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ONESHOT CALL

EPOS-BE

UPGRADE OF BELGIAN FEDERAL RESEARCH INFRASTRUCTURE FOR EPOS

Carine BRUYNINX, Koen VAN NOTEN, Fikri BAMAHRY, Andras FABIAN, Martin ZECKRA, Juliette LEGRAND, Giovanni RAPAGNANI, Bert FREDERICK, Anna MIGLIO, Dominique JACQUES, Dominique MESMAKER, Ann MOYAERT, Thomas LECOCQ

Royal Observatory of Belgium

EPOS-BE

Upgrade of Belgian federal research infrastructure for EPOS

Contract - FSIRI/33/EP1

English Summary

PROMOTORS: Carine BRUYNINX (Royal Observatory of Belgium)
Michel VAN CAMP (Royal Observatory of Belgium)

AUTHORS: Carine BRUYNINX, Koen VAN NOTEN, Fikri BAMAHRY, Andras FABIAN, Martin ZECKRA, Juliette LEGRAND, Giovanni RAPAGNANI, Bert FREDERICK, Anna MIGLIO, Dominique JACQUES, Dominique MESMAKER, Ann MOYAERT, Thomas LECOCQ (Royal Observatory of Belgium)

1. Context

The European Plate Observing System (EPOS), part of the European Strategy Forum on Research Infrastructures (ESFRI) roadmap, is the first and only pan-European research infrastructure for solid Earth Science. National Research Infrastructures (NRIs) provide data to EPOS via Thematic Core Services (TCS), which represent a subdiscipline of solid Earth Science (e.g. geodesy, seismology, volcanology). In each TCS, selected Service Providers (SP) ensure the data from the underlying NRI are standardized and quality-checked, allowing integration into EPOS' central data portal.
Following BELSPO's oneshot call for proposals to *"Upgrade federal research infrastructures already existing in the FSIs to become, in the medium term, key actors in the ESFRI RI or in the Belgian node*", the GNSS and Seismology-Gravimetry teams of the Royal Observatory of Belgium (ROB) joined forces to answer this call with the **EPOS-BE** project. The EPOS-BE proposal was accepted for funding and the project ran from 15/12/2018 to 15/06/2023.

2. Objectives

The **TCS 'GNSS Data and Products'** (EPOS-GNSS) aims to provide access to GNSS data, metadata and products of minimum 3000 GNSS stations. These data measure precise ground deformations caused by e.g. volcanoes, earthquakes or anthropogenic subsidence. EPOS-GNSS is built on the existing EUREF Permanent GNSS Network (EPN), a European network of about 400 continuously operating GNSS stations. Since ROB hosts the EPN Central Bureau, it was opportune to become one of EPOS' key Service Providers. However, to allow so, ROB's existing EUREF infrastructure and services needed to be adapted to EPOS' needs and workflows (*Objective 1*).
By integrating the data of ROB's own network of high-quality Belgian GNSS stations in EPOS, it is possible to compare the GNSS results with those from other disciplines, increase trust in the results, and improve the measurement and understanding of these small movements. However, first, the outdated hardware and infrastructure of the GNSS stations needed to be upgraded (*Objective 2*).
The **TCS "Seismology"** builds on three service-providing European infrastructures, one of which is ORFEUS (Observatories & Research Facilities for European Seismology). For many years ROB and ORFEUS have been collaborating to provide open access to seismic waveform data through the ORFEUS Data Centre (ODC), one of the nodes within the European Integrated Data Archive (EIDA). Currently, the ROB is streaming data from five broadband seismometers from the Belgian seismic network to ORFEUS. To maintain this provision of high-quality data, the infrastructure of the Belgian seismic network needed to be upgraded and seismic data streaming needed to be improved (*Objective 3*).
In addition, detailed knowledge of the subsurface below the Belgian stations is critical to understand modification of seismic data due to local geology. Hence, in the EPOS-BE project the structure below seismic stations sites of the entire Belgian seismic network needed to be characterized using modern, non-invasive methods (*Objective 4*).

3. Methodology

a. EPOS-GNSS services

In a first step, the EUREF services most suitable to become future EPOS-GNSS services, were selected:

1. The 'Metadata Management and Distribution System for Multiple GNSS Networks' (M^3G), which collects, validates, and distributes the metadata of the EPN stations.

2. The ROB-EUREF data repository that includes all daily GNSS data of the EPN stations since 1996.
3. The 'Data Quality Monitoring Service' (DQMS) monitoring and validating GNSS data quality.
4. The ground deformation monitoring service that regularly computes the positions, velocities, and position time series

In a second step, in consultation with EPOS, it was investigated how the above services could be integrated into the EPOS-GNSS workflows, followed by the actual upgrade of the services.

b. Upgrading infrastructure

The purchase of new state-of-the-art instruments to upgrade both ROB's GNSS stations and the permanent Belgian seismic network, occurred via the process of public procurement after which the hardware was tested and installed (see final report for more details), and the data streaming was set up allowing for data comparison between old and renewed stations.

c. Site characterization

To perform the site characterization, it was opted to move away from classic and expensive seismograph systems and purchase non-stationary nodal systems. Because nodes, to our knowledge, have not yet been used in site characterization, their performance and usage, needed to be studied in detail. A variety of both seismic array and single station methods and configurations were developed and applied during the EPOS-BE project. These methods were then subsequently used to invert a subsurface model (i.e. velocity profile) of the elastic parameters at depth.

4. Results

a. EPOS-GNSS services

To accommodate the large number of expected EPOS stations and new users, **M³G** user-friendliness was increased, its responsiveness was improved by redesigning its database and using a new database server, and the management of personal data was improved to comply with GDPR. In addition, a large number of EPOS-specific functionalities were implemented and administrator tools were developed. As a result, M³G now includes metadata of 3000 permanently tracking GNSS stations and is used by almost 150 European agencies to collect, validate and distribute the metadata of their GNSS stations. The ROB-EUREF data repository was transformed into an **EPOS-GNSS data node** by (1) increasing the reliability of included GNSS data, (2) convincing the EPN stations to share their data with EPOS, (3) installing the GLASS software on top of the data repository, and (4) developing new software for data integration. However, despite successful validation by EPOS, challenges remain with the GLASS software. The improvement of the node software will be tackled in the new ESFRI-FED SERVE project. The **DQMS** was upgraded by implementing new software to monitor data availability, download the data quality metrics from the 10 nodes and forward data quality alarms to node managers. Despite issues with bugs in the node's GLASS software, the DQMS is operational since 2022 as a prototype service, which will be fine-tuned in the SERVE project.
Finally, the EUREF **ground deformation service** was updated by (1) developing new criteria for velocity quality assessment allowing to refine the station classification, (2) implementing a refined outlier rejection of position time series, and (3) integrating Galileo (besides GPS and GLONASS) observations. The service is currently applied in EPOS-GNSS to calculate ground deformations from EPN stations with the highest precision.

b. Upgrading infrastructure

For the purchase of the 6 new **GNSS receivers**, a public tender was issued in 2020 from which the supplier was selected. The equipment was delivered early 2021, tested and installed in ROB's EUREF stations. The data flow to ROB was set up and the data were then integrated in EPOS through the pre-operational ROB-EUREF data node.

After the call for tender finished, 6 new **broadband seismometers** were bought in early 2021. The selected seismometer is the Nanometrics Trillium Compact Posthole 20 s combined with the Centaur datalogger. After the installation of all stations, the seismic waveform data was directly streamed to the ROB and incorporated into the routine processing tasks, after which a clear data quality improvement was noticed. Even though it was not implemented in the EPOS-BE project proposal, we also renewed the Belgian **accelerometric network** as a dedicated budget has been allowed to renew 16 old, outdated Kinemetric-ETNA accelerometers by Nanometric Titan strong motion accelerometers.

After careful reviewing of different **nodal systems**, the decision was made to buy 21 new IGU-16HR SmartSolo® 3-component (3C) 5 Hz geophones for conducting array measurements. To ensure their reliability for site characterization purposes, a series of lab- and field-based comparison tests were performed. These tests indicated that the new nodal systems had an excellent accuracy and low self-noise.

c. Site characterization

A detailed **site characterisation** was performed for 9 seismic stations that have a long performance history in the BE seismic network and that are installed on a typical geological subsurface that is widespread in Belgium. Applying array seismology, combined with known geological information, resulted in a detailed factsheet with site parameters and velocity profiles for each of the stations. The factsheets are made available online, and for stations available in ORFEUS the station book has been updated. Data upload to Orfeus will follow later in 2023.

From the site characterization of the key stations, it was clear that a prior geological investigation already could solve the EC8 soil classification. Hence, the results of the site characterization of the key stations could be extrapolated to all seismic (109) and accelerometric (16) stations in the Belgian seismic network. The seismic stations include all stations in the current network (46), stations in temporary arrays (34) and dismantled stations (29).

5. Conclusions

By the end of the EPOS-BE project, ROB's existing EUREF services were updated to EPOS' workflows, included in EPOS Pilot Operational Testing, and positively evaluated by EPOS. Hence, all were accepted as pre-operational EPOS services and the objective of EPOS-BE for the adaptation and implementation of the EUREF services in EPOS was reached. Similarly, the equipment of both ROB's GNSS stations and the Belgian seismic network (broadband seismometers, accelerometers and nodal systems) were upgraded and extended. This upgrade allows the continued provision of high-quality data and their integration into EPOS. Finally, EPOS-BE allowed the site characterization of the entire Belgian seismic network using geological information and geophysical field array techniques.

To conclude, thanks to the stimulus of EPOS-BE, ROB was able to establish itself as a key provider of (1) GNSS and seismic data, and (2) EPOS-GNSS services. EPOS now has access to ROB's upgraded observation infrastructure and services while ROB benefits from the novel technologies that EPOS is developing as a brand-new e-infrastructure.