D8.4
The FAIRness of ACTRIS

Work Package	WP8
Lead partner	NILU
Status	Final
Deliverable type	Report
Dissemination level	Public
Due date	28 February 2023
Submission date	16 March 2023

Deliverable abstract

This report presents the implementation of the FAIR principles by ACTRIS Data Centre over the period January 2019 – February 2023.

DELIVERY SLIP

	Name	Partner Organization	Date
Main Author	Cathrine Lund Myhre	NILU, Norway	08.03.2023
Contributing Authors	Markus Fiebig	NILU, Norway	
	Richard O. Rud	NILU, Norway	
	Lucia Mona	CNR-IMAA, Italy	
	Claudio Dema	CNR-IMAA, Italy	
	Nicolas Pascal	AERIS/ICARE, France	
	Patrice Henry	CNES/AERIS, France	
	Bénédicte Picquet-Varrault	IPSL/LISA, France	
	Guillaume Brissebrat	CNRS, IPSL/AERIS, France	
	Cathy Boonne	CNRS, IPSL/AERIS/ESPRI, France	
	Ewan O'Connor	FMI, Finland	
	Simo Tukiainen	FMI, Finland	
Reviewer(s)	Damian Boulanger	CNRS, France	15.03.2023
Approver	Andreas Petzold	FZJ	16.03.2023

DELIVERY LOG

Issue	Date	Comment	Author
V 0.1	08.03.2023		Cathrine Lund Myhre

DOCUMENT AMENDMENT PROCEDURE

Amendments, comments and suggestions should be sent to the Project Manager at
manager@envri-fair.eu.

GLOSSARY

A relevant project glossary is included in Appendix A. The latest version of the master list of the glossary
is available at http://doi.org/10.5281/zenodo.4471374.

PROJECT SUMMARY

ENVRI-FAIR is the connection of the ESFRI Cluster of Environmental Research Infrastructures
(ENVRI) to the European Open Science Cloud (EOSC). Participating research infrastructures (RI) of the
environmental domain cover the subdomains Atmosphere, Marine, Solid Earth and Biodiversity /
Ecosystems and thus the Earth system in its full complexity.

The overarching goal is that at the end of the proposed project, all participating RIs have built a set of
FAIR data services which enhances the efficiency and productivity of researchers, supports innovation,
enables data- and knowledge-based decisions and connects the ENVRI Cluster to the EOSC.

This goal is reached by: (1) well defined community policies and standards on all steps of the data life
cycle, aligned with the wider European policies, as well as with international developments; (2) each
participating RI will have sustainable, transparent and auditable data services, for each step of data life
cycle, compliant to the FAIR principles. (3) the focus of the proposed work is put on the implementation
of prototypes for testing pre-production services at each RI; the catalogue of prepared services is defined
for each RI independently, depending on the maturity of the involved RIs; (4) the complete set of
thematic data services and tools provided by the ENVRI cluster is exposed under the EOSC catalogue of
services.

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1   Introduction

The ENVRI-FAIR project's objective is to implement "FAIRness" for data produced in the European Research Infrastructures (RIs) organized in the Environmental Research Infrastructures (ENVRI) community, in order to make them ready for connecting to the European Open Science Cloud (EOSC). In this context, "FAIR" is an acronym comprising the aspects of "Findable", "Accessible", "Interoperable", and "Reusable" as specified by the FORCE11 community.

ENVRI-FAIR WP8 organises and conducts this implementation work for the community of ENVRI RIs in the atmospheric subdomain, comprised of the RIs ACTRIS, EISCAT, IAGOS, ICOS (atmosphere), and SIOS (atmosphere).

D8.3 Atmospheric subdomain implementation plan describing the implementation plan of FAIRness for the atmospheric sub-domain was ready March 2020. Later there is a revised version produced, taking the implementation of the ENVRI-Hub into account. This 2nd version was finalized September 2021, and is the most recent implementation plan for WP8.

Towards the end of the project, a set of deliverables are due M50 describing the implementation of FAIRness, for each RI.
- D8.4: The FAIRness of ACTRIS
- D8.5: The FAIRness of EISCAT_3D
- D8.6: The FAIRness of IAGOS
- D8.7: The FAIRness of ICOS-atm
- D8.8: The FAIRness of SIOS

This deliverable provides the "The FAIRness of ACTRIS" and is the status of the implementation in February 2023, in relation to the updated, 2nd version of the implementation plan from September 2021. A cross sub-domain FAIRness assessment will be performed in March 2023 to monitor the complete progress over the project period using FAIR Implementation Profiles (FIPs). This is ready in April, and will be reported in the Deliverable "D8.13 Atmospheric subdomain FAIRness assessment report" due May 2023 for all atmospheric RIs.

2   Background and the starting point for ACTRIS

2.1   Gap analysis

The RIs of the ENVRI atmospheric subdomain have conducted a comprehensive analysis of the FAIRness of their data management, in several steps.

The first step was an analysis of the FAIRness of their data centre, data curation and management in 2018 in relation to the proposal writing of ENVRI-FAIR. This resulted in a FAIRness matrix, guiding the tasks and development of the ENVRI-FAIR project.

After the project start in January 2019, a comprehensive FAIRness assessment was performed both within the atmospheric sub-domain and by WP5.
The identified gaps across the atmospheric sub-domain considered most important from a user perspective concern the following FAIRness functions:
- Findable: globally unique identifier; indexed in searchable resource.
- Accessible: (meta)data retrievable by standardised protocol
- Interoperable: common vocabulary
- Re-usable: established license, documented provenance, (meta)data meets community standards.

2.2 The FAIR implementation plan for ACTRIS

Based on the gap analysis and the 1st FIP a detailed implementation plan was developed for ACTRIS.

The tasks for implementing these functions were grouped by the following criteria:

1) Importance of the function for the user
2) Maturity of the function in the RI.

The 1st detailed implementation plan D8.3 Atmospheric subdomain implementation plan was ready March 2020. Later, there is a revised version, taking the requirements for setting up and contributing to the ENVRI-hub for ACTRIS into account. This 2nd version was finalized September 2021 and is the most recent implementation plan for ACTRIS.

For ACTRIS, the prioritized tasks were grouped into 3 categories, where some of the tasks are targeting harmonization across the atmospheric sub-domain, not only ACTRIS.

Immediate implementation: the function implemented is highly important for the user, the implementation plan is consolidated.
Including the following topics:
- Consolidation of consistent use of PIDs throughout data production workflow
- Common standard interfaces for metadata and data access
- Indexing of data resources in WIS, GEOSS
- Common use of authentication schemes
- Endpoint for providing service metadata to ENVRI-hub
- Recommendations on RIs graphical user interfaces (GUI)
- Documenting provenance
- Essential tasks for immediate implementation planning

Task for second half of project: the function implemented is considered important, but implementation can be postponed to allow focused work on the highly important FAIRness functions.
Including the following topics:
- Domain vocabulary / ontology for observed parameters, discovery and use metadata
- Consistent documentation of provenance throughout data production workflow
- Recommendations for licenses on metadata and data
- Semantic search for atmospheric ENVRI RI user interfaces Improve Graphical User Interfaces

Finally, a list of topics where planned for the second part of the project:
- Common metadata standards and interfaces for use of metadata
- Machine-readable license and attribution metadata.
- Common strategy for structured search interfaces, including common base set of searchable items Structured search interfaces are preferred by expert users with a high knowledge about the data they are searching.
- Traceable post-production user feedback services
- Data indexing in further data portals. (e.g. Google, EOSC, WIGOS).
- Standards for RESTful APIs for metadata and data.
- Common interfaces for data, facilitating machine readability of data, e.g. in Virtual Research Environment (VRE)s.
- PIDs for organizations and instruments to be determined in consultation with experts in ENVRI-FAIR WP7.

3 Progress on FAIRness for ACTRIS

This section includes the progress reports of implementation of FAIRness within ACTRIS. We have evaluated the implementation of FAIRness in relation to the implementation plan in section 3.1: Furthermore, we have used the FIP analysis from WP5 to assess the internal progress for the ACTRIS DC reported in section 3.2.

ACTRIS DC consists of various units. The numerous measurement methodologies applied in ACTRIS result in a considerable diversity of the data collected. In accordance with these requirements, ACTRIS DC is organized in 6 Units, with clear links and procedures for interaction between the data centre Units, National Facilities (NFs) and topical centres (TCs). There are 5 units with complementary topic expertise and 1 unit with integrating activities (DVAS).
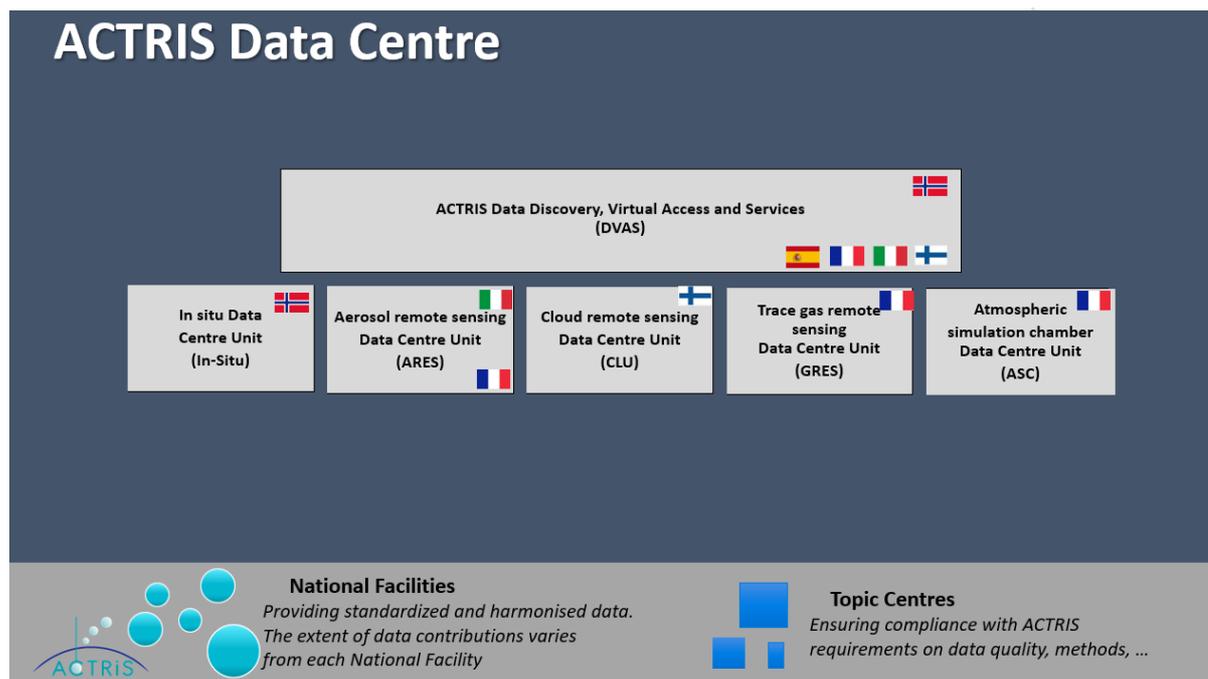

Figure 1: Architecture of the ACTRIS Data Centre

In this report the implementation and progress within each unit is shown. Note that in the FIP assessment for the full atmospheric subdomain (Deliverable 8.13), the DVAS is used, as this is the connection to the ACTRIS data users in the future.

3.1 Implementation of FAIRness in relation to the implementation plan

A table with the progress for each unit is included, together referring to the sections in D8.3 Atmospheric subdomain implementation plan . Symbols are used for more detailed information on the implementation of the tasks and progress of these. The symbols used in the tables are in the text box.

Legend	
🟢	Completed
🟡	In progress
⚫	Not started, according to plan (0)
🔴	New tasks not in the implementation plan

Table 1: Summary of implementation of FAIRness within ACTRIS -DVAS

Task and Milestones under implementation	Due month Implementation plan	Status June 2020	Status November 2022	Status February 2023
1.1 Use of PIDs throughout workflow				
ACTRIS: determine PID solution	3rd QTR 20	🟡	🟢	🟢
ACTRIS: implement primary DOIs	1st QTR 22	🟡	🟡	🟢
ACTRIS: PIDs pre-products implemented	4th QTR 22	🟡	🟡	🟡
ACTRIS: ORCiD and org. PIDs implemented	4th QTR 22	⚫	⚫	⚫
1.2 Standard interfaces for (meta)data access				
ACTRIS: metadata repository, 1st version	4th QTR 21	🟡	🟢	🟢
ACTRIS: metadata M2M interface available	3rd QTR 22	⚫	🟢	🟢
ACTRIS: THREDDS data repository and interfaces	4th QTR 21	🔴	🟢	🟢
1.3 Data indexing in WIS and GEOSS				
ACTRIS: link to GISC in WIS implemented	4th QTR 22	⚫	🟢	🟢
1.4 Common authentication schemes				
ACTRIS: ORCiD authentication implemented	4th QTR 22	⚫	🟡	🟡
1.5 Service endpoint to ENVRI-hub				
ACTRIS: set up PythonAPI endpoint	3rd QTR 22	🔴	🟢	🟢
ACTRIS: provide service record	3rd QTR 21	🔴	🟢	🟢
1.6 GUI recommendations				
ACTRIS: new portal dev. kick-off	2nd QTR 21	🟡	🟢	🟢
ACTRIS: new portal test release	2nd QTR 22	⚫	🟢	🟢
ACTRIS: new portal public release	4th QTR 22	⚫	⚫	⚫
1.7 Document provenance				
ACTRIS: first test version	4th QTR 22		🟡	🟡
ACTRIS: final version	4th QTR 22		🟡	🟡
Task where implementation plan is needed				
2.1 Domain vocabulary / ontology	3rd QTR 22	🟡	🟢	🟢
2.2 Documentation of provenance	1st QTR 21	🟡	🟡	🟡
2.3 Recommendations for licenses	3rd QTR 22	⚫	🟢	🟢
2.4 Semantic search		⚫	⚫	⚫

ENVRI FAIR

Table 2: Summary of implementation of FAIRness within ACTRIS -In-Situ

Task and Milestones under implementation	Due month Implementation plan	Status June 2020	Status November 2022	Status February 2023
1.1 Use of PIDs throughout workflow				
ACTRIS: determine PID solution	3rd QTR 20	🟡	🟢	🟢
ACTRIS: implement primary DOIs	4th QTR 20	🟡	🟡	🟢
ACTRIS: PIDs pre-products implemented	2nd QTR 21	🟡	🟡	🟡
ACTRIS: ORCiD and org. PIDs implemented	4th QTR 21	⚫	🟡	🟡
1.2 Standard interfaces for (meta)data access				
ACTRIS: metadata repository, 1st version	4th QTR 20	🟡	🟢	🟢
ACTRIS: metadata M2M interface available	1st QTR 21	⚫	🟢	🟢
1.3 Data indexing in WIS and GEOSS				
ACTRIS: link to GISC in WIS implemented	3rd QTR 21	⚫	🟢	🟢
1.4 Common authentication schemes				
ACTRIS: ORCiD authentication implemented	4th QTR 21	⚫	⚫	⚫
Task where implementation plan is needed				
2.1 Domain vocabulary / ontology	1st QTR 21	🟡	🟢	🟢
2.2 Documentation of provenance	1st QTR 21	🟡	🟡	🟡
2.3 Recommendations for licenses	1st QTR 21	⚫	🟢	🟢
2.4 Semantic search	1st QTR 21	⚫	⚫	⚫
2.5 Graphical user interfaces	1st QTR 21	🟡	🟡	🟡

Table 3: Summary of implementation of FAIRness within ACTRIS -ARES

Task and Milestones under implementation	Due month Implementation plan	Status June 2020	Status November 2022	Status February 2023
1.1 Use of PIDs throughout workflow				
ACTRIS: determine PID solution	3rd QTR 20	🟡	🟢	🟢
ACTRIS: implement primary DOIs	4th QTR 20	🟡	🟡	🟢
ACTRIS: PIDs pre-products implemented	2nd QTR 21	🟡	🟡	🟢
ACTRIS: ORCiD and org. PIDs implemented	4th QTR 21	⚫	⚫	⚫
1.2 Standard interfaces for (meta)data access				
ACTRIS: metadata repository, 1st version	4th QTR 20	🟡	🟢	🟢
ACTRIS: metadata M2M interface available	1st QTR 21	🟡	🟢	🟢
1.3 Data indexing in WIS and GEOSS				
ACTRIS: link to GISC in WIS implemented	3rd QTR 21	⚫	🟡	🟢
1.4 Common authentication schemes				
ACTRIS: ORCiD authentication implemented	4th QTR 21	⚫	⚫	⚫
Task where implementation plan is needed				
2.1 Domain vocabulary / ontology	1st QTR 21	🟡	🟢	🟢
2.2 Documentation of provenance	1st QTR 21	🟡	🟡	🟡
2.3 Recommendations for licenses	1st QTR 21	⚫	🟢	🟢
2.4 Semantic search	1st QTR 21	⚫	⚫	⚫
2.5 Graphical user interfaces	1st QTR 21	🟡	🟡	🟢

Table 4: Summary of implementation of FAIRness within ACTRIS -CLU

Task and Milestones under implementation	Due month Implementation plan	Status June 2020	Status November 2022	Status February 2023
1.1 Use of PIDs throughout workflow				
ACTRIS: determine PID solution	3rd QTR 20	🟠	🟢	🟢
ACTRIS: implement primary DOIs	4th QTR 20	🟠	🟠	🟠
ACTRIS: PIDs pre-products implemented	2nd QTR 21	🟠	🟢	🟢
ACTRIS: ORCiD and org. PIDs implemented	4th QTR 21	⚫	🟢	🟢
1.2 Standard interfaces for (meta)data access				
ACTRIS: metadata repository, 1st version	4th QTR 20	🟠	🟢	🟢
ACTRIS: metadata M2M interface available	1st QTR 21	🟠	🟢	🟢
1.3 Data indexing in WIS and GEOSS				
ACTRIS: link to GISC in WIS implemented	3rd QTR 21	⚫	🟢	🟢
1.4 Common authentication schemes				
ACTRIS: ORCiD authentication implemented	4th QTR 21	⚫	⚫	⚫
Task where implementation plan is needed				
2.1 Domain vocabulary / ontology	1st QTR 21	🟠	🟠	🟠
2.2 Documentation of provenance	1st QTR 21	🟠	🟢	🟢
2.3 Recommendations for licenses	1st QTR 21	⚫	🟢	🟢
2.4 Semantic search	1st QTR 21	⚫	⚫	⚫
2.5 Graphical user interfaces	1st QTR 21	🟠	🟠	🟢

Table 5: Summary of implementation of FAIRness within ACTRIS -GRES

Task and Milestones under implementation	Due month Implementation plan	Status June 2020	Status November 2022	Status February 2023
1.1 Use of PIDs throughout workflow				
ACTRIS: determine PID solution	3rd QTR 20	🟡	🟢	🟢
ACTRIS: implement primary DOIs	4th QTR 20	🟡	🟡	🟢
ACTRIS: PIDs pre-products implemented	2nd QTR 21	⚫	🟡	🟡
ACTRIS: ORCiD and org. PIDs implemented	4th QTR 21	⚫	🟢	🟢
1.2 Standard interfaces for (meta)data access				
ACTRIS: metadata repository, 1st version	4th QTR 20	🟡	🟢	🟢
ACTRIS: metadata M2M interface available	1st QTR 21	🟡	🟢	🟡
1.3 Data indexing in WIS and GEOSS				
ACTRIS: link to GISC in WIS implemented	3rd QTR 21	⚫	⚫	⚫
1.4 Common authentication schemes				
ACTRIS: ORCiD authentication implemented	4th QTR 21	⚫	⚫	🟢
Task where implementation plan is needed				
2.1 Domain vocabulary / ontology	1st QTR 21	🟡	🟡	🟡
2.2 Documentation of provenance	1st QTR 21	⚫	🟡	🟡
2.3 Recommendations for licenses	1st QTR 21	⚫	🟢	🟢
2.4 Semantic search	1st QTR 21	⚫	⚫	⚫
2.5 Graphical user interfaces	1st QTR 21	⚫	🟡	🟡

Table 6: Summary of implementation of FAIRness within ACTRIS -ASC

Task and Milestones under implementation	Due month Implementation plan	Status June 2020	Status November 2022	Status February 2023
1.1 Use of PIDs throughout workflow				
ACTRIS: determine PID solution	3rd QTR 20	🟡	🟢	🟢
ACTRIS: implement primary DOIs	4th QTR 20	🟡	🟢	🟢
ACTRIS: PIDs pre-products implemented	2nd QTR 21	⚫	⚫	⚫
ACTRIS: ORCiD and org. PIDs implemented	4th QTR 21	⚫	⚫	🟡
1.2 Standard interfaces for (meta)data access				
ACTRIS: metadata repository, 1st version	4th QTR 20	🟡	🟡	🟢
ACTRIS: metadata M2M interface available	1st QTR 21	🟡	🟡	🟡
1.3 Data indexing in WIS and GEOSS				
ACTRIS: link to GISC in WIS implemented	*	⚫	⚫	⚫
1.4 Common authentication schemes				
ACTRIS: ORCiD authentication implemented	4th QTR 21	⚫	⚫	🟢
Task where implementation plan is needed				
2.1 Domain vocabulary / ontology	1st QTR 21	🟡	🟡	🟡
2.2 Documentation of provenance	1st QTR 21	⚫	⚫	⚫
2.3 Recommendations for licenses	1st QTR 21	⚫	🟡	🟢
2.4 Semantic search	1st QTR 21	⚫	⚫	⚫
2.5 Graphical user interfaces	1st QTR 21	⚫	⚫	🟢

Note – topic 1.3 it not relevant for the ASC data centre units.

3.2 FAIRness assessment based on selected FAIR Implementation Profiles (FIP)

For the ACTRIS DC we have also used the selected FAIR Implementation Profiles (FIPs) from WP5 and made an internal FAIRness assessment for ACTRIS DC and the units.

A commonly used measure of FAIRness is the FAIR convergence matrix. The FAIR Convergence Matrix is a platform that systematically guides any self-identified community (in this case the ENVRI community) in the decision process leading to optimal FAIR implementations and practices. The resulting collection of FAIR implementation choices composes the FAIR Implementation Profile (FIP) for that community.

These FIP profiles and assessments do not necessary cover the essential needs and priorities for ACTRIS as it is set up for the whole environmental domain. Accordingly, the progress related to the ACTRIS implementation plan in section 3.1 is the core for ACTRIS DC. Still, convergence and progress among all ACTRIS DC units on these selected FIPs are also interesting and valuable to assess. The outcome of the WP5 FIP assessment for ACTRIS DC is included here. Unfortunately, only results for 2019-2021 are available when this report is due, so it is not the final outcome. Still the results indicate very strong development and improvement of FAIRness across the ACTRIS DC. The last year implementation within the DC, and the FIP assessment for all years 2019-2022 ready April 2023 will just further confirm this.

One important concept for this assessment is the "the single FER (fair enabling resources) of a given subprinciple". Accordingly, for each of the principles Findable - Assessable - Interoperable Reusable, there is defined a list of predefined FERs across the project.

The FER for each FAIR subprinciple, and the development of the most frequent FER within the ACTRIS DC over the period is included in the appendix I, together with the list of Implementation profile per repository in appendix II. These are underlaying information used to develop the FAIR convergence matrices.

The actual convergence matrices are the parallel display of each ATRIS DC unit's FAIR implementation profile at subprinciple resolution, in Appendix II. The overview of the FAIRness development in accordance with the ENVRI-FAIR convergence matrix is included in figure 1. The values given are average implementation status of the list of predefined FERs used to monitor the implementation of FAIRness. The figures are also called "heat maps" and given in Figure 1.

The Figure clearly shows that there was large development from the start, and in 2021 many aspects were implemented and large improvement since 2019 and 2020. DVAS has the strongest improvement, but all units have improved their FAIRness considerably, and also the convergence internally is strong, documenting maturity and FAIRness across the full ACTRIS Data Centre.

2019

ave. Status repo	ACTRIS ARES	ACTRIS ASC	ACTRIS CLU	ACTRIS DVAS	ACTRIS Gres	ACTRIS inSitu
ACTRIS ARES		2,0	1,5	0,5	2,0	0,4
ACTRIS ASC	1,7		1,6	0,8	2,0	1,0
ACTRIS CLU	1,3	1,6		0,3	1,4	1,0
ACTRIS DVAS	0,5	0,8	0,4		0,8	0,4
ACTRIS Gres	1,7	1,9	1,4	0,8		1,0
ACTRIS inSitu	0,4	1,0	0,9	0,5	1,0	

2020

ave. status repo	ACTRIS ARES	ACTRIS ASC	ACTRIS CLU	ACTRIS DVAS	ACTRIS Gres	ACTRIS inSitu
ACTRIS ARES		2,0	1,6	0,5	2,0	1,7
ACTRIS ASC	1,7		1,7	0,8	2,1	1,6
ACTRIS CLU	1,4	1,6		0,4	1,5	1,7
ACTRIS DVAS	0,5	0,8	0,7		0,8	0,8
ACTRIS Gres	1,7	2,1	1,6	0,8		1,6
ACTRIS inSitu	1,7	1,8	1,8	0,8	1,8	

2021

ave. status repo	ACTRIS ARES	ACTRIS ASC	ACTRIS CLU	ACTRIS DVAS	ACTRIS Gres	ACTRIS inSitu
ACTRIS ARES		2,5	2,9	2,4	2,5	2,4
ACTRIS ASC	2,8		2,4	2,5	2,5	2,4
ACTRIS CLU	2,9	2,6		2,4	2,5	2,2
ACTRIS DVAS	3,0	2,6	2,4		2,6	2,8
ACTRIS Gres	2,8	2,5	2,4	2,5		2,4
ACTRIS inSitu	2,8	2,5	2,2	2,7	2,5	

Figure 2: The degree of ACTRIS DC repositories association, by count and status of mutually shared FERs. Values: average implementation status of the single FER (fair enabling resources) of a given subprinciple) by end of February 2023. The 2022 will be added in a later version of the report – May 2023.

4 Remaining tasks

Now at the end of the ENVRI-FAIR project, the ACTRIS DC units have the most essential data FAIRness functionalities in place, even if there is not full convergence (see section 3.2). The most essential data FAIRness functionalities comprise:

- identification of data products and pre-products
- machine interfaces to data and metadata repositories, in place.

Remaining gaps in these functionalities as listed in the tables above should be addressed as soon as possible.

5 Main achievements and improvement of FAIRness for ACTRIS

In the course of and due to the ENVRI-FAIR project, the ACTRIS DC has increased its data FAIRness in all parts of the concept:

- **Findability:**
  Most ACTRIS data are already findable and accessible through a common web-portal for human interaction. The next generation portal has been specified during the project and is currently under implementation. A common concept for data identification has been specified which is based on a unified granularity, allowing for consistent qualification of data use. The next generation data portal will be based on standardised, FAIR interoperability functions.

- **Accessibility**:
  All ACTRIS DC units have implemented standardised machine interfaces for metadata and data, or are in the course of finishing this implementation. These interfaces are the basis of the common ACTRIS metadata interface giving machine-access to ACTRIS data for everyone interested, as well as the basis for the next generation data portal for human interaction. The implementation has made ACTRIS data and metadata visible and accessible in e.g. the ENVRI-hub, Data indexing in WIS and GEOSS portal, and visible also in the EOSC market place.

- **Interoperability:**
  In an effort involving the whole research infrastructure, ACTRIS has established a common, FAIR compliant vocabulary for describing its data products, along with routines for maintaining the vocabulary. For describing variable names, the vocabulary complies with the RDA recommended I-ADOPT ontology, making it suitable for cross-domain integration.

- **Reusability**:
  ACTRIS has agreed on a concept of licences for both data products, pre-products, and software.

All of the above services, along with implementation plans for future ones, have been documented in a public data management plan and the FAIRness implementation plan is still an important document for further advancement of ACTRIS.

5.1 What can we do now which we could not before advancing of the FAIRness?

This section includes a list of functions, topics and aspects we can do now, compared to January 2019. The work enables user services such as:

- Direct citation of data (e.g. minting DOI on all quality assured data, with harmonised granularity across the data centre)
- Automatic data access into user applications.
- Access to ACTRIS data resources in VREs such as Jupyter notebooks.
- Reliable re-use of data due to license.

Some more details on new achievements are listed here:
- Machine access to the full ACTRIS data repository, in addition to metadata, with granularity corresponding to identification service.
- Improvement of the quality of our (meta)data in particular in terms of traceability and provenance across the whole DC even if we still need to complete the implementation (provenance, instrument PIDs are in progress)
- Identify datasets in the repository, both as full time series and as individual data deliveries, connected by documented provenance.
- Controlled vocabulary extending beyond our RI that has enabled better integration with other RIs and sub-domains, and internally within ACTRIS, not only for the data centre but crucial also for the interactions with the topic centres. This includes definition and use of FAIR and I-ADOPT compliant vocabulary.
- Detailed DMP for infrastructure, including all FAIRness aspects down to the level of data production workflows.
- Improve satellite data extraction and colocation through machine-to-machine interoperable services
- Established license for metadata, data and software

5.2 What would we like to do / achieve within the next 5 years?

- Implement new data portal for humans that makes use of all FAIRness achievements so far (vocabulary, easier machine data access, data streaming)
- Improving and enhancing the link between ACTRIS and EOSC, GEO, Copernicus.
- Integrate more ACTRIS resources (services and datasets) in the EOSC marketplace
- Utilize the recent cross RI FAIRness development and continue to develop cross RI services
- Cross-RI searching capability on RI portals (for example possibility on ACTRIS portal to query ICOS data for variables of interest in the same period /close by stations...)
- Implement service for identification of data collections.
- Fully implement documentation of data provenance, and make the information accessible and usable for the data user.
  - improvements on data provenance and traceability by providing for all new datasets (experiments) as a mandatory fields: a control experiment, the auxiliary mechanism (see DMP), the ORCID of the data provider, a flagging system providing information on the quality level of the data, assignment of PID to instruments
- Further improvements on data access: provide L2 data NetCDF format (in addition to the edf format used actually)
- CoreTrustSeal certification of data centre, including functional test of all FAIRness features.
- Make metadata available in RDF compatible format.
- Implement EOSC-compatible single-sign-on mechanism for services requiring authentication.
- Implement quantification of data use feature based on OpenAire API.
- Empowering search synergistic capability on ACTRIS data portal
- Improve the colocation tool and support more satellite data, for atmospheric science but also extended to solid earth, marine and surface observation
- Work more on machine actionability, provide user friendly API and develop on-demand processing services (through OGC WPS for instance)
  => dashboards or VREs (to cover either generic or specific needs), and maybe allow some users to build their own

6 Appendix I - FER frequencies

These are the counts of FER applications (per FAIR subprinciple, i.e., if a given FER is used by one repository for two different subprinciples, it's counted twice). As can be seen, there is difficult to understand all FERs (e.g., EBAS, CLU, SIOS metadata portal) and this will need more work within WP5 before the finale FAIR assessment of the atmospheric sub-domain.

FER count		reporting year			
FAIR principle	**FAIRenabling resource**	**2019**	**2020**	**2021**	total
⊟F	WMO Search	4	4	12	**20**
	DataCite	6	7	11	**24**
	DOI	4	5	10	**19**
	Handle System	1	1	6	**8**
	WMO core profile	2	2	3	**7**
	UUID	2	2	3	**7**
	DataCite Metadata Scheme	2	2	3	**7**
	r3data			2	**2**
	ACTRIS Data Portal	2	2	2	**6**
	SIOS Metadata Search			2	**2**
	GEOSS Portal		2	2	**4**
	ISO 19115	2	2	2	**6**
	ORCID			2	**2**
	CLU	2	2	2	**6**
	NetCDF CF1.7	2	2	2	**6**
	EBAS	1	1	1	**3**
	no choice	14	12	1	**27**
	ePIC		1	1	**2**
F result		**44**	**47**	**67**	**158**
⊟A	HTTPS	10	11	11	**32**
	OPENDATA	7	7	7	**21**
	OPeNDAP	4	5	6	**15**
	REST	5	5	5	**15**
	ACTRIS DMP		1	5	**6**
	ORCID	1	1	3	**5**
	no choice	11	9	3	**23**
	OAuth	1	1	3	**5**
	SAML1.1			2	**2**
	OAI-PMH	2	2	2	**6**
	CSW	1	1	1	**3**
	FTP	1	1	1	**3**
	eduGAIN	1	1	1	**3**
A result		**44**	**45**	**50**	**139**
⊟I	NetCDF	4	5	6	**15**
	NetCDF CF1.7	5	6	6	**17**
	ACTRIS Vocabulary	2	2	5	**9**
	no choice	13	11	4	**28**
	CF SN	2	2	4	**8**
	JSON	2	2	3	**7**
	JSON Schema	2	2	2	**6**
	GCMD	2	2	2	**6**
	GEOMS	2	2	2	**6**
	ISO 19115	2	2	2	**6**
	AERIS vocabulary	1	1	1	**3**
	WMO core profile	1	1	1	**3**
	WIGOS			1	**1**
	XML Schema	1	1	1	**3**
	DataCite Metadata Scheme			1	**1**
	EDF	1	1	1	**3**
	JCAMP-DX	1	1	1	**3**
I result		**41**	**41**	**43**	**125**
⊟R	PROV-O			8	**8**
	no choice	21	21	6	**48**
	CC-BY-4.0	1	1	6	**8**
	NetCDF CF1.7	2	2	2	**6**
	CC-BY-ND-4.0			1	**1**
	GPL-3.0-or-later			1	**1**
R result		**24**	**24**	**24**	**72**
total		153	157	184	**494**

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7 Appendix II: ACTRIS Data Centre convergence matrix

These are the actual convergence matrices, i.e.: the parallel display of each RI's FAIR implementation profile at subprinciple resolution) Values: average implementation status of the single FER (fair enabling resources) of a given subprinciple.

Implementation profile per repository

select reporting ye **2019**

average implementation status   repository

FAIR principle	FAIR subprinciple	ACTRIS ARES	ACTRIS ASC	ACTRIS CLU	ACTRIS DVAS	ACTRIS Gres	ACTRIS inSitu	total
A	A1.1-D	3,0	2,5	0,0	3,0	2,3	3,0	2,5
	A1.1-MD	3,0	3,0	2,0	3,0	3,0	3,0	2,8
	A1.2-D	0,0	3,0	3,0	0,0	3,0	3,0	2,3
	A1.2-MD	0,0	3,0	3,0	0,0	3,0	3,0	2,0
	A2	0,0	0,0	0,0	0,0	0,0	0,0	0,0
A result		**2,0**	**2,4**	**1,7**	**1,2**	**2,6**	**2,4**	**2,1**
F	F1-D	0,0	3,0	0,0	0,0	2,0	0,0	0,8
	F1-MD	0,0	3,0	0,0	0,0	2,5	0,0	1,4
	F2	3,0	2,5	3,0	2,0	2,5	3,0	2,6
	F3	0,0	2,0	3,0	0,0	2,0	0,0	1,2
	F4-D	0,0	2,0	3,0	3,0	2,0	3,0	2,4
	F4-MD	0,0	2,0	0,0	3,0	2,0	3,0	1,9
F result		**0,5**	**2,5**	**1,7**	**1,3**	**2,3**	**2,0**	**1,8**
I	I1-D	3,0	2,0	3,0	0,0	2,0	0,0	1,7
	I1-MD	3,0	3,0	3,0	0,0	3,0	3,0	2,5
	I2-D	3,0	0,0	1,0	0,0	0,0	0,0	0,7
	I2-MD	0,0	3,0	3,0	1,0	3,0	2,0	2,1
	I3-D	3,0	2,7	3,0	0,0	2,7	0,0	2,2
	I3-MD	0,0	3,0	0,0	0,0	3,0	3,0	1,5
I result		**2,0**	**2,4**	**2,2**	**0,2**	**2,4**	**1,3**	**1,8**
R	R1.1-D	0,0	0,0	3,0	0,0	0,0	0,0	0,5
	R1.1-MD	0,0	0,0	0,0	0,0	0,0	0,0	0,0

select reporting ye **2020**

average implementation status   repository

FAIR principle	FAIR subprinciple	ACTRIS ARES	ACTRIS ASC	ACTRIS CLU	ACTRIS DVAS	ACTRIS Gres	ACTRIS inSitu	total
A	A1.1-D	3,0	2,5	2,0	3,0	2,3	3,0	2,7
	A1.1-MD	3,0	3,0	2,0	3,0	3,0	3,0	2,8
	A1.2-D	0,0	3,0	3,0	0,0	3,0	3,0	2,3
	A1.2-MD	0,0	3,0	3,0	0,0	3,0	3,0	2,0
	A2	0,0	0,0	0,0	0,0	0,0	3,0	0,5
A result		**2,0**	**2,4**	**2,0**	**1,2**	**2,6**	**3,0**	**2,3**
F	F1-D	0,0	3,0	0,0	0,0	2,5	2,0	1,4
	F1-MD	0,0	3,0	0,0	0,0	3,0	0,0	1,5
	F2	3,0	3,0	3,0	3,0	3,0	3,0	3,0
	F3	0,0	3,0	3,0	0,0	3,0	3,0	2,0
	F4-D	0,0	3,0	3,0	3,0	3,0	3,0	2,7
	F4-MD	0,0	3,0	0,0	3,0	3,0	3,0	2,3
F result		**0,5**	**3,0**	**1,7**	**1,5**	**2,9**	**2,6**	**2,2**
I	I1-D	3,0	2,0	3,0	0,0	2,0	3,0	2,2
	I1-MD	3,0	3,0	3,0	0,0	3,0	3,0	2,5
	I2-D	3,0	0,0	1,0	0,0	0,0	0,0	0,7
	I2-MD	0,0	3,0	3,0	1,0	3,0	3,0	2,3
	I3-D	3,0	2,7	3,0	0,0	2,7	3,0	2,5
	I3-MD	0,0	3,0	0,0	0,0	3,0	3,0	1,5
I result		**2,0**	**2,4**	**2,2**	**0,2**	**2,4**	**2,5**	**2,0**
R	R1.1-D	0,0	0,0	3,0	0,0	0,0	0,0	0,5
	R1.1-MD	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	R1.2-D	3,0	0,0	0,0	0,0	0,0	0,0	0,5
	R1.2-MD	3,0	0,0	0,0	0,0	0,0	0,0	0,5
R result		**1,5**	**0,0**	**0,8**	**0,0**	**0,0**	**0,0**	**0,4**
total		1,6	2,3	1,7	0,8	2,3	2,3	1,9

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average implementation status   repository ▾

FAIR principle ▾	FAIR subprinciple ▾	ACTRIS ARES	ACTRIS ASC	ACTRIS CLU	ACTRIS DVAS	ACTRIS Gres	ACTRIS inSitu	total
⊟A	A1.1-D	3,0	2,5	3,0	3,0	2,3	3,0	2,8
	A1.1-MD	3,0	3,0	3,0	3,0	3,0	3,0	3,0
	A1.2-D	2,3	3,0	3,0	0,0	3,0	3,0	2,5
	A1.2-MD	2,3	3,0	3,0	0,0	3,0	3,0	2,4
	A2	0,0	3,0	3,0	3,0	3,0	3,0	2,5
A result		**2,5**	**2,9**	**3,0**	**2,0**	**2,8**	**3,0**	**2,7**
⊟F	F1-D	2,5	3,0	2,5	3,0	2,5	2,0	2,6
	F1-MD	2,7	3,0	3,0	3,0	3,0	2,0	2,8
	F2	2,3	3,0	3,0	3,0	3,0	3,0	2,8
	F3	2,5	3,0	3,0	3,0	3,0	3,0	2,9
	F4-D	2,0	3,0	3,0	3,0	3,0	3,0	2,8
	F4-MD	2,0	3,0	0,0	3,0	3,0	3,0	2,5
F result		**2,3**	**3,0**	**2,6**	**3,0**	**2,9**	**2,8**	**2,7**
⊟I	I1-D	3,0	2,0	3,0	3,0	2,0	3,0	2,7
	I1-MD	3,0	3,0	3,0	3,0	3,0	3,0	3,0
	I2-D	3,0	2,0	1,0	0,0	2,0	1,0	1,5
	I2-MD	2,0	2,3	3,0	1,0	2,0	3,0	2,2
	I3-D	3,0	2,7	3,0	0,0	2,7	3,0	2,5
	I3-MD	2,0	3,0	0,0	0,0	3,0	3,0	1,8
I result		**2,7**	**2,5**	**2,2**	**1,2**	**2,4**	**2,7**	**2,3**
⊟R	R1.1-D	2,0	2,0	3,0	2,0	2,0	2,0	2,2
	R1.1-MD	2,0	0,0	0,0	2,0	0,0	0,0	0,7
	R1.2-D	3,0	2,0	0,0	2,0	2,0	0,0	1,5
	R1.2-MD	3,0	2,0	2,0	2,0	2,0	2,0	2,2
R result		**2,5**	**1,5**	**1,3**	**2,0**	**1,5**	**1,0**	**1,6**
total		2,4	2,6	2,4	2,2	2,6	2,6	2,5

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