EUREF - an Important Component of the European Geodetic Infrastructure

Martin LIDBERG, Sweden, Wolfgang SOEHNE, Germany, Martina SACHER, Germany, Juliette LEGRAND, Belgium, Ambrus KENYERES, Hungary

Key words: Geodetic reference frames, height systems, GNSS, infrastructure

SUMMARY

The International Association of Geodesy (IAG) Reference Frame Sub-Commission for Europe, EUREF, merges efforts of National Mapping and Cadastral Agencies (NMCA), Universities and research institute to define, realize and maintain the European Terrestrial Reference System 1989 (ETRS89) and the European Vertical Reference System (EVRS) for scientific and practical purposes in Europe. These systems are the basis for geo-referencing in Europe and have been endorsed by the European Union INSPIRE directive (Infrastructure for Spatial Information in the European Community), Eurocontrol and EuroGeographics.

The realization, maintenance and development of the ETRS89 is primarily done through the EUREF Permanent GNSS Network (EPN). EPN consists of continuously operating GNSS stations (~350 stations), supported by Data and Analysis Centres and a Central Bureau that is responsible for the monitoring and management of the EPN. The backbone EPN has been complemented with additional national CORS networks with rigorously computed station coordinates and velocities. At present, the dense European network incorporates ten times more stations as the core EPN sites.

The physical height system EVRS is realized through common adjustment of the Unified European Levelling Network (UELN) where the vast majority of the European countries contribute.

Some current and future challenges in geodetic reference frames are also discussed. It is foreseeable an emerging mass market for precise positioning based on centimetre level positioning services worldwide without any regional or national reference frames. There will be also precise point positioning (PPP) service from Galileo and other provides. These worldwide services will most likely use ITRF in current epoch. We also see progress towards a first realisation of the International Height Reference System (IHRS).

At the end, we touch on the future role of EUREF in the emerging organizational landscape. For example, the European Plate Observing System (EPOS) will enter its operational phase in 2020, and progress is reported from the UN-GGIM Subcommittee on Geodesy, not to forget the operational processing of dense GNSS networks within the EUMETNET GNSS Water Vapour Programme (E-GVAP). This calls for mutual collaborations in order to achieve common goals to the benefit for the wider user society.

EUREF - an Important Component of the European Geodetic Infrastructure

Martin LIDBERG, Sweden, Wolfgang SOEHNE, Germany, Martina SACHER, Germany, Juliette LEGRAND, Belgium, Ambrus KENYERES, Hungary

1. INTRODUCTION

The International Association of Geodesy (IAG) Reference Frame Sub-Commission for Europe, EUREF, merges efforts of National Mapping and Cadastral Agencies (NMCA), Universities and research institute to define, realize and maintain the European Terrestrial Reference System 1989 (ETRS89) and the European Vertical Reference System (EVRS) for scientific and practical purposes in Europe. These systems are the basis for geo-referencing in Europe and have been endorsed by the European Union INSPIRE directive (Infrastructure for Spatial Information in the European Community), Eurocontrol and EuroGeographics.

The realization, maintenance and development of the ETRS89 is primarily done through the EUREF Permanent GNSS Network (EPN). EPN consists of continuously operating GNSS stations (~350 stations), supported by Data and Analysis Centres and a Central Bureau that is responsible for the monitoring and management of the EPN. All contributions to the EPN are provided on a voluntary "best effort" basis, with more than 100 European agencies/ universities involved. The EPN operates under well-defined standards and guidelines which guarantee the long-term quality of the EPN products.

In response to an increasing demand both from the National Mapping Agencies and research groups, the backbone EPN has been complemented with additional national CORS networks with rigorously computed station coordinates and velocities. At present, the dense European network incorporates ten times more stations as the core EPN sites and benefits from the contribution of 26 different Institutions.

The physical height system EVRS is realized through common adjustment of the Unified European Levelling Network (UELN) where the vast majority of the European countries contribute.

2. The EUREF Permanent GNSS Network - EPN

The EUREF Permanent Network (EPN) is a science-driven network of permanent GNSS tracking stations (http://epncb.oma.be/). Through its daily and weekly computed network solutions it is used by EUREF to realize and provide access to the ETRS89. The EPN includes:

- a network of about 350 continuously operating GNSS (Global Navigation Satellite Systems, such as GPS, GLONASS, Galileo, Beidou, ...) reference stations,
- data centres providing access to the station data,
- analysis centres that routinely analyze the GNSS data,
- product centres and coordinators that generate the EPN products,
- and a Central Bureau that is responsible for the daily monitoring and management of the EPN.

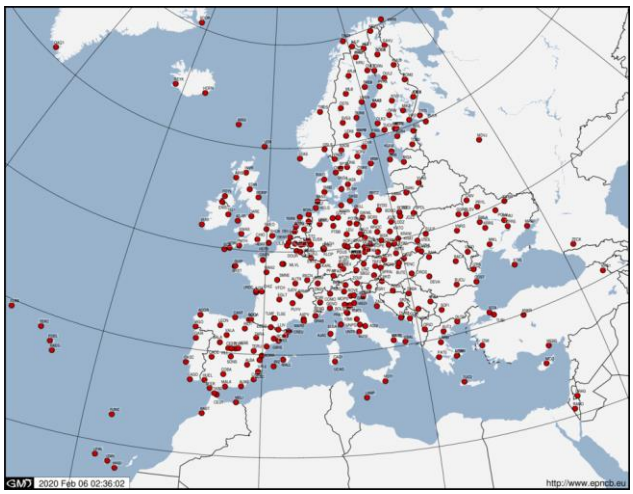

Figure 1. The EUREF Permanent Network, EPN.

The EPN provides access to the ETRS89 by making publicly available the GNSS tracking data as well as precise positions, velocities and tropospheric parameters of all EPN stations. Based on these products, the EPN contributes also to monitoring of crustal deformations in Europe, and supports long-term climate monitoring, numerical weather prediction and the monitoring of sea-level variations.

The EPN tracking stations are also integrated in the successive realizations of the International Terrestrial Reference System, which is the basis for the European Terrestrial Reference System 1989 (ETRS89). Since the EPN is the European densification of the network of the International GNSS service, IGS (http://igscb.jpl.nasa.gov/), a complete harmonization of standards between the global and European network is put forward.

All contributions to the EPN are provided on a voluntary “best effort” basis, with more than 100 European agencies/universities involved. The EPN operates under well-defined standards and guidelines which guarantee the long-term quality of the EPN products.

Operation and recent developments of the EPN

The EPN is managed by the Central Bureau (CB), which also acts as the Network Coordinator. The CB, managed by the Royal Observatory of Belgium, is operationally monitoring the EPN station performance in terms of data availability, correctness of metadata, and data quality. The maintenance of the station site logs has been automated by using the "Metadata Management and Dissemination System for Multiple GNSS Networks" (M^3G, available from https://gnss-metadata.eu) (Bruyninx et al. 2019). The EPN has been continusouly growing with 27, 15 and 20 new stations in the years 2017 to 2019, respectively. Emphasis is given to the fact that as many as possible stations should observe and transmit the observational data of the European GNSS Galileo, and optimally also the Chinese GNSS BeiDou. 72 % of the EPN stations provide Galileo data and 58 % BeiDou observations.

Products

The EPN Analysis Centers (ACs) operationally process GNSS observations collected at the EPN stations. EUREF is following a distributed approach, i.e. 16 ACs are providing final weekly and daily coordinate and other solutions of their designated subnetworks. The coordinate and troposphere parameters are combined to get the final EUREF solutions. To get homogeneous results following the state-of-the-art in modelling and processing, EUREF is reprocessing the whole network, following the global reprocessing within the International GNSS Service (IGS).

To maintain the European Terrestrial Reference System (ETRS89), EUREF releases, each 15 weeks, an update of multi-year coordinates and velocities of the EPN stations in the latest ITRS/ETRS89 realizations. The consistency of the EPN multi-year solutions is validated by comparison to, for example, the IGS multi-year solution and shows good agreement of 0.8 mm, 1.1 mm, 4.8 mm for the North, East and Up components, respectively. For stations with an observation period longer than three years also the velocities can be compared, the differences are below 0.2 mm/yr, 0.2 mm/yr, 0.7 mm/yr for North, East and Up components, respectively.

3. EPN Densification

EUREF introduced a project on EPN Densification (Kenyeres et al 2019), which as of today is a collaborative effort of 26 European GNSS ACs providing series of daily or weekly station position estimates of dense national and regional GNSS networks and delivered in SINEX format. The individual solutions are combined into one homogenized set of station positions and velocities. Such a set is extremely valuable for cross-border and large-scale geodetic and geophysical applications. The most recent results cover the period from November 2006 to April 2019 (GPS weeks 1400 to 2050) using inputs expressed in IGS14. The combined multi-year solution includes 31 networks with positions and velocities of 3300 stations, well covering Europe. The description of the EPN Densification, station metadata, and results are available from the EPN CB Densification webpages (http://epncb.oma.be_densification/).

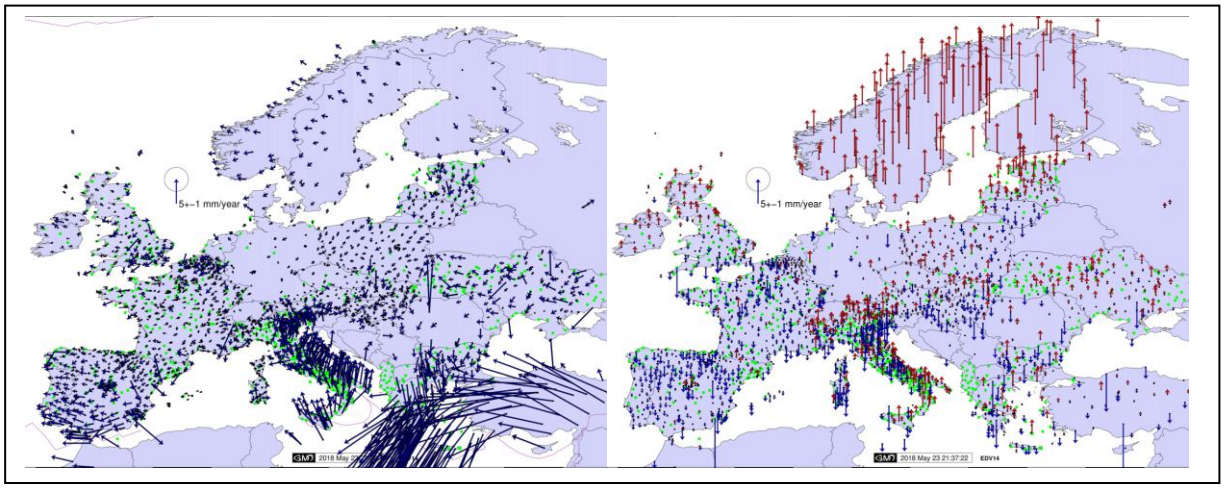

Figure 2. Horizontal and vertical velocities from the EPN Densification (in ETRS89).

4. European Dense Velocities

Complementary to the EPN Densification, EUREF introduced a project on dense velocities. The velocity estimates in ETRF2000, derived by currently 30 contributors, are the direct input to the generation process of a dense velocity field for Europe. In addition to results from GNSS permanent networks, densified solutions stemming from GNSS campaigns, InSAR or levelling are also included. In some countries, as e.g. in the Nordic countries, velocity models are already in use. They can be integrated to indicate possible differences between modeled and observed velocities. Also the results of the EPN Densification project are included. The alignment of the geodetic datum of each input is controlled by overlapping stations. About 6200 individual station velocities are available for Europe and more than 2000 sites are determined at least by two independent contributions. Several IGS/EPN stations are part of the majority of solutions. In average, the velocities agree for the horizontal component on a level of 0.2-0.3 mm/yr (standard deviation). The description and detailed results are available on http://pnac.swisstopo.admin.ch/divers/dens_vel/index.html.

5. European Vertical Reference System and Frame, EVRS and EVRF

The EVRS is the European Vertical Reference System that are (at least so far) realized through a common adjustment of available national precise levelling networks. The height reference is the level of the Normaal Amsterdam Peil, NAP.

The recent realization EVRF2019 (Sacher and Liebsch 2019) includes about 14 000 observations and 11 000 unknowns (nodal points). The average standard uncertainty of the observations is close to 1mm/√km. In areas with clear secular vertical velocities where

vertical velocity models are available (Fennoscandia and Switzerland), the epoch has been reduced to year 2000.0.

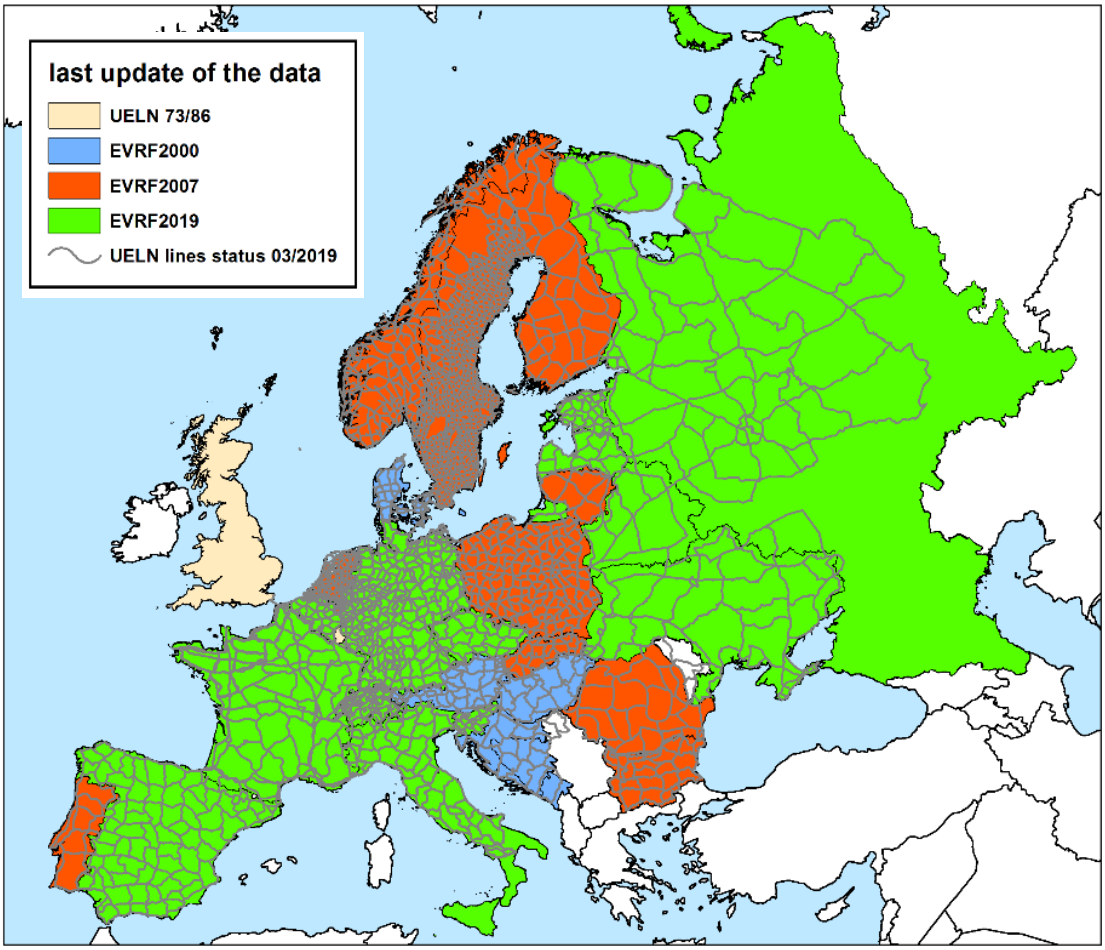

Figure 3. The United European Levelling Network, UELN, which is the basis for the recent new realization of the EVRS, EVRF2019.

At the global level, the International Height Reference System, IHRS, is under construction and we see progress towards its first realisation in the International Height Reference Frame, IHRF. Since EVRS and IHRS will be used in parallel for a long time, European IHRF stations should be a part of or connected to EVRF so the precise relation between IHRF and EVRF can be evaluated and determined.

6. Some foreseen challenges

In Europe, there are network RTK services available in most (all?) countries. These are usually operated so the user will get the position in the national reference frame, which in many cases is a realization of the ETRS89. It is, however, also foreseen an emerging mass

market for precise positioning based on centimetre level positioning services worldwide without any regional or national reference frames. There will be also precise point positioning (PPP) service from Galileo and other provides. These worldwide services will most likely provide the positions in a kinematic reference frame (in practice recent ITRF in current epoch). The need for the precise relations between realizations of ETRS89 and ITRF becomes therefore more important. The precise knowledge of the crustal deformations within the EUREF area of interest is therefore vital. A first version of such a European deformation model has been developed based on results from EPN Densification and European Dense Velocities (Steffen et al 2019).

From the organizational point of view, we see an emerging organizational landscape. For example, the European Plate Observing System (EPOS) (https://www.epos-ip.org/) will enter its (pre) operational phase in 2020, and progress is reported from the UN-GGIM Subcommittee on Geodesy, not to forget the operational processing of dense GNSS networks within the EUMETNET GNSS Water Vapour Programme (E-GVAP). EUREF have good relations and cooperation with these groups and organizations. Nevertheless, this calls for mutual collaborations in order to achieve common goals to the benefit for the wider user society.

ACKNOWLEDGEMENTS

The authors like to thank all those organizations and persons who contribute to EUREF with presentations at our yearly symposia or workshops, with analysis e.g. for the EPN and EPN densification, with products for the dense velocities and deformation models, and with data (e.g. GNSS, or precise levelling for the UELN). We are also grateful for the engagement and commitment from the members of EUREF Governing Board.

REFERENCES

Bruyninx, C., Legrand, J., Fabian, A., Pottiaux E., GNSS metadata and data validation in the EUREF Permanent Network, GPS Solut (2019) 23: 106. https://doi.org/10.1007/s10291-019-0880-9.

Ambrus Kenyeres, J. G. Bellet, C. Bruyninx, A. Caporali, F. de Doncker, B. Droscak, A. Duret,·P. Franke, I. Georgiev, R. Bingley, L. Huisman, L. Jivall, O. Khoda, K. Kollo, A. I. Kurt, S. Lahtinen, J. Legrand, B. Magyar, D. Mesmaker, K. Morozova1, J. Nágl, S. Özdemir, X. Papanikolaou,·E. Parseliunas, G. Stangl, M. Ryczywolski, O. B. Tangen, M. Valdes. J. Zurutuza, M. Weber. Regional integration of long-term national dense GNSS network Solutions, GPS Solutions (2019) 23:122. https://doi.org/10.1007/s10291-019-0902-7

Sacher M and G Liebsch (2019) EVRF2019 as new realization of the EVRS, Presentation at the EUREF Symposia in Tallinn 22-24 May 2019. http://www.euref.eu/symposia/2019Tallinn/01-01-Sacher.pdf

Steffen R, J Legrand, H Steffen, M Lidberg, A Kenyeres, E Brockmann, S Lutz (2019) Towards a Deformation Model for Europe using least square collocation, Presentation at the EUREF Symposia in Tallinn 22-24 May 2019.
http://www.euref.eu/symposia/2019Tallinn/01-04-Steffen.pdf

BIOGRAPHICAL NOTES

Dr. Martin Lidberg is head of the Geodetic Infrastructure Department at Lantmäteriet, the Swedish mapping, cadastral and land registration authority. He has a MSc in Surveying and mapping from the Royal Institute of Technology (Stockholm, Sweden) in 1988, and got his PhD from Chalmers University of Technology (Gothenburg, Sweden) in 2007. He has been working at Lantmäteriet since 1988. Martin is also since 2019 chairman of EUREF.

Dr. Wolfgang Söhne is a senior scientist working in the geodetic department of the Federal Agency for Cartography and Geodesy (BKG) in Frankfurt on Main, Germany. He got his PhD from the Technical University of Darmstadt in 1996. He has been working at BKG since 2001. Since then, he was involved in the EUREF Technical Working Group (now Governing Board) where he became official member in 2008. Since summer 2019, he is the chair of the EUREF Governing Board. He is also member of the IGS Governing Board and the IGS Infrastructure Committee.

Martina Sacher studied geodesy at the Technical University Dresden from 1979 to 1984. Since 1990 she has been working as a scientific assistant at the Federal Agency for Cartography and Geodesy in the field of physical heights. In the last years she was responsible for analyzing the measurements in the first order leveling network of Germany. Within the framework of EUREF, the IAG Reference Frame Sub-Commission for Europe, she works on the unification of European leveling networks. In this context she computed the last realizations of the European Vertical Reference System (EVRS).

Dr. Juliette Legrand received a Ph.D. in Space Geodesy at Paris Observatory, France, in 2007. She is a member of the GNSS group of the Royal Observatory of Belgium and the EPN CB. She is Reference Frame Coordinator of EUREF and member of the EUREF Governing Board. Her research focuses on GNSS data quality monitoring, GNSS time series analysis, and reference frames.

Dr Ambrus Kenyeres graduated as geophysicist at Lorand Eötvös University and received his PhD at Technical University of Budapest in 2001. Since 2010, he is the head of the LTK (Lechner Nonprofit Ltd) Satellite Geodetic Observatory, Penc. His main research field is the product level combination of permanent GNSS networks in the frame of EUREF as WG chair of EPN Densification with the contribution to EPOS GNSS products.

CONTACTS

Dr. Martin Lidberg
Lantmäteriet
Lantmäterigatan 2c
SE-801 82 Gävle
SWEDEN
Tel. +46 26 633842
Email: martin.lidberg@lm.se
Web site: www.lantmateriet.se