European Geodetic Status – European Geodetic Reference Systems

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Continental reference system realizations have a long tradition in Europe. First initiatives began in the 1860ies with the "Europäische Gradmessung", continued after the Second World War with the Central European Network and the RETRIG Commission. A Sub-commission EUREF of the International Association of Geodesy (IAG) was then founded in 1987 during the General Assembly of the International Union for Geodesy and Geophysics (IUGG) in Vancouver. "Sub-commission 1.3a Europe (EUREF)" is one out of six sub-commissions within the sub-commission 1.3 "Regional Reference Frames" of IAG commission 1 "Reference Frames". EUREF's characteristic is a flat hierarchy with the Technical Working Group (TWG) as the panel for technical and organizational issues, meeting three times per year, and the three-day annual symposium moving around the participating countries. EUREF has 35 member countries. The annual EUREF symposia take place since 1990 with an attendance of about 100-150 participants coming from more than 30 European countries and from other continents, representing Universities, Research Centers and the National Mapping and Cadastre Agencies (NMCAs). Being an open forum, it can be attended by any person interested in the work of this sub-commission.

The partnership between EUREF and EuroGeographics, the consortium of the European NMCAs, reflects the importance of EUREF for practical purposes. A Memorandum of Understanding (MoU) between EUREF and EuroGeographics was established in 2007. This MoU guarantees on one hand that developments made by EUREF are implemented by the NMCA; on the other hand it ensures that EUREF contributes to improving the work carried out by European NMCAs. The MoU is a consequence of the close relationship between both organizations over one decade.

The general goal of geodetic co-operation within European organizations like the Central European GPS Geodynamic Network Consortium (CERGOP) is to create the conditions to facilitate the data exchange, to promote the increase in the co-operation and to improve the densification of the European GNSS network for reference frame definition and geodynamics applications, and to support the Global Geodetic Observing System (GGOS).

Since 2009 EUREF is an associated member of the International Committee on Global Navigation Satellite Systems (ICG). Goals of the annual ICG meetings are to review and to discuss developments in Global Navigation Satellite Systems (GNSSs) and to allow ICG members, associate members and observers to consider matters of interest. ICG also addresses GNSS technology in the era of multi-system receivers and the impact of GNSS interoperability on timing and other user applications (4).

The long-term objective of EUREF, as defined in its Terms of Reference (5) is the definition, realization and maintenance of the European Reference Systems, in close cooperation with the IAG components (Services, Commissions, and Inter-Commission projects) as well as

EuroGeographics, the consortium of the National Mapping Agencies (NMAs) in Europe. Two main geodetic reference systems for Europe are supported in this context:

- European Terrestrial Reference System (ETRS89), and
- European Vertical Reference System (EVRS).

ETRS89 is defined as fixed to – or moving with – the stable part of Europe; so the velocities of the stations at this stable part are almost zero. Hence, coordinates expressed in ETRS89 have minimal time-dependency and are therefore for geo-referencing in Europe. The ETRS89 was defined as being coincident with the International Terrestrial Reference System (ITRS) at the epoch 1989.0. In this sense ETRS89 is based on ITRS.

The ITRS is realized by the International Terrestrial Reference Frame (ITRF). The ITRF is processed and analyzed through the combination of four individual and global techniques, Very Long Baseline Interferometry (VLBI), Satellite (and Lunar) Laser Ranging (SLR/LLR), Doppler Orbit determination and Radio-positioning Integrated on Satellite (DORIS) and the GNSSs, i.e. all existing and upcoming GNSSs are contributing to the ITRF. The ITRF is versioned which is indicated in its abbreviation by the ending year of the time span covered by the observations of the four techniques. Hence, within time the accuracy of the sequential ITRFyy is improving thanks to the longer periods covered by observations. Moreover, the quality of the technique-related contributions is steadily improving thanks to better modeling and reprocessing activities. More than 350 globally and equally distributed stations were contributing to the latest realization of the ITRS (1).

To take full benefit of improved realizations of the ITRF, transformations between different ITRFyy realizations and the corresponding realizations of the ETRF (ETRFyy) are carried out by a 14-parameter transformation taking into account the positions and velocities following formulas and parameters described in (2).

Europe contributes to the maintenance of the International Terrestrial Reference Frame (ITRF) through supporting GGOS. GGOS has been developed in order to meet the requirements of scientific and social applications of geodesy in the IAG. European NMAs help with networking among the IAG Services and Commissions and other stakeholders in the Earth science and Earth Observation communities. They provide scientific advice and coordination to develop products with higher accuracy and consistency meeting the requirements of particularly global change research and to improve the accessibility of geodetic observations and products for a wide range of users.

With strong support from the European side GGOS aims to integrate different techniques, different models, and different approaches to achieve a better consistency, long-term stability, reliability, and the temporal and spatial resolution required for the understanding of geodetic, geodynamic and global change processes. Research and services products address issues related e.g. to global risk management, geo-hazards, natural resources, climate change, severe storm forecasting, sea-level estimations and ocean forecasting, space weather, and others. EUREF in particular contributes to the definition the ITRF including all the physical and mathematical models needed to analyze related observations.

The backbone of EUREF is the EUREF Permanent Network (EPN). The EPN is a multi-GNSS tracking network of about 250 active stations with more than 65% of the stations providing GPS plus GLONASS data and almost 50% of the stations having real-time capability (3). Several stations are in the process of being upgraded for tracking Galileo data of the In-Orbit-Validation (IOV) satellites as well. The EPN could be seen as the regional densification of the International GNSS Service (IGS) global infrastructure. About 60 EPN stations are IGS stations as well. Finally, national campaigns with permanent and temporary occupied stations serve as densifications of the EPN.

EPN stations are quality-controlled by classifying them. So-called class A stations have a position accuracy of 1 cm for any epoch of the station's lifetime. The velocity repeatability should be below 0.5 mm per year. Usually, only stations with a lifetime longer than three years will belong to this group. Class B stations are younger stations with a position accuracy of 1 cm for the epoch of minimum variance and a velocity repeatability larger than 0.5 cm per year. This velocity is not published. The densification campaigns are only using class A stations as reference stations. The results of the campaign, station positions, usually belong to class B.

Since the establishment of ETRS89 in 1989, EUREF is promoting the adoption of ETRS89 in European countries and European organizations. Although most of the European countries have their own national reference frame, it is important to have these national reference frames referenced to a common continental frame. Since 1989, large parts of the European NMAs have adopted their national reference frames to ETRS89 by calculating national ETRS89 coordinates following the EUREF guidelines.

An important milestone was the recommendation of the European Commission (EC) to adopt ETRS89 and EVRS as geodetic datum for geo-referenced information (COGI action decision 2003 – F/GIS/69/EN). Consequently, EVRS and ETRS89 could be implemented in a spatial information system following the ISO 19111 standards. ETRS89 and EVRS have been adopted by the EC as coordinate reference systems in the Infrastructure for Spatial Information in the European Community (INSPIRE) for environmental policies, or policies and activities that have an impact on the environment. INSPIRE is a major development , namely the directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing INSPIRE entered into force on the 15th May 2007. The INSPIRE directive will be implemented in various stages, with full implementation required by 2019. The INSPIRE directive aims to create a European Union (EU) spatial data infrastructure. This will enable the sharing of environmental spatial information among public sector organizations and better facilitate public access to spatial information across Europe.

INSPIRE is based on the infrastructures for spatial information established and operated by the 27 Member States of the European Union. The Directive addresses 34 spatial data themes needed for environmental applications, with key components specified through technical implementing rules. "Coordinate Reference Systems" is one of the important themes there which establishes the geographical reference for many other themes. This makes INSPIRE a unique example of a legislative "regional" approach.

To ensure that the spatial data infrastructures of the Member States are compatible and usable in a Community and transboundary context, the Directive requires that common Implementing Rules (IR) are adopted in a number of specific areas (Metadata, Data Specifications, Network Services, Data and Service Sharing and Monitoring and Reporting). These IRs are adopted as Commission Decisions or Regulations and are binding in their entirety. The Commission is assisted in the process of adopting such rules by a regulatory committee composed of representatives of the Member States and chaired by a representative of the Commission (known as the Comitology procedure).

A European Spatial Data Infrastructure will assist in policy-making across boundaries. Therefore the spatial information considered under the directive is extensive and includes a great variety of topical and technical themes.

INSPIRE follows a number of common principles:

- Data should be collected only once and kept where it can be maintained most effectively.
- It should be possible to combine seamless spatial information from different sources across Europe and share it with many users and applications.
- It should be possible for information collected at one level/scale to be shared with all levels/scales; detailed for thorough investigations, general for strategic purposes.
- Geographic information needed for good governance at all levels should be readily and transparently available.
- Easy to find what geographic information is available, how it can be used to meet a particular need, and under which conditions it can be acquired and used.

To prepare for the future Galileo system, some EPN station operators make available GNSS observation data in RINEX version 3 format in addition to their routine data submissions in the RINEX 2.11 format. RINEX 3.0x is better suited to handle additional GNSSs such as Galileo, COMPASS/BeiDou 2 and QZSS as well as the various new signals of existing systems. The goal is to get experience with this different format and to foster the development of the EPN towards a multi-system GNSS network.

The EPN Project on "Real-time Analysis" (6) focuses on the processing of EPN real-time data to derive and disseminate real-time GNSS products. Satellite clock and orbit corrections are estimated and provided in the ETRS89 (realization ETRF2000). Based on these corrections, users can directly derive coordinates referred to ETRS89 with decimeter accuracy. One aim of the project is to increase the reliability of EPN real-time data flows and minimize outages. For this purpose, three regional broadcasters have been established in the Internet. Several stations and national broadcasters are uploading their data in parallel to all of the broadcasters.

Since 1994 EUREF has enhanced the Unified European Leveling Network (UELN) and defined the EVRS. About 50% of the participating countries provided new national leveling data to the UELN data centre since the release of the realization of EVRS, the European Vertical Reference Frame (EVRF) 2000. Therefore a new realization of the EVRS was computed and published under the name EVRF2007. The datum of EVRF2007 is realized by 13 datum points distributed evenly over the stable part of Europe. The measurements have been reduced to the common epoch 2000 using the land uplift model of the Nordic Geodetic Commission (NKG). The results of the adjustment are given in geopotential numbers and normal heights which are reduced to the zero tidal system. At the EUREF symposium June 2008 in Brussels, a resolution was approved proposing to the European Commission the adoption of the EVRF2007 as the mandatory vertical reference for pan-European geo-information.

The descriptions of national and pan-European geodetic reference systems are available by a Service System for European Coordinate Reference Systems (CRS), see (7). Transformation parameters between national geodetic reference systems and the European ETRS89 and EVRF2007 were calculated and are provided there. Additionally, an online-transformation capability for coordinates and heights of single points is implemented.

References

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