidal crust** (far away from the real earth shape – there is no reason for the non tidal concept)	Δg_z Stokes →	N_n (EGM96)				X_n ITRFyy, ETRFyy

Goals/ Project Objectives

Securing and maintaining the spatial reference frame for positioning and gravity-field-related heights, is one of the core tasks of EUREF. The strategic objective of this project is to realize an integrated geodetic reference frame for the entire territory of Europe.

In order to ensure the long-time stability of the terrestrial reference system with an accuracy of 10^{-9} at both the European and global scale, the interaction between the different time dependent influences of the system Earth on the terrestrial reference system and the related observation has to be considered in the evaluation models.

The availability of the reference frame for real-time and near-real-time positioning needs a high sensitive modeling of the time dependent phenomena of the solid Earth, the Earth gravity field, the ocean, the atmosphere and the hydrosphere. The recording of relevant data to describe and model these phenomena is an integrated part of the maintenance of the terrestrial reference system.

The height is the most important component of the three-dimensional positions of the participating ECGN stations. However, in the regional or global terrestrial reference system, heights are less accurately determined than the horizontal components. This is due to the geometry and the properties of the (mostly spatial) observations which are sensitive to various systematic errors. Therefore, improvements can be expected from the careful combination of different spatial observation techniques (preferably at the observation level), such as GPS and Satellite Laser Ranging (SLR), collocated at the same site, taking into account the strengths (and weaknesses) of each individual technique.

The complement of the geometrical positioning with the physical height component of matching accuracy, operability and efficiency needs the gravity and a high-precise geoid in the cm-accuracy range. The project contributes to gravity field modeling for the area of Europe and to the generation of the best possible global model.

The planned activities aim to link the spatial reference system with gravity field related parameters in order to contribute to a consistent description of the general processes of the system Earth. These processes shall be kinematically integrated into a combined monitoring system of position and gravity. Products of the satellite gravity field missions will be combined with the data of the integrated geodetic terrestrial reference frame.

On the one hand, absolute gravity time series are key information for long time stabilization of height reference systems. On the other hand, gravity time series need precise position information to extract position variations from gravity variations.

It is a matter of course that the European spatial reference system realized by the EPN is based on, resp. contributes to, global systems and therefore is also a component of the latter. Consequently, the entire project must be seen in the global context. The work on the integrated kinematic network must be understood as a European contribution to a global integrated geodetic network. EUREF wants to support with this project the activities towards an improvement of the European height reference system for scientific work and for the supply of relevant data to European authorities and institutions.

The analysis of GPS time series shows that the height component is not sufficient verified. The combination with other data with vertical information gives the possibility to stabilize the vertical velocities. The main technological aspect is the combination of time series of different techniques.

The project continues the tradition of the EUVN into a next stage. EUVN was especially related to the height component and the realization of a European kinematical height reference system with a continental accuracy of one cm by using time series of different observation techniques. For this it is necessary to consider the variation of the Earth surface and the gravity field.

The proposed ECGN may substantially contribute to meet the geodetic basic needs of the geoinformation sector within Europe. Moreover, in the course of the further development of the ECGN, the needs and requirements as well as the demands made on a DGPS Real-Time positioning service will be allowed for. Additionally ECGN could be a component of a future European disaster monitoring network. The tasks of relating geodata and geodynamic investigations require a precise spatial reference system in real-time or near-real-time which takes into account the complex interrelationships between the solid Earth and the ocean, the atmosphere, and the gravity field. Establishment of this network is carried out in accordance with the technological state of the art of positioning by means of satellite navigation systems and considers the foreseeable developments in the user strategies.

Principles of Network Structure

The ECGN is a European network for the integration of the spatial geodetic reference frame (GNSS - GPS/GLONASS and in the future GALILEO), gravity field related parameters (gravity, tides, ocean tides), and supplementary information (meteorological parameters, surrounding information of the stations e.g. eccentricities and ground water level) in a kinematic mode.

ECGN is the frame for the integration of spatial reference and the gravity field, the guiding principle consisting in making available time series of the methods to be combined on all stations involved especially.:

- Position through GNSS (GPS/GLONASS, GALILEO) with 10^{-9} and better – permanent,
- Gravity (absolute gravity measurements) with microGal – repeated,
- Gravity field-related heights (linkage of levelling to the EVRS) with 1mm/km – repeated.

On some selected stations the following data should be acquired in addition:

- Ocean tides and sea level changes (tide gauges at the European coast lines) – permanent,
- High-frequency gravity variations (measurements by means of super conducting gravimeter) – permanent,
- Vapour concentration in the atmosphere (vapour radiometer) – permanent.

Supplementary:

- Meteorological parameters – permanent,
- Eccentricities, local control network – repeated,
- Groundwater gauges – permanent.

Analysis of Present Status

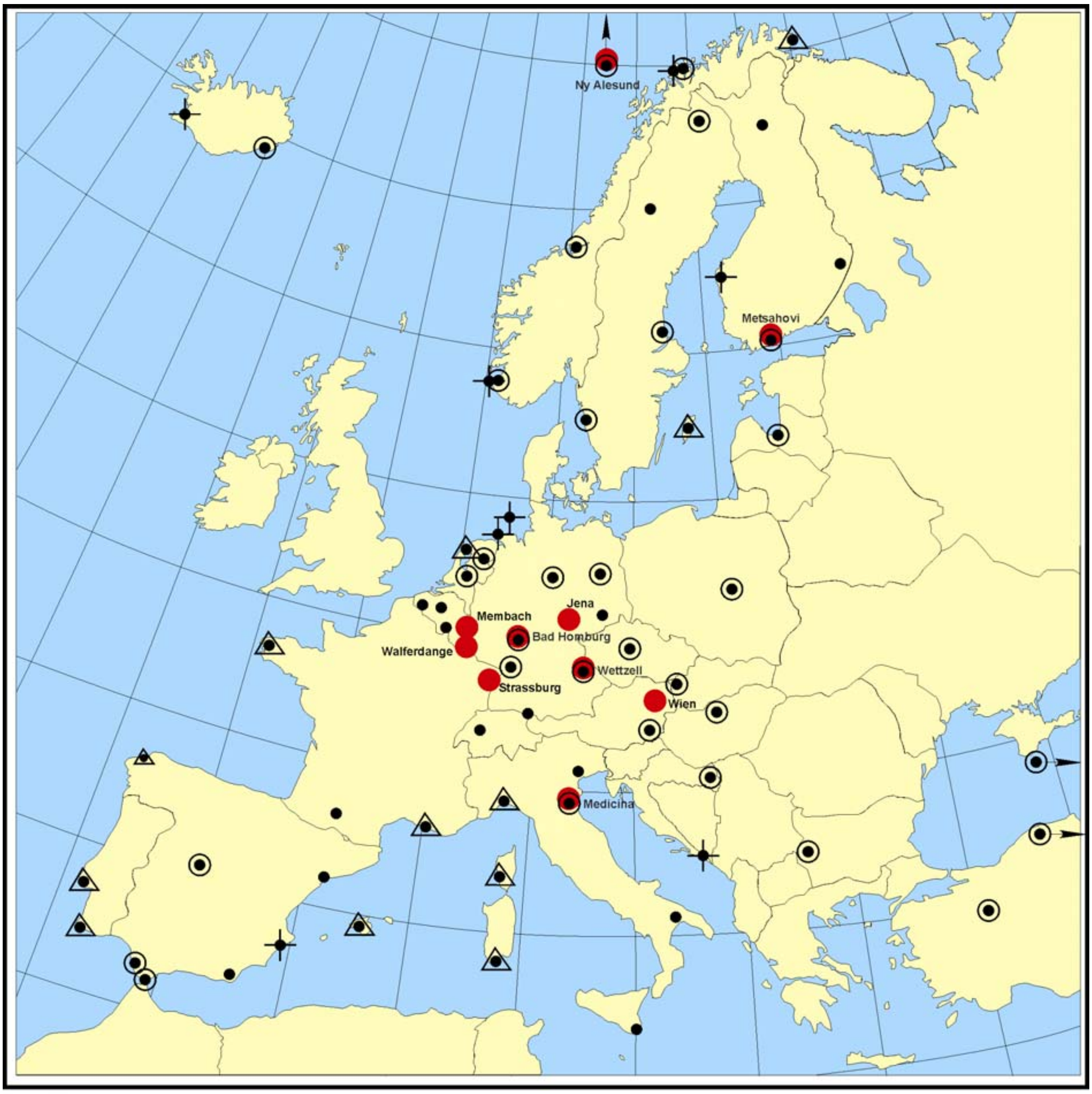
About 65 stations of EUREF's GPS permanent network EPN contain levelling, gravity and tide gauge observations (figure 1, table 3):

- 15 of them combine GPS and levelling,
- 37 of them combine GPS, levelling and absolute gravity,

- 10 of them are GPS/levelling/tide gauge stations and
- 8 of them are GPS/levelling/gravity/tide gauge stations.

The list of stations is not complete. The listed stations are candidates. The station responsibles still have to propose their stations to be included in the ECGN even if they are already contained in the table and/or in the figure.

The available infrastructure of EPN and UELN/EVRS should be left untouched but combined with new elements.



Legend:

- EPN station with GPS, and levelling
- EPN station with GPS, absolute gravity, and levelling
- EPN station with GPS, tide gauge, and levelling
- EPN station with GPS, tide gauge, absolute gravity (and levelling)
- Distribution of superconducting gravimeter in Europe

Figure 1: European Combined Geodetic Network (ECGN) – Distribution of candidate stations

Call for Participation

From the point of view of time the call for participation is structured in two stages. The first call is directed to the implementation of the ECGN stations following the concept of the project. In parallel the ECGN working group will prepare the second call for analysis and investigations. In the first step, the main action of the ECGN working group will be a pilot study of the combination of the different observations using available collocations at stations e.g. Medicina, Wettzell ect. and this to get experiences in the combination of spatial information with gravity field related data.

1st Call: Implementation of the ECGN stations

This call concerns the elaboration of the observation network of **ECGN stations**. The ECGN stations have the standard observation techniques

- GNSS (GPS/GLONASS, GALILEO) – permanent
- Gravity (super conducting gravimeter and/or absolute gravimeter) – permanent or repeated
- Levelling connections to the of UELN/EVRS – repeated
- Meteorological parameters – permanent.

For the realisation of the EVRS, the connection to tide gauge projects and the recording of vertical changes between sea level and the solid Earth surface, it is necessary to include selected tide gauges (permanent) along European coast lines.

Standard for the ECGN stations is a local network for the determination of eccentricities at a 1.0 mm accuracy level in all three spatial components (repeated). All types of observation techniques at a ECGN station should be situated within a distance of about 1 km.

Optional are the establishment of ground water gauges at gravity stations and absolute gravity observations at tide gauge stations.

It is proposed to qualify some stations as core stations. Core stations should give the possibility to study the combination of different observation techniques and kinematical effects in case.

Local data centers for the gravity data and sea surface observations should be established.

All ECGN stations are or should become part of the EPN. For GNSS observations and data flow, the guidelines for EPN stations & Operational Centres (`http://www.epncb.oma.be/guidelin.html`) have to be fulfilled.

For super conducting gravimeter observations, the Agreements and Standards of the Global Geodynamic Project (GGP) are definite (`http://www.eas.slu.edu/GGP/ggpas.html`).

For absolute gravity measurements, agreements and standards are in preparation, including data formats for archiving (Annex).

The tide gauges have to be realized following the requirements of the Permanent Service of Mean Sea Level PSMSL (`http://www.pol.ac.uk/psmsl/datainfo/contrib.html`).

Methodology and Analysis (Second Call)

For super conducting gravimeter data, the GGP data centre could be used for data collection. Levelling data of ECGN will be collected at the UELN/EVRS data center. Local data centers for absolute gravity data and super conducting gravimeter data should be installed in the first stage by the ECGN working group.

In a second call it could be asked for

- Analysis centers for the combination of time series observations of all ECGN stations
- Combination of space techniques (GPS/GLONASS, GALiLEO, VLBI, SLR)
- Methodical investigations for the combination of spatial observation data with gravity field-related data

Proposal

Proposals submitted in response to the 1st Call for Participation must include specific details on the technical support that will be offered by the organization and a management plan. These two main proposal sections will be used for proposal evaluation and to facilitate comparative analysis. Proposals must be signed by an official authorized to certify institutional support, sponsorship and management of the proposed activities.

The Proposal must contain:
- Cover Page (see below),
- Proposal Summary,
- Description of Proposed Activities,
- Management Proposal.

The Cover Page should contain: Parent/funding organization, name and title of authorizing official, name and title of primary point of contact, mailing address, phone/fax/e-mail, cooperation organizations/institutes, signatures (the cover page should be signed both by the Authorizing Official committing the organization/institution to the proposal and the primary point of contact involved).

It has to be mentioned that the project includes no funding.

Proposals should not exceed 10 pages. Deadline for the proposals is the 26 April 2003. Please send your proposal via e-mail (as ASCII or attached Word file) to: ecgn@bkg.bund.de.

In addition it is also possible to send it via postal mail to the ECGN chair:

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Proposal Evaluation and Selection

The principal criteria considered in evaluating the proposal are their relevance to the EUREF ECGN objectives, their intrinsic merit, and overall contribution to the service when compared to contributions available through other proposals. In addition to these criteria, management factors will be considered in the selection.

If the ECGN WG decides to accept only a portion of the proposal, the submitting organization will be given the opportunity to accept or decline such partial acceptance.

Action plan of ECGN activities

– Appointment of the members of the ECGN WG	Nov. 2002
– Call for participation stage1 observation	March 15, 2003
– Proposals stage 1 observation	May 15, 2003
– Kick off meeting of the ECGN WG and Proposal evaluation and selection	June 2003
– Report to the EUREF symposium 2003	June 2003
– Call for participation stage 2 analysis	Oct. 2003

Table with candidate ECGN Stations (Draft)

Site Name	EPN Code	DOMES #	Latitude	Longitude	Height (m) (Ellip)	Country	Position 0=coast 1=nearby >20km 2=inland	Tide gauge 0=complete 1=incomplete 2=Station close	EUVN - No (close to EPN Point)	Normal-Height in UELN-95/98	absolute gravity measurement	Super conducting gravimeter (SG)	SLR	VLBI	other Technologies
A Coruna	ACOR	13434M001	43,364	351,601	67	ES	0	0	ES05	12,123					
Ajaccio	AJAC	10077M005	41,928	8,763	99	FR	0	1	FR01	47,728			mobile		
Alicante	ALAC	13433M001	38,339	359,519	60	ES	0	0	ES01	9,998	1998;				
Almeria	ALME	13437M001	36,936	357,541	127	ES	0	2		74,251					
Ankara / Turkey	ANKR	20805M002	39,888	32,759	975	TR	2			939,301	1996;				
Bad Homburg			50,229	8,611	190	DE	2				time series	yes			
Borkum	BORK	14268M001	53,564	6,747	54	DE	0	0			2001;				
Borowa Gora	BOGO	12207M002	52,476	21,035	150	PL	2			108,760	1980; 1992;1995; 1996; 1997; 2000				
Braunschweig	PTBB	14234M001	52,296	10,460	130	DE	2				1977; 1994; 2000;				
Brest	BRST	10004M004	48,381	355,503	22	FR	0	0	FR04	53,301					
Brussels	BRUS	13101M004	50,798	4,359	150	BE	2			104,437	1995;1997 now own FG5				
Cagliari - Astronomi	CAGL	12725M003	39,136	8,973	238	IT	0	1	IT11	14,681			permanent		
CASCAIS	CASC	13909S001	38,693	350,582	77	PT	0	0	PT02	12,147					
Ceuta	CEUT	13449M001	35,896	354,689	52	ES		2			1994; 1998				
Dentergem	DENT	13112M001	50,934	3,400	64	BE	2			19,518					
Dourbes	DOUR	13113M001	50,095	4,595	283	FR	2			236,643					
Dresden	DRES	14108M001	51,030	13,727	203	DE	2				1994;				
Dubrovnik	DUBR	11901M001	42,650	18,110	454	HR	0	0	HR03	5,347	1999; 2000				
Ebre	EBRE	13410M001	40,821	0,492	108	ES	1	2		57,708					
FOMI Satellite Geode	PENC	11206M006	47,790	19,282	292	HU	2			248,387	1998; 2000;				
Genova - Istituto Id	GENO	12712M002	44,419	8,921	137	IT	0	1	IT05	4,014					
Graz-Lustbuehel	GRAZ	11001M002	47,067	15,494	538	AT	2			490,925	1998; 2001		permanent		
Helgoland Island / G	HELG	14264M001	54,175	7,893	48	DE	0	0			1997; 2001				
Hoefn / Iceland	HOFN	10204M002	64,267	344,802	82	IS	1				1997; 1998			mobile (1992)	PRARE (permanent)
Joensuu permanent GP	JOEN	10512M001	62,391	30,096	114	FI	2			96,694	1999;				
JOZEFOSLAW	JOZE	12204M001	52,086	21,033	141	PL	2			110,244	time series Jozefoslaw				
Karlsruhe	KARL	14216M001	49,011	8,411	183	DE	2				1988; 1993; 1994; 1995				
Kellyville (Kangerlu)	KELY	43005M001	66,987	309,055	231	DK					1995; 1996; 1997; 1998;1999				
Kiruna	KIRU	10403M002	67,857	20,968	*	SE	2				1995;				
Kiruna	KIR0	10422M001	67,878	21,060	498	SE	2			469,536	1995;				
Kloppenheim	KLOP	14214M002	50,220	8,730	222	DE	2				time series Bad Homburg?				
Kootwijk Observatory	KOSG	13504M003	52,178	5,810	98	NL	2			53,589	1991; 1996				
LAGOS	LAGO	13903M001	37,099	351,333	63	PT	0	0	PT05	2,597					
Maartsbo	MAR6	10405M002	60,595	17,259	75	SE	1	2		50,728	1993; 1995;				
Madrid Deep Space Tr	MAD2	13407S012	40,429	355,750	*	ES	2				1989; 1998; now own 'FG5				
Madrid Deep Space Tr	MADR	13407S012	40,429	355,750	*	ES	2			762,103	1989; 1998; now own FG5				
Marseille	MARS	10073M008	43,279	5,354	62	FR	0	0	FR06	12,394					
Matera	MATE	12734M008	40,649	16,705	535	IT	2			490,042			permanent	permanent	PRARE
Medicina (BO) - Radi	MEDI	12711M003	44,520	11,647	50	IT	2				time series since 1996	yes			
Membach			50,617	6,000	250	BE	2				time series	yes			
METSAHOVI	METS	10503S011	60,218	24,395	95	FI	1	2		75,986	time series	yes	permanent	mobile (1989); perma-nent under construction	DORIS (permanent), SG
Modra-Piesok	MOPI	11507M001	48,373	17,274	579	SK	2				1998; 2000;				

Site Name	EPN Code	DOMES #	Latitude	Longitude	Height (m) (Ellip)	Country	Position 0=coast 1=nearby >20km 2=inland	Tide gauge 0=complete 1=incomplete 2=Station close	EUVN - No (close to EPN Point)	Normal-Height in UELN-95/98	absolute gravity measurement	Super conducting gravimeter (SG)	SLR	VLBI	other Technologies
Moxa			50,645	11,616	455	DE	2					yes			
Noto - Radioastronom	NOTO	12717M003	36,876	14,990	*	IT				84,441					
Ny-Alesund	NYA1	10317M003	78,920	11,870	83	NO	0	1			1998; 2000; 2001; time series	yes	yes		DORIS;PRARE
Ny-Alesund	NYAL	10317M001	78,930	11,865	*	NO	0				1998; 2000; 2001				
ONSALA	ONSA	10402M004	57,395	11,926	47	SE	1			9,129	1993; 1995; 1998			permanent	GLONASS / GPS
Osijek	OSJE	11902M001	45,561	18,681	154	HR	2				2000;				
Palma de Mallorca	MALL	13444M001	39,553	2,625	62	ES	1	2		10,083					
Pecny, Ondrejov / CZ	GOPE	11502M002	49,914	14,786	593	CZ	2			547,696	time series since 1978;now own FG5				
Pfaender/Moos/Bregen	PFAN	11005S002	47,517	9,700	1040	AT	2			1043,183	1988;BREGENZ				
Potsdam, GeoForschun	POTS	14106M003	52,380	13,070	174	DE	2			104,216	76; 78; 80; 83; 86; 88; 90; 94; 97				
Reykjavik / Iceland	REYK	10202M001	64,139	338,045	93	IS	0	1	REYK		1988; 1997				DORIS (permanent)
RIGA permanent GPS	RIGA	12302M002	56,949	24,059	35	LV		2		14,017	1995;1996;		permanent		
San Fernando	SFER	13402M004	36,464	353,794	86	ES	1				1994; 1998		permanent		
SODANKYLA permanent	SODA	10513M001	67,421	26,389	300	FI	2			279,309	1976; 1980; 1988; 1992; 1998				
Sofia / Bulgaria	SOFI	11101M002	42,556	23,395	1120	BG	2				1998; 2001;				
STAVANGER	STAV	10330M001	59,018	5,599	*	NO	0	0	NO02	1,886	1991; 1993; 1995				
STAVANGER	STAS	10330M001	59,018	5,599	105	NO	0				1991; 1993; 1995				
Strasbourg			48,622	7,685	180	FR	2				time series	yes			
Terschelling	TERS	13534M001	53,363	5,219	56	NL	0	1	TERS	14,718					
Thule AFB, Greenland	THU1	43001M001	76,537	291,212	55	DK					1988;				
Toulouse	TOUL	10003M004	43,561	1,481	*	FR	2			157,740					
Trabzon / Turkey	TRAB	20808M001	40,995	39,776	99	TR		2			1996;				
Tromsoe	TRO1	10302M006	69,663	18,940	142	NO					1992; 1993; 1995; 1998;			mobile (Aug-1997)	SATREF
Tromsoe	TROM	10302M003	69,663	18,940	*	NO		1	TROM		1992; 1993; 1995; 1998;				
TRONDHEIM	TRDS	10331M001	63,371	10,319	318	NO		2			1995; 1998				
TRONDHEIM	TRON	10331M001	63,371	10,319	*	NO					1995; 1998				
UNIVERSITY OF PADOVA	UPAD	12750M002	45,407	11,878		IT	2			39,582					
VAASA permanent GPS	VAAS	10511M001	62,961	21,771	58	FI	1	1	VAAS	40,382	1995; 1999				
VARDOE	VARD	10322M002	70,336	31,031	*	NO	0	0	NO12	3,042					
Vienna			48,249	16,358	192	AT	2					yes			
Vilhelmina	VIL0	10424M001	64,698	16,560	450	SE				420,321					
Visby	VIS0	10423M001	57,654	18,367	80	SE	0	1	VISO	54,846					
Walferdange			49,665	6,153	295	LU	2				time series	yes			
Westerbork Synthesis	WSRT	13506M005	52,915	6,605	86	NL	2			40,747	1991; 1996				
Wettzell / Germany	WTZR	14201M010	49,144	12,879	666	DE	2			619,339	time series	yes	permanent	permanent	
Zelenchukskaya / Rus	ZECK	12351M001	43,288	41,565	1167	RU	2				1994;				
Zimmerwald L+T 88	ZIMM	14001M004	46,877	7,465	957	CH	2			906,877	1997		permanent		Earth tide gravimeter

Annex with Standards for Absolute Gravity Measurements

Absolute Gravity Measurements - Agreements and Standards

Station selection

Location: The absolute gravity station should be located in a direct connection to the EPN, super-conducting gravity, levelling or tide gauge station. "Direct" can mean for the EPN, levelling and super-conducting stations in the same building; for tide gauge stations it is preferred to carry out the gravity observations in a separate location with similar geological conditions which is more protected from the sea influence.
Places with high micro seismic level (machines, cranes, railways, roads with heavy traffic) should be avoided. Bigger mass changes and vertical movements will propagate into the gravity signal.
Eccentric sites for tide gauge stations require a levelling connection to the absolute gravity station.

Building: Indoor absolute gravity station; point location on separate pillar or directly on the ground floor level. Building or foundation should be more than 10 years old with the expectation of some more decades without major constructive changes (e.g. public buildings)

Room: A separate room on the lowest floor which can be closed to avoid temperature variation.
Room size > 2 * 2 m^2, room height 2.0 m, door width > 80 cm
Space for gravity sensor installation: 1.00 x 1.00 m^2 with solid and flat surface, horizontal to 1 cm / m; this can be a pier (optimal with grounding on bed rock) or the (stable) fundament of the building. No covering materials (e.g. tiles) on the ground. The surrounding walls should not be closer than 0.6 m.
Power requirements: 220 V, 1000 VA
Room temperature between 15^0 and 25^0 C, temperature changes < 1^0 C / h and < 5^0 C / day (air conditioning would be optimal)
Access to the room should be possible at every time of the day during the measurements.
The installation of a ground water gauge is recommended.

Absolute gravity measurement

Gravimeter: For the super-conducting gravity stations it is recommended to carry out the absolute gravity measurements with the highest precision which would be 1-2 μGal for the FG5 gravimeters. This high level of precision is required to verify the zero reference of the super-conducting gravity measurements and to determine possible drift effects. For EPN or tide gauge stations a lower precision level of 2-5 μGal will still provide valuable information about the stability of the gravity signal.

Additional parameters: Ground water level, air temperature, air pressure etc. (cf. data format description)

Measurement repetitions: On super-conducting stations and key stations of the network one occupation at least every 6 months, on other stations one measurement every 12 to 24 months is recommended.

Gravimeter inter-comparisons: The absolute gravimeters should be compared with other absolute gravimeters at a reliable gravity station where super-conducting gravity measurements are carried out at a yearly interval.

Data Formats

BGI-Format: The data format for the exchange of measurement results and additional information should relate to the BGI format specifications for absolute gravity measurement results. This format specification is presently being revised and will be the reference for the future data base at BGI data bank.