



Collection of NFDI4Earth One-Pagers

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Acronyms

CMS	Content management system
EduHub	Education and training hubs
EduTrain	Education and training material platform
ESS	Earth System Sciences
FAQ	Frequently asked questions
KH	Knowledge Hub
LHB	Living Handbook
OER	Open Educational Resources
OS4A	OneStop4All
SOP	Standard operation procedure

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Introduction

The mission of NFDI4Earth is to address the digital needs of the Earth System Sciences (ESS). We develop several components, services and concepts within NFDI4Earth. To improve the internal and external communication, we provide One-Pagers for selected central components, services and concepts, which describe them from the usage / user perspective on one to a maximum of two pages.

The One-Pagers follow a common structure, starting with the overall aim of the related NFDI4Earth software component or concept. After that, we briefly describe core problem(s) and innovative approaches to solutions. NFDI4Earth is a community-driven project. We therefore identify users of the components / concept and the intended benefits for them.

Moreover, innovations have adoption units (see Rogers, 2003¹). These can be individuals (e.g., a researcher) or organizations (e.g., a research institute that commits to operate a service after its development). We point out the intended adoption units with respect to the below-mentioned expected outcomes and evaluation criteria.

¹ Rogers, E. M. (2003) *Diffusion of innovations*. Simon and Schuster.

Software Architecture

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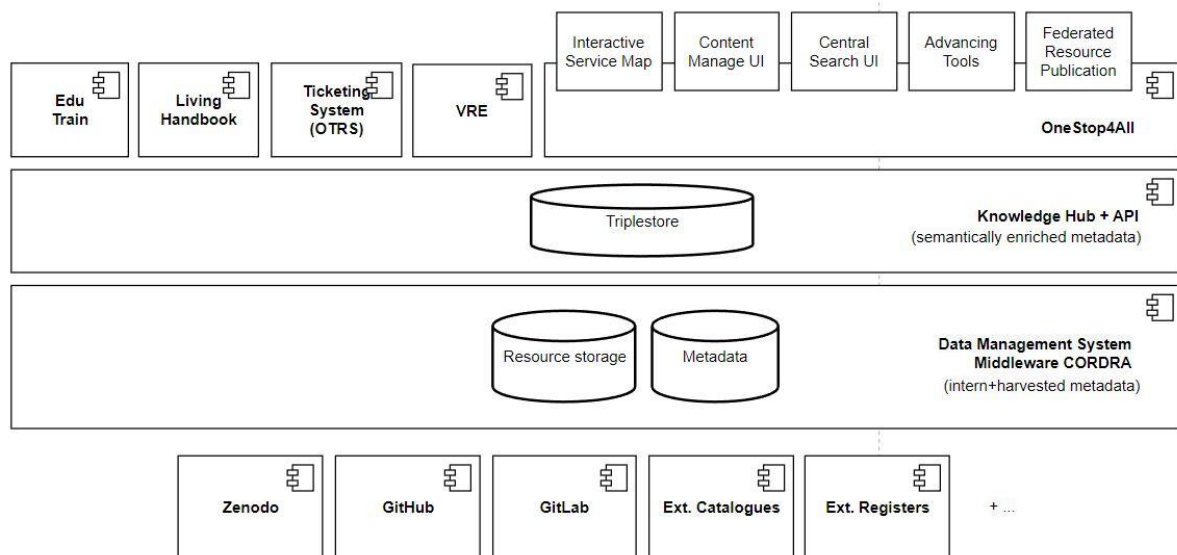
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The architecture of the NFDI4Earth describes the different software components built to make resources from the Earth System Sciences (ESS) findable, accessible, interoperable and reusable, as well as the requirements for interfaces enabling their interaction.

Problem: NFDI4Earth comes with at least five software components: the Knowledge Hub (stores interlinked metadata in a structured format), the Living Handbook (stores and manages web-based, interactive articles about topics relevant to the community and the documentation of the NFDI4Earth products), the EduTrain (stores and manages educational resources of the ESS community), OneStop4All (user-centered search and interactive exploration of ESS resources), and the User Support Network (distributed helpdesk). A clear specification of the interfaces of each component is needed to ensure their smooth interaction, and ultimately the best experience to users of the NFDI4Earth infrastructure.

Our solution: The current version of the NFDI4Earth architecture is shown on the figure below. The architecture features a resource layer (data sources), data management layer, a semantically-enriched metadata layer, and an application layer (EduTrain, Living Handbook, Ticketing System, Virtual Research Environments, and OneStop4All). An important feature of the **resource layer** is that all metadata about the research products are stored in such a way that they are accessible through an Application Programming Interface (API). Living Handbook articles and EduTrain material are stored in GitHub/Gitlab and will be harvested through their APIs. Documents (e.g., scientific publications, deliverables) can be stored in Zenodo and will then be harvested through its API. External data sources (e.g., catalogues/registers) with an API will be integrated to the NFDI4Earth architecture.

Through the use of a **data management layer** that stores all manually-created and harvested metadata in Cordra, the architecture supports the management and provision of FAIR digital objects. The Knowledge Hub is the only component of the **semantically-enriched metadata layer**. It stores all metadata in RDF (Resource Description Framework) and is accessible through a SPARQL API. The communication between the OneStop4All and the Knowledge Hub happens through that SPARQL API. The implementation of the data management, semantically-enriched and application layers happens in NFDI4Earth through open-source software.



Simplified version of the key components of the NFDI4Earth architecture

Users: We anticipate two types of users for the NFDI4Earth architecture: internal developers of the different NFDI4Earth components (EduTrain, Living Handbook, Knowledge Hub, OneStop4All) and the developers that use NFDI4Earth to develop services for the Earth System Sciences.

Intended benefits for users:

- Internal developers of the NFDI4Earth components can find specifications of other NFDI4Earth components and integrate this within their own development workflows
- Developers of services for the Earth System Sciences can find out how to use existing NFDI4Earth components and how to add components to the NFDI4Earth infrastructure or remove them

Intended adoption units: Innovations have adoption units (see Rogers, 2003). These can be individuals (e.g., a researcher) or organizations (e.g., a research institute that commits to operate a service after its development). We anticipate that our architecture can serve as a blueprint for other organizations (e.g., consortia) interested in realizing research data infrastructures.

Evaluation criteria:

- Adaptability (ease of performing changes, add/remove some components from the architecture)
- Number of scenarios covered by the software components of the architecture (provided functionality)
- Conceptual integrity (doing similar things in similar ways, e.g., similar solutions for Living Handbook and EduTrain)
- Provided interfaces / Interoperability

Knowledge Hub Concept

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Updated last: 25.10.2022

The Knowledge Hub serves as one major backend service of NFDI4Earth. It integrates metadata about all NFDI4Earth resources and is accessed via an Application Programming Interface (API). We want to learn what it takes to 1) set up such an infrastructure of metadata, 2) ensure its adoption, 3) keep it up-to-date, and 4) make it operational for a decade.

Problem: research products from the Earth System Sciences (ESS) are increasingly difficult to find. **There is a need for tools that automate their discovery.** 'Research products' is used here as a catch-all term that includes 1) datasets, 2) services, 3) tools, 4) vocabularies, 5) reports, 6) scientific papers, and 7) peer reviews.

Our innovations: Structured and interlinked metadata for ESS resources produced in NFDI4Earth or relevant for the NFDI4Earth. These ESS resources can be any research product listed above, an article of the Living Handbook, or an educational material from the EduTrain. We use RDF (Resource Description Framework) as an encoding format

Structured and interlinked metadata for ESS resources hosted by NFDI4Earth partners

NFDI4Earth label - compiled based on the available metadata - as an indicator of the extent to which services are FAIR, and in particular, the degree of interoperability of the services

Users:

- Consumers: people who have basic skills in programmatic data access (i.e. they are able to program a short snippet of code in a programming language to retrieve data).
- Producers: these create/edit metadata for the Knowledge Hub. They may have programming skills (in which case they create/edit metadata via the API of the Knowledge Hub) or have no programming skills (in which case they do the creation/editing via a user interface).

Intended benefits for users:

- Provide answers to questions pertaining to *all* products of the NFDI4Earth (services/tools/vocabularies/reports/scientific papers/open peer reviews) via an API. This presupposes structured metadata generation for all these products. Services include data catalogues, repositories, and OGC services.
- Support users with programming skills in retrieving all known facts about researched individuals/categories/relations (e.g., all known facts about the

Thwaites Glacier [individual], all known facts about the Glaciers [category], and known facts about the relationship (correlation, causation) between the melting of the Thwaites Glacier [property of an individual] and sea-level rise over a period of time [individual]).

- The Knowledge Hub provides input for search functionalities in the OneStop4All and the Living Handbook.

Intended adoption units: We anticipate that the Knowledge Hub will be used by individuals (e.g., data scientists), who find it useful for their work. Adoption by organizations is indirect and a by-product of the adoption by individuals.

Expected outcomes:

- Structured metadata in RDF about ESS research outputs (including data repositories) and NFDI4Earth components (e.g., Living Handbook and EduTrain)
- One API that enables programmers to retrieve and edit that metadata
- The NFDI4Earth label as a digital badge
- User interfaces to enable non-programmers to *edit* the metadata. Non-programmers who want to retrieve the metadata can do so via the user interface provided by the OneStop4All

Evaluation criteria:

- Knowledge Hub usage (through the number of API calls and their spatial and temporal distribution)
- Usage of the NFDI4Earth label (through the number of websites/catalogs that embed it)
- User feedbacks about the learnability of the API, the completeness of the metadata, and the completeness of the services indexed by the Knowledge Hub

OneStop4All Concept

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Updated last: 12.12.2022

The OneStop4All is the primary visual and user-friendly NFDI4Earth access point. It offers a coherent view on and points to all relevant (mainly distributed) Earth System Sciences (ESS) RDM resources provided by NFDI4Earth members and the ESS community, such as data repositories, software tools, information on Research Data Management (RDM), education and training materials etc. It also guides users through NFDI4Earth resources according to their specific ESS RDM and Data Science requirements and capabilities. Moreover, it provides relevant information on engagement and networking cooperation - both on a national and international level. The OneStop4All also fosters a seamless transition to a distributed user support network.

Challenges: Research products² from the ESS community are diverse and increasingly difficult to find. There is thus a need for platforms that efficiently organize the access to ESS resources, in particular quality-assured resources. These platforms should be:

- User-friendly and easy-to-use, taking specific user characteristics and needs into account
- Flexible enough to integrate future RDM services (e.g., address multidisciplinary use cases with other NFDIs, link to EOSC services).

Our innovation(s):

- Central search on NFDI4Earth resources and distributed sources, including relevant governmental, research and other open data sources
- Innovative user interfaces to explore the linked ESS resources (e.g., on the ESS repository landscape, or on ESS education and training material) that adapt to the needs of different user groups
- Intelligent functionality to connect Living Handbook information for registered resources
- Seamless transition from machine-based to human-based support
- A community tool fostering the sharing of high-quality information and resources

Users: We envision the following types of primary users:

- Users, who are looking for ESS research products as defined above and ESS RDM information (e.g., events, networks)

² 'Research products' is used here as a catch-all term that includes 1) datasets, 2) services, 3) tools, 4) vocabularies, 5) reports, 6) scientific papers, 7) educational material and 8) peer reviews.

- Users, who are looking for support, e.g., on NFDI4Earth tools or on how to use NFDI4Earth services
- Users, who want to offer information/research products
- Users, who want to provide feedback (e.g., improve the quality) on the OneStop4All content

Intended benefits for users:

- Single point of access to all linked resources collected by NFDI4Earth that are managed in the Knowledge Hub
- User interfaces to interactively explore resources with respect to ESS community needs and characteristics
- Greater visibility of resources for providers

Intended adoption units:

- Individuals

Expected outcomes: OneStop4All portal:

- User interfaces for search and discovering information from the Knowledge Hub
- Included ticketing system to contact the User Support Network
- Included EduTrain with specific functionality for education and materials
- Included Living Handbook providing guidance and overviews on services
- User interface for managing metadata on registered resources
- Integrated information hub for calls, events, networks

Evaluation criteria:

- Spatial distribution as well as the times of use (clock times, duration, completion time)
- Quantifiable data on usage for the usage (retention rate, conversion rate, error rate, ...)
- User feedback about their experience during usage (accompanying evaluation e.g., CSAT, NPS, CES, ... ³)
- Feedback on user experience via user feedback groups/focus groups

³ CSAT - Customer Satisfaction Score, NPS - Net Promoter Score, CES - Customer Effort Score

Living Handbook Concept

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Updated last: 05.10.2022

The Living Handbook (LHB) provides an encyclopedia style documentation for all aspects related to the NFDI4Earth, its services and outcomes in a human readable form. As such, the LHB serves as the public interface to the Knowledge Hub. The LHB is closely linked to the EduTrain, whose contents will be part of the Living Handbook where appropriate. LHB documents will – for example – also include best and failed practices from within and outside the NFDI4Earth related to all aspects of Earth System Sciences (ESS) research data. The experience and knowledge acquired by the user support network will result in an FAQ that is provided as LHB documents. The LHB is connected to the OneStop4All (OS4A), which serves as its entry point, i.e., parts of the OS4A search results will direct a user to LHB documents.

Problem: Many researchers, societies, funding agencies, companies, authorities, or the interested public are not familiar with each aspect of the NFDI4Earth, its services, or ESS research data in general. A core service with overview documents of such topics is, hence, required. The various user needs, and prior knowledges must be reflected in these documents, i.e., these must provide a flexible granularity, from being brief and informal to being comprehensive and detailed.

Our innovation(s):

- Structuring and harmonizing all aspects of NFDI4Earth as well as ESS related information from different, also previously unpublished, sources.
- Curate and present information about the NFDI4Earth as a collection of edited, inter-linked, human-readable documents of various types (documentation, report, article, manual, tutorial, ed-op, etc.) that are externally linked with general ESS resources.
- Compilation of documents tailored to the different proficiency levels and backgrounds of readers by a combination of automatic re-combination and re-arrangement of the document's elements.

Users:

- Consumers: Users with interest in NFDI4Earth, NFDI or else ESS related information, data, services, concepts, software etc. We expect users with a high variety in their backgrounds and prior knowledge.
- Editors/authors: Persons that provide and regularly quality check the LHB contents.

Intended benefits for users:

- Quick access of relevant (background) information, manuals, explanations, tutorials – basically the encyclopedia of the NFDI4Earth and the network/infrastructure it is embedded in.
- Increasing the visibility of data providers, repositories, and tools, and enabling quick feedback about problems or outdated information

Intended adoption units: The LHB will be beneficial to e.g.:

- Researchers as a manual how to use NFDI4Earth and related external products and to learn what the scope of the NFDI4Earth and its services are.
- Scientific and professional societies as a place to refer their members as a resource for ESS data related topics.
- Funding agencies to understand how researchers are using and providing ESS data
- Authorities to get and provide information about ESS data
- The interested public as the first stop to find ESS related information

Expected outcomes:

- A collection of internally and externally linked documents explaining the NFDI4Earth with all its services, and products, as well as ESS data related topics.
- A wiki-style user interface for an intuitive navigation through the living handbook
- A collection of templates assisting the production of the various document types
- A CMS for editors and/or authors to add and update documents

Evaluation criteria:

- User and focus group feedback on the LHB usability, quality, and comprehensiveness.
- Page statistics
- Usage of inter- and cross-links

User Support Network Concept

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Updated last: 19.12. 2022

The User Support Network (USN) will provide distributed, cross-institutional user support based on the services of the existing partner institutions' services and the upcoming NFDI4Earth innovations. To keep an overview on the distributed services, the USN has to be in close cooperation with the OneStop4All, the Living Handbook and the Knowledge Hub.

Challenges: Research data services from the Earth system sciences community are diverse and until now mainly directed to a smaller community, e.g., an institute. We will work on a structure in the USN that allows to map the different resources and to access them. The USN will also evaluate if an open community support system (like stackoverflow) will be of value next to the institutional RDM support of the USN team. To work on that evaluation, we need a solid idea of what kind of user questions are asking, which we expect to get by running the ticketing system.

Our innovation(s):

- Single point of access to a national expert pool offering individual support for ESS RDM problems for all phases of the data lifecycle
- Collection, harmonization and provision of expert knowledge based on institutional experience, e.g., via Living Handbook
- Creation of standard operation procedures (SOPs) for user support

Users: we envision the following types of primary users:

- Users, who are looking for general information, e.g., on NFDI4Earth tools or on how to use NFDI4Earth services
- Users, who are looking for support in ESS research data management (RDM)

Intended benefits for users: The user will benefit from a guided ticketing system as a single point of access to a national ESS RDM expert pool for individual support and a documentation of frequently asked questions (FAQs) on ESS RDM provided as Living Handbook articles.

Intended adoption units:

- Individuals
- Research institutions

Expected outcomes:

- USN ticketing system linked to OneStop4All
- Standard Operation Procedures

- Identification of missing support structures in certain ESS RDM topics

Evaluation criteria:

- Monitoring of which support is requested most often (e.g. number of tickets about NFDI4Earth tools)
- Improved RDM concepts, strategies and implementations at the partner institutions at all stages of the data life cycle

Education and Training Materials and Services

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Updated last: 03.11.2022

The NFDI4Earth education & training team aims to enable widespread uptake of NFDI4Earth to conduct open and sustainable research by Earth System Science (ESS) stakeholders. FAIR, Open, ready-to-use modular course material and curricula will be developed based on the community's needs. They will be available via a single point of access, which will also contain a catalogue of external training and education materials for ESS. Moreover, education and training events will be organized regularly using the developed materials. In particular, an NFDI4Earth research data curation certificate course will be offered.

For the long-term and sustainable development of ESS competencies, an open network of education and training hubs (EduHubs) will be established. EduHubs are run by partners who commit themselves to permanently offering education and training services for ESS-related research data management and spatio-temporal data science. The EduHub activities will be coordinated in collaboration with the NFDI4Earth User Support Network.

Problem: A lack of FAIR and open educational resources is one of the biggest obstacles to scientific activities. Although substantial effort has already been put into developing Open Educational Resources (OERs), many issues still exist, e.g., peer-reviewing the content, maintenance responsibility, quality control, management, and lack of funding for the development and maintenance. Another major problem is that most existing FAIR principles and Open Science materials are generic. At the same time, ESS-specific materials that outline adapting the FAIR principles and Open Science concepts are highly needed but mainly missing ⁴[1].

Our innovation(s)/services:

- Development and maintenance of OERs and curriculum based on regular educational needs assessment of the ESS community
- Continuous collection and evaluation of existing OERs in research data management tailored for ESS, spatio-temporal data literacy, and spatio-temporal data science
- Funding the development of new open-licensed materials to meet the educational needs of the ESS community by publishing calls for educational pilots
- Development of target group-specific curricula

⁴ Peter Pelz *et al.*, Working Group Charter Training Infrastructures, <https://doi.org/10.5281/zenodo.6478698>, 2022.

- Regular revision of the developed contents and curricula based on user feedback
- Creating a single point of access to organize, manage, search for, and access materials collected and developed, supported by standardized metadata
- Build the first NFDI4Earth education and training hub (NFDI4Earth EduHub)

Users:

- Scientists, ranging from early-career researchers (Ph.D. students, Post-Docs) to experienced senior scientists and professors
- Master students
- Bachelor students
- Educators and training professionals (e.g., professors, lecturers, teaching assistants)

Intended benefits for the user:

Benefits for the learners:

- Access to educational resources that ESS experts have reviewed
- Reduced educational expenses
- Improved learning experience through using high-quality and interactive training material
- Long-term education and training services, thus sustainable competency development based on advances in ESS by EduHubs

Benefits for the educators and educational institutions:

- Prepare lectures more efficiently by adapting provided peer-reviewed resources
- Tailor learning and teaching resources that fit a specific context
- Enable interdisciplinary training by integrating resources from multiple ESS sub-domains
- Active collaboration within the ESS community to create new resources
- Steering the development of spatiotemporal data literacy and science in the ESS by EduHubs to train the next generation of ESS researchers
- Recognition and reputational benefits
- Reduce the costs of creating educational materials

Intended unit of adoption:

- Individuals
- Higher education institutions
- Research centres

Expected outcomes:

- Single point of access for quality-controlled educational materials
- FAIR, modular educational materials and curricula for the NFDI4Earth community published under an open license
- Creating the first NFDI4Earth EduHub

Evaluation criteria:

- Course statistics
- Qualitative feedback from learners and trainers

Pilots Concept

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Updated last: 03.08.2022

The Earth System Science (ESS) Pilots are small projects from various disciplines of the ESS community usually lasting for one year. They leverage existing and novel technologies for ingesting research data into the scientific workflow. Pilots are used to assess and define requirements in other task areas and promising results will be integrated into the NFDI4Earth infrastructure. The first round of 14 pilots has started in April 2022, two more rounds will follow in 2023 and 2024/2025.

Problem: To achieve acceptance and adoption of the community as well as a cultural change, NFDI4Earth must not implement top-down solutions but involve ideas and existing tools from the research community. Different domains of ESS face different challenges in interoperability, standardization of data, methods and workflows. Expertise and technologies are existent but need further development to meet domain specific requirements and often lack transferability for usage beyond a small user group.

Our innovation(s):

- Agile projects that directly reflect researchers' needs in data management and implement novel solutions for research data management
- Bottom-up innovation scouts for other Task Areas of NFDI4Earth
- Focus on transferability of results and enhancement of technologies to make use of existing resources and foster community driven design of NFDI4Earth

Users: The target community are researchers from the ESS community working on tools that enhance research data management. The solutions implemented from the pilots are targeted to the respective scientific community.

Intended benefits for the participants / user:

- Funding for development of new tools needed in their research
- Networking within ESS, synergies and collaborations within the community
- Increased visibility of their solutions and support from NFDI4Earth
- Possible long-term integration and follow up funding in NFDI4Earth

Intended adoption units:

- NFDI4Earth includes pilots' results into their infrastructure
- User communities of different domains that adopt the newly developed tools by pilots

Expected outcomes:

- Implemented solutions that can be transferred to or used by other domains
- Integration of ready-to-use tools into the OneStop4All / Knowledge Hub / Living Handbook
- Integration of ready-to-use tools into the Academy and EduTrain
- Integration of pilots into TA2 for further development
- Integration of prototype tools into Academy for testing

Evaluation criteria:

- Number of implemented tools delivered on time
- Number of tools that have been adopted beyond development team
- Number of pilots integrated into Task Area 2
- Number of Living Handbook and Knowledge Hub entries based on pilots' results