Deliverable 8.1: Report on planned joint activities and synergies with other RIs and e-RIs

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Background and purpose of this document

The aim of this report is to describe the role of ACTRIS in the wide ESFRI scenario to provide examples of exploiting synergies with top research/science players through the rich network of relationships and collaborations established to ensure more extensive impact and effectiveness for ACTRIS action.
The variety of processes and parameters of ACTRIS interest is so wide to make ACTRIS potentially linked to almost all the RIs in the environmental sector and, as underlined in the ESFRI Roadmap, can enjoy interconnections in all scientific domains, with cross-cutting aspects touching the whole European RIs ecosystem

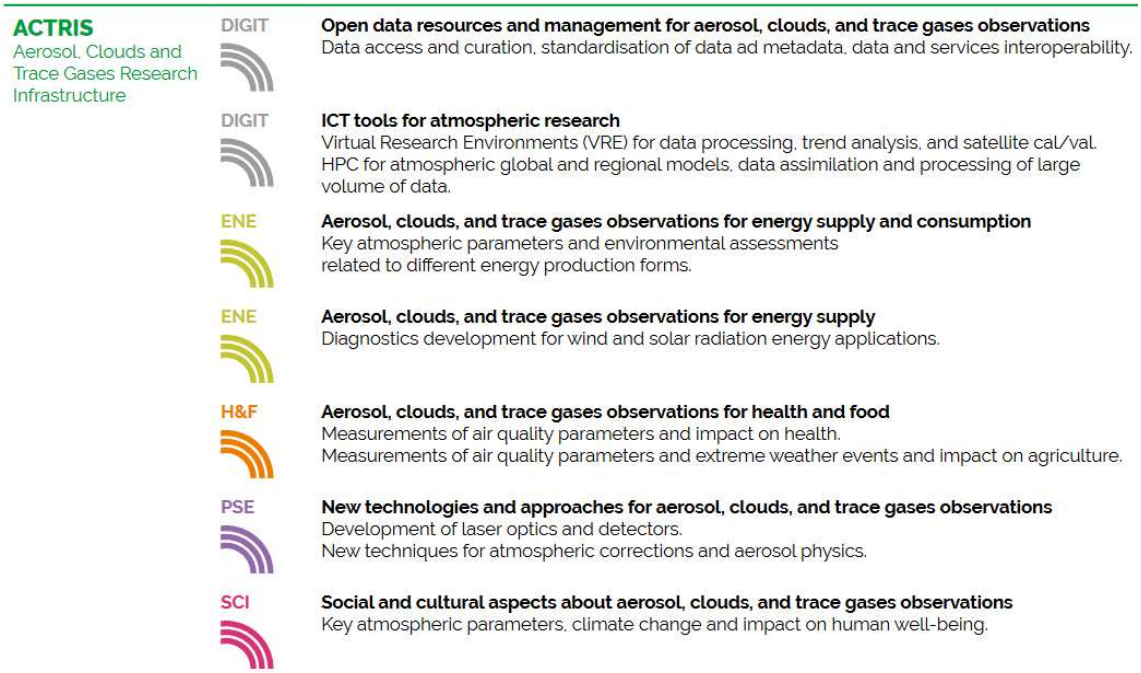

Figure 1 *Interconnections between ACTRIS and scientific domains.* Excerpt from the 2021 ESFRI Roadmap, Part 2, Landscape Analysis.

At the same time, this variety makes ACTRIS an example of complex RI in which the data management systems and solutions should handle and manage specific needs for each component. ACTRIS can be therefore regarded as an example of platform for testing developments for interoperable systems and addressing vocabularies and semantic issues.

The current document aims to provide an overview of the current ACTRIS efforts made in synergy with the other RIs and finally to define the actions which could further foster the stronger link with them in order to strengthening the impact of the whole RI system on the European (and not only) society as a whole.

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Projects and activities with RIs

ACTRIS is currently active in designing and developing, together with other RIs in the atmospheric field, solutions for addressing the current scientific and societal hot topics like the air quality and greenhouse gases monitoring, but even for guarantying the plethora of potential users of these RIs with an appropriate and easy access to all RI services.

These actions are carried on through some projects described below. In particular details are provided about the synergistic specific actions put in place for each one of the projects.

ATMO -ACCESS

ATMO-ACCESS project (Solutions for Sustainable Access to Atmospheric Research Facilities, 2021-2025, coordinated by CNRS) is a successful fruit of the sound cooperation established between ACTRIS, ICOS and IAGOS to address the common need for developing appropriate access strategies and concepts that will allow the viability of long-term access provision both for the access providers and for the users. The project is funded by the EU in the frame of the H2020 INFRAIA-03-2020 Call: Pilot for a new model of Integrating Activities.
Based on the principles of open access, and considering the peculiarities of the atmospheric RIs, the project aims to propose suitable governance, management and funding mechanisms that could lead to the sustainable provision of access to distributed atmospheric research infrastructures.

All work in ATMO-ACCESS integrates experiences from past access programs, thus, synergistically streamlining the work and avoiding duplication of efforts. The project provides the ideal framework for designing, testing and refine some joint activities to facilitate and integrate the access procedures, to improve the services the infrastructures provide and offer innovative cross-RI services.

Figure 2 below illustrates the main logic behind the project activities and pillars.

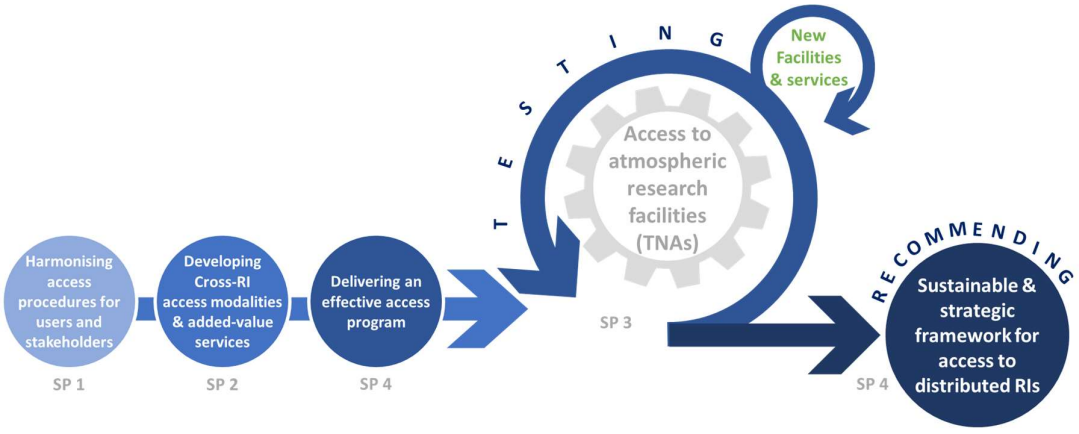

Figure 2. *ATMO-ACCESS Strategic pillars (SP) and logic*

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Recommendations on procedures and activities will build also on the experience, feedback and areas of improvements coming from Transnational Access (TNA) realized in the project to test the harmonized access procedures and cross-RI access modalities and services developed.
ATMO-ACCESS will support the trans-national, physical, and remote access to 43 operational European atmospheric research facilities, many of them are co-located with other RIs and offer unique possibility for synergies and cross-disciplinary research, as shown in **Table 1** below.

#	SHORT NAME	NAME	TYPE	Involved RIs
1	AGORA	Andalusian Global ObseRvatory of the Atmosphere	Obs.	ACTRIS
2	ATMOS	AThens MOnitoring Supersite	Obs.	ACTRIS, ICOS
3	BCN	Barcelona Atmospheric Research network	Obs.	ACTRIS
4	CAO	Cyprus Atmospheric Observatory	Obs.	ACTRIS
5	CESAR	Cabauw Experimental Site for Atmospheric Research	Obs.	ACTRIS, ICOS
6	CIAO	CNR-IMAA Atmospheric Observatory	Obs. / Central Lab	ACTRIS
7	CMN-PV	Monte Cimone - Po Valley	Obs.	ACTRIS, ICOS
8	CO-PDD	Cézeaux-Aulnat Opme Puy de Dôme	Obs.	ACTRIS, ICOS
9	EVASO	EVora Atmospheric Science Observatory	Obs.	ACTRIS
10	FKL	Finokalia station	Obs.	ACTRIS, ICOS
11	FMI PAL-SOD	Pallas-Sodankylä Atmosphere-Ecosystem Supersite	Obs.	ACTRIS, ICOS, eLTER
12	HTM	Hyltemossa Research Station	Obs.	ACTRIS, ICOS
13	ISAF - (IZO)	Izaña Subtropical Access Facility	Obs. / Central Lab	ACTRIS
14	JFJ	High Altitude Research Station Jungfraujoch	Obs.	ACTRIS
15	Melpitz	TROPOS Research Station Melpitz	Obs.	ACTRIS
16	NAOK	National Atmospheric Observatory Košetice	Obs.	ACTRIS
17	OPAR	Observatoire de Physique de l'Atmosphère à La Réunion	Obs.	ACTRIS
18	RADO	Romanian Atmospheric 3D research Observatory	Obs., Central Lab.	ACTRIS
19	SBO	Sonnblick Observatory	Obs.	ACTRIS, eLTER

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20	SIRTA	Site Instrumental de Recherche par Télédétection Atmosphérique	Obs.	ACTRIS, ICOS, InGOS
		SIRTA CCRES- ACMCC	Central Lab	ACTRIS
21	SMEAR II	Station for Measuring Ecosystem - Atmosphere Relations II	Obs.	ICOS, ACTRIS, eLTER
22	WOS	Warsaw Observatory Station	Obs.	ACTRIS
23	ACD-C / LACIS-T	Aerosol Chamber of the Atmospheric Chemistry Department	Sim. Chamber	ACTRIS
		Turbulent Leipzig Aerosol Cloud Interaction Simulator		
24	AIDA	Aerosol Interaction and Dynamics in the Atmosphere	Sim. Chamber / Central Lab	ACTRIS
25	AURA	Aarhus University Research on Aerosols chamber	Sim. Chamber	ACTRIS
26	CESAM	Experimental Multiphasic Atmospheric Simulation Chamber	Sim. Chamber	ACTRIS
27	ChAMBRe	Chamber for Atmospheric Modelling and Bio-Aerosol Research	Sim. Chamber	ACTRIS
28	ESC-Q-UAIC	Environmental Simulation Chamber from the “Alexandru Ioan Cuza” University of Iasi	Sim. Chamber	ACTRIS
29	EUPHORE	EUropean PHOtoREactor	Sim. Chamber	ACTRIS
30	HELIOS	Outdoor Atmospheric Simulation Chamber of Orléans	Sim. Chamber	ACTRIS
31	IASC	Irish Atmospheric Simulation Chamber	Sim. Chamber	ACTRIS
32	KASCs	Kuopio atmospheric simulation chambers	Sim. Chamber	ACTRIS
33	MAC	Manchester Aerosol Chamber	Sim. Chamber	ACTRIS
34	PACS-C2	PSI Atmospheric Chemistry Simulation Chambers	Sim. Chamber	ACTRIS
35	QUAREC	Quartz Reactor	Sim. Chamber	ACTRIS
36	SAPHIR	Simulation of Atmospheric PHotochemistry In a large Reaction Chamber	Sim. Chamber	ACTRIS
37	FCoMLab	Finland Combined Mobile Laboratory	Mobile	ICOS
38	FORTH-MSC	FORTH Mobile Atmospheric Simulation Chamber	Mobile	ACTRIS
39	LACROS	Leipzig Aerosol and Cloud Remote Observations System	Mobile	ACTRIS
40	USRL	Unmanned Systems Research Laboratory	Mobile	ACTRIS
41	CiGAS-CH	Centre for Reactive Trace Gases In Situ Measurements	Central Lab	ACTRIS

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42	ICOS-ATC	Integrated Carbon Observation System Atmospheric Thematic Center	Central Lab	ICOS
43	WCCAP	World Calibration Center for Aerosol Physics	Central Lab	ACTRIS

Table 1 *List of RIs' Facilities providing TNA in ATMO-ACCESS*

While work on virtual access and new integrated digital services will start in 2023, the initial results and outcomes achieved so far in terms of standardization of physical and remote access procedures among the involved RIs include:

- standard service descriptions
- common access process centrally managed for all the ATMO-ACCESS facilities
- common, simplified application forms, tailored for the different categories of services provided
- common TNA general evaluation guidelines for the review and selection of access to ATMO-ACCESS facilities

ATMO-ACCESS progresses are proving to benefit the user's communities and lead to an increased and better use of the RIs' resources, thus encouraging further collaboration in forthcoming proposals.

RI-URBANS

RI-URBANS (Research Infrastructures Services Reinforcing Air Quality Monitoring Capacities in European Urban & Industrial AreaS, 2021-2025, coordinated by Agencia estatal Consejo Superior de Investigaciones Cientificas) project is the demonstration of the relevant position of ACTRIS in the frame of the Air Quality monitoring at European level. Based on the collaboration between Air Quality management networks (AQMN), air quality experts, ACTRIS and IAGOS RIs, RI-URBANS will apply existing methodologies to the urban areas, developing new suited service tools, enhancing the synergies with AQMNs through knowledge transfer and offering a sustainable framework for providing dedicated and focused urban service tools. The project is funded by the EU in the frame of the H2020 LC-GD-2020 Call: Building a low-carbon, climate resilient future: Research and innovation in support of the European Green Deal.

RI-URBANS responds to the need to substantially reduce air pollution across the EU and reduce the associated health impacts. RI-URBANS is built on the expertise and knowledge developed within IAGOS and ACTRIS research infrastructure and from their existing collaborations with air quality monitoring systems for demonstrating how service tools from atmospheric Research Infrastructures can be adapted and enhanced to better address the challenges and societal needs in European cities and industrial, harbor, airport and road traffic hotspots concerning air quality (AQ), as areas with significant levels of air pollution and associated health effects.

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The overall strategy in RI-URBANS recognizes that scientific and technological improvements are still needed to efficiently address the provision of sustained long-term, harmonized, high quality data that document the complex inter-linkages between ambient levels of air pollutants, their emission sources, and their impact on human health. Developing, testing and proposing cost-effective tools that complement and support the current activities of AQMNs is, therefore, essential in RI-URBANS. RI-URBANS recognizes the value of co-designing a strategy that may lead to evolving AQ and health policies in Europe in a harmonized way, involving all actors, including citizens.

The RI-URBANS concept and organization is visualized in Figure 3. The activities are organized around 5 strategic pillars (Table2) going from gaps identification till sustainability actions for developed service tools. The project builds on existing initiatives for advanced research-driven observations of aerosol properties currently carried out in European cities to identify, develop and test the innovative service tools (reported in Table 3) that will serve a more effective AQ monitoring supporting AQ management in a 2030 horizon timeline.

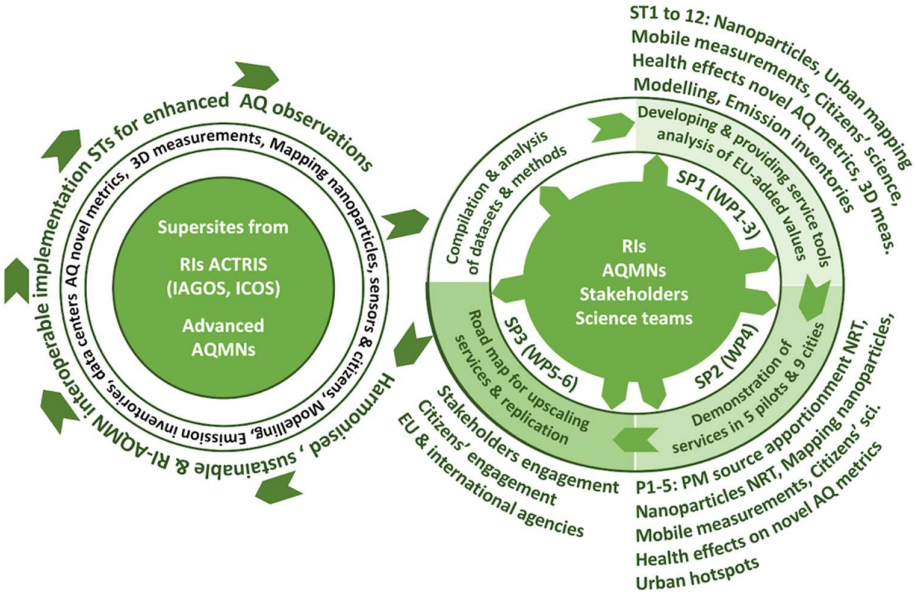

Figure 3. *RI-URBANS concept*

	Strategic Pillars
SP1	Identifying gaps and providing STs for advanced AQ observation and forecasting considering AQ policy and health impact requirements.

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SP2	Demonstrating the feasibility and added value of RI-URBANS STs through a series of pilot implementation projects in different European cities
SP3	Providing guidance for implementing RI-URBANS STs at a wider scale
SP4	Supporting project development, implementation, communication, dissemination and exploitation

Table 2 *Strategic pillars of the RI-URBANS project.*

The implementation of 5 pilots (Table 4) involving 9 cities is used to demonstrate the ability to integrate complementary measurement systems and methods, as well as data quality control, managing and communication using FAIR (Findable, Accessible, Interoperable, Re-usable) principles.

Delivering strategic guidance in RI-URBANS is based on close collaboration at all levels in the project with national, regional, and local administrations, and policy-related bodies such as EEA, UNECE and WHO.

	Service tools
ST1	Measurement of ambient concentrations of nanoParticle Number Size Distributions (PNSD)
ST2	Online and offline PM speciation
ST3	Measurements of ambient Black Carbon (BC)
ST4	Measurements of ambient concentrations of Volatile Organic Compounds (VOCs)
ST5	Measurements of ambient concentrations of urban ammonia (NH3)
ST6	Advanced source apportionment tools
ST7	Measuring vertical and horizontal variability (3D measurements) of specific pollutants and key meteorological parameters
ST8	Mapping urban outdoor concentrations of nanoparticles and other pollutants by using mobile measurements, urban scale modelling and citizen's science (smart sensors)
ST9	Evaluating the health effects of the novel AQ metrics and source contributions

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ST10	Engaging citizens in urban AQ observatories
ST11	Improved regional scale modelling tools (1 x 1 km2 in the region of the city and with some zooms over cities and 6 x 6 km2 in the European domain)
ST12	Improve urban emission inventories

Table 3 *Service tools of RI-URBANS.*

RI-URBANS will implement 5 pilot studies in 9 selected European cities (Athens, Barcelona, Birmingham, Bucharest, Helsinki, Milan-Bologna, Rotterdam-Amsterdam and Zurich) for testing and demonstrating services of Table3. These selected European cities represent different AQ environments They combine the existence or the ability to perform advanced long-term AQ observations and commitment of the local and/or regional AQMNs to benefit from the corresponding pilot actions.

	Pilot study	Cities
P1	Innovative near-real-time (NRT) aerosol source apportionment for online PM and BC measurements in urban environments	Athens- GR Helsinki- FI Milan-Bologna- IT Paris – FR Zurich - CH
P2	NRT data provision of nanoparticles and their size distributions	Barcelona – ES Birmingham – UK Helsinki- FI
P3	Innovative tools for mapping nanoparticles and other pollutants on urban scale with modelling, mobile measurements and citizen's science and smart sensors, coupled with regional modelling tools	Birmingham - UK Bucharest - RO Paris – FR Rotterdam-Amsterdam - NL
P4	Health effects of novel AQ metrics and their source contributions, including PM components (mass	Athens – GR Barcelona – ES

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	concentrations) and nanoparticles (number concentrations)	Zurich -CH
P5	Characterizing nanoparticle contributions from urban hot spots and characterizing the levels of nanoparticles in hotspots: roadsides, airports, industry, and harbors	Bucharest -RO Milano-Bologna - IT Rotterdam - NL

Table 4 *Pilot studies considered in the Ri-URBANS project with indication of the cities involved for each one of the pilots.*

RI-URBANS paves the way towards optimization of operations as it resembles the key activities that are needed to develop and sustain complementary capabilities between RIs and AQMNs. These include development of novel and localized domain-specific urban/cities observations that can be connected to AQMNs through enhanced monitoring capacity, pilot development, which is supported by relevant, interoperable observations, data systems, and ad-hoc STs in the European community.

Progresses and more tightening collaborations with air quality and model communities will certainly stimulate further developments for forthcoming proposals and fertilizing the use at wide scale of ACTRIS expertise, data, and services.

PAUL

The "Pilot Application in Urban Landscapes" (PAUL, 2021-2025, coordinated by ICOS) project supports the European Green Deal by creating capabilities to observe and verify greenhouse gas emissions from densely populated urban areas across Europe. It aims to increase our understanding of specific needs of greenhouse gas emission assessment in urban environment; it compares available and novel observational approaches and implements an integrated concept for a city observatory, providing unique data sets that feed diverse modelling approaches, scientific studies and will be the base of services towards the city administrations. A specifically innovative approach is the co-design of services, models and observations between city administrators and scientists from multiple disciplines including social and governmental sciences. The PAUL co-design approach will explore the needs of the cities and combining these with the scientific outcomes. This allows to introduce smart services to the cities, supporting evidence-based decisions on climate action and strategic investments. Overarching goals of PAUL are to: 1) implement elements of a pilot city observatory in a large (Paris), a medium (Munich) and a small (Zurich) European city, 2) collaborate with city stakeholders and engage citizens in co-designing services that are required for GHG monitoring in order to validate the implementation of Paris Agreement, and 3) increase our understanding of specific needs of GHG assessment in urban environment and create a service portfolio for setting up an urban greenhouse gas observatory.

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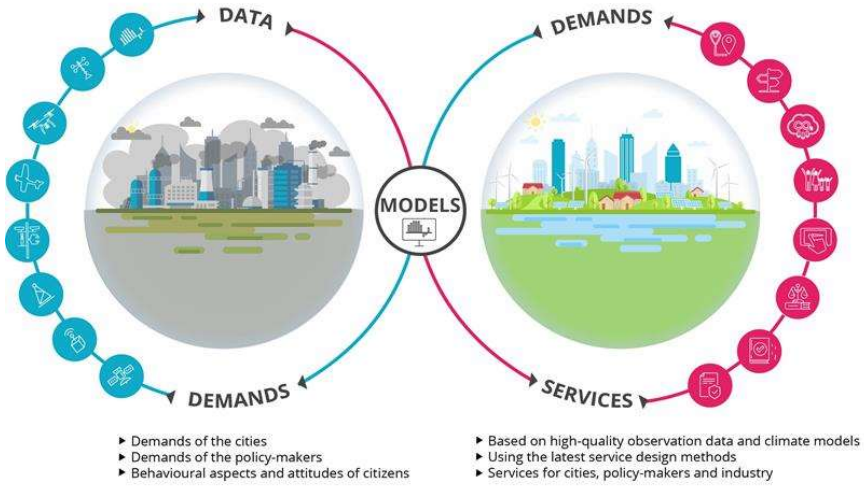

Figure 3: general concept of the PAUL project

While ICOS (and ICOS-ERIC) is leading the project, ACTRIS is involved in PAUL through a specific partnership and specific duties. In particular, determination of the Atmospheric Boundary layer heights is essential to support observations during PAUL pilot experiments and this is part of strategic services that are connected to ACTRIS.

The possible synergies with PAUL are organized also through the joint RI-URBANs/PAUL operations in certain cities and particularly Paris and Zurich, where pilot experiments of both projects will take place. It was agreed already during the proposal writing phase on close cooperation in the field of co-emitted species which connects AQ and climate change mitigation scientifically, in common data approaches and connections to the European Open Science Cloud and in common communication efforts. Cooperation between the two projects will lead to the most important synergy, the development of a common concept on how ICOS, and ACTRIS (and IAGOS) can integrate urban observations and respective services to the cities into the portfolio of European Environmental Research Infrastructures.

KADI

The project 'Knowledge and climate services from an African observation and Data research Infrastructure' (KADI, 2022-2025, coordinated by ICOS) aims to provide concepts for developing the best available science and science-based services in Africa that are needed to sharpen our common action on climate change as outlined in the Paris Agreement and the UN Sustainable Development Goals, in particular SDG 13 'Take urgent action to combat climate change and its impacts'. The concept is improving the knowledge base on climate change in Africa and developing the tools to combat the negative consequences of it. This basic objective shall be achieved by a consortium that combines partners from Africa and Europe but also combines diverse experiences, backgrounds and viewpoints. The common goal is to provide a comprehensive concept that supports the important societal role of research outlined above by co-designing research capacities for climate change observation with

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societal demands and expectations, in our case called 'climate services' and to pave the way for their implementation.

KADI is built upon cooperation between European RIs and some of their counterparts in Africa. The project conceptualize climate change observation in an inter-disciplinary African-European cooperation and consist of three major parts: i) is a systematic compilation of climate services with several pilots in WP2 that deepen and test the concept by providing experience to co-design the requirements of climate services with technical feasibility, ii) organizing extensive exchange and knowledge sharing between Africa and Europe, in both directions, and iii) provide the required policy support as well as the connection to the major global observation systems, such as GCOS and WMO (including its GAW and GBON programs). ACTRIS, together with the ESFRI Landmarks ICOS, IAGOS, EuroARGO and the ESFRI project eLTER, will provide input towards the dialogue between the African and European Unions and identify potential donors. In particular, based on the long experience of international co-operation acquired in the framework of WMO GAW, ACTRIS partners will contribute to supporting the pan-African integration as well as the connection to the major global observation systems, such as GCOS and WMO (WP5), and will work at designing a concept for a distributed RI on climate observation along the Southern African coast (WP3).

Further collaborations and ACTRIS positioning in next calls

The fruitful collaborations established, and the satisfactory results obtained in the above-mentioned projects induce the ENV Research Infrastructures to continue enhancing and exploiting synergies for better results. A proof of this is, among others, the considerable amount of effort put into preparing, in very tricky conditions (during the summertime and with the Covid-19 restrictions hindering the possibility to exchange ideas and discuss in in-person preparatory meetings) a large and ambitious proposal for the HORIZON-INFRA-2021-SERV-01 Call (Research infrastructure services to support health research, accelerate the green and digital transformation, and advance frontier knowledge).

Though unsuccessful because of the evident need to have more time and suitable conditions for developing concepts and ideas, making their added value prominent, the proposal[1] assembled an unprecedented range of European Research Infrastructures[2] to work together at a suite of new services to accelerate cross-disciplinary research into climate-related risks on the environment. While being aware of all the adverse conditions for answering the call the involved RIs decided nevertheless to join efforts to attempt designing and submitting a proposal to provide significant and sustainable integration of RI services through work on communication, administration of services, integration of scientific products, harmonization through standards, creation of a Data Space and delivery of an extensive programme of Transnational and Virtual Access.

[1] The Environmental Research Infrastructures (RIs) Services for Climate Risks (ENRISK)

[2] ACTRIS, AnaEE, DANUBIUS-RI, eLTER, EMBRC, EMPHASIS, EUFAR, HEMERA, IAGOS, ICOS, IS-ENES, JERICO, LIFEWATCH, SeaDataNet, SIOS directly participating in the consortium, with GEOLAB and HYDRALAB contributing in the frame of the ENVRI community collaboration.

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Despite the challenges and the result, all RIs share the willingness to build from this work for further opportunities to collaborate to design and implement e.g.:

- New services combining resources from multiple Research Infrastructures and addressing key climate-related risks;
- Seamless access to resources from multiple Research Infrastructures for cross-disciplinary research teams;
- Services to deliver data from multiple repositories into a Data Space configured to support cross-disciplinary research on climate related risk on the environment;
- An environmental Data Space providing access to data and digital services for cross-disciplinary research teams.

Atmospheric RIs may need to further develop the use of mobile embedded systems in their operations. Embarked onto mobile vectors (drones, trains, aircrafts), embedded systems may provide added-value information as respect to fixed systems to extend observation capacity and design the associated services to be operating in the next 5 to 10 years in the RI. Essential steps in designing use of mobile instruments lies in the development of the suitable physical (hardware robustness, miniaturization, maintenance, calibration procedures, autonomy/energy consumption, etc..) and computing systems (software, visualization, data retrieval/transmission, data management, usage, and advanced data products), but also in the capacity to connect the retrieved information to the original RI data provision and eventually to other components of the atmospheric observing system (space-based information).

Calls contributing to the INFRATECH (next generation of scientific instrumentation, tools and methods and advanced digital solutions) destination of Horizon Europe aim to prepare the next generation of scientific instrumentation, tools and methods and advanced digital solutions. Scientific communities in the ENVRIs, but more particularly in the Atmospheric domain of ENVRI, can organize evolution of their technological and research challenges jointly through the INFRATECH opportunities. ACTRIS, ICOS, and IAGOS can benefit from calls contributing to the INFRATECH destination to study joint development of ground-breaking RI technologies.

Projects and activities with e-RIs

ENVRI FAIR

ENVRI-FAIR project (2019-2023, coordinated by Forschungszentrum Julich Gmbh) is the connection of the Cluster of Environmental Research Infrastructures (ENVRI) to the European Open Science Cloud (EOSC). The goal of ENVRI FAIR is that all participating Research Infrastructures 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. The project is funded by the EU in the frame of the H2020 LC-GD-2020 Call: Horizon 2020 INFRAEOSC-04-2018; Connecting ESFRI infrastructures through Cluster projects

The overarching goal of ENVRI-FAIR is to implement the FAIR principles in the ENVRI community and connect it to the European Open Science Cloud (EOSC). Common policies, open standards,

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interoperability solutions, operational services, and stewardship of data on the basis of FAIR (Findable, Accessible, Interoperable, Re-usable) principles require a common approach. The final aim is to provide open access for interdisciplinary environmental research data in the European Research Area utilising the EOSC. This overall objective will be reached working on the following topics:

- Common data policies for further development of the common standards and policies for data life cycle, cataloguing, curation, provenance and service provision within Environmental Research Infrastructures;
- Open science for an adoption of an open approach to sharing data and software;
- Capacity building for improved skills of the Research Infrastructure personnel so they can develop and maintain the FAIR infrastructures;
- Innovation potential for Increased potential for innovation of each Research Infrastructure by establishing a specific ENVRI-FAIR service catalogue section in the EOSC catalogue;
- Global cooperation for a cohesive global Research Infrastructure landscape, including other Research Infrastructure clusters, regional and international initiatives in the environmental expose thematic data services and tools from the RI catalogues to the EOSC catalogue of services, COPERNICUS, GEO and other end-users.

Cross disciplinary and transversal work carried on within ENVRI-FAIR fertilize each and all the participating RIs thanks to best practice and advancement within participating RIs. Figure 4 shows the variety of the RI infrastructure part of the ENVRI-FAIR consortium.

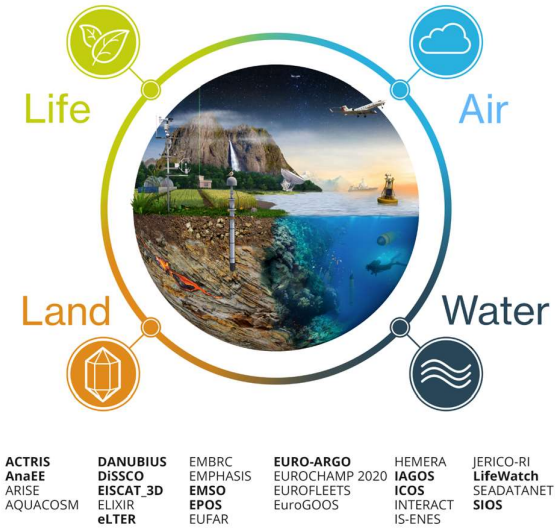

Figure 4. *Research infrastructure involved in ENVRI FAIR for the 4 subdomains.*

ACTRIS has a primary role into the project: ACTRIS coordinates the efforts of all RIs involved in the atmospheric domain (leading of WP8 – Atmospheric subdomain implementation; ACTRIS co-leads with ICOS the WP5 about the *Common requirements and testbed for (meta)data services, community*

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standards and cataloguing and participates through the different partners of the ACTRIS DC to all the transversal WPs (WP3-WP7) related to: the alignment with national and international stakeholders , community development and innovation activities; FAIR policies; training and capacity building; and common implementations and support. In particular, ACTRIS is participating (in one case leading) all the Task forces (listed in Table 5) implemented in ENVRI FAIR in order to fostering harmonized implementations of FAIR solutions among the ENVRI RIs.

	Task force topic	Leading RI/initiative
1	ENVRI Catalogue of services (FAIR)	EPOS
2	ENVRI (VO) AAI implementation	EPOS
3	PIDs, identification, types and registries	FAIR
4	Triple stores and data storage, certification	FAIR
5	Licenses, citation and usage tracking (of data and VRE) (IR)	ACTRIS
6	User oriented cross-domain demonstration cases in e.g., Jupyter (IR)	IAGOS

Table 5 *Task forces set up in ENVRI FAIR for fostering harmonized implementations of FAIR solutions among the ENVRI RIs.*

EOSC - Future

ACTRIS is participating in the EOSC (European Open Science Cloud) Future project (2021-2023, coordinated by the ATHENA Research Centre) as a linked third party through ICOS. In the EOSC-Future project, ACTRIS will be a part of the EOSC-Future science projects. The goal is to understand the impacts of a changing climate on biodiversity, environment and societies creating a cross domain demonstrator service. The cross-domain demonstrator will be a dashboard on the state of the environment for policy makers, researchers, industry, and the public.

The dashboard will contain easily understandable real-time indicators on the state of the environment and will serve as a front-end of the ENVRI-Hub developed within ENVRI-FAIR (see section **Error! Reference source not found.**). The goal of the dashboard is to have it integrated as a part of the EOSC portal to demonstrate and promote the benefits and potential of web-based science using EOSC services. The hope is to mobilize and empower a larger community of researchers and potential data providers.

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ACTRIS strategy for synergies with RIs and e-RIs

The European Strategy Forum on Research Infrastructures (ESFRI) recently published its new roadmap for research infrastructures describing the current ecosystem of research infrastructures (RIs) and its possible evolution in the next years.

ACTRIS naturally develops its strategy in the framework of the Environmental RIs (ENVRIs), which constitute an essential part of the ESFRI strategy. Despite a highly fragmented landscape of ENVRIs in Europe, with single-sited facilities, distributed facilities integrating resources across the European regions, and networks of national facilities, there are clear potential synergies to develop amongst ENVRIs and with other research infrastructures. These synergies are currently developed within the ENVRI-related projects (ENVRI, ENVRI-PLUS, ENVRI-FAIR) and within some additional EOSC related projects (EOSC-FUTURE).

The challenge for ACTRIS in the near future is to maintain and enhance its capacity to support frontier research and address the emerging and new scientific and societal objectives associated with the transition towards a sustainable and resilient Europe. It naturally should find additional users by developing ties with RIs even outside the atmospheric and environmental domains.

Major drivers for RIs' interlinkages are today's world challenges, which have non-disciplinary nature and require effective interconnections and shared work plans among the RIs: climate change, human health (as the COVID-19 pandemic clearly demonstrated), resource scarcity (natural resources primarily, but also financial and human resources). ACTRIS is a research infrastructure addressing grand societal challenges which, per-se, are fundamentally bridging across different disciplines, different fields, and different technologies. For example, improving air quality, a key contribution of ACTRIS, is strongly connected to human health, demographic change, and wellbeing, but is also relevant for developing a secure, clean and efficient energy sector in Europe and a smart, green and integrated transport sector. Similarly, contributing to provision of data on climate forcers is central to the EU action on climate, environment, resource efficiency and raw materials but it has also strong implications towards the evolution of societies in a changing world, in Europe and beyond.

ACTRIS related studies are in fact regularly addressing issues connecting different fields. For example, ENV/Health & Food domains are jointly addressed in deriving human exposure to air pollutants and premature mortality in Europe, such as in the studies of Rivas et al., 2020 Environment International Volume 135, February 2020) or Dallenbach et al., 2020 (Nature, December 2020) used for attributing sources to impacts on human health.

The ENV-H&F link is also a key when addressing persistent organic pollutants (POPs). Not formally part of ACTRIS or any of the current RIs in the atmospheric domain, POPs and also microplastics (MPs) are mostly dispersed in the environment through aerial transport before entering the food chain after deposition to the ecosystems. ACTRIS contributes to mapping deposition fluxes of aerosol species (and hence the particulate component of POPs or MPs) but does not address the behavior of POPs or MPs in the ecosystems. Recently, the ACTRIS network of National Facilities was mobilized for a European scale study on POPs. There, collaboration with the new ESFRI project EIRENE and ACTRIS will be essential, to ensure provision and access to atmospheric data, on both short-lived species and long-lived species POPs are organized to the benefit of users.

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Similarly, ENV/ENE domains are linked through ACTRIS-related studies on radiation reaching the ground. This is illustrated by a recent study of Van Heerwaarden et al., 2020 (Nature February 2020) showing how spring 2020 broke sunshine duration records across Western Europe. The coinciding irradiance extreme and a reduction in anthropogenic pollution due to COVID-19 measures triggered the hypothesis that cleaner-than-usual air contributed to the record. Although the analysis is pointing that reduced aerosols and contrails due to the COVID-19 measures are far less important in the irradiance record than the dry and particularly cloud-free weather, it is illustrating how ACTRIS studies can easily be connected to estimating solar energy power potential. The accurate quantification of direct solar irradiance has a key role during the planning and designing stages of solar power plants. This topic can be extremely important in desert and arid places where a sudden and large increase of aerosol optical depth can be eventually expected, and this is the case in the southern regions of Europe. ENV-ENE and ENV-H&F are also connected when investigating the effect of different engine running conditions on exhaust emissions of regulated or unregulated pollutants in atmospheric simulation chambers such as the one operated in ACTRIS.

ACTRIS interlinkage with Physics and Engineering is mostly driven by technologies. A major challenge in ACTRIS will be to continue to be at the forefront of atmospheric research and to provide all users with state-of-the-art platforms for studying atmospheric composition changes and the complex interactions between its components. Measurement technologies are rapidly evolving, towards more sophisticated instruments used in laboratory experiments or deployed for remote and in situ measurements and affordable low-cost sensors that will be more widely used for various applications. It is clear that electronic miniaturization has led to a growth in the prominence of so-called low-cost instruments (LCSs) or non-conventional sensors. ACTRIS needs to investigate applications of LCSs in terms of technical performance and suitability for applications in the areas covered by the RI.

Cross-over activities between ENV and DIGIT are for ACTRIS mostly addressed through a participation to the ENVRI cluster where data policies, high-performing computing, and data licensing are jointly addressed. However, in addition to ENVRI related developments, it is evident that ACTRIS should investigate how its service portfolio will take advantage of the new opportunities brought by artificial intelligence (AI). The development of AI has led to a new era that can be used in a huge variety of applications in atmospheric and climate sciences. These can be data-driven problems concerning optimization, classification, or prediction, among others. A very good example is the current analysis performed within ACTRIS for detecting the impact of reduced emission due to COVID-19 restrictions with the need for selecting days with similar meteorological conditions in the past 5 years as a basis for comparison with 2020 data, that would most easily be done with AI methods.

Finally, ENV-SCI links are not yet sufficiently developed, although they are essential as climate change and air quality are fundamentally societal issues. ACTRIS long term data are used to evaluate the effectiveness of policies for reducing emissions of pollutants and to connect intervention policies and public acceptance from local to national context. Evolving technologies are always an important component, but others are equally important, such as the change of social behavior that must be integrated into policy related work. Here, the drivers for crossovers are possibly the need to integrate citizen science in ACTRIS data production. Over the last decade, several initiatives have emerged documenting the usefulness of citizen science initiatives for providing information on local air quality. The new era of simple low-cost devices to measure levels of key air pollutants has opened new paradigms in pollution monitoring. Coupled with adequate quality control, and with new data

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digitalization approaches, the potential of citizen's initiatives has been proven in several cities, complementing the standard monitoring. Increasing the capacity in ACTRIS to integrate and operate networks of low-cost sensors, operated by citizen's and combined with more organized data treatment possibly in real-time could clearly improve the quality of the current air quality (AQ) information.

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