GNSS SEMINAR – IMPULS PROJECT
REPUBLIC GEODETIC AUTHORITY
Presentation of the proposed regional GNSS center

Motivation, concept, resources, expectations, benefits

Danko Dučić, Zoran Veljković, Saša Lazić, Dejan Stojanović

Belgrade, December 2014
IMPULS Project
(Infrastructure for Spatial information in the region of Western Balkan)

Component 5:
DISSEMINATION / DEMOINSTRATION & PILOTS

Activity / Use Case 1:
REGIONAL GNSS DATA INTEROPERABILITY AND
ESTABLISHING OF ANALYSIS CENTRE OF WESTERN BALCAN
AS A SUBNETWORK OF EUREF PERMANENT GNSS NETWORK

Financed by Swedish International Development Cooperation Agency
Technical support by Lantmäteriet as twinning partner
OUTLINE

1. Motivation for proposing establishment of a Regional GNSS Analysis center
2. Description of the capacities and resources
3. GNSS processing procedure
4. Analysis results
5. Benefits
6. Conclusions
Motivation and objectives for establishment regional GNSS center

The proposed project contains actions oriented via producement of a **common consistent, densified and continuous official GNSS solution in ITRFyy** for the western Balkan area.

That include e.g. **harmonization and combination of different GNSS solutions from participating countries**, providing further EPN densification in this region.

**Need for dense and consistent field of station velocities time series in global ITRFyy frames** in order to maintain national ETRS89 realizations in the future.

**Intensification of regional cooperation in the field of high-precision GNSS analysis** through implementation of uniform and consistent working procedures and building capacities for CORS data processing in Bernese environment, according to EUREF standards.

**Conducting of joint scientific research activities on international level and application developing**

**Existence of similar regional centers in Europe (NKG AC) and successfully operating of EPN LAC in RGA since April 2011, as a positive precondition for establishing**
The plan is, that for the beginning the headquarters of the proposed regional analytical center would be in Belgrade, in the RGA, in the control center of AGROS CORS network.

**Trimble Pivot Platform ver. 352 successfully implemented since October 2014**

FTP server for bidirectional exchange of CORS RINEX data and storing the processing results would be operated and maintained by the RGA IT sector. Data security ensured by assignment of username and passwords for accessing to FTP.

Application Bernese 5.2 would be installed and performing data analysis on this virtual FTP server (batch scripts and perl modules also be placed on this FTP)

Original CORS observation data of each participating country should be available in the 30-sec RINEX format as Hatanaka compressed or ZIP archived files (other formats are also acceptable)

GNSS raw data would be uploaded daily in a separate directories on RGA FTP server and deleted after successfully performed analysis.

All relevant results of the GNSS processing could be stored on the mentioned RGA FTP server or could be distributed directly to the participating institutions.

Belgrade, December 2014

Capacities and resources – Shema of proposed regional GNSS center

The schematic view of data interoperability

- Username and password for FTP access
- Algorithm based on Bernese 5.2 modules following EUREF LAC guidelines
- Reference frame for results is ITRF2008 (IGS08 and IGB08) (ETRS89-ETRF2000)
- No direct communication and real time connectivity between CORS stations
- Receiving, downloading and quality control of CORS data of beneficiary country
- Downloading data from IGS/CODE/EPN ftp servers
- Downloading of AGROS data
- Campaign setup and conducting automated real-time processing
- Deleting Rinex data from RGA FTP
- Uploading analysis results to the RGA FTP server (if requested)
- Visual web presentation of Bernese results (if requested)

Belgrade, December 2014

Routine based data processing algorithms in “real-time” mode (RNX2SNX, CLKDET, ORBCMP, ADDNEQ2, FODITS…)

Solution generation is going to be carried out daily by RGALAC staff following the “Guidelines for EPN Analysis Centers” and “Guidelines for EUREF densifications”

**Software package used for analysis:**
Bernese GPS Software Version 5.0 up to 1751 GPS week
Bernese GNSS Software Version 5.2 since 1752 week (August 4th 2013)

Optimal automatization of working procedures (batch scripts, Perl modules, scheduled applications)

CODE/IGS products (ephemeris, IERS 2010 EOP files, global ionospheric maps, differential code biases and clock corrections), VMF coefficient maps and EPN absolute PCV antenna model, IGb08 reference files
Functional flow diagram of standard processing in Bernese 5.0

**ORBIT PART**
- EOP preparation
- orbit generation

**SIMULATION**
- simulation of observations

**TRANSFER / CONVERSION PART**
- import/export of observations
- extraction of meta-information from external sources

**PROCESSING PART**
- preprocessing of observations
- session solution
- multi-session solution

**SERVICE PART**
- tools to:
  - manage observation files
  - browse/analyse residual files
  - manipulate/verify coordinate files

**result files**
GNSS processing – RGA EPN Local Analysis Centre

- 16 EUREF LAC (RGA)
- April 2011 (1632 GPS week)
- Bernese 5.2 implemented (August 2013)
- Using CODE orbits/clocks
- VMF troposphere model

http://www.epncb.oma.be/
http://www.euref-iag.net/
Automated working procedures
Daily/Weekly/Monthly position and troposphere solutions
Results validation by BKG DC

Number of processed CORS
- 55 EPN Subnetwork
- 33 Serbia
- 14 MAKPOS
- 12 + 2/3 Neighbouring countries

Belgrade, December 2014
The Regional GNSS center will provide mandatory the following products:

- Daily/weekly rapid/final free-network position estimates (SINEX format)
- Ephemeris comparison and quality control
- Satellite/CORS clock correction
- Cumulative multi-year velocity solution
- Final daily Zenith Path Delay estimates and tropospheric gradients
- Local and regional ionosphere maps (Klobuchar model or PPP solution)
- CORS coordinate repeatability statistics
- Analysis of residual position time series
- Cumulative estimation of CORS velocity field with ultra-rapid, rapid and final IGS/CODE ephemeris which can be used for various kind of scientific applications (consistent results after 3 year calculation period)
- The daily computation of CORS stability
- Quality control of distributed GNSS corrections
- Implemented SWEPOS application for normal equation stacking
Following the example of NKG GNSS Analysis centre (NKG AC) the proposed organizational structure of **Regional GNSS centre** should also consist of the following Working groups:

- **“WG of Geodynamics”** (modeling velocity field, earthquake prediction, ground deformation)
- **“WG of GNSS Infrastructure”** (GNSS antenna phase center variations)
- **“WG of Geoid and Height Systems”** (user-oriented applicative solution)
- **“WG of Positioning and Navigation”** (GNSS tracking)
- **“WG of Reference Frames”** (ETRS89 densification, coordinate transformations, time series analysis)
- **“WG for modeling atmospheric refractions and ephemeris quality”**

*Regional GNSS center is going to be managed by a Presidium and the actual work will be done in WG and WG projects.*

RGA = stakeholder institution in the project beginning
Benefits of integrated GNSS processing

More reliable processing products due to higher density of CORS stations proposed for analysis in Regional GNSS center

Possibility for visual presentation of the processing results on the web (increased transparency of the systems operation)

Results of this pilot project could be also included into other pan European products (EUREF, AIUB, CODE, NASA …)

Future projection for geodetic datum unification of the western Balkan countries (ITRF2008)

Possibilities of implementing AGROS applicative solutions in other countries

Development of software for near real-time earthquake prediction and early warning system applications (time series analysis)

Technical assistance from the RGA (Control center AGROS) to participating countries for independent testing and control validation of the processing results of ETRS89 densification campaigns which need to be officially verified and accepted by EPN TWG

Belgrade, December 2014

Defining the Regional GNSS center for continuous routine processing.

Data processing optimization managed through implementation the principle of distributed analysis.

In this approach the Regional GNSS center going to be divided in well-defined subnetworks which are separately processed by different beneficiary countries following the rules and guidelines set up by the International GNSS Service and supplemented by the EUREF Technical Working Group.

A detailed plan will include:
- Definition of subnets and other processing related issues (campaign setup and uniformization of processing algorithm)
- Precise definition of data policy (rules about data exchanging and using of analysis results)
- Resources (processing facilities, software, staff)
- Responsibilities (institutional level)
- Schedules (flow diagram with planned activities)
- Stacking solutions for time series
- Studying various combination techniques in order to publish an official solution (coordinates and velocities)

Belgrade, December 2014

Important precondition for proposing the establishment of Western Balkan Regional GNSS analysis center

http://www.nkg.fi/

Belgrade, December 2014

International experiences and practices in similar projects

http://epncb.oma.be/_documentation/guidelines/

Guidelines for the EPN Analysis Centres
Prepared by the EPN Coordination Group and the EPN Central Bureau
Contact: epn_acr@wetsus.be

Changes
28-01-2010
- Complete revision of the guidelines (all sections)
- Meaning separate EPN Processing Options Table as addendum in the guidelines

19-11-2013
- Final daily coordinate solutions became mandatory
- Recommendation for troposphere gradients submission
- Update of processing options (e.g. mapping functions)
- Minor changes to keep the Guidelines up-to-date

This document comprises the guidelines for EPN Analysis Centres specifying the analysis procedure and submission of the results. The reader is introduced into the EPN analysis method and the connection between the sub-network analysis, the combination and the Projects. But this document gives no detailed explanation of the last two items. All steps for becoming an Analysis Centre are explicitly listed and the processing instructions include the processing scheme as well as the required options. The submission guidelines give the file name convention and address the upload of the analysis results. It is also explained how the Analysis Centres could check their performance against the combination. The addendum holds detailed information about processing options and the history, which could be helpful to understand inconsistencies in coordinate time series.

1. EPN Analysis Components

The strategy to analyse EPN observations is in accordance with the so-called distributed processing approach. Local Analysis Centres (LACs) process the observations of a dedicated sub-network of EPN stations. The EPN Central Bureau (CB) assigns stations to the particular sub-networks following proposals from the Analysis Combination Centre (ACC) and the LACs as far as appropriate, ensuring that each station will be processed by at least 3 LACs, and considering further aspects that will be explained below. The LACs submit their sub-network coordinate solutions to the ACC, who processes the EPN combined solutions. EPN products are published at the EPN CB and Regional Data Centres (RDCs). Each component of the EPN analysis will be described separately in the following.
Final remarks - conclusion

Long-term opportunities for further sustainable investments in the GNSS analysis researching, as important institutional priority (development and implementation of new services oriented towards clients).

The lack of appropriate legislation and regulations in the field of exchanging and using the GNSS data between the beneficiary countries of this project.

The necessity of continuous training of employees who work on GNSS processing and following emerging trends in this area which is rapidly evolving (Bernese training course).

More intensive collaboration between the experts in this field on the regional and international level.

Belgrade, December 2014

Web presentation of Bernese processing results

http://agros.rgz.gov.rs/

AGROS - Active Geodetic Reference Network of Serbia

Belgrade, December 2014

Web presentation of Bernese processing results

http://agros.rgz.gov.rs/agros/efemeride.php
Web presentation of Bernese processing results

Zenith path delay for AGROS CORS stations

http://agros.rgz.gov.rs/agros/tropo.php

Belgrade, December 2014

The graph shows the estimated values of precise clock corrections for the 28 CORS receivers of the Serbian GNSS network - AGROS and clock deviations of electronically visible GPS satellites.

A corrective clock parameters are calculated at the time intervals of a 20 minutes, in the 24-hour format, on the basis of simple original code and phase measurements, on the so-called, zero level of analysis of GNSS data (zero-mean processing level), ie. without forming of linear combinations in mind of double differences which eliminates the impact of this error on the positioning quality. The definitive parameters have been determined under the condition that the sum of estimated errors of reference clocks is zero (zero-mean condition).

Clock corrections for a specific data, which can be chosen from the interactive calendar, are obtained on the basis of original all-day measurements collected from CORS stations of AGROS network, as well as on the basis of the coefficients of satellite clocks delay contained in the navigation messages of each AGROS CORS station. In addition to broadcasted ephemeris, as a priori information in the processing part, also was used predicted errors of atomic satellite clocks which is publicly available in a fast IGS ephemeris files, for the purpose of synchronization of the quartz oscillators in the terrestrial GNSS receivers to the standard GPS timescale.

GNSS clock biases, stored in the universal clock RINEX format, are the final result of an algorithmic scheme for automatic processing composed of several program modules for iterative estimation of unknown parameters, that are executed in the working environment of Application Bernese GPS Software 5.0. In addition, by the realization of this algorithm automatically are rejected all the "bad" measurements with a large number of missing epochs or unexpected large residues.

By comparative study of the diagrams, it can be concluded that the approximate accuracy of the clock offsets, obtained using rapid IGS ephemeris, is in accordance with published quality criteria of clock IGS products (http://igscb.jpl.nasa.gov/components/precision.html).

Belgrade, December 2014

Web presentation of Bernese processing results

http://agros.rgz.gov.rs/agros/velocity.php

Belgrade, December 2014

Web presentation of Bernese processing results

Coordinate repeatability statistics for CORS stations

Select data for display:
CORS station selection: RGA LAC, CP4R (Plzně, Czech Republic)

Quality criteria of estimated coordinate differences for component U

Quality criteria of estimated coordinate differences for component E

Quality criteria of estimated coordinate differences for component N

The graphs provide insight into the coordinate repeatability of selected CORS stations. For more details, please visit:

http://agros.rgz.gov.rs/agros/timeseries.php

Belgrade, December 2014

The graph shows the estimated values of tropospheric refraction effects on the quality of GNSS measurements collected on the CORS stations of EPN (EUREF Permanent Network) reference subnetwork, which is processed by the RGA LAC (Local Analysis Centre of Republic Geodetic Authority from Serbia), as well as values of the troposphere delay for the CORS stations of German and Netherlands national geodetic networks, provided since April 1st, 2011 (GPS week 1632).

Error values of GNSS measurements, caused by time delays of satellite signals spreading from the zenith direction, or respectively the disturbance of signal path which passes through electronically neutral tropospheric layer of Earth's atmosphere, are calculated on a daily basis using the program module for solving the system of normal equations with fixed phase ambiguities in the working environment of application Bernese GNSS Software. Time resolution of daily estimated tropospheric zenith path delay parameters is 1 hour. Within interactive calendar on the website it is possible to choose to display the information of tropospheric refraction for the corresponding CORS station of EPN LAC, AGROS or MAKPOS network from the drop-down list. The geodetic datum of GNSS network is defined by the condition of minimum constrained solution with the Helmert criterion of no net translation, so the calculation of the tropospheric refraction comes down to minimalization of the sum of diagonal elements of cofactor matrix of unknown parameters based on EPN stations that have been adopted as fixed. Elevation mask of processed RINEX data collected on CORS stations is less than 10 arc degrees, and therefore the impact of correlation between estimated tropospheric station-specific parameters and heights of GNSS stations, are eliminated.

The tropospheric delay depends on the distance traveled by the radio wave through the neutral atmosphere and is therefore also a function of the satellite's zenith distance $Z$. To emphasize this elevation-dependence, the tropospheric delay is defined as the product of the delay in zenith direction and a so-called mapping function (Z). For the purpose of mapping the troposphere parameters of the CORS stations, in the old 5.0 version of the Bernese GPS software, Niell mathematical model (dry and wet) was used as a product of the Saastamoinen zenith delay function and the Niell mapping function ($f(Z)$). This model was used for representing of the site-specific troposphere parameters obtained from a subjective GNSS data. Until 1751st GPS week, the dry part of the tropospheric delay

Belgrade, December 2014

http://agros.rg.gov.rs/agros/tropoepn.php
Web presentation of Bernese processing results

http://agros.rgz.gov.rs/agros/velocityepn.php
Web presentation of Bernese processing results

http://agros.rgz.gov.rs/agros/velocityepn.php

Belgrade, December 2014

Web presentation of Bernese processing results

### CORS stations velocities

<table>
<thead>
<tr>
<th>Code</th>
<th>City</th>
<th>Country</th>
<th>GPS week</th>
<th>Vx [cm/yr]</th>
<th>Vy [cm/yr]</th>
<th>Vz [cm/yr]</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALBA</td>
<td>Albacete</td>
<td>Spain</td>
<td>1632 - now</td>
<td>-1.32</td>
<td>1.93</td>
<td>0.95</td>
</tr>
<tr>
<td>AUT1</td>
<td>Thessaloniki</td>
<td>Greece</td>
<td>1632 - now</td>
<td>-1.42</td>
<td>1.94</td>
<td>0.42</td>
</tr>
<tr>
<td>BACA</td>
<td>Bacau</td>
<td>Romania</td>
<td>1632 - now</td>
<td>-1.64</td>
<td>1.48</td>
<td>0.9</td>
</tr>
<tr>
<td>BAIA</td>
<td>Baia Mare</td>
<td>Romania</td>
<td>1632 - now</td>
<td>-1.53</td>
<td>1.58</td>
<td>0.98</td>
</tr>
<tr>
<td>BBYS</td>
<td>Banska Bystrica</td>
<td>Slovakia</td>
<td>1773 - now</td>
<td>-1.71</td>
<td>1.65</td>
<td>0.88</td>
</tr>
<tr>
<td>BISK</td>
<td>Zlate Hory</td>
<td>Czech Republic</td>
<td>1773 - now</td>
<td>-1.25</td>
<td>1.49</td>
<td>1.6</td>
</tr>
<tr>
<td>BUCU</td>
<td>Bucuresti</td>
<td>Romania</td>
<td>1632 - now</td>
<td>-1.47</td>
<td>1.62</td>
<td>1.08</td>
</tr>
<tr>
<td>BUTE</td>
<td>Budapest</td>
<td>Hungary</td>
<td>1773 - now</td>
<td>-1.37</td>
<td>2.31</td>
<td>1.9</td>
</tr>
<tr>
<td>BZRG</td>
<td>Bolzano - Bozen</td>
<td>Italy</td>
<td>1832 - now</td>
<td>-1.15</td>
<td>1.99</td>
<td>0.95</td>
</tr>
<tr>
<td>CACE</td>
<td>Caceres</td>
<td>Spain</td>
<td>1632 - now</td>
<td>-0.78</td>
<td>1.97</td>
<td>1.34</td>
</tr>
<tr>
<td>CAEN</td>
<td>Caen</td>
<td>France</td>
<td>1632 - now</td>
<td>-1.17</td>
<td>1.73</td>
<td>0.89</td>
</tr>
<tr>
<td>CFRM</td>
<td>Frydek Místek</td>
<td>Czech Republic</td>
<td>1632 - now</td>
<td>-1.54</td>
<td>1.32</td>
<td>0.97</td>
</tr>
<tr>
<td>CNBB</td>
<td>Ceske Budejov</td>
<td>Czech Republic</td>
<td>1632 - now</td>
<td>-1.47</td>
<td>1.07</td>
<td>0.14</td>
</tr>
<tr>
<td>CNP</td>
<td>Pardubice</td>
<td>Czech Republic</td>
<td>1632 - now</td>
<td>-1.22</td>
<td>1.14</td>
<td>0.89</td>
</tr>
<tr>
<td>CREI</td>
<td>Creil</td>
<td>France</td>
<td>1632 - now</td>
<td>-1.25</td>
<td>1.76</td>
<td>0.88</td>
</tr>
<tr>
<td>CTAB</td>
<td>Tabor</td>
<td>Czech Republic</td>
<td>1632 - now</td>
<td>-1.42</td>
<td>1.62</td>
<td>0.97</td>
</tr>
<tr>
<td>DEVA</td>
<td>Deva</td>
<td>Romania</td>
<td>1632 - now</td>
<td>-1.35</td>
<td>1.64</td>
<td>1.02</td>
</tr>
<tr>
<td>DRAG</td>
<td>Metoki Dragot</td>
<td>Israel</td>
<td>1773 - now</td>
<td>-1.25</td>
<td>2.18</td>
<td>1.89</td>
</tr>
<tr>
<td>DYNG</td>
<td>Dionysos</td>
<td>Greece</td>
<td>1703 - now</td>
<td>0.98</td>
<td>1.04</td>
<td>-1.15</td>
</tr>
<tr>
<td>ELBA</td>
<td>San Piero Campo</td>
<td>Italy</td>
<td>1632 - now</td>
<td>-1.13</td>
<td>1.75</td>
<td>0.94</td>
</tr>
<tr>
<td>GOPE</td>
<td>Ondrejov</td>
<td>Czech Republic</td>
<td>1773 - now</td>
<td>-1.48</td>
<td>1.58</td>
<td>1.03</td>
</tr>
<tr>
<td>GRAZ</td>
<td>Graz</td>
<td>Austria</td>
<td>1632 - now</td>
<td>-1.16</td>
<td>1.73</td>
<td>0.98</td>
</tr>
<tr>
<td>GSR1</td>
<td>Ljubljana</td>
<td>Slovenia</td>
<td>1632 - now</td>
<td>-1.64</td>
<td>1.69</td>
<td>1.21</td>
</tr>
<tr>
<td>HUEL</td>
<td>Huelva</td>
<td>Spain</td>
<td>1632 - now</td>
<td>-0.63</td>
<td>1.92</td>
<td>1.48</td>
</tr>
<tr>
<td>ISTA</td>
<td>Istanbul</td>
<td>Turkey</td>
<td>1832 - now</td>
<td>-1.65</td>
<td>1.56</td>
<td>0.93</td>
</tr>
<tr>
<td>IZAN</td>
<td>Gumar</td>
<td>Spain</td>
<td>1632 - now</td>
<td>-0.22</td>
<td>1.79</td>
<td>1.49</td>
</tr>
<tr>
<td>KATO</td>
<td>Katowice</td>
<td>Poland</td>
<td>1632 - now</td>
<td>-1.28</td>
<td>1.62</td>
<td>0.98</td>
</tr>
<tr>
<td>KRA1</td>
<td>Krakow</td>
<td>Poland</td>
<td>1632 - now</td>
<td>-1.55</td>
<td>1.55</td>
<td>0.96</td>
</tr>
<tr>
<td>KUNZ</td>
<td>Kunzsk</td>
<td>Czech Republic</td>
<td>1632 - now</td>
<td>-1.57</td>
<td>1.68</td>
<td>0.99</td>
</tr>
<tr>
<td>LAGO</td>
<td>Lagos</td>
<td>Portugal</td>
<td>1632 - now</td>
<td>-0.67</td>
<td>1.97</td>
<td>1.41</td>
</tr>
<tr>
<td>LAMP</td>
<td>Lampedusa</td>
<td>Italy</td>
<td>1632 - now</td>
<td>-1.32</td>
<td>1.73</td>
<td>1.97</td>
</tr>
<tr>
<td>LIL2</td>
<td>Lille</td>
<td>France</td>
<td>1632 - now</td>
<td>-1.21</td>
<td>1.74</td>
<td>0.89</td>
</tr>
</tbody>
</table>

Belgrade, December 2014

IMPULS GNSS seminar - Proposed Regional analysis center

The areas from which accessed to http://agros.rgz.gov.rs (Google Analytics)
Thank you for your attention!

http://agros.rgz.gov.rs/
www.rgz.gov.rs/agros

Belgrade, December 2014