ANNALS OF GEOPHYSICS, 65, 2, DM208, 2022; doi:10.4401/ag-8756
OPEN ACCESS

The EPOS Research Infrastructure: a federated approach to integrate solid Earth science data and services

Massimo Cocco[*,1], Carmela Freda[2], Kuvvet Atakan[3], Daniele Bailo[1], Kauzar Saleh Contell[2,4], Otto Lange[5], Jan Michalek[3]

(1) Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy
(2) EPOS ERIC, Rome, Italy
(3) University of Bergen, Bergen, Norway
(4) ETH Zurich, Switzerland
(5) Utrecht University, Utrecht, The Netherlands

Article history: received November 15, 2021; accepted March 24, 2022

Abstract

The European Plate Observing System (EPOS) is a Research Infrastructure (RI) committed to enabling excellent science through the integration, accessibility, use and re-use of solid Earth science data, research products and services, as well as by promoting physical access to research facilities. This article presents and describes the EPOS RI and introduces the contents of its Delivery Framework. In November 2018, EPOS ERIC (European Research Infrastructure Consortium) has been granted by the European Commission and was established to design and implement a long-term plan for the integration of research infrastructures for solid Earth science in Europe. Specifically, the EPOS mission is to create and operate a highly distributed and sustainable research infrastructure to provide coordinated access to harmonized, interoperable and quality-controlled data from diverse solid Earth science disciplines, together with tools for their use in analysis and modelling. EPOS relies on leading-edge e-science solutions and is committed to open access, thus enabling a step towards the change in multidisciplinary and cross-disciplinary scientific research in Earth science. The EPOS architecture and its Delivery Framework are discussed in this article to present the contributions to open science and FAIR (Findable, Accessible, Interoperable, and Reusable) data management, as well as to emphasize the community building process that supported the design, implementation and construction of the EPOS RI.

Keywords: Research Infrastructure; Solid Earth Science; Open Science; FAIR Data Management; ERIC

1. Introduction

The term Research Infrastructure (hereinafter RI) refers to the facilities, resources and services that are used by the research communities to conduct research and foster innovation in their fields [EU Regulation No 1291, 2013]. RIs may include major scientific equipment (or sets of instruments, including distributed observational sensor networks), knowledge-based resources such as collections, archives and repositories of scientific data, but also e-infrastructures like data processing and computing systems, communication networks, and any other tools that are essential to achieve excellence in research and innovation[1]. Since a few decades RIs are playing a key role of enablers of scientific research and promoters of innovation in all scientific domains, as they trigger the generation and provision of high-quality scientific data and new technologies supporting science at the frontiers of knowledge. RIs are implemented through different organizational models either as central facilities and laboratories for on-site experiments and measurement sessions, or as centers for the coordination and management of geographically distributed observing systems and laboratories, remotely accessible computational resources and data repositories. RIs are nowadays assuming an ever increasingly central role in supporting "Open Science" by fostering the sharing of scientific data and products.

Open Science represents a specific and novel approach to the scientific process based on cooperative work and effective ways to share knowledge and scientific findings by using digital communication technologies and new collaborative tools [European Union, 2015]. The key role of RIs in supporting the digital transformation of science in general and the Open Science movement specifically is closely related to their capacity of enabling new forms of research and collaboration as well as providing solutions to share and distribute data and scientific products [Research Data Alliance, 2014]. In the context of data sharing, "openness" has an extended meaning, as the paradigm of open access demonstrates. The extended significance of openness relies on the fact that research data are a prominent part of the research process if compared to open access publications [Kunst and Degkwitz, 2018], the latter being only one, certainly important, stage of the data lifecycle [Sinaeepourfard et al., 2016]. Among the different motivations for sharing data, the traceability of research results and the re-use of scientific data for new research projects and investigations assume a particular value. Moreover, the key requirements for successful re-use of data are findability, accessibility and interoperability, aspects that are covered by the so-called FAIR principles (Findable, Accessible, Interoperable, Reusable) [Boeckhout et al., 2018; Mons et al., 2017; Wilkinson et al., 2016 and 2018]. FAIR data management is one of the current objectives for RIs in Europe and a global challenge requiring well-defined principles and shared practices. The RIs play a key role to achieve these goals by fostering research data management to support open science [Cocco et al., 2019].

In this article, we present and discuss a specific RI: the European Plate Observing System (EPOS, www.epos-eu.org). EPOS is a RI dealing with solid Earth science and a landmark in the ESFRI (European Strategic Forum on Research Infrastructures, www.esfri.eu) roadmap.

Solid Earth science encompasses the study of the planet Earth's solid surface (both on land and offshore) and its interior. It is dedicated to the understanding of the structure and the functioning of the Earth and its dynamics. Solid Earth science brings together many diverse disciplines such as geology, seismology, geodesy, volcanology, geomagnetism as well as chemistry and physics as they all apply to the workings of the Earth. As such, accessing data from the independent observing systems from these diverse disciplines is challenging, because of difficulties in finding and using the relevant data, as well as integrating them with other research data, which is essential to understand the Earth's complex dynamic processes. By improving and facilitating the integration, access, use, and re-use of solid Earth science data, research products, services and facilities, EPOS is developing a holistic, sustainable, multidisciplinary research platform to provide coordinated access to harmonized, interoperable and quality-controlled data from diverse solid Earth science disciplines, together with tools for their use in analysis and modelling. Specifically, the EPOS mission is to create and operate a distributed and sustainable research infrastructure that integrates the diverse European research infrastructures for solid Earth under a common framework. EPOS, relying on new e-science solutions, gives open access to solid Earth science data enabling a step change in multidisciplinary and cross-disciplinary scientific research in many, diverse fields of Earth science.

Indeed, solid Earth scientists have a long-lasting tradition in data acquisition, collection, quality-control and standardization. They are also the key actors for curating and implementing metadata and services for qualification,

1 https://ec.europa.eu/info/research-and-innovation/strategy/strategy-2020-2024/our-digital-future/european-research-infrastructures_en

storage and accessibility of research data. EPOS represents the collaborative framework where joining efforts and resources, sharing existing experiences and skills of domain scientists and e-scientists in order to develop a federated approach for integrating research data and scientific products to ensure data management and interoperability through e-science innovation. The EPOS RI has been envisioned and it is managed to accomplish this mission.

It is important to emphasize that the EPOS vision goes beyond data sharing. Rather, data integration is also envisioned to enable the use of different aggregated data sets through services for (data) visualization, analysis, and processing. This requires both a technological challenge, to build and operate the novel EPOS platform where interoperability is achieved, and a community building action to engage the different scientific communities through novel thematic services, and to coordinate data generation and preservation in solid Earth science. The EPOS data integration system will allow the full exploitation of the value of solid Earth science data, breaking down existing silos and establishing the cooperation necessary for sustainable data management in a digital era. In this article, we also describe and discuss the EPOS federated approach to integrate scientific data and foster FAIR data management in solid Earth science contributing to open science.

2. The EPOS Architecture

EPOS is a complex enterprise that can be successfully run only taking duly into account what has been built and learned in the previous phases of its lifecycle. Indeed, since its conception and design phase (2002-2009), EPOS is managing its complexity relying on a shared and effective roadmap toward construction in which the scientific concept and the architecture design are evolving consistently with the original EPOS vision and mission. Since the Preparatory Phase (2010-2014) the EPOS architecture has been planned and designed in such a way as to allow the enterprise to work as a distributed, sustainable research infrastructure. The decision to build and operate a single research infrastructure for the whole solid Earth science has been motivated by the awareness of the added value of data integration, and it has been strategic for the design and the implementation of the EPOS architecture during the Implementation Phase (2015-2019). The distinctive feature of the architecture design relies on assembling key elements belonging to four complementary categories (see Figure 1) mapping the data generation, qualification, integration and provision:

a) National Research Infrastructures (NRIs)
b) Thematic Core Services (TCS)
c) Integrated Core Services (Central Hub, ICS-C and Distributed, ICS-D)
d) EPOS ERIC Executive Coordination Office (EPOS ERIC ECO).

The rationale behind this architecture design is to guarantee the effective engagement of the communities providing the required skills for the data and service provision, while ensuring the coherency with and the effectiveness of the legal, governance, financial and technical frameworks in EPOS. The EPOS Delivery Framework (Figure 1) is composed of the TCS, ICS and EPOS ERIC ECO, and it is further described later in this article.

The National Research Infrastructures (NRIs) characterise the framework where data are generated, processed, analysed, and archived. They represent the foundation that is covered by the EPOS RI and its Delivery Framework. They also represent the key players of the EPOS conception phase and the reference framework where data providers have been engaged in EPOS since its Preparatory Phase (2010-2014). Most of the national research infrastructures engaged in EPOS are deployed for the monitoring of areas prone to geo-hazards and the surveillance of national territory including areas used for exploiting geo-resources. Providing access to data, scientific products and information to different stakeholders requires effective solutions and harmonization with national and international priorities and strategies [Atakan et al. 2022, this volume]. EPOS is responding to this need, and it has been designed to harmonize data and metadata and to ensure that new data products are accessible to both researchers and users across wider society.

High-quality data require an effective and sustainable management over the entire data lifecycle. With this perspective, the Thematic Core Services (TCS) have been established in EPOS since the Implementation Phase (2015-2019). The TCS[2] represent the community-specific integration and they bring in the governance framework

2 https://www.epos-eu.org/tcs

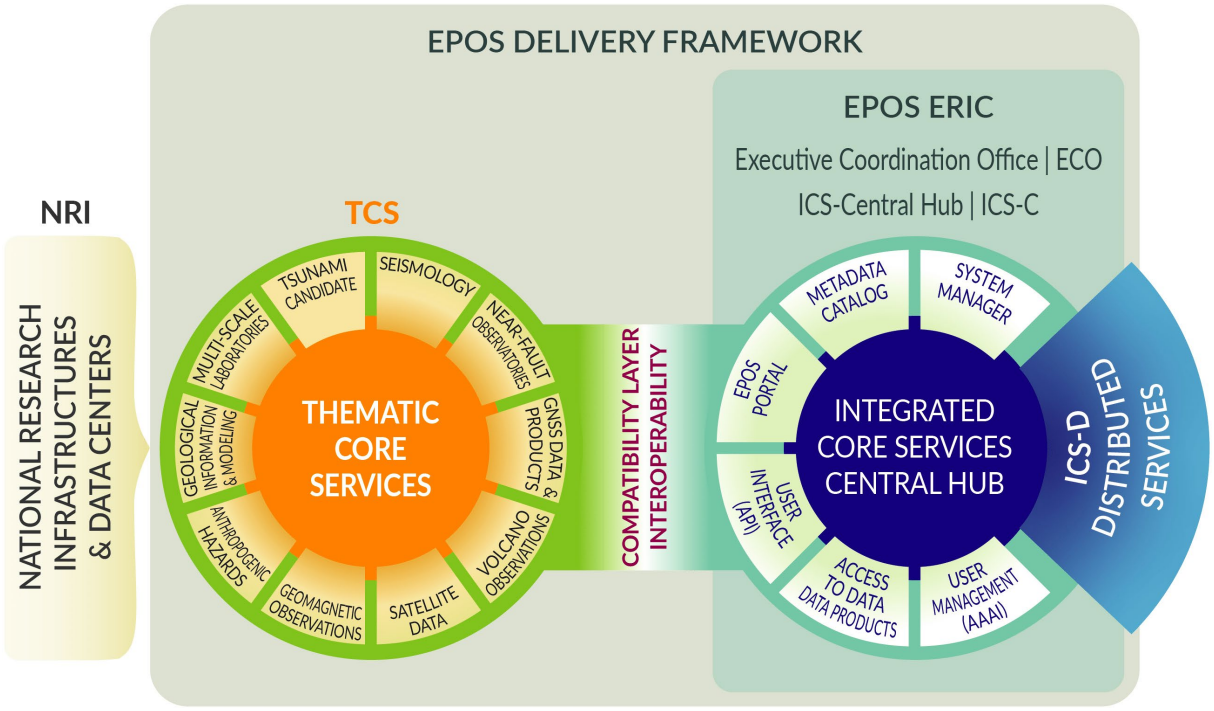

Figure 1. Main elements of the EPOS Architecture: NRIs, TCS and ICS (ICS-C & ICS-D) form the EPOS functional architecture, coordinated by EPOS ERIC, and designed to ensure the EPOS data and service provision. The Integrated Core Services Central Hub (ICS-C) and the Executive Coordination Office (ECO) belong to the EPOS ERIC legal subject.

that is needed to ensure the data and service provision (i.e., access to Data, Data products, Services and Software – DDSS) within the EPOS Delivery Framework. Currently, nine TCS (see Figure 2), are formally established through the signature of a Consortium Agreement among different research organizations, and they are providing implemented and validated services that are integrated in EPOS. These are Seismology, Near Fault Observatories, GNSS Data & Products, Volcano Observations, Satellite Data, Geomagnetic Observations, Anthropogenic Hazards, Geological information and modelling, and Multi-scale Laboratories. One more scientific community, the Tsunami Data and Services, recently joined EPOS as candidate TCS and it is presently discussing its governance structure and implementing its data and service provision [Babeyko et al., 2022, this volume].

The ICS has been implemented as the virtual environment where users can find, access, visualize and download data and data products through the novel EPOS data portal[3] (see Figure 3). The ICS is composed of the Central hub (ICS-C) and the Distributed Core Services (ICS-D). The latter represents the virtual research environment that provides access to services for the direct analysis of aggregated datasets and for developing computational Earth science applications and virtual research environments dedicated to solid Earth science. The ICS-C prototype has been implemented during the Implementation Phase (2015-2019) and it is currently under extensive testing for entering in the Operational Phase in 2023. Operating the ICS-C implies succeeding in making the different data, data products and services provided by TCS interoperable and accessible to users for fostering multidisciplinary research in solid Earth science [Bailo et al. 2022, this volume]. The ICS-D has been designed during the Implementation Phase (2015-2019) and a prototype is currently under implementation [Spinuso et al., 2021] also through related European Commission projects coordinated by the EPOS community (such us the CHEESE project[4]).

The ICS central hub (ICS-C) is hosted in France (BRGM) and UK (UKRI-BGS) and the hosting design has also involved GEUS (Denmark). EPOS has been implemented according to a governance model in which the ECO and the ICS-C belong to EPOS ERIC and are located inside the ERIC perimeter, as illustrated in Figure 1. The Executive

3 https://www.epos-eu.org/dataportal

4 https://cheese-coe.eu

Figure 2. Thematic Core Services currently integrated in EPOS

Coordination Office (ECO), hosted in Italy at the Istituto Nazionale di Geofisica and Vulcanologia, represents the legal seat of EPOS ERIC (see next section for further details). The ECO, guided by the Executive Director, ensures the administration, management and day-to-day operation of the ERIC and the coordination of the EPOS Delivery Framework.

3. The EPOS Delivery Framework

Solid Earth science data represent the knowledge base to unravel the physical and chemical processes that control earthquakes, tsunamis, volcanic eruptions, and ground instability, as well as processes driving tectonics and Earth surface dynamics. Understanding how the Earth works as an interconnected system of these processes is critically important to modern society. Indeed, society needs natural resources to support home life, industry, and business and it needs security in the face of natural hazards. Solid Earth science offers answers about how to maintain a safe, prosperous, and habitable planet, hence potentially addressing many of the 17 United Nations Sustainable Development Goals (UN-SDG). The key challenge is to make the enormous wealth of available solid Earth data openly accessible to promote cross- and multi-disciplinary science for society. To tackle this challenge EPOS has proposed a federated approach to integrate solid Earth science data according to the architecture described above. This federated approach relies on the construction of the Thematic Core Services (TCS), where data and metadata are generated, quality-controlled and standardized, as well as of the Integrated Core Services (ICS) where data and metadata can be integrated and used. The EPOS Delivery Framework is composed of the data integration system represented by the TCS and the ICS (hereinafter, TCS-ICS system) as well as EPOS ERIC (see Figures 1 and 3).

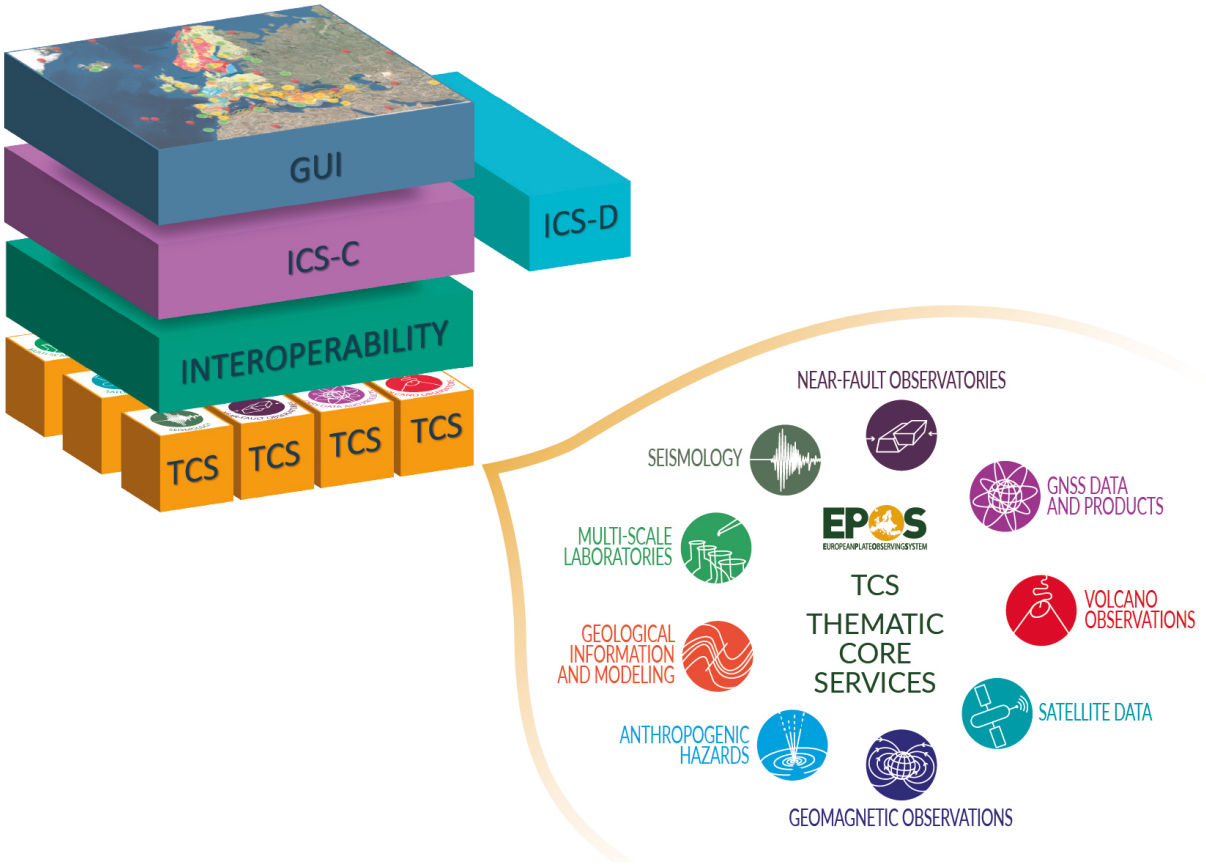

Figure 3. Sketch showing the anatomy of the TCS-ICS System: the Data Portal through the Graphic User Interface (GUI) is the access point to ICS-C for users. Established TCS are illustrated in the figure.

The TCS represent the key component of the EPOS distributed RI and the novel solution to build and operate the EPOS federated approach for data integration. Establishing the TCS is much more than linking national nodes by grouping NRIs. TCS represent the community governance of the data generation and management, ensuring participation, the sharing of the EPOS mission, the coordination of data and service providers according to agreed data policies and access rules, as well as the community building to tackle scientific challenges and innovation. The TCS are established through the signature of a Consortium Agreement, where the signatories are research institutions or organisations. The consortium takes the responsibility of the TCS governance and oversees the services and the data provision to EPOS through designated organisations (Service Providers); consequently, a legal agreement (Collaboration Agreement) is signed between EPOS ERIC and the Service Provider. The Service Providers bring together data providers through the shared EPOS data policy. Therefore, the TCS represent the new collaborative framework for contributing to the operation and development of the EPOS RI.

The pan-European dimension of the EPOS Delivery Framework is demonstrated by the number of countries and research organizations participating to the data- and service provision and to the TCS governance: 25 countries are involved in EPOS through nearly 140 research organizations. Among them 65 research organizations and 4 international organizations are formally engaged in the TCS consortia, belonging to 21 countries out of the 25 involved in EPOS. The data and service provision is currently ensured by 35 Service Providers, which are making available nearly 198 validated data, data-products and services (DDSS elements) provided through 238 services (Figure 4). If we look at the details of the data and services delivered by TCS to EPOS, it is possible to appreciate that they are not only composed of services, existing or new, that support already accessible data and products, but that they also cover data and products which are not yet accessible to users. It is illuminating here to emphasize again the relevance of the integrated use of different datasets (see Figure 4).

At this point it is useful to briefly describe the contents of the data and products provided by each of the nine TCS formally established so far.

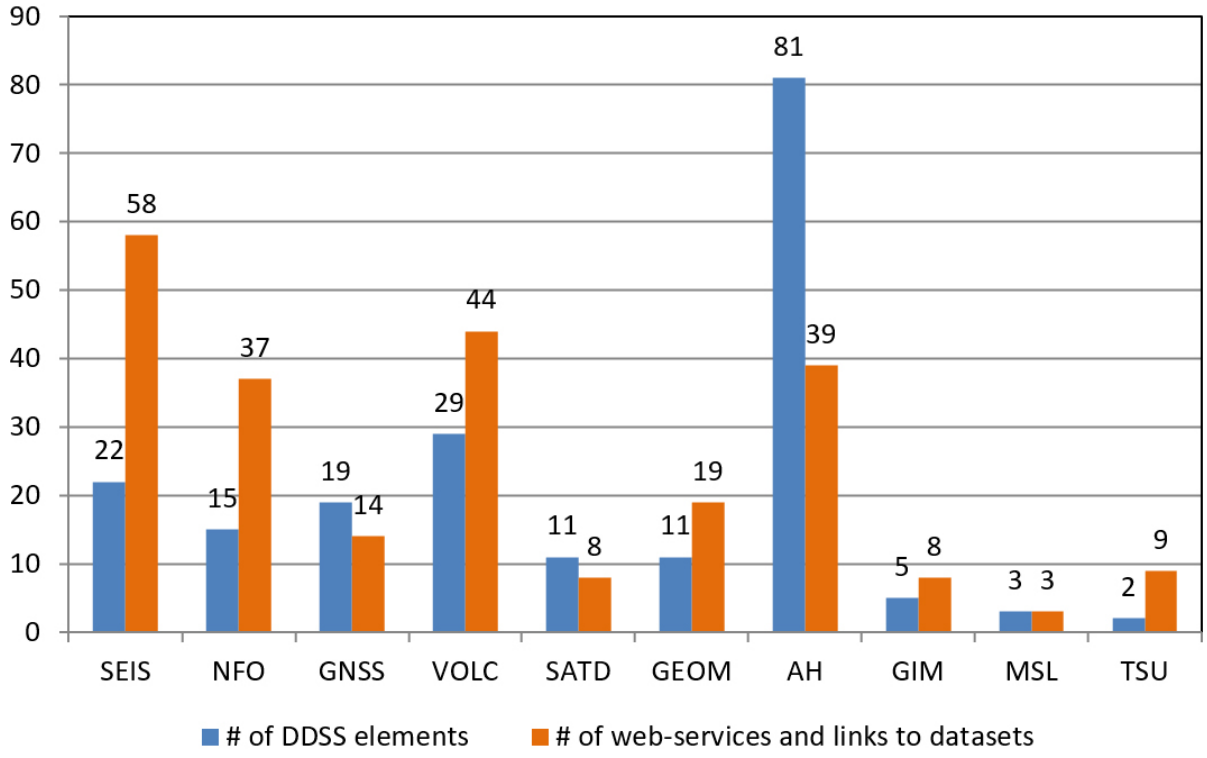

Figure 4. Histogram with DDSS (Data, Data products, Services, Software) provision per TCS, including the Tsunami Candidate TCS.

TCS Seismology is providing access to data, data products and services for seismic waveforms, seismological products (such as information about recent and historical earthquakes, among many others) as well as seismic hazard and risk products [Haslinger et al., 2022, this volume]. Three international research organizations participate to the TCS: namely, ORFEUS (Observatories & Research Facilities for European Seismology, http://www.orfeus-eu.org) [Cauzzi et al., 2021; Haslinger et al., 2019] and its European Strong-Motion [Lanzano et al., 2021] Integrated Data Archive and Service Infrastructure (EIDA) [Strollo et al., 2021] in charge of coordinating the access to waveform data, the EMSC (European and Mediterranean Seismological Centre, https://www.emsc-csem.org) [Mueller et al., 1980] in charge of coordinating the integration and the access to seismological products and information about the seismic events in the European region and beyond and EFEHR (European Facilities for Earthquake Hazard & Risk, http://www.efehr.org/) [Danciu et al., 2017] created over the last decade also with support from EPOS, providing open access [Cotton et al., 2021] to data, models, tools and expertise to assess seismic hazard and risk in Europe.

TCS Near-Fault Observatories (NFOs) is providing access to multidisciplinary data, including borehole (seismological, geodetic and geochemical) data, and scientific products to study the anatomy of active faults in Europe [Festa et al., 2018]. By providing access to multidisciplinary data and products from different solid Earth disciplines, such as geodesy, geochemistry, seismology and geology, the NFOs will foster scientific progress in understanding seismogenic processes, ground shaking and earthquake forecasting. The TCS NFO currently involves six observatories, located across Europe and the Mediterranean region, in areas of elevated seismic hazard, providing highly accurate information on the mechanics and the geometry of active fault systems [Chiaraluce et al., 2022]. It also includes a Geo-Hazard Supersite (the Marmara Sea and Istanbul) included in the GEO work program (Group on Earth Observations[5], www.geo-gsnl.org) [Ryan et al., 2014]. In addition, these on-site observatories can be considered as a natural laboratory to collect a broad range of signals related to the physical and chemical processes causing earthquakes and faulting, essential to model the causative processes down to very small spatial and temporal scales. These scientific data are also used to implement and operate innovative Early Warning Systems for the rapid detection of earthquakes, real-time estimation of earthquake magnitude, and notification of expected

5 https://www.earthobservations.org/documents/gwp20_22/GSNL.pdf

shaking. This community has been established in EPOS and the data and services delivered by this TCS were not previously available in a structured, integrated, form.

TCS GNSS Data and Products (GNSS) is providing access to data, metadata, scientific products and services to foster research on geodesy and the Earth's surface motion in different timescales [Fernandes et al., 2022]. The TCS GNSS is also coordinating the archiving of relevant GNSS data, metadata and data products, promoting best practices for GNSS station operation, data quality control and data management, maintaining and developing GNSS data products and open-source software [Menut et al., 2019]. In particular, the TCS GNSS has developed the open-source GLASS platform to allow users to store and disseminate data and metadata from an integrated network of GNSS stations operating in Europe. The planned activities are performed in close partnership with the geodetic GNSS community represented by EUREF, the IAG sub-commission for the European Reference Frame (http://www.euref.eu).

TCS Volcano Observations (VO) integrates the available multidisciplinary data (seismic, geodetic, electromagnetic, geochemical, and environmental data) collected on European volcanoes and their geodynamic surroundings [Spampinato et al., 2019; Puglisi et al., 2022]. The TCS VO provides scientists access to a portfolio of data, scientific products and services as well as coordinates the trans-national access to Volcano Observatories and facilities to foster scientific research on volcanic processes and related hazards. The TCS VO also includes two Geo-Hazard Supersites (the Italian and the Icelandic Volcanoes) declared in the GEO work program (Group on Earth Observations[4], www.geo-gsnl.org). The data and the products provided by the TCS VO are also used to assess volcanic hazard and to support governmental and private decision-making.

TCS Satellite Data (SD) uses satellite measurements to foster research on Earth's ground deformation phenomena and their causative processes, such as earthquakes, landslides and volcanic activity [Manunta et al., 2019]. It develops, harmonizes and integrates these satellite measurements into services and products that can be exploited by the solid Earth science community. The TCS SD will allow users to discover and download satellite data products generated over selected areas, including time series, and to remotely process satellite datasets. Satellite data products are mainly generated through radar techniques from the ESA Sentinel-1 constellation of the Copernicus Program. The TCS SD is collaborating with the European Space Agency (ESA) and its Geohazards Thematic Exploitation Platform (https://geohazards-tep.eu, GEP) [Foumelis et al., 2019], a user-driven environment specifically designed for the advanced exploitation of Earth Observation data. GEP is using cloud processing facilities to enable the community to tailor different ways of visualizing data, in a user-friendly way. The TCS SD is also coordinating the interactions with national space agencies to foster the use of satellite data.

TCS Geomagnetic Observations (GEOM) coordinates magnetic observatories and provides usable and easy access to geomagnetic data, taking advantage of the enormous amount of high-resolution data and large datasets that were made possible with the beginning of the digital era [Flower et al., 2017]. Access to accurate and integrated geomagnetic data is vital to the well-functioning of navigation systems, the interpretation of tectonic plates' movement, and the accuracy of European mapping agencies, among other important applications. The TCS GEOM aims to consolidate the geomagnetic community and break down barriers to data access, by modernizing data archival and distribution and creating new services for magneto-telluric data and geomagnetic model.

TCS Anthropogenic Hazards (AH) provides data on the human-induced seismicity in the form of "episodes" [Orlecka-Sikora, 2017; Lasocki et al., 2022]. Each episode consolidates geophysical data provided by public research infrastructures and industry on anthropogenic activities in a time-limited frame, thus allowing researchers to evaluate the temporal evolution of the seismic hazard throughout time. Episodes are collected and organized in the EPISODES platform (https://tcs.ah-epos.eu) [Orlecka-Sikora et al., 2020] to foster both research and training on induced seismicity and hazards related to the exploration and exploitation of geo-resources. Through this workspace, users can process the open access episodes, tailor the data visualization and analysis according to their needs with custom packages and collaborate with other researchers. TCS-AH coordinates the integration and the access to facilities, datasets, and scientific products on anthropogenic hazards.

TCS Geological Information and Modeling (GIM) develops and integrates the information and data infrastructures operated by the international community, such as the European Geological Surveys [Urvois et al., 2020; 2022]. Shared reference datasets on geological maps, boreholes (vertical shafts constructed for water, oil, or gas extraction), 3D and 4D geological models, mineral resources, geohazards, and groundwater will be made accessible to the users through the EPOS Data Portal. By providing virtual access to borehole data and catalogues of geological maps, users can retrieve consolidated information concerning geological data and scientific products. The TCS GIM is also coordinating the sharing of new data and information produced by researchers ensuring quality control

and standardization, thus further engaging the geological community in the EPOS Delivery Framework also in collaboration with EuroGeoSurveys (https://www.eurogeosurveys.org).

TCS Multi-scale Laboratories (MSL) preserves and harmonizes experimental laboratory data that are representative of the physical and chemical processes acting at different scales [Elger et al., 2022; Willingshofer et al., 2021]. The TCS MSL also coordinates trans-national access (TNA) to over ninety laboratories affiliated with eleven institutes in eight European countries. They operate world-class experimental apparatuses, such as electron microscopes, deformation testing machines, and paleomagnetic measurements, divided into four sub-domains of the solid Earth Science: (i) analogue modeling of geologic processes allowing researchers to model the tectonic processes and analyze the properties of materials; (ii) rock and melt physical properties fostering research on earthquake mechanics and volcanic processes; (iii) paleomagnetic and magnetic measurements that provide records of the strength and polarity reversals of the Earth's magnetic field; (iv) geochemical and microscopy data, which facilitate the study of elements and minerals' composition and the study of the rocks age. The TCS MSL is establishing a collaborative network of European experimental laboratories for solid Earth science. The TCS Multi-scale laboratories will make available, through the EPOS Portal, data, products, and software from several types of laboratory infrastructures while offering trans-national access (TNA) to the newest and most advanced solid Earth laboratory facilities in Europe. A dedicated TNA portal will be implemented in the ICS-C [see Wessel et al., 2022].

The multidisciplinary breadth of the data and service provision ensured by TCS corroborates the scientific impact of the EPOS RI and the community building behind the EPOS federated approach. The success in making all these data and scientific products interoperable and accessible through the ICS-C in a FAIR compliant way [Bailo et al., 2020] further confirms the importance of promoting the integrated use of these data to users and stakeholders. Figure 5 illustrates the integration of data, metadata and services provided by TCS through the ICS-C as well as the different stakeholders categories envisioned in EPOS. This figure depicts the centrality of the TCS-ICS system as the engine of the EPOS Delivery Framework as well as the importance of providing access to distributed core services (namely, the ICS-D) to fully exploit the multidisciplinary data and scientific products (see also Figure 4) made available through the ICS-C. Worthy of note is the vision to engage scientists from other Earth science domains to foster cross-disciplinary research, with particular attention to environmental science [Kutsch et al, 2016; Sorvari et al., 2016].

4. EPOS ERIC

An ERIC (European Research Infrastructure Consortium) is a specific legal form that facilitates the establishment and the operation of RIs with pan-European dimension. By granting the status of ERIC to a RI, the European Commission acknowledges the new legal subject entitled to govern the RI. The establishment of an ERIC is a long-lasting process, which usually starts during the preparatory phase together with the design of the RI. The decision body of an ERIC is its General Assembly composed of Members representing National Authorities and funding agencies.

EPOS decided to adopt the ERIC model to govern and coordinate the Delivery Framework at the beginning of the Preparatory Phase in 2010. This decision has been then implemented and finalized during the two key stages of EPOS RI lifecycle, namely the Preparatory Phase (2010-2014) and the Implementation Phase (2015-2019). Indeed, the European Commission granted the ERIC status to EPOS on October 30, 2018. The main task of EPOS ERIC is to provide an effective governance framework to drive the integration and coordination of the TCS and to build and provide governance for the ICS. EPOS ERIC has been established to design and implement a long-term plan for the integration of research infrastructures for solid Earth science in Europe.

As anticipated above, the legal seat of EPOS ERIC, the Executive Coordination Office (ECO), is hosted in Rome (Italy) in the headquarter of the Istituto Nazionale di Geofisica e Vulcanologia (INGV). Currently, EPOS ERIC is composed of thirteen Country Members (Belgium, Denmark, France, Greece, Iceland, Italy, Norway, Poland, Portugal, Romania, Slovenia, The Netherlands, United Kingdom) and one Observer (Switzerland).

According to the EPOS architecture and the EPOS ERIC governance model, there are two elements included within the EPOS ERIC perimeter (Figure 1) representing assets of EPOS ERIC: the ECO and the ICS-C. These two elements represent the capacity of EPOS ERIC to operate and govern its Delivery Framework. From a financial perspective, the costs for operating the ECO and the ICS-C are supported through the provision of host contributions by hosting countries, namely Italy for the ECO, and France and UK for the ICS-C. Host contributions are necessary to run the ECO and the ICS-C without financially impacting on the EPOS ERIC cash flow provided through the membership fees from the Members and the Observer of the ERIC. Therefore, from a governance perspective

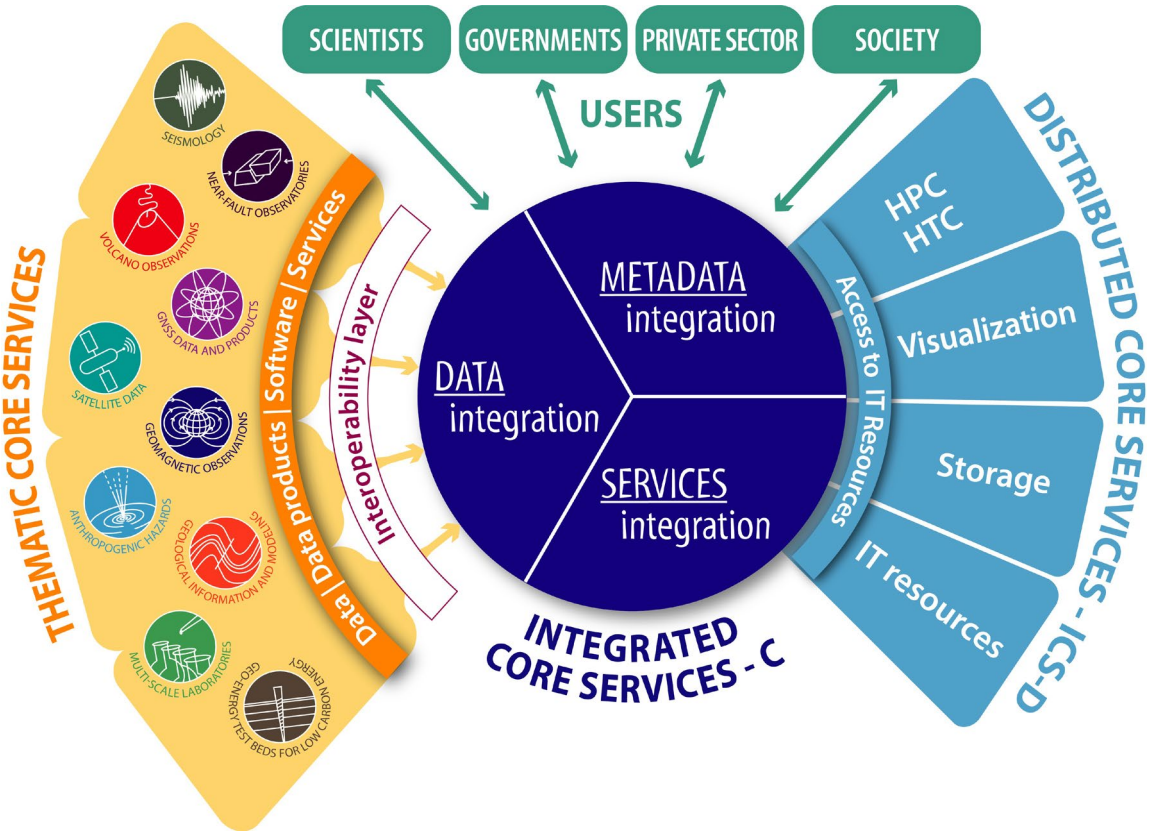

Figure 5. The TCS-ICS System representing the EPOS Delivery Framework.

the commitments of ERIC Country Members to provide host contributions to host and operate the ECO and the ICS-C strengthen the long-term sustainability of the EPOS RI. From a legal perspective, the partnership agreement signed by EPOS ERIC and the hosting organizations transforms the agreed financial and technical frameworks into an effective governance background for operating the EPOS RI.

Thematic Core Services (TCS) represent the foundation of the EPOS Delivery Framework. They are located outside the EPOS ERIC perimeter, but within the perimeter of the EPOS Delivery Framework (Figure 1). This because the TCS have their own governance structure operated by the involved research organizations and scientific communities. From a technical perspective, each TCS is linked to EPOS ERIC through the interoperability layer (Figure 5) built to establish the TCS-ICS system. From a legal perspective, the TCS are linked to EPOS ERIC through dedicated collaboration agreements for the data and service provision and for their governance and coordination. According to the EPOS ERIC Statutes, the costs for operating the TCS, as defined in the TCS cost-book, are only partially supported by the ERIC and mainly at national level by the involved research organizations. This is an essential element of the EPOS ERIC sustainability plan [see Saleh Contell et al., 2022, this volume], because TCS operation relies on in-kind resources provided by research organizations owning the NRIs as well as on further in-kind contributions provided by national authorities (ERIC Country Members).

Presently EPOS is in a peculiar stage of the RI lifecycle, namely the transition from the implementation to the operational phase. The latter is referred to as the EPOS Pilot Operational Phase (EPOS POP) and it is the stage in which EPOS ERIC is called to test both the readiness of the TCS-ICS system and the robustness of its Delivery Framework to allow a successful transition to the Operational Phase in 2023.

5. Discussion

EPOS is a distributed RI of pan-European dimension, as corroborated by the number of countries (25) and research organizations (≈140) participating to its integration plan. The dimension of the EPOS distributed RI requires the adoption of an effective and shared governance to harmonize the national strategies and priorities with

the EPOS needs and requirements [see Atakan et al, 2022, this volume] while ensuring an added value for sharing resources and strengthening the sustainability of the Delivery Framework.

The EPOS ERIC Statutes have been implemented to regulate the governance and financial frameworks, according to the ERIC Regulation (Council Regulation (EC) No 723/2009 of 25 June 2009), strengthening the EPOS ERIC role. The recognition of the EPOS role by the national authorities (ERIC Country Members) and the confirmation of their commitments to support the EPOS RI is essential to tackle the challenge of ensuring the long-term sustainability of the EPOS RI [Saleh Contell et al. 2022, this volume]. The participation of national and international RIs to the EPOS integration plan has fostered their inclusion in the national roadmaps for RIs, thus ensuring the provision of national funds to support their operation. This has certainly represented one of the main impacts of EPOS on the participating communities.

The community building has been a key factor for creating the conditions to integrate NRIs and establish the TCS and the ICS. The pro-active participation of solid Earth scientists and e-scientists to the design, implementation, and construction of the EPOS Delivery Framework (that is, the novel TCS-ICS system) represents a further positive impact of EPOS on its scientific community. It is worth noting that the co-design approach involving domain scientists and e-scientists to implement the EPOS RI has been adopted since the Preparatory Phase and it is continuing nowadays. This is also a key indicator of the wide perspective of EPOS contributions to multidisciplinary research in Earth sciences as well as to cross-disciplinary collaborations in environmental science. EPOS is indeed cooperating with other RIs in the environmental domain under the ENVRI (Environmental Research Infrastructures, https://envri.eu) [Petzold et al., 2019] umbrella to support the sharing of data in Earth sciences, fostering FAIR data management and cross-disciplinary research.

The EPOS integration plan has still ample space for further developments, as for example promoting the use of data and services to generate new scientific products to be shared and made accessible through the EPOS data Portal after quality-control and standardization. This corresponds to transforming users into data product providers, which directly contribute to foster open science and the culture of data sharing coherently with FAIR data management. These actions have to be coordinated by the thematic communities (TCS), because they are in charge of ensuring quality control and the adoption of shared standards for data and metadata. According to the EPOS vision and mission, the scientific community is the key enabler of innovation and scientific progress effectively supporting open science.

The impact of the EPOS RI can be also measured in terms of the added value for science and society. The impact on science is corroborated by the size and diversity of the EPOS data and service provision, determining the contents of the EPOS Delivery Framework. It will be further assessed and, hopefully, confirmed by the number of users that will have access to the EPOS services and the number of applications and scientific products that will be shared through the EPOS platform when it will become operational. The added value for society is ensured by the use of solid Earth science data for geo-hazards assessment and risk mitigation and by the engagement of the data and service providers formally committed to carry out the surveillance of the national territory from natural and anthropogenic events. This implies the necessity for EPOS to consider the ethical dimension of providing access to scientific information and services to stakeholders and society at large [see Martì et al., 2022, this volume].

EPOS is not unique in the global landscape of research infrastructures. There are similar initiatives in Australia (Auscope, https://www.auscope.org.au) and United States (Earthscope, 2003-2018, https://www.earthscope.org and EarthCube https://www.earthcube.org/) which are dealing with the sharing of data and services in solid Earth sciences. What makes EPOS unique is its federated approach involving different European countries, diverse national landscapes, and numerous data and service providers. Moreover, the EPOS vision and mission to share and integrate data, fostering FAIR data management, is a current paradigm worldwide, placing EPOS in a global perspective in data science. Indeed, the EPOS community is adopting concrete actions to make FAIR data principles a practice [Bailo et al., 2020; Bailo et al. 2022-a; Bailo et al, 2022, this volume; Cocco et al., 2019] and, importantly, to make FAIR data management sustainable for solid Earth science in Europe.

6. Conclusions

The European Plate Observing System (EPOS) is a distributed research infrastructure (RI) whose vision is to ensure sustainable and universal use and re-use of multidisciplinary solid Earth science data and products fostering state-of-the-art research and innovation. Consequently, the EPOS mission is to establish and underpin sustainable

and long-term access to solid Earth science data and services integrating the diverse European research infrastructures under a common federated framework governed by EPOS ERIC. The design and implementation of the EPOS integration plan has required a decade (2010-2019) in which the EPOS community has shared the vision and worked together to accomplish the mission. Considerable advances in information technology and e-sciences have made the integrated approach possible by easing the access to the wealth of data and products available across solid Earth science and related fields. During the past decade an enormous, highly skilled, workforce has been engaged in EPOS. The success of any RI relies on the engagement of highly motivated and skilled people as well as on the capacity to manage the human resources to have the right people in the right place, something which is a key element to tackle the challenge of sustainable operation of the RI. Preserving their enthusiastic engagement is a priority action to deal with long-term sustainability.

This article has presented and described the EPOS RI, emphasizing the successful outcomes of the preparatory and implementation phases, and has discussed the current construction stage that will yield to the Operational Phase in 2023. Accessible datasets will bring novel cross-fertilization of ideas and lead to innovative research that is the key to foster a science for society. Through the integration of data, models, and facilities EPOS will allow the Earth science community to make a step change in developing new concepts and tools for key answers to scientific and socio-economic questions concerning geo-hazards and geo-resources as well as Earth sciences applications to the environment and to human welfare.

The work done to make the data and the services provided by TCS interoperable and integrated in the novel platform represented by the ICS represents a good practice in data science to promote Open Science and make FAIR data management practicable. This makes EPOS visible and well positioned in the European and global landscape of FAIR data management. We have also presented the EPOS architecture and the Delivery Framework discussing the proposed federated approach to govern data integration. We have pointed out the strength of the approach and the impact on solid Earth science, emphasizing the successful community building that is supporting the current EPOS construction. These results corroborate that the operation of the EPOS RI is viable. Ensuring the long-term sustainability of a pan-European research infrastructure such as EPOS, is the current challenge that has to be tackled to plan and execute the operational phase for the next decades.

Acknowledgements. We wish to thank the EPOS ERIC Service Coordination Committee composed of TCS and ICS representatives, who are working hard to make the EPOS RI operational, as well as to the IT board for the continuous efforts to ensure RI progress toward operation. We also wish to thank the Executive Coordination Office whose staff is fully committed to build and operate EPOS ERIC. Special thanks to all the people who worked actively in EPOS in past years, in particular to Torild Van Eck and Russ Evans who passed away leaving us their heritage of humanity in this professional endeavor. We wish to thank Helle Pedersen for chairing the Service Coordination Board and Carine Bruyninx for chairing the Implementation Phase Council during the implementation phase. We wish to thank Barbara Angioni for her support in the graphic design and for the figures. This work has received funds from the EC project EPOS SP (contract number 871121) funded in the framework of the Horizon 2020 program.

References

Atakan K., M. Cocco, B. Orlecka-Sikora, R. Pijnenburg, L. Ottemöller T. Langeland, J. Michalek, C. Rønnevik C., Olszewska D., Górka-Kostrubiec B., et al. (2022). National EPOS initiatives and participation to the EPOS integration plan, Ann. Geophys., this Volume.

Babeyko A., S. Lorito, F. Hernandez, J. Lauterjung, F. Løvholt, A. Rudloff, M. Sørensen, A. Androsov, I. Aniel-Quiroga, A. Armigliato, M. A. Baptista, E. Baglione, R. Basili, J. Behrens B. Brizuela, S. Bruni, M. D. Cambaz, J. Cantavella-Nadal, F. Carrilho, I. Chandler, D. Chang-Seng, M. Charalampakis, L. Cugliari, C. Denamiel, G.G. Dogan, G. Festa, D. Fuhrman, A.-A. Gabriel, P. Galea, S. J. Gibbons, M. Gonzalez, L. Graziani, M.-A. Gutscher, S. Harig H. Hebert, C. Ionescu, F. Jalayer, N. Kalligeris, U. Kânoğlu, P. Lanucara, J. Macías, S. Murphy, Ö. Necmioğlu, R. Omira G.A. Papadopoulos, R. Paris, F. Romano, T. Rossetto J. Selva, A. Scala, R. Tonini K. Trevlopoulos I. Triantafyllou, R. Urgeles R. Vallone I. Vilibić, M. Volpe, A. C. Yalciner (2022). Towards 1 the new Thematic Core Service Tsunami within the EPOS Research Infrastructure, Ann. Geophys., this Volume.

Bailo, D., R. Paciello, M. Sbarra, R. Rabissoni, V. Vinciarelli, and M. Cocco (2020). Perspectives on the Implementation of FAIR Principles in Solid Earth Research Infrastructures, Front. Earth Sci., 8, 3, https://doi.org/10.3389/feart.2020.00003.

Bailo D., K. G. Jeffery Atakan K., L. Trani, R. Paciello, V. Vinciarelli, J. Michalek., A. Spinuso (2022). Data integration and FAIR data management in solid Earth science, Ann. Geophys., this Volume.

Boeckhout M., G.A. Zielhuis and A.L. Bredenoord (2018). The FAIR guiding principles for data stewardship: Fair enough?, Eur. J. Hum. Genet., 26, 931-936, https://doi.org/10.1038/s41431-018-0160-0.

Cauzzi, C., J. Bieńkowski, S. Custódio, S. D'Amico, C. Evangelidis, P. Guéguen, C. Haberland, F. Haslinger, G. Lanzano, L. Ottemöller, S. Rondenay, R. Sleeman, A. Strollo (2021). ORFEUS Services and Activities to Promote Observational Seismology in Europe and beyond, EGU21-6119, https://doi.org/10.5194/egusphere-egu21-6119.

Chiaraluce L., G. Festa, P. Bernard, A. Caracausi, I. Carluccio, J. Clinton, R. Di Stefano, L. Elia, C. P. Evangelidis, S. Erginta, O. Ianu, G. Kaviris, A. Marmureanu, S. Šebela, E. Sokos (2022). The Near Fault Observatory community in Europe, Ann. Geophys, in press.

Cocco M., D. Bailo, R. Paciello, C. Freda and K. Jeffery (2019). The FAIRness horizon: from principles to practice the EPOS experience in solid Earth science, Geophys. Res. Abstr., 21 (2019), https://meetingorganizer.copernicus.org/EGU2019/EGU2019-13137.pdf.

Cotton F., H. Crowley, L. Danciu, C. Beauval, O. Ktenidou, P. Mäntyniemi, A. Correia, S. Wiemer S., D. Giardini and G. Weatherill (2021). Towards open, reproducible and transparent European seismic hazard and risk models. EFEHR vision and data policy, http://www.efehr.org/.

Council Regulation (EC) No 723/2009 of 25 June 2009 on the Community legal framework for a European Research Infrastructure Consortium (ERIC) Current consolidated version: 26/12/2013 – ELI: http://data.europa.eu/eli/reg/2009/723/oj.

Danciu, L., S. S. Wiemer, F. Haslinger, P. Kastli and D. Giardini (2017, April). EFEHR-the European Facilities for Earthquake Hazard and Risk: beyond the web-platform, In EGU General Assembly Conference Abstracts (17834), https://meetingorganizer.copernicus.org/EGU2017/EGU2017-17834.pdf.

Elger K., G. ter Maat, R. Caldeira, C. Cimarelli, F. Corbi, S. Dominguez, M. Drury, F. Funiciello, O. Lange, A. Ougier-Simonin, M. Rosenau, R. Wessels, E. Willingshofer, A. Winkler (2022). The EPOS Multi-Scale Laboratories: A FAIR Fram, ework for Stimulating Open Science Practice across European Earth Sciences Laboratories, Ann. Geophys., in press.

EU Regulation No 1291/2013. Establishing Horizon 2020 – the Framework Programme for Research and Innovation (2014- 2020). Article 2 (6) 11 December 2013.
https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:347:0104:0173:EN:PDF
https://ec.europa.eu/info/research-and-innovation/strategy/strategy-2020-2024/our-digital-future/european-research-infrastructures_en.

European Union (2015). Open Innovation, Open Science, Open to the World – a vision for Europe. ISBN 978-92-79-57345-3, https://doi.org/10.2777/552370.

Fernandes R., C. Bruyninx, P. Crocker, J-L. Menut, A. Socquet, M. Vergnolle, A. Avallone, M. Bos, S. Bruni, R. Cardoso et al. (2022). A new service to share GNSS Data and Products, Ann. Geophys., in press.

Festa, G., L. Chiaraluce, L., H. Valdimarsdóttir, and S. Ergintav (2018, April). Near Fault Observatories within EPOS-IP: multidisciplinary data, high-level data products and community web services, In EGU General Assembly Conference Abstracts (17081), https://meetingorganizer.copernicus.org/EGU2018/EGU2018-17081.pdf.

Flower, S., P. Hejda, A. Chambodut, J. J. Curto, J. Matzka, A. Thomson and K. Kauristie (2017, April). Progress of Geomagnetism towards integration of data and services in EPOS. In EGU General Assembly Conference Abstracts (8339), https://meetingorganizer.copernicus.org/EGU2017/EGU2017-8339.pdf.

Foumelis, M., T. Papadopoulou, P. Bally, F. Pacini, F. Provost and J. Patruno (2019, July). Monitoring Geohazards using on-demand and systematic services on Esa's Geohazards exploitation platform, In IGARSS 2019-2019 IEEE International Geoscience and Remote Sensing Symposium, 5457-5460, IEEE.

Haslinger, F. (2019). The current status and vision of coordinated services for seismology in Europe-EPOS Seismology, In Geophysical Research Absstract, 21, https://meetingorganizer.copernicus.org/EGU2019/EGU2019-15278-1.pdf

Haslinger F., R. Basili, R. Bossu, C. Cauzzi, F. Cotton, H. Crowley, S. Custodio, L. Danciu, M. Locati, A. Michelini, I. Molinari, L. Ottemöller and S. Parolai (2022). Coordinated and Interoperable Seismological Data and Product Services in Europe: the EPOS Thematic Core Service for Seismology, Ann. Geophys., this Volume.

Kunst S. and A. Degkwitz (2018). Open Science – the new paradigm for research and education? Information Services & Use 38 (2018) 203-205 203 DOI 10.3233/ISU-180014, IOS-Press.

Kutsch W.L., A. Asmi A., P. Laj, M. Brus and S. Sorvari (2016). Environmental Research Infrastructures providing shared solutions for science and society (ENVRIplus), Geophysical Research Abstracts. https://meetingorganizer.copernicus.org/EGU2016/EGU2016-16250.pdf.

Lanzano G., L. Luzi, C. Cauzzi et al. (2021). Accessing european strong-motion data: An update on orfeus coordinated services, Seismol. Res. Lett., 92:1642-1658. https://doi.org/10.1785/0220200398.

Lasocki S., B. Orlecka-Sikora, J. Kocot, K. Chodzińska,A. Leśnodorska A. (2022). Sharing data and services on anthropogenic seismic processes for research, education and innovation, Ann. Geophys, in press.

Manunta, M. (2019, January). The satellite component of the EPOS infrastructure: Thematic Core Service Satellite Data, In Geophysical Research Abstracts, 21. https://meetingorganizer.copernicus.org/EGU2019/EGU2019-16052.pdf

Marti M., F. Haslinger, S. Peppoloni, G. Di Capua, H. Glaves, I. Dallo (2022). Addressing the challenges of making data, products, and services accessible: an EPOS perspective, Ann. Geophys. this Volume.

Menut, J. L., P. Crocker, J. Douša, C. Bruyninx, M. Bos, M. Vergnolle, ... and P. Vaclavovic, (2019, January). GLASS, a tool for quality-controlled GNSS data and product dissemination. In Geophysical Research Abstracts, Vol. 21, https://meetingorganizer.copernicus.org/EGU2019/EGU2019-15253-1.pdf.

Mons B., C. Neylon, J. Velterop, M. Dumontier, L.O.B. Da Silva Santos and M.D. Wilkinson (2017). Cloudy, increasingly FAIR; Revisiting the FAIR Data guiding principles for the European Open Science Cloud, Inf. Serv. Use, 37, 49-56, doi:10.3233/ISU-170824.

Mueller, S. (1980). The European-Mediterranean Seismological Centre (EMSC), European Earthquake Prediction Program, 189-193.

Orlecka-Sikora, B. (2017, April). EPOS Thematic Core Service ANTHROPOGENIC HAZARDS (TCS AH)-development of e-research platform. In EGU General Assembly Conference Abstracts, 14546, https://meetingorganizer.copernicus.org/EGU2017/EGU2017-14546.pdf.

Orlecka-Sikora, B., S. Lasocki, J. Kocot, T. Szepieniec, J. R. Grasso, A. Garcia-Aristizabal, ... and T. Fischer (2020). An open data infrastructure for the study of anthropogenic hazards linked to georesource exploitation, Sci. data, 7, 1, 1-16, https://doi.org/10.1038/s41597-020-0429-3.

Petzold, A., A. Asmi, A. Vermeulen, G. Pappalardo, D. Bailo, D. Schaap, H. M. Glaves, U. Bundke, and Z. Zhao (2019). ENVRI-fair-interoperable environmental fair data and services for society, innovation and research. Proceedings – IEEE 15th International Conference on EScience, EScience, 2019, 824068, 277-280, https://doi.org/10.1109/eScience.2019.00038.

Puglisi G., D. Reitano, L. Spampinato, K.S. Vogfjörd, S. Barsotti, L. Cacciola, A. Geyer Traver, D.S. Guðjónsson, Y. Guehenneux, J.C. Komorowski, P. Labazuy, A. Lemarchand, R. Nave, J.M. Saurel, P. Bachelery (2022). The integrated multidisciplinary European 1 volcano infrastructure: from the conception to 2 the implementation, Ann. Geophys., in press.

Research Data Alliance (RDA) Europe Report (2014). The data harvest: how sharing research data can yield knowledge, jobs and growth. RDA Europe 2014, Report available at: https://rd-alliance.org/sites/default/files/attachment/The%20Data%20Harvest%20Final.pdf

Ryan, B. and D. Cripe (2014). The Group on Earth Observations (GEO) through 2025, 40th COSPAR Scientific Assembly, 40, A0-1.

Saleh Contell K., K. Karlzén, H. Pedersen, M. Cocco, K. Atakan, D. Bailo, O. Lange, Mercurio D., G. Maracchia, A. Sangianantoni, D. Piras, M. Fredella and C. Freda (2022). Long-term sustainability of a distributed RI: the EPOS case, Ann. Geophys., this Volume.

Sinaeepourfard, A., X. Masip-Bruin, J. Garcia and E. Marín-Tordera (2015). A Survey on Data Lifecycle Models: Discussions toward the 6Vs Challenges, Technical Report (UPC-DAC-RR-2015-18), https://www.ac.upc.edu/app/researchreports/html/RR/2015/18.pdf.

Sorvari S., W.L. Kutsch P. Laj, A. Asmi and M. Brus (2016). ENVRI Cluster – a community-driven platform of European environmental research infrastructures for providing common solution for science and society, Geophysical Research Abstracts, https://meetingorganizer.copernicus.org/EGU2016/EGU2016-15226.pdf.

Spampinato, L., P. Bachelery, A. G. Traver, J. C. Komorowski, G. Puglisi, K. Vogfjörd and G. Vougioukalakis (2019, January). The contribution of the European Volcanology community to the implementation of the European

Plate Observing System (EPOS) infrastructure, In Geophysical Research Abstracts, 21, https://meetingorganizer.copernicus.org/EGU2019/EGU2019-19201.pdf.

Spinuso, A, M. Veldhuizen, D. Bailo, V. Vinciarelli, T. Langeland (2021). SWIRRL Managing Provenance-Aware and Reproducible Workspaces, Data Intelligence J. on Canonical Workflow Frameworks for Research, https://doi.org/10.1162/dint_a_00129.

Strollo, A., D. Cambaz, J. Clinton, P. Danecek, C. P. Evangelidis, A. Marmureanu, … and N. Triantafyllis (2021). EIDA: The European integrated data archive and service infrastructure within ORFEUS, Seismol. Soc. Am., 92, 3, 1788-1795. https://doi.org/10.1785/0220200413

Urvois, M., Grellet, S., Feliachi, A., Lorenz, H., Haener, R., C. Brogaard Pedersen, M.Hansen, L. Guerrieri, C. Cipolloni and M. Carter (2020, May). Open access to geological information and 3D modelling data sets in the European Plate Observing System platform (EPOS), In EGU General Assembly Conference Abstracts, 5131, https://doi.org/10.5194/egusphere-egu2020-5131.

Urvois M., S. Grellet, C. Loiselet, M. Harrison, H. Lorenz, R. Haener, M. Krivic, C. Brogaard Pedersen, M.B. Wiese, A. Baptie, M. Nayembil, J. Trench, I. Marsh, C. Cipolloni, C. D'Ambrogi, M.P. Congi (2022). Integrating geological data in Europe to foster multidisciplinary research, Ann. Geophys., in press.

Wessels R., G. ter Maat, E. Del Bello, L. Cacciola, F. Corbi, G. Festa, F. Funiciello, G. Kaviris O. Lange, J. Lauterjung, R. Pijnenburg, G. Puglisi, D. Reitano, C. Rønnevik, P. Scarlato, L. Spampinato (2022). Transnational access to facilities for Solid Earth Sciences: a service to promote 1 multi-domain research in Europe, Ann. Geophys., in press.

Wilkinson, M. D., M. Dumontier, Ij. J. Aalbersberg, G. Appleton, M. Axton, A. Baak, N. Blomberg, J.-W. Boiten, L. B. da Silva Santos, P. E. Bourne, J. Bouwman, A. J. Brookes, T. Clark, M. Crosas, I. Dillo, O. Dumon, S. Edmunds, C. T. Evelo, R. Finkers, … B. Mons (2016). The FAIR Guiding Principles for scientific data management and stewardship, Sci. Data, 3, 160018. https://doi.org/10.1038/sdata.2016.18.

Wilkinson M.D., S.A. Sansone E. Schultes, P. Doorn, L.O.B. Da Silva Santos and M. Dumontier (2018). Comment: A design framework and exemplar metrics for FAIRness, Sci. Data, 5, doi:10.1038/sdata.2018.118.

Willingshofer, E., F. Funiciello, M. Rosenau, G. Schreurs, F. Zwaan, S. Buiter, … and F. Corbi (2021). Sharing experimental data and facilities in EPOS: Updates on services for the analogue modelling community in the TCS Multi-scale Laboratories, EGU21-16301, Copernicus Meetings, https://doi.org/10.5194/egusphere-egu21-16301.

***CORRESPONDING AUTHOR: Massimo COCCO**,
Istituto Nazionale di Geofisica e Vulcanologia,
Rome, Italy,
email: massimo.cocco@ingv.it