



GNSS DATA AND
PRODUCTS

EPOS' progress towards making quality-controlled (meta)data discoverable from thousands of GNSS stations

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Royal Observatory of Belgium

+ several teams involved in EPOS (OCA, UBI, INGV,...)



Webinar Nov. 30, 2023



GNSS data in a nutshell



- Global Navigation Satellite Systems, e.g. GPS, Galileo, GLONASS, BeiDou
- GNSS satellites emit radio signals captured by **GNSS stations** installed at fixed locations on the Earth
- GNSS data used for **multi-disciplinary applications**: surveying/mapping, monitoring of ionosphere, troposphere, **monitoring of ground deformations**, ...

Mission of GNSS component of EPOS

- Make openly available data from as many as possible permanently tracking GNSS stations
- Generate and distribute GNSS data products tuned to the needs of EPOS users through the EPOS data portal





GNSS DATA AND PRODUCTS

EPOS data portal

<https://www.ics-c.epos-eu.org/>

Access to multi-disciplinary data & products

EPOS 1.0.24
EUROPEAN PLATE OBSERVING SYSTEM

Free text search

Filters

Category	Count
All data and services	259
Seismology	66
Near Fault Observatories	40
GNSS Data and Products	13
Volcano Observations	34
Satellite Data	8
Geomagnetic Observations	15
Anthropogenic Hazards	46
Geological Information and Modeling	8
Multi-scale Laboratories	6
Tsunami	23
Favourites	0

500 km | Leaflet | Powered by Esri | Earthstar Geogra



ROYAL OBSERVATORY OF BELGIUM



GNSS DATA AND
PRODUCTS

The challenge when we got started

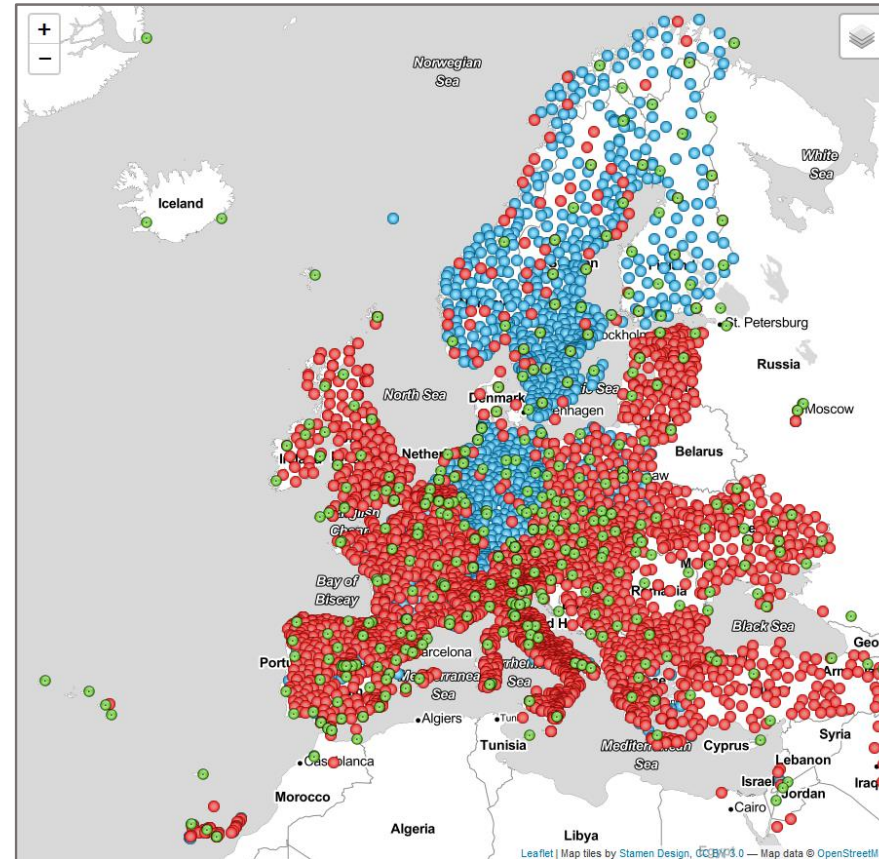
~5000 existing GNSS stations with data operationally analyzed for high-precision applications

→ Huge potential for integration in EPOS RI

GNSS data used for multi-disciplinary applications

- Reference frames (EUREF)
- Surveying
- Ground movements and strain rates
- Space weather
- Numerical weather prediction
- Sea-level monitoring
- Soil moisture
- Ice and snow thickness
- ...

EUROPEAN PLANETARY OBSERVING SYSTEM



- 100s of different agencies
- Diverse communities, not necessarily talking to each other
- Different modus operandi and objectives
- Only small part of GNSS data discoverable in an organized way (EUREF stations < 400 – in green in map)



GNSS DATA AND
PRODUCTS

From 2015 on ...



Bring diverse GNSS communities together using an inclusive approach and **construct new GNSS infrastructure** inspired by the existing EUREF network

- ✓ Set up governance framework which also includes representatives from data providers and users
- ✓ Design and implement the necessary procedures and building blocks to provide operational services ensuring
 - Discoverability of quality-checked GNSS data and station metadata
 - Generation and discoverability of GNSS products
- ✓ Using international community-agreed standards

RELIABLE PRODUCTION CHAIN FOR PROVISION OF THE GNSS SERVICES



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RELIABLE PRODUCTION CHAIN FOR PROVISION OF THE GNSS SERVICES



GNSS DATA AND
PRODUCTS

Community-agreement on basic principles

- 1) Daily GNSS data – 30 sec. sampling
- 2) GNSS station metadata
 - i. All GNSS stations MUST provide and maintain up-to-date descriptions of the configuration in their GNSS stations (e.g. antenna changes)
 - ii. All GNSS station descriptions must be available to the user
- 3) **Centralized access** to GNSS data based on distributed infrastructure of data nodes
- 4) GNSS data quality
 - i. All GNSS data must undergo data quality control
 - ii. Results of the GNSS data quality control must be provided to the user and the station manager
- 5) **Recently: FAIR data** principles
 - i. All GNSS datasets must have a data license
 - ii. All GNSS datasets must have a DOI



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GNSS DATA AND PRODUCTS

Mandatory for all GNSS stations whose data are integrated in EPOS

GNSS station metadata (M³G)

<https://gnss-metadata.eu>

Collection, validation, and distribution of GNSS station metadata

Using international standards

GUI & API



M³G Metadata Management and Distribution System for Multiple GNSS Networks

Welcome!

3053 GNSS stations with metadata in M³G

Updates

- SZOL00HUN** today
Receiver changed to LEICA GR50 (SN:2091474) (FW:4.70/7.813)
- ERLA00DEU** today
Receiver changed to JAVAD TRE_3 DELTA (SN:04117) (FW:4.1.06-221128)
- GYOM00HUN** yesterday
Receiver changed to LEICA GR50 (SN:2091375) (FW:4.70/7.813)
- ASGEOPOS** yesterday
Station ZAM00POL included to the ASGEOPOS network.
- ASGEOPOS** yesterday
Station WIKO00POL included to the ASGEOPOS network.
- ASGEOPOS** yesterday
Station STCE00POL included to the ASGEOPOS network.
- ASGEOPOS** yesterday
Station SLUP00POL included to the ASGEOPOS network.
- ASGEOPOS** yesterday
Station PISZ00POL included to the ASGEOPOS network.
- ASGEOPOS** yesterday
Station OSMM00POL included to the ASGEOPOS network.

Leaflet | Map tiles by © Stadia Maps © Stamen Design © OpenMapTiles © OpenMapTiles © OpenStreetMap contributors | GNSS Station Layer by © ROB - CC BY 4.0



GNSS DATA AND
PRODUCTS

GNSS station metadata (M³G)

Home / ROB / Station Metadata / All Metadata

Update BRUX00BEL

Edit BRUX00BEL(A) site log
published version: 2023-01-24

[Import site log](#)
[Export last saved version](#)
[Restore published](#)
[Save all to draft](#)
[Submit saved draft for publication](#)

Search station

- AARS00BEL
- ANTW00BEL ^D
- ARLO00BEL
- ATWR00BEL
- BATT00BEL
- BERL00BEL
- BERT00BEL
- BEZA00BEL
- BGGN00BEL
- BLIG00BEL
- BRCT00BEL
- BREE00BEL ^I
- BRGG00BEL

Sections

Prepared By

GNSSatROB (gnss@oma.be) #5

Date

2023-05-17

- Alert(s)
- Identification
- Location
- Receiver
- Antenna**
- Local Ties
- Frequency Standard

Antenna

2006-07-07 - 2008-03-19 ✓	2008-03-19 - 2008-06-17 ✓
2008-06-17 - 2008-09-02 ✓	2008-09-02 - 2008-09-22 ✓
2008-09-22 - 2008-10-02 ✓	2008-10-02 - 2008-10-20 ✓
2008-10-20 - 2011-03-07 ✓	2011-03-07 - 2018-02-01 ✓
2018-02-01 - 2021-04-20 ✓	2021-04-20 - CCYY-MM-DD ✓

Show/Hide previous GNSS Antenna Information

Antenna * JAVRINGANT_DM

Serial Number * 00464

Antenna Reference Point * BPA: bottom of preamplifier (IGS conventional ARP for "JAVRINGANT_DM" an

Marker->ARP Up Ecc. (m) * 0.4689 m

Marker->ARP North Ecc(m) * 0.0010 m

Marker->ARP East Ecc(m) * 0.0000 m

Alignment from the North *



Community-agreement on basic principles

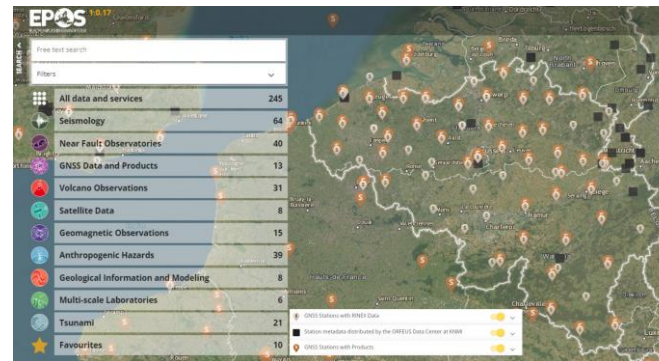
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GNSS DATA AND
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GNSS data dissemination concept

Portal of Integrated Core Services
<https://www.ics-c.epos-eu.org/>



Web services



GNSS data gateway

<https://gnssdata-epos.oca.eu/>

Web services



EPOS-GNSS product portal

<https://gnssproducts.epos.ubi.pt/>

Marker	Site Name	Lat	Lon	Alt	Install Date	End Date	Country	State	City	Agency	Network
<input type="checkbox"/>	AAR500BEL	50.963	4.836	104.660	2002-10-04 ...		Belgium	Vlaams-Bra...	Aarschot	Flemish info...	FLEPOS

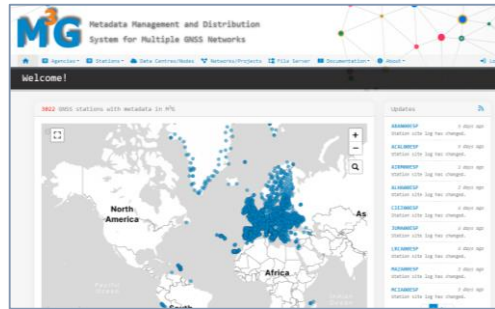
9-Char ID	Site Name	Altitude	Country	City	Agency	Network	Availability
002000EU	Frankfurt Ober, DE	108.97	Germany		Not disclosed	EPNO	<input type="checkbox"/>
002000EU	Guben, DE	109.28	Germany		Not disclosed	EPNO	<input type="checkbox"/>
012000EU	Rothenburg, DE	210.43	Germany		Not disclosed	EPNO	<input type="checkbox"/>
014700EU	0147	380.39	Germany		Not disclosed	EPNO	<input type="checkbox"/>



GNSS DATA AND PRODUCTS

GNSS data dissemination concept

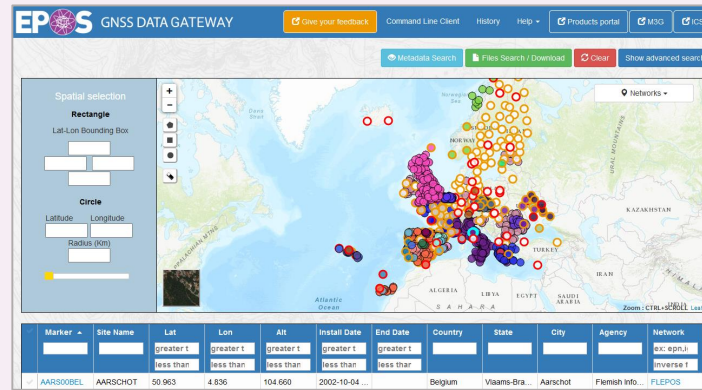
GNSS station metadata



Belgium, ROB



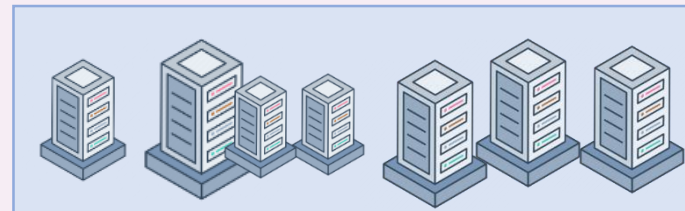
GNSS data gateway



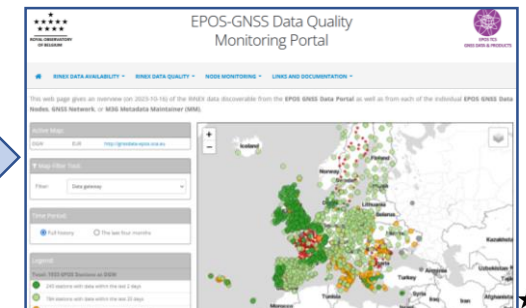
France, OCA



GNSS data nodes



GNSS data quality monitoring service



Belgium, ROB





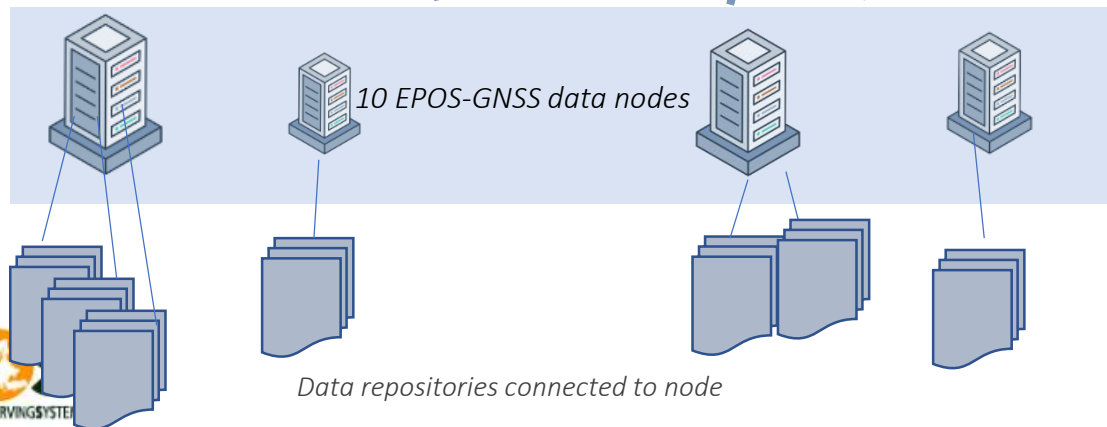
GNSS DATA AND
PRODUCTS

Distributed data access

GNSS Data Gateway

<https://gnssdata-epos.oca.eu>

Marker	Site Name	Lat	Lon	Alt	Install Date	End Date	Country	State	City	Agency	Network
▲	AARSOBEL	greater t	greater t	greater t	greater t	greater t	Belgium	Vlaams-Bra...	Aarschot	Flemish Info...	FLEPOS
▲	AARSCHOT	less than	less than	less than	less than	less than					



Simplified workflow

Station operators upload their GNSS observation data to a data repository

On top of the data repositories: virtualization layer = data node

To make these GNSS data visible to EPOS:

1. Nodes index the GNSS data files in the repository
2. Nodes send <https://...> location of the GNSS data files in the repository to the GNSS Data Gateway

When users connect to GNSS Data Gateway, they will be redirected to the data repositories

GNSS Data Gateway offers centralized access to GNSS (meta)data via

- Web interface
- APIs



GNSS DATA AND
PRODUCTS

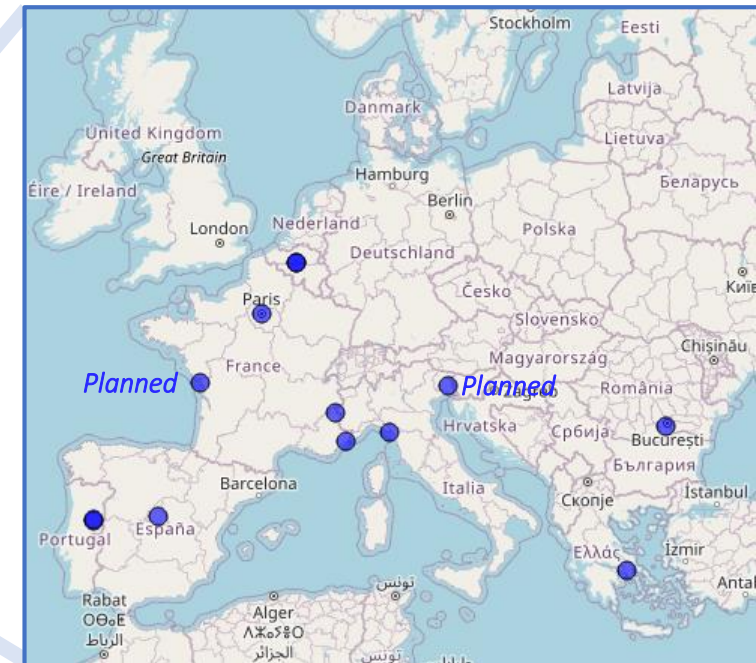
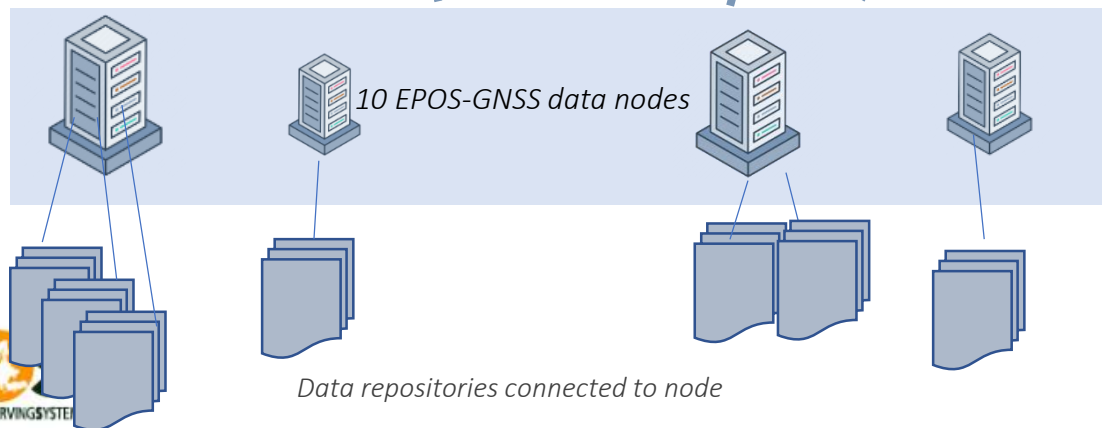
Distributed data access

EPOS GNSS Data Gateway
<https://gnssdata-epos.oca.eu>

Marker	Site Name	Lat	Lon	Alt	Install Date	End Date	Country	State	City	Agency	Network
	AARSOBEL	greater t	greater t	greater t	greater t	greater t	Belgium	Vlaams-Bra.	Aarschot	Flemish Info.	FLEPOS
	AARSCHOT	less than	less than	less than	less than	less than					

Planned in Geo-INQUIRE: SONEL data node: GNSS stations at tide gauges

EPOS-GNSS data nodes

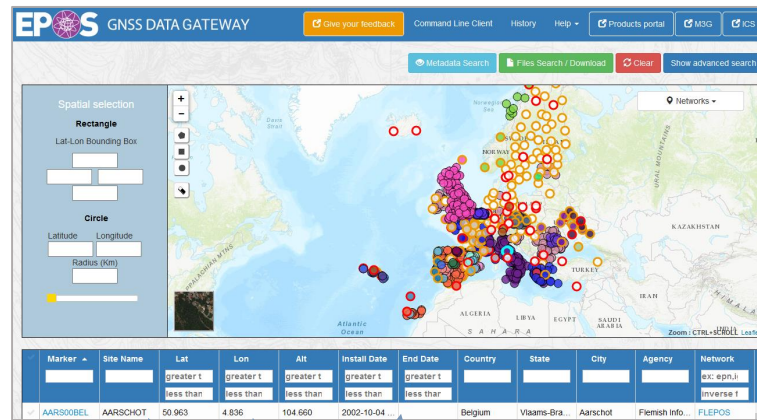




GNSS DATA AND PRODUCTS

Distributed data access

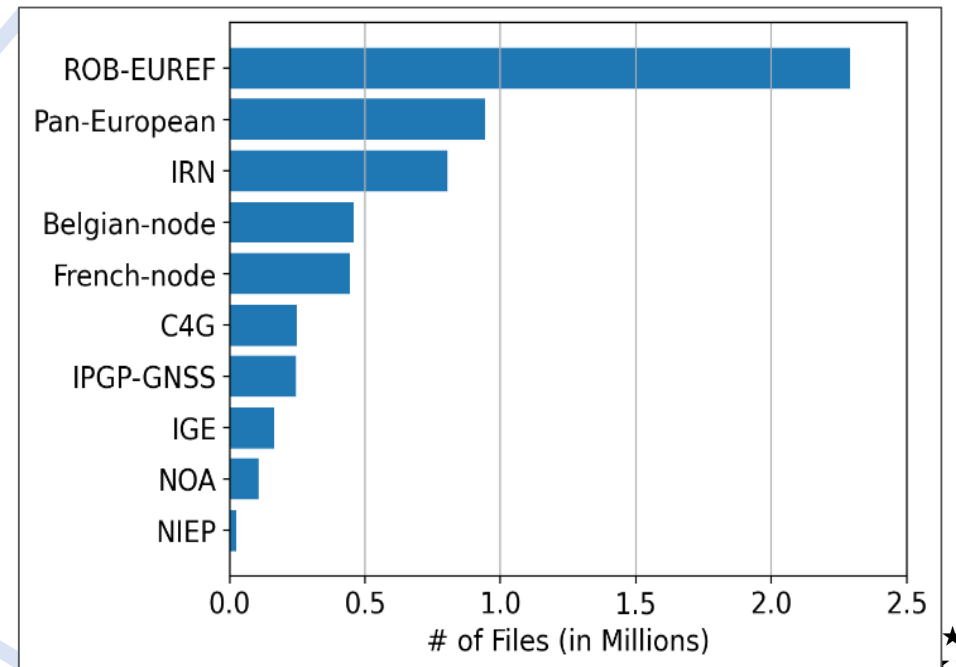
EPOS GNSS Data Gateway
<https://gnssdata-epos.oca.eu>



10 EPOS-GNSS data nodes

Data repositories connected to node

EPOS-GNSS data nodes



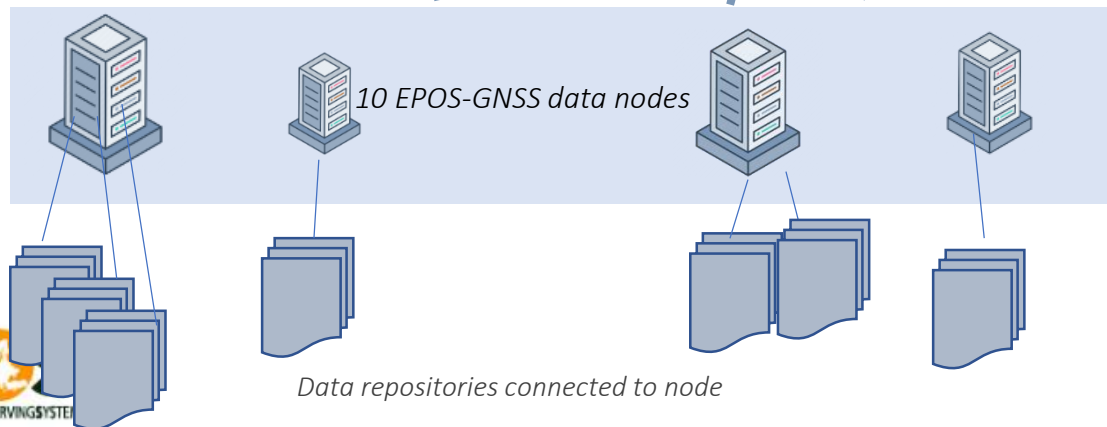


GNSS DATA AND
PRODUCTS

Distributed data access

EPOS GNSS Data Gateway
<https://gnssdata-epos.oca.eu>

Marker	Site Name	Lat	Lon	Alt	Install Date	End Date	Country	State	City	Agency	Network
+	AARSCHOT	greater t less than	greater t less than	greater t less than	greater t less than	greater t less than	Belgium	Vlaams-Bra.	Aarschot	Flemish Info...	FLEPOS



GLASS software ensures harmonization of data nodes:

All nodes perform same 'processing' on GNSS data

- Crosscheck of GNSS metadata in the data files with GNSS station metadata in M³G
- Data quality control of GNSS data (G-nut/Anubis)
- Decide what to do with GNSS data files
 - If 'critical' metadata error, do not inform GNSS Data Gateway of new data
 - If metadata OK, inform GNSS Data Gateway on new data + provide info on data quality



GNSS DATA AND PRODUCTS

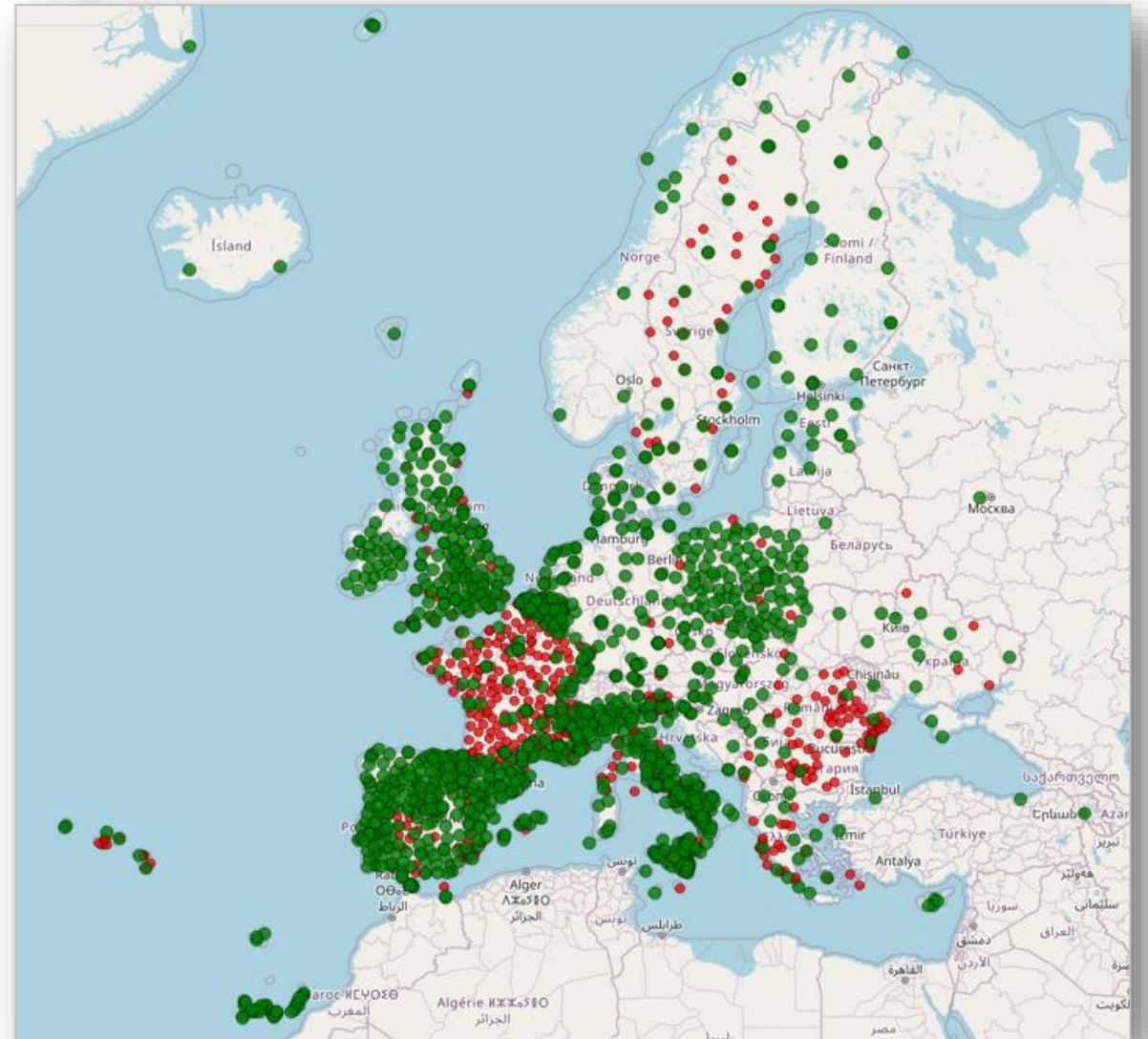
1959 GNSS stations

Legend:

- Proposed EPOS-GNSS stations: 579
- Included EPOS-GNSS stations: 1380

250 GNSS datasets integrated during Geo-INQUIRE

EPOS-GNSS station network





Community-agreement on basic principles

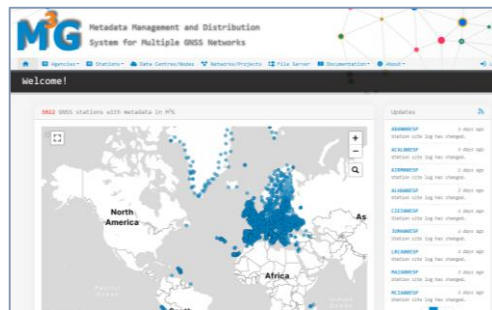
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GNSS DATA AND PRODUCTS

GNSS data quality monitoring

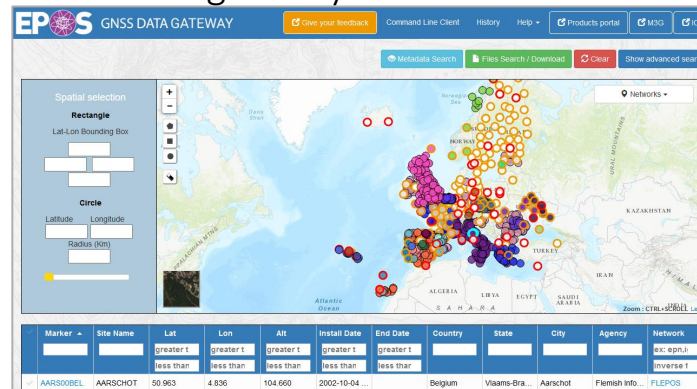
GNSS station metadata



Belgium, ROB



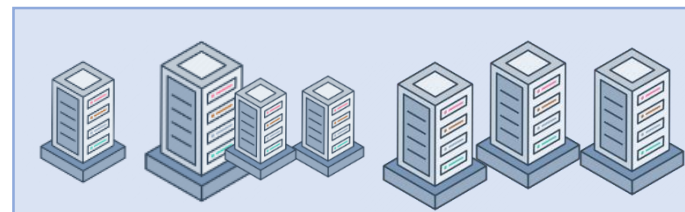
GNSS data gateway



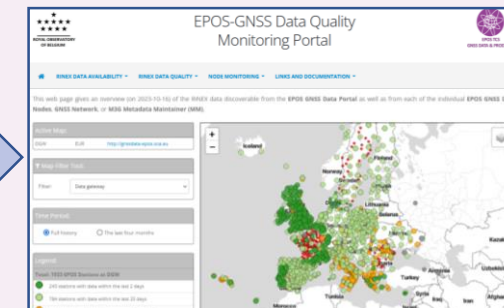
France, OCA



GNSS data nodes



GNSS data quality monitoring service



Belgium, ROB





GNSS Data Quality Monitoring Service (DQMS)

- Nodes are running data quality checks on the data
- GNSS data quality monitoring service
 - retrieves the results of these data quality checks from the nodes
 - computes Data Quality Indicators (DQI)
 - provides DQI plots on DQMS web site
- DQMS web site provides information on
 - GNSS data availability
 - GNSS data quality information

<https://gnssquality-epos.oma.be/>

EPOS-GNSS Data Quality Monitoring Portal

ROYAL OBSERVATORY OF BELGIUM

Home / RINEX Data Availability / DGW

DGW

This web page gives an overview (on 2023-10-16) of the RINEX data discoverable from the EPOS GNSS Data Portal as well as from each of the individual EPOS GNSS Data Nodes, GNSS Network, or M3G Metadata Maintainer (MM).

Active Map:
 DGW EUR <http://gnssdata-epos.oma.be/>

Map Filter Tool:
 Filter: Data gateway

Time Period:
 Full history The last four months

Legend:
 Total: 1933 EPOS Stations at DGW
 ● 243 stations with data within the last 2 days
 ● 784 stations with data within the last 25 days



GNSS DATA AND PRODUCTS

GNSS data availability

Active Map:

DGW EUR <http://gnssdata-epos.oca.eu>

Map Filter Tool:

Filter: Data gateway

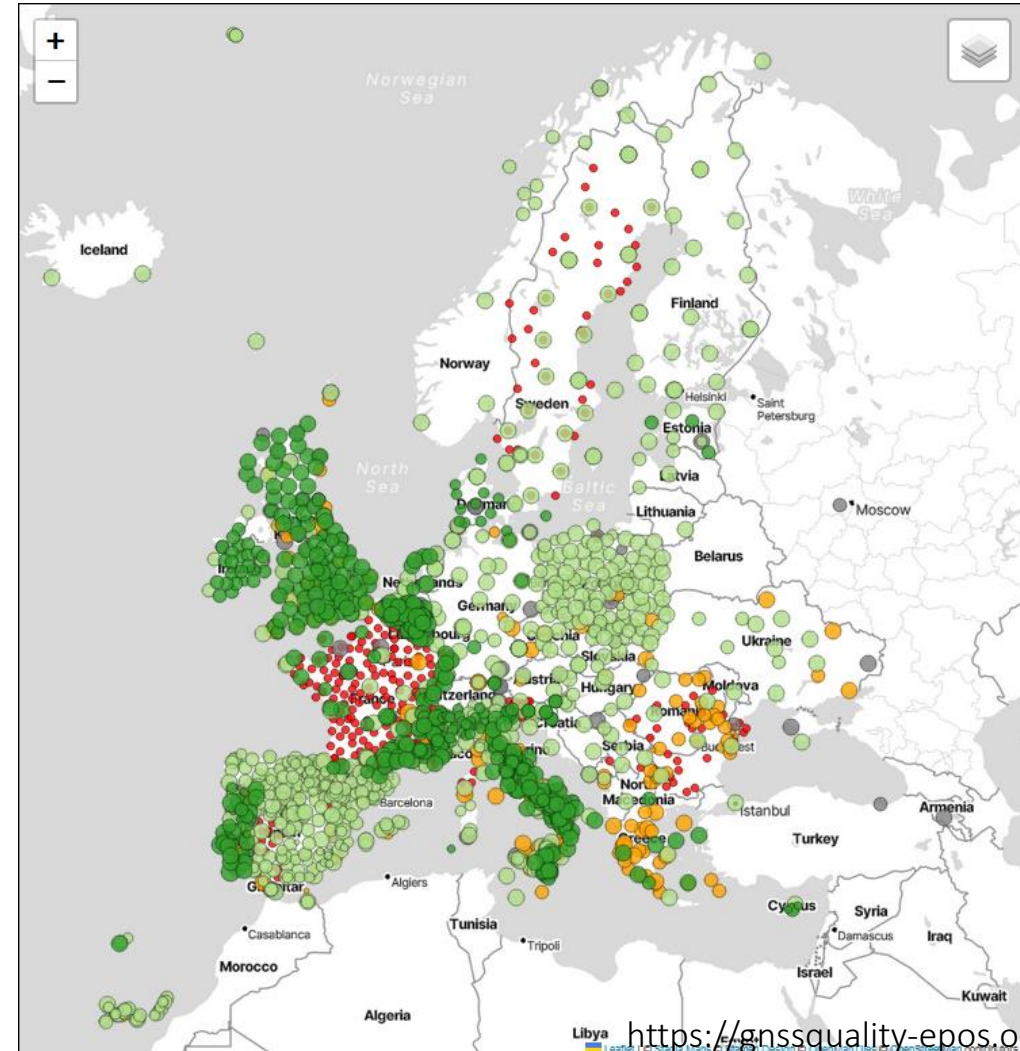
Time Period:

Full history The last four months

Legend:

Total: 1959 EPOS Stations at DGW

- 505 stations with data within the last 2 days
- 721 stations with data within the last 25 days
- 276 stations with data older than the last 25 days
- 137 decommissioned stations with data
- 320 stations without data



EUROPEAN PLATE OBSERVING SYSTEM

<https://gnssquality-epos.oima.be>



ROYAL OBSERVATORY OF BELGIUM

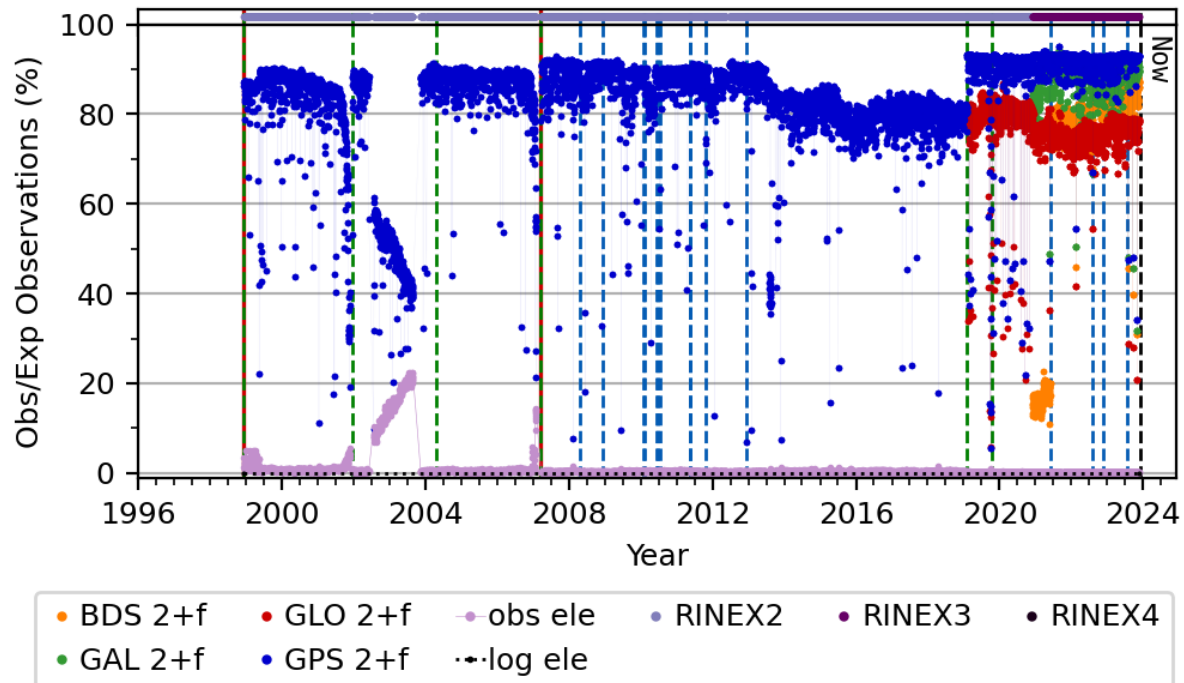


GNSS DATA AND
P

GNSS data quality monitoring

Observed/Expected Observations

ACOR00ESP - ROB-EUREF data node



Sun Nov 26 16:17:25 2023

©GNSS@ROB

- Several DQI are computed
- Use the data quality indicators to **generate alarms** when a the data quality of a station is degraded
- Notify station manager that station is not performing as expected
- 1000+ GNSS stations → challenge

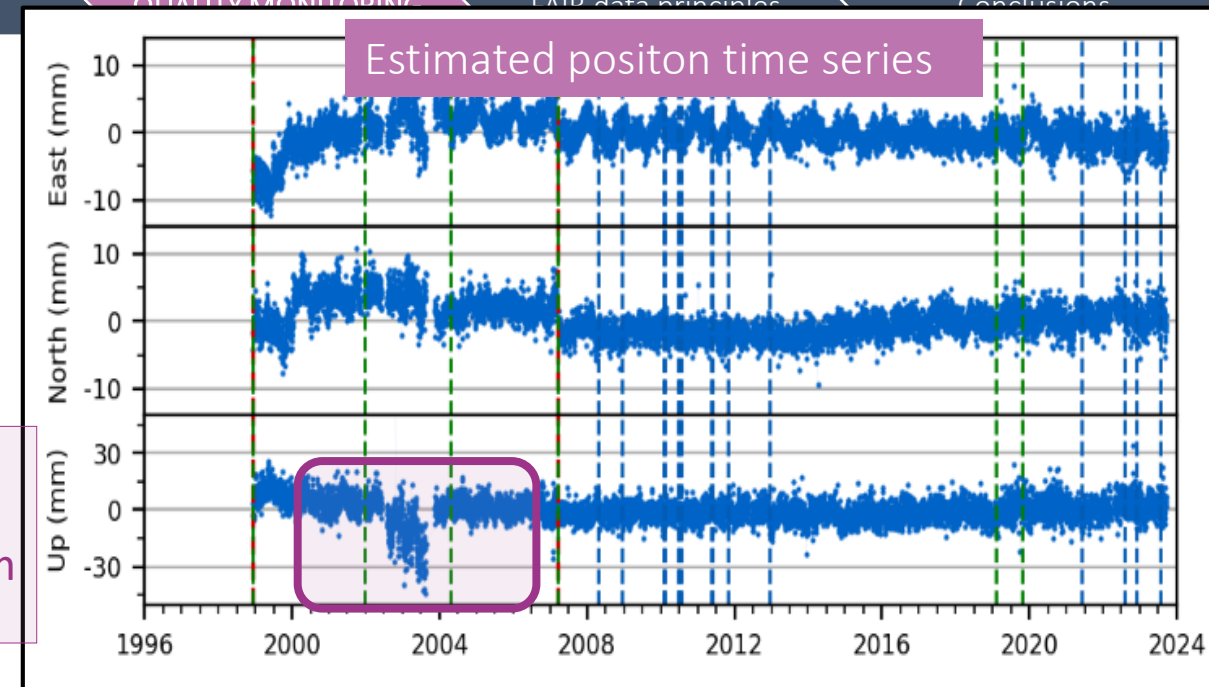


Added-value of GNSS data quality monitoring

Subsidence of the station of about 3 cm

M³G & DQMS

provide valuable information to help identifying if a computed change in the position of a GNSS stations is caused by a real ground movement or not





GNSS DATA AND
PRODUCTS

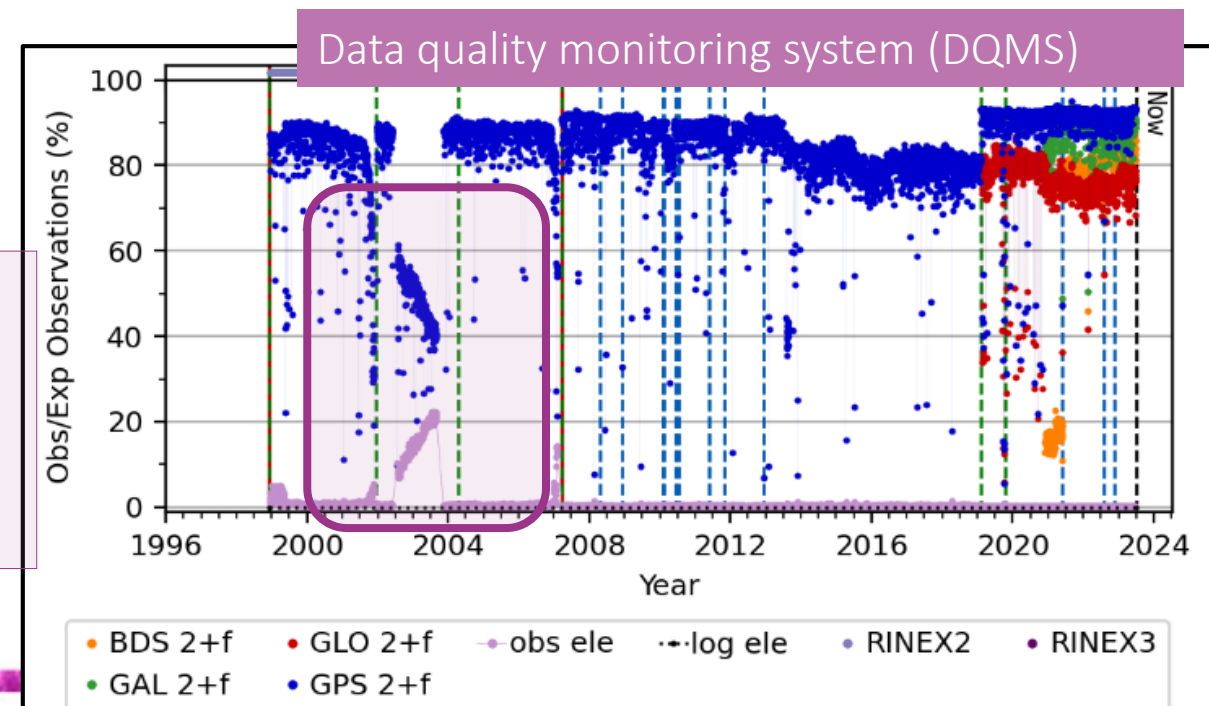
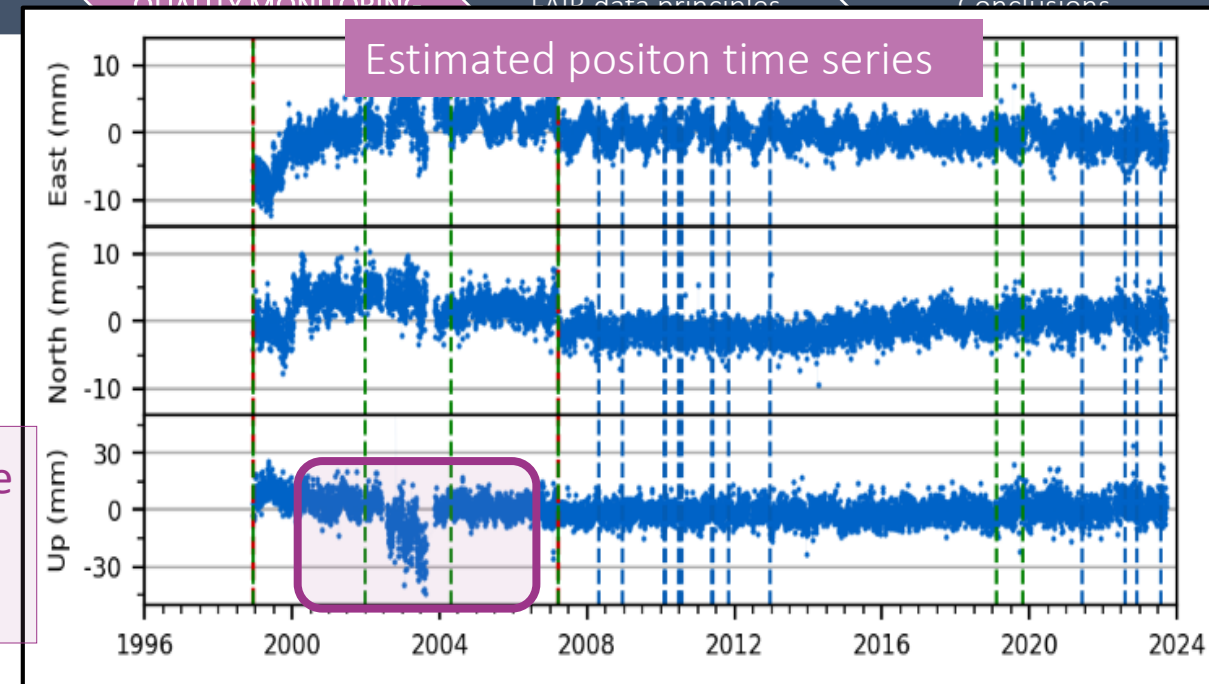
Added-value of GNSS data quality monitoring

Apparent subsidence
of the station of
about 3 cm

M³G & DQMS

provide valuable information to help
identifying if a computed change in the
position of a GNSS stations is caused
by a real ground movement or not

Computed
subsidence is not
“real”, but caused
by degraded data
quality





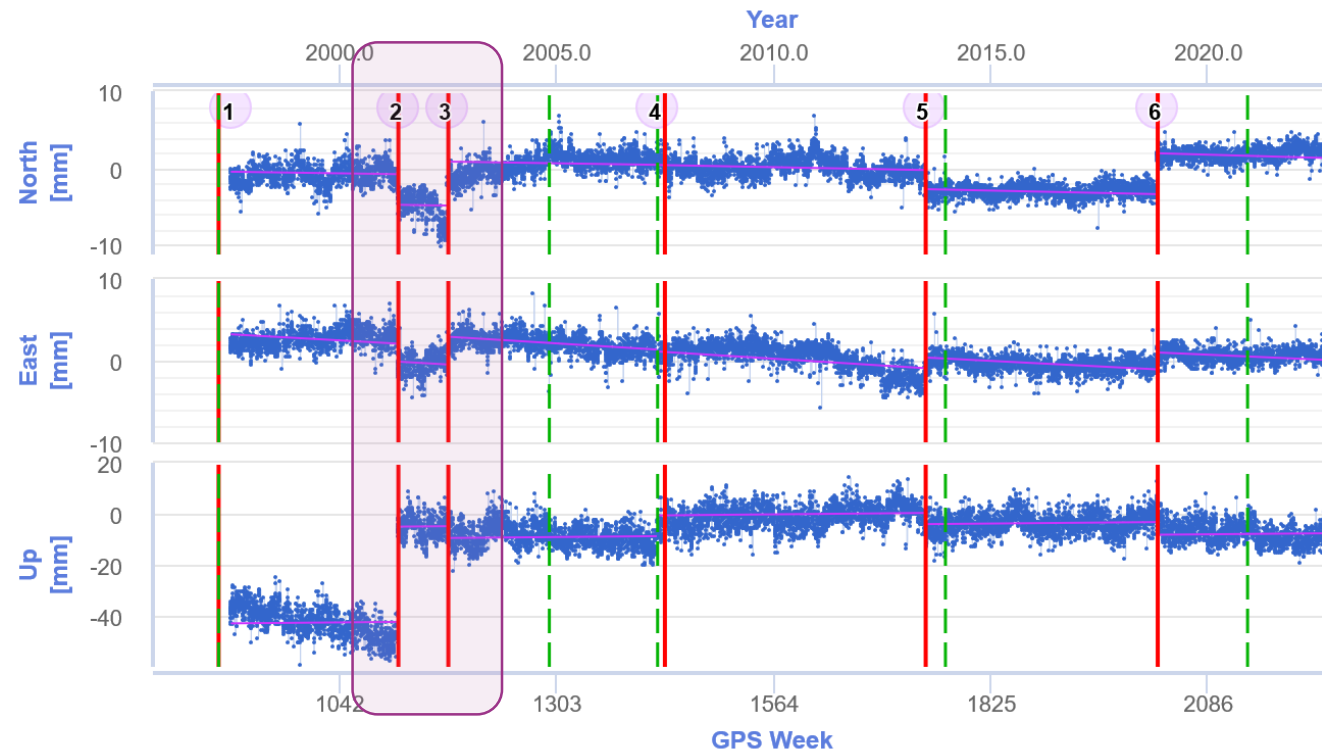
GNSS DATA AND
PRODUCTS

Added-value of GNSS station metadata (M³G)

Vertical red lines → antenna change based
on GNSS station metadata inserted in M³G

Correct documentation of antenna changes
is crucial to properly interpret the
estimated position time series!

Estimated position time series





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GNSS DATA AND
PRODUCTS

FAIR data principles - Rich metadata

Steps towards FAIR

A. Attach rich metadata to the GNSS data

B. Attach a PID (DOI) to the GNSS data

C. Make GNSS (meta)data available through API

First: Collection of rich metadata

- 100% station descriptions
- 100% GNSS data quality information
- 100% of the GNSS datasets have a data license



GNSS DATA AND
PRODUCTS

FAIR data principles - DOI

Steps towards FAIR

- A. Attach rich metadata to the GNSS data
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DOI (Digital Object Identifier) for GNSS data

M³G V5.0

- Allows to insert GNSS station and network DOI
- Few DOIs inserted in M³G up to now

Future M³G functionality/workflow

Station manager can request the set up of a DOI for the dataset of their GNSS station

Pre-conditions:

- only if no DOI is already existing
- only if GNSS dataset in ROB data repository (~500 EPOS-GNSS stations)





GNSS DATA AND PRODUCTS

- M³G generates DataCite metadata + template of DOI landing page
 - ✓ Extract as much as possible DOI metadata from information/metadata already available in M³G
 - ✓ Standardization of DOI metadata in collaboration with GGOS
- Station manager approves (edit) the proposed metadata/landing page
- ROB mints the DOI and set up the DOI landing page (€/DOI)



FAIR data principles – DOI in M³G

Request DOI/Update DataCite for BRUS00BEL

DataCite metadata for BRUS00BEL

DOI	https://doi.org/10.24414/ROB-EUREF-BRUS00BEL
Title	GNSS data of BRUS00BEL - Brussels (Brussels, Belgium)
Sub Title(s)	Select sub-titles
Author	Royal Observatory of Belgium
Contributor(s) *	Select not registered contributors
Publisher:	Royal Observatory of Belgium (ROB)
Published	2023
Description	Permanent GNSS stations dataset as daily RINEX files
Additional Description	Select description
Data Citation	Royal Observatory of Belgium (2023): GNSS data of BRUS00BEL - Brussels (Brussels, Belgium), Available from Royal Observatory of Belgium. https://doi.org/10.24414/ROB-EUREF-BRUS00BEL
Resource Type	Dataset
Data Access	BKGI IGS/EPN Regional Data Centre (BKG) - access info Belgian EPOS-GNSS Node (ROB) - access info EPOS-GNSS Data Gateway (OCA) - access info ROB EPN Historical Data Centre (ROB) - access info ROB-EUREF EPOS-GNSS Node (ROB) - access info
Data Licence	CC BY 4.0
More metadata	GNSS station metadata - GeodesyML DOI metadata - DataCite M³G Object Identifier

Back

Request/Update DOI





FAIR data principles – DOI in M³G

Only for datasets in ROB data repository

For GNSS datasets in other repositories, M³G could help to

- generate DataCite metadata
- template of DOI landing page (harmonisation/standardization)

DOI minting itself needs to be discussed !



GNSS DATA AND
PRODUCTS

FAIR data principles - API

Steps towards FAIR

- A. Attach rich metadata to the GNSS data
- B. Attach a PID (DOI) to the GNSS data
- C. **Make GNSS (meta)data available through API**

- API to retrieve GNSS (meta)data, but original API not developed with FAIR data principles in mind → improvements will be necessary (long term goal)
- Requires background work on standardization of rich metadata (e.g. GNSS-DCAT-AP) in agreement with international GNSS community
- Currently, not all available rich metadata can be retrieved from EPOS data portal



Conclusions

- New GNSS e-infrastructure providing data (and data products) of 1000's of GNSS stations to EPOS
- Centralized access to GNSS (meta)data based on distributed infrastructure of data nodes
- Special attention to collection of GNSS station metadata and GNSS data quality control to enable correct interpretation of GNSS data products
- E-infrastructure is operational, but not yet 'finished'
 - Optimize the chain of operational services
 - Add new GNSS datasets and new data nodes
 - Improve GNSS node software GLASS
 -

Challenges tackled in Geo-INQUIRE WP2 :

- *Add GNSS datasets/nodes: geographical gaps, GNSS stations at tide gauges, NFO, Volcanoes*
- *Integration of high-rate data*
- *Standardization/assignment/ collection/distribution of DOI*



Contact

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