Towards a Deformation Model for Europe using least-square collocation

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Abstract

One of the goals of the EUREF working group on Deformation Models is to develop a deformation model for entire Europe. However, the irregular and partly sparse distribution of GPS stations makes it difficult to obtain a complete picture of the horizontal deformation for Europe. The solution for this problem is to use an interpolation. However, most well-known interpolation techniques (e.g., triangulation, spline interpolation) have the disadvantage that the entire signal is used while every signal always includes noise due to unknown errors or local effects. Additionally, those interpolation techniques can only be applied to one component at a time. The least-square collocation solves both problems of dividing the dataset into a signal and noise component and applying different datasets simultaneously. This method of filtering and interpolation is widely used in Physical Geodesy. However, when applied to velocity fields, the advantage of the collocation with using more than one dataset at the same time is not utilized. This implies that no correlation between the horizontal components is assumed. Here, we will show results of applying a combined least-square collocation for the example of Europe. Different European-wide GPS datasets will be tested as well as the effect of reducing a background model for northern Europe due to glacial isostatic adjustment. The effect of interpolation parameters (e.g., choice of covariance function, correlation length) will be presented as well.
Abstract
The last realization of EVRS, EVRF2007, was adopted at the EUREF symposium 2008 in Brussels. As announced in the last years, a new realization of EVRS has been computed. It contains new data of many countries and includes for the first time also data of Russia, Belarus and Ukraine.

The presentation describes the parameters of the adjustment, the realization of the datum, the treatment of the permanent tides and the reduction to a common epoch. The special treatment of the data of Belgium, France and Great Britain in the computation is explicated. The results of the adjustment are compared with the former realization EVRF2007.

The preliminary solution of EVRF2019 has been distributed to the participating countries in March 2019, together with a questionnaire, where the individual countries could decide about the publication of their national EVRF2019 heights. The results of the questionnaire are evaluated in the presentation.
Present and future of European reference frames – (more than) 30 years of EUREF

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Abstract
Since 1989, the IAG regional reference frame sub-commission 1.3a EUREF has merged efforts of National Mapping and Cadastral Agencies (NMCA), Universities and Research Institutes to define, realize and maintain the European Terrestrial Reference System 1989 (ETRS89) and the European Vertical Reference System (EVRS). Technical development, new applications and increased accuracy of observations are setting new demands for the realizations of the reference systems.

The EUREF community is providing a large variety of data and data products. The product catalogue covers file-based and real-time GNSS data, position and velocity estimates from multi-year solutions, position time series, zenith path delay estimates, and real-time GNSS corrections.

Crustal deformations and movements deteriorate the accuracy of static reference frames and heights. Monitoring the deformation within EUREF is a necessity for the future, but this alone does not answer the question of future reference frames. It is foreseeable an emerging mass market for centimetre level precise positioning services which very much rely on a technical body with an European dimension such as EUREF for validation and compliance with European regulations, such as the INSPIRE Directive.

We are facing the European-wide question on the future of reference frames and the role of EUREF. The release of the International Terrestrial Reference Frame ITRF2014 raised also the question on needs and ways to renew the realization of the ETRS89 both for practical and scientific purposes. For some years to come we may have a two frame approach where ETRF and ITRF will be used together. Using European-wide 3D deformation models, and a dense network of permanent GNSS stations, we may link these together (semi-kinematic approach). On the gravity related global heights we do not yet have a similar approach, which will take even more time to get adopted. However, on European basis, EUREF keeps very close collaborations with NMCAs with the intent of merging the national high precision levelling data bases and define a European system of gravity related heights with commonly agreed standards.
Maintenance of the National Realization of ETRS89 in Sweden: re-analysis of 20 years’ GPS data for SWEREF stations

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Abstract
The national geodetic reference frame of Sweden, SWEREF 99, was adopted in 2000 by EUREF as the realization of ETRS89 in Sweden and was officially introduced in 2001 as a national reference frame, that eventually in 2007 replaced the former national reference frame. SWEREF 99 is defined by an active approach through the 21 fundamental SWEPOS permanent GNSS stations, hence relying on positioning services such as the network real time kinematic (NRTK) and post processing service. The SWEREF 99 coordinates are assumed to be fixed in time and no temporal variations are expected. However, the stability of the stations and their coordinates can be altered due to equipment or software changes as well as local movements at the reference stations.

To be able to check all alterations mentioned above and having a backup national network of GNSS stations, approximately 300 passive so-called consolidation stations are used. The consolidation stations are a subset (main part) of the so-called SWEREF stations established from 1996 and onwards. The 300 stations are remeasured with static GNSS for 2x24 hours using choke ring antennas on a yearly basis with 50 stations each year. The original processing was done with the Bernese GNSS software (here called Bernese original) and the reprocessing was carried out with both the Bernese and the GAMIT-GLOBK software packages during 2017-2018.

The resulting coordinates in SWEREF 99 from GAMIT and Bernese processing are equal at ~1.2 mm level for horizontal and 4 mm for vertical components (1 sigma) when using the same models and processing strategy. The original processing, which partly is based on other models and parameters, differs slightly more (rms 2.4 mm) for the north component. Our analysis both from Bernese and GAMIT shows that the standard uncertainties for a single SWEREF 99 determination (2x24 hrs) is ~2 mm for the horizontal components and ~6-7 mm in height. It is interesting to note that the repeatability is on the same level also for the original processing, where we have differences in models and parameters used during the years. This indicates that the SWEREF-concept of determining SWEREF 99 coordinates has worked well on the mentioned uncertainty level.

We performed trend analysis and statistical tests to investigate the stability of the estimated SWEREF 99 coordinates. The analysed station time series (minimum and mainly three observations) showed that about 14% of the stations had significant trends at the 95%-level, but we should note the low degree of freedom and that many of the significant trends are small in relation to the uncertainty of a single
SWEREF 99 determination and the time span between first and last observation. The possible explanation for trends can be either local deformation and/or residuals of uplift model and/or computational effects such as lack of good or enough close-by stations for Helmert transformations from ITRF to SWEREF 99.

The outcomes of the new processing and analysis reported here, are used to analyse the stability of SWEREF 99 after two decades. The results have also been used to define the SWEREF 99 component in the fit of the new geoid model SWEN17_RH2000 to SWEREF 99 and RH 2000 (the Swedish realisation of EVRS).
Abstract

EUREF activities started in Estonia in 1992, when EUREF-BAL92 campaign was carried out, resulting in the inclusion of 5 points from the campaign as the EUREF densification in Estonia, class C (EUREF, 1993). In 1995 the establishment of a new Estonian geodetic network was initiated, consisting altogether of 212 points, from which 13 belong to the first order and 199 to the second order network. As a result, the EUREF symposium held in Prague in 1999 approved the results of EUREF-EST97 campaign as new EUREF densification for Estonia that corresponds to class B accuracy (EUREF, 1999).

We are presenting a multi-year solution for the ESTPOS network. We used data from 2006 to 2018, with mean epoch of 2013.00. For the computation Bernese GNSS 5.2 software was used, for reference frame alignment and final coordinate and velocity computation CATREF was used.
Abstract

The primary purpose of the EPN (EUREF Permanent GNSS Network) multi-year coordinate & velocity solution is to provide access to the European Terrestrial Reference System 89 (ETRS89) which is the standard precise GNSS coordinate system throughout Europe.

The EPN multi-year solution densifies the IGS14 realization of the ITRS in Europe. It is based on daily solutions coming from the EPN-repro2 completed by operational EPN solutions. It is computed with the CATREF software (Altamimi et al., 2007) and is expressed also in ETRF2000 and ETRF2014.

The presentation will present the latest updates of the solutions and will focus on the improvement of the station classification. More criteria have been investigated such as the sensitivity of the velocity and its error estimation with respect to time correlated noise, used software, and tracking performance of the station. This study allows assessing the quality of the stations, but it also provides more general results on the stability of the velocity estimation for a network such as the EPN.
Towards a European Dense Velocities Field as a basis for Maintaining the European Reference Frame


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Abstract

The project “EU Dense Velocities” under the umbrella auf EUREF (European Reference Frame in Europe) was established in May 2017 to enable the generation of an European-wide dense velocity field. The project follows the classical approach of densifying national and regional velocity fields. The method is based on the contributions of individual velocity fields generated by the national mapping agencies and other analysis centres. Those institutions know their processed station well and are able to model possible jumps in the time series best possible. Beside velocity fields from permanent networks, also dense velocity fields stemming from campaigns are integrated. Examples of the Central East European Initiative and from Switzerland are shown. Velocity fields from levelling can be used to improve the vertical velocity information. As an example of the strength of the method, results from a very dense combined INSAR/GNSS analysis are integrated for the area at the borders of Germany, France and Switzerland. Finally, complete velocity grids can be used in the combination process. This is important in regions, such as Scandinavia, where users already use velocity fields in praxis and where the velocity fields where generated based on a combination of several methods.
More than 20 velocity fields in a common reference system ETRF2000 have been collected. Totally, about 5000 stations with velocity information are available. More than 2000 sites in Europe are available in two or more solutions. The velocities were analysed and successfully combined. The agreement of the solution is for the horizontal components on a level of 0.2 – 0.3 mm/yr (standard deviation) covering usually 50-200 common stations. Solutions in the “faster” (3-4 cm/yr) moving regions of southeast Europe show slightly worse agreements. A web platform (http://pnac.swisstopo.admin.ch/divers/dens_vel) gives feedback to the contributors of the velocity fields so that possible discrepancies may be eliminated.

The European dense velocity field is the basis for a deformation model for Europe. It allows an interesting knowledge exchange with geologists, seismologists and geophysicists and it is an important part to enable the maintenance of the European reference frame, which currently assume no deformations of the European plate. Due to the high precision of the current GNSS methods and due to an age of 30 years of ETRS89 and of many other the European national reference systems, the small but significant movements within the European plate need to be modelled in order to ensure a horizontal reference frame realization of below 1-2 cm also for the next decades.
Abstract

In this paper will be introduced the project MontePN, financed by the Ministry of Science of Montenegro, with the integration of Montenegrin scientific institutions into World and European scientific and professional organizations, participation in European projects, adoption of standards and usage of innovative potentials are improving. The subject of the project relates to the establishment of the infrastructure of a permanent station network with the possibility of receiving signals from GPS, GLONASS, Galileo and BEIDOU systems. The existing permanent station network on the territory of Montenegro, which realizes the national reference system, does not participate in the European Permanent Network (EPN). The national reference system of Montenegro is implemented through the existing permanent stations network and is related to the ITRS. One of the goals of the MontePN project is to constitute a new permanent station that will fulfill the conditions for the accession of the EPN in order to achieve the preconditions for adopting the new national reference system ETRS89 in the territory of Montenegro, which is a practice in all European countries. The paper will describe the conceptual solution related to the method of stabilization of the new reference geodetic points of the permanent GNSS antenna in accordance with the rules of density increases of the EUREF network and the given guidelines for connecting the GNSS networks of permanent stations to the EPN.
Networks: EPN, UELN, Densification

Report of the Troposphere Coordinator

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Abstract

This presentation will give an overview of the status of the EPN Troposphere Products based on EPN Repro2 for the period 1996-2014 and on operational solutions afterwards. Particular attention will be given to the test phase set up to evaluate the impact of Galileo observations, in addition to GPS and GLONASS, on troposphere parameters and to the following switch to 3G (GPS+GLONASS+Galileo) solutions in operational EPN products.
EPN data quality in a multi-GNSS environment

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Abstract

GNSS is the primary means to access (international or regional) Terrestrial Reference Frames (TRF). When using network-based differential GNSS processing techniques, the analyst includes TRF stations in its data analysis in order to tie its network to the chosen reference frame. The selection of the most appropriate reference stations depends not only on their geographical location, but also on station performance. In Europe, the EUREF Permanent Network (EPN) provides the GNSS reference stations to access the European Terrestrial Reference Frame. For the user, it is important to know at each epoch, which EPN stations perform according to expectations so that they can be effectively used as reference station during the data analysis.

For that reason, the EPN Central Bureau (CB) is operationally monitoring EPN station performance in terms of data availability, correctness of metadata, and data quality. The data quality checks are partly based on G-nut/Anubis developed by the Geodetic observatory Pecný, Czech Republic (Václavovic P, Douša J, 2016), and complemented with in-house developed software. Based on a reprocessing of all EPN data since 1996, an initial set of the data quality metrics relevant for EUREF applications has been derived. However, due to the increased complexity of the tracked satellite constellations and signals, the interpretation of the temporal variations in these data quality metrics and the generation of operational alarms remains challenging. A first analysis of the results showed already: a) the importance of using RINEX v3 (above RINEX v2), even if only processing GPS and GLONASS, b) the need to keep receiver firmware up to date, and c) the necessity to careful select the tracked satellite constellations for receivers with a limited number of channels.
Abstract

The presentation gives an update on the efforts of the regional and global real-time GNSS community, which has the aim of using and distributing open formats and open standards. In particular, we highlight the improvements concerning long mount-point names, for stations providing data as well as for derived products. We discuss the reviewing process of organizing the structure of the broadcasters within the International GNSS Service (IGS), the status of important projects within the Radio Technical Commission for Maritime Services (RTCM), namely the standardization of State Space Representation (SSR) and the status of Multiple Signal Messages (MSM), i.e. the support of all GNSS constellations. Finally, we look on a European project in the Baltic Sea where GNSS positioning in real-time played a major role, and on the usage of global SSR corrections for troposphere parameter estimation.
Present Day Geokinematics of Central Europe Part 1: the Central European GNSS Research Network (CEGRN)


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Surface deformation in Central Europe can be studied at relatively large scales by modern Global Navigation Satellite System GNSS geodesy if velocity data from a homogeneous and dense network of high quality stations are available for a sufficiently long lapse of time. The Central European GNSS Research Network (CEGRN) collects GNSS data since 1994 from contributors which today include 42 Institutions in 33 Countries. CEGRN returns a set of coordinates and velocities computed according to international standards and the most recent processing procedures and recommendations. We present a set of 1229 positions and velocities resulting from 3 or more repetitions of coordinate measurements of each site over 4 or more years. The velocity data result from a combination of eight multiyear, partially overlapping networks, using 234 stations of class A of the European Permanent Network (EPN) for alignment to the ‘European Fixed’ ETRF2000 Reference Frame. We show that the rms (root mean square) of the 8 individual contributions to the combined solution, after a 7 – parameter Helmert transformation, is less than 5 mm in the observation period 1996-2017. We also show that the combined CEGRN network maintains the origin coincident with that of the ETRF2000 reference frame to within 1.8 mm rms for the entire period of analysis, and that the mean positions and velocities of common EPN Class A and CEGRN stations differ by 0.0 ± 1.1, 0.5 ± 1.0 and 0.1 ± 2.7 mm for the coordinates and 0.06 ± 0.13, -0.07 ± 0.12, 0.38 ± 0.28 mm/yr for the velocities respectively for the North, East and Up components at epoch 2010.0. These indicators of reference frame stability and alignment to a European Reference Frame are crucial for a subsequent analysis done in Part 2 of this paper, where changes of velocities will be investigated in relation to large scale European tectonic structures.
**The Analysis of the Italian GNSS Network at the University of Padova: ETRS89 densification and Scientific GNSS Backbone Network**

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**Abstract**

The University of Padova (UPA) contributes to EUREF in two different ways: routine and research. Routine activities include daily processing of a subnetwork of the EPN as a EPN Local Analysis Center (LAC) and Densification Center (DAC); in parallel, a network of up to 700 permanent Italian GNSS stations is processed (GPS+Glonsass operational, Galileo in test mode; rapid and final orbits), archived and checked for metadata using IGS/EPN procedures and logsheets. Routine activities also include the support to regional surveyors by delivering free RTK (GPS+GLONASS) data via NTRIP to some 200 users, on behalf of the Regional Government of Veneto, based on a network of some 30 permanent sites the coordinates of which are weekly checked for consistency with the ETRF2000. Research activities include the derivation of a dense velocity field for the Italian area, and the active involvement in the Deformation Models Working Group (chaired by M. Lidberg), EPN Densification Working Group (chaired by A. Kenyeres), and European Dense Velocities Working Group (chaired by E. Brockmann). For the densification of the velocity field we are testing an independent approach which consists in stacking SINEX files resulting from multiyear cumulative solutions generated by several Analysis Centers contributing to the CEGRN (Central European GNSS Reference Network). The alignment to the ETRF2000 frame is accomplished by solving for Helmert parameters and for their rates, using minimal constraints on position and velocities of common EPN sites of Class A. The derived velocities are then converted to strain rates by weighted least squares collocation and the implied deformation is examined in the context of independent knowledge from seismicity and structural geology. Thematic maps of strain rates (scalar values and eigenvectors) at specific seismogenic faults in Italy are generated as a final product. MultiGNSS has evolved into a high priority activity. A Matlab based program has been developed with capabilities to estimate coordinates, receiver clock and Tropospheric Zenith Delay solutions using simultaneously Rinex 3.0x data from GPS, Glonass, Galileo, Beidou, Navic, QZSS and SBAS satellites, and broadcast or SP3 (if available) orbit products. This work as resulted in a accurate monitoring of the system clock alignment of the GNSS constellations relative to GPS time, and of individual, receiver specific biases for about 30 permanent European multiGNSS sites contributing to the MGEX project of the IGS. For Galileo, specific studies are done on the dependence of the coordinate results on the F/NAV and I/NAV broadcast message, and on the agreement level of broadcast satellite positions relative to postcomputed (SP3) positions. The ultimate goal is to understand how interoperable the several GNSS constellations are, and hence to which extent the simultaneous use of multiple GNSS data enables the final user to derive coordinates consistent with the ETRS89 standard prescribed by the INSPIRE Directive of the EU.
Reprocessing of the Iberian network at IGE LAC

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Abstract

In addition to the routinary processing activities carried out within the framework of EUREF, IGE analysis center has implemented other continuous and specific processing. Among them, the IBERRED project stands out. In this project, almost 400 stations are being processed, located mainly in the Iberian area and archipelagos (Balearic Islands, Canary Islands, Azores). In addition to coordinates and velocities used for geodynamic purposes, other products are being obtained from this network.

Although there was a continuous process of this network and solutions were submitted to the “EUREF Dense Velocity project”, these solutions were not homogeneous with the current ones due to different frames, software versions, models and options used. Due to these reasons, a whole reprocessing of the network has recently carried out taking into account historical data from year 2000 until now. Time series and velocities from almost 20 years of data have been obtained for all stations and local or regional behaviors of the stations have been detected. Results have been combined with other processes to implement the official reference frame in ETRF00 (epoch 2018.0).

Related to the processing of this network, IBERRED coordinates are being used other continuous processing activities such as E-GVAP hourly processing or the Volcanic Monitoring System in Canary Islands with a dedicated network. In addition, some of these stations are located in the coast and data are being tested through reflectometry techniques to determine the mean sea level. In some cases results are compared with tide gauges data in co-located stations. Other IBERRED stations are also being used for studying the viability of tsunami detection observing the ionosphere perturbation.
Abstract

EPN provides observations from 333 reference stations. Today 198 of them provide also Galileo data. Since GPS week 2044 by decision of the EPN Analysis Coordinator most of the Analysis Centres started to use Galileo observation in the routine solutions. MUT AC was one of them. This decision was preceded by previous analyzes, which are presented on this poster.

Today GAMIT/GLOBK v 10.70 allows to process separately of GPS, Beidou, Galileo and Glonass data. Therefore the quality of combined multi-GNSS solution depends directly on the quality of individual solutions. In 2018 the number of EPN stations providing Rinex3 data with Galileo observations increased from 136 to 181. This is a significant increase. We prepared twin solutions using all stations that provide at least observations from both systems: GPS and Galileo. Then we evaluated the quality of the Galileo solution in relation to the GPS solution. Analysis cover full year 2018. There is a clear improvement in solutions based on Galileo observations over the time. The wide-lane ambiguities resolutions for Galileo solutions are close to GPS and sometimes even better. For narrow-lane we resolve about 5% less ambiguities for Galileo than GPS. The poster also presents information about the repeatability of coordinates and systematic differences at individual stations.
Combining IGb08 and IGS14 normal equations: Impact on the cumulative time series caused by the switch from igs08.atx to igs14.atx

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Abstract

On January 29th 2017 (GPS week 1934), the IGS adopted IGS14 as the new reference frame realization, which is based on ITRF2014 and an update of the former satellite and ground antenna calibrations file igs08.atx. As announced in IGSMAIL-7399 "The igs08.atx to igs14.atx ground antenna calibration updates will provoke additional coordinate changes for many stations. This effect will mainly be antenna-type-dependent, but will also depend on station location."

In this presentation, we demonstrate the impact of the switch from igs08.atx to igs14.atx antenna calibration models using the multiyear ARA EPN Densification solution series. In several stations we find, due to this antenna model switch, more than 10 mm offsets, especially in the Up component, that must be properly handled to avoid the introduction of a new unnecessary discontinuity.

We show how to apply the latitude-dependent coordinate change models provided by the IGS to largely eliminate coordinate offsets at GPS week 1934.

The advantage of this approach is that the manipulation can be done at the normal equation level (SINEX).

Based on the results we highlight the need for a proper position offset application in order to have continuous time series and correct velocity estimations in the stations where the antenna models are affected by the aforementioned offsets. This correction however should be considered as a temporary solution and will not prevent the future reprocessing of the national level densification solutions.
Abstract
The presentation covers the activities of the EPN Analysis Centres Coordinator (ACC) during the last year. The EPN ACC combines and analyses GNSS daily solutions provided by 16 EPN Analysis Centers (AC).

In 2018, the EPN ACs were asked to build their capabilities in processing Galileo observations (Resolution 1 of the EUREF Symposium 2018). Seven ACs, in parallel to operational solutions based on GPS and GLONASS observations, generated test solutions including also Galileo observations. These solutions were used by the ACC to analyse the impact of Galileo observations on EPN combined coordinate solutions. After the test phase, the EUREF Governing Board decided that EPN ACs are allowed to include Galileo observations in their operational solutions. Therefore, starting with GPS week 2044 (March 10, 2019) the official EUREF combined coordinate solutions are based on observations from three GNSS: GPS, GLONASS, and Galileo. In the presentation we will discuss the results from the comparison of the combined operational coordinate solutions with the combined solutions based on 3 GNSS AC test solutions, and present the status of 3 GNSS solutions provided by EPN ACs after week 2044.
NKG GNSS Analysis Centre: ITRF2014 densification for the Nordic and Baltic countries

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Abstract

The GNSS Analysis Centre (AC) of the Nordic Geodetic Commission (NKG) has worked on densified GNSS solutions for the Nordic and Baltic countries to fulfil the common needs in maintenance of national reference frames and geodynamic studies. The NKG GNSS AC was launched in 2012 and declared fully operational in April 2017. Now we have produced a densified ITRF2014 position and velocity solution for the area. The data between 1997 and 2017 was reprocessed by eight national analysis centres and the NKG EPN analysis centre. The subnet solutions were first combined into daily solutions and second to a cumulative position and velocity solution. The time series were rigorously analysed utilising the local knowledge of the conditions and actions at the stations. Finally, the noise characteristics of the residuals were studied to estimate realistic uncertainties for the stations. We present the final densified velocity field and the results of the uncertainty analysis.
Abstract

The east region of the East European Craton has too few stations in the free international GNSS network to study the regional geodynamics in detail. In fact hundreds GNSS stations of various surveying companies are located here. Some of these stations have a long observational history and were used to form and maintain free access velocity database (VDB). The GNSS position series have many irregularities and discontinuities. Velocity estimation in the VDB includes (i) consequent outliers filtering of time series, (ii) exclusion of seasonal variations and discontinuities of different nature and (iii) evaluation velocity errors depending on the type of noise distribution. For the beginning of 2019 the VDB has uniformly processed by Gipsy 6.4 data for more than 350 GNSS stations. All standard model parameters and corrections are taken into account. The VDB is available on the website of the Pulkovo’s observatory where the full description of used technique is also provided: http://www.gaoran.ru/russian/database/station/databasev_eng.html.
Multi-epoch GNSS campaigns of the national geodetic network in Estonia

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Abstract

The measurements of the EUREF (IAG Regional Reference Frame Sub-Commission for Europe) densification in Estonia were conducted in the summer of 1997. The network has since been remeasured twice (in 2008 and 2017), including also available national GNSS reference stations. In the present study all three campaigns have been recomputed and the results are expressed in the latest International Terrestrial Reference Frame ITRF2014 (ITRF, 2019). As a result, the coordinates of the 1st order geodetic points were specified. The RMS errors of the individual coordinate components with respect to the average of the three campaigns were 1.9 mm, 2.9 mm and 2.8 mm for north, east and up components, respectively. Also, the velocity estimates for the points were estimated and compared to corresponding regional velocity models. The discrepancies (in terms of standard deviation) with land uplift model NKG2005LU were in average 0.2 mm/year only. The resulting horizontal velocities however are subject to further research.
EG2000 – the new gravity reference frame of Estonia

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Abstract

The new gravity reference frame EG2000 as a realization of Estonian gravity system is presented. EG2000 relies on the absolute values of gravity acceleration determined at seven points from 1995 to 2017 by using JILAg and FG5(X) absolute gravimeters. Based on these absolute measurements the gravity values and their uncertainties at epoch 2000.0 were estimated for the points of first, second and third order gravity networks. The relative gravity measurements collected since 1992 by LCR G and Scintrex CG5 relative gravimeters were used as additional data in the weighted least-squares adjustment of the networks. All the gravity data were corrected due to the GIA related mass change and land uplift by applying NKG2016LU_gdot – the recent model for surface gravity change by the Nordic Geodetic Commission (NKG). The accurate gravity frame with correct error propagation from absolute gravity points to gravity survey data through the nationwide networks is crucial for high quality applications like a national 5 mm geoid model computation.
Abstract

EPN Densification (EPND) as a joint activity of most European countries targets to produce a unique quality, homogeneous position and velocity database. The first release included weekly position solutions as input up to GPS week 1933 (January 2017) was published in 2018, where all input were expressed in IGb08 and also used the igb08.atx PCV model collection. The solution, called D1993 was however expressed in ITRF2014 and ETRF2000.

New releases are regularly planned adding new weekly solutions to the multiyear combination. As since GPS week 1934 the IGS14.atx is used in all GNSS analyses, which may cause coordinate offset in the time series therefore the conversion of the solutions before GPS week 1934 had to be converted to be compatible with IGS14. The conversion was done using the conversion tool and latitude dependent correction models provided by the IGS. Some statistics are provided in the presentation.

The homogeneous velocity solution including the time series and realistic velocity estimates is an extremely important information in several application fields. Exploiting the availability of long term combined time series information we compute realistic velocity estimates using the MLE (Maximum Likelihood Estimator) approach. This information is essential for geophysical applications like the realistic strain computations by the WG on Deformation Models.

Additional key application of EPND will be in the European Ground Motion Service, where the homogeneous velocities together with the time series can be used either for the mosaicing of the InSAR patches of validating the InSAR results. EU-GMS will start in 2020 and we plan to provide EPND for this key future service.
Abstract

The Royal Observatory of Belgium continues to develop the metadata management system for multiple GNSS Networks (M3G). The active usage and continuous integration of the EUREF network helped to improve the system significantly. We also integrated several new requirements formulated by the EPOS community such as GDPR compatibility, user/contact information handling, extended network management, and the collection of additional metadata. The new version of the M3G is also incorporating previously missing functionalities, for example: DOMES number check or the site log import from an external source. We will show these new functionalities and the main concepts behind the changes.
Techniques: GNSS, Levelling, Combination

Germany: Integrated Geodetic Spatial Reference 4.0

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Abstract

In the classic approach the geodetic reference frames were provided by more or less separate control point framework of position, height and gravity. This viewpoint has gradually changed since about the beginning of the 1990s with the increasing use of the GNSS measurement technique. It became possible to create control point frameworks that met the requirements of the new measurement technology and of a standardised Europe-wide reference system.

Consequently, the classic triangulation networks were gradually replaced, i.e. they ceased to be used. By establishing permanent GNSS reference stations nationwide starting in the second half of the 1990s, it became possible, for the first time, to provide the spatial reference in the form of the operational satellite positioning service SAPOS® in real time, which allows a position to be determined with an accuracy range of 1 to 3 centimetres and thusly meets the requirements of legally secure real estate surveys. Today SAPOS®, which integrates ‘cm geoid GCG2016’, can be also used to determine normal height. The integrated geodetic spatial reference is considered a basic infrastructure and part of AdV’s legal remit.

Through the coupling of the SAPOS® services of individual Laender and the nationwide coverage of the GREF network of BKG, a national standardised spatial reference can be established. In a standardised evaluation (DREF-online) the necessary link to the superordinate European and global reference networks can be created.

The committees of AdV coordinate the standardised course of action of all parties of the federal government and the Laender and define nationwide standards. During a time when product and quality consciousness were gaining ground in governmental action, the geodetic spatial reference frame with its satellite positioning services, had already established appropriate standards. Quality management, transparent to the public, already documented, at an early stage, the capacities of the national infrastructure. This transparency is a stand-out feature of the Official Surveying and Mapping authorities.

With the help of the so-called “Guidelines for a standardised integrated geodetic spatial reference of the official surveying and mapping of the Federal Republic of German” the product vision, including a
quality security framework, is being applied to the entire product range of the geodetic spatial reference. The surveying and mapping authorities put a holistic approach of the geometrically and physically defined components of “Location, 3D position, height, respectively geopotential altitude and gravity” into effect which has been kept separately until now. The AdV project “Re-measurements in the German Height Reference System (DHHN) – a worldwide unique measurement campaign between the years 2006 and 2017 – forms the framework for the new understanding of “Integrated Geodetic Spatial Reference 4.0”. With this, Germany has laid the base for a geodetic infrastructure, which is prepared for future applications, like e. g. centimetre-level accurate vehicle navigation as a component for autonomous driving or for so-called “precision farming”. The geodetic spatial reference opens up rapidly for new fields of operations. High-precision positioning will no longer be a discipline for specialists but will instead be “daily business”. With Galileo a further satellite positioning system is currently incorporated into the national infrastructure which then will strengthen the overall system in regard to all aspects – reliability, accuracy and speed.
Techniques: GNSS, Levelling, Combination

Robot vs chamber calibration-derived antenna PCC models differences and their impact on GNSS positioning

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Abstract

In recent years, the GNSS systems have been intensively modernized, the result of which is, among others, introduction of new carrier frequencies in the GPS and GLONASS and development of new satellite systems: Galileo and BDS. For this reason, the results of the absolute field antenna calibrations, performed so far for only two carrier frequencies of the GPS and GLONASS systems, seem to be insufficient. All antennas which are used in precise surveying applications will require re-calibration of their phase centre variations for the new signals, to ensure the highest measurement accuracy. Currently, two absolute methods are used to calibrate GNSS antennas: field calibration using robot and calibration in anechoic chamber. Unfortunately, differences in these methodologies also result in disparity in the obtained antenna phase centre corrections (PCC).

In this paper, the differences between PCC obtained with the two abovementioned calibration methods were analysed. In addition, the influence of these differences on GNSS-derived position time series for 19 EUREF Permanent GNSS Network (EPN) stations, was also assessed. The obtained results show that the calibration method has a visible impact on PCC models. PCC differences, determined for iono-free combination may reach up to 20 mm, and are transferred to the position domain. Our tests show that height component differences reach up to over 10 mm for some stations, depending on the type of the used PCC model.
Techniques: GNSS, Levelling, Combination

Towards the establishment of the Absolute Gravity Network Ireland

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Abstract

The project for the establishment of a modern gravity control for Ireland, entitled Absolute Gravity Network Ireland, had been initiated by Ordnance Survey Ireland (Republic of Ireland) and Land and Property Services (Northern Ireland) with the support of the Institute of Geodesy and Cartography (Poland). This presentation includes the description of activities that were undertaken to design the project as well as initial results.

In the first step the current state of the previous gravity network and its latest realization (IGSN71) was analysed as well as the possibility of using the existing geodetic infrastructure for the establishment of a new gravity control was evaluated.

The design of the network includes 50 field stations of gravity control as well as 6 stations of the gravimetric calibration baseline. Whenever possible, gravity network stations had been collocated with GNSS stations. At the same time all stations will be connected to national vertical control for a reliable height reference. Survey plan also includes gravity resurvey of all IGSN71 stations identified in Ireland (7 locations) to create a link between the old and newly established gravity datum. Special emphasis is put on the quality assurance of the reference gravity value including periodic calibration of the A10-020 sub components (laser, clock, and barometer) as well as participation of the A10-020 gravimeter in absolute gravimeter comparison campaigns.

The primary measurement technique to be used in the establishment of the gravity control will be absolute gravimetry. Gravity at all newly established stations are to be measured with an absolute gravimeter. As stations are designed to be located in the open field, the A10 absolute gravimeter (sn 020) will be implemented, owned by the Institute of Geodesy and Cartography, Warsaw, Poland. Separate part of the project is related to the evaluation of the ocean tidal loading effect which in Ireland can reach ±15 µGal. The evaluation will be done upon tidal records of an LCR model G gravimeter with a self-made recording system at a carefully prepared location in Dublin, Republic of Ireland. First results of tidal record analysis will be discussed in this presentation.

Presentation also includes initial results of height and position determination, absolute gravity determinations (first in Ireland history with a modern type ballistic gravimeter) and vertical gravity gradient determinations from the first survey campaign performed in September 2018.
Abstract

In recent years, the Global Navigation Satellite Systems (GNSS) have been intensively modernized resulting in the introduction of new carrier frequencies in Global Positioning System (GPS) and Global Navigation Satellite System (GLONASS) and development of new satellite systems: Galileo and BeiDou Navigation Satellite System (BDS). For this reason, the results of the absolute field antenna calibrations, performed so far for only two legacy carrier frequencies of the GPS and GLONASS systems, seem to be insufficient. Hence, all antennas which are used in precise surveying and geodetic applications will require a re-calibration of their phase center variations (PCV) for the new signals, to ensure the highest measurement accuracy. Currently, two absolute methods are used to calibrate GNSS antennas: field calibration using robot and calibration in an anechoic chamber. Unfortunately, differences in these methodologies also result in disparity in the obtained antenna phase center corrections (PCC). In this paper, the differences between individual PCC obtained with the two abovementioned calibration methods were analyzed. In addition, the influence of PCC differences on GNSS-derived position time series for 19 EUREF Permanent GNSS Network (EPN) stations was also assessed. The obtained results show that the calibration method has a visible impact on PCC models. PCC differences determined for iono-free combination may reach up to 20 mm, and are transferred to the position domain. Further tests show that height component differences reach up to over 10 mm for some stations, depending on the type of the used PCC model.
Techniques: GNSS, Levelling, Combination

The Kingdom of Saudi Arabia Geodetic and Vertical Reference Frames – the main Components of National Spatial Reference System

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Abstract

The Kingdom of Saudi Arabia (KSA) Geodetic Reference Frame (KSA-GRF17) and Vertical Reference Frame (KSA-VRF14) are presented as main components of KSA Spatial Reference System (KSA-SRS). Both reference frames are described as the core of national geodetic infrastructure which needs to unify all geodetic related applications in social, industrial, economical, scientific and etc. aspects of the Kingdom’s development according to new 2030 vision. KSA-GRF17 and KSA-VRF14 have been designed, established and disseminated following state of the art methods, technologies and standards which assure their vast national coverage, the highest possible accuracy and efficient applicability in many different areas and activities linked to geodesy.

This presentation is focused on: advanced technical & management methodologies utilized; possible applications of both reference frames; opportunities for cooperation with other national and international spatial reference infrastructures in local, regional and global scale and last but not least – their contribution to everyday activities over the KSA, Middle East Region and the entire globe.
Abstract

National Geographic Institute of Spain (IGN) is Analysis Center of EUREF since 2001, carrying out weekly and daily processes of a subnetwork of GNSS permanent stations covering mainly the Western Europe part (Spain, Portugal, France, Italy, Great Britain, Ireland...). This processing is focused on contributing to the definition, realization and maintenance of the European Geodetic Reference System.

Since then, new GNSS data processing projects have emerged, not only those who require a punctual processing, but others requiring continuous solutions. In some of them a network of more than 330 stations is processed. The objectives of these projects are not only the obtaining of coordinates of GNSS permanent stations, but also other objectives such as obtaining and analyzing geodynamic time series or calculating in almost-real time the tropospheric delay signal for meteorological applications.

The latest advances in GNSS, especially the addition of Galileo to the Global GNSS constellations and the upgrade of some receivers to multi-constellation devices, have made possible to include Galileo observations to the data processing. A test campaign, using Bernese 5.2 software, was carried out with the objective of evaluating the impact of including these observables in the solution. Other parameters, such as the network configuration, have been tested in the campaign in order to reach the optimal processing strategy.

A description of the different projects and the results obtained in the Galileo test campaign are presented.
EXPERIENCE WITH GNSS DATA QUALITY MONITORING OF THE SKPOS REFERENCE STATIONS

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Abstract

Monitoring of GNSS data quality and availability of the GNSS reference stations is one of the key tasks in ensuring their smooth and error-free operation as well as for verification of the quality of the reference station coordinates. In September 2018, Geodetic and Cartographic Institute Bratislava developed a new web application called SKPOS Quality Control used for data quality monitoring of all SKPOS, foreign SKPOS and EPN stations included in the daily SKPOS solutions. When creating the application, the inspiration was drawn from EPN website. The application allows us to track and analyze station’s time series, the number and percentage of observations, multipath errors, cycle slips, skyplots, as well as RINEX availability and real-time data delay. By analyzing these data, we are getting a real view about quality parameters of the SKPOS reference stations and we are able to respond quickly to the potential problems, or even better, to prevent them. Experience with firmware/ hardware problems of SKPOS reference stations discovered by SKPOS Quality Control app will be presented too.
Techniques: GNSS, Levelling, Combination

New horizontal intraplate velocity model for Nordic and Baltic countries

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Abstract

Fennoscandian region with its surroundings is effected by the Glacial Isostatic Adjustment (GIA) resulting in intraplate crustal motions up to a few millimeters per year in horizontal coordinates and up to a centimeter per year in heights. The national reference frames in Nordic and Baltic countries are plate-fixed and based on European Terrestrial Reference System 1989 (ETRS89) and European Vertical Reference System (EVRS), as regulated by the European Union’s Inspire directive. In maintenance of the national reference frames and in the most accurate georeferencing applications the GIA effect must be accounted for.

The Nordic countries have a long tradition on studying the GIA (or land uplift) phenomenon. Latest efforts have been conducted in collaboration under the Nordic Geodetic Commission (NKG) and have resulted in some common Nordic-Baltic land uplift and deformation models. For example, the NKG2005LU model has been used e.g. in levelling adjustments as the basis for Nordic European Vertical Reference Frame (EVRF) realizations and the NKG_RF03vel model e.g. for transforming International Terrestrial Reference Frame (ITRF) coordinates accurately to national ETRS89 realizations.

In late 2016, the NKG decided to release a new land uplift model package consisting three models: NKG2016LU_abs/lev, NKG_RF17vel and NKG2016LU_gdot. NKG2016LU is a model describing vertical motions either as absolute (ellipsoidal) or levelled (from geoid) heights and it was released in 2016. NKG_RF17vel is a 2D+1D model to be used with three-dimensional geometrical coordinates where the NKG2016LU_abs forms the basis for vertical part of the model. NKG2016LU_gdot describes gravity change rate due to the GIA.

In this presentation we describe the development of the horizontal intraplate velocities of the NKG_RF17vel model. The horizontal velocities of the model are comprised of the BIFROST and the NKG GNSS Analysis Centre (NKG AC) GNSS velocity solutions and a new GIA model called NKG2016GIA_prel0907. The GIA velocities were first aligned from a GIA frame to a geodetic reference frame by a Helmert fit using GNSS velocities. Then the final adjustment was done with least-squares collocation also accounting for the GNSS velocity uncertainties. We will describe the methodology and show results of the NKG_RF17vel model. Moreover, we will discuss about its use in transformations from global ITRF coordinates to the national ETRS89 realizations. This can be seen as an implementation of a semi-dynamic reference frame or as a link between the reference frames in so called two-frame approach.
Abstract

The globally averaged mean sea level rise is 1.7 mm/yr (UN Intergovernmental Panel on Climate Change AR5 report). The Baltic Sea is a semi-enclosed water body, which is connected to the global sea through the narrow Danish straits. Therefore, the sea level behaves differently and the velocity of sea level rise is presumably not the same in the Baltic Sea compared to the global average. Additionally, postglacial rebound causes the vertical movements of the Earth’s surface in the Baltic Sea area. In this study, the velocities of Estonian coastal tide gauges and GNSS permanent stations were calculated in order to estimate regional absolute sea-level rise. The time series from eight GNSS stations (2008-2016) and ten tide gauges (1954-2014) were analysed with different stochastic noise models using software Hector. From the GNSS time series, absolute vertical velocities and their realistic uncertainties were obtained in ITRF2008 reference frame. The apparent vertical velocities relative to the actual mean sea level and their realistic uncertainties were estimated from the time series of tide gauges. These results were verified using the land uplift models, like NKG2016LU and glacial isostatic adjustment model NKG2016GIA. This contribution combines the obtained absolute vertical velocities of the GNSS stations with the tide gauges' apparent vertical velocities using two different approaches: i) geostatistical method Kriging, and ii) least squares collocation, in order to estimate regional absolute sea-level rise on the Estonian coast. Based on the results, the average mean sea level rise on the Estonian coast in the period 1956-2014 was up to 1.97 mm/yr.
Techniques: GNSS, Levelling, Combination

GOP real-time analyses and data quality for Europe

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Abstract

Multi-GNSS observations from many stations belonging to the European Permanent Network (EPN) are disseminated in real-time data streams besides providing mandatory daily RINEX files. Products in support of various real-time applications can be generated in European scope, in particular when considering optimal use of the Galileo system. While global products such as satellite orbits and clocks together with code and phase satellite hardware biases are essential for Precise Point Positioning (PPP), local augmentation services providing atmospheric parameters are necessary for a fast ambiguity resolution.

Since GNSS data providers often distribute real-time data without a quality control, GOP has improved the G-Nut/Anubis software for this purpose. Differences in terms of the data quality between observations stored in RINEX files and those distributed via real-time streams can be non-negligible. We will show a number of qualitative and quantitative characteristics for both scenarios.

We also developed a real-time processing of EPN data for providing GPS and Galileo satellite clock corrections and tropospheric parameters, such as Zenith Total Delay (ZTD), horizontal gradients and, optionally, slant delays. A traditional processing strategy uses code and carrier-phase observations from the ionosphere-free linear combination. Recently, we have implemented in the G-Nut software a strategy utilizing also undifferenced and uncombined observations which do not eliminate the first order of ionospheric delays and thus need additional modelling by introducing new parameters. One of advantages of this strategy is that both tropospheric and ionospheric parameters can be estimated efficiently and reaching a high accuracy within a single processing run. Moreover, multi-frequency and multi-constellation observations can be more flexibly and optimally used.

We routinely process real-time data streams from almost 200 stations in Europe. Estimated atmospheric parameters will be evaluated by comparing them with the reference products and cross-validated when obtained at the nearby collocated stations.
Abstract

The primary role of EUREF as an IAG (International Association of Geodesy) affiliated organization is to provide geodetic reference frames such as ETRS89 for GNSS and EVRF2007 for height referencing. To fulfill this task, EUREF established and maintains long-term continental scale infrastructure such as EPN (EUREF Permanent Network) and UELN (United European Leveling Network), and publishes the related standards and databases.

EPN and UELN also serves as interface for various geoscience applications including atmospheric and solid Earth studies. In this connection, two standardizing activities shall be highlighted here: (1) EPN Densification and (2) EUVN_DA (European Vertical Network Densification Action).

(1) EPN is used to interconnect the national GNSS networks and serves as a backbone for the EUREF flagship EPN Densification. The project delivers a homogenized regional position and velocity product based on the long-term combination of the national scientific processing results. The recently published solution (D1933) includes 31 networks with some 3200 stations, made available at the EPNCB website. The positions and the velocities can be used as reference for national solutions and for the large-scale tectonic interpretations in geosciences. EPN Densification is also being part of EPOS (European Plate Observing System), which provides access to a wide range of geodetic and geophysical information and may also contribute to the new EU “European Ground Motion Service” initiative.

(2) EUVN_DA integrates the ETRS89 positions and EVRF2007 height information available at more than 1300 selected UELN benchmarks, where high precision GPS/GNSS measurements were performed. Since the publication of the database in 2009 huge amount of new and updated leveling information is available, and therefore an update of the EUVN_DA solution is planned.

The new EUVN_DA database together with the latest European geoid solution can serve as an example for modern, GNSS-based height determination.
Consistency and impact of mixed receiver antenna phase centre models in regional GNSS networks

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Abstract

The Institut für Erdmessung (IfE) at the Leibniz University Hannover calibrates GNSS antennas determined by the well known robot based concept in the field. Our group has recently improved the calibration procedure to support absolute receiver antenna calibrations for all GNSS frequencies (GPS L1/L2/L5, GLONASS L1/L2 and Galileo E1/E5).

To fully use the advantage of multi GNSS processing capabilities for absolute and relative precise positioning, accurate and consistent receiver antenna calibration patterns of ground stations are required. Currently, in IGS and EPN they are available by chamber calibration method for some antennas. However, systematic and sometimes significant differences exist between both approaches (field robot and chamber) that have to be studied in detail to identify the causes and to fix these issues.

In this contribution, we present first robot based multi GNSS patterns from IfE. Furthermore, a study is performed, to show and evaluate the impact from the observation domain (differences of antenna phase centre patterns) to the parameter domain (position, troposphere, ambiguities). In this study, we used reference stations from the EPN network which provide individual antenna patterns obtained from both approaches (field robot and chamber). Baselines of lengths ranging from 150-600km and one of 1670km are analysed. We found that on the one hand, differences between both pattern sets do not met the proposed 1mm-rule-of-thumb in the most of studied cases. On the other hand, we show that in cases of consistent antenna pattern sets no significant differences in the parameter domain are obtained. However, mixing patterns from different approaches implies deviations of up to 1cm (in one case up to 2cm) mostly in the topocentric height component. These differences are directly aligned to the differences in the antenna pattern.
Techniques: GNSS, Levelling, Combination

From traditional levelling to combinations of different epoch geodetic data in Western Latvia

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Abstract
Geodetic observations as a complex activity to recognize quality of geodetic infrastructure we can count in Latvia since Danish-Baltic sector program from 1998. Test bed for that was chosen Western part of Latvia. At that time like 20 years ago main source as most expensive one was traditional first order geometric levelling. And at our disposal is data from first order levelling line going from Kronstadt Tide Gauge near St.Petersburg to Mamonovo in Kaliningrad near Polish border. There we chose to measure same 20 km of first order line near town Auce. And combinations of different epoch geodetic data sets also where assumed as very essential. At some extend there also reflections of Fennoscandinavian land uplift should or must appear. In parallel there must be mention establishment of settled gravity network for follow-up relative gravity surveys. Also around 40 special sites were observed in dedicated GPS campaign to obtain evenly geographically-based single point cluster with homogeneous geodetic heights based on ETRS89. The work started twenty years ago is topical for providing a unified national geodetic infrastructure today and in the future, as well as in the context of science and education.
Techniques: GNSS, Levelling, Combination

Height datum modernization based on GNSS leveling

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Abstract

In the Netherlands, the realization of the height datum NAP is achieved purely by leveling of benchmarks. The heights of deeply founded first order benchmarks have been determined by a primary leveling relative to Amsterdam, and this network is further densified by yearly secondary leveling campaigns. Heights measured with GNSS can be transformed to NAP heights using the new NLGEO2018 geoid model. To support this conversion an innovation function estimated from GNSS leveling points has been added to the gravimetric quasi-geoid. Nevertheless, in practice, a connection by leveling to a local NAP benchmark is often still required, especially if a higher accuracy is needed.

An alternative realization could be achieved by defining the height datum on an equipotential surface only, which is realized by a geoid model. Such a geoid-based height reference system directly supports the use of GNSS for height determination and does not require large scale leveling campaigns. This is especially beneficial for areas where an accurate conversion model to account for differences between the gravimetric geoid and the height datum can not be computed. However, the accuracy of the heights depends on the accuracy of GNSS which may not be sufficient for applications that require sub-cm accuracy.

Here we present a hybrid approach to height datum modernization, applied to the Dutch NAP network. It uses GNSS measurements taken at NAP benchmarks, which are transformed to normal heights using a gravimetric quasi-geoid. Then these heights are used as datum points in a least-squares adjustment to compute normal heights at all benchmarks in the leveling network. The results of this approach are compared to the heights determined through traditional leveling.


Multi-GNSS receiver antenna calibration: the way forward in the IGS

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Abstract

In preparation of the planned reprocessing effort for the ITRF2020 contribution the IGS analysis centers held a dedicated workshop at GFZ Potsdam in April 2019. A deep discussion on the inclusion of Galileo into the reprocessing and the related handling of the receiver antenna corrections has taken place based on numerous experiments done before the workshop.

From the presentations and discussions a summary on the aspects will be given that are relevant to EUREF EPN processing.
Recent Crustal Deformation of the Alps derived from GNSS observations

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Abstract

This study originated in 2004 when the EU-funded ALPS-GPSQUAKENET Interreg IIIb project established a geodetic network of more than 35 new permanent GNSS stations in the Alpine Space. With a project duration of only three years, it was not possible to estimate all the deformation of the Alps with highest precision and high resolution. For this new study, we collected the data of more than 200 continuously operating GNSS stations from Italy, France, Switzerland, Germany, Austria and Slovenia. We processed all available data between 2004 and 2016 in order to derive precise positions and velocities of each available station. The newest processing standards were applied in order to determine 3-D coordinates with highest precision in the IGb08, epoch 2010.0, which was the relevant realization of the ITRS at the time of processing the data. The mean precision of the station velocities is 0.2 mm per year for the North and East component, while the height velocity is determined to be 0.4 mm per year.

In a second step, we derived deformation models for the Alpine mountain belt. It consists of a horizontal and a vertical deformation model, which were derived base on the geodetic least-squares collocation (LSC) method. There have been only very few permanent GNSS stations in Switzerland. However, to get a homogeneous data coverage in the Central Alps, we used IGb08-based station velocities of the Automated GNSS Network for Switzerland (AGNES). The deformation models show larger horizontal deformation signals in the Friuli region, which is well known for its seismic activity. The uplift rates across the entire Alpine mountain belt are significant. The largest rates of up to 2.6 mm per year are observed in the central area of the Western Alps, in the Swiss Alps and the Southern Alps. The results of this study were processed by the EUREF working group on European Dense Velocities. They complement the existing velocity field and agree very well with the existing deformation patterns.
On the Future High-Precision European GNSS CORS Infrastructure

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Abstract

Thousands of continuously operating GNSS reference stations (CORS) cover Europe. Their data are used for high-precision applications ranging from reference frame maintenance, monitoring of tectonic deformations, monitoring of sea-level variations, long-term climate monitoring, numerical weather prediction, space weather applications.

The EUREF Permanent Network (EPN), created in 1996, was the first pan-European effort to coordinate the exchange of data and metadata of GNSS CORS and focussed primarily on reference frame applications. Today, this network contains more than 300 participating stations that comply with EUREF guidelines, and whose observation data and metadata are provided to EUREF for further validation, dissemination and generation of dedicated products. In 2010, EUREF took the initiative to coordinate also the data analysis of an EPN densification network consisting of more than 3000 GNSS stations for which also metadata are collected and validated. The goal of the EPN densification is to determine a dense European velocity field.

In addition to the EUREF networks, the EUMETNET EIG GNSS water VApour Program (E-GVAP, 2005-now) coordinates the collection and distribution of GNSS tropospheric delays and water vapour data obtained from the near real-time data analysis of more than 3000 GNSS stations, from which about 2700 are located in Europe. E-GVAP itself does not distribute GNSS station metadata nor data.

Finally, Europe is today constructing the European Plate Observing System (EPOS), which contains also a European GNSS network, but now aiming to support Solid Earth science. EPOS will collect and validate GNSS station metadata and data and will also organise their operational analysis. In January 2019, almost 800 GNSS stations were proposed to EPOS.

The goal of this presentation is to give a comparative overview of the pan-European GNSS networks mentioned above in order to highlight their overlaps and differences, and map their weaknesses and strong points. Then, we will investigate which steps are necessary to homogenise their activities and provide users with a comprehensive overview of all available GNSS CORS data, metadata, and products suitable for high-precision applications in Europe.
A time dependent model of elastic stress in the Central Apennines, Italy

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Abstract

Seismicity in the Central Apennines is characterized by normal faulting with dip NE-SW near 45°. If the stress at the hypocenter of the 2016 Norcia (Mw=6.5) and 2009 L’Aquila (Mw=6.3 on the Paganica fault) earthquakes originated only from stress transfer from previous historical events, the orientation of the principal stress axes would have been inconsistent with the observed tensional regime. The additional contribution of a regional stress is thus required, but GNSS geodesy provides only stress rates. We empirically estimate a time multiplier for the regional stress rate, computed with a dense GNSS network, such that the principal stress axes resulting from the sum of the stress transferred by previous events and the regional stress rate multiplied by the empirical temporal scale are consistent with normal faulting, both at the L’Aquila and Norcia hypocenters. Based on a Catalogue of 36 events of magnitude larger than 5.6 we estimate the total Coulomb stress at depths and along planes parallel to those of L’Aquila and Norcia. We provide evidence of an asymmetry of the Coulomb stress leading to a stress concentration near the hypocenter of the two events just prior of the 2009 and 2016 earthquakes. This stress anomaly disappeared after the two events. Similar stress patterns are observed for earlier events which took place in 1461 at L’Aquila, 1703 on the Montereale plain and in 1703 at Norcia/Valnerina. The 1997 sequence of Colfiorito exhibits a similar, anisotropic Coulomb stress pattern. Other areas with a similar stress anisotropy could be seismic gaps.
Present Day Geokinematics of Central Europe Part 2: Selected profiles

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Abstract

Based on a set of rigorously computed velocities of GNSS sites of the CEGRN network in Central Europe we identify a number of areas with large scale tectonic structures and interpolate the velocities to the profiles by least squares collocation. The resulting velocity field provides an invaluable data set for the investigation of present day crustal deformation at the continental scale. We present six velocity profiles covering structural features of Central Eastern Europe and at the same time well populated by GNSS sites, to minimize interpolation errors. One N-S profile samples the extensional stretching of the crust in the Balkan Aegean region, three E-W profiles sample the part of Central Europe north of the Black Sea, one profile SW NE crosses the Trans European Suture Zone. A sixth profile outlines the shear deformation associated with the eastward extrusion of the Eastern Alps towards the Pannonian Basin. Analytical modelling of the first and last profiles, for which there is a significant deformation, provides quantitative constraints on the relation between back arc retreat and extensional deformation in the continental crust (Aegean-Balkan profile), and model parameters such as the locking depth of faults accommodating the lateral extrusion of the Eastern Alps. For the four remaining profiles, across the TESZ and the Central Europe through the Carpathians, we report a westward velocity East of the TESZ and Carpathians. The velocities appear to drop West of these structures, suggesting that in a conventional ‘European fixed’ reference frame the East European Craton is generating a small compressional strain in a nearly E-W direction.
Characterizing atmospheric humidity in Eastern Europe during the last two decades by using GNSS-derived integrated water vapour

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Abstract
In this presentation we focus on (1) the GNSS-derived integrated water vapour (IWV) data quality, (2) its long-term variations and (3) seasonal diurnal cycle as well as (4) determining the GNSS’ capabilities to detect extreme weather events. We aim to describe regional changes and regularities in Eastern Europe based on data collected since 2000. The data from 46 GNSS stations belonging to the European Reference Frame Permanent Network (EPN) were processed with the GAMIT software. Nine out of these stations (in the area defined by 35–68°N and 17–33°E) with relatively long record were included in the analysis of the IWV diurnal cycle in order to determine the timing of the maximum and minimum as well as peak-to-peak values. In addition, data from seven stations were used in comparison with co-located radiosonde and AERONET Sun photometer. As an example of using GNSS for detecting extreme precipitation we have investigated heavy snowfall event that occurred at the Northern Baltic Sea in January 2016.
Applications: Earth Sciences, Geo-Information

BEV Transformer - Coordinate Transformation Tool

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Abstract

Coordinate Transformation is the daily business of each geo-related activity. But in practice we noticed that many of our customers are not quite firm with the different realisations of National and International Coordinate Systems. Even its hard to understand why a complete coordinate definition needs epoch and velocities too. Therefore we decided to establish an online Coordinate Transformation Service where everyone can easily transform between different systems. With our application interface (API) the customers can include the transformations to other programs and applications. Besides the 3D-Transformation there is an mode for height transformation as well as grid transformation. In this presentation we will show you the way how we define Coordinate Reference Systems (CRS) as well as transformations and how this service can be used by the international community too. Establishing this service was an important step for a service oriented administration.
Latvian CORS Time Series Analysis for 2011-2018

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Abstract

This study is a continuation of a work on the Latvian continuously operating reference station (CORS) time series analysis started at the Institute of Geodesy and Geoinformatics of the University of Latvia. The time span of processed solutions has now been extended to eight years: 2011-2018. The objective is to obtain horizontal and vertical velocities and their uncertainties of the Latvian CORS daily coordinate solutions.

The raw observation data are collected from Latvian CORS of two permanent GNSS networks: LatPos (26 stations in 2019) and EUPOS®-Riga (5 stations). Bernese GNSS Software V5.2 is used in a double-difference mode for obtaining daily solutions. 8-9 IGS/EPN reference stations with minimum constrained coordinates and velocities in reference frame IGb08 and IGS14 (since the beginning of 2017) were used to compute the coordinates of Latvian CORS. Obtained daily solutions are transformed to ETRF2000.

Tsview software has been used for time series analysis. Outlier detection, offsets and displacements identification, trend, seasonal variation and uncertainty estimation was performed. Obtained results have been compared to previous solutions from shorter time series and to Nordic Geodetic Commission’s NKG_RF03vel and NKG2016LU_abs velocity models.
GEOSPATIAL METHODS: INTRODUCTION INTO INTERNATIONAL EDUCATIONAL COURSES IN ENVIRONMENTAL PROTECTION AND DISASTER RISK MANAGEMENT


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University of Minho (PORTUGAL)
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Abstract

Different types of disasters such as draughts, floods, landslides, debris flows, earthquakes, and extreme temperatures have struck the region of Central Asia and other parts of the World as well. Spatial Information Science and Technologies, including Geographical Information Systems, Remote Sensing, and Spatial Data Infrastructures have proven to be crucial for environmental protection and disaster risk management. “Environmental Protection in Central Asia (EPCA): Disaster Risk Management using Spatial Methods (EPCA)” is a European Commission funded project under ERASMUS+: Higher Education – International Capacity Building programme (Project No 585382-EPP-1-2017-1-SE-EPPKA2-CBHE-JP). It began in October 2017 and will run until October 2020. Initiated by the Lund University and partners from the Central Asia countries, the EPCA project is an ambitious project aiming to match labour market needs with geospatial education offer both in Europe and Central Asia countries.

The aim of this three-year project is to build capacity using spatial methods for better environmental protection and disaster risk management in Central Asia.

The objectives of the project are:

- Developing innovative and blended courses in Spatial Information Science and Technology (SIST) for environmental protection and disaster risk management (EP-DRiM): The developed courses will be taught at the partner universities with the aim of skill formation and filling knowledge gaps. The graduated students will be skilled professionals, who can potentially be employed by relevant stakeholders to develop and improve the application of spatial methods in EP-DRiM.
- Training of trainers: Faculty members at the regional partner universities will be trained on how to teach the developed courses.
- Improving quality of education and teaching: Online learning techniques/tools have revolutionized the pedagogic world. CA partners will be equipped with e-learning and open network learning (ONL) tools.

- System development: Internet-based information Management System for Environmental Protection and disaster risk management (iMSEP) will be developed and implemented. The aim is to make a GIS system widely available for stakeholders to be able to use it for data collection, storage, analysis, and decision-making.

- Dissemination of the outcomes: Environmental protection and disaster management authorities, at policy-making, planning, and operational levels, will become aware of the advantages and applications of SIST in environmental protection and disaster risk management to support the development and use of SIST in their countries.

In total 3 distance learning courses will be developed jointly by partner institutions in Europe and the Central Asia. The main aim of the network is to promote the use of spatial information and earth observation for environment protection and disaster risk management and modelling through capacity building and institutional development, via a network in which all partners would contribute from their own positions of strength.
Results of Project - Creation of Joint GI Education to Increase Job Opportunities in the Region

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Abstract
Nowadays no specialist or business organisation can ignore the importance of GIS opportunities for the professional process planning, management and monitoring of the implementation of activities. In the near future GIS capabilities for systems and its’ influence will only grow: improving hardware tools, thus in particular increasing the accumulated and acquired spatial data volumes and their quality. Professionals and workers with no knowledge of GIS and the available data application possibilities will not be competitive in labour market.

Therefore this project aims to increase job opportunities and work force mobility, to develop new GIS competencies matching labour market needs in the region and to improve joint GI education services and training available. Specialists with better skills working in the Programme region, will increase its’ competitiveness. Employable people will see the region as an attractive place for working and settling down.

Project will produce these outputs: trainers will increase their qualification with up to date GI knowledges, two improved GI competencies centres for joint use will be created in the region and around two hundred trainees will participate in joint training. Students, employees, business organisations and also local community will benefit greatly from this project. This project is cross-border, as it is cost effective and most effective way. Implementing a project with transnational partners will help to obtain reliable results, share good experience, thus it will help to spread the information about the project’s outcomes widely. Learning what is needed in both countries will enable students to get the best experience and will allow then to become more employable. For joint training workshops and seminars will be organized in the participating organisations. Project outcomes will connected people in the region for common training and research purposes.

Project main results – number of trainers with improved qualifications: 40 improved educational and training facilities for joint use: 2 number of participants of joint training: 200. Project results contribute to reach programme results indicator “Number of people receiving upgraded skills matching labour market needs per year”. During project, 40 trainers will increase their qualification. 200 trainees in improved infrastructure objects will receive new skills matching labour market needs.

The presentation is developed with financial support from the European Union. The project partner LLU is fully responsible for the content of this presentation and in any circumstances does not represent official position of the European Union.
NKG2016LU_gdot – a new model of the postglacial gravity change in Fennoscandia

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Abstract

The vertical deformation in Northern Europe, induced by glacial isostatic adjustment (GIA), is a well-known and extensively studied phenomena. A new, state of the art model of the vertical deformation rate, NKG2016LU, was recently released by the Nordic Geodetic Commission (NKG). This model has now been accompanied by a model of the GIA-induced surface gravity change, NKG2016LU_gdot.

Knowledge about the GIA-induced gravity change is important, for example, for reduction of terrestrial gravity observations to a certain epoch, as ground truth for satellite missions, and for constraining and tuning GIA-models. A trustworthy relation between the gravity change and vertical deformation rate also allows to make transformations between, and combine, the two observables.

NKG2016LU_gdot was constructed as the absolute land uplift converted to gravity change with a linear relation found from GIA modelling and confirmed by 688 repeated absolute gravity (AG) observations spanning over three decades. Here we present the model and describe and motivate our choices of strategies and parameters.

Glacial Isostatic Adjustment in Europe - how much do we know and how accurate can we describe this signal?

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Abstract

The term glacial isostatic adjustment or GIA describes the response of the solid Earth to the waxing and waning of ice sheets and corresponding changes in ocean loads. The adjustment leads to changes in shape, geopotential, rotation and stress. Most of these changes can nowadays be well traced with geodetic methods. This includes effects due to the last major glaciation that peaked about 20,000 years ago but also due to recent climate change-induced ice melt in polar and mountain areas.

GIA in Europe is a well-known and extensively studied phenomenon with first investigations in the 17th and 18th century. Today, GIA is especially in northern Europe a major geodynamic signal in Global Navigation Satellite System (GNSS), levelling and terrestrial and space-borne gravity observations.

The presentation will first review the effects of GIA in geodetic observations in Europe. We will then highlight, i.e. by comparison to models of GIA, how much we (don’t) know, how accurate the signal can be detected or modelled and what is needed to improve our understanding of GIA so that better GIA correction models can be provided. In this regard, we will briefly discuss recent efforts and the latest models, not only for Northern Europe but also for whole Europe.
The Astigan High Altitude Pseudo-Satellite (HAPS) platform

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Abstract
Since 2014, Ordnance Survey, alongside a team of aeronautic engineers within Astigan Ltd, has been developing a High Altitude Pseudo-Satellite (HAPS) platform. This solar-powered aircraft will fly at 20,000m, weigh less than 149kg, fly for 90 days at a time without the need for landing, have a wingspan of 38m and can be positioned to view any part of the Earth.

The Astigan platform will be able to carry a range of remote sensing sensors as well as GNSS augmentations.

This short paper and presentation covers the technical details of Astigan and it’s potential for collection of a wide variety remotely sensed geo data.
Sea Level Network in Estonia and its Applications in Supporting Marine Science, Hydrographic Works and Safety of Navigation

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Abstract
The aim of the poster is to give an overview of necessity, establishment, development and operational issues of the sea level network in Estonia. It explains how the network data is applied in hydrographic works, safe navigation and marine science. The network that records sea level in Estonian coastal and inland waters has several stations – 16 of which are operated by the Department of Marine Systems of Tallinn University of Technology. Every station is equipped with a staff gauge and pressure sensor that transmits sea level data in near real-time every 10 to 30 minutes via a GSM connection. The results are represented with the help of web-based solutions.

After the common European height system EVRS (European Vertical Reference System, also known as Amsterdam Ordnance Datum) was adopted in Estonia in 2018, the reference level in all stations had to be recalculated to present water level in the new system. In order to ease the transition from one system to another, the data is simultaneously available in both height systems.

Estonia keeps one of the longest time series of water level measurements in the world. The first observation dates to the beginning of the 19th century. Since then one of the challenges was to maintain a precise and reliable link between staff gauges and the height system, which connects various gauges into one water level network. Nowadays all staff gauges in Estonia are well connected with the newly reconstructed height system and all sea level data from different stations has a common reference level. Regular levelling of staff gauges with supplement of visual observations ensures high-quality data. In 2009 six tide gauges (staff + pressure sensor) were installed to the biggest islands of Estonia to connect geodetic height of mainland and islands. Up-to-date sea level information is essential for a variety of applications: marine science, engineering, hydrographic survey, etc. Although nowadays for some applications (i.e. hydrography) vertical component is achieved by using GNSS methods (RTK), it is still considered good practice to correlate the results against tidal observations obtained by traditional methods [1].

References:
On E-GVAP (EUMETNET GNSS Water Vapour programme)

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Abstract

The main purpose of E-GVAP is to provide GNSS derived atmospheric delay estimates for usage in operational meteorology. In the presentation we review the present status and future plans. The use of GNSS ZTDs in numerical weather prediction enhances the skill of the models, examples will be given.
High frequency precise displacement monitoring with GNSS techniques during mining seismic events

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Abstract

One of two Polish mining areas, where anthropogenic seismicity is observed, is Legnica-Głogów Copper District. Monthly 15-20 mining tremors of magnitude bigger than 2 occurs there. The strongest earthquakes reach the magnitude of 4.5. These events are shallow, with depth of less than 1 km and therefore felt on the surface and cause the infrastructure damage. Accelerometers, seismometers and high-rate GNSS stations were installed at the area of interest to detect the ground motion during these events.

Within the EPOS-PL project the strategy of high-rate GNSS data processing for natural seismicity monitoring was adopted to monitor the high-rate ground displacement caused by the mining industry. It includes the kinematic Precise Point Positioning (PPP) as well as long-range kinematic double-difference GNSS solutions, Position Domain Sidereal Filtering (PDSF) and digital filtering of resultant displacement time-series. The poster presents the processing strategy, examples of its use during natural and anthropogenic seismic events, and the quality assessment of detected displacements.
ASSESSMENT OF MARINE GEOID MODELS BY SHIPBORNE GNSS AND AIRBORNE LASER SCANNING PROFILES

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Abstract

The geoid is an equipotential surface that the oceans would take at rest, being affected only by the influence of gravity and rotation of Earth. Thus, it roughly coincides with the mean sea level. A modelled surface of the gravity field potential requires an external verification for validating its accuracy. On land, geoid models are customarily evaluated by using precise GNSS-levelling points, whereas offshore such control points cannot be established. Instead, marine geoid models can be assessed by shipborne GNSS measurements or airborne laser scanning (ALS). Accordingly, emphasis of the study is on principles of using the shipborne GNSS and ALS profiles for validation of existing geoid models. Methods for elimination of sea surface oscillations (i.e. data filtering) are investigated. Tide gauge records in conjunction with a regional hydrodynamic model are used for accounting sea level dynamics. For example, comparisons with the new official high-resolution geoid model EST-GEOID2017 yield 1.4…4.6 cm accuracy along various profiles. It is concluded that both shipborne GNSS and ALS profiles have a potential in providing complementary constraints in problematic geoid modelling areas.
New 5 mm geoid model for Estonia

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Abstract
Computational stages of a new high-resolution 5 mm quasigeoid model for Estonia are explained. Certain requirements for the quality and coverage of gravity data in the context of 5 mm geoid modelling were fulfilled. The gravity data coverage over the target area is 1 point per 10 km2, less dense in adjacent land and marine areas. The average uncertainty estimate of gravity data within the target area is about 0.5 … 0.75 mGal. The gravity data were merged, cleaned, analysed, reduced and gridded to yield a seamless gravity anomaly field. A least squares modified Stokes formula that combines local terrestrial gravity anomalies and the global geopotential model derived long-wavelength component in a truncated Stokes’s integral yielded the best gravimetric geoid modelling results. The combined uncertainty for most of the used GNSS-levelling points is not exceeding 5 mm, allowing an adequate verification of the geoid modelling quality. Inter-comparison of the geoid model, GNSS-derived and spirit-levelled heights at discrete points was conducted for geoid modelling assessment. A two stage stochastic spatial prediction was applied to obtain an optimal fit between precise GNSS-levelling data and the geoid model. The location-specific post-fitting uncertainties of the resulting model EST-GEOID2017 revealed standard deviation of 4.2 mm, i.e. the same level as the accuracy of the used GNSS-levelling control points.
National Reports

National Report of Estonia

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Abstract

The short presentation of the main developments in Geodesy at the Estonian Land Board
SAPOS and Open Data - the user requirements

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Abstract
The Surveying Authorities of the Laender of the Federal Republic of Germany (AdV) provide the spatial reference in the form of the operational satellite positioning service SAPOS® in real time, which allows a position to be determined with an accuracy range of 1 to 3 centimetres and thusly meets the requirements of legally secure real estate surveys.

In the last year several Laeder startet to provide SAPOS for free as part of open data initiatives, especially for the agricultural sector.

The autor wants to present the "new" user requirements.
National Report of Switzerland

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Abstract
The short presentation highlights the main developments in Geodesy at the Swiss Federal Office of Topography
National Reports

National Report of Great Britain

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Abstract
Report on activities in Great Britain of interest to the EUREF community
National Reports

National Report of Austria

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Abstract
National Report of Austria
National Reports

National Report of Sweden

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National Reports

National Report of Iceland

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Abstract
National Report of Iceland
National report of Slovakia 2019

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Abstract
National report of Slovakia. News from geodetic controls administration, from GNSS, levelling, gravimetry, metrology and other related fields from Slovakia will be presented. News from research and development will be presented as well.
National Reports

National Report of Finland

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Abstract
National Report of Finland
Abstract
Since 2017 the main geodetic activities at the national level in Poland concentrated on maintenance of gravity control and geomagnetic control, continuing operational work of permanent IGS/EPN GNSS stations, GNSS data processing on the regular basis at the WUT and MUT Local Analysis Centres, activities of MUT and WUT EPN Combination Centre, activity within the EUREF-IP Project, works on GNSS for meteorology, monitoring ionosphere and ionospheric storms, improving consistency between SLR and GNSS solution, maintaining the ASG-EUPOS network in Poland, modelling precise geoid, the use of data from satellite gravity missions, monitoring gravity changes, activities in satellite laser ranging and their use, geodynamics.
National Reports

National report of the Netherlands

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Abstract
Current status and developments in the Dutch national geodetic infrastructure
In the National Report, recent works carried out by IGN-E during past year are presented. They include all projects related to the National GNSS Permanent Stations Network (ERGNSS) and the real time positioning service, the current status of the levelling and gravimetric networks and the associated projects that are being developed using the geodetic infrastructure.

In 2018, more than 100 stations are part of the ERGNSS national active network, including 4 IGS and 25 EPN stations. A free-service of real time positioning with network-based solutions is running using ERGNSS and almost all stations of Autonomous Regions networks. Currently the service is available with about 240 stations participating in the solution. Running over GNSMART (Geo++) the stations are divided geographically in 18 clusters with overlapping and 10 servers are processing in parallel, providing VRS, MAC, FKP and single point solutions to the users, all with GPS+GLONASS.

Respecting IGE Analysis Center, there are several projects where IGN-E is involved with a continuous GNSS processing: as routine EUREF Analysis Centre, Dense Velocities field project (around 400 stations), E-GVAP and many other national projects like the Volcanic Monitoring System, IBERRED, GNSS-Reflectometry, etc.
NATIONAL REPORT OF LITHUANIA TO EUREF 2019


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Abstract

LitPOS (Lithuanian Positioning System) is an active geodetic network of permanent reference GNSS stations in Lithuania. This network is part of National Geodetic Control infrastructure. LitPOS network consists of 31 stations, located evenly in country’s territory, and regional management center. The stations are equipped with Trimble NetR9 GNSS receivers and Choke ring antennas. Additionally 9 stations from abroad are incorporated in LitPOS network (3 from Poland and 6 - Latvian). Overall running and management of LitPOS network is executed by Trimble Pivot Platform software. The network densification adding 5 new stations is foreseen in 2019.

Operational processing of LitPOS data was started in 2018 applying Bernese 5.2 software. 6 fiducial stations of EPN are used in operational processing. Time series of stations geodetic coordinates are analysed applying FODITS (Find Outliers and Discontinuities in Time Series), CATREF and TsView software.

The re-measuring of the points of GNSS first order network of Lithuania was started in 2018. 52 points will be re-observed in total. The duration of the sessions is 4 days. The processing of the observations data is done by Bernese 5.2 software.

The modern gravity survey of the territory of Lithuania was started in 2016 and finished in 2018. The gravity acceleration at gravity survey points was observed by single Scintrex CG-5 gravimeter. In total 5 gravimeters were employed. The analysis of the calibration results of the gravimeters is done also. The standard deviation of the gravity acceleration at gravity survey points 20 µGal is received. The standard deviation of calculated Bouguer anomalies is about 23 µGal. In total about 33000 gravity points were observed giving the density of 1 point per 2 sq. km.
EUREF Related Activities in the Czech Republic 2018 - 2019: National Report

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Abstract
The report describing the EUREF related activities performed in the Czech Republic in 2018 – 2019 was jointly prepared by two institutions of the National Mapping and Cadastral Agency of the Czech Republic - the Land Survey Office and the Research Institute of Geodesy, Topography and Cartography. After a brief introduction into the NMA structure a review is given of the 3D, horizontal, vertical and gravity reference frames in the Czech Republic, their realization and maintenance. GNSS CORS stations in the CR are described in detail with a special regard to operation, administration and services of the CZEPOS network operated by the LSO. Different kinds of transformations are described – ETRS89 vs S-JTSK (national user system), geometric vs gravity space (ETRS89 vs Baltic Height system), BHS vs EVRS. Research activities performed by the RIGTC – Geodetic Observatory Pecny including currently running international projects are briefly summarized.
National Report of Portugal to the Euref Symposium 2019

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Abstract

The present report covers the work developed during the last year by the Directorate-General for Territory (DGT) regarding the EUREF activities.

At the end of 2018, two new tide stations were installed in Cascais and Lagos, consisting of radar technology level sensors and meteorological sensors for the measurement of air and water temperature and atmospheric pressure. These sensors allow the accurate and continuous measurement of sea level and will allow real time data availability to the entire scientific community.

This year we acquired new sensors for the Portuguese CORS Network- ReNEP, which will allow the Portuguese EPN stations to receive Galileo data; the data of the 44 Portuguese stations are available for EPOS project.

The preliminary results of the study of adopting a new realization of ETRS89, based on the ETRF2014 in Portugal are presented.
National Reports

National report of Belarus

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Abstract

The national report covers activities in the field of the geodesy for the time, that has passed since the EUREF symposium 2018. The state enterprise “Belgeodesy” has been carrying out a complex of works on the transition to the geocentric reference coordinate system and the new vertical reference system.

These works include the following:

- repeated adjustment of the 1st order passive satellite geodetic network in order to improve the accuracy of geodetic heights. The goal is to ensure the compatibility of the passive satellite geodetic network and the network of CORS, especially in relation to geodesic heights;

- a multivariant adjustment of the 1st and 2nd order leveling networks in order to identify the most stable points, the heights of which have minimal changes due to the vertical movements of the earth's crust;

- three-day satellite observations on the node points of the 1st order leveling were performed. The observation post-processing was performed using software BERNESE, version 5.2.

- at present an integrity inspection of the fundamental benchmarks of the 1st and 2nd order leveling networks is carried out. In autumn a performing of the satellite observations on the fundamental benchmarks is sheduled.

Since, unfortunately, we do not have CORS that were built on the ground (all our stations were built on buildings), we continue to control the stability of the spatial position of our CORS and create time series. The velocities were calculated on the base of almost eight years of continuous processing using the software BERNESE. In the future, we would like to master other software for velocities estimate. We continue to pay attention to the compatibility of the permanent network and the passive geodetic network. We finished the estimation of the deformations in the urban networks. Now we are carrying out reconstruction of urban geodetic networks in several cities.

The state enterprise “Belgeodesy” seeks to adjust national geodetic infrastructure in accordance with the international standards and considers a creation of a modern gravimetric network and a national gravimetric quasigeoid model as the most important tasks.

For the first time, absolute determinations at the points of the fundamental gravimetric network were performed in 2009 by specialists from Russia using absolute gravimeter FG5. Repeated absolute observations are planned in nearest future.
During the last year, the state enterprise “Belgeodesy” bought three relative gravimeters Scintrex CG-6. Next year we start creation the 1st order gravimetric network.