

Future and development of the European Combined Geodetic Network ECGN

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Abstract.

In this paper we discuss future, need and structure of the European Combined Geodetic Network ECGN. It combines the integration of time series of spatial/geometric observations with GNSS technique, and physical quantities with gravity field related observations and parameters including precise levelling, tide gauge records, gravity observations, and earth and ocean tides. The objective of ECGN as an integrated European Reference System for Spatial Reference and Gravity is the maintenance of the terrestrial reference system with long-term stability for Europe.

1. Background

The European Combined Geodetic Network (ECGN) was initiated by the IAG Commission 1 (Reference Frames) Sub-Commission 1.3.a for Europe EUREF, and IAG Sub-Commission for Europe of the International Gravity and Geoid Commission (IGGC) in the business meeting of the IGGC at the Gravity and Geoid 2002 Symposium in Thessaloniki. The primary idea was in connecting the height component with the gravity field related observations and parameters including precise levelling, tide gauge records, gravity observations, and earth and ocean tides. Objectives were defined as maintenance of a long time stability of the terrestrial reference system with an accuracy of 10^{-9} for Europe, especially in the height component, and modelling of influences of time-dependent gravity-related parameters. Moreover, a large variety of supplementary information (meteorological parameters, surrounding information of the stations, e.g. eccentricities and ground water level) also exist.

In order to ensure the long-time stability of the terrestrial reference systems with an accuracy of 10^{-9} in the global and continental scale, the interactions between different time dependent influences of the system Earth to the terrestrial reference systems and the related observations have to be considered. This implies the combination of geometric positioning with physical height and gravity parameters in better than 1 cm accuracy level and the modelling of influences of time depended parameters of the gravity field, atmosphere, oceans and hydrosphere.

During last decades geodetic observations and permanent observing networks have provided a more detailed picture of the Earth's surface and gravity, their temporal variations in all scales, and global changes in the Earth's shape, mass distribution, sea level and orientation in the inertial frame. The increased accuracy reveals inconsistencies between observing techniques, requires more precise reference frames, and especially requests combination of techniques and observing networks, both space-borne and traditional ones, under an integrated geodetic observing system. Such an integrated infrastructure for geodetic observations is asked for a wide range of scientific and practical applications both regionally and on the global level.

In 2007 at the XXIV General Assembly of the International Union of Geodesy and Geophysics (IUGG) in Perugia, Italy, the Global Geodetic Observing System, GGOS, became a full component of the International Association of Geodesy (IAG) as its permanent observing system. Current status and goals are described in (Pearlman and Plag, 2009). GGOS is based on existing IAG Services, see (<http://www.iag-aig.org/>) for details and access points to the services and their products.

The development of the GGOS started already in the beginning of 2000's (Beutler et al., 2000, Rummel et al., 2000). Parallel to the development of the GGOS regional systems were also initiated. These included the ECGN (European Combined Geodetic Network; Ihde et al., 2004, 2005). Originally, such regional observing systems as ECGN were thought to be regional densifications of GGOS. Development of the GGOS, however, lead to a structure where regional "GOS"s do not play a significant role but GGOS is based on the existing IAG services. This put the regional observing systems in a situation where their tasks and future status is to be reconsidered. Definitions of ECGN originally included also their status as a regional implementation and densification of GGOS. A similar development happened with the Nordic Geodetic Observing System, NGOS (Poutanen et al., 2005, 2007). In the General Assembly of the Nordic Geodetic Commission (NKG) in Sundvollen, Norway in September 2010, NGOS was integrated as a part of the NKG working group of Geodetic Infrastructures (NKG, 2010).

2. ECGN first call and current status

The first call for participation in the ECGN in 2003 was directed to the implementation of the ECGN stations. The call for Participation was sent out to about 150 potential institutions and organisations in Europe. As a response more than 20 European countries sent proposals. About 70 stations were proposed to participate in the ECGN, and after the evaluation of their suitability, the final number was reduced to 62 (status of 2007-07-02).

The accepted stations included the standard GNSS observation techniques, gravity (superconducting gravimeter and/or absolute gravimeter), levelling connections to nodal points of the European levelling network (UELN) and meteorological parameters. The stations were divided into four categories:

- *core* (criteria for ECGN are fulfilled and there are additionally some special conditions like fundamental station/observatory and/or measurements of SG)
- *OK* (criteria are fulfilled at present or will fulfilled in the future)
- *candidate* (few of the criteria are not fulfilled (e.g. perm GPS not yet realised))
- *proposed* (some more criteria are at present and perhaps will not be fulfilled in the future).

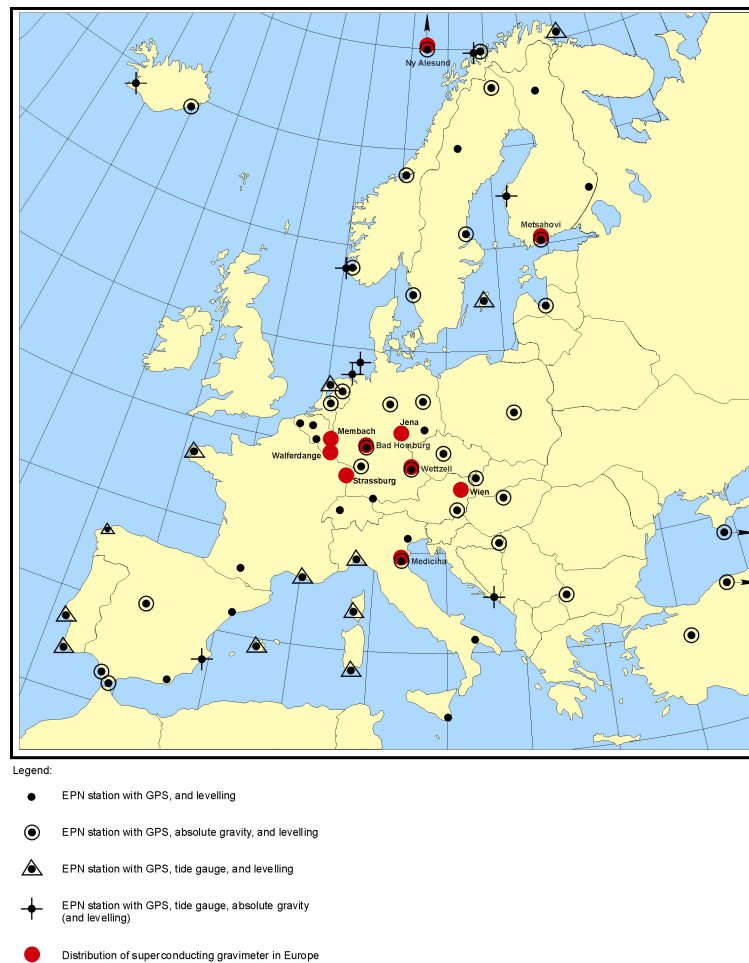


Figure 1. ECGN candidate stations after 1st call.

After the first call, stations and their information were listed on the ECGN web page, http://www.bkg.bund.de/nn_165056/geodIS/ECGN/EN/Home/homepage_node.html_nnn=true. Guidelines for different components were also prepared. Components which were considered as a part of ECGN developed independently but ECGN itself was not much advanced. In addition to the lack of time, development of GGOS was followed to see the direction where to develop the observing system. Most of the components are in place, and no further efforts are needed to establish any new structure. In the following there is a short summary of them.

Status of GNSS: The European Permanent GNSS network (EPN, <http://www.epncb.oma.be/>) is up and running and it is fully organized. There exist operational and analyzing centers, as well as data base which is easy to access. Standards for becoming a GNSS EPN Station are given on the EPN web page.

Status of levelling network: The United European Levelling Network (UELN) exists, data are archived in a data bank, and European-wide adjustments have been made. In the viewpoint of the ECGN no further action is needed. The rules for connection the ECGN station to UELN are described in the guideline and the corresponding measurements data should be registered in the ECGN Levelling Form. All ECGN stations should be connected to UELN (see <http://crs.bkg.bund.de/evrs>).

Status of gravity measurements: Currently, there exist a data base and archive for AG measurements maintained by the BKG (<http://agrav.bkg.bund.de/agrav-meta/index.html>), but still a lot of data are missing there. There exists also ECGN guidelines for Absolute Gravity measurements and for SG observations (under the Global Geodynamic Project, GGP). For superconducting gravimetry a common data base exists via the GGP. Relative gravimetry data are in many cases not freely available and there exist no common data base. Gridded data or Bouguer anomaly maps are in most cases available from various sources.

Status of Tide gauge measurements: For Tide Gauge measurement the data of Permanent Sea Level Observing System - PSMSL and the project European Sea Level Service - ESEAS should be used. There exists the ECGN Standards for Tide Gauge measurements. Contrary to the other techniques, many tide gauges are maintained and owned by non-geodetic organizations. This implies either lack of full control over physical existence of the stations or some restrictions to the data access.

Status of VLBI, SLR and DORIS: These techniques are not considered as an active part of the ECGN. All these stations are included in the respective IAG services. If needed, data access and results are obtained via the services.

Co-located sites, local ties and metadata: A crucial aspect is the co-location of different techniques. The observations of different techniques should be in a close range according to the conditions of the ECGN station. Each type of observation has its own reference, and local ties between the instrument and a local reference network should be obtained in a mm-accuracy. The accuracy should be consistent and reliably controlled over long time periods. Currently, local ties are not fulfilling all requirements, and further development must be done in the future to reach the goal. The goal is common with e.g. GGOS.

The metadata base should be an essential part of ECGN. There exists the ECGN metadata form but the database is not complete and more effort is needed to obtain all necessary information; some of data (e.g. some local ties, meteo data, ...) may not yet exist.

3. Defining the objectives and tasks of ECGN

The original motivation for the ECGN was to integrate the monitoring of gravity (repeated absolute gravity, superconducting gravimeters) and gravity-related heights to the monitoring of the 3-D reference for Europe. According to the definition of GGOS, it will not have a regional substructure, and it is not to be concerned with continental networks of precise levelling like the UELN. In this respect there is an obvious task for ECGN to develop as a program of monitoring gravity-related heights (i.e. geopotential) in Europe, which is a task well suited for a regional organization like the EUREF, using its regional tools (EPN, UELN) as a basis.

Spatially dense European datasets of continuous GNSS time series connected to UELN network and combined with repeated absolute gravity measurements on same sites would be the core of the ECGN. Such spatially dense GNSS sets connected to the levelling network are being created at the national level in many countries. Tide gauges and local ties will be a part of this schema, quite much as they exist in the first plan of the ECGN.

Satellite gravity was mentioned in the first call of ECGN participation. Monitoring changes in regional geopotential requires that GRACE and its follow-up need to be used. The geopotential differences across Europe will come from GOCE at least as accurately as from the UELN. The GOCE must be integrated with the UELN and the time evolution of the outcome monitored as a task for the ECGN.

Combining and analyzing multiple space techniques (like SLR, VLBI, GNSS) at a limited number of fundamental stations is more properly done within a global framework under the GGOS. Therefore these techniques are not included in the plan of the second phase ECGN.

The revised objectives of ECGN can be summarized as follows:

- Maintenance of a long time stability of the terrestrial reference system with an accuracy of 10^{-9} for Europe, especially in the height component
- In-situ combination of geometric positioning (C-GNSS time series) with physical height (UELN) and repeated gravity measurements in 1 cm accuracy level or better
- To use the products of current and future gravity satellites for monitoring regional gravity changes and to obtain precise geopotential differences across Europe
- To provide connection to the sea level and sea level changes via tide gauges in the area
- To maintain databases (via existing components, such as EPN) and a metadata base for access to the data and product of the ECGN

Structure and components of the ECGN; next tasks:

Components and their role are shown in Table 1. Current steering committee consists of all necessary components of the ECGN; a questionnaire to the members to ask if any revision is needed.

Databases exist, metadata base to be created/updated. Call for volunteers to maintain it.

Inventory of EPN stations what do we know about gravity measurement, and connection to the UELN. Do we have all necessary information; circular and invitation to the station owners.

Step2: running the ECGN.... t.b.d.

Table 1. Techniques and components considered to the ECGN

Technique	Objective	Accuracy	Component(s)
GNSS	Point positioning relative to a satellite system	E: 1-2 cm ^{*)} C: 1-2 mm	Surface displacement Reference frame
Levelling	Height differences of points relative to the geoid, UELN	< 1 mm/km ^{1/2}	Surface displacement Reference frame
Tide gauges	Height of points relative to sea level, sea level changes	E: 10 cm C: 1 cm	Surface displacement Reference frame
Absolute gravimeters	Absolute gravimetric accelerations	2-3 µGal	Surface displacement; Gravity; Reference frame
Superconducting gravimeters	Relative gravimetric accelerations	0.1 µGal (< 1 nGal periods)	Surface displacement; Earth rotation, Gravity; Reference frame; local effects
Spring gravimeters	Relative gravimetric accelerations	2-3 µGal	Gravity Reference frame
Gravity satellites	Regional geopotential differences and temporal variations		Geopotential differences, temporal variation, reference frames
Local ties	Connecting different techniques	1-5 mm	reference frame
Metadatabase			

^{*)} E means episodic and C continuous measurements

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:

Revised definitions of ECGN stations:

Core ECGN station: C-GNSS in EPN class A, regularly repeated absolute gravity measurements, superconducting gravimeter, leveling connection to the UELN.

Regular ECGN station: C-GNSS in EPN class A, leveling connection to the UELN.

Candidate ECGN station: C-GNSS in EPN class A, absolute gravity measurement(s) exist, but the leveling connection to the UELN is missing.

- Position through GNSS 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.
- Local ties between techniques
 - 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 (by means of superconducting gravimeter)
 - permanent,
- Water vapour concentration in the atmosphere (vapour radiometer)
 - permanent.

Supplementary observations:

- Meteorological parameters
 - permanent,
- Groundwater gauges
 - permanent.

Gravity satellite data, analysis of time series, combination???