EPOS-GNSS - Improving the access to GNSS data and products from CORS stations in Europe

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SUMMARY

The majority of the GNSS CORS stations installed in Europe are maintained by many different agencies with different technical and scientific objectives. In fact, many of these networks have been installed to provide support for geo-referencing applications, mainly datum definition and materialization, and surveying. This creates large difficulties when someone attempts to access data and derived products at a Pan-European level.

EPOS (European Plate Observing System) is a European Union Research Infrastructure created with the goal to integrate Infrastructures for Solid Earth Sciences Research across Europe. It is formed by a consortium of potential stakeholders and users from academy, governmental and industrial institutions, scholars, and students that need data, data products, software, and services on different areas of Solid Earth.

One of the EPOS Thematic Core Services is GNSS Data & Products, which members aim to harmonize and standardize GNSS data collection and processing and to design and establish dedicated products and services that benefit the existence of national and pan-European infra-structures (in particular EUREF), optimized for, but not limited to, Solid Earth Research applications.

We present here a distributed software architecture called GLASS, a tool for quality-controlled dissemination of RINEX data and derived products for Solid Earth (time-series, velocities, and strain rates) of thousands of CORS stations in Europe but that can be potentially used anywhere in the world. We describe how the data flow from the agencies managing the GNSS networks to the analysis centers and to the various EPOS data portals. We also describe the quality control steps that are performed in the GNSS Data and Products by validating the station metadata, obtaining quality metrics of the RINEX files, and by checking the stability of time series by detecting outliers and offsets.

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1. INTRODUCTION

1.1 EPOS – European Plate Observing System

The European Plate Observing System (EPOS) is a distributed research infrastructure aimed at providing a comprehensive and integrated view of the physical processes controlling earthquakes, volcanic eruptions, and other natural hazards in Europe. EPOS is a pan-European initiative that brings together researchers, institutions, and national funding agencies from more than 20 countries across Europe.

The EPOS infrastructure comprises a network of geophysical, geodetic, geological, and geochemical observatories, laboratories, and data centers that are interconnected to provide a centralized platform for sharing, archiving, and processing of data and information related to Earth sciences. The EPOS architecture includes four core components: (1) Thematic Core Services, (2) Integrated Core Services, (3) Shared Services, and (4) Governance.

The Thematic Core Services include the integration of data from different disciplines, such as geodesy, seismology, and volcanology. These services also provide standardized data formats, data quality control, and access to metadata and documentation.

The Integrated Core Services are designed to provide advanced computing and data processing capabilities, such as data assimilation, modeling, and simulations. These services aim to support research on the dynamics and evolution of the Earth system and provide decision-support tools for natural hazard mitigation and management.

The Shared Services component provides access to generic infrastructure services, such as data storage, networking, and security, to support the operation and maintenance of the EPOS infrastructure.

Finally, the Governance component ensures the coordination and management of the EPOS infrastructure, including the establishment of policies, procedures, and guidelines for data access, sharing, and use.

1.2 GNSS Thematic Core Service

The mission of the EPOS-GNSS TCS is to provide, in the context of EPOS, open access to GNSS data, metadata, products, and software in support of the Solid Earth sciences in Europe. Most of the European continent and its margins are covered by dense networks of GNSS CORS (Continuous Operating Reference Stations) maintained by many agencies with different technical and scientific objectives. During the H2020 EPOS Implementation Phase project that ended in 2019, approximately 5000 GNSS stations with the potential to be included in the EPOS network have been identified (cf. Figure 1).

Figure 1 – GNSS CORS identified during the EPOS Implementation Phase project in Europe and surrounding areas

However, most of these GNSS stations have been installed for geo-referencing applications (mainly surveying) and only about 350 of them were providing open access to their data in a coordinated way through the EUREF Permanent GNSS network. Until EPOS, there had yet been no effort in Europe to coordinate the provision of data and products for Solid Earth applications of all available European CORS. This differs from other regions of the globe, like Japan and Western USA, where dedicated GNSS networks were implemented using centralized and consistent projects with the main objective of producing information to study and monitor natural phenomena.

Consequently, the optimized dissemination and use of the data from European GNSS networks for Solid Earth studies created additional challenges from an organizational and technical point of view that are being tackled through EPOS-GNSS.

EPOS-GNSS aims to consolidate the disperse GNSS activities in Europe to provide access to all the GNSS data and products through two gateways: the EPOS-GNSS Data Gateway and the EPOS-GNSS Product Portal (cf. Figure 2). This has facilitated the interface with the Integrated Core Service (ICS) of EPOS (https://www.ics-c.epos-eu.org/) where all multidisciplinary data and products made available by the different TCSs are discoverable. These two EPOS-GNSS gateways run all the webservices that are necessary to make the data and products from the other EPOS-GNSS Service Providers available to the ICS. As a direct consequence, the content distributed by the two GNSS gateways to the ICS mainly depends on the underlying distributed GNSS Service and Data Providers, which, in turn, have no direct link with the ICS anymore, but are still crucial for the functioning of the EPOS-GNSS and its data and product provision to the ICS.

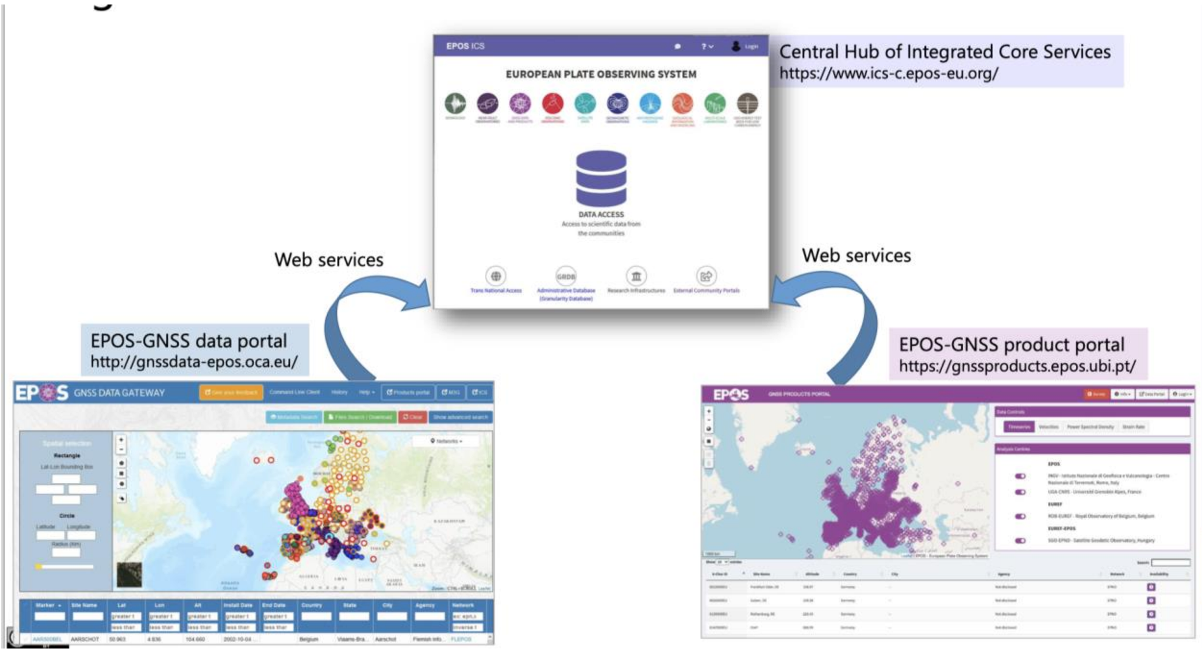

Figure 2 – Organization of GNSS Portals in EPOS

2. GNSS New Services

EPOS-GNSS defined a total of 20 services which will lay the foundation to realize its missions, that are divided in 4 pillars. Most of these services, except for the EUREF services, are new services that have been designed and implemented specifically to satisfy the needs of the EPOS community.

2.1 Governance

The above-mentioned EPOS-GNSS objectives are being implemented formally by eleven institutions from ten different countries, who signed a Consortium Agreement in 2020 to operate the pan-European EPOS-GNSS services necessary to achieve these goals. The EPOS-GNSS Service Providers consists of a multidisciplinary team with experience in the management (quality control and dissemination) of data and metadata from GNSS networks and analysis of the derived products specifically for Solid Earth studies. In addition, it is supported by a strong group of IT experts. However, these EPOS-GNSS collaborations are not limited to the EPOS-GNSS Service Providers, but also involve GNSS Data Providers, researchers, and other stakeholders.

2.2 GNSS Data Dissemination

The EPOS GNSS data and metadata dissemination system integrates several independent nodes as well as a GNSS station metadata collection service (M^3G, maintained at ROB, Belgium), through a central gateway, the EPOS-GNSS Data Gateway (maintained at CNRS-OCA, France, cf. Figure 3). As mentioned in the introduction, the EPOS-GNSS Data Gateway makes the data and metadata from the numerous GNSS data suppliers discoverable.

Currently EPOS-GNSS focuses on the distribution of daily RINEX data at a 30-second rate. To provide open and free access to their daily RINEX data, the station operators must i) sign the EPOS-GNSS data supplier letter; ii) provide station metadata (equipment information, data license, data ownership, etc.) to M^3G; and iii) make their data available at a data repository linked to an EPOS-GNSS data node.

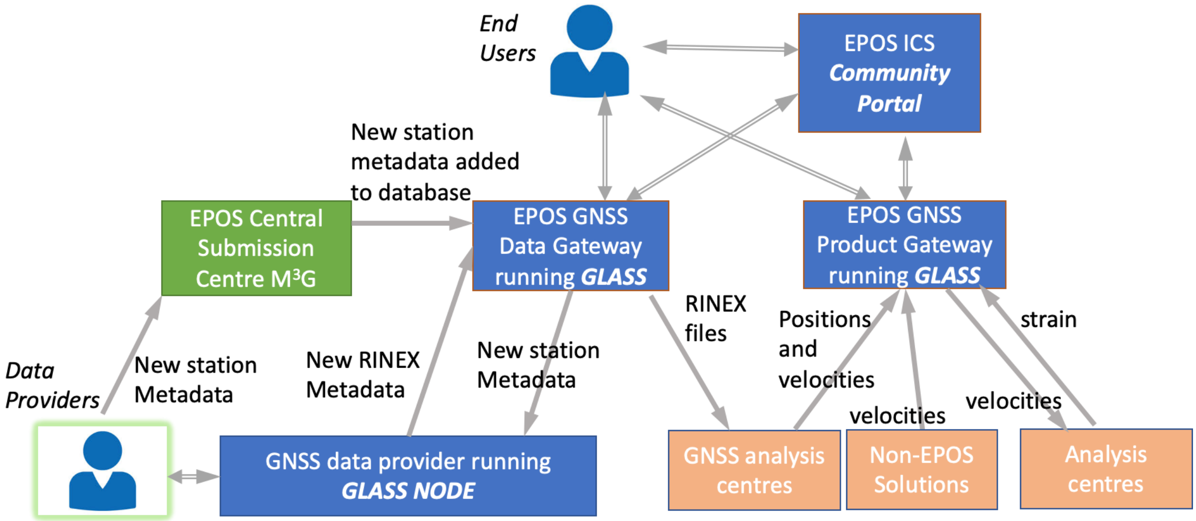

Figure 3 – Data Flows within the EPOS-GNSS framework as seen by a Station Manager and End User

Each of the EPOS-GNSS data nodes uses GLASS (Geodetic Linkage Advanced Software System) (see section 2.4), as a virtualization level on top of the data repository itself. GLASS also indexes the GNSS data files, validates GNSS data with respect to station metadata synchronized from the central metadata database located at the Data Gateway, computes data quality metrics, and stores all information in the local node database. GLASS then ensures the synchronization of this local database with the EPOS-GNSS Data Gateway. In this perspective, the GNSS quality control process, performed at each EPOS-GNSS data node with the G-Nut/Anubis software.
The EPOS-GNSS Data Gateway offers three ways to access to data and metadata: a web client, a command line client and a RESTfull API. The web client (https://gnssdata-epos.oca.eu, cf. Figure 4), which is maintained at CNRS-OCA (France), is a convenient and attractive way to visually explore available data and metadata. Its main interface allows an easy and quick visualization, selection and filtering of stations using geographical, temporal, organization (agencies, networks) or name criteria. An advanced search interface offers selection criteria among all the station, file and quality control metadata (e.g., instrumentation, percentage of data availability, minimum years of data). With criteria set up, a detailed view of all the station or file metadata is shown. Station metadata can be downloaded in 3 different formats (JSON, GeodesyML and IGS Site Log), and file metadata (e.g., url, size, md5) in one format (JSON). The RINEX files that meet the selection criteria can also be downloaded directly.

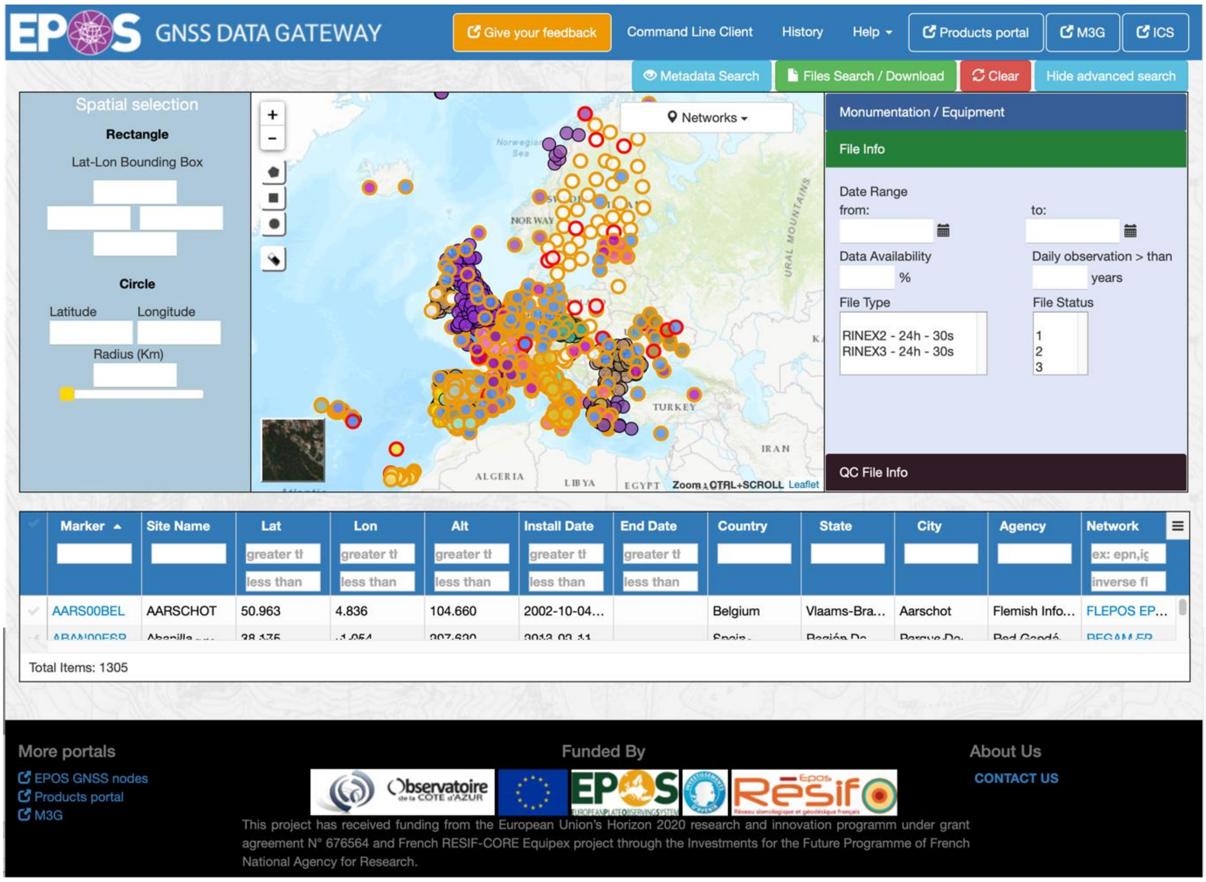

Figure 4 – Web client of the EPOS-GNSS Data Gateway, one of the three available ways to discover and access the EPOS-GNSS metadata and data.

Up to now, more than 65 agencies have signed the EPOS-GNSS data supplier letter, inserted their GNSS station metadata in M^{3}G (total of 1300+ stations) and offered to provide daily RINEX data to EPOS.

2.3 GNSS Products

A major goal of the EPOS-GNSS is to facilitate the access and the use of GNSS derived products, so that they can be more easily analyzed and interpreted, including by non-geodetic experts such as geophysicists, seismologists, structural geologists, hydrologists, modelers, oceanographists, meteorologists, data scientists, or by mapping agencies or engineering offices (cf. Figure 5).

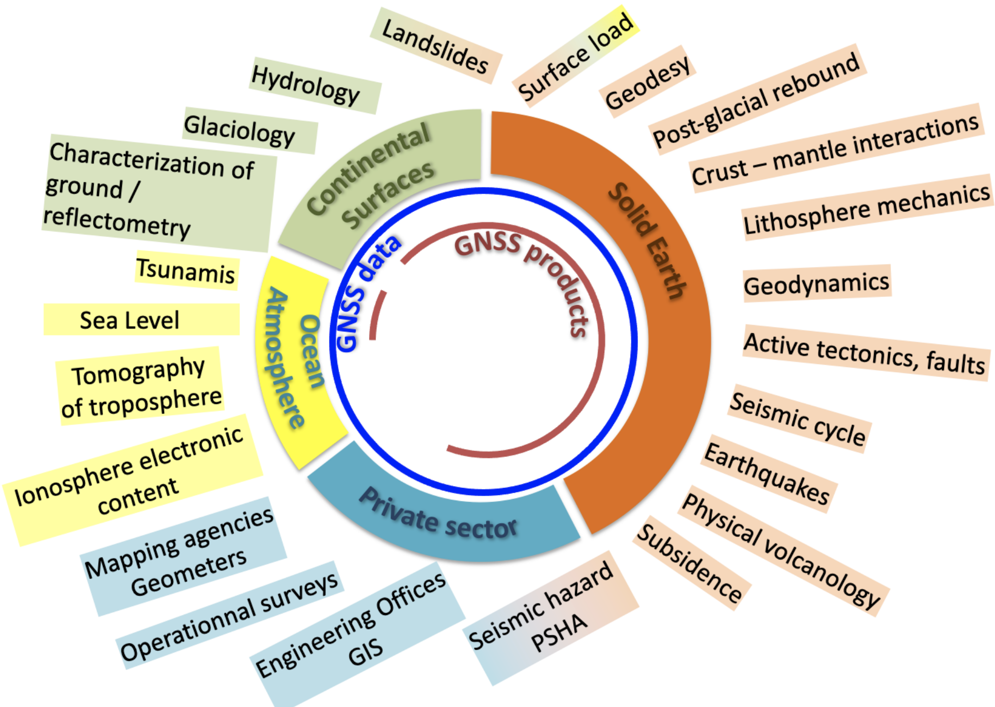

Figure 5 – The different scientific domains in which GNSS data and products can be used.

EPOS-GNSS permits the access to products with a high standard of quality that are represented in Figure 6.

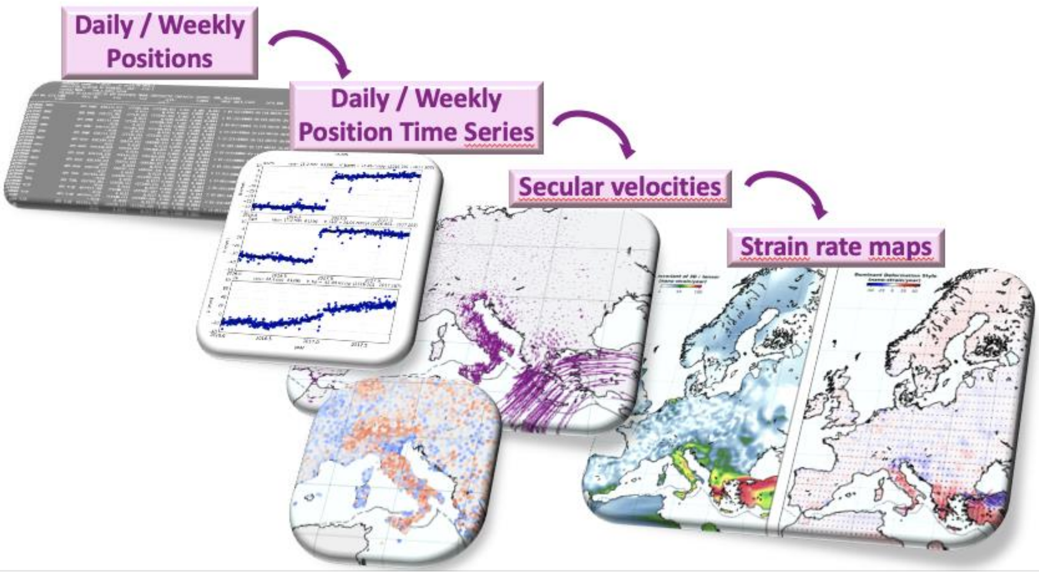

Figure 6 – GNSS products generated and distributed through EPOS-GNSS Products Portal: SINEX files, position time series, secular velocities, strain rate maps

The GNSS products distributed through the EPOS-GNSS Products Portal are organized into three categories: EPOS, EUREF, EUREF-EPOS (described below). The different solutions are generated by 5 Pan-European Processing Centers (INGV, Italy; CNRS-UGA, France; SGO, Hungary; WUT, Poland; and ROB, Belgium) and ~30 Regional Analysis Centers (cf. Figure 7). An additional Pan-European service provider is in charge of the computation of strain rates (LM, Sweden). Figure 8 shows the organizational scheme being developed by EPOS-GNSS to create and disseminate through the Products Portal (UBI, Portugal) the different products calculated by the different Analysis Centers.

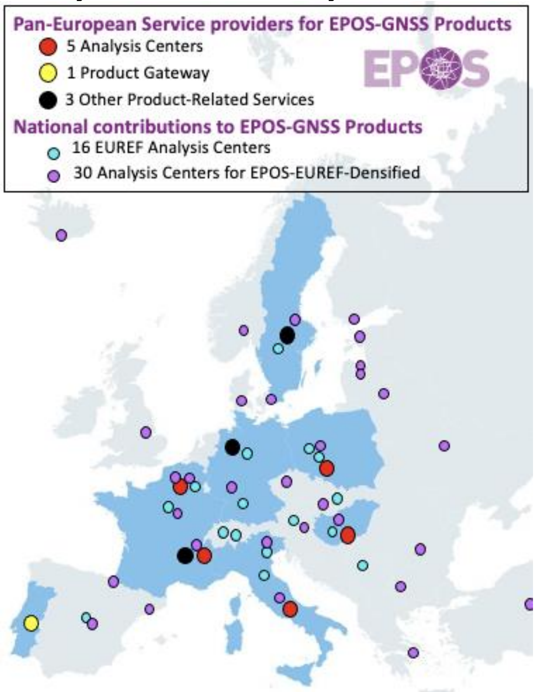

Figure 7 – Service providers for the GNSS products generated and distributed through EPOS-GNSS Product Portal.

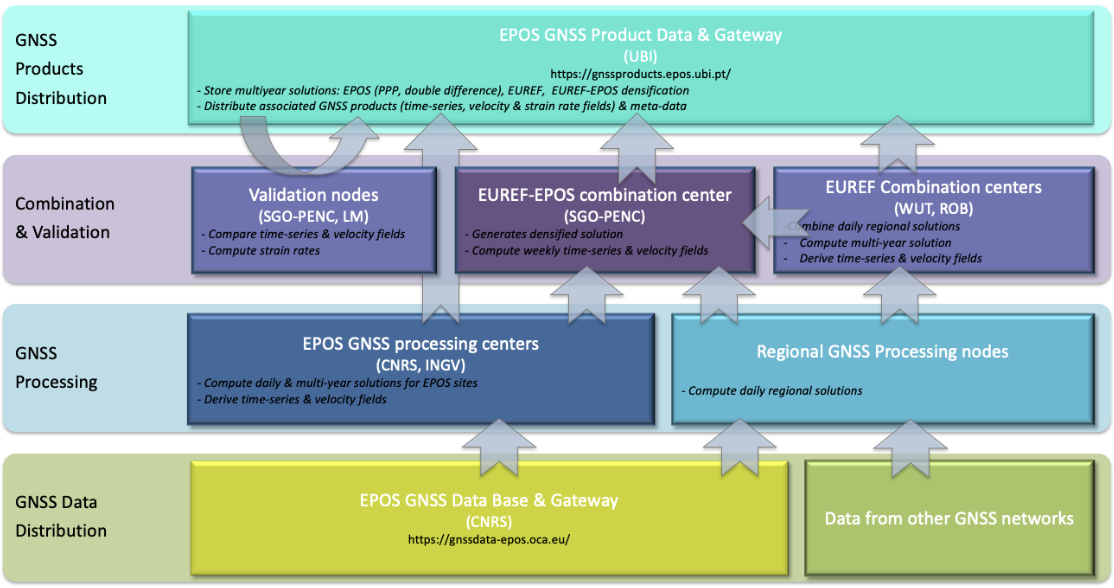

Figure 8 – Organization scheme for the creation and dissemination of the products provided by EPOS-GNSS

2.4 Software Provision

GLASS, a distributed software architecture to disseminate quality controlled GNSS Data and Products, started to be developed during the EPOS Preparatory Phase. It has been developed by a joint effort of 5 European groups at UBI (Portugal), CNRS-OCA (France), INGV (Italy), GOP (Czech Republic), IMO (Island) and ROB (Belgium). The goal was to implement an integrated package to be installed at all levels of a single/multi-level GNSS infrastructure. This package is constituted by several components:

- A common database scheme (including metadata, data & products);
- Web Services for queries and data mining on the data and metadata;
- Quality Control tools;
- Submission and Validation of metadata;
- Tools to guarantee synchronization and consistency of the databases;
- Tools to guarantee redundancy and uniqueness of data and metadata.

GLASS follows a standard three-tier in which the functional logic, data access, data storage, and user interfaces are developed and maintained as independent modules on the same or separate platforms. Conceptually, all GLASS components can be installed in a single server, or, as it is the case of EPOS, in a distributed environment.

3. Conclusions

It has been a long way since the EPOS-GNSS community has initiated its activities with the main goal of offering centralised and open access to GNSS data and products for Solid Earth research. Today, an established group of data providers and service providers enable access to quality-controlled GNSS data and products that are serving not only EPOS researchers, but also other communities that use these GNSS data and derived products for technical and scientific applications.

EPOS-GNSS has achieved several important milestones:

a) Establishment of the governance framework with the aim that the entire community, from data providers to end-users, will be represented and their efforts recognized.
b) GLASS development – a new complete software package for the dissemination of GNSS data & products guaranteed with several quality control checks.
c) Products dissemination – internally consistent GNSS solutions associated with the dedicated products (time-series, velocities, and strain-rates) created from a big data set using state-of-art methodologies.

A more interested reader is referred to Fernandes et al. (2022)

References

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