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Addressing the challenges of making data, products, and services accessible: an EPOS perspective

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Abstract

Novel measurement technologies, additional sensors and increasing data processing capacities offer new opportunities to answer some of the currently most pressing societal and environmental questions. They also contribute to the fact that the available data volume will continue to increase. At the same time, the requirements for those providing such data rise and the needs of users to access it. The EPOS Delivery Framework aims to support this endeavour in the solid Earth domain by providing access to data, products, and services supporting multidisciplinary analyses for a wide range of users. Based on this example, we look at the most pressing issues from when data, products, and services are made accessible, to access principles, ethical issues related to its collection and use as well as with respect to their promotion. Among many peculiarities, we shed light on a common component that affects all fields equally: change. Not only will the amount and type of data, products, and services change, but so will the societal expectations and providers capabilities.

Keywords: EPOS Delivery Framework; Access; Ethics; Communication; User; Provider

1. Introduction

Climate change, volcanic eruptions, pandemics, financial crises, or large earthquakes; the problems societies must deal with nowadays are often complex and multifaceted. Consequently, they demand sophisticated, multi-disciplinary approaches that explore and create unprecedented solutions. In a world where more and more data is generated and archived, data repositories and the analysis of their holdings serve an important role in solving such complex problems. Combining data from diverse sources in new and innovative ways is a critical element of developing these solutions, and the framework allowing such data access are of particular importance. Nonetheless, establishing these frameworks to ensure data is findable, accessible, interoperable, and reusable (FAIR) is also

a difficult task as the European Commission emphasizes: "[…] attention needs to be paid to the extremely challenging task of developing FAIR data frameworks across disciplines and for interdisciplinary research" [European Commission Expert Group on FAIR Data, 2018].

The European Plate Observing System (EPOS), the research infrastructure (RI) for the solid Earth domain in Europe[1], is one such framework. It is a multidisciplinary, distributed research infrastructure that facilitates the integrated use of data, data products and services, and facilities from across the European solid Earth science community. EPOS aims to support multidisciplinary analyses for a wide range of users including scientists, authorities, disaster managers, or stakeholders from the private sector. To this end, information in different formats coming from various institutions must be collected, processed, and exposed for future use. This results in a transnational dataset that is openly available for the purposes of studying geological phenomena without the limitations of national or institutional borders. While such a delivery framework brings obvious advantages, it also faces numerous challenges. This contribution is based on scientific evidence, as far as available, and on professional observations and experiences in the domain of data, products, and service provision for a diverse audience. Despite focusing on the EPOS Delivery Framework, our observations are equally relevant for any other context where a complex framework has been established to offer multidisciplinary data access.

Each offer needs a provider. Within the EPOS Delivery Framework, the Thematic Core Services (TCS)[2] take on this role and provide access to data, products, and services, both through the common Integrated Core Services central hub (ICS-C)[3] as well as through their own TCS-specific data portals and services. The ICS-C thereby serves as the interoperable cross-domain discovery and access platform for all EPOS assets. Despite their role, the TCS do not necessarily own the data but facilitate its access. The data is collected or generated at the level of international, national or regional institutions with different backgrounds and governance structures. In consequence, defining commonalities for offering data, products, and services and ensuring its (inter-)operability in the long-term comes with a set of potential issues. This includes among others challenges with respect to legal compliance, interoperability, policy, and governance. Most of the data currently made available by the TCS is not research data in the sense that it has been collected in the framework of a specific research project. It is rather 'generic' in the sense that it has not been collected for a narrowly defined purpose and is therefore of interest for a wide range of potential use cases. Examples for such generic data available from the EPOS TCS's include geological maps, geodetic ground motion data, geophysical satellite observations, seismological waveforms, or geomagnetic field observations.

Although providing such a variety of data based on a set of common standards is already highly demanding, it is not the end of the story. When being made available additional new challenges arise, in particular from a societal perspective. A significant proportion of the data made accessible through the EPOS Delivery Framework can be used to support hazard and risk assessments that form the basis for decisions on mitigation actions. Therewith, it has a direct or indirect societal value that goes beyond a pure scientific approach. Ethical and communication issues are already of relevance in the scientific discourse but become even more important when society as a whole is potentially affected.

This paper looks at the most pressing issues from when data, products, and services are made accessible, to access principles, ethical issues related to its collection and use as well as with respect to their promotion. For improved clarity and readability, we will use the term 'assets' to include everything that is made available through EPOS including datasets, metadata, products, services, guidelines etc. While in principle there is a difference between provider and producer of such assets, we will use the term 'provider' unless the distinction between provider and producer is relevant.

1 https://www.epos-eu.org/

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

3 https://www.epos-eu.org/integrated-core-services

2. Assets' provider perspective

In this section we introduce some issues of relevance and concern to providers of assets within EPOS.

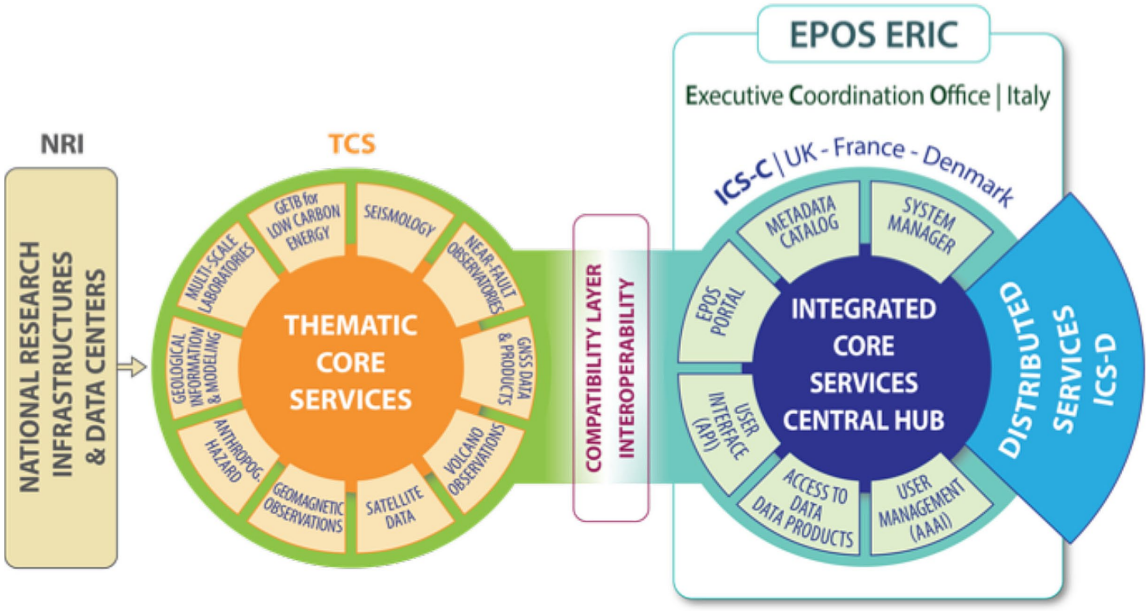

Figure 1. The EPOS architecture (concept). The TCS and ICS (-C and -D) together make up the 'EPOS Delivery Framework' (From an EPOS Scientific and Technical description, internal document, 2018).

2.1 Asset providers in the EPOS architecture

Within the EPOS architecture (Figure 1), assets are made available by the TCS both on their own access platforms as well as via the ICS, in particular the central ICS-C platform. The TCS in turn receive much of the assets from contributing institutions in their realm, the 'National Research Infrastructures and data centres' (NRI) layer in the EPOS architecture. These institutions are of various types and legal settings: academic research institutions like universities, national research organizations, governmental entities such as geological or geodetic surveys, other national public entities with a service mandate, and other potentially mixed constructions. What they have in common is that they are governed by relevant national legislation, which may be quite different from country to country. These institutions are the primary providers of assets, from raw observation data like seismic waveforms or geodetic displacement to highly complex scientific products like seismic source models or geodetic strain maps, to give just a few examples. Some data products, for example the European Seismic Hazard and Risk models, are produced and provided by collaborations between institutes from different countries, and the legal organization of these collaborations can take very different forms, from non-existing to project-based consortia to proper legal entities.

Within many TCS, important roles are taken by international organizations or initiatives, either with a European focus like ORFEUS, EMSC and EFEHR in seismology, EuroGeoSurveys in geology, EUREF in geodesy, or even global ones like Intermagnet in geomagnetism. These institutions are usually rooted in their scientific domain community, with governance structures that may exist since and potentially have evolved over decades.

Building the various TCS in a way that properly integrates that variety of institutions with due respect of these legacies is one of the successes of EPOS over the last ten years. It was achieved through intense discussions on organizational models and governance issues, finding compromises in the interpretation of roles and mandates, and retaining a pragmatic view of the final goal to improve access and use of the wealth of available assets. One important aspect in all TCS is that, while the assets are provided by a multitude of diverse contributing institutions, the services where those assets are then collected and made available are hosted and operated by some specific 'service provider' institutions. These service providers are again organized differently in the various EPOS TCS, but they are the interfaces that provide assets to the ICS-C and may also provide the same or other assets to other entities.

2.2 Origin and status of assets

The diversity in the organizational and legal setup of the asset providers also means that the legal status of assets may differ, following the specific governing regulations. This may for example affect ownership, intellectual property, usage conditions and licensing, responsibilities and boundary conditions for management and curation, or compliance with the General Data Protection Regulation [EU, 2016]. Similar legal status issues affect the access services, not only the (assets) content. While in this work we focus on the assets' providers within the TCS and NRI, the ICS-C (and likely future distributed components of the ICS, ICS-D) are likewise hosted and operated by specific institutions and thus fall under specific organizational and legal regulations.

Interestingly, only a rather small part of the assets that are currently available within the EPOS Delivery Framework result from specific (academic) scientific studies. For many TCS, most of their assets are generated either in the context of regulatory mandated monitoring of natural or anthropogenic geohazards, for mapping and monitoring georesources, or for more general surveillance services. While one of the stated purposes of the data collection, but also more generally any 'asset generation' normally is to be available and usable also for scientific studies, initial collection or generation of the assets is usually not targeted towards a specific scientific objective. This may pose a challenge in the context of the often used reference to 'research / scientific data' in the discussion on FAIR data [e.g. Wilkinson et al., 2016] and open science [e.g. UNESCO, 2021], as for example the boundary between 'public data' or 'governmental data' and 'research data' is not really clear.

2.3 Challenges in asset provision and curation

Throughout the asset life cycle, providers face various challenges that will appear in different forms depending on their specific setting and the characteristics of their assets. These challenges are also closely linked to implementation of the FAIR Data Principles and adoption of open science standards and policies.

Without claiming completeness, some of the significant issues that have emerged from various discussions within EPOS are: the availability and practical usability of standardized formats and protocols, tracking and recording of processing parameters, determining adequate granularities of data elements for application of unique persistent identifiers, the type of identifiers to use and how to generate them, defining and implementing appropriate mechanisms to support attribution (in particular for assets combining input from different sources), application and applicability of licenses (ownership/IPR and usage conditions), or addressing reproducibility of data selection by users (versioning). Another family of issues relates to the long-term (sustainable) preservation of assets and their continuous curation, starting with selection of a suitable repository – including the question whether it should or even has to be 'certified' [COAR, 2021]. One of the main concerns for long-term curation are still costs, and 'value for money' discussions on what assets to keep for how long (assuming that not all can be kept for eternity) and at what price still lack guidance, while it is even not clear where such guidance should come from and who should ultimately make those decisions. A general observation seems to be (offered without proof or reference) that over time many long-term data archives have proven useful and valuable for novel scientific analysis, while 'lost' data is greatly mourned.

Two further issues connected to data provisioning are worth mentioning: (i) thus far EPOS has been concerned mainly with standard and well-established assets (at least within their communities), there is little discussion or activity regarding the so-called 'long-tail of science', i.e., assets arising from one-time, particular / exotic activities that are difficult to access and not readily available for reuse. These assets are also often in danger of getting lost over time, in particular if they are originally deposited in connection with a researcher's 'private' repository / website. (ii) 'Citizen Science' and 'Internet of Things' data are starting to become of significant interest for solid Earth sciences. Apart from established processes of specific data collection, e.g., for earthquake felt (macroseismic) reports submitted by the public, there is to date little structured development towards standardized uptake and curation of such data within the EPOS Delivery Framework. Due to its comprehensive community representation, EPOS is well positioned to help advance these issues in the future, especially in partnership with those organizations that are seeking to raise the profile of citizen science such as the Group on Earth Observations [GEO-CITSCI, 2020].

EPOS provides a useful platform for coordination among asset providers in its community, and in particular may enable and strengthen the connection with other European or international initiatives that work on addressing these challenges in an even broader context, such as the European Open Science Cloud (EU/EOSC), the Inte-

grated Core Services (ISC), the international Research Data Alliance (RDA)[4] or the Committee on Data (CODATA)[5] of the International Science Council. As a participating institution of GEO, the Group on Earth Observations[6] (), EPOS is also well positioned to interact with and benefit from these discussions, e.g., the results of the Data Sharing and Management working group (GEO, 2015), now part of the 2020-2022 GEO work program Foundational Task 'GEOSS Data, Information and Knowledge Resources [GEO, 2020].

3. Assets user perspective

EPOS aims to provide fully open and easy access to homogeneous high-quality assets from many solid Earth science disciplines such as seismology, volcanology, geodesy, and geology. Depending on the nature of the assets, potential users face a variety of challenges when seeking to (re-)use them both independently and in combination with those from other disciplines and domains. These challenges relate to data accessibility including the permitted re-use of the data and products as specified through the licensing or policies applied by the data provider/creator, as well as the specific nature of the data as defined in the associated metadata and supporting information e.g., data formats, standards.

Users of EPOS assets are working both across the solid Earth domain and with other relevant disciplines with the aim of addressing a range of research questions, including those associated with societal benefits and challenges such as climate change and fulfilling the UN Sustainable Development Goals[7]. These users require a variety of asset types that can be readily accessed, integrated and utilized for their specific applications but they often face a number of barriers when accessing and re-using those assets.

3.1 Overcoming the technical barriers to data re-use

Many initiatives already exist with the specific goal of addressing the challenges encountered by users seeking to re-use the diverse range of assets that have been generated both from research activities and delivered from continuous monitoring programs. For example, the RDA brings together experts to address topics, both technological and sociological, that act as barriers to the sharing and re-use of research data. These challenges are associated with both locating and accessing the assets and using it in a combined form that requires integration of assets from multiple different providers.

Assets from the solid Earth domain are heterogeneous and highly fragmented having originated from a wide range of sources and delivered in a variety of different formats that can be based on either common standards or a proprietary output such as that delivered by certain types of environmental sensors. Appropriate re-use of these assets requires that they are described using established metadata standards, and the necessary supporting information must also be available to ensure that the users can both understand the asset and use it appropriately (see also section 4). To support this multidisciplinary re-use, the EPOS Delivery Framework aims to provide integrated assets from a range of distributed research infrastructures within the solid Earth domain (see previous section), through the implementation of common standards for metadata and data.

3.2 Navigating the cultural, legal, and social barriers to data re-use

In addition to the technical barriers faced by users, a range of guidelines, policies, and legislation at different levels from the institutional to the regional level introduce an added layer of complexity that makes it difficult for users to access and/or re-use assets. However, these mechanisms for managing and supporting reuse of assets also ensure they are used appropriately and that the originators receive the necessary credit.

4 https://www.rd-alliance.org/

5 https://codata.org

6 www.earthobservations.org

7 https://sdgs.un.org/goals

Licenses allow the creator or the provider of the asset to define the rules for its re-use, which can limit the types of users that can access it and restricts the acceptable purposes for which it can be used. Restrictions are imposed on access and reuse for various reasons such as where release could compromise national security, it is commercially sensitive or contravenes specific legislation e.g., GDPR. Users can also be discouraged from using individual datasets if they are unclear about the permitted usage even where they are fully accessible and available for reuse. As noted by Labastida [2020], all data and metadata should be made available with a clear and accessible license to facilitate reusability irrespective of whether it is fully open or subject to certain restrictions. To address these issues, open access licenses such as the Open Data Commons[8] and Creative Commons suite of licenses[9] have been developed, which are increasingly used by data providers to clearly define the permitted re-use of individual datasets and other resources even where there are limited restrictions imposed. The most widely adopted license for open access, including by the EPOS Research Infrastructure, is the Creative Commons by Attribution (CC BY 4.0[10]) that allows users to make unrestricted use of a dataset on the condition that the originator is appropriately credited.

One major argument for making CC BY the 'standard license' within EPOS is that it requests attribution, i.e., the use of a such licensed asset in any further publication needs to be referenced, and while the numbers of individual citations is still a key impact indicator in the academic community it supports this form of metrics. Discussions are ongoing, however, on the appropriateness of the CC BY license, mainly in two contexts. One issue concerns the support for open science that may call for even less restrictive licensing of information, as for example suggested in the factsheet on open science published by the Creative Commons initiative [Creative Commons, 2017] that argues for putting information in the public domain (e.g., by using a 'CC0' declaration or a public domain mark). The second issue regards the general applicability of a license to specific assets. A fundamental condition for licensing is the existence of intellectual property rights (IPR) on an asset, and there is evidence that at least raw observational data, and possibly also standardized derived products, do not carry such IPR. A study from data.europe.eu [European Commission, 2021] suggests that this non-licensability of assets may be overcome by introducing appropriate 'terms of use' for the services through which the assets are made accessible.

Mechanisms such as licensing are used to underpin the implementation of various policies for sharing and re-use of data, including those that foster open access which is increasingly being mandated at the national and regional level. For example, the European Commission Open Data Directive[11], which has been in force since 2019, laid the foundations for improved user access to public sector data. This has since been followed up by the EU Strategy for Data [2021] that advocates making data as widely available for re-use whilst ensuring that all "rules for access and use of data are fair, practical and clear". These actions are an illustration of the role played by the relevant national and regional government agencies in fostering and implementing open access policies, which enables greater re-use of data for a diverse range of applications.

In addition to these policies and legislation that mandate open access for selected research outputs, there are also an increasing number of initiatives that are producing guidelines and best practices that aim to encourage and facilitate data re-use. Probably the most notable of these are the FAIR Data Principles [Wilkinson et al., 2016] that were intended to "enhance the reusability of data holdings" by making them Findable, Accessible, Interoperable and Re-usable (FAIR). Implementation of these principles by data providers (see previous section) has facilitated re-use and made data more widely accessible for a range of users since these principles focus not only on individual users but also on making the data directly discoverable and accessible by machines. By encouraging adoption of these FAIR Principles throughout the solid Earth domain, the EPOS Research Infrastructure has succeeded in reducing data fragmentation and maximized opportunities for its discovery and reuse. Ensuring that EPOS data services are FAIR compliant allows users to discover and access a range of multidisciplinary data for a variety of applications both within the solid Earth domain and beyond. However, as noted by Bailo [2020], the EPOS Research Infrastructure actually predates the concept of FAIR but it is still fully compliant with these principles having already identified the requirements of users for fully accessible and interoperable data from the solid Earth domain.

8 https://opendatacommons.org/licenses/by/

9 https://creativecommons.org/about/cclicenses/

10 https://creativecommons.org/licenses/by/4.0/

11 https://digital-strategy.ec.europa.eu/en/policies/legislation-open-data

4. Ethical challenges

Ethics is a key topic for the development of modern scientific and technological activities, while respecting the needs and requirements of the scientific communities and societal stakeholders [Evers, 2001; ALLEA, 2013; AGU, 2017]. Ethical compliance influences the quality of data, results produced, and services provided: they are only as good as the values used to acquire/develop them. Ethics affects personal and collective conduct and thereby shapes relationships and their outcomes. Finally, ethics matters because research institutions/networks/organizations and their employees have a societal responsibility [Marti et al., 2019], since they belong to a community of people (stakeholders, partners, and society) and scientific and technological data, products, and services may have a direct or indirect impact on people's life. This implies that science and technological activities have to consider ethics to develop their full potential.

4.1 Has EPOS ethical responsibilities?

Assuring excellent science and technological activities (by applying updated knowledge and the best methods and instrumentations) within EPOS requires not only dedicated skills but also a high level of awareness with respect to the specific roles and responsibilities of scientists, technicians, and administrative supporting units especially when managing complex issues affecting data life-cycle management [EPOS-IP, 2018] and science-society interfaces [ISC, 2005]. The operational choices of EPOS operators and scientists cannot be considered completely neutral with respect to the decisions of target audiences and the consequences that EPOS products and services can have for stakeholders and partners. Ethical responsibilities of EPOS derive from the fact that operators and scientists within the EPOS Delivery Framework and in the NRI provide data and services which are helpful for hazard monitoring and assessment, risk mitigation, and geo-resources management. In addition, ethical issues often arise in relation to conflicts of interest, conflicting requirements, multiple objectives and diverging priorities, as well as different stakeholders including public-private sector relationships. Ethical issues involving the working environment and relationships among colleagues in order to achieve common goals, as well as publication ethics, are further important topics for the success of the activities carried out within EPOS.

4.2 Potential ethical issues in EPOS

Some of the practical issues related to EPOS services that can emerge are: inadequate or missing protection of institutional and personal scientific data; misuse of data and technological information [EC, 2016], also in the context of, for example, terrorism or other criminal purposes; misleading hazard and risk communication, with particular reference to crises and emergency phases [Cauzzi et al., 2018]; negative societal impact at the interface between civil protection officers and scientists, and other societal stakeholders.

Important and specific ethical concerns also rise when considering the two-way communication between individuals and EPOS services, such as citizen science activities for observations of natural and anthropogenic phenomena [Sanz et al., 2014; Lee et al., 2020], as well as potential conflicts between industrial needs and developments and societal interests. Especially important in this regard, is the objective and impartial role of research infrastructures in presenting scientific data and results, where such conflicting interests exist, keeping in mind the principle of impartiality for public good (referring to all those elements, information, and service provision for the benefit or well-being of the public, including individual and collective safety, knowledge development, and health).

4.3 Ethical background from EPOS-IP

In this perspective, the Ethics Working Group, established in the framework of the project EPOS-IP (Implementation Phase), had already identified the following macro-categories to synthetically map ethical issues in EPOS:

- Protection of personal data: activities involving collecting or processing personal data
- Misuse/abuse of data: activities having potential for terrorist or criminal abuse
- Communication and societal impact: communicating science vs. communicating risk
- Impartiality for public good

These four macro-categories were associated with three strategic actions characterizing the EPOS activity plan, namely: fostering open science, contributing to risk mitigation, and enhancing cooperation with the private sector.

4.4 A survey on ethics for EPOS-SP

In order to investigate the EPOS community's perception of the ethical and social implications of its scientific and technological activities related to data and service provision, a survey through an *ad hoc* online questionnaire was carried out in the European project EPOS-SP (Sustainability Phase) [Di Capua and Peppoloni, 2021]. The questionnaire, filled out anonymously, had also the aim of being a means to make participants (all involved in the TCS) more aware about issues related to ethics in their professional activities and in the science-society interface. The topics of the questionnaire concerned research integrity/science ethics and truthful conduct of research [Steneck et al., 2010], data ethics [Tranberg et al., 2018], open access policies [ERC, 2017], service accessibility and related issues like traceability, authorization, user profiling, data misuse, societal commitments of scientists/technicians, science, hazard and risk communication, public institutions-private sector relationships, conflicts of interests, and dissemination of scientific knowledge to the public.

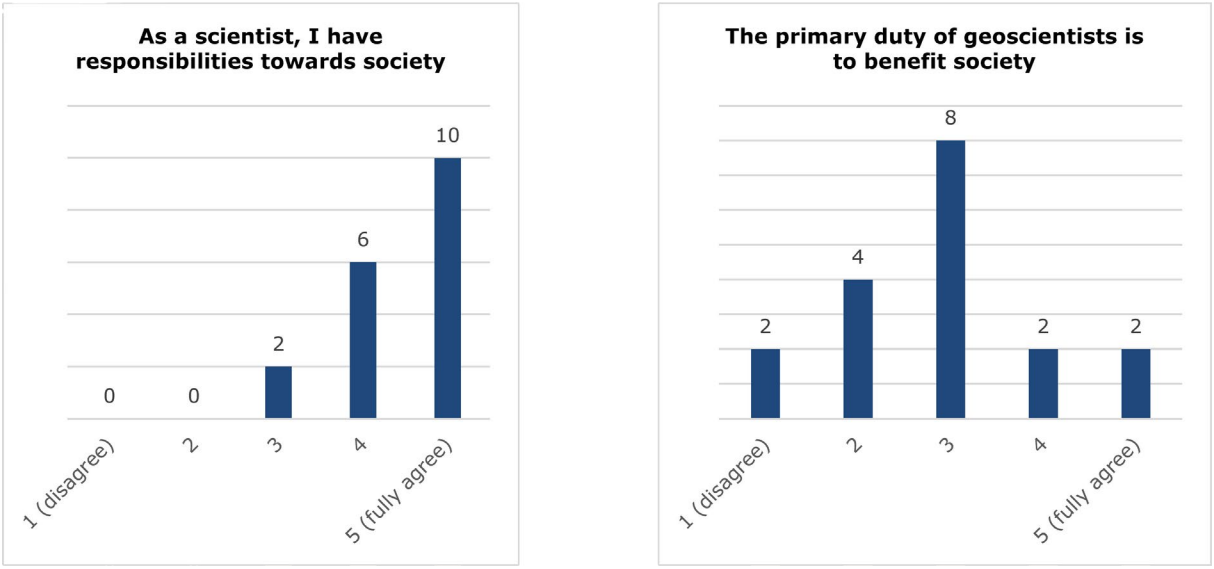

Figure 2. Results of the "ethical" questionnaire about scientists' responsibilities and duties towards society (in Di Capua and Peppoloni 2021). y-axis: number of respondents; x-axis: five-level Likert scale to investigate the agreement/disagreement with the sentence below each graph, ranging from 1=disagree to 5=fully agree.

The most relevant results of the survey [Di Capua and Peppoloni, 2021] are the following:

1) The questionnaire was filled in by a low number of EPOS TCS's representatives (only 18). This highlights that ethical issues are considered important from an ideal point of view, but also perceived as something theoretical that doesn't refer to one's own activities. This could also be due to a limited ability to refer ethics to real cases or behaviours.
2) Responsibility of scientists towards society is generally recognized as important, but it is not necessarily considered as a primary duty (Figure 2).
3) Differences between science communication and hazard/risk communication (that are multidisciplinary activities) were recognized by the majority of respondents, who agree that risk communication can have legal implications for communicators in cases such as the L'Aquila earthquake in 2009 (Italy) or more recently in New Zealand with respect to a deadly volcano eruption [Cocco et al., 2015; Lewis, 2021; Mutter, 2021].
4) There is a large consensus that scientists are science advisors and not decision makers. They have to provide relevant hazard and risk related data to society, and the general public should have open access to scientific information.

5) Personal data protection policies are necessary for EPOS operators and scientists. The majority of respondents agree on open access for data, data products, metadata (metadata should be fully open access), services for data visualization and analysis, and services for data processing and modelling generating new data products to all stakeholders, particularly to scientists, government agencies, students, and teachers. Some concerns were expressed about data, products, and services released to private companies, especially because in many cases those companies are reference stakeholders for scientific/technological activities, so "*there is always [a] risk when taking commercial obligations to contractors who are not indifferent to the delivered product's content*", "*most industrial partners keep the produced data for business needs and/or interest" (quotes of participants)* or public-funded data should be shared with private industry or commercial undertakings (Figure 3). This implies that ethical issues related to relationships between scientists and private companies should be carefully considered in future EPOS activities. Open data should be provided together with easy-to-understand description of the contents and instructions/recommendations to assist users (see section 4 for more details). Issues on how to guarantee open access to data, needs to be deepened, in order to clarify if and when user registration/authentication and/or authorization and/or profiling should be adopted. User registration is generally considered the best method. There is a wider agreement about the need for EPOS to collect information concerning the purpose the user wants to accomplish by having access to data and services. EPOS should ensure access related to relevant scientific products to national authorities, civil protection agencies and local authorities: this should be considered an ethical obligation where assets are relevant for mitigation and risk management decisions.
6) EPOS data are considered subject to be misused, particularly to feed scientific controversies and media scoops. In any case, this should not affect the open access to them and could be avoided or mitigated through *ad hoc* regulations.
7) Impartiality for public good regarding data and data products is fundamental for always acting in the public interest. Firstly, public research organizations committed to monitoring activities and secondly governmental authorities should be in charge of ensuring this principle.
8) Conflicts of interests compromise individual and institutional reputation and credibility, but for respondents, they are not so frequent and inevitable in the EPOS service management. In any case, they can be mainly solved by adopting appropriate codes of conduct, by increasing the ethical awareness of operators and scientists, or by declaring potential and current conflicts in advance to the respective institutional governing offices.
9) EPOS should consider developing tools to improve the understanding of scientific content to non-expert audiences. A communication strategy would help with this (see section 4).

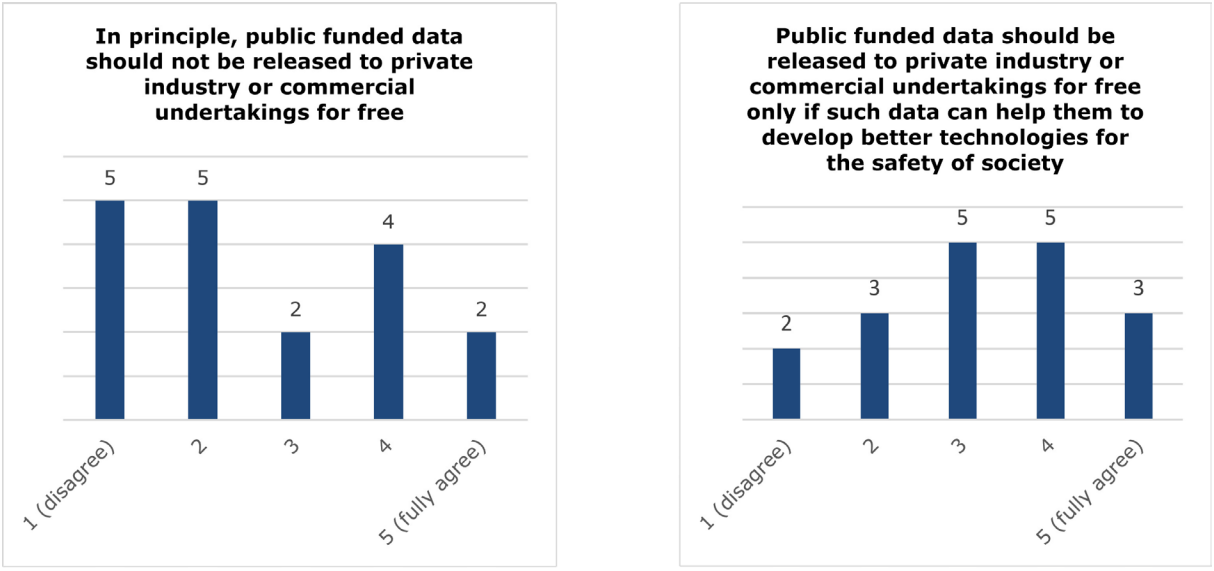

Figure 3. Results of the "ethical" questionnaire about public funded data-private companies' topic (in Di Capua and Peppoloni 2021). y-axis: number of respondents; x-axis: five-level Likert scale to investigate the agreement/disagreement with the sentence below each graph, ranging from 1=disagree to 5=fully agree.

Regarding the point 3) above, ethical challenges related to risk and hazard communication using the data, products, and services allocated by EPOS, are discussed in more detail in the next section.

5. Communication challenges

When providing access to assets, external communication is an integral component of making them known and reachable to the outside world. When provided in a framework such as EPOS, additional internal communication measures are required to coordinate these efforts. Developing and maintaining communication activities in such a context poses several challenges that can be grouped into the following areas:

1) Promoting access
2) Assisting users
3) Taking responsibility
4) Communicating internally

The findings of this section are mainly based on the insights gained through twelve semi-structured interviews with TCS representatives, user feedback retrieved from three online surveys with users of already operating TCS, and the ethical questionnaire introduced in section 3 [Dallo and Marti, 2020; Di Capua and Peppoloni, 2021]. Despite this focus, we assume the communication challenges that we identify within the EPOS Delivery Framework to be of relevance in any other context where assets are provided to different audiences.

Up to now, the TCS' target their offers towards predominantly professional users, mainly originating from the scientific community in the solid Earth domain (Figure 4). This target audience is highly motivated and trained to

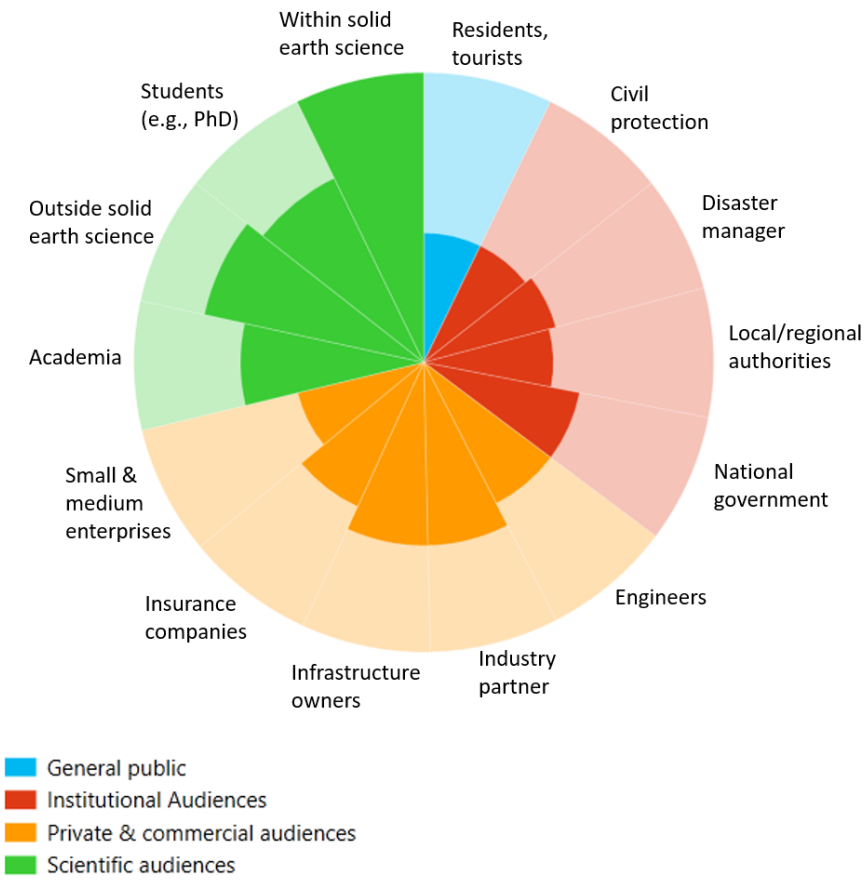

Figure 4. Current target audiences of the TCS. The main target audience is the "within solid earth science community". The total percentage of this main target audience was used to normalize the proportion of the other groups (dark colours).

work with the assets offered. They are also willing to invest time to read documentations and explore different access options. The results of the user surveys indicate that the TCS currently operating cover the needs of this target audience well. However, the majority of the TCS mentioned that they aim to reach a broader audience including institutional, private and commercial user groups as well as the general public in the mid- to long-term. This brings new challenges in all the aforementioned four areas as explored hereafter.

5.1 Promoting access

Now and even more in the future, access to assets within the EPOS framework must be promoted [Orlecka-Sikora et al., 2020]. The value and benefit of an offer is highly defined by its demand. A data repository, for example, can be as comprehensive as it may be, but if no one knows about it then its value is decreased. Up to now, TCS are mainly challenged in promoting their assets to their core target audience, which is the scientific community. However, they are also trying to reach other target audiences: *"[..] But, of course, the overarching goal is to serve not only scientific audiences, but also institutional audiences, if they are interested, for example municipalities, governments, industry partners" (quote of a participant)*. When aiming to reach a larger audience, providers should, before investing in additional promotion measures, first elaborate the following question: Are the assets relevant for the envisioned user groups?

From a user perspective, assets are relevant when they serve to advance their studies, be it for a scientific project, a professional mandate or a personal interest. Providers should orient their offers to the needs of users, not only considering the current situation, but also looking ahead assessing what could become of relevance for different user groups in the future. This assessment should then guide investment decisions and promotion measures. What might be a highly valuable source of information for scientists is probably not of interest for other stakeholders. In consequence, available resources should in this case be invested in promoting and improving the access rates of current target audiences.

From a providers' perspective, however, there is also a normative or even compulsory approach. Some information should or has to be available for specific target groups, because they must rely on it to make certain decisions. For example, civil engineers depend on the access to seismic hazard assessments for designing earthquake-resistant structures. Civil protection agencies could benefit from accessing certain data sets but would need to be made aware of this resource. Whereas from such professional target groups it can be assumed, when aware, that they have the necessary skills and knowledge to access it, higher requirements apply in other cases as a recently published article emphasizes. After the volcanic eruption at White Island (NZ) in 2019, it is debated whether the alert bulletin produced and published by a scientific institution had been sufficiently accessible and understandable for different user groups including tour operators frequently visiting the island [Lewis, 2021]. Providers are therefore prompted to increase their efforts if they see a need or are legally obliged to enhance the access to certain information for dedicated user groups. Besides raising awareness for the existence of certain information, dedicated training may be offered to support users in accessing and using it.

In consequence, before promoting any access, providers should first consider the relevance of their offers for different user groups. Secondly, before promoting it and raising expectations, they should ensure that their offers are accessible, which leads us to the next area of concern.

5.2 Assisting users

As emphasized by the FAIR principles [Wilkinson et al., 2016], assets must be accessible. From a communication perspective, this is more than supporting users in finding and accessing the data, it is also about availability of explanatory material, usability, product design, and training. Such comprehensive support becomes more costly the larger the envisioned target audience gets and therewith poses a big challenge to providers.

Surveys of the users of existing seismology services (EMCS, EFEHR, and ORFEUS) reveal that the majority finds them useful, trustful, and reliable. This is a positive outcome, indicating that the needs of the users predominantly working for research institutions are currently well met. However, the interviews with the TCS representatives as well as the ethical survey also disclosed their worries with respect to future use and user groups. A main concern raised in the ethical survey was *"[...] that the data, products or services could be misused by individuals or groups, and*

in turn, lead to ethical issues" (quote of a participant), which might include drawing misleading scientific conclusions, to support conspiracy theories or as a basis for media scoops. In addition, it is unclear for many TCS how to best deal with potential needs or requests from users from other domains such as those in the insurance or tourist sectors.

The majority of the TCS representatives agree that these concerns should not lead to any access restriction. We would like to add that it should also not restrict communications, on the contrary, providers should be eager to seek new and innovative ways to carefully embed their assets through the use of suitable communication tools. To this end, as also recognized in the ethical survey, an interdisciplinary collaboration between trained professionals and IT developers, communication specialists and graphic designers is advantageous. In addition, it is strongly recommended to test products and services with the targeted user groups before they are launched [Marti et al., 2020]. Another option is to co-produce products or services with future user groups or offer dedicated training e.g., in the form of webinars. Elaborating a dedicated communication strategy and policy will further support institutions with the handling of user requests as well as drive future updates and developments of communication measures.

The implementation of such a holistic view on data, product, and service provision requires dedicated resources, a real challenge for most providers, especially in the longer-term. Nonetheless, it is essential to consider appropriate communication measures to satisfy user needs and ensure that they actually benefit from an offer. It is also a question of responsibility as discussed in the next section.

5.3 Taking responsibility

Providers and users do not only have different needs, they also take different perspectives on responsibility issues. Providers are expected to establish and maintain access to the assets while users are required to respect access and copyright regulations. Technical measures such as user authorization or legal statements are one component to ensure responsible access [Manteigueiro et al., 2020], another is to provide open, clear, and comprehensive information supporting users in taking their share of this responsibility.

Again, the more users access certain assets the greater the value of the information dealing with responsibility aspects becomes. Whereas professional users may be well aware of the limitations of a specific data set, related uncertainties or copyright restrictions, less trained users could be unaware. Structuring content hierarchically starting from a very generic level and then going into more detail is an established pathway to guide users and address different levels of expertise and knowledge [Shou-Bin Dong, 2004]. In addition, important information from a providers' perspective should not be hidden somewhere, e.g. in the disclaimer, but should appear prominently for all users.

A particular communication challenge was emphasized by TCS providers related to the access of real-time or up-to-date data, in particular, when such data can be used to inform risk management. Besides legal and ethical considerations as discussed in sections 1 and 3, it is also challenging with respect to communication. Users may need 24/7 support for such access and explanatory material related to such information must be designed even more carefully. Further, not all TCS are legally allowed or have the mandate to communicate real-time information: *"[..] we cannot provide services dealing with real time data because we are not a national agency, you know, providing alerts. So, we have to keep in mind this kind of approach, let's say nearly real-time and just for scientific targets"(quote of a participant)*.

5.4 Communicating internally

The exchange of information between providers only needs to be considered when assets are offered within an institutional framework such as EPOS. In this case, providers must talk to each other to find common ground. With respect to communications, providers should take advantage of their network and exchange best practices. They are often facing similar challenges and, having tried different approaches to finding a solution, could potentially benefit from their mutual experiences. This is nicely summarized by one of the TCS representatives who noted: *"So, if the question is related to [my TCS], to me the main challenge is the coordination of these broad domains, and then show that it works. Because we are not really used to working together. We didn't do that in the past. It is something new that we are learning right now" (quote of a participant).*

6. Conclusions

Complex problems such as climate change, pandemics, or financial crises that severely impact society require comparable solutions. In a data-driven world, providing access to comprehensive, multidisciplinary data repositories to tackle such major challenges is indispensable. This is exactly what the EPOS Delivery Framework aims to deliver for the solid Earth domain. Although the importance of this undertaking is obvious, its implementation from the provision to the actual use of assets presents many challenges that must always be addressed from two very different perspectives: that of the provider and the user.

In this contribution, we have discussed the most pressing issues that may materialize when providing access to assets. At the very beginning, access to assets must be established. This is particularly challenging when, as in the EPOS context, data from diverse institutions are assembled. It not only requires consent on a technical level, but also from a legal and governance perspective. In addition, it is not a one-time effort, it needs constant maintenance to ensure operability and user satisfaction. This, in turn, demands constant investments in infrastructure and trained personnel. This will not become an easier task in the future, with a steadily growing amount of data to be handled as more and more sensors are deployed, for example, as part of the Internet of Things.

With the increasing amount of data and possibilities to provide and handle it, further issues arise. One of the most important being the ethics of data provision and use, which is already of relevance when gathering the data. A survey with data, product, and service providers within the EPOS Delivery Framework shows a theoretical awareness for ethical issues. Nonetheless, most struggle to apply this knowledge to their practical work and in consequence do not implement any mitigation measures. We therefore see a clear need to invest in training to help providers to become more aware of ethical considerations in their day-to-day activities.

However, it would be too short-sighted to only focus on the providers. There are reasonable fears that assets could be misused, for example to inspire scientific controversies or provoke media scoops. There is a clear agreement among current providers in the EPOS Delivery Framework that such fears should not lead to an access restriction or denial. However, additional efforts are needed to implement access in such a way that the conditions are ubiquitous for users. In addition, explanatory material as well as support options should be provided on a best effort basis to guide users and help them to make informed decisions.

Implementation of common access to assets combined with other user needs requires additional user support from both providers and the regulatory framework. This fuels the already omnipresent discussions within EPOS about the best use of available resources, and will gain even more importance the larger the potential target audience becomes. Currently, the scientific community is the main user, but the providers stated objective in the mid- to long-term is to reach a larger, more diverse audience. This is important from a societal and ethical perspective when a significant proportion of the assets can be used to assess hazard and risks, and thereby contribute to the design of appropriate mitigation measures. A larger audience means that more people and institutions can potentially benefit from accessing the EPOS Delivery Framework. However, it also requires a significant investment in supportive measures to facilitate access for these novel users, who are less experienced, and thus reduce the possible inappropriate use of the data provided.

Regardless of the path the EPOS Delivery Framework takes, constant readjustments on all levels will be needed to accommodate not only the changing nature of the assets, but also the evolving user needs, and our understanding of the social and ethical context. This requires the will and openness for internal debates within the EPOS community as well as regular interactions with current and future user groups.

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