European
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Principles for user-centric practices of cloud platforms

Voluntary guidelines for improving the user experience of cloud platforms

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Contents

Abstract

The report outlines the creation of heuristic principles aimed at enhancing the user experience for developers working on policy-relevant projects (defined in Kilsedar et al. 2023) within the cloud ecosystem. Recognizing the importance of interoperability, our approach considers the cloud ecosystem in its entirety rather than focusing on individual platforms. This perspective allows users to integrate services from multiple platforms seamlessly, which is essential for completing the development lifecycle of their projects. The findings of this study lead to a series of recommendations that extend beyond technical aspects and encompass governance considerations, ensuring a comprehensive strategy for user-centred digital platform improvement. The natural evolution of this work is the development of a guide which provides practical recommendations and self-assessment checklists.

Acknowledgements

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Executive summary

The report presents a comprehensive analysis geared towards refining the user experience on cloud platforms, particularly for developers crafting policy-relevant use cases. The policy context emphasises the European Commission's strategic vision to cultivate a cohesive digital single market for data sharing, aiming to boost the EU's competitiveness while upholding its data sovereignty and aligning technological advancements with core EU values and rights. This vision underscores the significance of user-centric platforms in the broad context of the EU Strategy for Data.

Our key conclusions reveal that the current cloud ecosystem, while rapidly expanding, often fails to meet user expectations, leading to a mismatch between the services provided and user requirements. The ecosystem's complexity and fragmentation, along with a top-down infrastructure design, contribute to this disconnection, raising questions about user base establishment and the sustainability of numerous initiatives.

The findings underscore the necessity for heuristic principles that address user needs across ten critical areas, including interoperability, access, discovery, and documentation. The report identifies actionable recommendations for each area, based on user feedback and a systematic analysis of existing use cases. These recommendations aim to foster an ecosystem that is not only globally robust but also finely attuned to the nuanced needs of individual users.

In conclusion, the report advocates for an integrated approach to cloud platform development and evolution, where user needs drive the co-design of services across the cloud ecosystem. By implementing federations of trust, services, and resources, along with advanced decision-support tools, the report sets forth a pathway towards a user-centric, interoperable, and sustainable cloud ecosystem that fully supports the development lifecycle of policy-relevant use cases.

1 Introduction

In recent years, digital technologies have revolutionized both the economy and society, influencing every sector of activity and permeating the daily lives of all Europeans. The European Commission has taken a proactive stance to harness its potential through the EU Strategy for Data. The vision set forth by the Commission is to establish a seamless digital single market for data sharing and exchange, designed to elevate the EU's global competitiveness and fortify its data sovereignty. This strategy is not merely an economic imperative; it is also a reflection of the EU's commitment to ensuring that technological evolution aligns with the core values and rights cherished across the Union.

The EU has made substantial investments in the development of data exchange and processing infrastructures, such as the Copernicus programme, and infrastructures such as the Copernicus Data Space Eco- system (CDSE) and the European Open Science Cloud (EOSC). Despite Europe's considerable achievements, certain challenges have emerged due to the rapid proliferation of these infrastructures. This proliferation has potentially lead to fragmentation, partly due to the heterogeneity, local and domain-oriented character of the data and services (data and services from different domains and with different onthologies and from different countries) used in research and decision-making, and arguably due to a top-down infrastructure design. Moreover, proliferation of EU infrastructures does not generally translate into users' satisfaction and could also raise questions about their sustainability.

Within this context, the field of Earth Observation (EO) served as a compelling case study to investigate these complexities. In this report, we summarise the findings of a two year research project, in which we scrutinised the misalignments between user expectations and service offerings, contemplated the implications of infrastructure design choices, and explored potential pathways to reconcile these divergences. By doing so, we aim to contribute to the shaping of a digital ecosystem that is both robust in its global stance and finely attuned to the needs of its individual users.

This report also integrates the outcome of the "Workshop on Co-Designing a 'Self Evaluation Framework for EO Platforms", organised by the Joint Research Centre (JRC) in collaboration with DG Research & Innovation (RTD), which took place on the 8 October, 2024, as a side event of the EuroGEO workshop 2024 in Krakow, Poland. During the workshop, users of cloud platforms had the chance to discuss their experiences, issues and wishes, at the same table with cloud service providers.

2 Methodology

Users of cloud platforms encompass a diverse group. They can be scientists conducting research, decision-makers shaping policy, or analysts driving commercial projects. Each type of user brings unique needs and expectations to the platform. Their workflows vary significantly, involving different steps to process raw data into products and services that offer actionable insights.

For the purposes of this work, the target user is the developer of a policy priority use case that requires the effective sharing of heterogeneous data at scale (Kilsedar et al. 2023).

User Experience (UX) in cloud platforms is of critical importance because it directly affects the ability to effectively access, interpret, and apply data in various applications, including policy-making, scientific research, and commercial ventures. An effective UX can lead to increased adoption and more effective use of cloud platforms, thereby maximizing the value of the data they provide.

Drawing inspiration from Usability Testing (Nielsen, 1992), we conducted a study along the line of a usability review. The above defined users normally leverage services from different platforms and combine data of different nature from different data sources. In an ideal world, the various cloud platforms should act in a completely seamless and interoperable way, data and services should be findable and accessible, models and computational facilities should be easily findable and ready to be deployed in the workflow, terms and conditions and costs should be transparent, and the learning curve should be minimised.

For this reason, in this work, we refer to the UX to the ecosystem of cloud platforms, as defined in Santoro et al. 2023 and Mazzetti & Nativi, 2024, as opposed to analysing one single cloud platform.

The following methodology was employed:

1. A systematic review of the documentation produced by existing use cases to extract detailed insights into the functionalities and performance of the platforms.

2. An inventory and classification of existing EO platforms to understand the landscape and categorize the platforms based on their features and user base.

3. A survey on the user experience of existing use cases to gather qualitative and quantitative data on user satisfaction and areas for improvement.

4. The development of a hands-on use case to practically explore the capabilities and limitations of current EO platforms.

5. The identification of user needs and the development of a framework of dimensions for cloud platforms self-evaluation, ensuring a comprehensive understanding of the user experience.

6. Validation of findings through workshops and additional surveys with stakeholders to refine the framework and confirm the relevance and accuracy of the conclusions drawn.

2.1 Systematic review of e-shape use cases

The first step was the analysis of notable use cases from the e-shape[1] project (Ranchin et al., 2021). E-shape is the flagship European project to ensure the optimal implementation of EuroGEO, it entails 37 use cases in various fields such as agriculture, health, energy, ecosystem, water, disaster management, climate and climate change. We conducted a systematic review of the documentation and literature produced by these use cases, applying web scraping and text mining to extract platform mentions and relevant information from web pages, reports and papers, in order to:

- Identify user needs in terms of data, products, services and functionality

- Identify most common requirements of users-designed use cases, commonalities, and bottlenecks faced in the implementation phase, the infrastructures they use and for which services, the datasets, their customers and any other common trends

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[1] https://e-shape.eu/

- Understand whether the current EO platforms cover the whole development lifecycle of a use case from data discovery to generating actionable knowledge insights

We analysed the development lifecycle (Figure 1).and investigated what are the current gaps.

The systematic review of e-shape use cases was based on the following questions:

1. Name of the case study

2. Sector (showcase, in the terminology used by e-shape)

3. Partners / consortium

4. Intended customers: categories (data science, academia, policy makers, business, analysts, agencies, etc.) and/or specific entities

5. Source data list

6. How are the source datasets published / available? Identify the services / infrastructures that serve the sources datasets. (Type of API / service)

7. Are end products / data / services published? If yes, how? (web pages, APIs, apps, etc.)

8. Are metadata of end product(s) available?

9. Data processing techniques used

10. Infrastructures used

Figure 1 The development lifecycle of our target user.

Source: Authors.

2.2 Inventory and classification of existing EO platforms

In parallel with the systematic review, we mapped over 150 existing platforms and initiatives, according to the services they offer, into the following categories:

- Data providers: cloud platforms that make EO datasets available within infrastructures;

- Cloud-based geoprocessing platforms: computational capacity offered by data providers according to the paradigm "bring the user to the data";

- Brokers and catalogues: they offer discovery services by harvesting metadata from existing catalogues;

- Thematic Hubs and Research Infrastructures: they incorporate EO data relevant to specific thematic domains, such as agriculture and atmosphere;

- Data cubes: they implement a multidimensional array structure, on which one can load several bands and perform operations;

- Virtual infrastructures: they place additional layers on top of existing platforms to facilitate data access and increase the discoverability of and interoperability among platforms;

- Initiatives and programmes: other EO-related, publicly funded programmes.

There is some level of overlap among the different categories. More information can be found in Di Leo et al., 2023.

2.3 Survey on the user experience of existing use cases

We also designed a survey for the users of the aforementioned platforms. The questionnaire is organised into 6 sections:

1. Sector of application, type of use case, and involved partners;

2. Identification of intended customers of the end product/service;

3. Nature of source datasets and technological challenges associated with their discovery, access and integration;

4. Nature of product or service delivered and technological challenges associated with the deployment;

5. Technologies and challenges associated with data processing;

6. Evaluation of the platforms currently used and reasons that drove the choice. Mention of platforms that have been considered but eventually not chosen, and reasons.

We asked the use case leaders of some EU flagship initiatives – including (in addition to e-shape) Open-Earth-Monitor[2] and GEOSS Platform Plus[3] – to respond to the survey to investigate their use of the platforms.

The 26 responses to the survey highlighted use cases in a wide range of sectors, including agriculture, energy, health, ecosystem, disaster management, water, climate and climate change, forestry and oceans.

2.4 Development of a hands-on use case

In addition to the information collected from use cases in EU-funded projects, we proceeded to build an additional prototypical use case to gain first-hand insights. The use case was titled: Above-Ground Biomass (AGB) maps derived from Vegetation Indices using Machine Learning (ML) models. In designing the use case, we exploited the requirements collected especially in the systematic review of existing use cases, in order for our use case to be as representative as possible

Our use case foresees a procedure to derive the values of Above-Ground Biomass (AGB) from Vegetation Indices (VIs) using Machine Learning (ML) models. The workflow is presented in Figure **Figure 2**. The first step

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is the definition of the Area of Interest (AOI) and the year of interest. For that region and time, Sentinel 2 imagery are selected based on cloudiness and quality, and vegetation indices are calculated. Due to the scarcity of real in-situ data, synthetic data are generated starting from the ESA Climate Change Initiative Above-Ground Biomass (Santoro et al., 2024), and the JRC global map of forest cover (Bourgoin et al., 2024). Tabular data are produced with the coordinates of the sampling points, the corresponding values of biomass and the vegetation indices. Different ML models are trained for calculating the AGB. Then, the models are used to produce biomass maps and compare results among different models.

Figure 2 Workflow of the AGB use case.

Above-Ground Biomass (AGB)

Source: Authors.

To delineate a representative trajectory for developers, and to craft our use case that capitalizes on GEO-related services and digital infrastructures, we adhered to the following guiding principles:

- Use of Open-Source software to minimise the risk of vendor and technology lock-in;

- Simple and agile processes (e.g., avoiding lengthy processes such as submitting application forms to use components);

- Leave data where they are (i.e., the "bring the user and the processing to the data" paradigm);

- Reuse of existing components whenever possible;

- Use of data from different services to test interoperability;

- Adherence to FAIR Principles (Wilkinson et al., 2016).

Building on the insights from the analysis of external use cases, we relied on the CREODIAS platform[4] as an example of an EU-funded open service granting access to Copernicus datasets[5].

Furthermore, we use the INSPIRE geoportal[6] and the GEOSS portal[7] as data catalogues, because they aggregate several data sources and have been popular choices among the e-shape use cases as well.

2.5 Identification of user needs and heuristic principles

In section 3, we discuss the development of a set of heuristic principles, which resulted from the above mentioned research. We have identified 10 main areas in which we detail user's pain points and formalise actionable recommendations.

The section also integrates the outcome of the "*Workshop on Co-Designing a 'Self Evaluation Framework for EO Platforms*", organised by the Joint Research Centre (JRC) in collaboration with DG Research & Innovation (RTD), which took place on the 8 October, 2024, as a side event of the EuroGEO workshop 2024 in Krakow, Poland. During the workshop, users of cloud platforms had the chance to discuss their experiences, issues and wishes, at the same table with cloud service providers. More information on the workshop can be found in the following box, reporting the original concept note.

Concept Note: Workshop on Co-Designing a 'Self Evaluation Framework for EO Platforms'

Title: Advancing EO Platforms through Co-Design and Self-Evaluation

Background: The development and use of Earth Observation (EO) platforms are essential for a wide range of users, including scientists, policymakers, and analysts. However, the complex and fragmented landscape of tools and infrastructures poses challenges in navigating and utilizing these platforms effectively. In response to these challenges, there is a need to co-design a self-evaluation framework for EO platforms to improve usability and user satisfaction. This workshop aims to foster discussions towards the definition of a self-assessment framework for EO cloud platforms.

Objective: The objective of the workshop is to bring together stakeholders from the EO community to co-design a self-evaluation framework for EO platforms. The workshop aims to identify user-driven requirements, promote collaboration among different user groups, and address challenges in the current offer of EO cloud platforms. The co-design methodology will be based on rigorous protocols to conduct co-design actions, ensuring the growth of the EO ecosystem in a resilient perspective.

Proposed Agenda:

1. Welcome and Introduction: Overview of the current landscape of EO platforms and

2. Co-Design Methodology Overview: Introduction to the concept of self-evaluation framework and discussion on the critical dimensions for the success of the framework in a long-term perspective

3. Interactive Co-Design Workshop and Breakout Sessions: Interactive sessions to brainstorm and co-design specific aspects of the self-evaluation framework; Collaboration among participants to propose good practices for improving EO platforms

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[4] https://creodias.eu
[5] https://dataspace.copernicus.eu
[6] https://inspire-geoportal.ec.europa.eu
[7] https://www.geoportal.org/

4. Panel Discussion and Future Directions: Panel discussion with experts and stakeholders on the future of Self Evaluation scheme on EO platforms; Exploration of principles such as FAIR and TRUST, open source components, and OGC standards in shaping the future of data platforms and infrastructures and Identification of next steps for further development and implementation of the self-evaluation framework

Expected Outcomes:

- Co-designed self-evaluation framework for EO platforms, incorporating user-driven requirements and dimensions

- Identification of good practices to improve the design and functionality of EO platforms

- Enhanced collaboration and knowledge sharing among stakeholders in the EO community

Target Audience: The workshop is open to stakeholders from the EO community, including scientists, policymakers, analysts, developers, data scientists, and platform developers. Participants with diverse backgrounds and expertise in EO platforms are encouraged to attend.

Date and Venue: 8 October 2024 at EuroGEO Workshop

Conclusion: The workshop on "Co-Designing a Self Evaluation Framework for EO Platforms" aims to address the evolving needs of users and improve the usability and user satisfaction of existing EO cloud platforms. By fostering collaboration and co-design, the workshop will contribute to shaping the future of data platforms and infrastructures in the EO domain.

As a next step, an ongoing survey will serve to estimate the priority of each principle, from good-to-have to critical.

3 Heuristic principles

3.1 Interoperability

User issues / needs / wishes

Users require seamless integration of data from heterogeneous data sources, hence interoperability for better and easier data access. To cover the development lifecycle, users wish to integrate services from different service providers in a seamless way, e.g. federation of services, federation of resources.

Table 1 Examples of strengths and weaknesses on interoperability emerged during consultation with users.

Weaknesses	Strengths
Changing data provider requires using a completely different API.	OpenEO API[8] offers standardized APIs and portability among platforms
The specs for accessing data collections vary from a platform to another	The SpatioTemporal Asset Catalog (STAC) specification provides a common structure for describing and cataloguing spatiotemporal assets
Naming of the collections are not standardized and are platform-specific, e.g. Sentinel 2, Sentinel-2, S2, S-2, etc.	Organise community-building events/hackathons on harmonization of methodologies to keep momentum and push platforms to harmonization as well.
Platforms as silos	Options to deploy various parts of a workflow to different platforms (e.g. data pre-processing on one, model inference on the other, results visualization on another), to allow to optimally use the benefits of various platforms.
Need to rewrite the code when changing platform	Notebook file transfer across platforms by Binder[9]
Vendor lock-in	Cloud agnostic workflow e.g. Virtual Earth Laboratory VLAB[10]. VLAB adopts mature containerization technologies to access models as source code and to rebuild the required software environment to run them on any supported cloud.
Difficulties in combining diverse datasets due to incompatible formats, standards, or platforms	Integration of EO data with other types of data, e.g., socio-economic data: the possibility to connect with repositories of socio-economic data, possibly provided by official bodies (e.g., Eurostat).
Challenges in connecting cloud platforms with other platforms to share data and services, such as code repositories, which can hinder the efficient deployment of applications and services	(Seamless) Integration with other platforms: the possibility to easily connect to other platforms, providing both data and other services (e.g., code repositories to facilitate application and services deployment).

Source: Authors.

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[8] https://api.openeo.org/
[9] https://mybinder.org/
[10] https://github.com/ESSI-Lab/VLab

Actionable recommendations

1) **Data interoperability**: Facilitating the integration of datasets from heterogeneous data sources.

2) **Model interoperability**: Facilitating collaboration and sharing of models and algorithms from contributors on the platforms.

3) **Service interoperability**: Facilitating the integration of external services or applications. Avoid vendor lock-in for services provided, or at least Information on which modules/features are interoperable, and which are platform-specific and will result in a dependency.

4) **Semantic interoperability**: Use of:

   - Standardized vocabulary
   - Standardized metadata
   - Standardized data offering
   - Standardized API's
   - Standardized export options
   - Semantic technologies for consistent and meaningful data interpretation
   - Adherence to established data exchange standards, such as ISO and OGC. Attention to de-facto standards (e.g. STAC)

3.2 Access

User issues / needs / wishes

User needs are diverse in terms of availability, variety, data types, granularity, resolution, coverage, timeliness, update frequency. Single sign-on, federation of trust, clear licensing and usage rights are among the most common requests.

Table 2 Examples of strengths and weaknesses on access emerged during consultation with users.

Weaknesses	Strengths
The discontinued Copernicus Open Access Hub allowed users to download a maximum of two images simultaneously	It would be better not to have such restrictions. Data providers could cooperate to provide access.

Weaknesses	Strengths
Downloading the data	It would be good to be able to modify the pre-built models and run the models where the data is; stop downloading the data. Furthermore, it would be better to keep the processed data in the cloud and share it with other researchers.
For some use cases, higher-resolution data is needed (such as for mapping wetlands).	Fix data gaps? Improve discovery? [see discovery section]
Need to manage different accounts for accessing different platforms	Single sign-on. E.g. EGI[11], GÉANT Core Authentication and Authorization Infrastructure Architecture (AAI)
Difficulty to assess data quality.	Each dataset should be accompanied by quality metrics
Downloading the whole scene even if a smaller region of interest is needed	It would be better to acquire the data pixel-wise, using a bounding box or a GeoJSON file, instead of downloading the whole scene (downloading on-demand)
One solution fits all	Make the distinction in service offering for research and operational purposes
Access to datasets may require authentication and authorisation	A network of trusted user profiles may be created to ease access to data/software. These people may belong to the GEO community or beyond. While some infrastructures, datasets and software may be public, some may require authentication and authorisation.
Some entities hesitate to share its data fearing to lose control over it	Ensure data sovereignty.
Data gaps, especially in situ. Data driven applications need large amount of data for calibration, e.g. ML models. In situ data across EU are often not harmonised, not shared, or inaccessible.	It would be useful to have access to in situ data for calibration of ML models that exploit EO data (high value datasets and data collected ad hoc)
Ambiguity in data sharing: without clear data sharing policies, users may face uncertainty about how they can share, access, or integrate data, leading to potential legal and privacy issues.	Data Sharing Policies: clear data sharing policies should be provided, including the policies for the integration of data from other platforms.
There is no formal commitment to service quality, availability, or performance. Roles and responsibilities in managing and maintaining integrations with other platforms are undefined, potentially leading to service disruptions or conflicts. The absence of explicit guidelines for integrating data from various platforms can result in technical hurdles,	Service Level Agreement: SLA should be provided, including for the integration with other platforms

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[11] EGI federation "the largest distributed computing infrastructures for researchers" https://www.egi.eu/publication/joining-the-egi-federation/

Weaknesses	Strengths
inefficiencies, and limited interoperability	
Limited access to historical data	Extend access to historical data
Uploading is-situ data into cloud or downloading EO data to integrate with in situ.	Have in-situ data to be actionable into cloud infrastructure

Source: Authors.

User quotations:

 "[…] providing especially historic in-situ data is often an effort for data providers as well as the harmonisation and proper documentation […]"

"[…] Main problem is, that data providers are usually not part of the projects and therefore no financial support could be provided for data harmonisation and documentation. Special efforts on the mobilisation of in-situ data needs to be taken."

"Especially for in-situ data more efforts on data mobilisation needs to be done […]"

"Pre-built models and methods are valuable but so far there is a limited availability of real useable code base. More investment is needed to support software development practices adopted by science in order to grow the useable code base"

Source: Survey

Actionable recommendations

1. **Access to data**: Quality assurance. Access to metadata. Compliance with FAIR and TRUST principles. Clear definition of licensing, terms and conditions

2. **Access to models**: Availability of pre-built models or algorithms within the digital platform. Platform's capacity to provide a library, or marketplace, of models that users can access and utilize for their specific needs

3. **Access to services**: Availability of service metadata. Availability of services related to emerging technologies such as GPUs, HPC, Edge Cloud, real-time update. Definition of different operational levels and development of targeted services. Large storage capacity. No-Code / Low-Code AI solutions. Containerization. Data cubes. MLOps. DevOps. Analysis Ready Data. Seamless access through federation of trust, federation of services, federation of resources.

4. **Diverse users**: Implementation of accessible web design principles, international accessibility standards, such as the Web Content Accessibility Guidelines (WCAG)

3.3   Discovery

User issues / needs / wishes

Sometimes it is difficult to pair the platforms' offer in terms of services (see e.g. Table 3) with the user's demand due to discoverability issues.

Table 3 Examples of services that might be offered by cloud facilities. Source: Authors

Service	Scope	Type
GPUs	AI, Deep Learning, Computer	Hardware

Service	Scope	Type
CUDA	Vision (CV)	Software libraries
HPC	Parallel Computing	Hardware with dedicated software stack
Kubernetes (e.g. KuberFlow)		Software
Edge Cloud	IoT data ingestion / processing	Hardware with dedicated software stack
Large Storage Capacity (e.g. CEPH, S3) / Distributed filesystem	Handling massive datasets (Big Data)	Hardware with dedicated software stack
(Near-) Real-Time update of data / models / continuous stream of data	Early Warning Systems	Hardware with dedicated software stack
Semantic Data Models / Graph DB / ElasticSearch / Solr / NoSQL	Handling Complex Databases	Software
OpenStack / OpenNebula / AWS / Azure / GCP	Cloud	Hardware with dedicated software stack
Docker / Kubernetes	Containerization management	Hardware with dedicated software stack
No Code / Low Code AI solutions	Pre-implemented models for Machine Learning that can be used by users with no coding skills	Hardware with dedicated software stack
MLOps / DevOps	Seamless and efficient developing and maintaining software and ML technical solutions	Methodology and software stack
Data Cube	Multi-dimensional array containing spatial, temporal and thematic dimensions	Software
Analysis Ready Data (ARD)	Esp. EO data are presented to the user already pre-processed and re-projected, ready for the analysis	Software

Source: Authors.

Metadata and keywords play a crucial role in helping users evaluate the data they encounter. Furthermore, providing details on the data's quality, resolution, and potential applications will assist users in understanding its value. The discovery process should be designed to serve not only experts but also those less familiar with the data, ensuring that a wider audience can comprehend and utilize the information effectively.

Table 4 Examples of strengths and weaknesses on discovery emerged during consultation with users.

Weaknesses	Strengths
In situ data are only shared within private networks that require submitting a research proposal to be admitted. Outside of the network, there is no information on the actual data that is available inside the network (coverage, timeliness)	Private datasets should have public metadata
Service metadata are incomplete or missing. No broker for services	It would be nice to be able to compare offers from a web page like car insurance or mobile plans
The experience of searching for data should be easier	Semantic searches, recommendations based on similar searches, recommendations by number of downloads for similar keywords
Data fragmentation should be eliminated.	Avoid duplicates, semantic search
Missing metadata	Data documentation should always be present, including the processing applied.
Sometimes licensing is not immediately clear when performing a search	In a repository of data/software, filtering by license would be useful.
The experience of searching for data should be easier	Search Customization: the possibility to be able to search data based on one or more additional constraints (filters) besides the default ones.
In situ datasets are difficult to find	Publish clear metadata for in situ data. Also for private data, metadata should be public, indexed by search engines and harvested by brokers

Source: Authors.

Actionable recommendations

1. **Integration with discovery platforms or portals**: Integration of services in discovery systems aggregating and providing access to multiple services, like e.g. ESA's NoR Portal (https://portfolio.nor-discover.org/)

2. **Data and service metadata completeness**: Complete and accurate metadata for datasets and services (see e.g. Table 3), that can be brokered and compared in web pages

3. **Analytics**: Usage data and analytics as a feedback for platforms to understand and improve how users discover and access the services

4. **Search Engine Optimization**: Optimization of service-related web pages for search engines

3.4   Documentation

User issues / needs / wishes

Participants emphasized the critical importance of maintaining up-to-date documentation and Frequently Asked Questions (FAQs). Outdated resources, such as articles or tutorials, can be confusing and lead to issues. Given that documentation and FAQs are often the first point of reference during a problem, their relevance

cannot be overstated. Additionally, high-quality training materials are essential for effective user onboarding and support.

Table 5 Examples of strengths and weaknesses on documentation emerged during consultation with users.

Weaknesses	Strengths
Diverse data cube technologies are hard to navigate	End-to-End Documentation: provide users with end-to-end documentation and examples for the most frequent use cases
Difficult to choose the right tool	Decision Tree: providing users with a tool that drives them through the decision process of which tools/features to use for the development of their service/application
Difficult to choose the right platform	Fitness for Purpose: providing users with a tool to help them assess the fitness for purpose of the specific platform to their use case
Difficult to understand the documentation	User Type: provide specific documentation and interfaces according to the different user types, e.g., developers, scientists, etc.
Difficult to navigate the documentation	Chat Box: provide users with a chat box tool which can be used to gain specific documentation information.
Having questions beyond the provided documentation	Discussion Forum: provide users with a forum to post their questions/issues and interact with both other users and platform experts
Difficult to navigate the documentation	Multimedia Documentation: provide documentation in multimedia formats, specifically video tutorials for most frequent use cases
Outdated documentation	Regular Updates: all documentation should be regularly updated
Comparing solutions	Standard Documentation: providing documentation according to the same standard can facilitate users in comparing the different solutions made available by the different platforms.

Source: Authors.

Actionable recommendations

1. **Completeness**: The documentation covers all relevant aspects of the digital infrastructure
2. **Frequency of updates**: Regular updates of the documentation
3. **Coverage of use cases**: Documentation offering several examples
4. **Findability**: Ease of finding relevant information in the documentation
5. **Demos and media**: Availability of notebooks, videos, tutorials, webinars
6. **Try before buy**: Possibility to explore the dev environment for a trial period or at reduced capacity

3.5 Customisation

User issues / needs / wishes

Users' workflows may vary a lot from researchers to analysts to early warning systems, to mobile apps developers. This is why there is no one-fits-all solutions, and platforms should be flexible enough to accommodate the various levels of customisation required.

Users need adaptable infrastructure that allows customisation of computing resources, such as CPU/GPU and storage. They require flexible metadata schemas and additional metadata fields for in-depth data analysis. Access to specialized Analysis Ready Data (ARD) tailored to their specific projects is desirable. Users also need services that can be fine-tuned to global, regional, or local contexts, and robust cross-platform support to seamlessly integrate with other platforms and services.

Table 6 Examples of strengths and weaknesses on customisation emerged during consultation with users.

Weaknesses	Strengths
Inflexible infrastructure that can't adapt to varied user needs for processing power and storage.	Infrastructure Customization: the possibility to customize the infrastructural resources to be utilized, including CPU/GPU, storage, etc.
Limited metadata retrieval options that may not meet all user requirements for data categorization and analysis.	Metadata Customization: the possibility to retrieve metadata according to different schemas and formats, as well as the possibility to request additional metadata fields besides the default ones
Inability to access tailored Analysis Ready Data (ARD), hindering efficient data analysis.	ARD Customization: the possibility to request specific types of Analysis Ready Data (ARD) to be utilized
Lack of customization options for services and applications that need to cater to specific geographical requirements.	Global/Regional/Local Customizations: the possibility to fine tune analysis, tools, visualizations, etc, according to the specific (Global/Regional/Local) level of the service/application to be developed
Unclear or absent service commitments, especially regarding interoperability with other platforms, leading to potential misunderstandings and dissatisfaction.	Service Level Agreement: SLA should be provided, including for the integration with other platforms
Inadequate support for users working across multiple platforms, which may result in unresolved issues and fragmented user experience	User Support Across Platforms: the possibility of integrating with other platforms requires specific solutions to handle the user support across different platforms.

Source: Authors.

User quotations:

"We originally got the data via CreoDIAS which we removed due to them being unable to provide the product on a consistent basis. [...] We abandoned CreoDIAS due to being unsatisfied with its quality of service and timeliness of its product delivery" [The product of this particular use case is a mobile app]

"[...] we switched to CreoDIAS for EO data availability" [The product of this particular use case is NOT a mobile app]

"On workflow customisation - for science we need as much flexibility as possible, and rely less on just using existing workflows."

Actionable recommendations

1. **Data visualization customisation**: Customisation of data visualization
2. **Data processing customisation**: Customisation of data processing and analysis tools
3. **Workflow customization**: Users can customise their workflows, ideally accessing resources from a federation of resources, in a seamless way
4. **User role and permission customisation**: Customise user roles and permissions
5. **Integration customisation**: Integration of the platform with external systems or services chosen by users
6. **Service Level Agreement (SLA):** SLA should be provided, including for the integration with other platforms, and for different operational levels (e.g. different timeliness of data provision for users that have to deliver continuously –e.g. mobile apps- or have immediate response to crisis – e.g. early warning systems- or static products –which can wait for data availability).

3.6 Customer support

User issues / needs / wishes

Support seems to be a very important and underestimated topic. Surprisingly, response time is not the most important for any user, though it is particularly relevant for use cases that have to deliver fast (e.g. early warning systems) or continuously (e.g. mobile apps). Everyone agreed that the most important aspects of good support are knowledge and expertise. Also, communications skills were indicated as extremely important. Also the support process improvement and the support team availability were acknowledged as very important.

Table 7 Examples of strengths and weaknesses on customer support emerged during consultation with users.

Weaknesses	Strengths
Support services may become outdated, lacking current knowledge of new technologies and solutions, which can lead to ineffective assistance and customer dissatisfaction.	Support should be up to date with new technologies and solutions.
Participants indicated that they wait for the first answer for a few hours and the feedback is that their issue was passed to another team. Then, they have to wait the next few hours for another response.	Participants suggested it would be great if issues/tickets were first evaluated by some kind of "first contact doctor"/'triage". Such a person would be responsible for recognition if the issue is data or cloud related problem and what is the complexity of the issue (is expert level required to resolve it). It could influence response time as the issue would be addressed faster to the proper person.
Participants indicated that they wait for the first answer for a few hours and the feedback is that their issue was passed to another team. Then, they have to wait the next few hours for another response.	A tag to identify the issue (data/cloud and complexity) should be addressed to the users by default during reporting the issue.
People do not want to talk with bot	Even if the answer takes longer, they would rather talk with the real person. EO/cloud related problems

	are so specific that bots could be easily confused and start repeating the same answers.
'First line' support people are not experts. Then, support's responses are not helpful or they pass the issue to the experts (if experts are employed in company). Of course, it makes response to be delayed.	It would be great to talk with experts directly.
Support team's answers are sometimes not understandable and confusing.	Improving clarity and communication skills of the support's responses
Support in different time zones can be delayed	Expand the availability of support teams for users on other continents – in fact they are excluded from continuous support if providers do not have night shifts.
Inefficient support	No more than two questions should be addressed to the users to identify the issue. More questions would be deterrent.

Source: Authors.

Actionable recommendations

1. **Response time**: Time needed to answer to user inquiries or issues should be customized based on the operational level

2. **Multilingual support**: Support in different languages

3. **Support team availability**: Availability of the support team to assist users during specified hours or through different channels (e.g., email, chat, phone)

4. **Support team expertise**: Level of expertise and knowledge of support team should be paired to user's issue avoiding unnecessary communication and wasting of time, e.g. first-line and second-line support (possibly assisted by AI)

5. **Support process improvement**: Ability to continuously improve its support processes based on user feedback and internal evaluations

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Proposal to improve support process (suggested by the participants)

First automated question presented to the user reporting an issue:

"Is it data or cloud related problem?"

Simple satisfaction survey:

"Was your problem resolved? Was the support expert enough?"

Internal support survey:

"Did I involve into problem more people? How many?"

The number of experts involved could be used as an indicator for cloud providers to identify complexity of the issues

3.7 Community

User issues / needs / wishes

Participants of the workshop agreed that several aspects were crucial: fostering community engagement, facilitating collaborative endeavours, promoting diversity and inclusivity, and encouraging the exchange of knowledge. Among these, diversity was recognized as a particularly critical component. Service providers are encouraged to engage with multiple communities, as limiting oneself to a singular group may result in a constricted worldview and a potential hesitation to adopt new technological advancements.

It is essential to recognise that the matter of diversity extends to the collective framework of companies and teams, not solely to the individual level. It is not a requisite for each employee to be actively involved in numerous communities; however, a heterogeneous workforce is essential.

Involvement in a community is frequently associated with contributions to open-source projects, which can enhance the credibility of a provider or developer. Moreover, active participation in communities is considered indispensable for specific marketing and public relations strategies.

The consensus among the workshop attendees was clear: prioritising diversity stands as the most significant factor, imparting benefits not only to providers by expanding skill sets and broadening perspectives but also to users by fostering positive public relations, facilitating interaction with providers, and enhancing trust.

Table 8 Examples of strengths and weaknesses on community emerged during consultation with users.

Weaknesses	Strengths
Limited community engagement	Foster active engagement within the community to enhance collaboration and knowledge sharing.
Lack of collaborative opportunities	Facilitate collaborative endeavours to leverage the collective expertise within the community.
Limited diversity and inclusivity	Promote diversity and inclusivity within communities to avoid a narrow worldview and innovation hesitance.
Constricted individual perspective	Encourage service providers to engage with multiple communities to broaden their perspectives.
Homogeneity within companies and teams	Aim for a heterogeneous workforce to bring a wide array of ideas and solutions.
Provider or developer credibility issues	Increase contributions to open-source projects to boost credibility and trust.
Inadequate marketing and public relations	Utilize active community participation as a key strategy in marketing and public relations efforts.
Potential barriers to trust and user-provider interactions	Prioritize diversity to expand skill sets, broaden perspectives, foster positive relations, and build trust.

Source: Authors.

Actionable recommendations

1. **Community engagement**: Engagement and participation of community members in the platform

2. **Knowledge sharing**: Tools/incentives for community members to share knowledge, insights, and experiences.

3. **Collaboration opportunities**: Presence of forums, discussion boards, or project collaboration features that facilitate interaction and cooperation among community members

4. **Community growth**: Growth rate of the community, number of new users joining the community used as a feedback by the platform

5. **Diversity and inclusivity**: Diversity and inclusivity of the community, representation of different user profiles, backgrounds, and expertise, indicating the platform's ability to create an inclusive and diverse community, used as a feedback by the platform

6. **User support and mentoring**: Incentives/recognition for support and mentoring provided by experienced community members to newcomers or less experienced users

3.8   Price transparency

User issues / needs / wishes

Cloud platform users have voiced concerns over price transparency, highlighting the unpredictability of costs and the potential for unexpected expenses. To address these, cloud providers should refine their pricing models for better predictability and offer usage alerts. Additionally, the complexity of using some resources poses a risk of incurring inadvertent charges; providers could combat this by improving management tools and offering clearer guidelines. Users also seek more customisable pricing options beyond one-size-fits-all plans to accommodate specific needs, suggesting a move towards more flexible and tailored pricing structures. Monitoring tools are currently seen as inadequate for tracking resource consumption effectively, signalling a need for enhanced real-time monitoring capabilities. The accuracy of pre-estimation for upgrade costs is a concern; timely and transparent communication from providers about upgrade plans, coupled with more accurate estimation tools, would greatly assist users in budget planning.

Table 9 Examples of strengths and weaknesses on price transparency emerged during consultation with users.

Weaknesses	Strengths
Unpredictable costs due to fluctuating resource usage. Potential for unexpected charges if usage spikes unexpectedly.	Pay per use
Risk of incurring costs for forgotten resources that are shelved but not terminated. Complexity in managing which VMs are shelved and which are active.	Possibility of shelving Virtual Machines when not in use
Challenging to compare offers from cloud providers for: cost breakdown; cost comparison; cost predictability. Lack of tailored or flexible pricing options for unique user needs. Oversimplification of pricing that may not reflect actual value or cost-efficiency for certain users.	Homogeneous price offers, easy to understand, e.g. mobile & telecom offers.
Insufficient granularity or real-time data in monitoring tools.	Better monitoring of your wallet of resources. Possibility of creating cost thresholds, pre-paid, etc.
Providers may fail to provide timely or accurate cost estimations for upgrades. Unplanned costs due to providers not adhering to their communicated upgrade plans.	Providers should inform in advance for their upgrade plans, providing an estimation of cost for their upgrades based on their policies.
Service agreements may still contain ambiguous language leading to unforeseen costs. Difficulty in	Clear service agreements, without hidden or

Weaknesses	Strengths
understanding the full scope of potential costs due to complex service structures.	unpredicted costs
Estimations may be inaccurate, leading to budget overruns. Lack of tools or expertise to accurately predict costs for complex or long-term projects.	Pre-estimation of costs for the development

Source: Authors.

Actionable recommendations

1. **Transparent prices**: Clarity and transparency of the pricing structure, easily accessible, understandable, and clearly communicated.

2. **Cost breakdown**: Clear breakdown of the different cost components, such as data access fees, processing fees, or additional service charges.

3. **Cost predictability**: Providing users with a clear understanding of the costs they can incur for using the services. Thresholding, pre-paid, or other mechanisms to prevent unexpected charges.

4. **No hidden costs**: Absence of hidden or unexpected costs. All costs disclosed upfront.

5. **Cost comparison**: Services to compare costs with alternative service providers or different pricing plans of the platform. Informed decisions for users based on cost comparisons.

6. **Cost optimization recommendations**: Providing users with recommendations or insights to optimize their costs, tools or suggestions to help users reduce their expenses while using the services.

3.9 Sustainability

User issues / needs / wishes

Sustainability is multifaceted, including social, economic and environmental perspectives. One aspect is related to the sustainability of the business model, as a proxy for the platform's longevity. In fact, a sustainable business model is crucial for the long-term viability and success of any service, as also emerged during the EuroGEO workshop 2023 (Kona et al., 2023).

Another aspect of sustainability is the environmental one (Rosario & Dias, 2023). Users provided recommendations aiming to create a more sustainable cloud platform that prioritises environmental efficiency, economic viability, and user education.

Table 10 Examples of strengths and weaknesses on sustainability emerged during consultation with users.

Weaknesses	Strengths
Risk of the platform's short-term existence and obsolescence	Ensure the longevity of the platform with long-term availability
Lack of tools for users to measure and manage their environmental impact	Provide a service to calculate a project's CO_2 footprint
Outdated services not meeting current sustainability standards	Regularly review and update the service offerings to ensure they meet current and future sustainability requirements

Weaknesses	Strengths
Inefficient data storage leading to unnecessary resource usage	Implement an efficient data management strategy that operates on a tiered basis, optimizing resource usage according to need.
Lack of financial stability threatening platform longevity	Secure long-term funding for the platform to guarantee its ongoing operation, which entails developing a robust business model
Pricing that may become uncompetitive or irrelevant	Frequently assess and adjust the pricing model to remain fair and relevant over time
Vulnerability to changing regulations and political influence	Maintain political neutrality, ensuring compliance with regulations at local, EU, and global levels
User behaviour contributing to inefficiency and environmental impact	Foster environmental awareness among users, educating them on how to use the platform in an eco-friendly and efficient manner
Wasted resources due to idle services	Implement automatic shutdown of resources when they are no longer required to minimize waste
Higher energy consumption during peak hours	Encourage energy-efficient usage of the platform, such as optimizing operations for night-time when energy demand may be lower
Code that is not optimized for energy conservation	Explore opportunities for users to write more energy-efficient code, contributing to the overall sustainability of the platform
Service interruptions and downtime affecting user trust	Guarantee the reliability and continuity of services, ensuring that they remain operational and consistent over time
Services becoming obsolete or not meeting user needs	Commit to the ongoing maintenance and support of services to prevent obsolescence and ensure they continue to meet user needs
Deteriorating performance and potential for system failures	Keep the platform in a consistently operational state, with a focus on performance and sustainability

Source: Authors.

Actionable recommendations

1. **Revenue growth**: Ability to generate increasing revenue over time, capacity to attract and retain paying customers. Proxy for platform longevity.

2. **Churn rate**: Rate at which customers leave the platform over a specific period.

3. **Longevity**: Commitment of service provider over an agreed period of time.

4. **Innovation and adaptability**: Platform's ability to innovate and adapt to changing market dynamics and customer needs.

5. **Carbon footprint**: GHG emissions due to platform operations.

6. **Renewable energy use**: Share of used energy from renewable sources.

7. **Power usage effectiveness**: Measure of a data centre efficiency, as total energy divided by IT energy; values close to 1 indicate high efficiency.

3.10 Performance

User issues / needs / wishes

Users reported specific issues related to performance, scalability, security, and efficiency in cloud platforms and suggested improvements.

Table 11 Examples of strengths and weaknesses on performance emerged during consultation with users.

Weaknesses	Strengths
Limitations in handling large-scale data transfers efficiently, which can lead to bottlenecks and slow response times for users. The adoption of DTNs aims to enhance the platform's ability to move substantial amounts of data swiftly and reliably.	Implement and test large data transfer capacity using Data Transfer Nodes (DTNs) technologies.
Outdated technology slowing down progress and innovation	Continuous improvements regarding state-of-the-art/technical progress
Inadequate availability and reliability of services	Guaranteed service levels (24x7 or 5x8)
High operational costs due to inefficient service usage	Workflows for the efficient use of service to minimize costs
Lack of visibility and tracking of performance metrics	Provide dashboards showing performance/KPIs
Insufficient processing resources to support user base	Scalability to accommodate users and processing power
Excessive resource usage contributing to higher CO2 emissions	Scale and use only what is needed (CO2 footprint)
Inadequate resources for cutting-edge research and development	Provide state-of-the-art tools & libraries
Data processing inefficiencies leading to data transfer overload	Allow processing near the data and download / transfer data / results when needed
Lack of guidance in optimising performance and resource usage	Support in optimisation approaches and how to implement them
Inefficient data transfer capabilities impacting performance	Use of data transfer nodes to test download/upload performance (DTN – GEANT and NRENs)
Vulnerabilities in data handling and integration	Secure (own) data integration
Potential security breaches and data protection issues	Security measures that protect users' data
Multiple authentication and authorization from various platforms	Authentication and authorisation infrastructure in trusted network (GEANT AAI)

Weaknesses	Strengths
Large data transfer capacity could be tested, using Data Transfer Nodes (DTNs) technologies	Limited capacity for large-scale data transfer operations

Source: Authors.

Actionable recommendations

1. **Responsiveness**: Platform uptime, speed of data retrieval.

2. **Scalability**: Ability to handle increasing data and model sharing demands.

3. **Security and privacy**: Robust data protection, privacy, security measures that protect users' data, with clear and transparent privacy policies (e.g., data encryption, access controls).

4. **Data Usage**: Number of data downloads, user interactions, frequency of data usage.

Other benchmarks are platform-specific.

4 Discussion and conclusions

In this work, the need emerged to address the cloud platforms ecosystem as a whole (Mazzetti & Nativi, 2024), as opposed to single platforms, because it is clear that users need to access a set of services from different providers and that are essential throughout the entire development lifecycle. Users desire the ability to integrate, as seamlessly as possible, services and data from various platforms. Consequently, our recommendations are designed to improve the user experience across this digital ecosystem. This comprehensive approach implies that our recommendations encompass multiple platforms within the cloud ecosystem, necessitating the inclusion of governance strategies that span all dimensions, extending beyond mere technical implementation.

The use of different platforms is beneficial for several reasons, including cost efficiency, avoidance of vendor lock-in, performance optimization, service outages resilience, diversity of geographical locations, etc. It is worth noting that this report does not imply any specific approach for the use of different platforms, focusing instead on the fact that users are provided with a working digital ecosystem environment, i.e. the underlying use of different platforms should be as transparent as possible for the user.

Several challenges and technical and governance recommendations have been provided by users in the tables presented in the individual chapters. Below, we are going to group the recommendations in 4 main areas that we believe summarise the vision of the users.

4.1 Recommendation #1: Federations

Federations (e.g. Baek, 2022, Mohr et al, 2025) play a crucial role in achieving this goal by linking various systems and services to operate for a common goal. There are several layers to consider in federation:

1. **Identity layer**: This involves creating a unified system for identity management, allowing users to access multiple services with a single sign-on. It simplifies the authentication process (verifying user identities) and authorization (granting permission to access resources), enhancing security and convenience across the cloud ecosystem.

2. **Services layer**: This layer focuses on the integration of different services across platforms, ensuring that they can work together seamlessly. It allows users to utilize and combine services from different providers without worrying about compatibility issues.

3. **Resources layer**: At this level, the aim is to streamline access to various resources, including data, infrastructure (e.g. computing power, storage, networking capabilities) and models. By federating resources, users can leverage a collective pool from different cloud providers, optimizing efficiency and scalability according to their needs.

Federations enable building bridges between different components of the cloud platforms ecosystem, allowing users to have a smoother, more secure, and integrated experience without the complexity that typically comes with using multiple cloud services.

Cloud federations can also enhance the longevity and resilience of platforms in a dynamic market by fostering trust, resource sharing, and service collaboration among cloud providers. These federations allow cloud providers to pool their resources, balance loads, reduce costs, and manage demand spikes more effectively. (Mashayekhy et al., 2019; Song et al., 2022).

4.2 Recommendation #2: Decision-support tools

Our goal is to empower users with advanced **decision-support tools** that streamline the selection of an optimal cloud environment for their specific workflows. Imagine an intuitive platform where users can design their workflow, submit it for assessment, and promptly receive personalized quotes from an array of cloud providers. These quotes would transparently outline a set of key elements (e.g. costs, processing times, data availability) providing users with the vital information they need to make choices that fit their use case (e.g. budget, timeline). On top of this, it would be possible to develop a recommendation engine, such as e.g. a decision tree, which would further aid users in pinpointing the ideal service provider by evaluating different elements, (including cost, performance, and service attributes). The same workflow might generate different recommendations based on different strategies, and users might choose different strategies according to specific phases of their application life cycle, e.g., they might want to minimize cost during development and instead minimize processing time in production.

For this to be achievable, it is essential that all offerings from service providers, including costs, come with complete and well-documented metadata (possibly standardised), enabling effective brokerage and comparison like services for car insurance or mobile phone plans. Enhanced semantic search capabilities, supported by detailed metadata and open cost models, will significantly improve the user's ability to search for, compare, and select the most appropriate cloud services with ease.

4.3 Recommendation #3: Service Level Agreements

A critical area for development is the adaptation of services to match the varying operational demands of users. Recognizing that users have distinct levels of needs, it is essential to provide tiered services complemented by transparent **Service Level Agreements (SLAs)** that accommodate a spectrum of user requirements, ranging from the foundational to the highly sophisticated. For instance, mobile app providers may require continuous data streams, early warning systems necessitate rapid data retrieval, while researchers often operate without immediate time pressures. Moreover, the customization should not be limited to a single platform; users increasingly seek the ability to streamline their workflows by integrating data and services from various providers. This flexibility is key to a user-centric approach and should be pursued through collaborative co-design efforts between users and platforms.

4.4 Recommendation #4: Access to in-situ data

Lastly, a problem specific to the studied EO use case is the problem of access to in-situ data has emerged as prominent for most applications. **In-situ data** is knowingly invaluable for various applications, e.g. for calibrating ML models derived from EO. However, a set of recurring challenges hinder their access and effective utilisation. One primary obstacle is the absence of a centralised access point for data discovery. Users often struggle to locate a comprehensive entry for data exploration and face bureaucratic barriers when attempting to access the data, not to mention the difficulty in obtaining sufficient metadata to ascertain the relevance of the discovered data for specific purposes.

The Open Data Directive identifies specific categories of high-value datasets that should be made available free of charge, in machine-readable formats, and via standard licenses that enable re-use, with the aim to unlock the economic potential of these datasets, stimulate the creation of innovative applications and services, improve transparency, and promote data-driven decision-making. However, accessibility is still a pervasive issue, as in-situ data are not always readily available for direct use. Instead, they may be locked behind layers of aggregation or presented only within the confines of reports, limiting their practical applicability. The delicate balance between utility and privacy presents a unique challenge. Efforts to anonymize spatial data for privacy reasons can render the data less useful for precise analyses where accurate geographic information is critical, leading to a trade-off that can compromise the integrity of research or operational tasks.

Furthermore, the harmonisation of in-situ data is a complex endeavour. Diverse collection protocols, units of measurement, and inventory designs tailored to individual countries or regions across the world, can stifle efforts to compare and integrate data across various jurisdictions. The task is further complicated by the variability in metadata quality, language barriers, and differing terminologies and definitions. The challenge of inconsistent data formats is another significant barrier to integration. The publication of in-situ data in different languages, formats and coordinate systems necessitates additional steps for conversion and alignment, impeding streamlined workflows and the synergistic use of data from multiple sources. On the other hand, each country has interest in keeping longitudinal consistency along time series, hindering the possibility to converge to a common reporting system.

As technology progresses and data-hungry models become increasingly prominent, it is evident the need of initiatives that promote the collection of ad hoc high-quality data for the purpose of calibration of ML models based on EO imagery, ensuring model accuracy and reliability.

4.5 Conclusions

This report has provided a comprehensive examination of user experiences with cloud platforms, particularly those engaged in policy-relevant projects within the European Union's cloud ecosystem. Our findings illuminate the need for a user-centric approach that addresses the complexity and fragmentation of the current ecosystem. We have identified user issues and proposed actionable recommendations across ten critical areas: interoperability, access, discovery, documentation, customisation, customer support, community, price transparency, sustainability, and performance.

From our analysis, it is clear that users desire a seamless integration of services across a federated cloud ecosystem. Federations of trust, services, and resources are essential to enable the effective and efficient use of multiple cloud platforms, ensuring that users can access and integrate heterogeneous services and data throughout the entire development lifecycle of their projects.

To empower users with advanced decision-support tools, we advocate for the development of cloud environment selection tools. Such tools would provide personalised quotes from various cloud providers, facilitating informed decision-making by offering transparent cost and service comparisons. Standardised metadata and open cost models will significantly enhance the ability to search, compare, and select the most appropriate cloud services.

We also highlight the importance of adapting services to meet the diverse operational demands of users. This includes the provision of tiered services and transparent Service Level Agreements (SLAs) to accommodate different user requirements. Customisation is vital for a user-centric approach and should be pursued through collaborative co-design efforts between users and platforms.

Furthermore, the report underscores the challenges associated with accessing in-situ data. Initiatives that promote the collection of high-quality data for the calibration of machine learning models derived from Earth Observation imagery are necessary to ensure model accuracy and reliability. Addressing the accessibility, harmonisation, and integration of in-situ data remains a high priority for the advancement of the cloud ecosystem.

In conclusion, the report calls for an integrated and sustainable approach to cloud platform development. By implementing the recommendations outlined, we envision a user-centric, interoperable, and resilient cloud ecosystem that fully supports the development lifecycle of policy-relevant use cases. This ecosystem will not only foster innovation and competitiveness but also align with the core EU values of transparency, sustainability, and inclusiveness.

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List of abbreviations and definitions

AGB	Above-Ground Biomass
AI	Artificial Intelligence
API	Application Programming Interface
COPERNICUS	European Union's Earth observation program
DTN	Data Transfer Node
EO	Earth Observation
FAIR	Findable, Accessible, Interoperable, Reusable
GEO	Group on Earth Observation
GEE	Google Earth Engine
HPC	High Performance Computing
LLM	Large Language Model
ML	Machine Learning
OGC	Open Geospatial Consortium
STAC	SpatioTemporal Asset Catalog
TRUST	Transparency, Responsibility, User focus, Sustainability, Technology
VM	Virtual Machine

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Getting in touch with the EU

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