EUREF 2017 Symposium

Wrocław, Poland
May 17-19, 2016

ABSTRACTS

Local Organizing Committee
of the **EUREF 2017** Symposium and Tutorial

Wrocław, Poland
May 17-19, 2017

Institute of Geodesy and Geoinformatics
Wrocław University of Environmental and Life Sciences (WUELS), Poland

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Dear Colleagues,

On behalf of the Institute of Geodesy and Geoinformatics, Wroclaw University of Environmental and Life Sciences we are pleased to cordially invite you to the annual EUREF 2017 Symposium, that will be held in Wroclaw, Poland, on May 17-19, 2017 (Wednesday to Friday).

EUREF annual Symposiums are of the utmost importance: they serve as a forum where the EUREF activities are discussed and resolutions are taken. EUREF Symposia have been organized since the first Symposium in Florence, Italy in 1990. The related materials (presented scientific papers, national reports, resolutions) are published on the EUREF website. This year there will be the opportunity of publishing peer-reviewed proceedings from EUREF 2017 Symposium as a special issue in Geodesy and Cartography – the official journal of the Committee on Geodesy of Polish Academy of Sciences.

The host city of the 27th EUREF Symposium is Wroclaw, located in western Poland at the River Oder in the Silesian Lowlands. Wroclaw is the 4th largest municipal centres in Poland with population exceeding 630 000 inhabitants. The constant growth of education level of the citizens as well as a substantial number of students (143 000) point to a high social potential of the city and its labour market. Because of its high cultural activity the city was granted the title of 'European Capital of Culture' together with Donostia (San Sebastian) and the 'World Book Capital' in 2016. This Central European city displays the vast variety of architecture styles, tourist attractions as well as cultural and sport events including the World Games (of non-olympic sports) organized in July 2017.

Wrocław University of Environmental and Life Sciences (WUELS) is a well-recognised scientific and educational centre, the only agricultural university in the south-west region of Poland. The WUELS employs about 1,500 people, (160 full and associate professors). Full and part-time students (11 000) are offered a wide range of degree courses in agriculture and related areas including geodesy.

We hope that the EUREF 2017 Symposium will continue the tradition to serve a stimulating forum for the international exchange of knowledge and closer collaboration between specialists.

We are looking forward to seeing you in Wrocław!

Markku Poutanen
EUREF Chair

Jan Kapłon
Chairman of EUREF 2017 Symposium LOC

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OPENING SESSION
Convener: Markku Poutanen

SESSION 1 — SYSTEMS: ETRS89, EVRS
Conveners: Zuheir Altamimi, Markku Poutanen

EUREF designed and established the European Geodetic Reference Systems. The European Terrestrial Reference System 89 (ETRS89) has a continent-wide significance. It is based on the International Terrestrial Reference System (ITRS), but tied to the stable part of Europe, so that the relationship between the two systems is entirely defined by a similarity transformation formula. ETRS89 unifies national reference systems for surveying, mapping, GIS and navigation in Europe. The benefit of ETRS89 is well demonstrated through its acceptance by several communities, e.g. EuroControl and the European Commission. The European Vertical Reference System (EVRS) is a kinematical height reference system. It is the basis for harmonisation of the vertical reference of spatial coordinates. Presentations of the session report on legal acceptance, potential usage in geo-referencing applications and benefit for practice of the outlined geodetic reference systems and their practical realizations.

SESSION 2 — NETWORKS: EPN, UELN, DENSIFICATION
Conveners: Elmar Brockmann, Ambrus Kenyeres

The reference networks through their observations are maintaining but also providing access to the reference system realizations. The EUREF Permanent Network (EPN) and the United European Levelling Network (UELN) are the core infrastructures of EUREF. The EPN is linked to the global network of the International GNSS Service (IGS) and contributes to the definition of the International Terrestrial Reference System (ITRS) realizations, but also serves as reference for the national permanent GNSS networks. This hierarchy ensures the conformity and homogeneity of the geodetic reference system realizations from the global to national level. The operation of a permanent GNSS network requires several well organized components: network coordination, data centres, analysis centres and product gateways. The routine cooperation with the station managers and the user community guarantees the appropriate implementation and usage of GNSS. The objective of the UELN is to establish a unified vertical datum for Europe at the one-decimetre level. Due to the different technology characteristics of GNSS and levelling, UELN is developing on a much longer time scale. However, the GNSS needs for interaction with the height reference systems and networks may leading to changes in the practical implementation. The session presents experiences and improvements of the provision and dissemination of data and results stemming from the geodetic reference networks. Improved analysis strategies and the latest results are expected to be presented.

SESSION 3 — TECHNIQUES: GNSS, LEVELING, COMBINATION
Conveners: Rolf Dach, Martina Sacher

Geometry and gravity related measurement techniques allow for implementation of a European geodetic reference frame. Nowadays, applications of a Global Navigation Satellite System (GNSS) are the dominant technique to measure the geometry for continental regions. Direct measurements of the gravity or levelling are techniques related to the gravity field of the earth. All techniques need to take variation of system earth into account, if a longer time period or higher accuracy of site locations is in the focus. Combination of different techniques is not only a validation of one technique against another one, but also opens new applications, e.g. levelling with GPS by using known geoids' information. EUREF supports such practical aspects by the EUVN and EUVN-DA actions. GNSS and levelling measurements refer to discrete points. Developments of remote sensing methods extend the measurement of geodetic reference frame components from points to the surface, e.g. Synthetic Aperture Radar (SAR) measures height changes of the earth's surface. The

combination of SAR and GNSS is a challenge for the future. A couple of developments, which include to transport GNSS observations in real-time (data streaming) and even to calculate the receiver position in real-time are almost completed. The provision of geodetic reference frames in real-time has an important impact on current practise. The installation of new satellite navigation systems beside GPS and GLONASS, such as Galileo, BeiDou and QZSS, results in autonomous stand-alone solutions and combined multi-GNSS techniques. More satellites for the multi-GNSS scenario are going for deployment in the near future and investigations to understand improvements for geodetic aspects have already started. This session presents developments, analysis and results of all techniques that are relevant for the establishment of reference frames. Real-time and multi-GNSS developments are of special interest.

SESSION 4 — APPLICATIONS: EARTH SCIENCES, GEO-INFORMATION
Conveners: Alessandro Caporali, Rosa Pacione

Geodetic techniques measure the situation on the earth's surface. Modern space techniques extend observations to satellites orbiting the planet earth or even to extraterrestrial targets. Today the position of particular sites on the earth's surface and its variation is known to the sub-millimetre level for the period of decades. These techniques are also sensitive for many occurrences within the system earth, e.g. changes in the atmosphere, movement of tectonic plates and the state of solar radiation. The cross-linking of geodetic findings and knowledge from other geosciences is in the focus of research projects since long time. Geodesy contributes to understand the system earth. This session presents recent research projects of geosciences such as the European Plate Observing System (EPOS) and also updated results of ongoing projects. Real-time analysis of GNSS observations provides geophysical parameters in real-time, e.g. information about the troposphere state. It contributes to online monitoring of the natural environment. Interdisciplinary cooperation for geo-monitoring and visualising in geo-information systems will be addressed here.

SESSION 5 — NATIONAL REPORTS
Conveners: Jan Kryński, Guenter Stangl

Representatives of European countries meet the challenge to report on national activities related to projects of geodetic reference systems. These are GNSS networks, height systems and geodetic methods based on the gravity field of the earth. New projects will be introduced, but also updated results of ongoing projects are of interest. Knowledge about progress in particular European countries provides valuable ideas for future planning in the home country and for a pan-European realisation of geodetic reference systems. The oral presentations should be concise, to allow plenty of nations to report.

POSTER SESSION
Convener: Krzysztof Sośnica

CLOSING SESSION
Convener: Markku Poutanen

SESSION 1

SYSTEMS: ETRS89, EVRS

Conveners: Zuheir Altamimi, Markku Poutanen

ITRF2014 Plate Motion Model and ETRS89 realization

Z. Altamimi, P. Rebischung, L. Métivier, H. Rouby, X. Collilieux

IGN France

ABSTRACT

For various geodetic and geophysical applications, users need to have access to a Plate Motion Model (PMM) that is consistent with the ITRF2014 frame. In particular, many national and continental reference frame implementations, such as the ETRS89, require access to the ITRF frame through pure plate rotation poles. After a brief description of the ITRF2014 PMM and main results, the paper will discuss the implications for the ETRS89 realization. In particular, an accuracy assessment of the Eurasia rotation pole estimations between ITRF2014-PMM and past ITRF models will be discussed. Moreover, station position and velocity changes between ETRF2000 and past ETRF frames and a possible ETRF2014 will be evaluated and discussed.

Keywords: ITRF2014, ETRS89, Plate Motion

Transition from IGb08 to IGS14 in the European reference frame realization and maintenance

A. Kenyeres[1], J. Legrand[2]

1. BFKH FTFF Satellite Geodetic Observatory, H-1149 Budapest, Bosnyak ter 5, Hungary
2. Royal Observatory of Belgium, Ringlaan 3,BE-1180 Brussels, Belgium
ambrus.kenyeres@sgo-penc.hu

ABSTRACT

The European densification of the ITRS realizations is being done using the regular updates of the multi-year combined SINEX solutions stemming from the EUREF Permanent Network (EPN). The current solution (C1934) is based the IGb08 reference frame realization and includes weekly SINEX solutions from GPS week 834 up to GPS week 1934. Following the IGS analysis strategy the EPN ACs are also changed from the IGb08.atx to IGS14.atx antenna PCV models and the related reference frame realization.

The reference frame change should also be completely implemented in the next EPN cumulative solution – C1950, which will be based on EPN REPRO_2 results (up to GPS week 1824), the routine EPN product (up to GPS week 1934) – both are bason on the IGb08.atx PCV model – and then the EPN product from GPS week 1935 based on IGS14.atx. The REPRO_2 and routine products up GPS week 1934 will be converted to IGS14 adding specific position corrections to the SINEX files.

Another important change will be that the follow on cumulative solution – C1950 – will be based on the daily combined EPN SINEX product. We expect that the change from the weekly to daily product as input will cause refined handling of station issues and a better reference frame realization.

Keywords: EPN, IGS, reference frame

The project: Dynamic reference frames on Iceland

H. P. Kierulf[1], G. Valsson[2], K. Evers[3], D. Prizginiene[2], H. Magnusson[2], O. Vestøl[1], M. Lidberg[4], P. Häkli[5], T. Saloriutta[5], M. Poutanen[5], P. Knudsen[6]

1. Kartverket, Norway
2. Landmælingar Íslands, Iceland
3. SDFE, Denmark
4. Lantmäteriet, Sweden
5. Finnish Geospatial Research Institute FGI, Finland
6. DTU Space, Denmark
corresponding author: halfdan.kierulf@kartverket.no

ABSTRACT

There is a general growing need for geodetic reference frames that on national level supports the increased use of global positioning services. As of today most countries have developed and are maintaining their own national reference frame, and global satellite systems, such as GPS and Galileo, and global positioning services may not be directly compatible with national geospatial data in those frames, especially in case of crustal deformations.

How to take full benefit of global services in practice is a subject for discussions and considerations. The current situation in Europe is that most countries have regional static reference frame aligned to ETRS89. As ETRS89 is defined to be co-moving with the Eurasian plate, such reference does not enable a direct access to the reference frame through the GNSS system without some kind of time dependent transformation.

Australia is meeting this future demand with another approach. They will in 2020 introduce a new national reference frame directly aligned to the latest ITRF and co-rotating with this global frame instead of the tectonic plate. In such a frame the coordinate of a point fixed to the ground, will have coordinates changing with time and is therefore often named a dynamic reference frame. New Zealand has chosen a way in between. Their national reference frame is static with reference epoch 2000.0, and a deformation model is closely integrated to allow transformation of new observation to the reference epoch. Updates of both the reference frame and the velocity model are allowed to happen when necessary.

It is a growing awareness that static reference frame like ETRF is not the ideal solution for all purposes in the future. To be prepared for the future the Nordic Geodetic Commission (NKG) have initiated a pilot-project to gain knowledge and end up with a „Project proposal for implementation of a dynamic reference frame in Iceland".

Iceland is in many ways an ideal case for such a project. On the one hand it is a tectonic active area lying on two continental plates affected by crustal deformation from earthquakes, volcanoes and melting glaciers. On the other hand it is a small sparsely populated country with limited GIS systems and hence the practical implementation of a dynamic reference frame might be easier.

This presentation will give an overview and status of the project.

Keywords: Dynamical reference frame, ITRF, ETRS89, semi-dynamic reference frame

Convergence of ITRF transformation parameters and impact of aligning ETRS89 to ITRF2014

J. Lesparre[1], L. Huisman[1,2]

1. Kadaster, Hofstraat 110, Apeldoorn, the Netherlands
2. Delft University of Technology, Stevinweg 1, Delft, the Netherlands
jochem.lesparre@kadaster.nl

ABSTRACT

With the release and adoption of ITRF2014, there is a need for transformation parameters between ITRF2014 and ETRS89. At the EUREF 2016 symposium in San Sebastian two alternative possibilities have been proposed next to the transformation from ITRF2014 to the conventional ETRF2000 frame (ETRF2000(R14)). The motivation to give alternative possibilities is based on the statement that the differences between the scale and origin of recent ITRS realizations have become small, thus the parameters of ITRF have converged.

In this presentation we show the stabilization of ITRF parameters. However, the transformation parameters have stabilized temporarily for a few years before, due to using the same data types and computation method of ITRF. Therefore, the transformation might only appear to be converged.

Next, we clarify the impact of the different choices for the transformation parameters between ITRF2014 and ETRS89 realizations on the coordinates by visualizing the differences on a regular spaced grid rather than on EPN stations only. The use of a grid gives a better image of the maximum absolute and relative differences over Europe.

Keywords: ITRS, transformation, ETRS89, 2014

On possible alternatives for the realization of ETRS89 based on ITRF2014

M. Lidberg

Lantmäteriet, Lantmäterigatan 2c, 801 82 Gävle, Sweden
Martin.Lidberg@lm.se

ABSTRACT

The ETRS89 was developed almost three decades ago. The background was clear needs from users to have a high quality geodetic reference system to support the development of the use of GPS for booth geodesy and navigation. During the first decade, the ETRS89 was realized through a new European Terrestrial Reference Frame based on each on each new release of the International Terrestrial Reference Frame. Thus, there have been 8 ETRFs in use from ETRF89 to ETRF97.

When ITRF2000 was released, also the ETRF2000 was developed and introduced following the established practice. However, when ITRF2005 was introduced it turned out that the ETRF2005 caused too large differences on the coordinate level compared to ETRF2000. It was therefore decided to keep ETRF2000 and introduce it as the conventional reference frame for ETRS89 also after the release of ITRF2005 and ITRF2008.

Now we have the situation that the ITRF2014 has been released. We also have used ETRF2000 for almost two decades, which imply that the proposed realization of ETRS89 have been

very stable and consistent. However, there are some limitations in ETRF2000 that partly is due to its basis in the "old" ITRF2000. Therefore there are also good arguments for renewing the realization of ETRS89 with a closer relation to ITRF2014.

In this presentation some alternatives for an ETRF2014 with minimized coordinate shift to ETRF2000 will be explained and discussed, together with possible advantages and drawbacks, and differences in methodology to the traditional realizations.

Keywords: ITRS, ITRF2014, ETRS89, ETRF2000, ETRF2014

Future of Reference Frames – from static to dynamic?

M. Poutanen, P. Häkli

Finnish Geospatial Research Institute FGI, Geodeetinrinne 2, 02430 Masala, Finland
markku.poutanen@nls.fi

ABSTRACT

Technical development, new applications and requests for increased accuracy in georeferencing are setting new demands for accuracy and reliability of reference frames. Traditionally, a reference frame is defined as static by a set of fixed benchmarks, the coordinates of which are given in the reference frame. Due to crustal deformations and local movements of benchmarks, such reference network deteriorates with time, thus eventually requiring update of the whole system. Frequency of the updates depends on size of the deformations and required precision (and accuracy) of the reference frame. Typically, for example in the presence of post-glacial rebound in the Fennoscandian region, height systems have been renewed after few decades and present demands for three-dimensional reference frames are even more challenging. Renewing a reference frame and associated geospatial data (registries etc.) is a laborious and expensive process which cannot be done very often. In some areas movements are so large or abrupt that even such regular update is not enough.

Increased accuracy requirements on the other hand implicate more frequent update which in practice is not possible. An alternative is to use continuous data of active control points, like permanent GNSS stations, instead of passive, fixed benchmarks to estimate station positions and motions in an accurate (global) reference frame (today practically ITRF). Together with the station velocities (or a model derived from those), one can compute transformation parameters that consider possible deformations between the global and the original (national) frame. Then user defines his/her position in the latest ITRF and with the (preferably seamless) transformation obtains consistent coordinates in the national frame. Such a system is called semi-dynamic, and for most cases this can considerably extend the life time of the existing frame.

The third alternative is to abandon the national reference frame and use only the global frame in all georeferencing activities. Such a system is called a dynamic reference frame and it implies that coordinates of all geospatial data are time-dependent. In addition to practical issues with changing coordinates, there will be also legal issues for example in cadastre work or any land-owning questions. Such issues must be solved for before the dynamic frame is taken in use.

In this presentation we discuss on various possibilities, technical issues, future aspects and needs in the viewpoint of National Mapping and Cadaster authorities.

Keywords: reference frames, dynamic, semi-dynamic, active benchmarks, precise positioning

The ETRS89 Questionnaire 2017 – results and evaluation

W. Söhne[1], A. Kenyeres[2], M. Poutanen[3]

1. Federal Agency for Cartography and Geodesy, Germany
2. Government Office of Capital City Budapest, Hungary
3. Finnish Geospatial Research Institute, Finland
wolfgang.soehne@bkg.bund.de

ABSTRACT

In 2016, a new realization of the International Terrestrial Reference System (ITRS), the International Terrestrial Reference Frame 2014 (ITRF2014) has been released. While the improved accuracy and stability of the origin and scale of ITRF2014 has been widely agreed on, the significance of an updated realization of the European Terrestrial Reference System (ETRS89) was lively debated during the EUREF annual symposium 2016 in San Sebastian. As a consequence of the discussion, the Plenary instructed the EUREF Technical Working Group (TWG) to elaborate, distribute and evaluate a questionnaire about the ETRS89 realization and urged the National Mapping Agencies (NMAs) to complete the questionnaire.

After some iteration within the TWG, the questionnaire about the use and realization of ETRS89 was finally sent out mid of March by the EUREF secretary. In addition, the questionnaire was published on the EuroGeographics web page.

This presentation shortly reviews the motivation for the EUREF questionnaire and reports on the responses of the NMAs and other organizations to this survey.

Keywords: ETRS89, realization, ITRF2014

The alignment to IGb08 of the EPN cumulative solutions

J. Zurutuza[1], A. Caporali[1], W. Söhne[2], A. Kenyeres[3], M. Bertocco[4]

1. University of Padova (Department of Geosciences), Via G. Gradenigo n. 6 35131- Padova (Italy)
2. Bundesamt für Kartographie und Geodäsie, Richard-Strauss-Allee 11, Frankfurt am Main, Germany
3. Institute of Geodesy, Cartography and Remote Sensing, Satellite Geodetic Observatory (SGO), Budapest, Hungary
4. Centro di Ateneo di Studi e Attività Spaziali "Giuseppe Colombo" – CISAS, Padova, Italy
jzurutuza@gmail.com

ABSTRACT

This study, first presented at the EUREF2016 Symposium, we reviewed the process of alignment to IGb08 of the European Frame realized through its successive cumulative solutions. To this purpose we reported on the results of Helmert transformation of each cumulative solution (one every 15 weeks, starting with week 1710) to the IGb08 coordinates of common sites, at epoch 2005.0. We also check the individual cumulative solutions with reference to the latest cumulative solution (C1875), always with a 4 parameter Helmert transformation. Finally we monitored the statistics of the repeatabilities of station coordinates and velocities, as the cumulative solution advances.

Our analysis consisted of time series of Helmert parameters (three translations and one scale). We show that the Helmert parameters were always consistent with zero, within one standard deviation, so that the alignment to Igb08 was granted. A more detailed analysis of the time series also showed that between week 1785 and week 1800 a small but rather evident discontinuity occured in the Tx and Tz, whereas Ty and the Scale are still coherent with previous solutions. While the Helmert parameters tend progressively to zero, the Tup parameter had a bell shaped trend which has still to be interpreted. A possible reason could be related to the switch from BSW50 to BSW52. Overall the alignment of the cumulative solution to IGb08 is very good. Future use of fully reprocessed (repro2) normal equations, and the addition of global sites is expected to make this agreement even better.

This presentation is an update of the results, including all the IGb08-based solution (C1710 to C1934).

Keywords: IGb08, EPN A, IGS08, Helmert parameters

SESSION 2

NETWORKS: EPN, UELN, DENSIFICATION

Conveners: Elmar Brockmann, Ambrus Kenyeres

Gravity corrections for the updated Italian leveling network

R. Barzaghi[1], D. Carrion[1], M. Carroccio[2], R. Maseroli[2], G. Venuti[1]

1. DICA – Politecnico di Milano, piazza Leonardo da Vinci 32, Milano, Italy
2. IGM – Direzione Geodetica, Via Novoli 93, 50127 Firenze, Italy
giovanna.venuti@polimi.it

ABSTRACT

Leveling increments must be corrected for gravity effects in order to get proper dynamic, normal or orthometric heights. Most of the Italian leveling lines are not complemented by the required gravity observations and leveling corrections were applied only on a subset of the existing lines.

However, gravity is densely observed over Italy and predictions of it along the leveling lines can be made. The reliability of such predictions in the computations of gravity corrections was assessed by some of the authors through a first test performed along a leveling line in the western Alps area, where the corrections significantly impact on the reduction of the misclosure errors of the considered leveling ring. Gravity derived from the EGM2008 global model was also used for the same task leading to poorer results.

Starting from this outcome, gravity predictions were performed along the leveling lines recently surveyed by the Istituto Geografico Militare (IGM), covering almost the whole Italian network (i.e., the peninsular area apart from the southern regions of Calabria and Puglia). Dynamic, normal and orthometric corrections were evaluated both from the predicted and the available observed gravity data. They were applied to the new leveling increments to get the updated Italian height datum, according to UELN standards. Statistics of the results obtained in this computation will be shown.

Keywords: gravity corrections, dynamic heigths, normal heights, orthometric heigths, gravity, leveling

Towards an European Dense Velocities Field

E. Brockmann[1], Joaquin Zurutuza[2], A. Caporali[2], M. Lidberg[3], C. Völksen[4], G. Stangl[5], E. Serpelloni[6], S.I. Bitharis[7], C. Pikridas[7], A. Fotiou[7], E. Mathis[8], J.A. Sánchez Sobrino[9], M. Valdés Péres De Vargas[9], P. Vernant[10], P. Franke[11], W. Söhne[11], A. Baron[12]

1. Swiss Federal Office of Topography, Seftigenstr. 264, 3084 Wabern, Switzerland
2. University of Padova, Italy
3. Lantmäteriet, Sweden
4. Commission for Geodesy and Glaciology, Munich, Germany
5. BEV, Vienna, Austria
6. Istituto Nazionale di Geofisica e Vulcanologia Centro Nazionale, Italy
7. Aristotle University of Thessaloniki, Greece
8. IGN France
9. IGN Spain
10. Laboratoire Géosciences Montpellier, France
11. BKG, Frankfurt, Germany
12. ICC, Barcelona, Catalonia, Spain
elmar.brockmann@swisstopo.ch

ABSTRACT

The presentation held at the last EUREF symposium in San Sebastian "Densifying Velocity Fields in Europe: Advantages of the classical Approach", produced an extreme positive feedback. In the following summer months participating colleagues made their existing velocity fields available. Other participants volunteered to contribute as soon as they have a velocity field calculated in the region of their interest or asked for having the possibility to share details on deriving velocities based on their daily network analyses with groups that are already experienced. Comparisons of the delivered velocities on commonly processed sites prove that a dense velocity field can easily be generated by combining (classical approach) individually generated velocity fields.

This paper shows the status and highlights the benefits of this classical approach, which is based on individual velocity fields only. Currently, velocity information of more than 2000 sites are available. Furthermore, the provided velocity grid of the Nordic Geodetic Commission shows a rough idea, how a dense European velocity field may look like.

It is intended that this work will be further developed in a EUREF working group as a complementary activity, rather than competing, to other initiative in this area like EPN densification and EPOS GNSS. A draft charter has been prepared. Almost all mapping agencies and many geophysical research institutes are potential candidates to participate to this activity. Reference frame maintenance is the main key task for all mapping agencies and the existing permanent networks allow extending the monitoring of the station coordinates with the aspect of velocities. The extension to velocities is a comparable small step if the agencies are already capable to process their data on a daily basis.

This activity will make use of the experiences of the contributing partners. They are the specialists and know details of their stations best. They are also capable to add further observations (levelling, GNSS campaigns) for an even better and denser velocity field. The final goal, a homogenized European velocity field combined in this way ensures compatibility with the national velocity fields and may find deep interest even in other geo-physical communities.

Keywords: Velocities, EPN

Enhanced Assessment of EPN Station Performance

C. Bruyninx, J. Legrand, A. Fabian, E. Pottiaux, F. Roosbeek

Royal Observatory of Belgium, Av. Circulaire 3, B-1180 Brussels, Belgium
C.Bruyninx@oma.be, epncb@oma.be

ABSTRACT

This presentation will first give an overview of the main changes in the EPN tracking network since last year's EUREF symposium. Then, we will focus on the upgrade of the EPN Central Bureau web site and monitoring tools. They include

- A more intuitive menu structure to navigate through the web site
- Extended station list with more station metrics
- Improved GNSS data quality checks (multi-GNSS) on both RINEX 2 and RINEX 3
- Improved station position time series
- Improved GNSS data availability and latency checks on both RINEX 2 and RINEX 3
- Full implementation of long RINEX3 station names
- Extended monitoring of real-time data streams, now also including RTCM3.2 and all 3 regional EPN broadcasters

We will show how the new and upgraded tools allow to improve the assessment of the EPN station performance and illustrate this with some practical examples.

Finally, we will give an insight in our future developments.

Keywords: EPN Central Bureau, EPN stations, data quality, data availability, time series

On the estimation of physical height changes using GRACE satellite mission data – A case study of Central Europe

W. Godah, M. Szelachowska, J. Krynski

Institute of Geodesy and Cartography, 27 Modzelewskiego St., 02-679 Warsaw, Poland
malgorzata.szelachowska@igik.edu.pl

ABSTRACT

The dedicated gravity satellite missions, in particular the GRACE (Gravity Recovery and Climate Experiment) mission launched in 2002, enriched the investigations concerning temporal variations of mass distribution in the Earth's system resulting in the geometry changes of the Earth as well as its gravity field. The main objective of this contribution is to estimate physical height (e.g. the orthometric height) changes over Central Europe using GRACE satellite mission data.

Temporal variations of geoid heights and vertical displacements of the Earth surface have been determined over the investigated area using RL05 GRACE-based global geopotential models. The resulting physical height changes have been analysed and modelled using two methods: the seasonal decomposition method and the PC/EOF (Principal Component or Empirical Orthogonal Function) method. The obtained results were discussed.

Keywords: GRACE, geoid height variations, vertical displacements, physical height changes

Evaluation of Transition to Updated Regional Q-geoid Model

Janis Kaminskis[1], Atis Vallis[2], Ineta Geipele[3], Iveta Stamure[4], Martins Reiniks[5], Una Krutova[6]

1. Geomatics Department, Riga Technical University, Riga, Latvia
2. Ltd. Geostar, Riga, Latvia
3. Institute of Civil Engineering and Real Estate Economics, Riga Technical University, Riga, Latvia
4. Institute of Civil Engineering and Real Estate Economics, Riga Technical University, Riga, Latvia
5. Geomatics Department, Riga Technical University, Riga, Latvia
6. Geomatics Department, Riga Technical University, Riga, Latvia
Corresponding author: janis.kaminskis@rtu.lv

ABSTRACT

During last year's we have got for our territory overlaying European and Nordic quasi-geoid models besides existing national q-geoid model. There are many ways for comparison and tests of results achieved so fare. We can compare models directly at some special geodetic co-location stations or use GNSS/levelling sites. We can involve in our research results from fundamental geodetic observations to have totally independent control for existing q-geoid models and accuracy evaluation.

The research aim is to evaluate the transition to the updated regional q-geoid model. The research objective is the following tasks: 1) investigated and analyzed the development of q-geoid model LV14; 2) realized precision researches; 3) assesses the challenges of the European Vertical Referent System; 4) draw conclusions that allow further research in this area full development and improvement.

During the development of research authors used a variety of research methods. Historical and logical approaches, comparative analysis and synthesis methods, as well as inductive – deductive data analysis methods are selected for the research.

As a conclusion for such kind of studies is to implement most appropriate q-geoid solution and to develop new astrogeodetic methods for unification, monitoring and for reliability of geodetic reference network.

Keywords: q-geoid model, accuracy evaluation, GNSS/levelling, Trimble Business Center

EPN Densification – Prepared to Publish

A. Kenyeres[1]
A. Baron – A. Caporali – B. Drošcak – F. de Doncker – A. Duret – P. Franke – I. Georgiev – D. Hansen – L. Huisman – O. Khoda – K. Morozova – J. Nagl – X. Papanikolaou – P. Pihlak – M. Ryczywolski – G. Stangl – M. Valdes – J. Zurutuza

1. BFKH FTFF, H-1149 Bosnyak ter 5, Hungary
kenyeres.ambrus@gnssnet.hu

ABSTRACT

The densification of the EPN is based on the SINEX products of the national permanent GNSS networks, where EPN provides the backbone to determine the multi-year position and velocity solution in unified reference frames. The combination is extended almost to the whole

continent with the participation of 19 analysis centres. The database includes more than 3000 stations, where ~70% have time series longer than 3 years. The quality and reliability of the solutions is checked with time series analysis tools and with collection and use of station meta data, based on station log files. The web pages under the EPBCB website are primarily designed for meta data collection and the publication of results.

After thorough preparations including meta data homogenization, data filtering we are reaching a milestone to release the position and velocity product. The time series plots are gradually uploaded to the EPNCB website and following the review and approval by the TWG the product will be released this autumn.

Keywords: time series analysis, velocity, SINEX, multi-year combination.

EPN Analysis Coordinator Status Report

T. Liwosz[1], A. Araszkiewicz[2]

1.Warsaw University of Technology, Pl. Politechniki 1, 00-661 Warsaw, Poland
2. Military University of Technology, ul. Kaliskiego 2, 00-948, Warsaw, Poland
tomasz.liwosz@pw.edu.pl

ABSTRACT

The presentation covers the recent activities of the EPN analysis centres coordinator during the last year. The EPN Analysis Coordinator combines and analyses GNSS weekly and daily solutions provided by the EPN Analysis Centers (AC). In 2016, a methodology for creating weekly combined EPN solutions was changed. Before the change, the weekly combined solutions were created directly from the AC weekly solutions. Since week 1925 (November 27, 2016) the daily AC solutions are combined for each day of the week, and then the seven daily combined solutions are stacked into a weekly solution. The new approach allows to more consistently handle position outliers on a daily level, and it helps to mitigate possible inconsistencies between AC solutions. Starting with GPS week 1934 (January 29, 2017), the new IGS14/igs14.atx framework has been used by ACs to genarate GNSS solutions, which replaced the IGb08/igs08.atx framework. With the change, also a new EPN antenna calibration model (epnc_14.atx) has been released by the EPN Central Bureau, which includes new and updated antenna calibrations for some stations. Since week 1934 all EPN combined solutions are aligned to the new IGS14 reference frame.

Keywords: EPN, GNSS

Data Management at AC and DC of BEV

P. Mitterschiffthaler

Federal Office of Metrology and Surveying, Schiffamtsgasse 1-3, 1020 Vienna, Austria
philipp.mitterschiffthaler@bev.gv.at

ABSTRACT

At the end of 2017 the contract (OLG) between the Austrian Academy of Science (AAS) and the Federal Office of Metrology and Surveying (BEV) will end. To keep the long tradition in Austria for GNSS analysis and the contribution to EUREF, we decided to migrate the data center as

well as the analysis center to BEV. Embedded in the IT infrastructure of BEV the services reached a better security level and a higher level of availability. We used this transition phase to adapt all our scripts and the data storage system too. Changes from OLG to BEV are shown in this presentation. The introduction of some new big data tools in the field of monitoring the data flow and the solutions, are shown and clarify how big data can make our life easier.

Keywords: Austria, analysis center, data center, Big Data

New data of Belarus and Estonia and the new Nordic land uplift model contribute to UELN

M. Sacher[1], K. Kollo[2], N. Rudnitskaya[3]

1. BKG, K.-Rothe-Str. 10-14,04105 Leipzig, GERMANY
2. Estonian Land Board, Mustamäe tee 51,10621 Tallin, ESTONIA
3. Belgeodesy, 220029 Minsk, 17 Masherov ave., BELARUS
martina.sacher@bkg.bund.de

ABSTRACT

The UELN data and analysis center continued to collect and process leveling data of European countries. Since the release of EVRF2007 the UELN has been expanded by leveling networks of two countries; the leveling data of six countries have been updated or supplemented. After the previous year's EUREF symposium in Donostia-San Sebastian the data of the first order leveling network of Belarus was provided for the first time. Estonia delivered new leveling data within a very high precision. The influence of the new data is shown in a common adjustment.

In EVRF2007, the postglacial rebound of the Nordic-Baltic region was considered arithmetically by using the landuplift model NKG2005LU of the Nordic Geodetic Commission. In 2016, the Nordic Geodetic Commission released the new uplift model NKG2016LU_lev. This model contains values also in such areas, where the former model NKG2005LU had been truncated to the value -2mm/year. The influence of the two different models on the adjustment results is examined for several national leveling networks as well as for a new common adjustment of UELN. The adjusted UELN heights differ by up to +/- 4cm.

Keywords: UELN, EVRS, NKG2016LU_lev, Belarus, Estonia

The CEGRN campaigns and densification of the ETRF in Central Europe

J. Zurutuza[1], A. Caporali[1], O. Khoda[2]

1. University of Padova (Department of Geosciences), Via G. Gradenigo n. 6 – 35131 – Padova (Italy)
2. Main Astronomical Observatory of the National Academy of Sciences of Ukraine 27 Academician Zabolotny Str., 03143, Kiev, UKRAINE
jzurutuza@gmail.com

ABSTRACT

The Central European GPS Geodynamic Reference Network (CEGRN) was established in the framework of the project called CERGOP in 1994. The Network was first surveyed in 1995. From 1996 to 2015, each 2 years, a weekly GNSS campaign has been carried out during the month of June. The number of participating countries was increased from 11 in 1996 with 41 sites (mostly non permanent sites) to the 23 of 2015 with 183 mostly permanent sites (available for the EUREF2016 Symposium). During 2016 and 2017 several private and government Agencies have shown their interest in getting involved in the CEGRN Network and have provided data, some starting in 2003, in both RINEX and SINEX formats. Also, the EUREF weekly SINEX files have been used in this study.

Therefore, the former CEGRN validated by the EUREF TWG in Leipzig (EUREF2015 Symposium) with respect to positions and a number of velocities, has been densified to large Network covering the whole Europe. The RINEX files have been processed whereas the SINEX weekly files have been stacked to feed the multiyear adjustment.

Keywords: CEGRN, SINEX, velocity field

3D Deformation in time of the ETRF2000 grid

J. Zurutuza[1], A. Caporali[1], E. Brockmann[2], M. Lidberg[3], M. Bertocco[4]

1. University of Padova (Department of Geosciences). Via G. Gradenigo n.6 - 35131- Padova (Italy)
2. Swiss Federal Office of Topography swisstopo, Geodesy Division, Seftigenstrasse 264, 3084 Wabern
3. Lantmäteriet, Gävle, Sweden
4. Centro di Ateneo di Studi e Attività Spaziali "Giuseppe Colombo" – CISAS, Padova, Italy
jzurutuza@gmail.com

ABSTRACT

The EUREF Densification solutions, which are all the solutions apart from A and B EPN class sites being submitted to the EUREF provide a large number of sites with high quality positions and velocities throughout all Europe. Such a density allows the creation of a velocity field, and therefore, a continuous deformation model respect an original grid, namely ETRF2000. In this presentation, the velocities provided by the Densification Centers (more than 500 only in Central Europe and Italy) have been used to create a very dense network and diminish the impact of distance in the interpolation methods.

The propagation of the velocities over time shows that the behavior of the ETRF2000 grid is not rigid across a considerable portion of Europe, including that traditionally considered as 'stable'. This presentation should be useful to give an idea on where the network should be densified to have a better understanding of the underlying geophysical processes that are visible on the surface. The

most notable examples relate to the vertical uplift in Fennoscandia, extension/compression/shear processes in the Central and Eastern Mediterranean, and active crustal deformation in the Pannonian and Carpathian regions. Thus this work could serve not only NMA's interested in keeping the alignment of the regional reference frame to some nominal coordinate grid, but also to projects such as EPOS which aim at an improved understanding of the European crustal dynamics by integrating a variety of observation techniques.

The three dimensionality of our approach addresses both the vertical and horizontal frames, the integration of which is a challenge which is expected to receive considerable attention in the years to come.

Keywords: ETRF2000, GNSS, dense velocity field, deformation in time

SESSION 3

TECHNIQUES: GNSS, LEVELING, COMBINATION

Conveners: Rolf Dach, Martina Sacher

Multi-GNSS developments for the EPN and for the Swiss networks

E. Brockmann, D. Ineichen, S. Lutz, S. Schaer

Swiss Federal Office of Topography, Seftigenstr. 264, 3084 Wabern, Switzerland
elmar.brockmann@swisstopo.ch

ABSTRACT

Today, many GNSS Permanent networks are enhanced from GPS or GPS/Glonass networks to Multi-GNSS networks supporting also the signals of the European Galileo and the Chinese BeiDou satellite system. The additional signals are beneficial to many applications. This paper focus on the impact on precise geodetic applications, such as precise coordinate determination based and daily solutions and also improvements on kinematic precise PPP solutions. Here, results from the complete processing chain are shown – from data collection to analysis.

Swisstopo, the Swiss Mapping agency enhanced its permanent network to Multi-GNSS beginning 2015. A complete MULTI-GNSS data flow based on RINEX3 is established parallel to the RINEX2 data flow mid-2015. Parallel to these developments also the field equipment was replaced after conducting a technical evaluation. All 200 reference stations were measured in 2016 by static Multi-GNSS observations of about 48 hours.

For the EPN, similar developments took place. These activities are coordinated by the Multi-GNSS working group and strong support by the EPN central bureau. Currently, about half of all EPN stations support RINEX3 files (and long file names) and in cooperation with the manufacturers many firmware bugs could be fixed.

On the analysis side the scientific Bernese Software was updated enabling multi-GNSS capability and making use of the IGS MGEX products (especially the CODE-derived Multi-GNSS orbits). These developments were used to analyse the Multi-GNSS data from the field campaigns as well as to analyse the permanent networks. As first analysis centre in Europe the contribution of daily and weekly solutions to the European Permanent Network (EPN) of EUREF was switched to Multi-GNSS mid-2016.

Intersystem parameters are an important indicator of the compatibility of the coordinates and troposphere parameters between the various satellite systems. Examples will show the order of magnitude these parameters can reach and will demonstrate its impact on the final results.

Keywords: Multi-GNSS, EPN, RINEX3, BSW, intersystem parameters

Interoperability of the GNSS's for positioning and timing

A. Caporali and L. Nicolini

University of Padova, Center for Space Activities CISAS "G. Colombo", Via Venezia 15/17
35131 Padova, Italy
Corresponding author: alessandro.caporali@unipd.it

ABSTRACT

Since 2014.0 we monitor 31 European multiGNSS sites with 5 different receivers (Javad, Leica, Septentrio, Topcon, Trimble), and various combinations of antennas and firmware. We work both in Single Point Positioning (SPP) mode (ionofree combination of pseudoranges, broadcast ephemeris), as a real time user would, and in Precise Point Positioning (PPP) mode (ionofree combination of carrier phases, SP3 precise ephemeris), as a post processing user would, using our

MATLAB based, multiGNSS software. We simultaneously process pseudorange and/or phase data from GPS, Glonass, Galileo, Beidou, QZSS, NAVIC (formerly IRNSS) and SBAS/GAGAN in different combinations, depending on availability and receiver tracking capability. We estimate at each epoch by least squares three coordinates, one Tropospheric Zenith Delay and nGNSS sums of the receiver time offset and the offset of the time scale of each GNSS relative to a common, interGNSS time scale, where nGNSS is the number of tracked GNSS constellations. Differentiation of such offsets relative to the GPS data yields epochwise for each receiver estimates of the time offset GNSS to GPS. Comparing across different receivers we find that such offsets can be biased relative to each other by as much as several tens of nanoseconds. We arbitrarily select the average of six Septentrio receivers as reference, and estimate the receiver biases relative to the average Septentrio. We find that for a given receiver brand, the bias relative to Septentrio for the various GNSS is very repeatable, with a few exceptions. We show that updating the firmware version does affect the GNSS dependent receiver bias. We finalize our work with a table of 'mean' calibrations, for each GNSS, of comparable receivers, whenever their bias to Septentrio is within one standard deviation, and a subtable of 'individual' calibrations for those receivers which fall out of the mean by more than one standard deviation.

Keywords: interoperability of GNSS, multiGNSS, precision positioning and navigation; time scales and synchronization

Data quality: from tracking to archiving with no gaps

F. Clemente, S. Dean, J. M. Sleewaegen, W. De Wilde

Septentrio NV, Leuven, Belgium
Francesca.clemente@septentrio.com

ABSTRACT

GNSS products for scientific, educational, and commercial applications rely on the quality and integrity of GNSS observational data such as satellite clock and orbit corrections, time series and velocities. By virtue of their low power, the quality of GNSS signals can be seriously compromised by interference be it intentional or unintentional. The intermittent nature of most jamming events makes them difficult to detect and even more difficult to diagnose, requiring specialist hardware and personnel. Reported cases of GNSS interference have increased rapidly over the last few years, a trend that shows no sign of abating.

Another crucial aspect to data quality is integrity. Automatic transfer of data from a receiver to a remote server can result either in lost data or, if data is detected as missing, the unnecessary retransmission of complete files. When data is transmitted over Iridium satellite links for example, this can be time consuming and expensive.

In this paper, we present innovative approaches to mitigating the effects of both GNSS interference and data gaps in transferred files. Real-life cases of interference are detailed along with their impact on data quality. We present how RF interference can be monitored and identified in the context of a GNSS receiver and describe Septentrio's on-board methods for suppression. In addition, an innovative method for preserving data integrity is presented that compares data on the receiver with that on the server then retransmits only the missing data.

Keywords: Interference, data archiving, GNSS, notch, chirp jamming, data products

A new GNSS station metadata management and dissemination system in support of multiple networks

A. Fabian, C. Bruyninx, J. Legrand

Royal Observatory of Belgium, Av. Circulaire 3, B-1180 Brussels, Belgium
A.Fabian@oma.be, epncb@oma.be

ABSTRACT

In July 2009, the EPN Central Bureau released its GUI for on-line validation and submission of GNSS site log files. Since that time, the EPN network has grown considerably in number of stations and complexity. In addition, with the upcoming European Plate Observing System (EPOS), there is now a need for a single European facility that has the capability to manage, validate, and submit the site logs of 3000+ of GNSS stations. Independently of the network (EPN, EPN densification, or EPOS), this facility should respond to one of the primary needs of the station managers: upload their station metadata just once and then these metadata are updated automatically within all metadata systems of the networks to which the station contributes. All this requires the usage of systems that facility machine-to-machine (M2M) exchange. Also recognizing this need, the International GNSS Service is currently developing, a new machine-to-machine exchange format (known as GeodesyML) for site logs.

In order to respond to all these needs, the Royal Observatory of Belgium is developing a completely new on-line GNSS station metadata management and dissemination system. In this presentation, we will explain the philosophy of the system and show the first demo version. For example, it will show how GNSS data providers can register and fill in on-line all information about their agency and then list the stations for which they wish to provide metadata. For each of the stations, the data provider can indicate to which networks it contributes (or is proposed to contribute) and what data it proposes to disseminate at which data centers.

To illustrate further usage of our new web application, we will demonstrate also in this presentation, a new functionality based on a Web service. This is useful for any third party application wishing to synchronize and download the collection of the metadata.

In addition to the submission of site logs, the system will in the future also allow to upload site pictures and individual antenna calibration files.

For the EPN, the transition from the present on-line site log validation and submission tool will be done gradually, one Operational Center (or data provider) at a time. It will start in the late summer of 2017. At the same time, also EPOS data providers will start using this new system.

Keywords: EPN, EPOS, site log, metadata

Establishment of Karadeniz Technical University Permanent GNSS Station As Reactivated of TRAB IGS Station

Zengin Kazancı S. and Tanır Kayıkçı E.

Karadeniz Technical University, Department of Geomatics Engineering, Trabzon, TURKEY
szengin@ktu.edu.tr

ABSTRACT

In recent years, Global Navigation Satellite Systems (GNSS) has gained great importance in terms of the benefits it provides such as precise geodetic point positioning, determining crustal deformations, navigation, vehicle monitoring systems and meteorological applications etc. As in Turkey, for this purpose, each country has set up its own GNSS station networks like **TNPGN-Active** named *Turkish National Permanent RTK Network* analyzed precise station coordinates and velocities together with the *International GNSS Service* (**IGS**), *Turkish National Fundamental GPS Network* (**TUTGA**) and *Turkish National Permanent GNSS Network* (**TNPGN**). TNPGN stations not only are utilized as precise positioning but also GNSS meteorology studies so total number of stations are increased. Permanent GNSS stations at Yildiz Technical University in Istanbul (YLDZ) and Afyon Kocatepe University in Afyon (AFKU) were added to TNPGN.

This work is related to the reactivated of the TRAB **IGS** station was established in Karadeniz Technical University, Department of Geomatics Engineering. Within the COST ES1206 Action (GNSS4SWEC) KTU analysis centre was established and Trop-NET system developed by Geodetic Observatory Pecny (GOP, RIGTC) in order to troposphere monitoring. The project titled „Using an Regional GNSS Networks to Strengthen Severe Weather Prediction" was accepted to the scientific and technological research council of Turkey (TUBITAK). With this project, we will design 2 new constructed GNSS reference station network. Using observation data of network, we will compare water vapor distribution derived by GNSS Meteorology and GNSS Tomography. At this time, KTU AC was accepted as E-GVAP Analysis Centre in December 2016. KTU reference station is aimed to be a member of the EUREF network with these studies.

Keywords: GNSS station, TRAB, IGS, EUREF

Role of Modernized GLONASS System in GNSS Positioning Improvement

Noureddine Kheloufi

Department of Space Geodesy, Centre des Techniques Spatiales CTS
BP 13 Rue de Palestine Arzew 31200, Oran – Algeria

ABSTRACT

The topic developed in this paper consists to perform a comparative study between two spatial positioning systems where geodetic networks survey using GNSS receivers are expressed. The modernized GPS and GLONASS restored and made available, with their associated datum, have become essential to express the coordinates of any point on Earth in a spatial and global repository. The need to have both points observation tools and to express their coordinates make that the two satellite constellations work together and are operational in most hybrid receivers.

In our work, the use of Trimble GNSS hybrid receivers has enabled us to make a comparative advanced detailed study between the Geodetic frames WGS84 of GPS and PZ90.11 of GLONASS based on the variation of observed parameters such as elevation mask, the carrier frequencies, cadence, duration of observation and type of ambiguity, ephemeris (Precise and broadcast) PDOP values and the use of one or both of the two constellations in the process of baselines and observed network adjustment.

This work therefore enabled us to reach important results concerning the reliability and especially the need to include the GLONASS constellation in the planning and processing of GNSS observations data.

Keywords: GPS, GLONASS, DOP, GNSS.

Multipath Detection with Three-frequency SNR Combination – Example from Urban Environment

P. Špánik, J. Hefty, Ľ. Gerhátová, J. Papčo

Slovak University of Technology, Faculty of Civil Engineering, Department of Theoretical Geodesy, Radlinského 11, Bratislava, Slovakia, email: peter.spanik@stuba.sk, jan.hefty@stuba.sk, lubomira.gerhatova@stuba.sk, juraj.papco@stuba.sk

ABSTRACT

Multipath is one of the most severe station-dependent error sources in both static and kinematic positioning. Relatively new and simple detection technique using the Signal-to-Noise (SNR) measurements on three frequencies will be presented based on idea of Strode and Groves. Exploitation of SNR measurements is beneficial especially for their unambiguous character. Method is based on the fact that SNR values are closely linked with estimation of pseudo-ranges and phase measurements during signal correlation processing. Due to this connection, combination of SNR values can be used to detect anomalous behavior in received signal, however some kind of calibration in low multipath environment has to be done previously. In case of multipath, phase measurements on different frequencies will not be affected in the same manner. Specular multipath, e.g. from building wall introduces additional path delay which is interpreted differently on each of the used carrier, due to different wavelengths. Experiment results of multipath detection in urban environment will be presented along with statistical analysis of kinematic positioning. Method is designed to work with three different frequencies in each epoch, thus only utilization of GPS block II-F and Galileo satellites is suitable for the experiment.

Keywords: multipath, detection, SNR, three-frequencies combination, GNSS positioning

SESSION 4

APPLICATIONS: EARTH SCIENCES, GEO-INFORMATION

Conveners: Alessandro Caporali, Rosa Pacione

Evaluation of the atmospheric water vapor content in the regional climate model ALARO-0 using GNSS observations from EPN Repro2

J. Berckmans[1], R. Van Malderen[1], E. Pottiaux[2], R. Pacione[3]

1. Royal Meteorological Institute, Brussels, Belgium
2. Royal Observatory of Belgium, Brussels, Belgium
3. e-GEOS S.p.A, ASI/CGS, Rome, Italy
julie.berckmans@meteo.be

ABSTRACT

The use of ground-based observations is suitable for the assessment of atmospheric water vapor in climate models. Global Navigation Satellite Systems (GNSS) provide information on the integrated water vapor (IWV), on a high temporal and spatial resolution. We used IWV observations at 100 European sites to evaluate the regional climate model ALARO coupled to the land surface model SURFEX, driven by the European Centre for Medium-Range Weather Forecasts (ECMWF) Interim Re-Analysis (ERA-Interim) data. The selected stations provide data for a minimum of 10 years, resulting from the second reprocessing campaign of EPN (EPN Repro2).

The yearly cycle of the IWV for the 18-year period from 1996 to 2014 reveals that the model simulates well the seasonal variation. Although the model overestimates IWV during winter and spring, it is consistent with the driving field of ERA-Interim. However, the results for summer demonstrate an underestimation of the modeled IWV and a larger standard deviation, which is not present in ERA-Interim. The spatial variability among the sites is high, and shows a latitudinal dependence with respect to the standard deviation. Overall, these findings are in agreement with the distribution of the cold and wet bias by the model in winter, and the cold and mixed dry and wet bias in summer.

Keywords: regional climate modeling, water vapor, longterm GNSS observations

EPOS-PL the initiative for European Plate Observation System in Poland, integrated infrastructure and new algorithms

Jarosław Bosy[2], Beata Orlecka-Sikora[5], Dorota Olszewska[5], Beata Górka-Kostrubiec[5], Grzegorz Lizurek[5], Adam Lurka[5], Waldemar Jóźwiak[5], Elżbieta Welker[3], Tomasz Werner[5], Rafał Junosza-Szaniawski[5], Andrzej Araszkiewicz[2], Jan Kapłon[2], Jan Kryński[3], Przemysław Dykowski[3], Wojciech Czuba[5], Tomasz Janik[5], Krzysztof Sośnica[2], Witold Rohm[2], Przemysław Tymków[2], Andrzej Borkowski[2], Tomasz Hadaś[2], Grzegorz Mutke[4], Adam Barański[7], Tomasz Szepieniec[6], Joanna Kocot[6]

1. Faculty of Civil Engineering and Geodesy, Military Univeristy of Technology, Warsaw, Poland
2. Institute of Geodesy and Geoinformatics, Wroclaw University of Environmental and Life Sciences, Wroclaw, Poland
3. Institute of Geodesy and Cartography, Warsaw, Poland
4. Central Mining Institute, Katowice, Poland
5. Institute of Geophysics Polish Academy of Sciences, Warsaw, Poland
6. Academic Computer Centre Cyfronet AGH University of Science and Technology, Krakow, Poland
7. Polish Mining Group partnership, Katowice, Poland

ABSTRACT

In the frame of the first call under Action 4.2: Development of modern research infrastructure of the science sector in the Smart Growth Operational Programme 2014–2020 in the late of 2016 the "EPOS – European Plate Observing System" (EPOS-PL) project has launched. Following institutes are responsible for the implementation of this project: Institute of Geophysics, Polish Academy of Sciences – Project Leader, Academic Computer Centre Cyfronet AGH University of Science and Technology, Central Mining Institute, Institute of Geodesy and Cartography, Wrocław University of Environmental and Life Sciences, Military University of Technology. In addition, resources constituting entrepreneur's own contribution will come from the Polish Mining Group.

Research Infrastructure EPOS-PL will integrate both existing and newly built National Research Infrastructures (Theme Centre for Research Infrastructures), which, under the premise of the European programme for the development of Research Infrastructure (RI) for Solid Earth Sciences – EPOS, are financed exclusively by the national founds. Following work packages (tasks) are going to be run together by geodesists, geophysicists and mining engineers.

The Centre for Research Infrastructure of Induced Seismicity (CIBIS – Task 2) will modernize and develop the existing infrastructure for collecting seismic data as well as their repository.

The Centre for Research Infrastructure of Geomagnetic and Magnetotelluric Data (CIBOGM – Task 3) will modernize and develop the existing infrastructure for the measurements of geomagnetic field and build up their repository and processing centre.

The Centre for Research Infrastructure of Analytic Laboratories (CIBOG – Task 4) will develop its existing computer infrastructure and build up the interface for feeding the database with archival and incoming data.

The Centre for Research Infrastructure of GNSS Data (CIBDG – Task 5) will construct the National GNNS Repository with data QC procedures and adaptat two Regional GNNS Analysis Centres for rapid and long-term geodynamical monitoring.

The main task of the Centre for Research Infrastructure of Gravimetric Observations (CIBOG – Task 6) is to build up the Central Repository of Gravity Data which will be modern database of absolute and relative gravity data, tidal gravimeter records, gravity products from GRACE and GOCE gravity missions.

The Centre for Research Infrastructure for Seismic Research of Lithosphere (CIBSBL – Task 7) will develop its existing infrastructure, transfer existing analogue data to digital format and build up the corresponding interface.

The integration of GGOS-PL infrastructure with developed infrastructure (Task 8) will provide accurate, easy accessible and reliable reference frame by integration of geometric and gravimetric observations. The build infrastructure comprise of: multiGNSS stations, microwave radiometers, gravimeters.

The Multidisciplinary Upper Silesian Episodes (MUSE) in Task 9 will deliver observations from specialised integrated networks combining underground seismic stations and surface observations (GNSS, LiDAR, SAR, levelling, gravimetry, translational and rotational seismic ground motion) both geometric and geophysical in the active mining and post mining areas.

The integrated platform (IS-EPOS platform) for visualising, analysing and dissemination of data and results from Task 2-9 (Task 10) will be developed in this task. Particularly, the 3D GIS will be implemented to allow more advanced spatial analysis on the subsurface and surface data.

Project outcomes will contribute to the Thematic Core Services of Anthropogenic Hazards as well as GNSS Data and Products and Satellite Data.

EUREF's Contribution to the European Plate Observing System

C. Bruyninx[1], J. Dousa[2], R. Fernandes[3], A. Kenyeres[4], J. Legrand[1], M. Lidberg[5], T. Liwosz[6], W. Söhne[7]

1. Royal Observatory of Belgium, Av. Circulaire 3, B-1180 Brussels, Belgium
2. Geodetic Observatory Pecný, Czech Republic
3. Universidade da Beira Interior, Portugal
4. Government Office of Capital City Budapest, Hungary
5. Lantmäteriet, Sweden
6. Warsaw University of Technology, Poland
7. Bundesamt für Kartographie und Geodäsie, Germany
C.Bruyninx@oma.be

ABSTRACT

The "European Plate Observing System" (EPOS, https://www.epos-ip.org/) integrates European Research Infrastructures (RI) for solid Earth science to monitor and understand the dynamic and complex solid-Earth System. EPOS brings together Earth scientists, national research infrastructures, ICT (Information & Communication Technology) experts, decision makers, and the public. EPOS provides its user community access to various kinds of data using one common integrated portal. EPOS started in 2010 with the so-called Preparatory Phase (EPOS-PP), followed by the Implementation Phase (IP), lasting from 2015 to 2019. Already during its implementation phase, from 2018 on, EPOS will gradually move towards operation under the "European Research Infrastructure Consortium" (ERIC), which will be the legal entity representing EPOS once EPOS is fully operational.

As one of ten Thematic Core Services (TCS), the GNSS component of EPOS organises open access to GNSS data, meta-data, and products in support of the Solid Earth Sciences. These efforts are done in close partnership with EUREF, the IAG sub-commission for the European Reference Frame. The EPOS partners are convinced that being part of the EPOS infrastructure will increase the visibility of the European GNSS community organized in EUREF and promote the usage of their Data beyond the "core" geodetic community. For that purpose, EUREF is setting up a dedicated interface to EPOS that allows the GNSS data from stations belonging to the EUREF Permanent Network (EPN) to be discovered by EPOS without any additional effort from their side and in a completely transparent way.

This presentation will outline the EUREF data and products that will become discoverable through EPOS as well as how this will be organised in practice.

Keywords: EPN, EPOS, GNSS

The Contribution of the GNSS EPOS-IP to Manage GNSS Data and Associated Products for Solid Earth at European Scale

R. Fernandes[1], M. Bos[1], C. Bruyninx[2], P. Crocker[1], J. Dousa[3], A. Walpersdorf[4], A. Socquet[4], A. Avallone[5], A. Ganas[6], C. Ionescu[7], A. Kenyeres[8], B. Ofeigsson[9], H. Ozener[10], M. Vergnolle[11], M. Lidberg[12], T. Liwosz[13], W. Soehne[14], P. Bezdeka[3], R. Cardoso[1], N. Cotte[4], R. Couto[1], N. D'Agostino[5], A. Deprez[4], A. Fabian[2], J. Legrand[2], J.-L. Menut[11], E. Nastase[7], K.-M. Ngo[11], F. Sigurðarson[9], P. Vaclavovic[3]

1. UBI/C4G, Covilhã, Portugal
2. ROB, Brussels, Belgium
3. GOP, Pecny, Czech Republic
4. CNRS-UGA, Grenoble, France
5. INGV, Rome, Italy
6. NOA, Athens, Greece
7. INCDFP RA, Bucharest, Romania
8. BFKH, Budapest, Hungary
9. IMO, Reykjavik, Iceland
10. KOERI, Istanbul, Turkey
11. CNRS-OCA, Nice, France
12. LM, Gävle, Sweden
13. WUT, Warsaw, Poland
14. BKG, Frankfurt-am-Main, Germany
wp10@epos-ip.eu

ABSTRACT

EPOS-IP WP10 – "GNSS Data & Products" is the thematic working package of the European Plate Observing System– Implementation Phase project that is in charge of establishing services that permit to access National and Pan-European GNSS Infrastructures to support Solid Earth research.

WP10 is currently formed by representatives of participating European institutions but in the operational phase contributions will be solicited from the entire geodetic community. In fact, WP10 also includes members from other institutions/countries that formally are not participating in the EPOS-IP but will be key players in the future services to be provided by EPOS. Additionally, several partners are also key partners at EUREF, which is also actively collaborating with EPOS.

The geodetic component of EPOS is dealing essentially with implementing an e-infrastructure to store and disseminate the continuous GNSS data and derived products (positions, velocities and strain rates). Present efforts are on developing geodetic tools to support Solid Earth research by optimizing the existing resources and also create some new services. However, other research and technical applications (e.g., reference frames, meteorology, space weather) can also benefit in the future from the optimization of the geodetic resources in Europe.

We present and discuss the status of the implementation of the thematic and core services (TCS) for GNSS data within EPOS and the related business plan. We explain the tools and web-services being developed towards the implementation of the best solutions that will permit to the

end-users, and in particular geo-scientists, to access the geodetic data, derived solutions, and associated metadata using transparent and standardized processes.

Keywords: EPOS, Research Infra-structures, Solid Earth

InSAR Based Ground Motion Service for Germany

M. Frei, A. Kalia, T. Lege

Federal Institute for Geosciences and Natural Resources – BGR, Hannover, Stilleweg 2, Germany
Michaela.Frei@bgr.de

ABSTRACT

Area-wide detection of land subsidence is an important information for well in-timed hazard mitigation and comprehensive geoscientific understanding of natural and anthropogenic impacts on land surface deformation. Using conventional measurement techniques (GNSS-, leveling campaigns) remains a challenge due to limitations in spatial coverage and temporal resolution. Advanced multitemporal spaceborne remote sensing techniques, e.g. SAR Interferometry (InSAR), allow for the detection of surface deformation with large spatial coverage and high temporal resolution. Radar data on a free an open data policy together with long-term mission strategy became for the first time available through the Copernicus program. The technological progress together with long-term data availability, causes an increasing interest within responsible authorities, e.g. from the field of geohazard mitigation, mining supervision, and infrastructure planning.

The intention of this presentation is to show the information content of InSAR and the information values with respect to an optimized hazard mitigation approach. Though the beneficial use of InSAR methods in tectonics, earthquake analysis and other geologic and geophysical branches is widespread in the scientific community it is still almost nonexistent in the day-to-day business of federal, state and municipal work and planning. An operational ground motion service, based on advanced InSAR (e.g. persistent scatterer interferometry, small baseline subset) methods, does not yet exist in Germany and thus the unique information content is not fully exploited by potential end-users. Therefore and due to considerably expressed demand from user panels the German government entrusted BGR (Federal Institute for Geosciences and Natural Resources) to keenly foster the integration of national space data together with scientific developments from the InSAR-community in every-day work of German administrative bodies.

Thus, a national ground motion database for Germany based on Copernicus Sentinel 1 data calibrated and validated with geodetic reference and geological evidence under the auspices of BGR is under construction. Within the context of this service pilot studies are performed. Two pilot studies are presented here in order to demonstrate application specific InSAR data and their related value-added products.

To mitigate impacts for the living environment and infrastructure protection anthropogenic and natural influences triggering land surface deformations need to be understood, detected and monitored. Throughout Europe, different national activities in the context of ground motion products/services based on SAR data exist already. Following these activities, the idea of a supra-national ground motion service is discussed recently on different platforms. The presentation illuminates the initiative Copernicus Sentinel based Supra National Ground Motion Service with regard to the infrastructures GREF and EPN (European permanent network).

Keywords: Ground Motion Service Germany, Copernicus-Sentinel, Persistent Scatterer Interferometry, Geodesy

Accuracy estimation of regional TEC maps by cross-validation and maximum likelihood

W. Jarmołowski, A. Krypiak-Gregorczyk, P. Wielgosz

University of Warmia and Mazury in Olsztyn, Oczapowskiego 2, 10-719 Olsztyn, Poland
wojciech.jarmolowski@uwm.edu.pl

ABSTRACT

High accuracy TEC maps describing the spatiotemporal variability of the ionosphere have to be based on high accuracy observations and well parametrized least-squares technique of modeling. The input data of these models is based on dual frequency carrier phase multi-GNSS signals. These satellite signals after calibrating carrier phase bias provide accurate TEC measurements in the ionosphere piercing points. The TEC modeling applies covariance matrices of the signal and noise that represent an actual state of the ionosphere, which varies dynamically in space and time affecting these matrices. The parameters of the matrices can be efficiently estimated in seconds using numerically effective application of maximum likelihood method and then validated by the cross-validation. These two methods are complementary and validate one another, in order to have maximum certainty about the parametrization results. This gives an advantage in optimum accuracy estimates of the models and their usefulness in the further applications. The objective of the parametrization, besides the optimum accuracy of the models, is the validation of a fast, derivative-based maximum likelihood calculation technique, by considering its coincidence with cross-validation and the speed of calculation. In addition, the final TEC maps are validated against differential slant TEC derived directly from carrier phase data.

Keywords: ionosphere, TEC, leave-one-out, maximum likelihood, least squares collocation

Precise astronomical positioning using motorized total station

R. Machotka, R. Kratochvíl, M. Kuruc

Brno University of Technology, Department of Geodesy, Brno, Czech Republic
machotka.r@fce.vutbr.cz

ABSTRACT

Field observations for astronomical vertical deflection determination is a specific part of geodetic astronomy and as such it needs special instrumentation. Mobile Automatic Astronomical System No 1. (MAAS-1) was developed on Brno University of Technology. It is based on motorized total station Topcon GPT 9001A supplemented by external CCD camera and portable computer. MAAS-1 measuring system is designed for fast and precise determination of astronomical coordinates intended for vertical deflections computation.

The process of measurement is fully automated which makes possible to eliminate personal influences on results, thus eliminating so called “personal errors”.

MAAS-1 was thoroughly tested with highly satisfactory results. The system was found to be reliable, user friendly and without significant faults. It’s results were compared with results of several other precise astrogeodetic instruments (notably Cirkumzenital VUGTK 100/1000 and digital zenith camera TZK2-D). External accuracy of results – vertical deflections components – was found to be in range 0.2–0.3 arc seconds for standard one hour field observation.

MAAS-1 was employed in several experimental projects. Till now, more than 100 astrogeodetic vertical deflections has been determined.

Keywords: geodetic astronomy, astronomical positioning, vertical deflections, total station

Densification of the GGOS infrastructure in Poland in the framework of EPOS-PL

K. Sośnica[1], J. Bosy[1], J. Kapłon[1], W. Rohm[1], T. Hadaś[1], J. Sierny[1], I. Kudłacik[1], R. Zajdel[1], J. Kryński[2], P. Dykowski[2], A. Araszkiewicz[3], G. Mutke[4], A. Kotyrba[4], D. Olszewska[5]

1. Wroclaw University of Environmental and Life Sciences
Institute of Geodesy and Geoinformatics, Grunwaldzka 53, 50-357 Wrocław, Poland
2. Institute of Geodesy and Cartography, Modzelewskiego 27, 02-679 Warszawa, Poland
3. Military University of Technology in Warsaw, Kaliskiego 2, 01-476 Warszawa, Poland
4. Central Mining Institute, plac Gwarków 1, 40-166 Katowice Poland
5. Institute of Geophysics Polish Academy of Sciences, Księcia Janusza 64, 01-452 Warszawa, Poland
krzysztof.sosnica@igig.up.wroc.pl

ABSTRACT

The project European Plate Observing System for Poland (EPOS-PL) was launched in January 2017 with a main objective of observing surface land deformations and seismicity affecting inhabitants, environment, infrastructure and buildings in the region of Upper Silesia, south Poland, where intensive activities related to coal exploitation take place or have recently been terminated. EPOS-PL engages scientists and industrial experts from many fields: geophysics, seismology, geodesy, mining, geology, geomagnetism, and gravimetry with a common goal of providing comprehensive and complementary information on the measured results and reasons of surface land deformations.

In order to fulfil the primary goals of the EPOS-PL project, a proper reference frame is indispensable. Therefore, the infrastructure of Global Geodetic Observing System in Poland will be extended, which includes new multi-GNSS receivers, radiometers, gravimeters, seismometers, and ground retroreflectors for synthetic aperture radar (SAR) observations. In total, 8 new GNSS

receivers will be installed; 4 of them as reference receivers installed in stable areas and another 4 receivers in the area, where surface displacements are expected. The receivers will have a full multi-GNSS capability by tracking six GNSS and RNSS systems: GPS, Galileo, GLONASS, BeiDou, SBAS, and QZSS with the possibility of 10Hz data recording. The high-rate GNSS data will be then compared with seismometry data for the integrated near real-time seismic wave detection. Two GNSS receivers will be supported by radiometers supporting the GNSS troposphere modeling. One reference GNSS receiver will additionally be supported with an external active hydrogen maser for future experiments with the clock parameter stability in multi-GNSS real-time Precise Point Positioning solutions. Finally, three new tidal gravimeters will serve as a basis for the integration between the observations of surface displacements, provided by GNSS and SAR, and the observations of inner mass redistributions and consequences of induced seismicity, provided by gravimeters and seismometers.

Keywords: multi-GNSS, reference network densification, European Plate Observing System

Crustal deformation implied by permanent GNSS sites in the area of the 2016 Central Italy earthquakes

J. Zurutuza[1], A. Caporali[1], M. Bertocco[2]

1. University of Padova (Department of Geosciences). Via G. Gradenigo n.6 - 35131- Padova (Italy)
2. Centro di Ateneo di Studi e Attività Spaziali „Giuseppe Colombo" – CISAS, Padova, Italy.
jzurutuza@gmail.com

ABSTRACT

The network of 600+ permanent GNSS sites processed daily at the University of Padova includes 22 sites within 100 km of the epicenter of the August 24, 2016 and October 30, 2016 Mw +6 events. The station AMAT (Amatrice) is located less than 10 km from the epicenter of the first event. To best detect 3D displacements in the epicentral area we used ADDNQ2 of Bernese Software 5.2 (Dach et al., 2015) and IGS/EUREF processing guidelines (Bruyninx et al., 2013) to stack daily normal equations of the national network, and extracted time series of sites nearest to the epicenter, after a Helmert transformation of the daily solution on the cumulative solution. Prior to the events we observe in the coordinate time series no particular systematic or sudden motion, within the measurement uncertainty (< 0.5 mm 1 sigma formal error). Likewise the postseismic time series at this time do not show any systematic trend which could lead to make hypotheses about postseismic relaxation. The pattern of observed coseismic coordinate offsets is in full agreement with the prediction based on the fault plane solution of an extensive deformation and on the Okada dislocation model in an elastic half space. The geodetic data are most sensitive to the location of the epicenter, which enables to discriminate among the several localizations proposed based on purely seismologic data.

Keywords: coseismic, permanent station, time series, earthquake

SESSION 5

NATIONAL REPORTS

Conveners: Jan Krynski, Guenter Stangl

National Report of the Netherlands

B. A. Alberts[1], L. Huisman[2], J. Lesparre[2]

1.Rijkswaterstaat, Delft, The Netherlands
2. Kadaster, Apeldoorn, The Netherlands
bas.alberts@rws.nl

ABSTRACT

An overview of EUREF related activities in the Netherlands during the last year will be presented.

Keywords: national report

National Report of Switzerland

E. Brockmann

Swiss Federal Office of Topography, Seftigenstr. 264, 3084 Wabern, Switzerland
elmar.brockmann@swisstopo.ch

ABSTRACT

The short presentation highlights the main developments in Geodesy at the Swiss Federal Office of Topography.

Keywords: National Report Switzerland

National report of Slovakia 2017

Branislav Droscak[1], Karol Smolik[1] Ivan Horvath[1] et al.[2]

1. Geodetic and Cartographic Institute Bratislava, Chlumeckeho 4, 827 45 Bratislava, Slovakia
2. Slovak University of Technology in Bratislava, Faculty of Civil Engineering, Department of Theoretical Geodesy, Radlinskeho 11, Bratislava, Slovakia
branislav.droscak@skgeodesy.sk

ABSTRACT

The national report of Slovakia contains the new information about activities from the geodesy, cartography and surveying field from Slovakia, especially information and news from geodetic controls, GNSS, levelling, gravimetry and metrology. The national report of Slovakia presents the new information from the research and development from geodesy and cartography field as well.

Keywords: Slovakia, SKPOS, national report

National Report of Greece to EUREF 2017

M. Gianniou, E. Mitropoulou, D. Mastoris

National Cadastre and Mapping Agency S.A., 288 Mesogion Ave., 15562 Athens, Greece
mgianniu@ktimatologio.gr

ABSTRACT

During the last months the main activities of the National Cadastre and Mapping Agency of Greece (NCMA SA) related to EUREF focused on geological phenomena that caused static and dynamic displacements. The most representative cases are presented in this national report:

- Assessment of crustal deformations associated with the 2011–2012 unrest of the Santorini volcano, Aegean Sea, Greece.
- Study of impact of the 2014 North Aegean Sea earthquake on HEPOS (Hellenic Positioning System) reference stations.

Keywords: HEPOS, crustal deformations, Santorini volcano unrest, 2014 North Aegean Sea earthquake

National Report of Great Britain 2017

M. Greaves

Ordnance Survey, Adanac Drive, Southampton, United Kingdom, SO16 0AS

ABSTRACT

National report into activities in Great Britain of interest to the EUREF community. Activities of the national mapping agency, Ordnance Survey, will be covered along with a summary of the activities of various GB academic institutions.

Keywords: 2017 EUREF, national report, Great Britain

National Report of Finland

P. Häkli, M. Poutanen, S. Lahtinen, H. Koivula, M. Bilker-Koivula, J. Jokela, J. Virtanen, and J. Näränen

Finnish Geospatial Research Institute, FGI
Geodeetinrinne 2, FI-02430 Masala, Finland
pasi.hakli@nls.fi

ABSTRACT

Finnish permanent GNSS station network, FinnRef, is the basis of the national reference frames. It was renewed in 2012–13 with 20 new stations, of which 11 are dual stations with the old FinnRef stations. The old FinnRef network consisted of 13 stations, of which nine stations were shut down in November 2016, only the EPN stations being continued. The old stations had the same type of receivers from the beginning (1996), Ashtech Z-12, that suffered of a week roll-over bug at

GPS week 1922. Even if the bug can be sidestepped, we decided to discontinue the use of Ashtech receivers due to major difficulties in maintenance of the receivers (support being discontinued a long time ago), some perpetual difficulties in data streams and due to the fact that we had already 2.5 years of common data at the dual stations to make the connection between the old and new station, the typical inter-station distance being only some meters. At the four remaining EPN stations Ashtech receivers were replaced with modern Javad receivers, the antennas still being untouched. All 20 new stations were proposed to the EPN network and currently 11 of them have been accepted as a part of the EPN, rest being in the proposed list. Two stations have been accepted to IGS network as well.

After renewal FinnRef is offering positioning services as well. There is an ongoing project to densify this network to meet the National Land Survey's own requirements in positioning. There is also an ongoing project to define official coordinates for the new FinnRef stations, being the highest order and defining stations, in the national ETRS89-based reference frame, EUREF-FIN. Key issues in coordinate computation are handling of the Fennoscandian post-glacial rebound, different alternatives for dual stations (network solution, short GNSS baseline and terrestrial measurements) and different antenna models used for different coordinate sets.

In 2016 about 40 new GNSS/leveling points were measured and about the same amount will be measured in 2017. These are mainly first order leveling points and together with the FinnRef stations will provide new data set for geoid verification and height reference surface calculation.

Metsähovi research station is under renewal: a new observatory building for the satellite laser ranging (SLR) has been built and a new telescope has been installed. Some final installations are still ongoing. As a part of the Metsähovi renewal, also a new VLBI system will be built. VGOS telescope procurement contract was signed in November 2016 and it will be installed in Metsähovi in the summer 2018. Infrastructure at Metsähovi will be upgraded for VGOS in 2017/2018 and the system is expected to be in routine operation in 2019.

A new geodesy strategy for Finland was prepared for the period 2017–2026. The main goals of the National Land Survey are that by 2026:

- we are ready for implementation of a semi-dynamic reference frame in all georeferencing and has studied possibilities to change to a dynamic reference frame,
- we have studied requirements for active reference frame definitions,
- Metsähovi geodetic research station is one of the international core stations as a part of the UN resolution and produces high-class research,
- new land uplift and geoid models provide accurate information for transformations required in semi-dynamic and dynamic reference frames and height systems,
- we have procedures to maintain national height systems and
- metrologically reliable and accurate terrestrial and vertical reference frames and gravity systems provide easily accessible spatial information to all applications.

Keywords: Finland, FinnRef, EUREF-FIN, Metsähovi research station

National Report of Sweden – geodetic activities at Lantmäteriet

Christina Kempe, Lotti Jivall, Dan Norin, Mikael Lilje, Martin Lidberg, Peter Wiklund, Jonas Ågren, Andreas Engfeldt, Holger Steffen

Lantmäteriet, SE-801 82 Gävle, Sweden
christina.kempe@lm.se

National Report of Poland to EUREF 2017

J. Krynski[1], J. B. Rogowski[2]

1. Institute of Geodesy and Cartography, 27 Modzelewskiego St., 02-679 Warsaw, Poland
2. Maritime University, 81–87 Morska St., 81-225 Gdynia, Poland
corresponding.author. krynski@igik.edu.pl

ABSTRACT

National Report of Poland to EUREF 2017 presents the main geodetic activities since 2015 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, validation of GNSS orbits using SLR, activity within the EUREF-IP Project, works on GNSS for meteorology, monitoring ionosphere and ionospheric storms, advanced methods for satellite positioning, maintaining the ASG-EUPOS network in Poland, modelling precise geoid, the use of data from satellite gravity missions, monitoring gravity changes, geodynamics, activity in satellite laser ranging and their use.

Keywords: control network, GNSS, gravity field modelling, geodynamics, Local Analysis Centres

National Report Austria

P. Mitterschiffthaler, G. Stangl, D. Ruess, E. Zahn, C. Ullrich, H. Titz, E. Imrek

Federal Office of Metrology and Surveying, Schiffamtsgasse 1-3, 1020 Vienna, Austria
philipp.mitterschiffthaler@bev.gv.at

ABSTRACT

The national report of Austria 2017 will focus on the investigations in our GNSS permanent network with introducing GALILEO and 3 new stations. As well as on the activities in the field of gravity and levelling up to the highest point (~2500m) in the levelling network. BEV took over all EPN AC and DC services from OLG.

Keywords: Austria, levelling, GNSS, gravity

National Report of Lithuania to EUREF 2017

E. Paršeliūnas[1], D. Šlikas[1], D. Popovas[1], R. Obuchovski[1], A. Būga[1], R. Baniulis[1], K. Galinauskas[1], V. Puškorius[1], J. Špūraitė[2], J. Aldonienė[2]

1. Institute of Geodesy, Vilnius Gediminas Technical University, Sauletekio al. 11, LT-10223 Vilnius, Lithuania, gi@vgtu.lt

2. National Land Service under the Ministry of Agriculture, Gedimino pr. 19, LT-01103 Vilnius, Lithuania, info@nzt.lt

ABSTRACT

LitPOS (Lithuanian Positioning System) is the global position determination system of permanent reference GNSS stations in Lithuania. This network is part of National Geodetic Foundation infrastructure. It allows users to evaluate their position by using RTK, transmitting corrections through communication channels from points of geodetic basis. It uses VRS and Ntrip corrections methods that were explained in previous chapter. LitPOS provides to users a possibility to reach centimeter-level accuracy with single standard rover receiver at any point of Lithuanian territory. LitPOS network consists of 31 station, located evenly in country's territory, and regional management center. The stations are equipted 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.

Coordinate time series were obtained from LitPOS reprocessing data for years 2008 – 2014. The reprocessing was done using Bernese 5.2 software. In this study Matlab program "GITSA" (GPS Interactive Time Series Analysis) and FODITS (Find Outliers and Discontinuities in Time Series) program of Bernese GNSS Software Version 5.2 was used to analyse the coordinates time series of 2008–2014 year period of LitPOS RTK network data.

The modern gravity survey of the territory of Lithuania was started in 2016. The gravity acceleration at gravity survey points is observed by Scintrex CG-5 gravimeter. In total 5 Scintrex CG-5 gravimeters are employed. The analysis of the calibration results of the gravimeters is presented also. Based on the first measurements results the standard deviation of the gravity acceleration at gravity survey points is received about 20 μGal. The standard deviation of calculated Bouguer anomalies is about 23 μGal.

Lithuania is successfully integrated in the European geomagnetic field research activities. Six secular variation research stations were established in 1999 and precise geomagnetic field measurements were performed there in 1999, 2001, 2004, 2007 and 2016. Obtained diurnal magnetic field variations at measuring station and neighbouring observatories were analysed. All measurements are reduced to the mean of the year using data from geomagnetic observatory of Belsk. Based on the measured data the analysis of geomagnetic field parameter secular changes was performed. Results of the presented research are useful for updating the old geomagnetic data as well as for estimation of accuracy of declination model. The most important achievement in 2016 is erection of the special wooden steel-free house for geomagnetic observatory needs in site Aukstadvaris.

Keywords: LitPOS, gravity survey, secular variations of geomagnetic field, geomagnetic observatory

POSTER SESSION

Convener: Krzysztof Sośnica

P01

Implementation of ITRF 2014 frame in EUREF regional GNSS networks

Mariusz Figurski, Grzegorz Nykiel

Gdansk University of Technology, ul. Gabriela Narutowicza 11/12, Gdansk, Poland
grzegorz.nykiel@pg.gda.pl

ABSTRACT

In January 2017 a new redefinition of ITRF (ITRF2014) was introduced. It is characterized by high internal consistency with the previous (ITRF2008). This is evidenced by the lack of global transformation parameters between these redefinitions, IGb08 and IGS14. Our analysis showed that the differences between ITRF2008 and ITRF2014 are minor. Despite the high internal consistency of the ITRF itself, the introduction of new calibrations of satellite and ground antennas phase centers (IGS14) leads to non-negligible differences in coordinates. They cause changes in the scale of the network, which we estimated at around 0.7 ppb. Also translation parameters are changed, especially for the Ty and Tz components, while the network orientation remains unchanged. Scale changes cause changes in baselines length between the stations (in most cases we obtained increased length). We also investigated, that the variable number of fixed stations in the GNSS local networks affects only the translation of the frame, whereas changes of translations parameters are correlated with number of fixed stations.

In our analysis, we used daily GNSS observations from 136 EPN reference stations located throughout Europe. These stations account for about 50% of the currently operating GNSS stations in the EPN. Analyzed time span covered six weeks (from 1928 to 1933 GPS week) when the IGb08 frame was in use and four weeks after the IGS14 was introduced (from 1934 to 1937 GPS week). Presented results were obtained using Bernese 5.2 software and differential GNSS approach.

Keywords: ITRF2014, GNSS, networks, antennas calibrations

P02

Assessing a new velocity field in Greece by combining GNSS campaigns towards the establishment of a new Reference Frame

S. Bitharis[1, 2], N. Papadopoulos[2], C. Pikridas[1], A. Fotiou[1], D. Rossikopoulos[1], V. Kagiadakis[2]

1. Department of Geodesy and Surveying, Aristotle University of Thessaloniki, Greece
2. Geodesy and Surveying Branch, Hellenic Geographical Service, Greece
smpithar@topo.auth.gr

ABSTRACT

The last decades various GNSS campaigns have been accomplished by various scientific organizations and agencies, as by the Hellenic Military Geographical Service (HMGS), the GNSS-QC research team of the Aristotle University of Thessaloniki (AUTh) and the Hellenic National

Cadastre & Mapping Agency (NCMA). These campaigns were carried out in different time periods and the derived results related to positioning, like point coordinates, were expressed in different Local and International Terrestrial Reference Frames (ITRFs).

The current official geodetic datum in Greece is the Greek Geodetic Reference System 1987 (GGRS87), a static datum based mainly on classical geodetic observations of more than thirty years and connected to modern ITRFs with a one to two-meter level accuracy. Since 2009 an auxiliary system adopted by NCMA, called HTRS07 (Hellenic Terrestrial Reference System 2007, epoch 2007.5) and based only on GPS observations, has been used to transform GNSS/GPS coordinates from HTRS07 to GGRS87 by means of grid-based transformation parameters for horizontal control, giving finally TM projection coordinates in GGRS87 with an uncertainty of some cm for a limited area of some km. HTRS07 which is a realization of ETRF05, is also a static geodetic system.

The need for the establishment of a new modern and satellite based geodetic datum becomes more and more obvious as the high geodynamic activity in Greece creates serious inhomogeneous crustal deformations. In this effort, the role of a reliable velocity field is very important. The last years, the GNSS-QC team of AUTh estimates and periodically updates an accurate velocity model for the earth crust in Greece, based on GNSS observations of almost 150 stations, most of them permanent.

The main aim of the present study is the assessment of the periodically updated new velocity model through the unification of four GNSS individual campaigns consisting of a big number of points, more than 3500, to provide a set of coordinates in a common frame. Using predicted velocities, all point coordinates of each campaign are transformed to a common epoch, e.g. 2016.01, at the same (initial) frame. Therefore, a Helmert transformation between different couples of campaign-frames, reflects on the fitting accuracy. This transformation is also applied for the same couples except that the used coordinates are the initial ones, not the transformed to the common epoch. The comparison between the transformation results (fitting measures) of the same couples, i.e. transformation with the velocity model versus with no velocity model, shows the effectiveness of the used model in case the improvement is significant. According to the results, the implementation of the new velocity model improves significantly the fitting between the different campaign frames in the horizontal component. Therefore, this study can provide a feasible method for different datum transformations in a new modern and semi-dynamic datum (ITRF-based), necessary for all geodetic and mapping activities in Greece. Also, the adoption of the AUTh's velocity model as the official model for high accuracy geodetic activities is proper.

Keywords: GNSS campaigns, crustal velocity field, reference frames, datum transformation

P03

Quality assessment of multi-GNSS orbits and clocks for real-time PPP

K. Kaźmierski, K. Sośnica, T. Hadaś

Wrocław University of Environmental and Life Sciences
Institute of Geodesy and Geoinformatics, C. K. Norwida 25, 50-375 Wrocław, Poland
kamil.kazmierski@igig.up.wroc.pl

ABSTRACT

Constantly growing number of satellites of the newly established and still being modernized Global Navigation Satellite Systems (GNSS) allow for improving the accuracy of positioning and for performing GNSS measurements in challenging environment. Multi-GNSS Experiment was

established in order to support currently available systems. Unfortunately, the most accurate products that allow calculations are provided with the latency up to 18 days which unable us to make measurements in real-time. One of techniques which may be used in real-time is Precise Point Positioning (PPP). PPP may take advantage of significant number of available satellites and signals provided by them. PPP needs precise a priori information about satellite positions and clocks that are used directly in the normal equation system. To take full advantage of PPP in real-time, the precise corrections for orbits and clocks should be delivered to the user. Currently available products are provided e.g. by RT-IGS (Real-time IGS) service or by Centre National d'études Spatiales (CNES). CNES delivers products for multi-GNSS constellation while RT-IGS supports only GPS and GLONASS. As opposed to the combined IGS final products, the CNES real-time products are not screened for outliers, therefore they should be appropriately verified in order to encourage potential users to employ real-time clock and orbit corrections.

The presented works check the real-time product availability and evaluate the quality of multi-GNSS real-time orbits and clocks. Orbits were assessed in three ways: by comparing to the post-processed MGEX products, by analyzing orbit discontinuities through fitting continuous arcs, and by validating using the Satellite Laser Ranging (SLR) technique. The clocks were evaluated using the post-processed MGEX products as a reference data and by the analysis of the clock stability using Modified Allan Deviation (MDEV). The conducted works show that the products quality depends not only on a specific GNSS system, but also on the orbital plane, elevation of the Sun above the orbital plane, as well as on the satellite block and generation. The mean availability for the test period was at the level of about 90% for GPS, GLONASS and Galileo, while for BeiDou equaled about 80%. The 3D orbit RMS, when compared to the post-processed MGEX products is 5, 11, 17, 19 and 42 cm for GPS, GLONASS, Galileo, BeiDou MEO and BeiDou IGSO, respectively. The presented works allow for a further study connected e.g. with the appropriate observations weighting for the real-time PPP processing using multi-GNSS data.

Keywords: Multi-GNSS, GPS, GLONASS, Galileo, BeiDou, Real-time processing, PPP

P04

Determination of Galileo, GLONASS, BeiDou and QZSS orbits using SLR observations

Grzegorz Bury, Krzysztof Sośnica

Wroclaw University of Environmental and Life Sciences, Faculty of Environmental Engineering and Geodesy, Institute of Geodesy and Geoinformatics, ul. Grunwaldzka 53, 50-357 Wrocław, Poland, grzegorz.bury@igig.up.wroc.pl

ABSTRACT

The International GNSS Service (IGS) established a Multi-GNSS Experiment (MGEX) due to the emerging of global navigation satellite systems (GNSS) such as European Galileo, Chinese BeiDou, and regional navigation satellite system (RNSS) i.e., Japanese QZSS, and Indian NavIC, The goal of the MGEX is to prepare the IGS to generate operational products for both, new navigation systems, and the modernized GPS and GLONASS constellations. Currently, all new active navigation satellites are equipped with Laser Retroreflector Arrays (LRAs) for range measurements. The International Laser Ranging Service (ILRS) supports space missions by providing special tracking campaigns and the list of satellite priorities to be tracked by the SLR stations. Three special GNSS tracking campaign took place so far resulting in a significant growth

of SLR observations to GNSS satellites. Range measurements to GNSS satellites serve as a validation tool for the microwave orbits as they carry an independent information about the quality of GNSS-derived orbits. However, SLR observations can also be used for the determination of GNSS orbits.

The work covers the results from the multi-GNSS orbit determination using solely SLR data. We consider the whole GLONASS constellation, all active Galileo satellites (apart from four spacecraft launched in November 2016), four BeiDou satellites (1 MEO, 3 IGSO), and the only one QZSS spacecraft. We calculate orbits in the modified version of Bernese GNSS Software 5.2. In order to be consistent with MGEX, we use official MGEX products from the Center for Orbit Determination in Europe (CODE) as a priori orbits and as a reference for the comparison with estimated orbits using SLR data. We chose CODE solution because it was the first analysis center that provided a five-system orbit and clock MGEX solution, including GPS, GLONASS, Galileo, BeiDou, and QZSS. We also use the same solar radiation pressure model as CODE – the new Empirical CODE Orbit Model (ECOM2). The results of orbit determination for GLONASS, Galileo, and BeiDou MEO spacecraft are very promising. The median RMS of a comparison between 7-day orbital arcs determined using SLR data with microwave orbits equal: for GLONASS: 3.4, 11.0, and 15.5 cm in radial, along-track, and cross-track direction, respectively, for Galileo 4.0, 15.6, and 27.3 cm in radial, along-track, and cross-track direction, respectively, and for BeiDou MEO: 4.4, 13.4, and 22.9 cm in radial, along-track, and cross-track direction, respectively. We also investigate a length of an orbital arc in order to both, maximize the number of SLR observations to GNSS satellites, and avoid outdating of the empirical orbit parameters. We test 3-, 5-, 7-, and 9-day arc length solutions for all GNSS spacecraft. For the most intensively tracked satellites 5- and 7-day arcs seem to be the optimal solution. For less intensively tracked satellites, 9-day arcs constitute the best solution. BeiDou IGSO and QZSS are characterized with RMS higher by a factor of 8 and 24, respectively than MEO satellites. The reason of a poor orbit quality is the regional range of IGSO and QZSS, limited number of tracking SLR stations, poor observation geometry and twice longer revolution period as compared to MEO.

It is possible to determine multi-GNSS orbits using solely SLR observations. As a result one can deliver an independent orbit solution that is free of systematic errors typical for GNSS solutions, thus satellite laser ranging to global and regional navigation satellite systems should be performed continuously.

Keywords: multi-GNSS, SLR, Precise Orbit Determination

P05

ROBER: A New Tool for Step-wise Analysis of the Quality of GNSS Network-based Processing

M. Chatzinikos[1], E. Pottiaux[1, 2], C. Bruyninx[1], J. Legrand[1]

1. Royal Observatory of Belgium (ROB), 3 avenue Circulaire, 1180 Brussels, Belgium
2. Solar-Terrestrial Centre of Excellence (STCE), 3 avenue Circulaire, 1180 Brussels, Belgium
Corresponding author: miltiadis.chatzinikos@oma.be

ABSTRACT

Global Navigation Satellite Systems is a reliable technique for many geodetic applications, the estimation of the crustal deformations, the realization or maintenance of a reference frame and the monitoring of the Earth's atmosphere are some of these. For this, continuously operating GNSS

reference stations have been installed all over the world, and specifically, over the last 10 years the number of these permanent stations was increased significantly due to the installation of many national permanent GNSS networks.

Handling and monitoring the processing of such a big amount of GNSS data and meta-data is the next challenge that should be achieved in order to keep all these GNSS products reliable and manageable. For this reason, a new tool 'ROBER' was developed by the Royal Observatory of Belgium (ROB) to monitor and analyze the intermediate and final products of a GNSS network solution.

ROBER was specifically designed to follow every GNSS data processing step of the BERNESE GNSS software V5.2 (Dach et al. 2015). Three are the main goals of the tool ROBER, first of all, to monitor the procedure that the BERNESE GNSS software applies for the solution of a network, to manage the metrics and the products of the GNSS data processing procedure in a database and to identify imprecise results which may cause accuracy degradation of the final products. Several Key Performance Indicators have been developed to examine the performance of each GNSS data processing step, and a number of decision models were tested so as to improve the reliability and the precision of the network solution. Finally, the tool ROBER also has a web-based user interface which shows the results of each step of the performance monitoring procedure. This user interface is designed to provide all the relevant information of the monitoring procedure in the form of graphs, maps and reports, and provides at the same time statistical indicators for the performance of each processing step and meta-data information.

Keywords: GNSS data processing, quality assessment, GNSS network solution, BERNESE GNSS software, key performance indicators, decision models.

P06

Impact interference factors on changes of GNSS coordinate time series

Adrian Kaczmarek, Bernard Kontny

Institute Geodesy and Geoinformatics, Wroclaw University Environmental and Life Sciences
Grunwaldzka 53, 50-357 Wroclaw, Poland
adrian.kaczmarek@upwr.edu.pl

ABSTRACT

In this poster were presented results analysis of impact interference factors: atmospheric pressure loading (APL), hydrology (HYDRO) and non-tidal ocean loading (NTOL) on changes of GNSS time series. Analysis were performed for North, East and Up component. The analyses were used data for interference factors – GGFC model (Global Geophysical Fluid Center) and the coordinate time series of IGS stations – CODE Repro2013. During the analysis were calculated correlation coefficients between coordinate time series (for each component) and sum APL, HYDRO and NTOL). The analyses were performed for randomly selected GNSS stations.

Keywords: correlation coefficients, GNSS time series, atmospheric pressure loading, non-tidal ocean loading, hydrology

P07

GOVUS: A new on-line service for evaluation of multi-GNSS orbit quality

R. Zajdel, K. Sośnica, G. Bury

Institute of Geodesy and Geoinformatics, Wroclaw University of Environmental and Life Sciences, Grunwaldzka 53, 50-357 Wroclaw, Poland
radoslaw.zajdel@igig.up.wroc.pl

ABSTRACT

Nowadays, SLR technique is a foundation of space geodesy, which generates the most accurate products of precision range up to few millimeters. With reference to the merits of SLR technique deployment, next generations of GNSS satellites have been equipped with Laser Retroreflector Arrays. A major motivation was to cross-link the observational network of GNSS and SLR by common space targets. However, it brings more potential benefits: (1) improve the consistency between different techniques used for the ITRF realization, (2) eliminate some systematic errors caused by local ties in the ground segment, (3) provide independent source of microwave GNSS orbit quality, (4) deliver valuable information on the orbit and antenna offset in the initial stage of satellite mission.

In the last decade, the GNSS satellite constellation is the most fast-growing group of objects launched into the Earth's orbit. Many new Global and Regional Navigation Satellite Systems have been being developed since the beginning of the millennium. On the other hand, over the last twenty years, the International GNSS Service (IGS) has been improving the quality of GPS and GLONASS orbit and clock products. Nevertheless, the dynamic progress in new navigation systems has coerced IGS to proper preparation for the new era of multi-GNSS. For this reason, in 2011 the IGS initiated the Multi-GNSS Experiment, which is now conducted as the "IGS Multi-GNSS Pilot Project".

A new online service – GOVUS (multi-GNSS Orbit Validation visualizer Using SLR) has been created with reference to the benefits of multi-technique integration, as well as the challenges of the multi-GNSS realizations. The main task of the service is to: (1) store archival and current information about the ILRS laser stations and the GNSS satellites, (2) store the multi-GNSS microwave orbit validation results using SLR (3) allow for fast and advanced online analyses on stored dataset, (4) provide autonomous computing center, generating up-to-date dataset and reports from daily validation of microwave orbits using SLR data from last 20 days. In order to meet the service expectations, 6 main modules have been created: (1) Plot analyses, (2) Table list, (3) Station statistics, (4) Satellite statistics, (5) Report module, (6) Interactive map.

The service database consists of detailed information about 39 laser stations (distinguishing between different types of photon detector, max repetition rate, timer type) and 51 satellites from 4 navigation satellite systems (16 of Galileo, 30 of GLONASS, 4 of BeiDou, 1 of QZSS). It covers the timespan from 1st January 2014 till now. The service allows for the analysis of the validation results of microwave MGEX CODE's five system orbit solution. The orbit validation is processed using the Bernese GNSS Software, modified version 5.2. Since March 2017, the GOVUS service is a part of ILRS Associated Analysis Center at the Institute of Geodesy and Geoinformatics, Wroclaw University of Environment and Life Science.

Keywords: SLR, ILRS, MGEX, precise orbit determination, orbit validation

P08

EUPOS countries network RTK quality monitoring tool (status in 2017)

Karol Smolik, Branislav Droscak

Geodetic and Cartographic Institute Bratislava, Chlumeckeho 4, 827 45 Bratislava, Slovakia
karol.smolik@skgeodesy.sk, branislav.droscak@skgeodesy.sk

ABSTRACT

Monitoring tool for the network RTK quality of EUPOS countries was developed as a product of EUPOS Working Group on Service Quality Monitoring by Geodetic and Cartographic Institute Bratislava. The application uses virtual monitoring stations generated as VRS by the EUPOS countries positioning determination services instead of the physical monitoring stations monumented in regions. Results from the monitoring give to user useful information in real time about network RTK quality of monitored countries 24 hours a day. From the analysis of the results it is clear that monitoring tool works right and it could serve for comparison of countries or software based network RTK as well.

Keywords: EUPOS, network RTK, quality, monitoring

P09

Adequacy of GNSS antenna calibration model – case study

Ł. Borowski[1], J. Kudrys[2]

1. Lublin University of Technology, Lublin, Poland
2. AGH University of Science and Technology, Kraków, Poland
l.borowski@pollub.pl, j.kudrys@agh.edu.pl

ABSTRACT

In the presentation, results of research on adequacy of GNSS antenna calibration model are presented. The research were conducted based on ASH701945_C SNOW and TRM57971.00 NONE antennas. Height differences between antennas were determined with different methods – EPN combined solutions, Precise Point Positioning and single baseline solution. For PPP and baseline solutions the Bernese software were used as well as Trimble Business Center and GNSS Solutions. Results of GNSS processing were referenced to direct geometric leveling results.

Keywords: GNSS, antenna phase center, PCC, Ashtech ASH701945_C SNOW, Trimble Zephyr Geodetic

P10

Combined adjustment of networks of relative vertical crustal movements from levelling and GNSS data

Kamil Kowalczyk, Jacek Rapiński, Joanna Kuczyńska-Siehień

Faculty of Geodesy, Geospatial and Civil Engineering
University of Warmia and Mazury in Olsztyn, Oczapowskiego 2, Olsztyn, Poland
joanna.kuczynska@uwm.edu.pl

ABSTRACT

Vertical movements of the Earth's crust can be defined as relative, „observed", levelling, and absolute movements. At GNSS stations these movements are determined as absolute movements. Determination of relative vertical movements at GNSS stations allows for simultaneous alignment of the vertical relative movement networks developed from GNSS and levelling data, which is the aim of this research.

The research based on the height differences between the permanent stations of the Polish ASG-EUPOS network obtained between 2008 and 2013, and the measured elevations from repeated levelling campaigns. The vertical movement was determined on each levelling line, creating the network of vertical movements. Similarly, the network of vertical movements was defined on the ASG-EUPOS stations using the Delaunay triangulation.

The received networks were linked through a common point of constant speed. The created networks of vertical movements were adjusted. As a result, relative vertical movements of the Earth's crust were obtained at the points of connected networks, i.e. at ASG-EUPOS stations and nodes of levelling nets.

Keywords: vertical crustal movements, levelling, GNSS time series

P11

Joint estimate of height changes from GNSS solutions of short vectors and PSI measurements using Envisat and TerraSAR-X satellite data

J. Krynski, L. Zak, D. Ziolkowski, M. Lagiewska, J. Cisak

Institute of Geodesy and Cartography, 27 Modzelewskiego St., 02-679 Warsaw, Poland
jan.krynski@igik.edu.pl

ABSTRACT

Time series of weekly and daily solutions for coordinates of permanent GNSS stations may indicate local deformations in Earth's crust or local seasonal changes in the atmosphere and hydrosphere. The errors of the determined changes are relatively large, frequently at the level of the signal.

Satellite radar interferometry and especially Persistent Scatterer Interferometry (PSI) is a method of a very high accuracy. Its weakness is a relative nature of measurements as well as accumulation of errors which may occur in the case of PSI processing of large areas especially on

the areas characterized by dynamic weather conditions which can result in strong spatial variation of the delay or radar signal in the atmosphere. It is thus beneficial to confront the results of PSI measurements with those from other techniques, such as GNSS and precise levelling.

PSI and GNSS results were jointly processed recreating the history of surface deformation of the area of Warsaw metropolitan with the use of radar images from Envisat and TerraSAR-X satellites which differ in wavelength, spatial resolution and frequency of registration of the images. GNSS data from Borowa Gora and Jozefoslaw observatories as well as from WAT1 and CBKA permanent GNSS stations were used to validate the obtained results. Observations from 2000–2016 were processed with the Bernese v.5.0 software. Relative height changes between the GNSS stations were determined from GNSS data and relative height changes between the persistent scatterers located on the objects with GNSS stations were determined from the interferometric results.

The consistency of results of the two methods was 3 to 4 times better than the theoretical accuracy of the GNSS measurements. The joint use of both methods allows to extract a very small height change below the level of measurement error.

Keywords: height changes, GNSS, Persistent Scatterer Interferometry

P12

Seismic deformation due to the 17 Nov. 2015 M6.5 Lefkada earthquake from GNSS and InSAR observations: evidence for seismic gaps in central Ionian Sea

Athanassios Ganas[1], Panagiotis Elias[2], Pierre Briole[3], Isaak Parcharidis[4], Antonio Avallone[5]

1. Institute of Geodynamics, National Observatory of Athens, Athens, Greece
2. Institute of Astronomy, Astrophysics, Space Applications and Remote Sensing, National Observatory of Athens, Athens, Greece
3. CNRS / Ecole Normale Superieure, Paris, France,
4. Harokopio University of Athens, Athens, Greece
5. INGV, Rome, Italy
corresponding.author.aganas@noa.gr

ABSTRACT

The 17 November 2015 M=6.5 Lefkada earthquake (Ionian Sea, Greece), produced tens of centimetres of co-seismic motion in both Lefkada and Cephalonia islands. We present the full picture of the seismic displacements (co-seismic and postseismic) as mapped by space geodesy, Sentinel 1A INSAR and GNSS stations. We use this data together with the constraints from seismology to invert for fault location and geometry, size and slip distribution. We observed postseismic displacements throughout most of southern Lefkada and northern Cephalonia islands, recorded at the two NOA GNSS stations of PONT and SPAN and four additional permanent and six campaign GNSS stations installed after the earthquake. Those displacements range from a few centimetres near the epicentre to a few millimetres far from the fault. We model the post-seismic displacements as due to uniform slip on the same fault plane that ruptured during the main event. The model shows a right-lateral afterslip along the fault but with slightly larger dimensions in comparison to the co-seismic slip, and deeper. This transient strain followed the main event during a short period of 80 days as modelled with an exponential law fit to the daily data of GNSS station

PONT. Currently, the post-seismic deformation is being investigated by exploiting multi-temporal Sentinel 1A/B InSAR processed among others with ESA's Geohazards Exploitation Platform and SNAP software. The M6+ earthquakes occurred in the Central Ionian area since 1983, studied both by seismology and space geodesy imply a seismic gap offshore NW Cephalonia, as well as a gap along Lefkada' s west coast that need to be monitored.

Keywords: Earthquake, seismic gap, Lefkada, GNSS

P13

The improved semi-empirical Fennoscandian postglacial land uplift model NKG2016LU

Olav Vestøl[1], Jonas Ågren[2], Holger Steffen[2], Halfdan Kierulf[1], Martin Lidberg[2], Tõnis Oja[3], Andres Rüdja[4], Tarmo Kall[5], Veikko Saaranen[6], Karsten Engsager[7], Casper Jepsen[8], Ivars Liepins[9], Eimuntas Paršeliūnas[10], Lev Tarasov[11]

1. Kartverket, Hønefoss, Norway
2. Lantmäteriet, Gävle, Sweden
3. Maaamet, Tallinn, Estonia
4. AS Planserk, Laagri, Estonia
5. Estonian University of Life Sciences, Tartu, Estonia
6. Finnish Geospatial Research Institute FGI, Maasala, Finland
7. Geodetic Consulting, Copenhagen, Denmark
8. Agency for Data Supply and Efficiency, Copenhagen, Denmark
9. Latvian Geospatial Information Agency, Riga, Latvia
10. Vilnius Gediminas Technical University, Vilnius, Lithuania
11. Memorial University of Newfoundland, St. John's, Canada
Olav.Vestol@kartverket.no

ABSTRACT

NKG2016LU is a semi-empirical land uplift model computed in Nordic-Baltic cooperation in the Nordic Geodetic Commission (NKG) Working Group of Geoid and Height Systems. The model gives the vertical land uplift rate in two different ways: (1) NKG2016LU_abs with the absolute land uplift in ITRF2008 (i.e. relative to the Earth's center of mass), and (2) NKG2016LU_lev with the levelled land uplift, i.e. uplift relative to the geoid.

NKG2016LU has been computed using a remove-compute-restore technique based on (1) an empirical land uplift model derived from geodetic observations and (2) a geophysical GIA model called NKG2016GIA_prel0306. The empirical model has been computed from uplift results of Global Navigation Satellite System (GNSS) time series from the Baseline Inferences for Fennoscandian Rebound Observations, Sea-level and Tectonics (BIFROST) and levelling data. Compared to the previous model NKG2005LU, no tide gauge information was used. The geophysical model is based on a spherically symmetric (1D), compressible, Maxwell-viscoelastic earth model applying the viscoelastic normal-mode method. Ice history information is taken from Glaciological Systems Model (GSM) results, a set of 25 different 3D thermo-mechanically coupled glaciological models calibrated against ice margin information, present-day uplift, and relative sea-level records. The best-fitting geophysical Earth model to both the BIFROST uplift and Fennoscandian relative sea-level histories simultaneously has a 160 km thick lithosphere, a viscosity of 7×10^{20} Pa s in the upper mantle, and of 7×10^{22} Pa s in the lower mantle.

No apparent model (i.e. uplift relative to Mean Sea Level over a certain time period) is released for the time being. This is mainly motivated by the (accelerating) contemporary climate-related sea level rise, which implies that the apparent land uplift is different from the levelled land uplift and dependent on the chosen time interval.

Our presentation will introduce the model and its computation as well as discuss the problematic issue of handling tide gauge information. We will present climate-related sea-level changes by comparing NKG2016LU_lev with apparent uplift in tide gauges for a number of selected time periods. Of special interest in the perspective of EUREF is its use in management of geodetic reference frames and in transformation of coordinates.

Keywords: Land uplift model, GIA model, sea level rise, reference frames

P14

Aspects of establishing a modern gravity control: case study Borowa Gora Observatory

P. Dykowski, J. Kryński

Institute of Geodesy and Cartography, 27 Modzelewskiego St., 02-679 Warsaw, Poland
przemyslaw.dykowski@igik.edu.pl

ABSTRACT

The trend in the establishment of modern gravity control assumes using absolute gravity measurement as the primary measurement technique shifting relative gravity measurements to the secondary role of a supporting technique applied e.g. for gravity gradient determinations. Classic gravity control based on relative gravity measurements proves to be not as reliable as the one based on AG surveys

AG measurements requires higher standards for applying corrections to the measurements as well as monitoring the performance of the absolute gravimeter. This work presents results from absolute gravity measurements with the A10-020 gravimeter on the open field station at Borowa Gora Observatory. This station represents a typical open field station of a modern gravity control, susceptible to the full (local and non local) hydrological signal, hence is a valuable study object. Gravity surveys taken in 2015 and 2016 provide the unique time series of quasi-regular measurements on monthly basis. In the measurements evaluated with a standard set of corrections (IAG suggested models) remains a strong annual residual signal with a peak to peak variation of 20 μGal, associated with hydrology.

The use of selected correction models to elaborate AG measurements with special emphasis on hydrology will be discussed considering data from local hydrological sensors as well as from global hydrological models, e.g. GLDAS. These models will be used to evaluate the observed gravity variations with the A10-020 absolute gravimeter. Gravity changes due to hydrology for the area of Poland as well as recommendations for methodology of data elaboration will be presented.

Keywords: absolute gravimeter, gravity control, hydrological modelling

P15

E-GVAP, status and future

Henrik Vedel[1], Siebren de Haan[2], Jonathan Jones[3], Gemma Halloran[3] and Owen Lewis[3]

1. Danish Meteorological Institute (hev@dmi.dk)
2. Royal Meteorological Institute of the Netherlands
3. UK Met Office

ABSTRACT

E-GVAP (the EIG EUMETNET GNSS Water Vapour Programme) is an operational service providing GNSS atmospheric delay estimates (zenith total delays) for use in weather forecasting in near realtime.

E-GVAP is based on a close collaboration between geodetic and meteorological institutions.

The use of GNSS data in numerical weather prediction models is found to increase the skill of the weather forecasts. In the presentation we review the current status and future prospects.

P16

COST Action ES1206: Advanced GNSS Tropospheric Products for Monitoring Severe Weather Events and Climate (GNSS4SWEC)

J. Jones[1], G. Guerova[2], J. Dousa[3], S. de Haan[4], O. Bock[5], G. Dick[6], E. Pottiaux[7], R. Pacione[8]

1. Met Office, United Kingdom
2. Sofia University, Bulgaria
3. Geodetic Observatory of Pecny, Czech Republic
4. Royal Netherlands Meteorological Institute, Netherlands
5. Institute Geographique National, France
6. GFZ German Research Centre for Geosciences, Germany
7. Royal Observatory of Belgium, Belgium
8. e-geos S.p.A. ASI/Centro di Geodesia Spaziale, Italy
jonathan.jones@metoffice.gov.uk

ABSTRACT

GNSS is a well established atmospheric observing system which can accurately sense water vapour, the most abundant greenhouse gas, accounting for 60–70% of atmospheric warming. Water vapour observations are currently under-sampled in operational meteorology and obtaining and exploiting additional high-quality humidity observations is essential to improve severe weather forecasting and climate monitoring. Inconsistencies introduced into long-term time series from improved GNSS processing algorithms make climate trend analysis challenging. Ongoing re-processing efforts using state-of-the-art models are underway which will provide consistent time series' of tropospheric data, using 15+ years of GNSS observations and from over 600 stations

worldwide. These datasets will enable validation of systematic biases from a range of instrumentation, improve the knowledge of climatic trends of atmospheric water vapour, and will potentially be of great benefit to global and regional NWP reanalyses and climate model simulations (e.g. IPCC AR5).

COST Action ES1206 is a 4-year project, running from 2013 to 2017, which has coordinated new and improved capabilities from concurrent developments in GNSS, meteorological and climate communities. For the first time, the synergy of multi-GNSS constellations has been used to develop new, more advanced tropospheric products, exploiting the full potential of multi-GNSS on a wide range of temporal and spatial scales – from real-time products monitoring and forecasting severe weather, to the highest quality post-processed products suitable for climate research. The Action has also promoted the use of meteorological data as an input to real-time GNSS positioning, navigation, and timing services and has stimulated knowledge and data transfer throughout Europe and beyond.

Keywords: GNSS, GPS, humidity, water vapour, climate

P17

Continental-wide maps of TEC variations as a tool for monitoring of ionosphere. Status and prospects

G. Nykiel[1], M. Figurski[1], Yu. M. Yampolski[2], Y. M. Zanimonskiy[2]

[1] *Gdansk University of Technology, Poland*
[2] *Institute of Radio Astronomy, National Academy of Sciences of Ukraine*
grzegorz.nykiel@pg.gda.pl

ABSTRACT

Multiposition radio sounding of the near-Earth plasma by the signals of global navigation satellite system (GNSS) can be efficiently used for studying the ionospheric processes. This became possible due to development of the networks of dual-frequency receivers originally designed primarily for solving geodetic tasks.

Using the technique of orthogonal projection of variations in electronic content when processing the data from a large number of closely located stations allows obtaining the maps of ionospheric variations with high spatial resolution.

We used them in monitoring the state of ionosphere. It turns out that the TEC irregularities are present at any time and in any of geomagnetic activity.

They can be divided into three categories – random background variations, quasi-deterministic wave-like travelling ionospheric disturbances (TID) and chaotic ones, which occur during the geomagnetic storm active phase.

The regular dependence of the RMS value of background variations on the time of day can be clearly seen. The highest values are obtained for the hours about the midday. This is, of course, caused by the higher level of TEC at this time, and it is normal for the quiet days.

Analyzing the maps using two satellites near zenith we can obtain the possibility to estimate the height of the layer of localization of electron concentration irregularities. In most cases at quiet days, this height corresponds to the one of F2 ionospheric layer maximum. On stormy days, this height increases up to 600–700 km.

TIDs are detected regularly, to several times a day and are observed within few tens of minutes to an hour. The motion direction in most cases is opposite to the horizontal wind direction calculated by the HWM07 model at the height of F2 ionospheric layer maximum. The amplitude of

TEC variations during the TID passage is proportional to the TEC background value, and the more so, the higher is the level of geomagnetic disturbances.

Extremely high TEC variations were recorded during a severe geomagnetic storm on the St. Patrick's Day (March 17, 2015). In addition, the speed, as well as the direction of apparent motion of irregularities, were significantly dependent on the latitude.

Further work will be made to classify in detail the irregularities and investigate the quantitative relation between the measured parameters of TIDs and modeled speed of horizontal winds, as well as accumulate more statistics on appearance and characteristics of TIDs, depending on the season and level of geomagnetic activity. We intend to construct the Internet site presenting regularly the maps of TEC variations over Europe as pictures and text files.

Keywords: ionosphere, GNSS, TEC, map, disturbance

P18

Horizontal gradients of troposphere delay for GNSS-SLR co-located stations

M. Drożdżewski, K. Sośnica

Wroclaw University of Environmental and Life Sciences, Institute of Geodesy and Geoinformatics
Grunwaldzka 53, 50-357 Wrocław, mateusz.drozdzewski@igig.up.wroc.pl

ABSTRACT

The International Terrestrial Reference Frame (ITRF) is based on four techniques of space geodesy: SLR, GNSS, DORIS and VLBI. As opposed to GNSS, DORIS and VLBI products, SLR-based solutions do not consider the horizontal gradients of the troposphere delay. The present accuracy of SLR solutions is thus limited by the modeling of the troposphere delay, especially the unmodeled horizontal gradients. However, most of the SLR stations are co-located with GNSS receivers, thus GNSS-derived horizontal gradients of the troposphere delay may support the SLR solutions.

In this paper, we examine three dedicated approaches of the horizontal gradient modeling for SLR. In the first case, we analyze the troposphere delay series using up to 14 years of GNSS-derived horizontal gradients from the GNSS solutions provided by the Center for Orbit Determination in Europe (CODE) reprocessing campaign (repro2) generated in the framework of the preparation for ITRF 2014. In the second approach, we employ horizontal gradients derived from the European Centre for Medium-Range Weather Forecasts (ECMWF). In the last case we use horizontal gradients estimated when enhancing the number of estimated parameters in the SLR solutions using observations to LAGEOS-1 and LAGEOS-2.

We apply the spectral FFT analysis for the horizontal gradient time series. Most of the GNSS stations have significant annual and semi-annual signals in the East and North components of the horizontal gradients. However, the fundamental period of the GPS named "draconitic" year, whose interval is 351.2, strongly aliases to the annual and semi-annual seasonal periods. Secondly, we fit a function with an offset, a linear trend and two seasonal components into the series of GNSS-derived, SLR-derived, and ECMWF gradients using a standard least squares method (LSM). The GNSS-derived offsets are at a submillimeter level with a maximum value of north-south offsets NSO = 0.5 mm for the station Arequipa in South America, and a minimum value of NSO = -0.7 mm. The maximum value for EW offset amounts to 0.7 mm for the station Wuhan in China. The minimum EW offset = -1.18 mm for the station Kashima in Japan. The horizontal gradients derived

for GNSS-SLR co-located stations for the elevation angles 10 degrees achieve values up to 20 mm, thus they are important for both, GNSS and SLR solutions. The comparison between SLR-derived gradients and GNSS-derived gradients show a good agreement in terms of the mean annual offsets for the north and east components in case of the SLR core stations. The annual and semi-annual signals show just a moderate consistency in terms of the SLR, GNSS and ECMWF gradients. Typically, the GNSS-derived gradients are overestimated by a factor of 1.5-2.0 when compared to SLR and ECMWF solutions. SLR-derived gradients are typically instable due to a low number of SLR observations, especially for non-core SLR stations.

Keywords: GNSS-SLR collocated stations, satellite geodesy, Satellite Laser Ranging, Troposphere delay modelling, horizontal gradients, ECMWF

ABSTRACTS

Contents
(in alphabetical order)

Session 1

Session 2

Session 3

Session 4

Session 5

Poster Session

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