



**GNSS DATA AND
PRODUCTS**

EPOS' GNSS infrastructure and it's FAIR-aligned data management

Carine Bruyninx

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Royal Observatory of Belgium

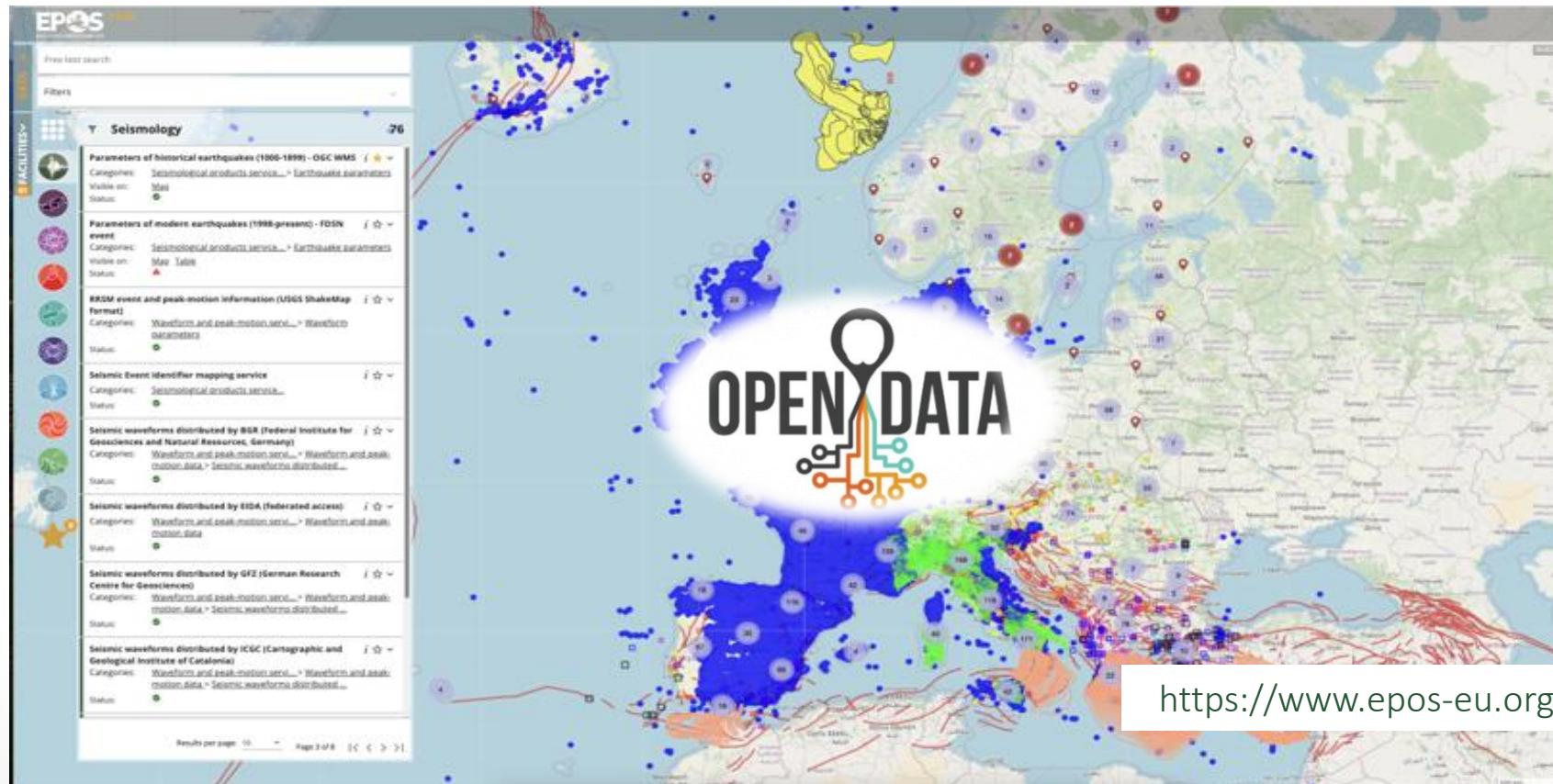
PITHIA-NRF Second High Profile Meeting
March 14, 2025



European Plate Observing System

EPOS is the European Research Infrastructure serving Solid Earth science

Multidisciplinary research platform to provide access to quality-controlled data from diverse Earth science disciplines, together with tools for their use in analysis and modelling



<https://www.epos-eu.org/dataportal>

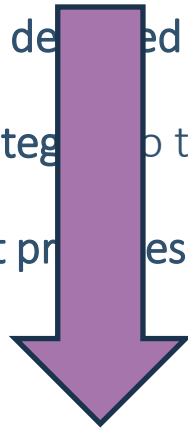
Thematic Core Services (TCS)

- 10 different solid Earth science disciplines **ensure data provision to the EPOS data portal**
- TCS are **transnational governance frameworks** enabling community-specific coordination
- Each TCS is established as a **Consortium** of research organizations with its own governance
- TCS Consortia are designed to:
 - ✓ adopt **joint strategies** to tackle scientific, technical, financial, legal and ethical issues
 - ✓ develop of **best practices** for data harmonization and interoperability



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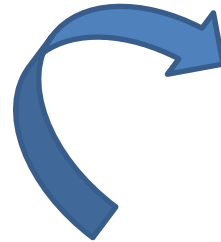
GNSS DATA AND
PRODUCTS

TCS GNSS data and products



EPOS data portal

Web services



Web services



EPOS-GNSS data gateway
<https://gnssdata-epos.oca.eu/>

The screenshot shows the EPOS-GNSS data gateway interface. It features a map of Europe with various colored markers representing GNSS stations. On the left, there are spatial selection tools for rectangles and circles. Below the map, there is a table with columns for Marker, Site Name, Lat, Lon, Alt, Install Date, End Date, Country, State, City, Agency, and Network. The table lists several stations, including AARSCHOT in Belgium.

Marker	Site Name	Lat	Lon	Alt	Install Date	End Date	Country	State	City	Agency	Network
AARS00BEL	AARSCHOT	50.963	4.836	104.660	2002-10-04	...	Belgium	Vlaams-Bra...	Aarschot	Flemish Info...	FLEPOS

EPOS-GNSS product portal
<https://gnssproducts.epos.ubi.pt/>

The screenshot shows the EPOS-GNSS product portal interface. It features a map of Europe with various colored markers representing GNSS stations. On the right, there are data controls for Timeseries, Velocities, Power Spectral Density, and Strain Rate. Below the map, there is a table with columns for S-Char ID, Site Name, Altitude, Country, City, Agency, Network, and Availability. The table lists several stations, including Frankfurt, Gießen, and Rottenburg in Germany.

S-Char ID	Site Name	Altitude	Country	City	Agency	Network	Availability
0022000EU	Frankfurt Oder, DE	108.97	Germany	...	Not disclosed	EPND	...
0020000EU	Gießen, DE	209.38	Germany	...	Not disclosed	EPND	...
0139000EU	Rottenburg, DE	220.43	Germany	...	Not disclosed	EPND	...
0147000EU	0147	388.99	Germany	...	Not disclosed	EPND	...



GNSS DATA AND
PRODUCTS

TCS GNSS data and products



EPOS data portal

Web services

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EPOS-GNSS data gateway

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Marker	Site Name	Lat	Lon	Alt	Install Date	End Date	Country	State	City	Agency	Network
<input checked="" type="checkbox"/>	AARS00BEL	AARSCHOT	50.963	4.836	104.660	2002-10-04	Belgium	Vlaams-Brabant	Aarschot	Flemish Info...	FLEPOS

EPOS-GNSS product portal

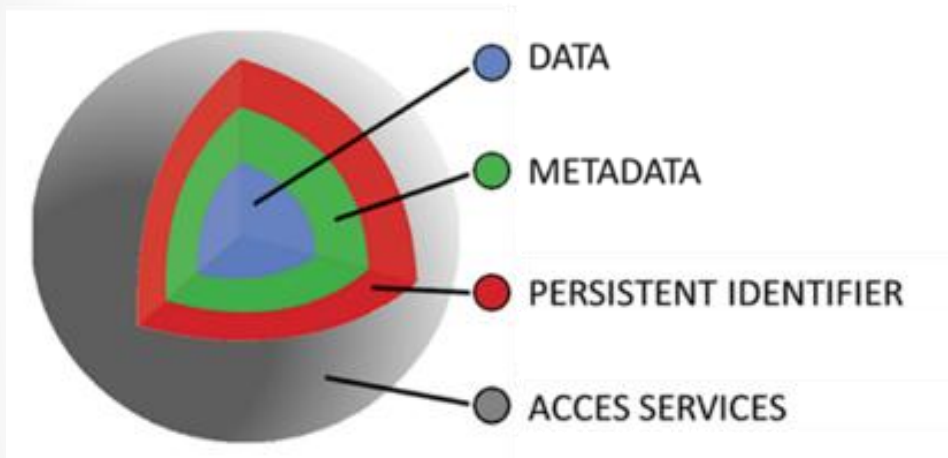
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0022000EU	Frankfurt Oder, DE	108.97	Germany	...	Not disclosed	EPND	<input checked="" type="checkbox"/>
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0139000EU	Rothenburg, DE	220.43	Germany	...	Not disclosed	EPND	<input checked="" type="checkbox"/>
0147000EU	0147	388.99	Germany	...	Not disclosed	EPND	<input checked="" type="checkbox"/>

FAIR data principles - Methodology

CREATION OF FAIR DIGITAL OBJECTS (FDO)



EPOS-GNSS implementation started in 2015

FAIR data principles were not on the table at that time

These last years → effort to catch up

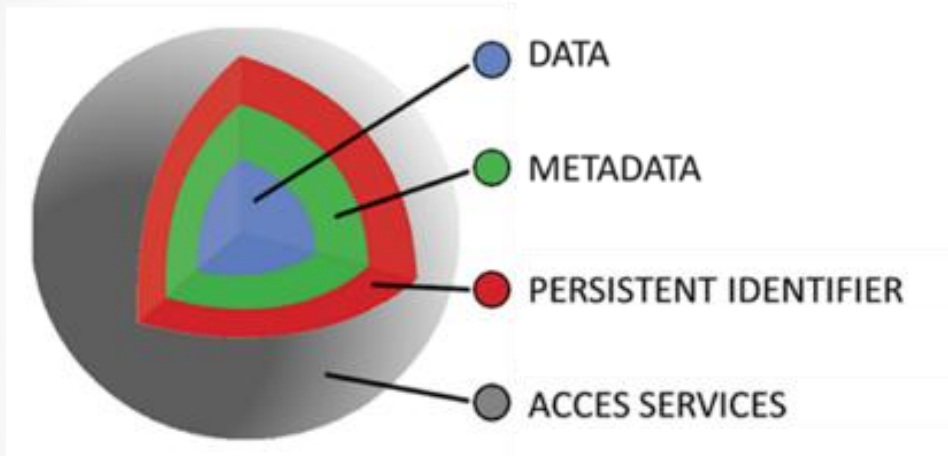
The action plan “Turning FAIR into reality” from the EC expert group on FAIR data (2019)*

- Originally introduced the concept of **FAIR Digital Objects (FDO)**
- Turn your data into FAIR Digital Objects

* *Turning FAIR into Reality: Final report and action plan from the European Commission expert group on FAIR data. Publications Office of the European Union. <https://doi.org/10.2777/1524>*

FAIR data principles - Methodology

CREATION OF FAIR DIGITAL OBJECTS (FDO)



Step 1: Construct a metadata shell around GNSS data files

- Metadata must provide all necessary information a user needs to know about the data
- Use of standardized metadata schema and controlled vocabularies
- Ensure metadata is machine-readable for automated processing.

Step 2: Assign Persistent Identifiers (PIDs)

- URLs that provide long-term (persistent) link to the data
- Enhance findability and long-term accessibility.

Step 3: Implement GNSS data access services

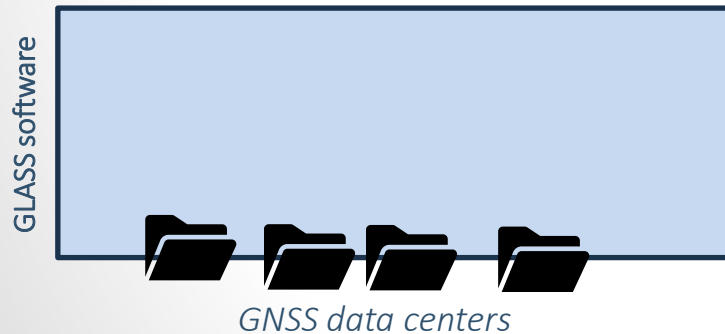
- Users need search services to find relevant GNSS data and metadata
- Ensure efficient data discovery and retrieval.

EPOS-GNSS data flow concept



GNSS data centers

EPOS-GNSS data flow concept

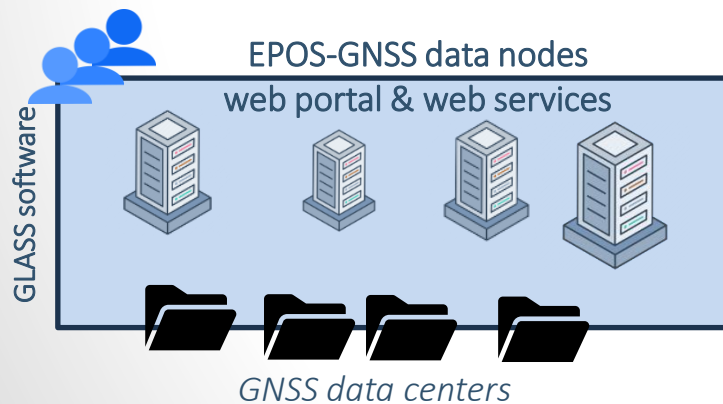


GLASS software: Make data in a GNSS data center discoverable within EPOS

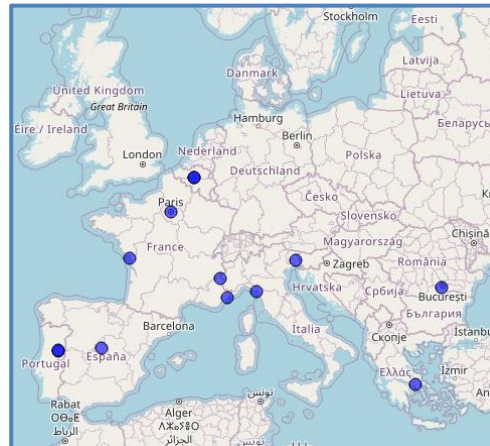
GLASS software

1. Performs GNSS (meta)data quality control
2. Stores results in local database
3. Provides access to GNSS data in data center(s) and results of quality control through web portal and web services (API)
4. If data OK: make data discoverable to the EPOS-GNSS data gateway (web portal and web services) and EPOS portal who will redirect users to the data centers for data downloads

EPOS-GNSS data flow concept



GNSS data nodes

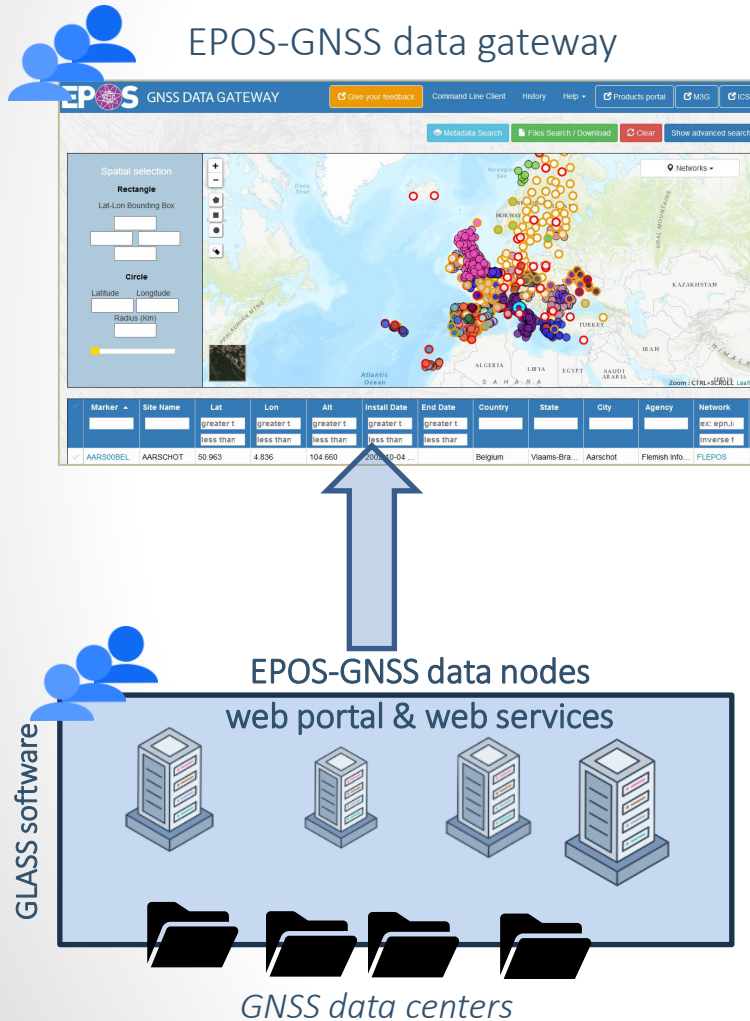


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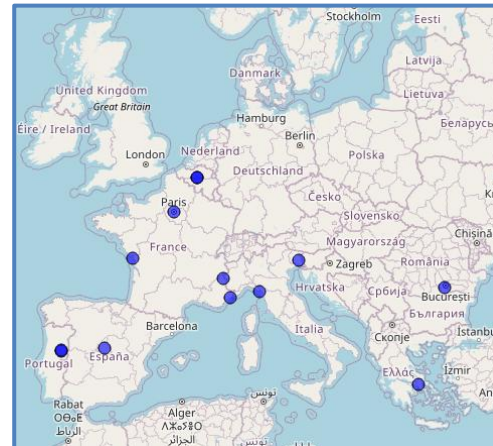
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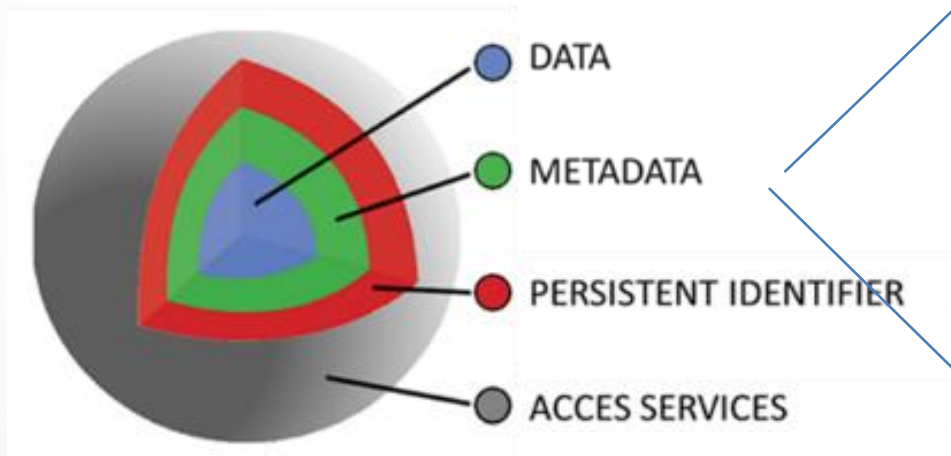
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Steps towards FAIR data

CREATION OF FAIR DIGITAL OBJECTS (FDO)



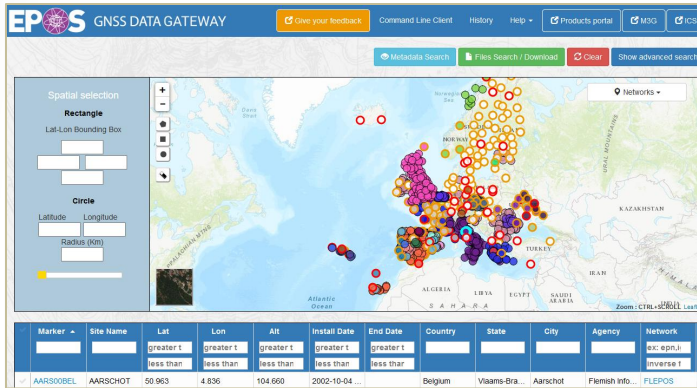
Step 1: Construct a metadata shell around GNSS data files

Collection of rich metadata

- Technical descriptions of GNSS stations
- Data licenses
- Data provenance
- GNSS data quality information → *generated at data nodes and made available through web services*

Collection of GNSS station metadata

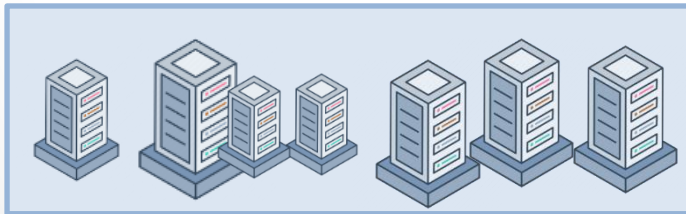
GNSS data gateway



The screenshot shows the EPOS GNSS Data Gateway web application. It features a map of Europe with numerous colored dots representing GNSS stations. On the left, there are search filters for 'Spatial selection' (Rectangle and Circle) and a table of station data. The table includes columns for Marker, Site Name, Lat, Lon, Alt, Install Date, End Date, Country, State, City, Agency, and Network. The first row of data is highlighted.

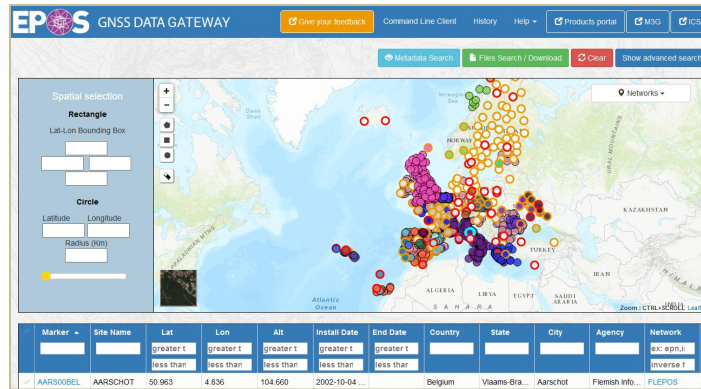
Marker	Site Name	Lat	Lon	Alt	Install Date	End Date	Country	State	City	Agency	Network
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GNSS data nodes

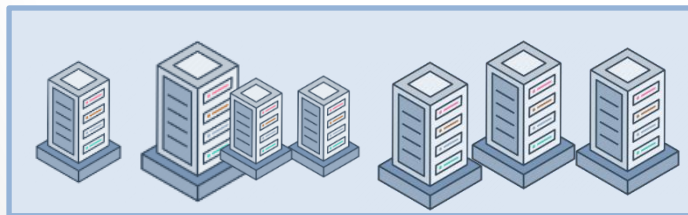


Collection of GNSS station metadata

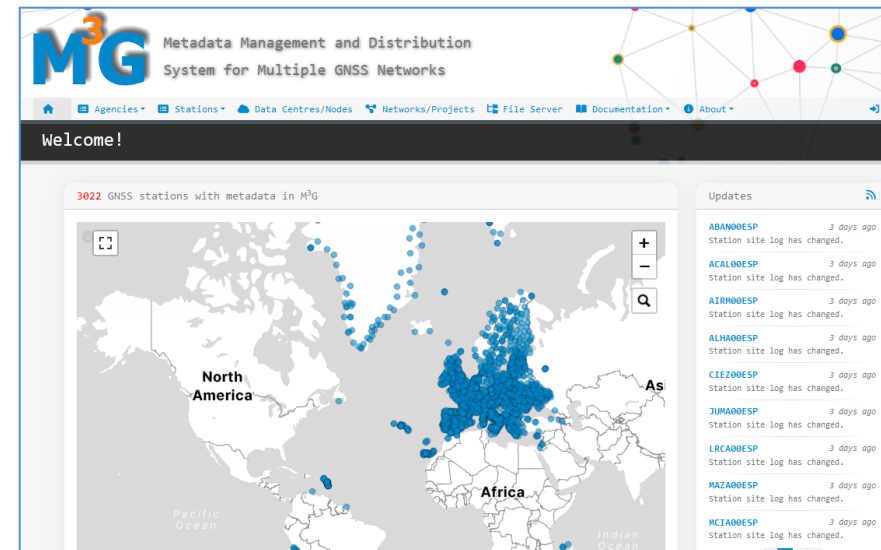
GNSS data gateway



GNSS data nodes



M³G: GNSS station metadata



Operated by Royal Observatory of Belgium, ROB

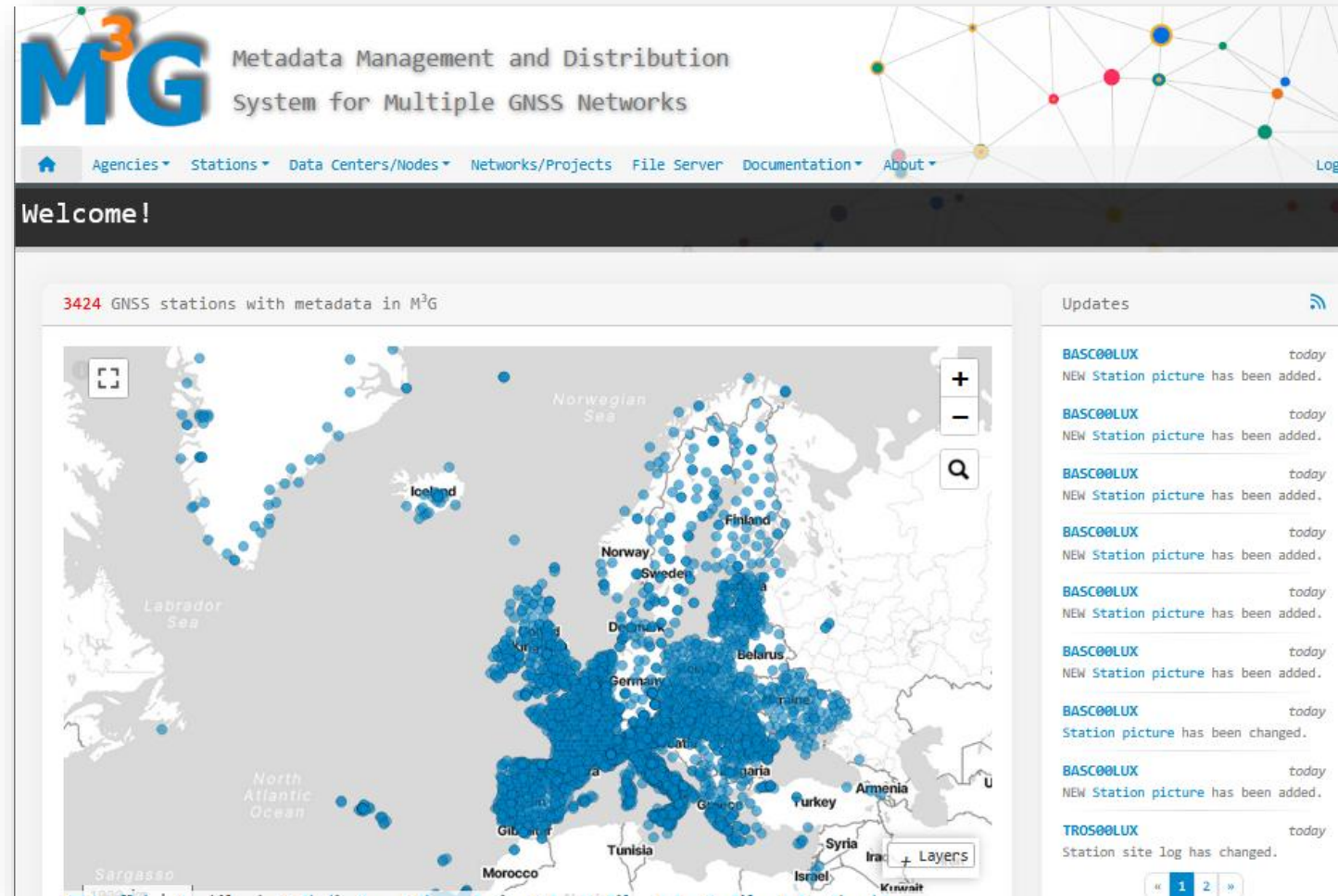
Collection of GNSS station metadata (M³G)

Mandatory for all GNSS stations whose data are integrated in EPOS

<https://gnss-metadata.eu>

Using international standards

GUI & API





Metadata Management and Distribution System for Multiple GNSS Networks



Agencies ▾

Stations ▾

Data Centers/Nodes ▾

Networks/Projects



Login

GNSS stations with metadata in M³G

Technical description of GNSS stations

Data license
Information maintained by the station
owners (registered accounts)

9-CHAR ID ▾	COUNTRY	INSTALLATION DATE	GNSS RECEIVER	GNSS ANTENNA	ANTENNA RADOME TYPE	LAST TRACKED SATELLITE SYSTEMS	LAST UPDATE OF SITE LOG	DATA LICENSE
(all)	(all) ▾	(from-to)	(all)			(all)	(from-to)	(all) ▾
AARS00BEL	Belgium (BEL)	2002-10-04	LEICA GR50	LEIAR25.R3	LEIT	GPS+GLO+GAL+BDS	2024-03-15	CC-BY-4.0
ABAN00ESP	Spain (ESP)	2013-02-11	LEICA GR30	LEIAR25	LEIT	GPS+GLO+GAL+BDS	2024-10-30	CC-BY-4.0
ABBS00GBR	United Kingdom of Great Britain and Northern Ireland (the) (GBR)	2004-10-29	LEICA SR530	LEIAT504	LEIS	GPS	2023-04-06	CC-BY-4.0
ABD000GLP	Guadeloupe (GLP)	2012-10-05	SPECTRA SP90M	AERAT1675_120	SPKE	GPS+GLO+GAL+BDS+SBAS	2024-10-10	CC-BY-4.0
ABDZ00GLP	Guadeloupe (GLP)	2012-10-05	TRIMBLE NETR9	AERAT1675_120	SPKE	GPS+GLO+GAL	2024-09-13	CC-BY-4.0
ABEA00GBR	United Kingdom of Great Britain and Northern Ireland (the) (GBR)	2005-12-05	LEICA RS500	LEIAT504	LEIS	GPS	2023-04-06	CC-BY-4.0
ABEP00GBR	United Kingdom of Great Britain and Northern Ireland (the) (GBR)	2005-07-21	TRIMBLE ALLOY	LEIAR25	LEIT	GPS+GLO+GAL+BDS	2024-01-18	CC-BY-4.0
ABG000GLP	Guadeloupe (GLP)	2017-05-18	LEICA GR25	LEIAR10	NONE	GPS+GLO+GAL+SBAS	2025-01-06	CC-BY-4.0
ACAL00ESP	Spain (ESP)	2013-02-11	LEICA GRX1200GGPRO	LEIAT504GG	LEIS	GPS+GLO	2024-10-30	CC-BY-4.0
ACER00ITA	Italy (ITA)	2007-07-11	TRIMBLE ALLOY	TRM159900.00	SCIS	GPS+GLO+GAL	2024-12-09	CC-BY-4.0
ACHE00FRA	France (FRA)	2021-03-08	SPECTRA SP90M	AERAT1675_120	SPKE	GPS+GLO+GAL+BDS	2023-12-07	CC-BY-4.0
ACIN00ESP	Spain (ESP)	2010-01-19	LEICA GR50	LEIAR20	LEIM	GPS+GLO+GAL+BDS	2024-04-24	CC-BY-4.0
ACNS00ESP	Spain (ESP)	2008-02-14	TRIMBLE NETR9	TRM59900.00	SCIS	GPS+GLO+GAL+BDS	2023-05-31	CC-BY-4.0
ACOM00ITA	Italy (ITA)	2003-07-01	STONEX SC2200	ASH701945E_M	SCIT	GPS+GLO+GAL+BDS+QZSS+IRNSS+SBAS	2024-12-05	CC-BY-4.0
ACOR00ESP	Spain (ESP)	1998-03-06	LEICA GR50	LEIAT504	LEIS	GPS+GLO+GAL+BDS	2025-01-28	CC-BY-4.0
ADAR00GBR	United Kingdom of Great Britain and Northern Ireland (the) (GBR)	2009-03-04	SEPT POLARX5	LEIAR20	LEIM	GPS+GLO+GAL+BDS	2023-06-28	CC-BY-4.0
ADCS00ROU	Romania (ROU)	2019-05-14	LEICA GR30	LEIAR10	NONE	GPS+GLO+GAL+BDS	2023-03-21	CC-BY-4.0



Metadata Management and Distribution System for Multiple GNSS Networks



Agencies ▾

Stations ▾

Data Centers/Nodes ▾

Networks/Projects

File

Provenance information: data
owner, metadata maintainer,
data node

Login

GNSS stations with metadata in M³G



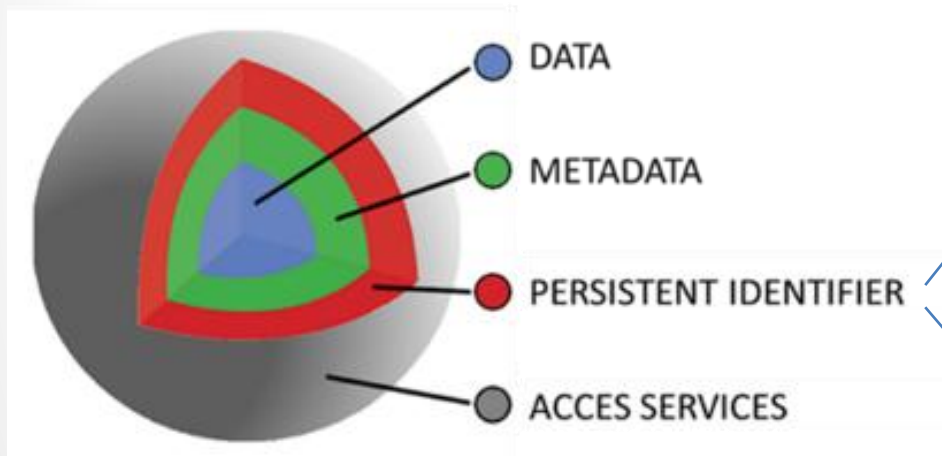
Select Columns for Export ▾

Select Export Format ▾

9-CHAR ID ↕	COUNTRY	METADATA MAINTAINER	RESPONSIBLE AGENCY	DATA CENTERS/NODES
(all)	(all) ▾	(all) ▾	(all) ▾	(all) ▾
AARS00BEL	Belgium (BEL)	ROB	DV	Belgian-node
ABAN00ESP	Spain (ESP)	CARM	CARM	IGE
ABBS00GBR	United Kingdom of Great Britain and Northern Ireland (the) (GBR)	OS	OS	Pan-European
ABD000GLP	Guadeloupe (GLP)	IGN_RGP	TERIA	IPGP-GNSS
ABDZ00GLP	Guadeloupe (GLP)	OVSIG-IPGP	IPGP	IPGP-GNSS
ABEA00GBR	United Kingdom of Great Britain and Northern Ireland (the) (GBR)	OS	OS	Pan-European
ABEP00GBR	United Kingdom of Great Britain and Northern Ireland (the) (GBR)	OS	OS	Pan-European
ABG000GLP	Guadeloupe (GLP)	OVSIG-IPGP	IPGP	IPGP-GNSS
ACAL00ESP	Spain (ESP)	CARM	CARM	IGE
ACER00ITA	Italy (ITA)	INGV	INGV	IRN
ACHE00FRA	France (FRA)	IGN_RGP	TERIA	French-node
ACIN00ESP	Spain (ESP)	IGEAR	IGEAR	IGE
ACNS00ESP	Spain (ESP)	ITACYL	ITACYL	IGE

Steps towards FAIR data

CREATION OF FAIR DIGITAL OBJECTS (FDO)



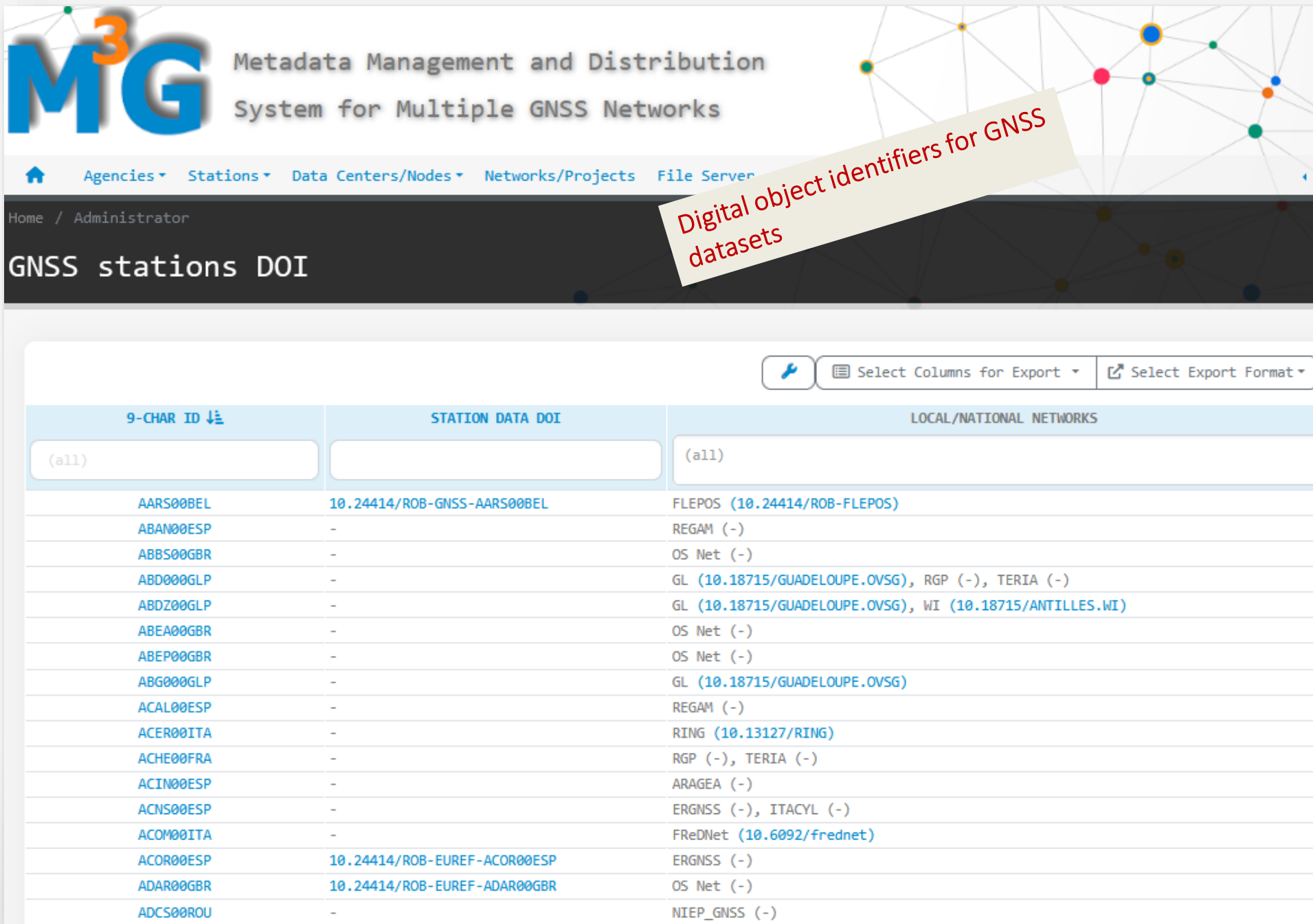
Step 2: Assign Persistent Identifiers (PIDs):

Collection of Persistent Identifiers → Digital Object Identifiers (GGOS)

- Standardization of DOI metadata for GNSS datasets
- DOI for datasets of GNSS stations
- DOI for datasets of GNSS networks

Community engagement

- Encourage GNSS station owners to assign DOI
- Help GNSS stations owners to get DOI
- Cite usage of GNSS data through DOI



MG³ Metadata Management and Distribution
System for Multiple GNSS Networks

Home / Administrator

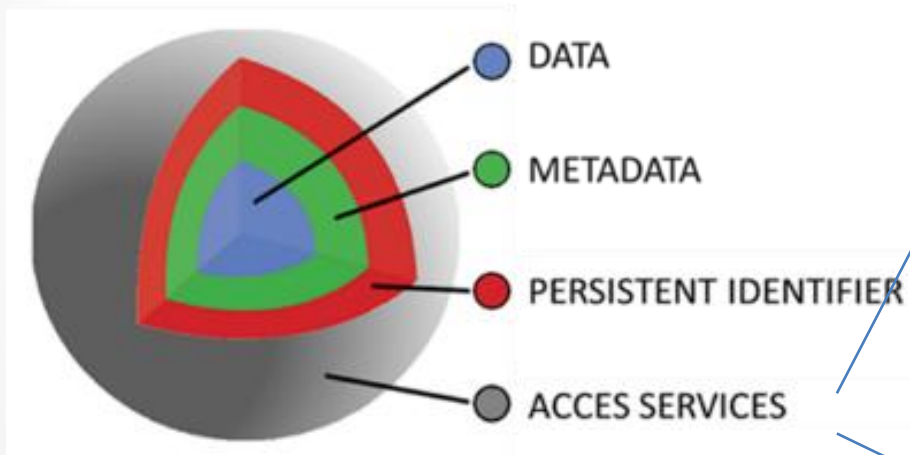
GNSS stations DOI

Digital object identifiers for GNSS datasets

9-CHAR ID ↓	STATION DATA DOI	LOCAL/NATIONAL NETWORKS
(all)		(all)
AARS00BEL	10.24414/ROB-GNSS-AARS00BEL	FLEPOS (10.24414/ROB-FLEPOS)
ABAN00ESP	-	REGAM (-)
ABBS00GBR	-	OS Net (-)
ABD000GLP	-	GL (10.18715/GUADELOUPE.OVSG), RGP (-), TERIA (-)
ABDZ00GLP	-	GL (10.18715/GUADELOUPE.OVSG), WI (10.18715/ANTILLES.WI)
ABEA00GBR	-	OS Net (-)
ABEP00GBR	-	OS Net (-)
ABG000GLP	-	GL (10.18715/GUADELOUPE.OVSG)
ACAL00ESP	-	REGAM (-)
ACER00ITA	-	RING (10.13127/RING)
ACHE00FRA	-	RGP (-), TERIA (-)
ACIN00ESP	-	ARAGEA (-)
ACNS00ESP	-	ERGNSS (-), ITACYL (-)
ACOM00ITA	-	FReDNet (10.6092/frednet)
ACOR00ESP	10.24414/ROB-EUREF-ACOR00ESP	ERGNSS (-)
ADAR00GBR	10.24414/ROB-EUREF-ADAR00GBR	OS Net (-)
ADCS00ROU	-	NIEP_GNSS (-)

Steps towards FAIR data

CREATION OF FAIR DIGITAL OBJECTS (FDO)



Step 3: GNSS data access services

EPOS-GNSS Data gateway/nodes and M³G have API to retrieve GNSS (meta)data

- But original EPOS API not developed with FAIR data principles in mind → improvements necessary
- Require background work on
 - standardization of rich metadata (e.g. GNSS-DCAT-AP)
 - Upgrade web services

→ Currently, not all collected rich metadata can be retrieved from EPOS data portal

ROB's: Already existing Open data portal aligned with FAIR data principles:
Paper submitted to GPS sol. with detailed description of methodology

<https://gnss.be/opendataportal>


<https://fair-gnss.oma.be> + link to webinar

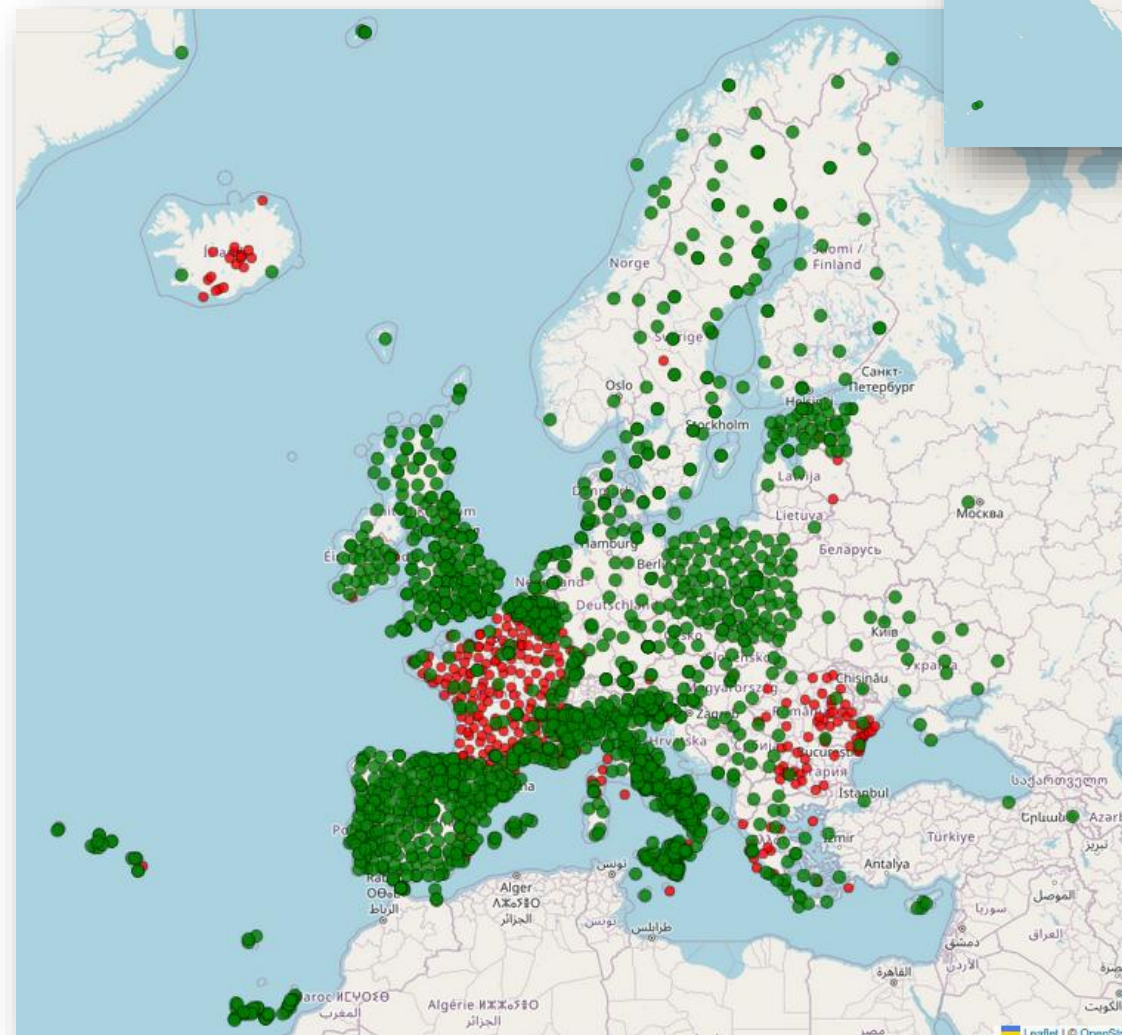
EPOS-GNSS stations : Available data

2110 GNSS stations

Legend:

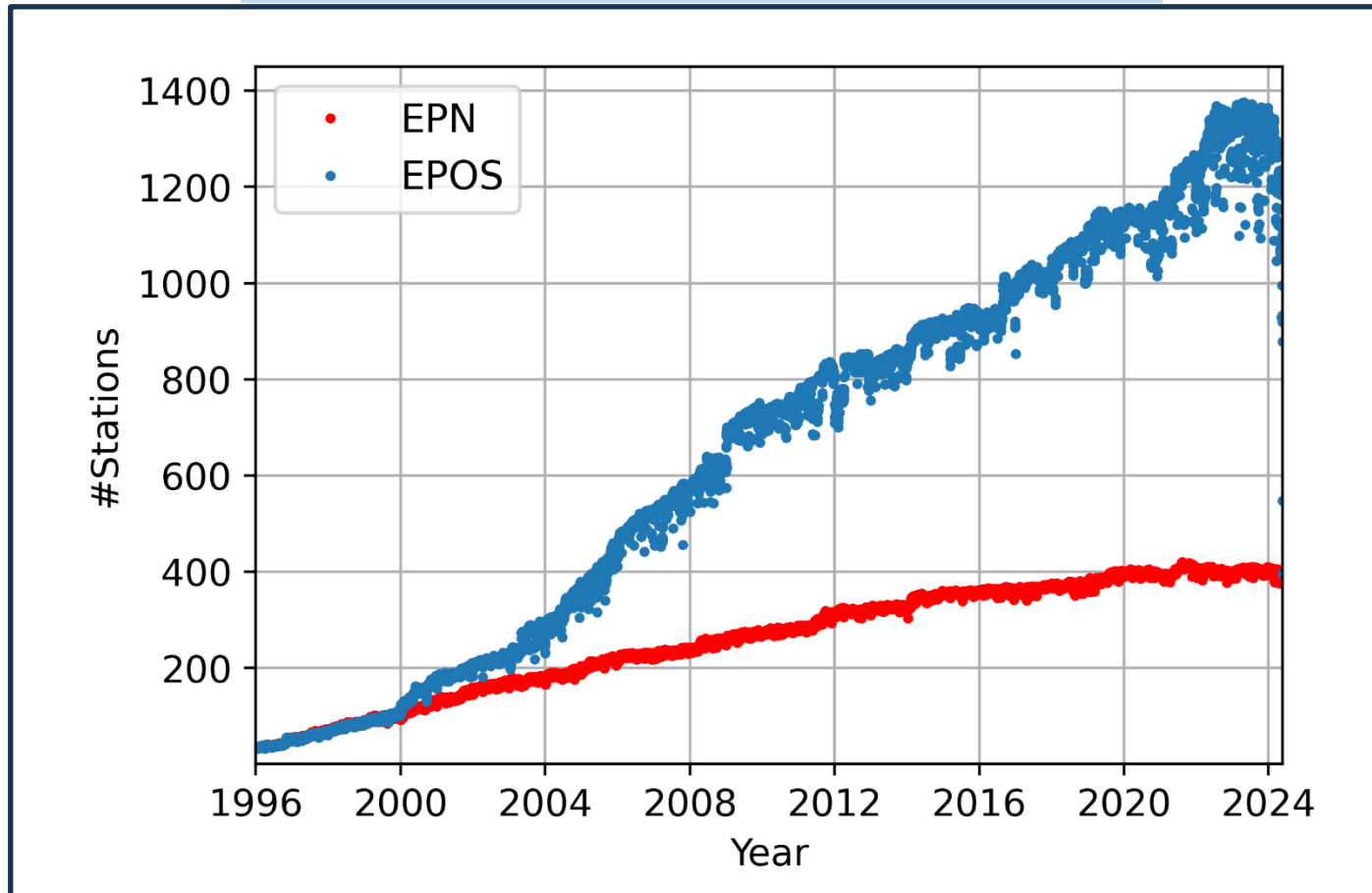
 Proposed EPOS-GNSS stations: **353**

 Included EPOS-GNSS stations: **1757**



Increase of available GNSS data files

Number of stations with GNSS RINEX files

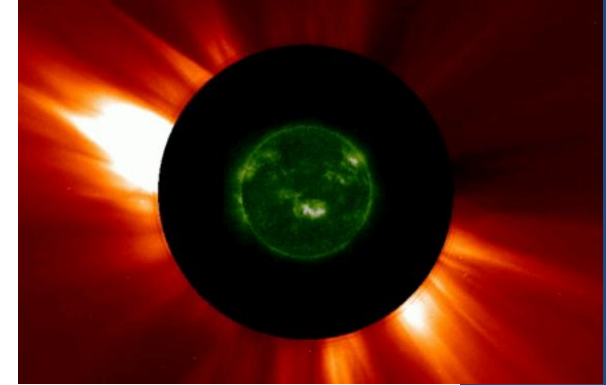


Added-value of increased GNSS data availability

Exercise

Solar storms of May 2024 was a series of powerful solar storms with extreme solar flares and geomagnetic storm components that occurred from 10–13 May 2024 during solar cycle 25.

Pierrard et al, 2025, Effects of the Geomagnetic Superstorms of 10–11 May 2024 and 7–11 October 2024 on the Ionosphere and Plasmasphere, Atmosphere 2025, 16(3), 299; <https://doi.org/10.3390/atmos16030299>



Effect on GNSS operations : interruptions in GNSS signal reception ?

- Quantification of % increase of signal interruption wrt baseline values (28-04-2024 to 05-05-2024)
- Using on one hand EUREF's GNSS network and on the other hand EPOS' GNSS network



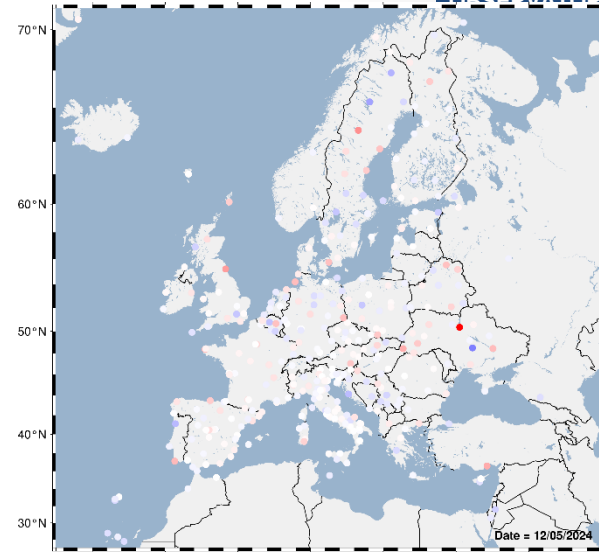
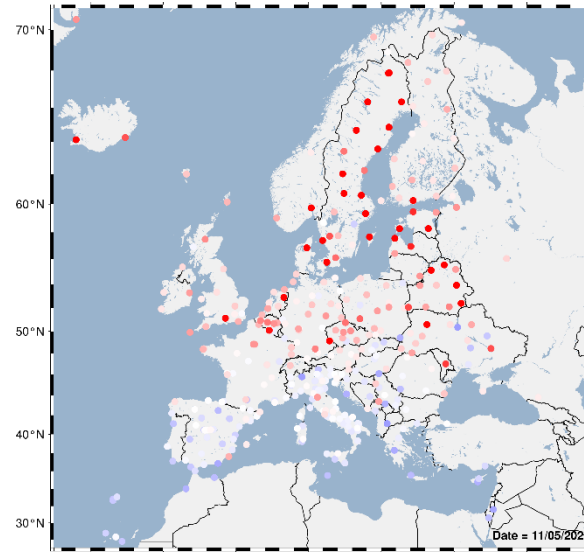
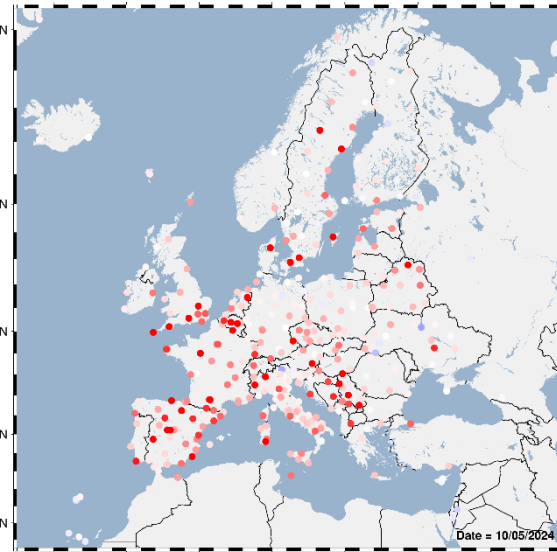
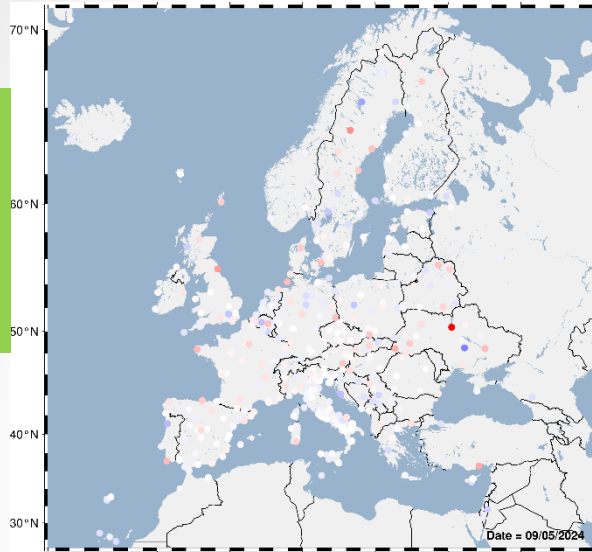
May 9

May 10

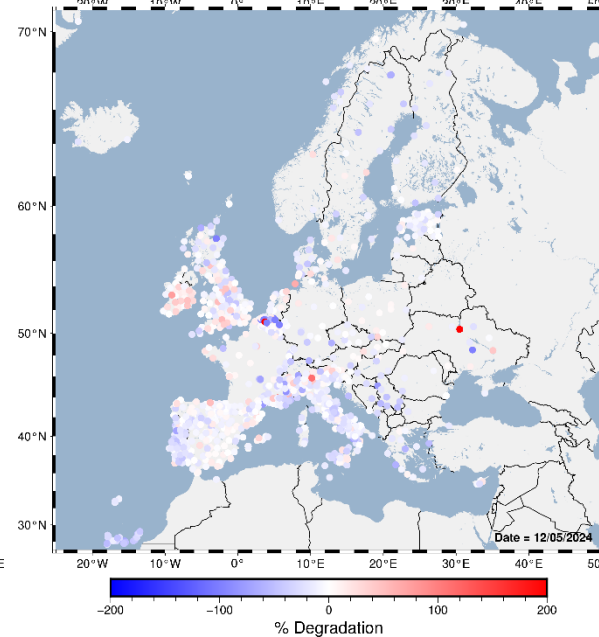
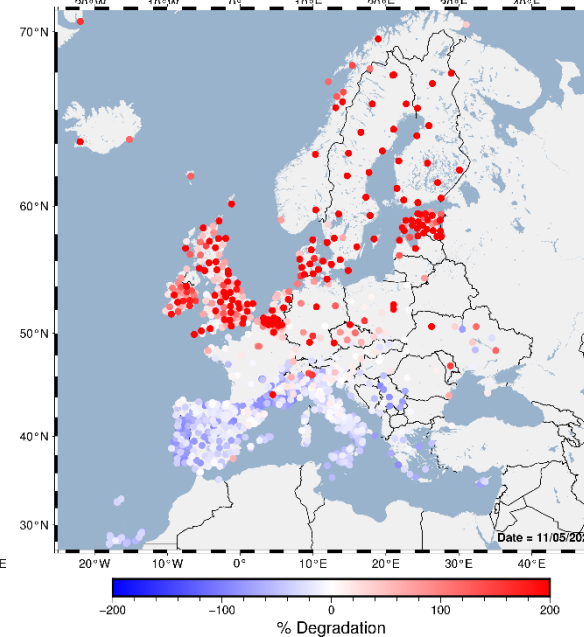
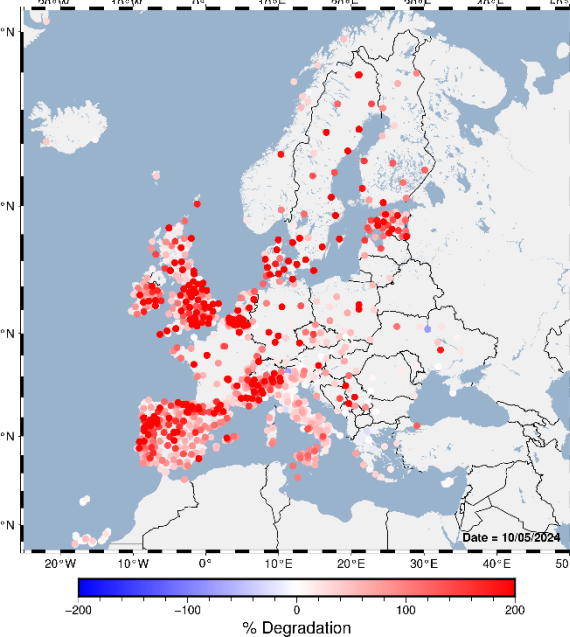
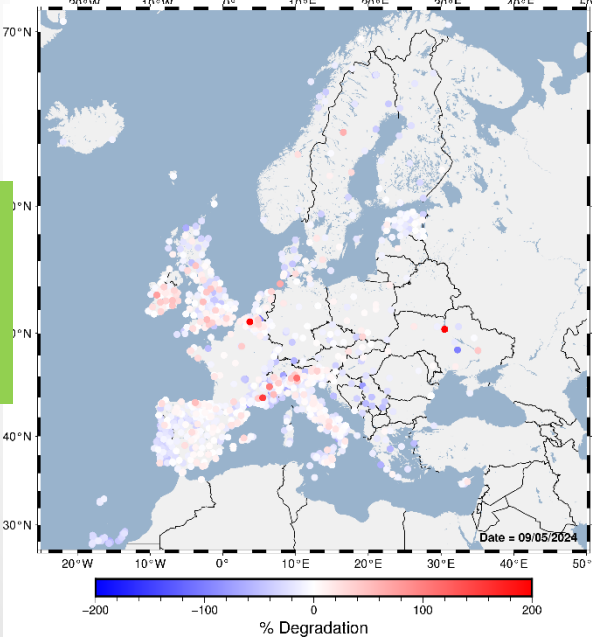
May 11

May 12 2024

EUREF



EPOS



Concluding remarks

- EPOS is example of a European Research Infrastructure Consortium (EPOS ERIC)
 - Members are countries that pay annual membership fee and commit to support EPOS activities in their countries
 - Sustainability of the services remains a challenge
- EPOS-GNSS provides centralized access to GNSS data (and data products) of 1000's of GNSS stations
 - Valuable source of information for multi-disciplinary research and generation of operational products
 - Distributed infrastructure of data nodes and GNSS metadata system (M³G)
 - Implementation of FAIR data principles is ongoing

Contact

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ROB's EPOS team
epos@oma.be

The EPOS@ROB activities received funding from



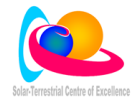
Belgian Science Policy Office under grant agreements No
FSIRI/33/EP1, EF/211/SERVE, and B2/202/P2/FAIR-GNSS



the European union's Horizon 2020 research and innovation
programme under grant agreements No 871121 and 101058518



the European Plate Observing System Research Infrastructure
Consortium



the Solar-terrestrial Centre of Excellence