INTEGRATING ROMANIAN GNSS PERMANENT NETWORKS FOR GEOSCIENCE PURPOSES

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ABSTRACT

Romania is covered by more than one hundred GNSS (Global Navigation Satellite System) permanent stations, that have been set up over the last seven years, maintained by different agencies and having different technical architectures and scientific objectives. Many of these stations provide support for geo-referencing applications such as surveying, the network being developed by National Agency for Cadaster and Land Registration (ANCPI) and by a private company, TopGeocart. Two networks are developed with scientific purposes: one developed by the National Institute for Earth Physics - NIEP and the other one developed by the National Institute for Research and Development on Marine Geology and Geo-ecology – GeoEcoMar. Several limiting factors were identified in terms of utilization: no site uniqueness, no file redundancy, no quality control or hardwire web service. Our goal is to collect all those GNSS data in order to standardize, perform quality control and harmonize for creating the metadata.

We present and discuss step by step all the implementation levels of standard tools necessary for generating, validating and disseminating pre-defined GNSS metadata, tools for the generation and dissemination of metadata. All those will allow the end-users, and in particular, geoscientists, to freely access the geodetic data, derived solutions, and associated metadata using a transparent and standardized process. Finally, we detail the technologies and software that were used and developed to build this e-infrastructure, the system output data and the conclusions derived in terms of data volume, security and usefulness.

The involvement in EPOS – IP project as a member of GNSS Data and Products Working Group helps us evolve in the same direction, test and implement GLASS software package for the dissemination of GNSS data & dedicated processing outcomes, time-series, velocities, and strain-rates - to be created using state-of-the-art methodologies for a better understanding and completion of the tectonic puzzle pieces of Solid Earth processes in this challenging structure of Southeastern Europe.

Keywords: *GNSS metadata, GLASS, EPOS – IP*

INTRODUCTION

Romania is covered by more than one hundred GNSS permanent stations, that have been set up over the last seven years, maintained by different agencies and have different technical architectures and objectives.

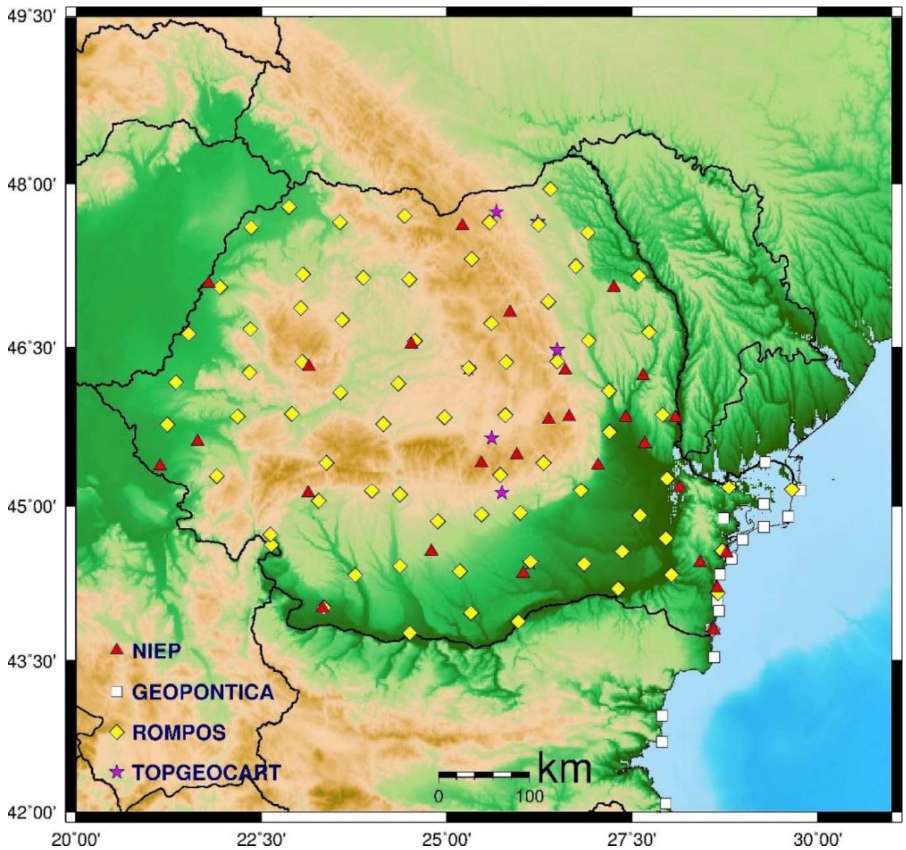

Figure 1: GNSS permanent reference networks in Romania: NIEP(red), TGREF(magenta), GeoPontica(white), ROMPOS(yellow)

The modern Romanian GNSS/GPS network started in 2001 when the first permanent station was installed on the Lacauti peak in the mountainous zone of the Carpathian Bending Zone, west of the Vrancea epicentral area. Since then the network has grown to 30 stations and is still expanding. The network was established as a result of an international research project based on a strategic partnership between: the National Institute for Earth Physics (NIEP), the Faculty of Geology and Geophysics – University of Bucharest (FGG), Delft University of Technology, the University of Utrecht and the Netherlands Research Center for Integrated Solid Earth Sciences (ISES). Starting with 2013, the GPS network is maintained and developed by NIEP. As network objectives can be mentioned: monitoring of crustal changes occurring in the Romanian territory in correlation with tectonic processes in South-East Europe (Africa-Europe plate interaction), observation of crustal movements in order to establish the surface-to-depth relationship of deep earthquakes in the area of the Eastern Carpathians bend zone (Vrancea region), improving the accuracy of the coordinates of the national seismic network stations. The network can also provide improved, reliable, high-accuracy environmental measurements for global weather forecasts, climate monitoring, earthquake precursors (ionospheric studies), coseismic studies, GNSS positioning and navigation, and other research for complementary purposes [1].

The GeoPontica permanent GPS network is developed and maintained by The National Research and Development Institute for Marine Geology and Geoecology (GeoEcoMar). GeoPontica (represented by 18 ground settlement stations) and provides data from the West side of the Black Sea geodetic networks – both in Romania and Bulgaria concerning the vertical movements of the Earth's Crust (isostasy, elevation, land subsidence, basining etc.)

The TGREF - TopGeocart permanent GPS network appeared as a natural response to the growing demands of users of the Leica GNSS equipment. TGref is in full development and currently covers RTK 8 cities in central and eastern Romania and provides DGPS corrections for almost the entire territory of the country.

The ROMPOS permanent network has 74 stations, is a commercial network with the goal of providing DGNSS/RTK correction services that are subsequently used for cadastral purposes, represents a project of the National Agency for Cadastre and Land Registration.

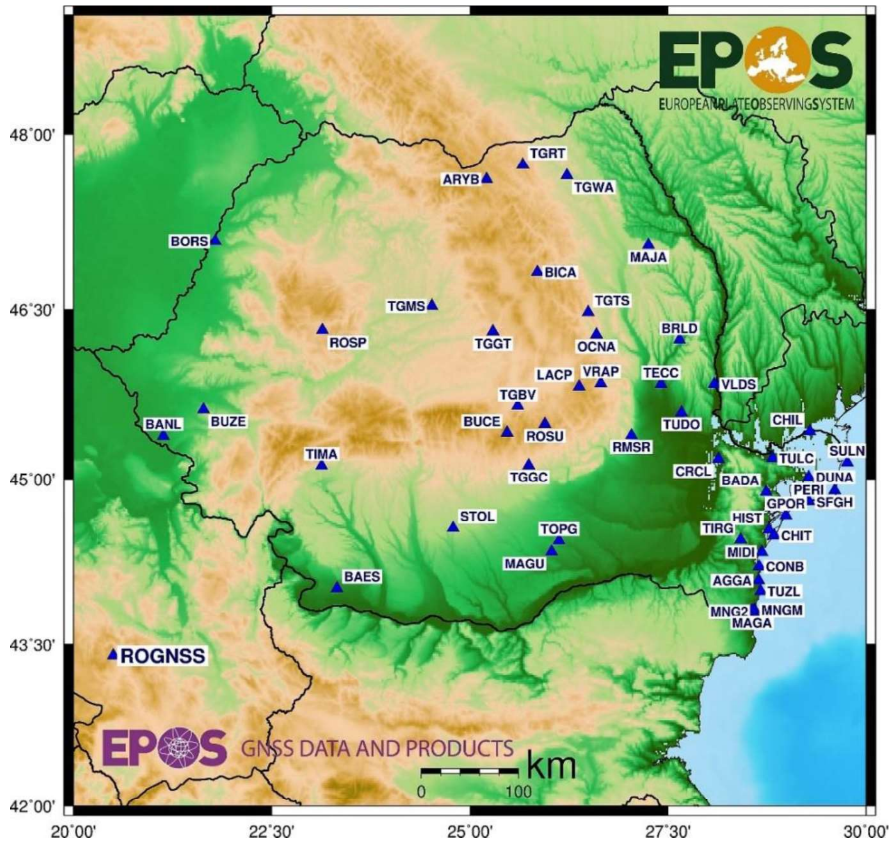

Figure 2: ROGNSS network, stations submitted in EPOS project

The networks being developed for different purposes, we found several limiting factors for data utilization: some of them had no site uniqueness, no file redundancy, no quality control or hardwire web service. Our goal was to collect all those GNSS data in order to standardize, perform quality control and harmonize for creating the metadata and use them for scientific purposes. After we performed the steps mentioned previously: site uniqueness, file redundancy, quality control or hardwire web service, metadata, we distributed the data to a dedicated online GNSS station metadata management and dissemination system called M3G for “Metadata Management and distribution system for Multiple GNSS Networks” at https://gnss-metadata.eu/ (Figure 3). Through M3G, an Operational Center maintains online the GNSS stations` metadata for EPOS stations and performs various quality checks. The system is based on the model-view-control architecture. The architecture is divided into three components: 1) the model is managing the data of the application, 2) the controller is defining the working logic and 3) the view is interacting with the users. Management of the Operational Center Information includes the agency name, address, contact person emails, list of GNSS stations.

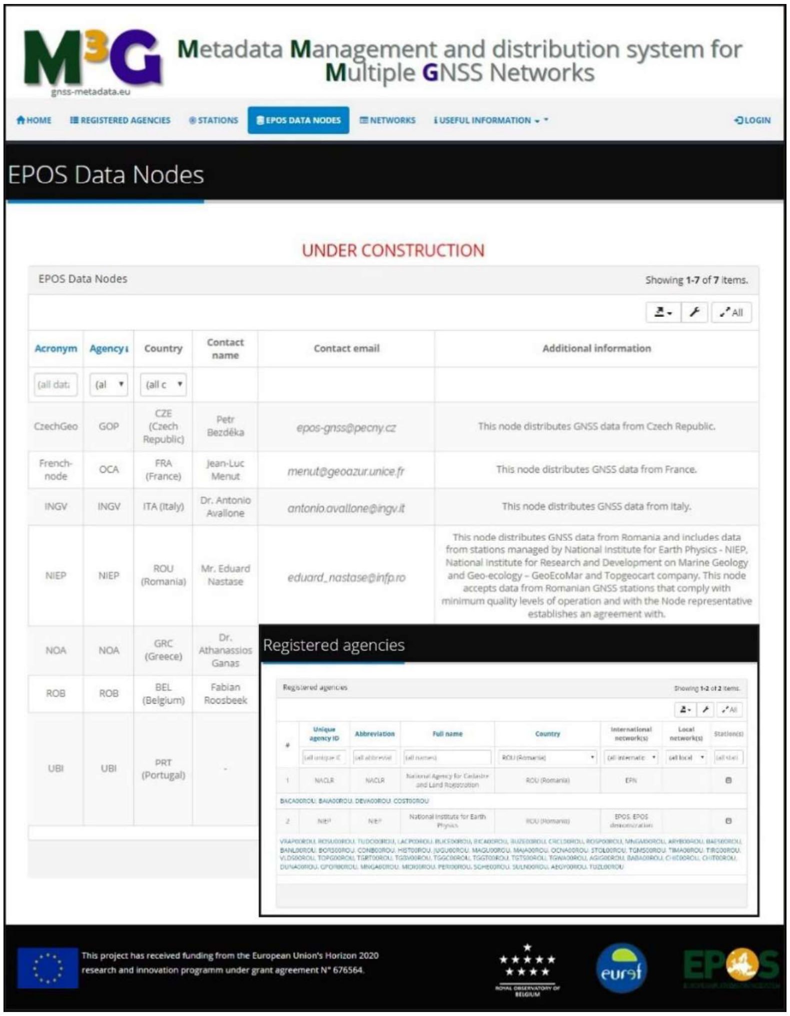

Figure 3: M3G data portal. EPOS NIEP Data Node and National registered agencies and stations

The involvement in EPOS (European Plate Observing System) project where we are a national GLASS node (Geodetic Linkage Advanced Software System, an integrated software package to be deployed in a GNSS infrastructure), helped us in achieving the objectives we envisaged. GLASS is an integrated software package deployed in a GNSS infrastructure to manage data and metadata. Developed from the original Geodetic Seamless Archive Centers (GSAC) concept that was created by UNAVCO (a non-profit university-governed consortium in the United States that facilitates geoscience research and education using geodesy), GLASS is an open-source platform, developed by EPOS GNSS Data and Products team, under Creative Commons licensing. It will make possible to compute the velocity of a station using external information to detect co-seismic offsets and co-seismic displacements associated with strong earthquakes. [2] GLASS network consists of individual nodes representing a structure for disseminating GNSS data and products. The integration starts from national RIs over national nodes up to EPOS integration service. In the GLASS philosophy, the GNSS raw data (RINEX) are not physically located at the GNSS data gateway but remain on the underlying data nodes. GLASS offers the means to make this data discoverable at the data portal. Figure 2 only shows the stations that are included in the NIEP GLASS node. This node distributes GNSS data from Romania and includes data from stations managed by the National Institute for Earth Physics - NIEP, National Institute for Research and Development on Marine Geology and Geo-ecology – GeoEcoMar and TopGeocart company. This node accepts data from Romanian GNSS Stations that comply with minimum quality levels of operation and in accordance with the representative Node’s established standards. The data from ROMPOS were not included in the agreement due to administrative rules, the network contributes only with the EUREF common stations.

Moving on with the testing procedure, test metadata was retrieved from https://gitlab.com/gpseurope/test-data-and-tools. Insertion of T1 metadata into the database proceeded with no errors and was confirmed, as well as the insertion of data center metadata.

For data services, a dedicated data portal for accessing data (RINEX) was created, as well as a metadata of stations from different local data centers. The GNSS Data Gateway (Figure 4) provides access to information about the GNSS stations, information on the file and allows to download data. Access to the metadata and data is provided through the web and a command-line client.

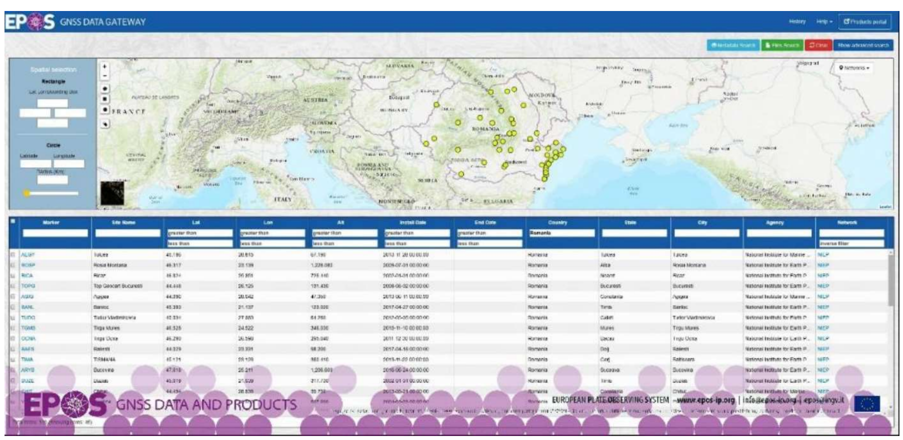

Figure 4: ROGNSS metadata interface on the GNSS Data Portal

The GNSS products consist of the multi-year positions and velocities of all stations (Figure 2) together with the position time series. The GNSS data of all sites are processed with the GNSS Inferred Positioning System and Orbit Analysis Simulation Software - GIPSY-OASIS v.6.2 software, using the Precise Point Positioning - PPP strategy, [3] generating position solutions from each individual observation file. GIPSY is a state-of-the-art analysis tool, which includes a comprehensive suite of models to correct for all thinkable effects, ranging from wet and dry atmospheric distortions of the measurements to ocean loading displacements of the sites. The GNSS data were processed locally for all the permanents networks that are distributed homogeneously on the Romanian territory. Figure 5 shows the results of the horizontal component and time series of 4 stations from the networks detailed in the paper.

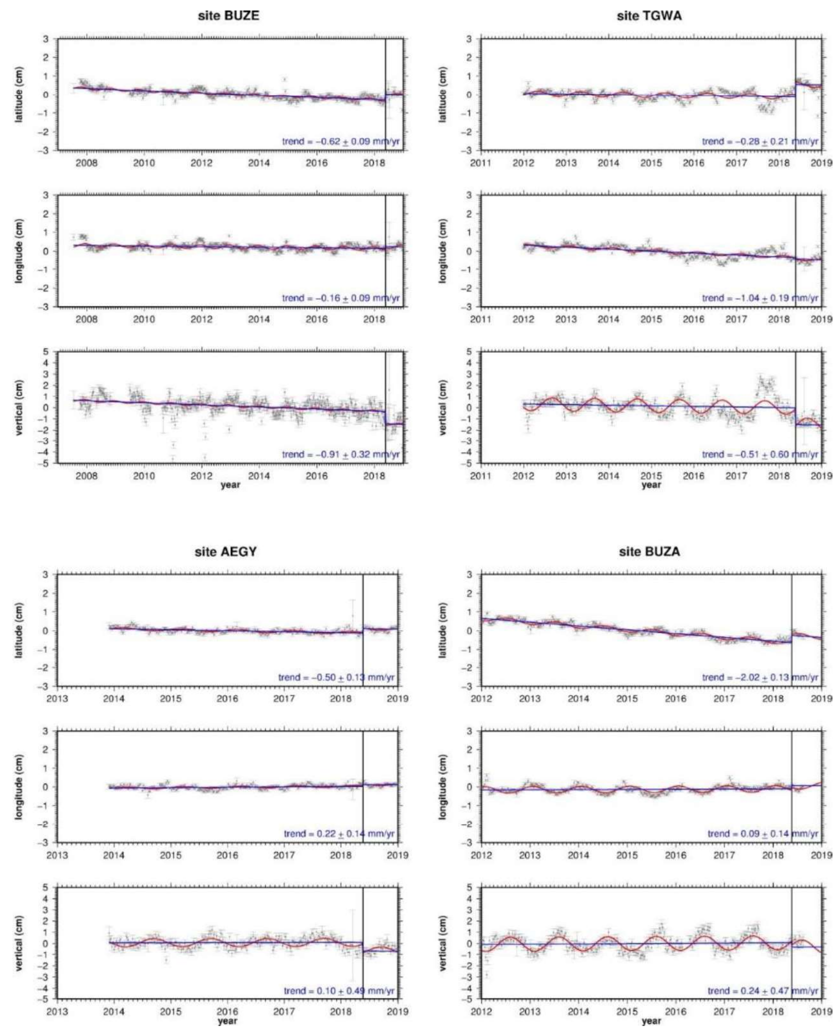

Figure 5: Four examples of the linear regression of the 3-D GPS position solutions

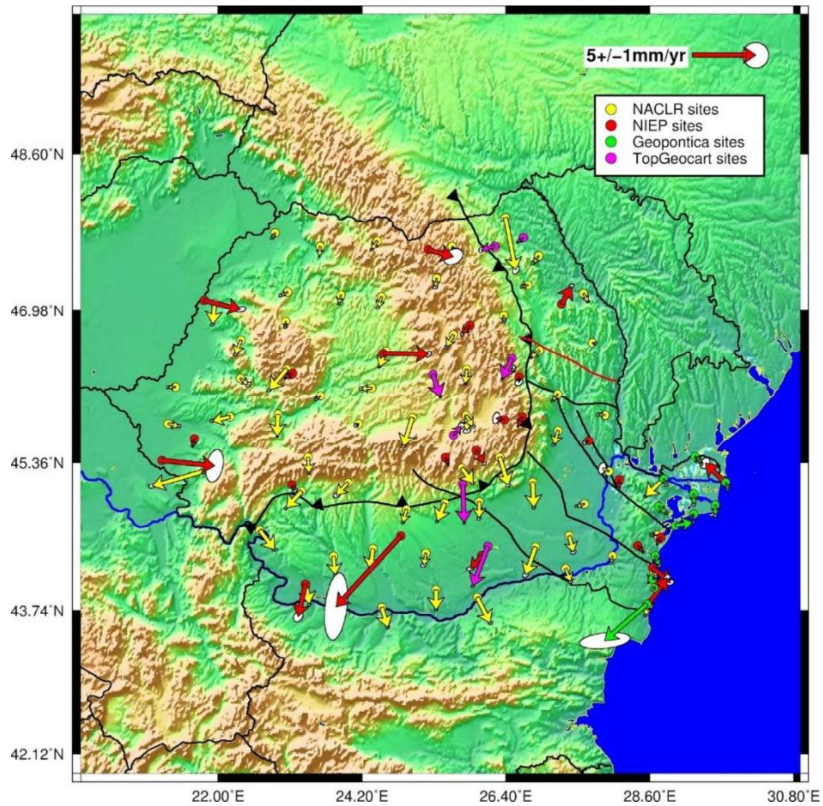

Figure 6: Horizontal motion vectors derived from the GPS observations

CONCLUSION

The work performed is very important because we managed to create a unique GNSS database from a homogeneous combination of all permanent networks and to create metadata in a proper, international standard format, for all stations. We think that for future national and international projects, it will be easier to make a research study having all these stations at our disposal, to promote interdisciplinary interoperability**,** with a special focus on seismology and geology. With GNSS we can study deformation associated with earthquakes. These measurements are complementary to seismological data because they document the full earthquake cycle, including interseismic and transient postseismic processes, as well as coseismic deformation. [4]

The results obtained until now, having only NIEP stations, show that the area tends to move slightly southward relative to Eurasia, at velocity rates of about 2.5 – 3.0 mm/yr. [5] We speculate that this could be a far-field effect of slab roll-back due to the subduction of the African under the Eurasian plate at the Aegean trench, way far to the south.

Having now a dense and homogenous permanent network will help us to understand the geodynamic processes that occurred at national level (Romania) and there is a clear need to think of an interpretation into a large geodynamics framework, looking at the larger interaction effects between the Pancardi system, the southeastern East European and Scythian Platform, the Aegean System and all the way south to the North African Domain.

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