THE INGV GNSS PROCESSING ENGINE FOR ACTIVE TECTONICS AND GEODYNAMICS

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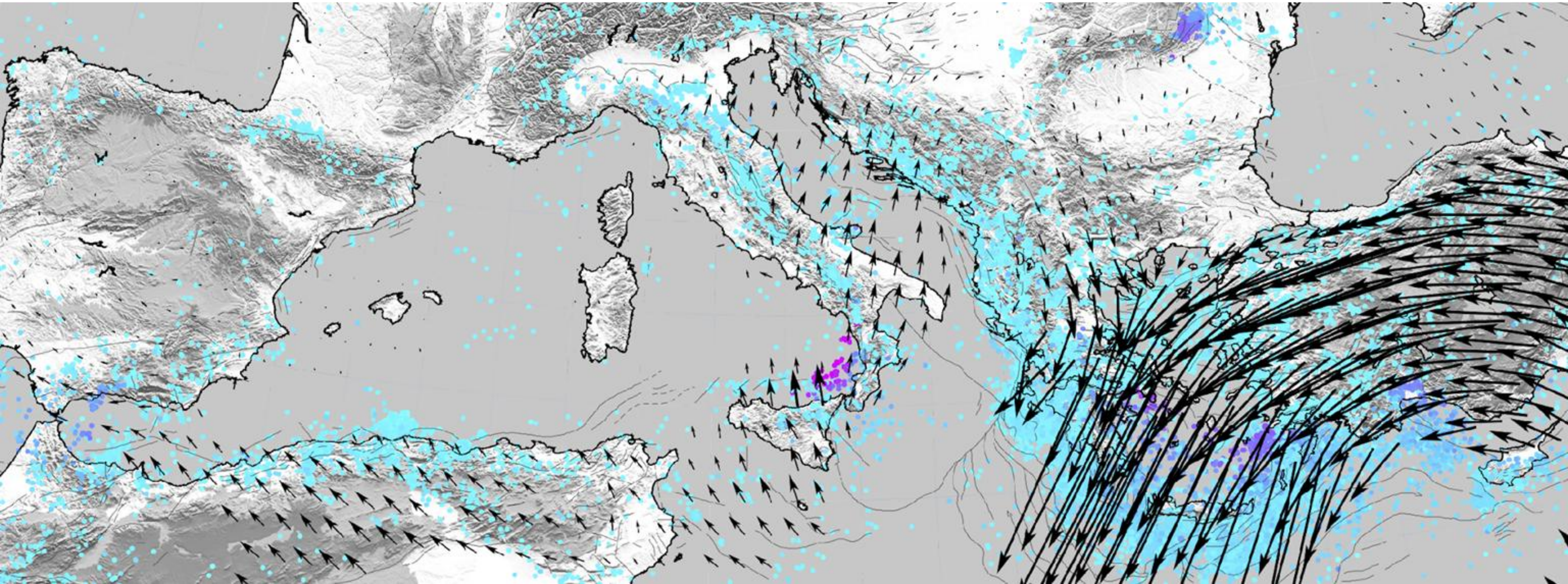
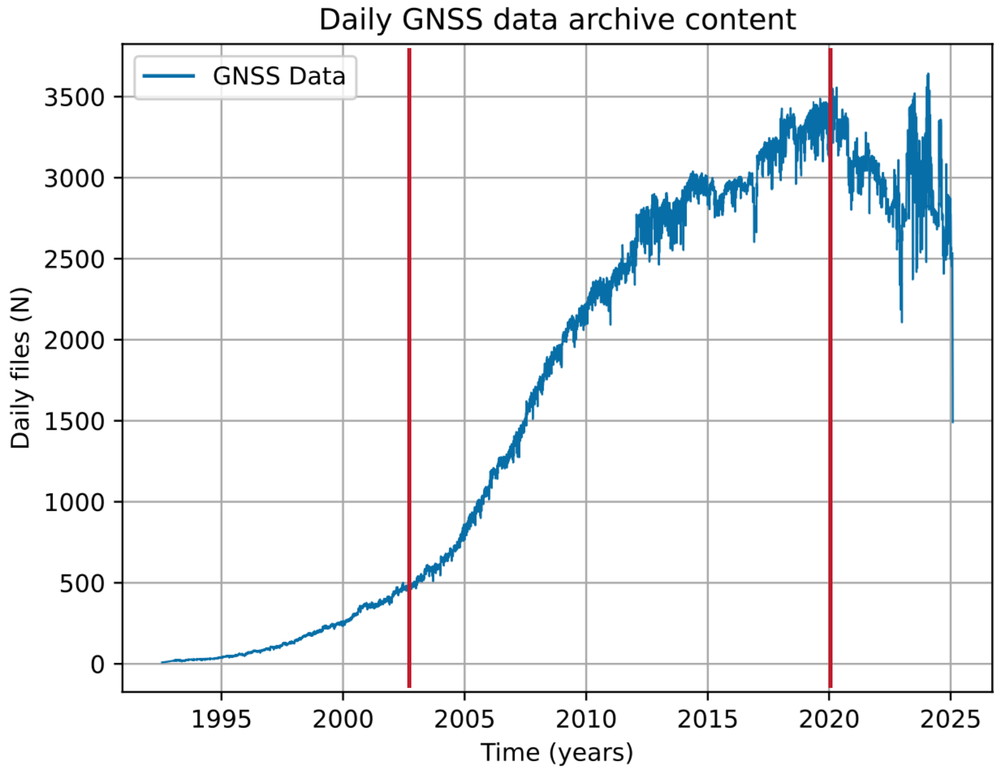


GNSS NETWORKS

We have archived **RINEX** files of **~5500** continuous GNSS **stations** (from >100 networks), located in the **Eurasian** and **African regions**.

The number of stations has increased rapidly from 2005 to 2015, and is now fluctuating.

We realized a computational infrastructure able to **automatically retrieve**, **archive** and **analyze GNSS observations** and **metadata**, updating position time-series, velocities and strain-rates on a daily/weekly basis.



GNSS NETWORKS

Topographic **Geodetic** **Geophysical**

Increasing quality?

THE INGV MEDITERRANEAN GNSS ARCHIVE

We developed a **software tool** (using also procedures developed in the framework of the **EPOS TCS** “GNSS Data and Products) to:

1) manage **RINEX retrieval** from different GNSS **remote archives**, adopting **different protocols**

2) manage **RINEX2** and **RINEX3** (all sites are given **RNX3 naming convention** in the **DB**)

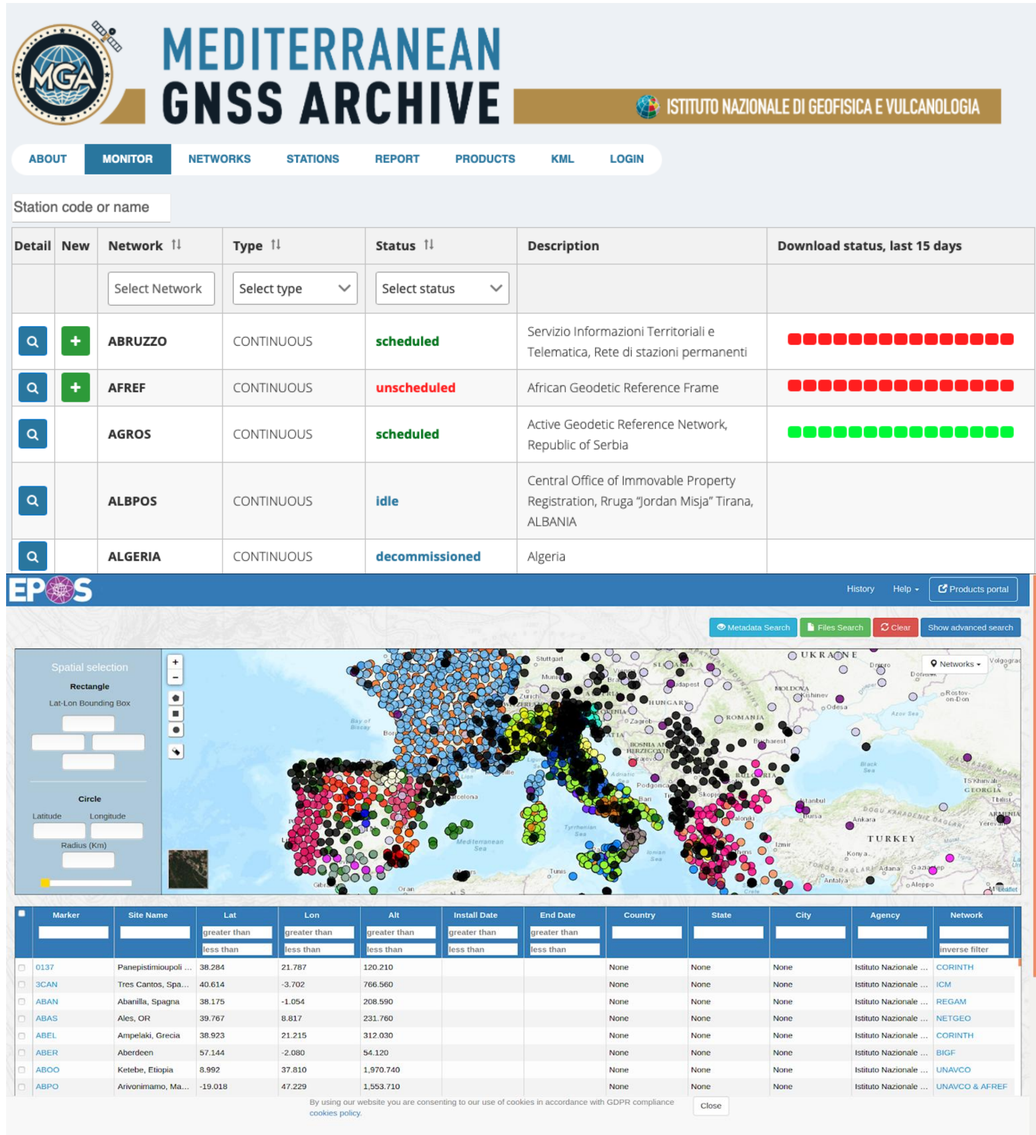
3) feed a PostgreSQL **database** that allows us to efficiently **manage** the archive **information** content

4) **alert** analysis centers for **new** networks/sites or **missing sites**/downloads, also through a **web-based monitor** and a Glass interface

5) perform **QC** of all RINEX files (using **ANUBIS**)

6) **merge metadata** from different sources (**SITELOG** and/or **RINEX**) while **handling errors** in SITELOG or RINEX headers (e.g., non-standard ANT/REC codes)

7) locally **manage conflicts** in **station’s IDs automatically generating unique alias** for **RINEX** files, a-priori **coordinates** and **metadata** files.



Randazzo D., Cavaliere A., Bruni S., Martelli L., Serpelloni E., Devoti R., (2022). PyGLogDB: software to generate STATIONINFO files for GNSS data analysis. Rapp. Tec. INGV, 446: 124, https://doi.org/10.13127/rpt/446

Bruni S., Randazzo D., Devoti R., Serpelloni E., Cavaliere A., Martelli L., Pietrantonio G., D’Agostino N., (2022). The INGV Mediterranean GNSS Archive (MGA). Rapp. Tec. INGV, 456: 122, https://doi.org/10.13127/rpt/456

INGV GNSS ANALYSIS CENTERS

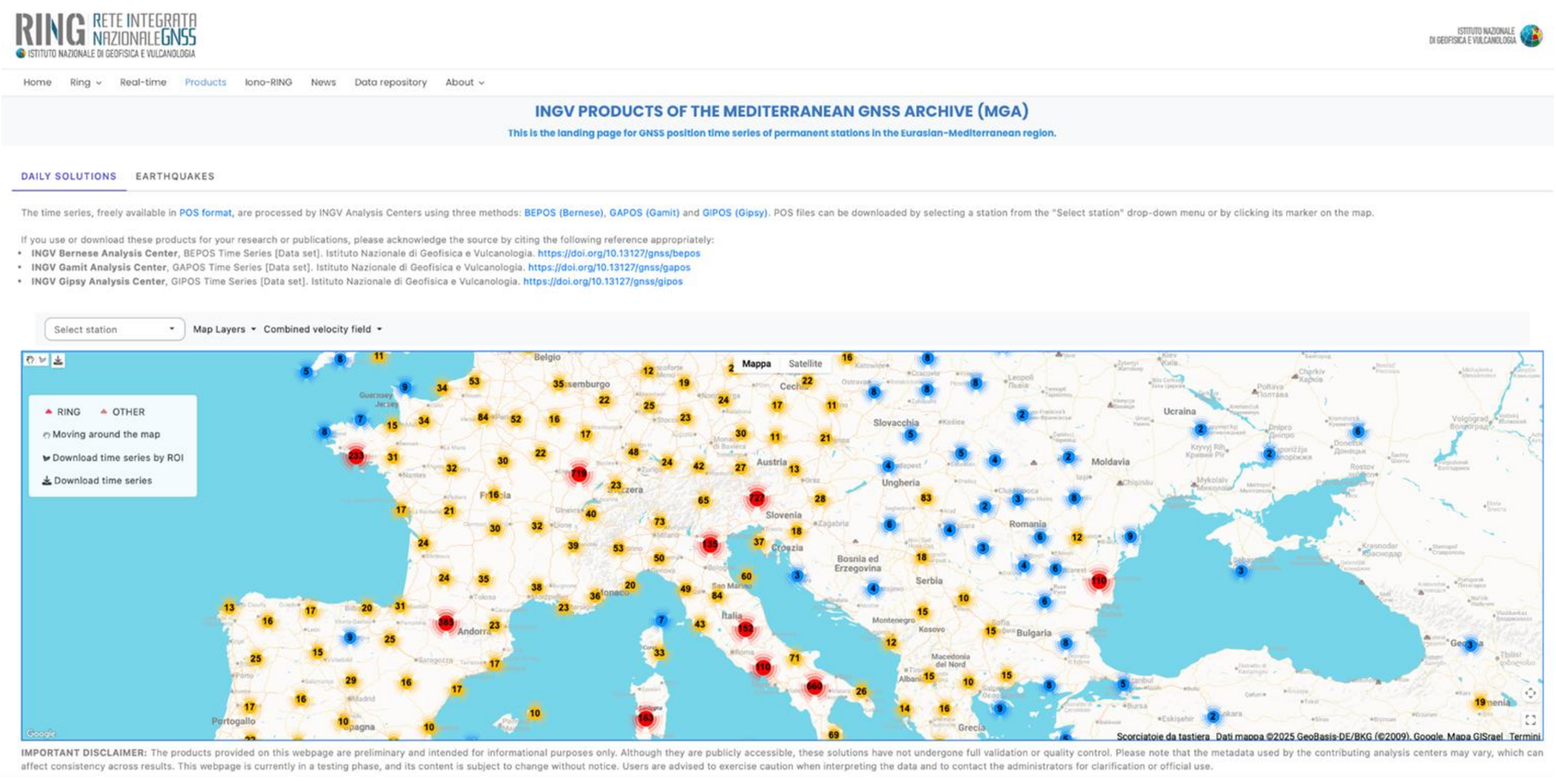
Actually **3** GNSS data **analysis centers** are operating at INGV:

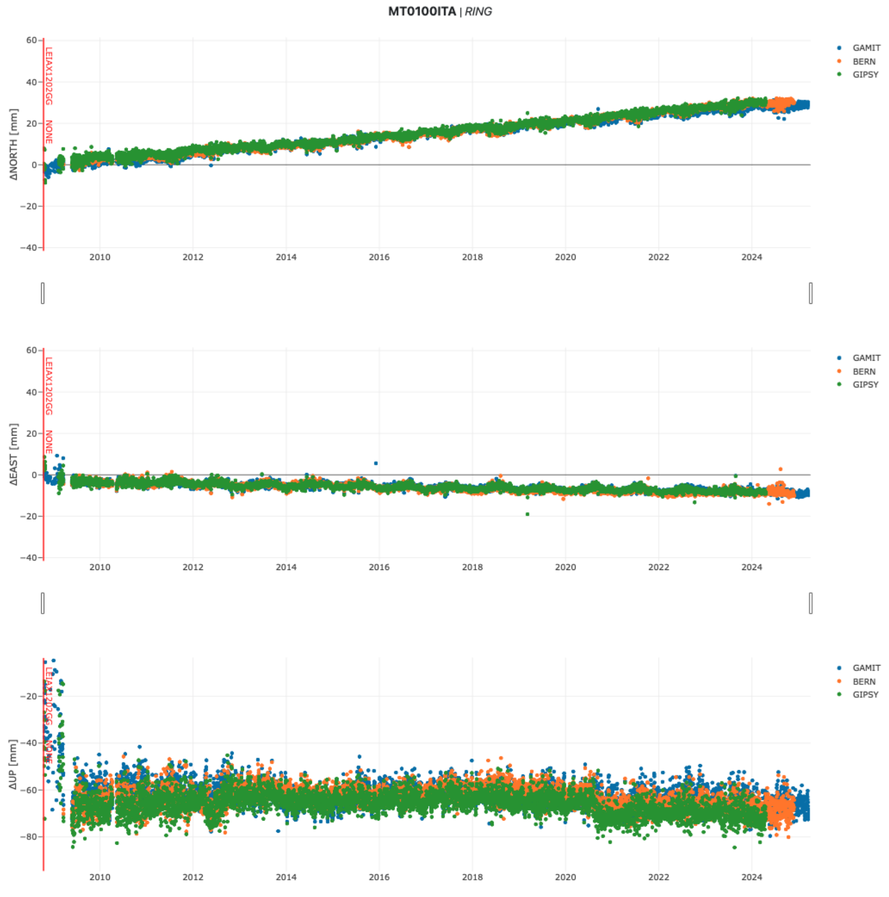
1) **INGV@Bologna**: **GAMIT/GLOBK** (Serpelloni/Martelli) processing the Euro-Mediterranean and African regions

2) **INGV@Roma**: **BERNESE** (Devoti/Pietrantonio) processing the Central Mediterranean region

3) **INGV@Roma**: **GIPSYX** (D'Agostino/Silverii) processing the Euro-Mediterranean and African regions

The different time-series are available at **https://webring.gm.ingv.it/index.php/data-analysis-and-product/** (**still under construction!**).

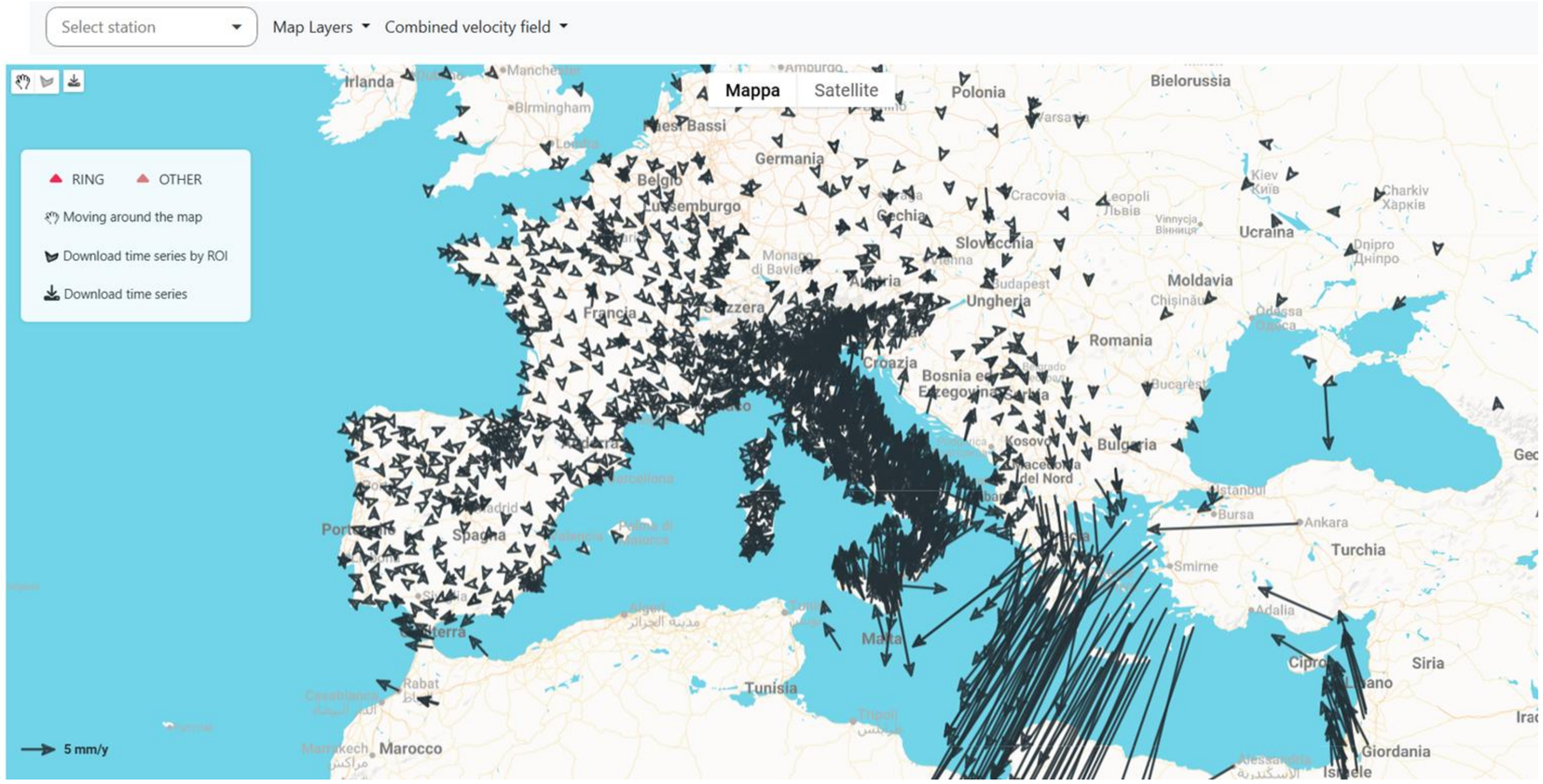


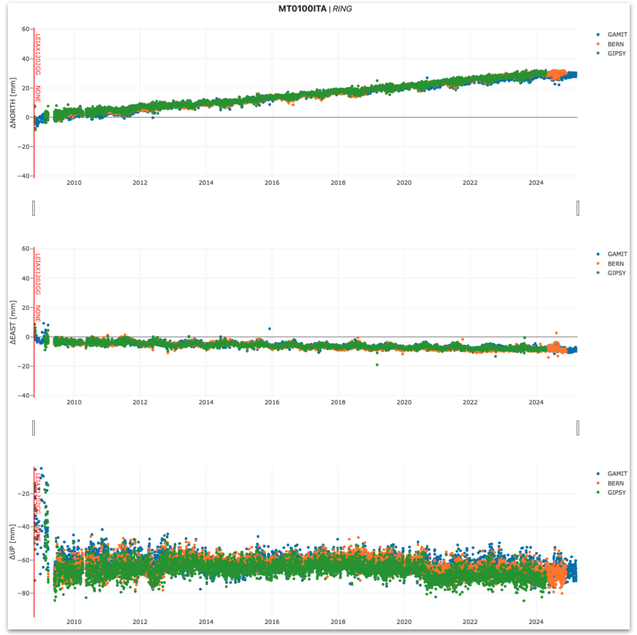


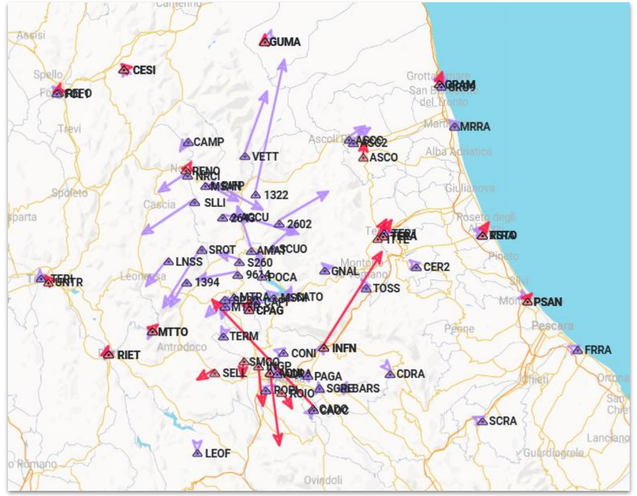
INGV PRODUCTS PORTAL

- Time-series
- Velocities
- Co-seismic displacements
- Co-seismic time series (high frequency)
- …

are available at https://webring.gm.ingv.it -> Products (**still under construction!**).







MULTI-SOFTWARE GNSS PROCESSING ENGINE

We are moving towards a **multi-software** automatic GNSS data **processing** platform on a **HPC infrastructure** installed at the **Bologna Tecnopolo** (https://www.damatecnopolo.it/en), which hosts several HPC computational facilities (e.g., ECMWF data center, LEONARDO supercomputer)

Currently the **GAMIT/GLOBK** software (10.71) and **GipsyX** (2.1) are running on the same dataset on the ADA HPC cluster.

We are working to have **Bernese** running on the same infrastructure and datasets.

The G/G analysis of 1 month of data (~2.200 tasks) requires ~**3 hours**. The GipsyX analysis of 1 months of data (~75.000 tasks) requires **~5 hours**. We update daily the data and solutions of the last 25 days.

INGV ADA HPC cluster

17 nodes (+4 GPU nodes)

1308 (2616) cores (threads)

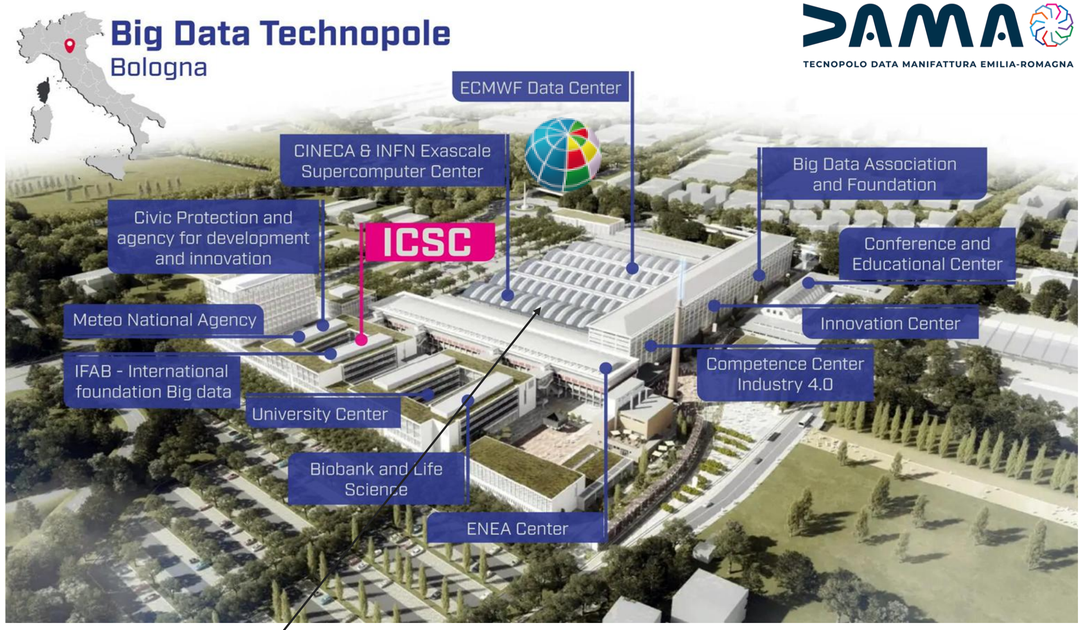
480 (960) with priority for GNSS processing

10TB RAM

100 Gb infiniband connectivity and **10GB ethernet**

SLURM resource manager and scheduler

160 TB disk space dedicated for GNSS data and products



INGV ADA HPC cluster

LEONARDO
CINECA

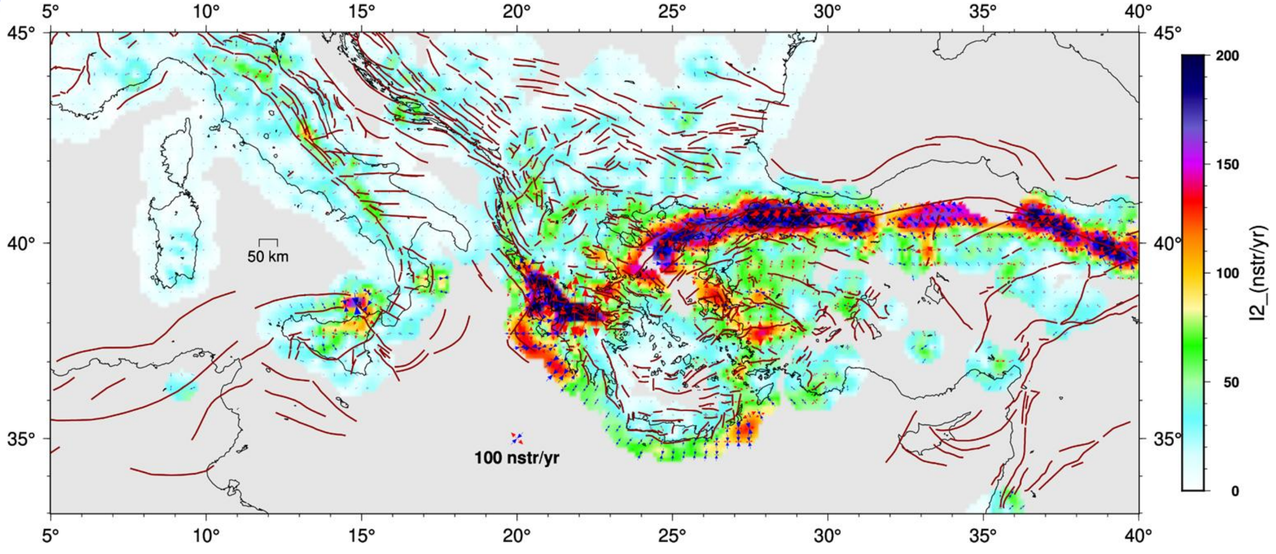
GNSS PRODUCTS

Four routine analysis we apply a **standard linear trajectory model** to the absolute position time-series (moving to IGS20), modeling a linear term, annual and semi-annual seasonal terms, instrumental offsets, co-seismic offsets and post-seismic decays.

We use daily updated **metadata** to set the epochs of **instrumental jumps**.

Co-seismic offsets are **assigned** based on the **magnitude** of instrumental earthquakes, retrieved from seismic bulletins, and the **distance** of each station from the epicenter.

Velocities are used to estimate strain-rates using different methods (Nucci et al., 2023).



EPOS Mission

“To provide a sustainable and long-term access to solid Earth science data and services integrating diverse European Research Infrastructures under a common federated framework.”

EPOS Goals:

★ Build Integrated, Multidisciplinary Research Infrastructure

★ Promote Research on Geodynamic and Natural Processes

★ Provide Open Science and Open Access

★ Support Society, Policy Makers, Stakeholders

★ etc…

Key Objectives:

- To test and validate data and metadata provided in EPOS.
- To provide scientifically reliable products for good research.

EPOS is expected to ensure consistent, high-quality standards for data, metadata, and any resulting products or services delivered through its infrastructure.

GNSS Data and Products

Shaping the EPOS vision: core drivers for the GNSS TCS

With a multidisciplinary scientific community as its reference user base, what core elements should drive the EPOS vision for the GNSS Thematic Core Service?

1. ***High Quality Data and Metadata*** (Monument, Geodetic receivers, antenna calibration, history of antenna/receiver changes, ect)
2. ***Completeness in time domain*** (ensuring long-term, continuous data availability—not restricted to specific project phases or recent periods.)
3. ***Spatial Densification*** (achieving broad coverage to support high-resolution geophysical analysis, avoiding renaming of stations)

Any adopted requirement, policy or guideline that limits the above requirements should be carefully considered to avoid failing to meet the overall EPOS objectives.

Examples of requirements gap …continued

Avoid renaming of stations.

Many stations have long-established site identifiers that have been in use for decades. However, upon integration into EPOS, these identifiers were changed. In some cases, such as SWEPOS, the original station IDs are still used in public data dissemination. The renaming of station identifiers introduces ambiguity, complicates data provenance, and hinders the integration and interoperability of both legacy and newly added stations within the infrastructure.

Examples:

0ARJ00SWE (SWEPOS)	vs.	ARJ000SWE (EPOS)
0VIB00SWE (SWEPOS)	vs.	VIB000SWE (EPOS)
UDIN00ITA (Marussi)	vs.	RUDI00ITA (EPOS)
AMPE00ITA (Marussi)	vs.	RAMP00ITA (EPOS)
MULA00ESP (REGAM)	vs.	MUL100ESP (EPOS)
LORC00ESP (REGAM)	vs.	LRCA00ESP (EPOS)
TRAM00ESP (IGNE)	vs.	TRAU00ESP (EPOS)

The INGV contribution to GNSS-TCS

INGV strongly supports the EPOS vision of a multidisciplinary, integrated research infrastructure that provides high-quality, standardized data to advance Earth science research across diverse domains. We are aware that the EPOS research infrastructure is a unique opportunity to develop a pan-European platform that enables access to high-quality data and services, fosters collaboration across scientific communities, and supports innovative research in Earth system science.

We will actively contribute to the EPOS initiative by :

- Collecting and distributing GNSS observational data through the RING network.
- Perform data analysis of EPOS stations using state-of-the-art software and geophysical models.
- Contribute to the development of GLASS system

and could contribute to:

- Validate and harmonize legacy and historical data and metadata for EPOS stations.
- Cooperate in the ingestion of historical data and metadata within the EPOS data repositories.