Summary

The project "Open Data Portal for European and Belgian GNSS Reference Station Data Collections, Built Upon FAIR Guiding Principles" (FAIR-GNSS), funded under BRAIN-be 2.0, ran from 15 December 2020 to 15 March 2023. It was coordinated by the GNSS team of the Royal Observatory of Belgium (ROB), with support from Ghent University (UGent).

The ROB has long maintained repositories with decades of GNSS (Global Navigation Satellite Systems, e.g., GPS and Galileo) observation data from Belgian and European stations, including the publicly accessible EUREF Permanent Network (EPN) data. These data underpin a wide range of scientific and operational applications—such as monitoring ground deformation and climate change, studying space weather, and enhancing numerical weather predictions.

Despite their wide usage, accessing GNSS RINEX data at ROB was challenging. Issues included limited data discoverability, lack of machine-readable metadata, missing provenance and licensing information, and the absence of standard citation practices. This highlighted the need to modernize GNSS data management at ROB using FAIR (Findable, Accessible, Interoperable, Reusable) data principles.

Objectives

The FAIR-GNSS project aimed to:

1. Improve access to and reuse of GNSS data while building user trust;
2. Support long-term preservation of GNSS datasets;
3. Contribute to the standardization of data citation practices;
4. Develop an open data portal for Belgian and European GNSS data.

Methodology

To meet these objectives, the project adopted a structured, multi-step methodology inspired by FAIR implementation roadmaps:

1. FAIRness assessment: A gap analysis was performed using tools such as the FAIR-Aware questionnaire and FAIRsFAIR Data Object Assessment Metrics to evaluate the initial FAIR maturity of ROB's GNSS repositories and identify areas for improvement.
2. Creating FAIR Digital Objects (FDOs): GNSS data were enriched with rich, machine-readable metadata and assigned Persistent Identifiers (PIDs). This required engaging the GNSS community to define appropriate metadata content and structure, ensuring compliance with community standards (e.g., vocabularies from the International GNSS Service) and selecting or extending existing metadata schemas

(e.g., DCAT, schema.org). The use of PIDs also enhanced findability, accessibility, interoperability, and reusability.

3. Restructuring of repositories: Internal databases and data flows were redesigned to support the inclusion of rich metadata. New tools were developed to automate tasks like data validation and repository population. The repositories were also evaluated using the CoreTrustSeal+FAIR CapMat maturity model, with the goal of evolving into FAIR-enabling, trustworthy data infrastructures.
4. Implementation of FAIR data access: Web APIs were developed to support machine-actionable access to metadata and data. These APIs used open standards (e.g., HTTPS) and supported formats like JSON, XML, and JSON-LD. Existing GNSS APIs were reviewed for compatibility with FAIR requirements and user needs.
5. Development of an Open Data Portal: A beta version of the Open Data Portal was deployed to serve as a central platform for users to discover and access GNSS data and metadata. The portal integrates API access, data search tools, and documentation. Its design was informed by a landscape review of European FAIR and GNSS initiatives.
6. Iterative development: The project followed a logical progression: starting with the enrichment of GNSS (meta)data, followed by improvements in data access protocols, and culminating in the development of user-facing services such as the data portal.

Key results

Two proposals for standardized GNSS metadata were developed: one for station-specific metadata and one for GNSS RINEX files. The station metadata proposal was endorsed by the International GNSS Service (IGS) GeodesyML Task Force.

A metadata model was designed to support DOI-based citation of GNSS datasets, in collaboration with the GGOS DOI Working Group. A software tool and web interface were created to facilitate DOI assignment by data providers.

ROB's internal data workflows were revised to systematically capture provenance information, improve data traceability, and document data corrections.

The Open Data Portal https://www.gnss.be/opendataportal/ and the API support provide enhanced access to curated GNSS data, benefiting scientific research and public/private georeferencing applications.

Conclusions

The FAIR-GNSS project significantly improved the FAIR maturity of ROB's GNSS data repositories. The integration of standardized metadata, PIDs, and open APIs has

enhanced the discoverability, accessibility, and reusability of GNSS datasets. These improvements directly benefit scientific communities focused on environmental monitoring, earth sciences, and geospatial applications.

Recommendations

Implementing a FAIR data ecosystem requires sustained investment in expertise, infrastructure, and collaboration with data stewards and domain experts.

Long-term planning and continuous FAIRness assessments are essential to keep pace with evolving standards and community needs.

Engagement with the GNSS and broader geoscience communities is vital for establishing shared standards and ensuring adoption.

While resource-intensive, each development cycle contributes to improved data quality, trust, and service to users.

A key takeaway from FAIR-GNSS is that applying FAIR principles is not a one-time effort but a continuous process that yields cumulative improvements. ROB's GNSS services now better support the needs of Belgian, European, and global users, while laying the groundwork for future trust certification.