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Book of Abstracts

ITINERIS
3rd Project Meeting

September 25-26, 2025 - Rome

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Supplementary materials

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About this Book of Abstracts

This Book of Abstracts compiles 61 contributions presented during the ITINERIS 3rd Project Meeting, held on 25–26 September 2025 in Rome. The meeting provided an important platform for young researchers engaged in the project: early- career scientists, technologists, and PhD students contributed actively, showcasing their work and present results from project activities and reflecting the dedication of the authors, project teams, and the wider scientific community involved.
This publication serves as a comprehensive reference for the current research progress within the ITINERIS project, and a valuable resource supporting collaboration and innovation across the landscape of environmental Research Infrastructures.
The abstracts are organized across the main topics of the ITINERIS project:

- Access to facilities, fair data and related services
- Atmosphere domain
- Marine domain
- Terrestrial Biosphere domain
- Geosphere / Land Surface domain
- Virtual Research Environments and Cross-disciplinary Activities
- e-Science

The PowerPoint presentations associated with the abstracts can be accessed at this link.

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Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor European Commission can be held responsible for them.
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Topic 1

Access to facilities, fair data and related services

RIs as knowledge-sparkling environment among the Ecosystems of Territorial Cohesion strategy: a study case about the social impact of the ITINERIS Project

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The way RIs can enhance their fruitful impacts on local communities from both social and economic perspectives, cannot be measured by scientific publications, while rather on the concrete implications achieved on territorial stakeholders through improving their policies and procedures focused on fulfilling peoples' real needs (Russo, 2025a).

One of these policies in the framework of the *Ecosystems of Territorial Cohesion* strategy effectively involved in promoting virtuous social and economic impact is tackling educational poverties in marginal areas today's facing demographic and cultural desertification (Russo, 2025b).

The objective of this research has been therefore observing how by opening RIs to new user categories mobilized by the Third Sector in collaboration with schools and municipalities can result in maximizing RIs societal value (Loperte et al., 2025).

The research experience in based on a training-intervention implemented at the ITINERIS' RIs, Lifewatch (https://www.lifewatchitaly.eu/) and Actris (https://www.actris.eu/), involving minors in educational poverty from southern Salento. A total of n. 34 students between 9 and 14 years old have been mobilized to live a special learning daily activity powered by the *Ecosystems of Territorial Cohesion* strategy at work (Russo, 2025c). They had a special chance to personally and actively operate in laboratory experiences titled "Hidden Biodiversity" at Lifewatch (University of Salento and CNR-IRET) and "Sky Discovering" at Actris (CNR-IMAA). The consistent emphasis on how science is delivered, rather than solely on the content, has been a key element. Those experiences highlight students' "inquisitive nature" and their confidence in answering questions without fear. This indicates that for kids in educational poverty conditions, engagement stems less from curriculum coverage and more from fostering intrinsic motivation through direct experience, curiosity, and a supportive, non-judgmental environment. One additional interesting elements for the students is to see such excellence in science in their own territory in South of Italy.

Despite the demonstrated effectiveness of these interventions, their implementation, particularly in contexts of educational poverty, faces significant challenges rooted in resource limitations and pervasive systemic barriers. Without addressing these fundamental infrastructural barriers, the effectiveness and scalability of programs will be inherently limited. This implies that policy decisions aimed at fostering educational equity must extend beyond curriculum development and teacher training to include substantial investments in community-level infrastructure that directly supports learning and holistic child development. Crucially, programs should conduct thorough community needs assessments to ensure that the interventions offered are genuinely valuable and relevant to the specific community. This involves co-creating programs with community stakeholders, fostering a sense of shared ownership and ensuring that the initiatives are perceived as a service to the community rather than an imposition.

Evaluation of the interventions in the framework of the *Ecosystems of Territorial Cohesion* strategy tackling educational poverties in marginal areas should extend beyond traditional academic metrics to assess outcomes related to STEM attitudes,

interest, identity, and self-efficacy, as these are fundamental for long-term STEM persistence and engagement. While individual student outcomes are vital, the call for community impact assessments and consideration of sociopolitical contexts suggests a need to measure impact at a systemic level. If interventions are truly addressing educational poverty, their evaluation should also capture broader changes in community engagement, access to resources, and the diversification of the STEM pipeline, moving towards a more complex, ecological evaluation model that captures ripple effects and contributes to understanding how interventions drive broader societal equity.

While challenges related to resource limitations lack of territorial capacity building and the complexities of family engagement persist, the insights gleaned from successful models such as Lifewatch and Actris offer interesting pathways forward. Sustained investment, cross-sectoral collaboration and innovative policies that address fundamental inequities in education, when powered by open Research Infrastructures, are clearly helpful to ensure that all youth, regardless of their socioeconomic background, have equitable opportunities to engage with and contribute to the world of science while achieving concrete social mobilization results.

Special acknowledgment to Prof. Alberto Basset and Franca Sangiorgio (UniSalento), Ilaria Rosati (CNR IRET), Aldo Amodeo, Francesco Cardellicchio and Marco Rosoldi (CNR IMAA).

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Semantic Interoperability in Environmental Sciences: insights from ITINERIS

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Semantic interoperability is crucial for the accurate interpretation of digital resources in environmental sciences. The variety of data and digital objects produced and shared across disciplines necessitates open and shared semantic artefacts and services for the integration and reuse of digital objects. While semantic artefacts define domain-specific concepts, semantic services support their retrieval and reuse. Significant progress has been made within the ITINERIS project to implement FAIR practices for the Environmental Research Infrastructures community. A key achievement has been the FAIRification of semantic artefacts used/managed by Research Infrastructures through publications in semantic catalogues and enhanced metadata descriptions, ultimately increasing their findability, accessibility and reuse. In addition, a cross-infrastructure thesaurus has been generated, validated by the ITINERIS community, and aligned with existing standards to support infra- and inter-community shared knowledge on actors, facilities, services and research products provided and used by Research Infrastructure communities operating in the environmental domain. Lastly, a Terminology Service has been developed to ensure a seamless human and machine access and reuse of semantic artefacts distributed across different semantic catalogues (N = 30), managed and/or used by the ITINERIS community. The Terminology Service provides a unique access point to distributed semantic artefacts enabling the federated search and retrieval of multi- and interdisciplinary classes/concepts. The service integrates a semi-automatic mapping tool for improving alignments between classes/concepts and monitors updates (versioning) of semantic artefacts available within the connected catalogues. The service was designed as a flexible tool to be integrated into (meta)data management systems for semantic annotation, and it can be also adapted to different domains and applications within and beyond the panorama of national and European environmental Research Infrastructures. Through this approach, ITINERIS strengthens the semantic backbone within the field of environmental science, laying the groundwork for enhanced interdisciplinary semantic interoperability at national and international level.

Keywords: Interdisciplinary, Semantic Interoperability, Environmental Research

ITINERIS–ACTRIS Pilot Access Program: Enhancing Scientific Collaboration through Coordinated National and European Infrastructure Access

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The ITINERIS–ACTRIS Pilot Access Program introduced, for the first time in Italy and the EU, a coordinated and nationally funded scheme for access to ACTRIS facilities. The initiative allowed international scientists to use advanced Italian platforms within ACTRIS and supported Italian researchers in accessing ACTRIS facilities across Europe and beyond, fostering scientific exchange and collaboration in atmospheric sciences.

Running until July 2025, the Program facilitated access to 62 cutting-edge facilities, including observational sites, simulation chambers, mobile units, and central laboratories, fostering interdisciplinary research with implications for climate, air quality, health, and energy. In some projects, sequential use of multiple facilities was also achieved.

A key innovation was the funding scheme—aligned with EU practices—covering part of travel and subsistence costs and directly managed by the ERIC. This significantly reduced access barriers, improved inclusiveness, and increased management efficiency.

Scientific uptake was strong: 63 applications received, with a total of 58 concluded Access project and a total of 113 users. Physical access accounted for 64% of applications, remote access 12%, and combined access 24%. Notably, about 70% of users applied to access Italian facilities confirming the effectiveness of the measure.

Independently peer review consistently assessed the proposals as scientifically sound, innovative, and often highly interdisciplinary. By integrating diverse access opportunities under a single framework, the Pilot Call demonstrated that a nationally funded scheme can successfully sustain open access to European research infrastructures. Unlike traditional mechanisms relying solely on EU calls, ITINERIS–ACTRIS positioned Italy as a pioneer, setting a precedent replicable by other countries.

The presentation will highlight Key Performance Indicators (KPIs)—including accesses metrics, user profiles, facilities accessed, and access modalities —together with selected results and impacts on scientific knowledge, underscoring the Pilot's role in shaping future access policies.

Keywords: Research infrastructures, Access schemes, Scientific collaboration

FAIR convergence analysis across ITINERIS Research Infrastructure

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The adoption of shared and technologically advanced FAIR practices among digital Research Infrastructures (RIs) is crucial for efficient collection, dissemination, and reuse of scientific data and digital objects. Within this framework, the ITINERIS research infrastructure was designed as the central HUB for accessing Italian digital resources of the environmental domain. However, knowledge of current FAIR practices within the Italian RIs participating in ITINERIS is fragmented, making difficult to assess the degree of convergence towards common approaches. Here, through the formal methodology of FAIR Implementation Profiles, we described the FAIR Enabling Resources (FER) of 14 Italian ITINERIS nodes and compared them with the European landscape and ITINERIS HUB choices to assess convergence and the ITINERIS HUB's potential for harvesting and disseminating digital resources. Results revealed a substantial degree of FAIR convergence between the ITINERIS HUB and several RIs. The highest number of shared FERs occurred with long-standing infrastructures such as ACTRIS, ICOS, and LifeWatch. At the domain level, the ITINERIS HUB showed stronger alignment with atmospheric and marine domains, whereas significant gaps were detected for biosphere and geosphere. By considering individual FAIR principle, the HUB demonstrated greater convergence in accessibility and interoperability, reflecting specific development activity in these two critical aspects. Finally, the network analysis of potential connectivity showed the HUB widely linked to the majority of RIs, highlighting its interdisciplinary nature. Nevertheless, ITINERIS has not yet achieved a fully central role in the network and further technological developments are required to strengthen its role as a universal aggregator of digital products from Italian environmental research. Enhancing alignment with broader FAIR practices and expanding cross-domain integration will be crucial to fully realise the potential of this strategic infrastructure.

Keywords: FAIR principle, FAIR Implementation Profile, convergence analysis

The ITINERIS Catalogue: Unifying Environmental Resources Across Research Infrastructures

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Understanding environmental challenges requires navigating a complex network of interconnected systems, where Research Infrastructures (RIs) play a key role in integrating observations, data, and services to develop actionable strategies for understanding and predicting the Earth's system. In this multifaceted environmental research domain, it is crucial to harmonize multi-source datasets (characterized by diverse variables, technologies, and spatio-temporal scales) and to provide interoperable services and tools. Within this framework, the *ITINERIS HUB* acts as a unified access point to the knowledge, data, analytical tools, and services provided by multiple Italian environmental RIs.

The *ITINERIS HUB* offers the metadata-driven *ITINERIS Catalogue* that goes beyond a simple archive. The *ITINERIS Catalogue* is inherently multidisciplinary and cross-RI, bridging gaps across domains and communities. It organizes, describes, and makes discoverable a wide range of resources, including datasets, services, research products, training resources, virtual research environments (VRE), and information on resource providers. Its key innovation lies in the adoption of standardized resource profiles, which ensure automated metadata harvesting, alignment with recognized metadata standards, and multidomain. This approach translates into tangible benefits for diverse stakeholders. Policymakers can access data and tools that support evidence-based strategies for sustainable development. Agencies and local authorities can benefit from resources enabling environmental monitoring and assessment of ecosystem health and pollution levels. Scientists and practitioners can leverage data and models to develop early warning systems for natural hazards and climate-related risks. Researchers, educators, and industry can exploit advanced modelling and visualization tools to explore scenarios, improve predictions, and design innovative solutions.

Thanks to the native support for resource cataloguing through profiles in D4Science Infrastructure's Catalogue, this approach guarantees sustainable integration and transparent, simplified access to environmental resources. By fostering Open Science and the FAIR principles (Findable, Accessible, Interoperable, Reusable), the *ITINERIS Catalogue* promotes standardized sharing and reuse of resources across communities.

Keywords: Open Science; FAIRness; Environmental domain; ITINERIS HUB

Advancing User-Centered Strategies for Integrated Environmental Research Infrastructures: The ITINERIS Approach

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The ITINERIS User Strategy establishes a comprehensive and integrated framework to improve accessibility, usability, and impact across Italian environmental Research Infrastructures (RIs). Bringing together 22 national nodes operating in the atmospheric, marine, terrestrial, and geosphere domains, ITINERIS is designed to deliver coordinated and interoperable services to a diversified user community. Fully aligned with European frameworks such as ESFRI and EOSC, the strategy supports long-term sustainability, interoperability, and societal relevance.

The approach is structured around sequential and interconnected steps. User mapping and classification have been carried out through surveys and desk research to identify both current and potential communities, including academia, industry, public authorities, and civil society. Process harmonization addresses heterogeneous maturity levels across RIs, defining common standards for access and service provision. Access enhancement is pursued through simplified procedures, a unified catalogue of services, flexible modalities, and innovative financial support (e.g., user grants). In addition, community enlargement is promoted via targeted outreach actions such as newsletters, online events, and communication campaigns. Capacity building is fostered through training activities to broaden knowledge and strengthen professional skills. Finally, stakeholder engagement is advanced by building strategic alliances with institutions such as ARPA and Civil Protection, contributing to an innovation-oriented RI ecosystem and promoting science diplomacy.

The initial implementation has yielded significant outcomes: increased visibility and attractiveness of ITINERIS services, greater engagement of non-academic users, progress towards harmonized access policies and catalogues, and reinforced training activities.

This presentation will highlight key experiences in applying the user strategy across diverse user types and ITINERIS scientific sub-domains.

Overall, the ITINERIS User Strategy offers an innovative, user-centered model for RI management, providing a replicable framework nationally and internationally. It maximizes the contribution of environmental RIs to research excellence, innovation, policy support, and sustainable development.

Topic 2

Atmosphere domain

Assessing Outdoor Thermal Comfort through Microclimatic Modeling: A Case Study in Lecce (Italy)

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This study aims to analyze thermal comfort in a selected area of Lecce, a typical Mediterranean city, using a modelling approach to evaluate the microclimatic mitigation effects of urban greenery. The study involves the use of ENVI-met, a CFD (Computational Fluid Dynamics) microclimatic model to reproduce the physical and thermal behavior of urban spaces. It accounts for surface characteristics, vegetation, and atmosphere interactions, allowing for a detailed assessment of thermal comfort conditions. The methodology involved three microclimatic simulations based on distinct scenarios: (1) the current urban configuration; (2) an identical scenario to the current one but without vegetation; and (3) a future scenario featuring the replacement of impervious surfaces with permeable materials, the substitution of some existing vegetation with more shading species, an increase in overall vegetation density, and the addition of a fountain as a water feature. The three microclimatic simulations were performed in ENVI-met for a typical summer day in Lecce. Thermal comfort is evaluated through UTCI (Universal Thermal Climate Index), which shows an improvement during the day in scenario (3) compared to (1), especially in the central hours of the day, with a peak reduction of the "*very strong thermal stress*" of 30%. These results highlight the crucial role of urban greenery in enhancing thermal comfort and underscore the importance of incorporating sustainability principles into urban planning through the identification of effective microclimate mitigation strategies. Future analyses using the same methodology are intended to be conducted in other areas of Lecce and other Mediterranean cities, investigating the beneficial effects of more suitable mitigation solutions to improve thermal comfort for residents.

Keywords: thermal comfort, ENVI-met, UTCI

On the discrimination between volcanic ash and desert dust leveraging photometer and depolarization lidar measurements

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This study investigates the potential for automated discrimination between volcanic ash and desert dust aerosols using AERONET (Aerosol Robotic Network) sun photometer data, in support of EARLINET (European Aerosol Research Lidar Network) lidar measurements. The motivation stems from the challenge that both ash and dust exhibit similar optical signatures in atmospheric lidar signals, in fact they are treated as the same type in most automatic aerosol typing techniques, complicating real-time identification during volcanic events. A curated dataset was compiled, including ash-dominated observations from the 2010 Eyjafjallajökull and the 2021 La Palma eruptions and dust-dominated cases from Potenza, in Italy. A set of key optical and microphysical properties, such as single scattering albedo, complex refractive index (real and imaginary parts), absorption Ångström exponent, and coarse-mode radius, was used to train and evaluate several machine learning classifiers. Among these, logistic regression and random forest achieved the best balance between interpretability and accuracy, both exceeding 85% F1 scores (i.e., predictive performance) with strong recall on the ash class. The trained classifier is further tested against a pre-classified EARLINET/AERONET dataset, including only dust observations, demonstrating a solid foundation for at least non heavily polluted sites. This approach provides a promising avenue for integrating sun photometer data into aerosol typing frameworks and offers insights into the most discriminative spectral features separating ash from dust.

Keywords: aerosol typing, desert dust, volcanic ash, machine learning, aviation

Experimental activities at ChAMBRe

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ChAMBRe (Chamber for Aerosol Modelling and Bio-aerosol Research) is an atmospheric simulation chamber (ASC) managed by the Genoa division of INFN at the Department of Physics of the University of Genoa. The ASC is characterized by a high versatility of applications, due to the wide range of instruments that can be connected. Several examples of these applications will be presented at the meeting in order to share the experimental activities performed in the ITINERIS project context. Among these applications, the most relevant are generation of standard soot particles and their use for different purposes (i.e., oxidative potential and toxicological assays), definition of a procedure to characterize carbonaceous aerosols and combustion emissions in general, aging of soot particles, investigation of the effects of air quality on bacteria viability, and study of the interaction between plant species and air pollutants. Experimental setups, methods, and highlights of obtained results will be the focus of the presentation. An overview of the activities related to the ITINERIS access program will also be included.

Keywords: atmospheric simulation chamber, carbonaceous aerosol, bioaerosol, pollutants

Characterization of volatile organic compounds in two urban sites in the Italian Po Valley: Milan and Bologna

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Volatile organic compounds (VOCs) emitted into the atmosphere from natural and anthropogenic sources play a crucial role in atmospheric chemistry. These compounds react with atmospheric oxidants, leading to the formation of secondary organic aerosols and tropospheric ozone, which influence air quality, human health, and climate.

In Europe, air quality policies implemented over the last decades have successfully reduced concentrations of some pollutants. For example, nitrogen dioxide and particulate matter levels decreased by 30-50% between 2000 and 2010, resulting in a decline in related adverse health effects. Yet, 70% of the EU population resides in urban areas, and 97-99% of these urban inhabitants are exposed to fine particulate matter and ozone levels exceeding the 2021 WHO guidelines for public health protection (EEA, 2021). The Po Valley in northern Italy is among the most polluted regions in Europe, frequently exceeding air quality limits.

Within the framework of the EU-funded RI-URBANS/ ACTRIS and ITINERIS projects, we carried out two field campaigns in two urban areas, situated approximately 200 km apart in the Po Valley: Milan and Bologna. VOC measurements were performed using a Vocus CI-ToF 2R mass spectrometer (Tofwerk, Switzerland), which operated in Milan from January 2023 for one year, and subsequently in Bologna for one month beginning in September 2024. Our study focuses on sixteen VOCs commonly detected at both sites, identified and quantified using a certified VOC standard mixture, spanning a mass range of 42–371 amu. We analyze the concentrations, along with the diel and seasonal variations of VOCs in Milan and Bologna, emphasizing the influence of atmospheric dilution and chemical reactivity on the observed levels. Additionally, implications for the formation of ozone and secondary organic aerosols are discussed.

Keywords: Urban atmospheric chemistry, VOC, Po valley

A lifetime effort at Cimone to understand the black carbon climatology though observations and modelling

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Black carbon (BC) is a key short-lived climate forcer, with atmospheric concentrations influenced by both emissions and meteorological processes. In the Mediterranean—where climate change and air quality challenges intersect—understanding the drivers of BC trends is critical. This study investigates whether observed BC reductions are solely due to air pollution control policies or if emerging climate-related feedback are influencing its variability.

We analyze 17 years (2007–2024) of equivalent BC (eBC) observations from the Monte Cimone global GAW station (2165 m a.s.l.), within the ACTRIS framework. Over 4478 days of valid measurements were used to quantify long-term trends and seasonal patterns. FLEXPART simulations were employed to assess emission sources and transport regimes, while ERA5 reanalysis data provided insight into meteorological drivers at synoptic and climatological scales.

Results show a clear seasonal cycle, with higher summer eBC linked to increased boundary layer influence and biomass burning. A general long-term decrease (~ –0.09 μg m^{-3} per decade) was observed, though multiple and short tendencies raise the question of whether climate change is enhancing BC transport or reducing removal efficiency.

This study combines long-term observations, atmospheric transport modelling, and reanalysis data to explore the evolving balance between policy-driven reductions and climate feedback affecting BC.

Keywords: ACTRIS-RI, COPERNICUS, FLEXPART

Advancing Aerosol Characterization Through Combined Depolarization and Fluorescence Lidar Observations at CIAO

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Since 1993, atmospheric aerosol studies based on multi-wavelength Raman lidar observations have been one of the core research activities at the CNR-IMAA Atmospheric Observatory (CIAO). Over the years, the observatory has significantly contributed to the understanding of various aerosol types, including mineral dust, biomass burning aerosol, and volcanic ash, and their role in atmospheric processes.

At the heart of these activities is POLPO (POtenza Lidar for Particle Observation), a state-of-the-art multi-wavelength lidar capable of measuring the aerosol depolarization ratio and backscatter coefficient at 355, 532, and 1064 nm, and the extinction coefficient at 355 and 532 nm. These capabilities enable a detailed optical and microphysical characterization of atmospheric aerosols. However, to further enhance the aerosol typing potential of the observatory, we have recently initiated the integration of a fluorescence lidar system alongside POLPO.

While fluorescence-based techniques are well established in several branches of environmental science, they have remained underutilized in lidar remote sensing of aerosols. Only recently have fully calibrated aerosol fluorescence spectra been reported, notably by the German Meteorological Service using the RAMSES lidar. These pioneering results have highlighted the significant added value of fluorescence information in refining aerosol classification, especially when combined with conventional elastic and Raman signals.

Building on this foundation, we have set up a new fluorescence lidar at CIAO. The spectrometer used for fluorescence detection was fully calibrated in June 2025, allowing the first fluorescence measurements at the observatory. The synergy between multi-wavelength depolarization data from POLPO and spectrally resolved fluorescence will be exploited to better characterize the nature and origin of aerosol events, with a particular focus on Saharan dust and biomass burning plumes. Preliminary results from these first observations will be presented at the conference.

Keywords: dust, biomass burning, fluorescence

3D scanning atmospheric - marine LIDAR

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For the first time, we present the results obtained from an innovative instrument purchased with the support of the ITINERIS project within the European Research Infrastructure Consortium – Aerosols, Clouds, and Trace gas Research InfraStructure (ERIC-ACTRIS). Light Detection and Ranging (LIDAR) techniques have proven to be a highly reliable tool for studying both the atmospheric domain, with several applications to study aerosols and water cycle, and the marine environment to measure sea temperature profiles, oil spills, chlorophyll-a concentration and Ocean Colour parameters.

In this context, we present the first Raman depolarisation fluorescence LIDAR instrument capable of combining atmospheric and oceanic measurements. Active remote sensing of marine aerosols and air-sea interface processes using a pulsed laser will enable the development of new combined atmospheric and marine LIDAR products. It will also allow for the regular monitoring of relevant atmospheric and marine variables, as well as innovative studies on air-sea interaction. The instrument can be used in conjunction with the automatic photometer installed on the observation deck of the National Research Council (CNR) oceanographic vessel "Gaia Blu".

This presentation shows preliminary near-real-time data results from the R/V Gaia Blu during the ITINERIS' EYES oceanographic campaign conducted in Mediterranean waters in July 2025, which involved multi-platform experiments to acquire several Essential Variables (EVs).

Studying and observing marine aerosols and physical processes at the air-sea interface, the role of which in climate regulation is poorly understood, will help us to gain a more comprehensive understanding of changes in air quality and climate caused by human activities.

Keywords: LIDAR, remote sensing, ocean colour

Comparison of Online and Offline XRF Techniques for Atmospheric PM10 Measurement

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The negative impact of atmospheric particulate matter (PM) on human health has driven research toward its chemical and elemental characterization, essential for identifying pollution sources [1].

Energy dispersive X-ray fluorescence (ED-XRF) is widely used for elemental analysis of PM due to its non-destructive nature and lack of sample pre-treatment. While typically applied to Teflon filters, quartz filters are often preferred in monitoring campaigns, as they support additional analyses (e.g., organic and elemental carbon, water-soluble species) and are easier to subdivide. Recent studies confirm the reliability of quartz filters for ED-XRF anal-ysis [2].

This study compares elemental data from two ED-XRF systems: an online instrument (Xact® 625i) using Teflon tape, and an offline benchtop ED-XRF (XEPOS05, Spectro) analyzing quartz filters. The Xact® 625i, operating at the Environmental-Climate Observatory (ECO, part of the ACTRIS network), provides near real-time elemental composition data with a 3-hour resolution. It collects PM_{10} at 16.7 L/min and analyzes samples directly, delivering results within approximately 6 hours. It is also equipped with a meteorological station, enabling potential correlation between meteorological parameters and elemental concentrations for source apportionment.

Simultaneously, daily offline sampling is performed at ECO using a dual-channel SWAM sampler (Fai Instruments, 2.3 $m^3 h^{-1}$), which also provides mass concentration via β-attenuation [3]. Filters collected on quartz are analyzed for elemental composition using the benchtop ED-XRF system.

Daily-averaged Xact measurements will be compared to corresponding offline data to validate the online system. While the benchtop ED-XRF is well-established, the online system offers continuous, faster data access—avoiding delays due to filter handling and analysis.

Additionally, we present the first high-time-resolution elemental data series from ECO, focusing on tracers of sources such as African dust, biomass burning, road traffic, and fireworks.

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Keywords: XRF intercomparison, PM10, online measurement

Integrating remote sensing and in-situ measurements to assess the impact of PBL dynamics on air pollution in Milan, Po valley (Italy)

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The Planetary Boundary Layer (PBL) is the atmospheric layer where most mixing of aerosols and gases occurs. Understanding its dynamics is crucial to interpret ground-level pollutant variability. This study combines remote sensing and in-situ measurements to investigate the interplay between emissions and atmospheric dilution, focusing on Milan during the year 2023 (Po Valley), one of Europe's most polluted regions. The work is part of the EU H2020 RI-URBANS project.

An ACTRIS-RI platform near Linate airport (hotspot site) measured aerosol optical properties, size distribution, nitrogen oxides, and meteorological data. A second, urban background site monitored aerosol and gas composition, black carbon, and greenhouse gases. Two Automated Lidar-Ceilometers (ALCs), operating at Bicocca University and Rubattino within the ALICENET network, provided continuous aerosol vertical profiles. Using the ALC-tool, the Mixed Aerosol Layer (MAL) height was derived as a proxy for the PBL.

We compared seasonal and site-dependent variations in MAL height and key aerosol parameters, including equivalent black carbon (eBC). As expected, eBC concentrations were higher in winter, while MAL height was greater in summer, highlighting the importance of vertical mixing in pollutant dispersion. The diurnal cycle of primary pollutants at the hotspot site was strongly linked to MAL evolution.

In August 2023, for instance, daily variation of eBC at Linate closely followed MAL dynamics from Bicocca. A strong anti-correlation ($R^2 = 0.81$) confirmed the role of vertical dilution in shaping primary pollutant levels. Conversely, secondary pollutants like fine particles showed no correlation with MAL, suggesting additional formation processes.

A ventilation index was also derived to assess the efficiency of vertical mixing. Future work will explore its variability and pollutant-specific sensitivity to both vertical and horizontal atmospheric dynamics.

Keywords: PBL dynamics, ground-level concentrations, Po valley

High time resolution measurements of equivalent black carbon in an urban background site of Italy

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Carbonaceous aerosols represent a significant component of atmospheric aerosol. Among them, the equivalent black carbon (eBC), identified as the result of optical determination of the carbon content in the atmospheric aerosol (PM), has become a serious concern because of its detrimental impact on human health, and because it is regarded as the second most major contributor to global warming after CO_2. Also the recent EU Directive 2024/2881 highlights the need to monitor emerging pollutants like black carbon more effectively.

This study presents results from an intensive field campaign, between March and April 2023, at an urban background site (southern Italy), for characterizing the carbonaceous aerosols. Daily samples of PM_{10} and $PM_{2.5}$ were analyzed using a Sunset thermal-optical analyser to determine organic and elemental carbon (OC, EC), while real-time equivalent black carbon (eBC) was measured with three independent instruments: MAAP and Giano BC1 for the PM_{10} fraction, while AE33 for the $PM_{2.5}$ fraction. Total carbon (TC) was monitored using an online TCA08 thermo-catalytic analyser, working in together with AE33 in order to obtain secondary organic carbon (SOC) and primary organic carbon (POC) evaluation for $PM_{2.5}$. The average concentration of PM_{10} was 17.1 μg/m^3 and 10.4 μg/m^3 for $PM_{2.5}$. On average, OC and EC represented 16.5% and 3.6 % of PM_{10} mass, and 22.6% and 5.5% of $PM_{2.5}$, while the SOC accounting for the 36% of the measured OC in the fine PM fraction. The in-situ MAC, recalculated for the ECO site ranged between 8.0 m^2/g and 12.22 m^2/g. eBC measurements shown a pattern modulated by both the daily evolution of the planetary boundary layer height and combustion sources (traffic and biomass burning). The apportionment of eBC was: 65% of fossil fuel (eBC_{ff}) and 35% of biomass burning contributions (eBC_{bb}). Biomass burning emissions are confirmed by optical measurements of brown carbon (BrC).

Keywords: in-situ MAC estimation; black carbon apportionment; brown carbon.

Unraveling the Synergistic Impact of Anthropogenic and Biogenic Emissions on New Particle Formation: Evidence from the CERN CLOUD Chamber

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New particle formation (NPF) plays a critical role in the atmospheric aerosol population, influencing both climate and human health (Lai, 2024). Understanding the driving mechanisms behind this process is essential for accurately assessing the anthropogenic impact on our planet.

Several studies have recently pointed out the crucial role covered by RO2-RO2 interactions and their contribution to dimers formation and consequently to NPF (Kenagy, 2024). Here, the understanding of the synergistic effects of biogenic and anthropogenic volatile organic compounds (BVOC and AVOC, respectively) on dimers formation and NPF is proposed. The study explores three distinct scenarios: emissions dominated by biogenic VOCs (representing a forest environment), a mix of anthropogenic and biogenic VOCs (typical of suburban areas), and emissions dominated by anthropogenic VOCs (characteristic of highly polluted urban settings).

Data presented have been collected at CERN CLOUD (Cosmic Leaving Outdoor Droplets) chamber, located in Geneva. Continuous sampling using mass spectrometers, particle size distribution analyzers, and filter deposition techniques enables real-time monitoring of the evolution of various compounds, allowing for the isolation of their contributions from the gaseous phase to the particle phase.
The goal is to provide a clear understanding of the gas-to-particle mechanisms driving NPF, with a focus on assessing the contribution of human emissions on climate and on clarifying the role of RO2 on atmospheric mechanisms.

Lai S., Ximeng Q. et al (2024), Atmos. Chem. Phys., 24, 2535–2553.
Kenagy H. et al (2024), Sci. Adv, 10, eado1482.
Keywords: Dimer formation, Anthropogenic-Biogenic Interaction, Air quality

Analysis And Characterization Of Wind Circulation In A Central Mediterranean Site During Heatwave event

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Heatwaves, often associated with quasi-stationary anticyclones, can be locally mitigated by coastal land-sea breeze circulations. To investigate this mechanism, the MESSA-DIN (MEditerranean Sea Salt And Dust Ice Nuclei) campaign was carried out by CNR-IMAA in Soverato (Southern Italy, 38°41′16″N 16°33′00″E) from June to November 2021. Ground-based remote sensing instrumentation, including a Doppler wind lidar, was deployed to analyze the variability of the land-sea breeze in relation to synoptic circulation, marine aerosol transport, Saharan dust intrusions and Heatwave event.

Results show a well-defined land-sea breeze regime during July–September, with daily onset around 05:00–06:00 local time, reaching up to 750 m a.g.l. at midday, and reversing at night. In October–November, the circulation weakens under the influence of low-pressure systems. Wind speed profiles reveal moderate intensities (0–10 m s^{-1} up to 2 km) with maxima around 20 m s^{-1} near the top of the boundary layer. A comparison with a inland site of the Mediterranean region (Potenza) is performed in order to to verify the effective mitigating action of breezes in coastal sites.

A comparison with ERA5 reanalysis confirms the seasonal evolution of the breeze system and its potential role in modulating local impacts of extreme heat under climate change. These findings emphasize the importance of characterizing coastal atmospheric dynamics to better understand and mitigate temperature extremes in the Mediterranean region.

Keywords: remote sensing, heatwave, wind circulation

Tracing Carbon in the Sky: CO_2 and CH_4 Isotope Signatures under Dust and Fire Events at the POT Station, Part of the CIAO Observatory (CNR-IMAA)

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A new atmospheric station dedicated to the observation of greenhouse gases has recently been implemented at the CNR-IMAA Atmospheric Observatory (CIAO). The station, called POT, is part of the Integrated Carbon Observation System (ICOS) Research Infrastructure and provides continuous measurements of carbon dioxide (CO_2) and methane (CH_4) atmospheric concentrations.

Thanks to the ITINERIS project, its observation capability has recently been enhanced with the acquisition of a high-resolution and high-precision Picarro G2201 continuous analyser for the investigation of the behaviour of stable carbon isotopes in CO_2 and CH_4 and this contribution has been essential to the development of a high-resolution isotopic dataset.

Isotopic analysis represents a powerful tool for source attribution, enabling the identification of emission origins through the isotopic signature left by various physical and chemical processes occurring in the atmosphere.Located in a strategic position at the heart of the Mediterranean Basin, CIAO provides optimal conditions for the monitoring and investigation of the frequent Saharan dust intrusions affecting the Mediterranean region. Continuous air sampling from the 100-meter tower of the POT station enabled the detection of isotopic shifts following multiple dust events observed in March 2025. These in-situ observations represent the first field evidence in Mediterranean area suggesting a potential link between mineral dust and methane oxidation, possibly driven by fractionation mechanisms that favour the atmospheric removal of lighter $^{12}CH_4$, resulting in an enrichment of $^{13}CH_4$. Such findings could support the hypothesis that mineral aerosol can influence methane isotopic signatures through heterogeneous processes, offering new insights into the interactions between dust and greenhouse gases in the free troposphere.

In addition to the POT station demonstrated also sensitivity to long-range fire events. Infact a distinct increase in CO concentrations was observed following the intense Canadian wildfires occurred in June 2025, in agreement with signals reported across multiple European stations. Therefore, based on this observation, our research focused on the characterization of local fire events through the stable carbon isotope analysis. The application of the Keeling plot methodology enabled the identification of combustion-related isotopic signatures, highlighting the potential of isotopic tracers for distinguishing fire-derived contributions to regional greenhouse gas variability.

Keywords: carbon isotopes, methane oxidation, Keeling plot

Tracking the source: first evaluation of benzothiazoles in airport non-exhaust emissions

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The steady expansion of the aviation sector, a pillar of global connectivity, demands growing attention to its environmental footprint, particularly with regard to air quality.[1] While exhaust gas emissions have been extensively investigated, non-exhaust sources such as tire wear particles (TWPs) remain comparatively underexplored.[2] These particles constitute a major source of microplastics and associated pollutants, releasing chemical additives including benzothiazoles (BTHs), widely employed as tracers of road traffic emissions.[3–6] Yet, their occurrence and abundance in airport-related non-exhaust emissions have never been assessed.

In this study, leveraging the enhanced analytical capabilities of the Centre for Trace Analysis (CeTrA) within the ITINERIS framework and in collaboration with ARPA Lombardia, we provide the first characterization of BTHs in the airborne particulate matter (PM_{10}) at Milano Linate Airport. The investigation employed an advanced analytical platform to resolve the aerosol chemical composition and identify traces and ultra-traces of BTHs alongside other relevant molecular markers.

The results demonstrate that the airport is a significant source of BTHs, particularly elevated in BTH, BTH-NH_2, BTH-MeS, and BTH-SO_3H. The aerosol composition at the airport closely parallels that found in high-traffic urban areas, yet the BTHs signature itself is highly distinctive. A weekly pattern further differentiates this source, and the novel observed correlation between BTH-NH_2 and BTH-SO_3H suggests airport-specific dynamics as the underlying driver of these pollutant profiles.

The chemometric analysis resolved three distinct pollution profiles: one driven by aircraft and ground-support vehicle emissions, a second associated with de-icing operations, and a third linked to medium-range atmospheric transport and secondary chemical processes. Beyond addressing a major knowledge gap in the literature, this study provides critical evidence to advance the understanding of airport-related impacts on air quality and to inform effective mitigation strategies.

Keywords: non-exhaust emissions, benzothiazoles, airport

Non-refractory submicron aerosols in the Po Valley: Sources, vertical transport, and chemical composition from measurements at Bologna (54 m a.s.l.) and Mt. Cimone (2167 m a.s.l.) within AirPoDynamic

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Atmospheric submicron aerosols have long been studied due to their impact on climate, ecosystems, and human health. Organic Aerosol (OA), the predominant constituent of PM_1 mass, can be directly emitted (Primary OA, POA) or formed through atmospheric processes (Secondary OA, SOA). Understanding the evolution and oxidation of OA during atmospheric transport is a key research focus.

This study aims to investigate OA ageing along a vertical transport in the Po Valley, from an urban site (Bologna, 54 m a.s.l., BO) to a high-altitude remote station (Monte Cimone, 2167 m a.s.l., CMN), in relation to Planetary Boundary Layer (PBL) dynamics. Measurements were conducted simultaneously at CMN and BO during August–September 2024 using a Time-of-Flight Aerosol Chemical Speciation Monitor (ToF-ACSM) and a Quadrupole-ACSM (Q-ACSM), respectively, within the ITINERIS activity 4.14 and *AirPoDynamic* framework.

The selected period comprises the transition from summer to early autumn evidencing the effect of PBL evolution on the chemical composition of non-refractory PM_1 (NR-PM_1), sulphate, ammonium, nitrate, and organics (OA), at the two sites. NR-PM_1 components at CMN summit show the alternation between the Free Troposphere (FT), characterized by lower concentrations, and PBL-influenced periods, exhibiting a decreasing PM_1 concentration trend over the campaign. Conversely, BO shows a progressive increase in NR-PM_1 concentration as a consequence of the reduction in PBL height resulting from the seasonal decrease in solar radiation. At both sites, OA constitutes the dominant NR-PM_1 fraction. Conversely, sulphate tends to be relatively more abundant at CMN than at BO in the colder periods, while nitrate is the second more important NR-PM1 component at low altitude in autumn.

OA composition was further analysed through source apportionment (SA) techniques (seasonal-PMF by ME-2). Findings indicate that the lower Po Valley is characterized by fresher, local anthropogenic emissions, despite a significant SOA presence. In contrast, aged OA prevails at CMN, although vertical transport from the Po Valley enhances the presence of less oxidized OAs at the summit during warmer days, particularly in the afternoon when aerosol mixing is enhanced.

Keywords: Vertical transport, ACSM, Source Apportionment

The ACTRIS in-situ aerosol National Facility at CIAO: Advancing integrated ground-based atmospheric observations

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The CNR-IMAA Atmospheric Observatory (CIAO), located in Potenza, Southern Italy, has recently enhanced its observational capabilities with the implementation of a state-of-the-art aerosol in-situ facility (Laurita *et al.*, 2025), made possible also thanks to the ITINERIS project. This new component complements CIAO's remote sensing infrastructure, providing continuous, high-quality ground-level measurements of key aerosol properties. In February 2024, the facility achieved initial acceptance as an ACTRIS National Facility for aerosol in-situ observations, aligning CIAO with European standards for long-term monitoring. The facility is currently in Step 1b of the ACTRIS labelling process, which covers the implementation and pre-operation phases.

Integrating in-situ aerosol data with advanced remote sensing yields a comprehensive, vertically resolved characterization of aerosol properties. This synergy improves remote sensing retrieval validation, supports aerosol classification, and enhances analysis of aerosol transport and transformation.

To highlight the added value of this integrated approach, selected case studies conducted within ITINERIS will be presented, including episodes of wildfire smoke and Saharan dust transport, both phenomena frequently observed at CIAO (De Rosa *et al.*, 2025). These examples demonstrate how combining surface in-situ and profiling observations provides deeper insight into aerosol vertical structure and evolution.

Furthermore, the first annual dataset collected by the facility since operations began in 2024 will be shown. This initial record documents seasonal aerosol variability and establishes a robust reference for long-term monitoring. This major upgrade, made possible also thanks to the ITINERIS project, reinforces CIAO's strategic role within ACTRIS and its contribution to international research on air quality and climate.

Laurita, T. et al.: CIAO main upgrade: building up an ACTRIS-compliant aerosol in situ laboratory, Atmos. Meas. Tech., 18, 2373–2396, 2025.

De Rosa B. et al.: Characterization of fresh and aged smoke particles simultaneously observed with an ACTRIS multi-wavelength Raman lidar in Potenza, Italy, Remote Sens., 2025.

Key words: ACTRIS, aerosol in-situ observations

Comparison of reference upper-air GRUAN and homogenized RHARM data with GNSS-RO

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The study of thermodynamical variables, such as temperature and relative humidity in the upper troposphere/lower stratosphere (UT/LS), is one of the key elements for understanding climate change. Several studies estimated trends both regionally and globally in the UT/LS, using both satellite and ground-based data and different measurement techniques. However, the accuracy and spatial-temporal coverage of measurements can significantly affect trend estimates. This work investigates the consistency of temperature and humidity measurements by comparing upper-air data from three sources: GRUAN (Global Climate Observing System (GCOS) Reference Upper-Air Network), RHARM (Radiosounding HARMonization), and GNSS-RO (Global Navigation Satellite System - Radio Occultation) from COSMIC and METOP B-C missions.

RHARM, a bias-adjusted radiosounding dataset based on IGRA and processed mimicking the GRUAN data processing, includes uncertainty estimates and covers ~700 stations worldwide. For this study, a subset of 100 long-term stations, since 2006, was selected for comparison. GNSS-RO data were collocated using a 200 km / 3 h criterion and interpolated at mandatory pressure levels (850-10 hPa). Comparisons were performed across latitude bands: mid-latitudes (NH), polar regions (NP), and tropics (TR).

Results show that RHARM profiles exhibit smaller biases compared to GRUAN (up to 0.1 K), while IGRA shows larger discrepancies (up to 0.25 K). GNSS-RO data, when compared to RHARM, reveal temperature biases up to 0.3 K and relative humidity biases up to 12% in tropical regions. RHARM consistently shows better agreement with GRUAN than IGRA, especially in the UT/LS region. This dual comparison allows assessing the performance of satellite-based profiles both against reference and homogenized ground-based observations.

These findings highlight the importance of homogenized radiosounding datasets for climate applications and support the integration of GNSS-RO data into global monitoring frameworks. Future work will extend the analysis to all RHARM stations and explore seasonal and latitudinal variability.

Keywords: upper-air climatology, radiosounding homogenization, GNSS-RO validation.

Enhanced atmospheric observation capacity of the Seneca III airborne platform

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Within the ITINERIS project (WP 4 – Atmosphere), significant progress has been made in upgrading the OGS PA-34 Seneca III research aircraft to host advanced aerosol and meteorological instrumentation, compliant with ACTRIS standards. The activity focused on the procurement, calibration, and integration design of a comprehensive payload, including an isokinetic sampling inlet, a microphysical package (CPC, SMPS/FMPS, APS/OPC), an optical suite (aethalometer AE33, nephelometer Aurora 3000), and a high-frequency meteorological probe (AIMMS-30). Mechanical, electrical, and aerodynamic customizations were studied in detail, resulting in a dedicated power distribution system, optimized inlet and probe placements, and modular racks for cabin payload. The certification pathway has been defined, and an application for Major Change was submitted to EASA in May 2025, paving the way for full approval and flight testing beyond the project's timeframe. This work represents a substantial step forward in reinforcing Italy's capacity to contribute high-resolution, vertically resolved aerosol observations to the European airborne research infrastructure. The collaboration between CNR-ISAC and OGS ensures continuity towards operational deployment and scientific exploitation in international campaigns.

Emissions of climate-altering species from open vegetation fires in the Mediterranean region: methods and data review

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Climate change in the Mediterranean region raises serious concerns about the role of open vegetation fires in the climate-altering species. This study reviews current methodologies for quantifying greenhouse gas and black carbon emissions from open vegetation fires and examines the data provided by four state-of-the-art inventories of carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O) and black carbon (BC) in the Mediterranean region from 2003-2020.

Only a limited number of studies have addressed the quantification of emissions from open fires in this region. Our review revealed discrepancies among the four inventories (GFED v4.1s, GFAS v1.2, FINN v2.5, and EDGAR v8.0). FINN v2.5 consistently reported the highest emissions, while GFED v4.1s reported the lowest. The relative ranking of total emissions varies by species (e.g., CO2 vs. CH4), and different proportions are attributed to the countries within the Mediterranean domain. These differences arise from variations in the spatial resolution of fire detection, the approaches to estimating fuel loads, and emission factors applied.

The three inventories that reported wildfire emissions identified consistent peaks in 2007, 2012, and 2017. These peaks are likely linked to extreme fire seasons and may have been influenced by La Niña events. To improve the accuracy and consistency of emission estimates for the region, we recommend combining bottom-up methods with the top-down approaches based on satellite and in situ atmospheric observations.

Keywords: wildfires, Mediterranean, emission inventories

Mountain Intercomparison of Radon Analyzers (MIRA)

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The main objective of this project was to assess the reliability and suitability of Pylon detector (TEL model) Rn analyser for scientific applications, particularly in complex mountain environments. This evaluation was carried out within the ITINERIS TNA Access, with the specific goal of testing the performance of the Pylon detector coupled with the Radon Mapper Monitor developed by Tecnavia/Mi.am (Italy).

To achieve this, an intercomparison campaign was conducted with the reference radon detector operated at the high-altitude research station of Jungfraujoch (JFJ, 3454 m asl), Switzerland, representative of free troposphere and mountain environments. The campaign took place in July 2025 and combined physical access for installation and dismantling with remote access for continuous monitoring and real-time data collection.

This activity builds upon the experience gained at Ottavio Vittori Observatory, Mt. Cimone (Italy, 2165 m asl), where a similar Pylon detector (TEL model) coupled with a Radon Mapper Monitor unit has been operating continuously since 2023.

In addition to validating the instrument's performance at JFJ, this comparison with the reference detector provides an opportunity for cross-validation across sites characterized by different altitudes and atmospheric dynamics, thus strengthening the reliability of radon observations in diverse mountain contexts. Besides the technical characterization of instruments, the field campaign offers a good opportunity to conduct a comparative study on the influence of PBL dynamics on the free troposphere of two European mountain sites, both referring to ACTRIS and ICOS RIs.

All data generated during the campaign will be stored in the ITINERIS HUB repository, ensuring compliance with FAIR principles (Findable, Accessible, Interoperable, Reusable), and will be integrated into the CNR-ISP mountain hub catalogue to support future research and data sharing initiatives.

Keywords: Atmospheric radon, Instrument intercomparison, Mountain observatories

Datasets, methodologies and indicators for open-fire emission studies

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Open fires represent one of the most influent events on ecosystems, climate, and human health. Their study is a challenging research topic, set to lead to a better understanding of their impact.

The ITINERIS project allowed us to empower and strengthen the observation capability of the main chemical-physical parameters involved in open fire events, via the implementation of new instruments and methodologies. The purpose of this presentation is showing some results obtained, during the project ITINERIS, as synthesis of a comprehensive elaboration and evaluation of the most important parameters influencing climate such as combustion outputs from open fire phenomena and their intercorrelation to identify local and long range important events influencing our observational site.

In this work, we describe two types of datasets released by our research team, accounting for: wind speed and direction profiles useful for possible direction of detected fire products, stable carbon isotope measurements of carbon dioxide ($\delta^{13}C\text{-}CO_2$) and methane ($\delta^{13}C\text{-}CH_4$) to differentiate the nature of mass-burning, and summer 2025 ITINERIS open fire campaign (in preparation).

The existing long-term observations at LMT allow us to determine a new methodology for "blind" background greenhouse gases determination to be applied in different site (*e.g.* coastal, rural), as base of background values meant to isolate peaks and better identify outliers, and data exceeding select thresholds. Via these filters, it is possible to identify pollution events.

Integrated methodologies for forest fire detection applied at the Lamezia Terme (LMT) site are also applicable to other sites, with minimal adjustments depending on the specific characteristics of each site these methodologies are applied to.

Keywords: Greenhouse gases, aerosol, open fire, background values, isotopic measures

Simultaneous advection of volcanic ash and desert dust in Naples Mediterranean aera

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The volcanic aerosol plume following the paroxysmal event of Mount Etna on 2nd June 2025 was detected and characterized in the Mediterranean area of Naples city (Italy), together with transported Saharan dust, using remote sensing and satellite observations in combination with back-trajectory and dispersion model simulations.

Lidar profiles obtained using an Elastic/Raman system of the Naples National Facility of the ACTRIS Research Infrastructure were acquired from 3rd to 5th June 2025 and analysed together with aerosol column properties derived from sun-sky-lunar-photometers of the AERONET network.

Vertically resolved lidar data allowed clearly distinguishing the main atmospheric aerosol components by means of the spectral dependence of their optical properties, which permit a detailed aerosol characterization.

Satellite data of sulphur dioxide from Copernicus were used to track plume dispersion in the atmosphere from Mount Etna to Naples, in combination with HYSPLIT back-trajectories, confirming the transport of sulphur dioxide over the measurement area.

The obtained results demonstrate how the combination of a multi-parametric lidar with other instruments and techniques allows gaining a clear classification of the atmospheric aerosols, even for multilayered atmospheric conditions.

Moreover, the analysed case study highlights the complexity of the Mediterranean aerosol environment addressing the effectiveness of combining observational measurements and modelling.

Keywords: Etna Activity, Remote Sensing, Long-Range Transport

Topic 3

Marine domain

The ITINERIS' EYES oceanographic cruise: InTegrating, INnovating, Evolving Research InfraStructures for hEalthY and predicted marine ecosystemS

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ITINERIS' EYES is an inter-disciplinary research cruise designed to tackle the health of Mediterranean planktonic ecosystems, and improve their predictability, through multi-platform experiments acquiring several ocean, climate and biodiversity Essential Variables (EVs). The approach of ITINERIS' EYES is to leverage on the technological contribution of 11 European and national Research Infrastructures (RIs) operating in the marine, atmospheric and biodiversity domains in the framework of the ITINERIS project, the Italian Integrated Environmental Research Infrastructures System (https://itineris.cnr.it/): EURO-ARGO, EMSO, ICOS, ACTRIS, DANUBIUS, EUROFLEETS, JERICO, eLTER, DISSCO, SIOS, and LNS.

The mission of ITINERIS' EYES has been designed to advance our understanding of Mediterranean marine planktonic ecosystems, their biodiversity, functioning and adaptations to climate change. The cruise also aimed to improve our ability to predict the behaviour of marine ecosystems in four dimensions (4D) by addressing gaps in data collection of EVs, also thanks to the deployment of autonomous platforms that are collecting data in scarcely observed areas. Besides, data collected by various RIs' technologies have been integrated and made FAIR; while fostering capacity building of RIs and promoting activities of science communication.

ITINERIS' EYES has been carried out on board the CNR's R/V Gaia Blu between 8th to 30th of July 2025 by 31 units of scientific and technical personnel (61% of ITINERIS's recruited personnel and early career). We have encompassed the Western Mediterranean Sea, across the Tyrrhenian Sea, the Sardinia Channel, the Algero-Provençal basin and the Ligurian Sea. About 80 autonomous Argo floats and lagrangian drifters have been deployed in multi-platform experiments to extend our observation capabilities beyond the cruise.

Here, we will present the cruise, achievements and preliminary results. The efforts pursued to efficiently integrate RIs at sea and how this will be reflected into the marine IT-IOOS will be discussed.

Keywords: Marine, Gaia Blu, Multi-platform

The Ocean Sound monitoring Sub-system

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In the framework of ITINERIS, Laboratori Nazionali del Sud (LNS) of Istituto Nazionale di Fisica Nucleare (INFN) is leading the implementation of the Ocean Sound Subsystem (OS-SS), part of the ITalian Integrated Ocean Observing System (IT-IOOS), will establish for the first time a national-level integrated platform with standardized procedures, guidelines, and tools for collecting, analyzing, and sharing ocean sound data in accordance with best practices.

The main purpose of OS-SS is to expand the accessibility and usability of acoustic data in marine environment for multiple applications, like monitoring acoustic pollution, search for soniferous marine species, identifying surface and underwater vehicles, and studying geological events like earthquakes. This initiative will also define and disseminate a set of recommendations and best practices for collecting, analyzing, and distributing ocean sound data among all the Research Infrastructures (RIs) operating acoustic devices in Italian waters. Furthermore, the OS-SS is transversal, providing services and information from/to multiple IT-IOOS RIs to produce ocean sound data and time series from recorded raw acoustic data. To ensure data transparency, each dataset produced by ITINERIS RIs will be accompanied by a corresponding metadata set. Metadata play a key role by providing the contextual details required to interpret primary data, including information such as time, location, and collection methods. This contextualization is crucial for ensuring the reproducibility of scientific results, forming a fundamental pillar of scientific advancement.

Acoustic data from INFN – LNS subsea assets are now released in the project through an Environmental Research Division's Data Access Program (ERDDAP) server. In this contribution, an overview of the project is discussed, and an example of preliminary analysis of ambient noise monitoring will also be presented.

Keywords: IT-IOSS, OS-SS, Passive acoustic monitoring

From project to ocean: First ITINERIS glider-based insights in the Ligurian sea

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The ocean regulates Earth's climate, sustains biodiversity, and supports key human activities such as fisheries, transport, and coastal economies. Monitoring these complex systems requires continuous and reliable observations of "Essential Ocean Variables" (EOVs). Marine gliders—autonomous vehicles that move by changing buoyancy—are increasingly used to collect EOV data due to several advantages. They provide long-term, persistent monitoring at lower cost than ship-based surveys, can operate in difficult or remote areas, and deliver high-resolution water column measurements. Unlike fixed buoys or satellites, gliders follow planned routes and transmit data in real time, improving early warning systems for environmental events. As such, they are key components of the global ocean observing system, contributing to climate models, weather forecasts, and sustainable resource management.

Two glider campaigns—AMBO25 and EYES ON GLIDERS—were carried out in the Ligurian Sea in April and July/August 2025 using SEAEXPLORER platforms acquired under ITINERIS project to support the JERICO research infrastructure. The AMBO25 mission (almost 17 days) deployed the SEA113 glider "Morgana" along a 10 km transect near Deiva Marina. Equipped with CTD, dissolved oxygen, and bio-optical sensors, the glider recorded the ocean response to strong winds and harsh weather conditions. An episode of intense fishing activity was also reported in the area toward the end of the campaign.

The EYES ON GLIDERS campaign was run in parallel with the Gaia Blue R/V Campaign and deployed SEA112 ("Pandora") and Morgana. Morgana followed a 70 km × 60 km L-shaped transect starting from the Arenzano area, while Pandora performed a similar transect near Chiavari, including current and turbulence sensors. Morgana operated for ~20 days, whereas Pandora completed only 4 days due to technical issues. These early campaigns demonstrate the suitability of the new JERICO gliders for multi-scale EOV observations and enhanced assessment of coupled physical–biogeochemical processes.

Keywords: Ocean gliders, EOV observations, Research Infrastructures.

Strengthening Long-Term ecological observations in marine and transitional eLTER sites through the ITINERIS project

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eLTER-RI is a pan-European in-situ Research Infrastructure whose mission is to study long-term ecological changes in terrestrial, freshwater, coastal and transitional ecosystems through a holistic "whole system" approach, based on the integration of different environmental disciplines, to understand the role and interactions of multiple and complex ecosystem variables. The Italian network, LTER-Italy (https://ror.org/05ma8mw15), includes over 60 research sites nationwide. Through the ITINERIS project, a subset of marine and transitional water sites has been significantly enhanced with new instrumentation and improved observation strategies. Key improvements in the monitoring of biological Essential Variables have been achieved. In particular, innovative technologies allow for the mapping and real-time observation of key groups such as fish and gelatinous macrozooplankton, using imaging systems integrated with Automatic Identification Systems (AIS). Automation of biological data acquisition has also advanced, through instruments such as cytometers and ZooScan, enabling high-resolution monitoring of phytoplankton and zooplankton and supporting broad taxonomic identification. The project further supported the deployment of shared instrumentation across multiple marine and transitional sites to improve data comparability and foster synergies between different basins and regions, enabling coordinated observations across the eLTER network. Integration and enhancement of sensors for physical-chemical parameters strengthened the connection between oceanographic and biological/ecological data, supporting more comprehensive ecosystem assessments. Finally, the LTER-Italy network Digital Asset Registry (LTER-Italy DAR - https://dataregistry.lteritalia.it) was implemented, providing data and metadata sharing through services based on international standards and compliant with eLTER-RI specifications. These developments represent a significant step forward the implementation of long-term, interoperable, and multi-variable ecosystem observations, aligning with eLTER-RI's vision and ITINERIS goals, while establishing a foundation for enhanced marine ecosystem monitoring and research coordination.

Keywords: long-term series, marine and transitional waters, ecosystems

Advancing the integration of monitoring and modelling of the physico-chemical and biogeochemical state of the Marano and Grado Lagoon (Italy)

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This study investigates the physical-chemical and biogeochemical dynamics of the Marano and Grado Lagoon (northern Italy) using a combination of observational data and simulations from the coupled SHYFEM-BFM model. A data assimilation approach is applied to integrate monitoring information into the model, improving the representation of lagoon processes. Model outputs are validated against in situ measurements and previous studies, showing strong agreement for water level and temperature, and good performance for salinity. Dissolved oxygen and nitrate also match observed spatial and seasonal patterns, while chlorophyll-a and phosphate are more variable, with location-dependent discrepancies. These limitations highlight the need for improved monitoring data, which will be provided by the new MALO network developed under the ITINERIS project, and that will contribute to the DANUBIUS infrastructure. MALO includes four instrumented buoys with CTDs measuring temperature, conductivity, pressure, chlorophyll-a, turbidity, and dissolved oxygen. Five ADCPs at lagoon inlets provide current profiles, and a nutrient analyser with integrated CTD complete the system, offering continuous, high-frequency data to strengthen the integration of monitoring and modelling.

A preliminary test of a modified nudging technique within SHYFEM assimilated salinity data from existing probes in the western lagoon, originally installed for hypoxia/anoxia monitoring. While assimilation improved model performance, some discrepancies remained due to probe limitations. Assimilation of higher-quality MALO data is expected to enhance accuracy further once the network is fully operational.

Scenario simulations explored the lagoon's response to nutrient load variations. Phosphate, nitrate, and ammonia inputs from rivers were altered by ±50%, and additional simulations doubled and quadrupled these inputs. The resulting spatial distributions are compared with literature data, highlighting seasonal ecosystem responses and the lagoon's sensitivity to nutrient changes. These findings are key for informing nutrient management strategies aimed at achieving water quality targets.

Keywords: environmental dynamics, numerical simulations, coastal lagoon

Upgrades to the Italian Marine Research Observatory in the Arctic Region

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The Institute of Polar Sciences (ISP) of the Italian National Research Council (CNR) actively contributes to the overall goals of the Global Ocean Observing System Italy by participating in the Svalbard Integrated Observing System (SIOS) through the national marine infrastructure in the Arctic region. This infrastructure consists of four moorings positioned at various coastal and offshore (Co-managed by ISP-CNR and OGS) sites, enabling the observations and analysis of both short- and long-term oceanographic processes essential for monitoring and understanding the Arctic environment and its change over time. In the framework of the Italian PNRR project ITINERIS, the Italian Marine Observatory in the Arctic region has significantly upgraded the number of Essential Ocean and Climate variables observed. A new coastal facility in the Kongsfjord jointly managed by ISP-CNR and INM-CNR was installed and real-time data transmission capabilities from the Arctic were developed, together with a data management workflow fully compliant with FAIR (Findable, Accessible, Interoperable, and Reusable) principles. The expansion of Essential Ocean and Climate Variables now emphasizes new biogeochemical and biological parameters. Additionally, the new coastal facility features an innovative automated seawater sampler designed for biodiversity assessment through metagenomic analysis. These upgrades are intended to serve the international scientific community by providing future access and supporting the primary objective of advancing knowledge about the current and future state of the Arctic ecosystem, a key component of the global climate system.

From Nets to Imaging: Towards Next-Generation Zooplankton Monitoring in ITINERIS

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Zooplankton plays a fundamental role in marine food webs and biogeochemical cycles. However, its diversity and dynamics remain challenging to assess, primarily due to the high taxonomic complexity and pronounced spatial-temporal variability of planktonic communities.

Traditional methodologies, based on plankton net sampling and stereomicroscopic identification are the standard approach for achieving species-level taxonomic resolution and ensuring the comparability of datasets. Nevertheless, these methods are time-consuming, require a high level of taxonomic expertise, and may underrepresenting taxa that are rare or fragile.

To address these limitations, within the framework of the PNRR ITINERIS project, we explored innovative technologies for zooplankton monitoring in coastal and offshore environments, embedding this approach within the Long-Term Ecological Research (LTER) network and the Distributed System of Scientific Collections (DiSSCo) infrastructure.

A dedicated test approach was implemented during the ITINERIS' EYES oceanographic cruise carried out on board CNR's R/V Gaia Blu in July 2025 where the Underwater Vision Profiler 6 (UVP6) was installed on the CTD rosette and successfully operated in situ. This setup allowed the acquisition of vertical profiles of plankton abundance, size spectra, and particle fluxes, providing high-resolution insights into the spatial distribution of organisms directly in the water column. In parallel, ZooScan and FlowCam will be employed for laboratory-based image acquisition, enabling semi-automated classification and quantification of zooplankton samples collected with the WP2 net. The integration of machine learning algorithms further enhanced the efficiency and consistency of image-based identification.

Preliminary results confirm that combining classical and innovative approaches improves the robustness of biodiversity assessment: traditional taxonomy provides ground-truthing and species validation, while imaging systems expand throughput, standardization, and long-term interoperability of data across sites and infrastructures. Here, we present evidence that integrating advanced technologies within several research infrastructures enhances efficiency, scalability, and reproducibility in zooplankton biodiversity assessment, supporting community studies under changing environmental conditions.

Keywords: Zooplankton, Imaging Technologies, Biodiversity Assessment

IT-IOOS: how to integrate multi-source digital data and their near real time processing for management phases

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Italy is actively involved, through the promotion and guidance of marine research infrastructures (RIs), to contribute to the European strategy for ocean observation and the ESFRI roadmap. Each RI works autonomously and independently of the others, defining its own rules for access to data and services. This makes access to national marine data complex and fragmented. It is in this panorama that the IT-IOOS was designed, a national platform for the harmonisation of national contributions to marine RIs. IT-IOOS is part of a process of integration of multi-source digital data and their near real time processing for management phases. The system is structured on the concept of 'information modelling' to accommodate and manage real physical data on the digital twin and remotely provide all that is needed for decision-making, in ordinary and emergency conditions. They have long since found use and widespread use in a wide variety of sectors, taking the form of genuine decision support and planning systems.

Thanks to the development of WebGis software, it has now become much easier to share this type of information with a potentially unlimited number of users. The objective of a WebGIS DSS (Decision Support System) and the digital twin of the ocean as what-if-scenario is therefore to collect, transform and disseminate information in an 'intelligent' way, to help the user make decisions, without however substituting itself for the user; in fact, the decision is obtained by combining human evaluations with the information processed by the system. The IT-IOOS aims to coordinate national observations to improve the quality and interoperability of ocean data (including freshwater river outflows) for three critical topics: climate, operational services and marine ecosystem health. IT-IOOS is designed to incorporate and augment existing ocean observation capabilities through the integration and harmonisation of observations made by RIs.

Keywords: Data Access Portal, Data integration, Marine infrastructures

Towards Interoperable Ocean Observations :

Demonstrating Cross-Infrastructure Integration in the South Adriatic

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Within Work Package 5, Activity 5.20 is dedicated to demonstrating the advantages of cross-infrastructure data integration, combining both Eulerian and Lagrangian observations to generate a comprehensive spatial and temporal overview of key ocean variables. By merging datasets such as temperature, salinity, and oxygen from multiple research infrastructures (including stand-alone moorings, surface buoys, shipboard measurements, Argo surveys, etc.) the activity aims to provide integrated and multidisciplinary insights that advance our understanding of open-sea processes. This integrated approach not only improves scientific knowledge but also strengthens the capacity to develop effective strategies for ocean conservation and sustainable management. A prototype system has been developed to showcase these benefits, highlighting the added value of harmonising observations across infrastructures.

The South Adriatic test site, long recognised for its continuous time series and strategic role in regional circulation studies, was selected as the reference area for this activity. Under ITINERIS, the site has been enhanced with additional instruments and new sensors, further expanding its monitoring capacity. This multidisciplinary campaign was designed and implemented in line with the objectives of Task 5.20 and Deliverable 5.16, and brought together major European research infrastructures (RIs) including EMSO, Euro-Argo, ICOS, and Eurofleets.

The adoption of best-practice methodologies in this cross-infrastructure campaign enabled the alignment of observational strategies and facilitated seamless data integration. Results from the South Adriatic case study demonstrate how coordinated efforts across RIs strengthen interoperability, enhance data quality, and maximise scientific return. Ultimately, this initiative illustrates the potential of collaborative, multi-platform ocean observation to address critical scientific and societal challenges within the framework of European marine research.

Keywords: Cross-Infrastructure, South Adriatic, Research Infrastructures

Topic 4

Terrestrial Biosphere domain

Comparative Analysis of Enterococcus spp. from Conventional and Organic Farms: Impact of Antibiotic Use on AMR Profiles

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Antimicrobial resistance (AMR) represents a growing global threat with significant implications for both human and veterinary health. Among the microorganisms commonly associated with AMR, *Enterococcus* spp. play a relevant role. As commensals of the gastrointestinal tract in humans and animals, they are known for their ability to acquire and transfer resistance genes, thus contributing to the spread of AMR along the agri-food chain. In addition to intrinsic resistance to several antibiotic classes (e.g., cephalosporins, sulfonamides, lincosamides), enterococci can acquire resistance to vancomycin, macrolides, glycopeptides, and aminoglycosides, making them important indicators in AMR surveillance programmes.

This study aimed to compare the AMR profiles of enterococci isolated from three dairy farms selected based on their antibiotic use: high, low, and no use (organic). Sampling was conducted between 2023 and 2024 on environmental matrices (milking parlour, manure pit, bedding) and bulk milk. Identification by MALDI-TOF MS revealed multiple *Enterococcus* species. *E. faecalis* and *E. hirae* were most prevalent in the low-use (37.5%, 18.5%) and organic farm (29.7%, 24%). *E. malodoratus* was more frequently isolated from the farms using antibiotics (22% and 18%), while *E. canintestini* (20%) appeared exclusively in the high-use farm, suggesting a link between antibiotic pressure and microbial community composition.

E. hirae, the most widespread in environmental samples across all farms, was selected for whole-genome sequencing using the Oxford Nanopore GridION platform to identify AMR genes and mobile genetic elements (plasmids, transposons, integrons). Preliminary results revealed the *aac(6')-Iid* gene in 90% of isolates, encoding an aminoglycoside N-acetyltransferase conferring resistance to some aminoglycosides (streptomycin, tobramycin).

These findings highlight the potential role of *E. hirae* as an environmental AMR reservoir. A complete AMR profile analysis of dominant species will help clarify their contribution to AMR gene dissemination along the dairy chain.

Keywords: AMR, Enterococcus, antibiotics

Cross-RI dataset provision of UAV multi platform hyperspectral data and site level measurements over different RI ecosystem sites (eLTER, ICOS, ANAEE) and comparison with satellite products.

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This work proposes frameworks to improve vegetation monitoring using airborne and satellite remote sensing imagery. Remote sensing enables rapid, georeferenced assessments of crops and ecosystems based on the spectral properties of canopy components. However, traditional approaches, such as vegetation indices rely on empirical methods that use few spectral bands, limiting their ability to estimate plant traits. Additionally, image interpretation is affected by sensor-specific factors (e.g., spatial/spectral resolution), acquisition geometry, and atmospheric conditions. Coarse-spatial resolution can result in mixed spectral signatures, particularly in heterogeneous landscapes. Our approach addresses these limitations through physically based processing strategies.

This study presents a hybrid approach for crops and forests monitoring integrating canopy reflectance spectra simulated with radiative transfer models, like PROSAIL with remote sensing images using machine learning. This method enables estimation of plant traits, such as chlorophyll content, Leaf area index or water content, considering all bands and minimizing external factors. This study also presents the integration of airborne images for unmixing spectral signatures in coarse-spatial resolution satellite images using multiple endmember spectral mixture analysis (MESMA).

The hybrid model showed accurate results in agricultural scenarios, including i) identification of nitrogen (N) treatments and early N status estimation, ii) distinguish between traditional and intensive olive orchard management practices with satellite time series, and iii) detecting periodical cuttings of alfalfa forage production to maximize yield and quality. The model also displayed good results in forest ecosystems by i) estimating Gross Primary Productivity in European forest types combining plant traits and by ii) early detection of a fungus outbreak in a pine forest. The use of a spectral library obtained with high-resolution aerial images allowed unmixing spectral signatures in PRISMA satellite products for urban and rural landscape planning. Overall, this work refines and validates remote sensing modelling techniques to enhance decision-making in vegetation management and territorial planning.

Keywords: Remote sensing, Radiative transfer models, Multiple endmember spectral mixture analysis.

Assisted regeneration of *Quercus robur* (L.) from laboratory to the field in the Castelporziano Presidential Estate (Roma, Italy)

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The restoration of fragile Mediterranean ecosystems is crucial to maintaining biodiversity and ecological stability. Deciduous oak forests are experiencing severe decline due to climate change, oak dieback, and low natural regeneration rates. Among environmental drivers, radiation is one of the most important meteorological variables measured in terrestrial ecosystems, as it regulates photosynthesis, plant growth, and forest regeneration. Our research aims to enhance regeneration success by combining vegetative propagation techniques with ecophysiological monitoring of light dynamics in Castelporziano, a Mediterranean biodiversity hotspot near Rome.

The first objective focuses on vegetative propagation through epicormic shoot induction from *Quercus robur* branches. Statistical analyses demonstrated that genotype and nodes significantly influenced shoot emergence, while the effect of branch diameter was not statistically significant.

The second objective aims to examine the impact of light dynamics on *Quercus robur* regeneration in Castelporziano, investigates how fluctuating light regimes affect seedling physiology and regeneration. Continuous high-frequency measurements of photosynthetically active radiation (PAR) are being conducted in both Castelporziano and greenhouse at Tuscia University using a network of calibrated quantum sensors.

Controlled light treatments simulated sunfleck patterns, and physiological responses are assessed through gas exchange and fluorescence measurements, under variable light conditions using (LI-6800 Portable Photosynthesis System), to evaluate dynamic response of the photosynthetic, water use efficiency, and interactions with water stress. Preliminary results indicate that seedlings exposed to dynamic light conditions exhibited improved photosynthetic and water-use efficiency compared to those under constant shade. Further analyses will be carried out after completing the data collection for radiation dynamics measurements, assessing leaf morphology and growth responses.

This integrated approach, combining biotechnological techniques and ecophysiological monitoring, aims to provide guidelines for assisted regeneration of *Quercus robur* in Castelporziano. Our findings will support adaptive forest management, conservation, and reforestation strategies to enhance the resilience of Mediterranean oak ecosystems under changing environmental conditions.

Keywords: Regeneration, Light dynamics, *Quantum sensors.*

Plant growth-promoting rhizobacteria as a sustainable method to enhance drought tolerance in tomato crop

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Biostimulants are emerging as sustainable strategies to improve crop tolerance to drought. We investigated the effects of two plant growth-promoting rhizobacteria (PGPR) strains cable of modulating plant stress hormones: *Serratia odorifera*, a producer of 1-Aminocyclopropane-1-Carboxylate (ACC)-deaminase that inhibits stress-induced ethylene formation, and *Pseudomonas sp.*, a producer of Indole-3-acetic acid (IAA). Experiments were conducted using *Solanum lycopersicum* L. grown under well-watered and water-stressed treatments in both pot and field conditions. Plants were inoculated with a mixed PGPR consortium (MIX) prior to the onset of water stress in both experimental settings. We evaluated the interaction between water treatments and PGPR inoculation by measuring plant growth, gas exchange, chlorophyll fluorescence, abscisic acid (ABA) content, biometric traits, and rhizosphere composition. In the pot experiment, MIX-inoculated plants under water stress increased photosynthesis (A), A/C_i (intercellular [CO_2]) curve parameters (A_{max}, J_{max}, V_{cmax}), and stomatal conductance compared to non-inoculated, water-stressed plants. These results highlight the synergistic potential of ACC-deaminase and IAA-producing PGPR in enhancing drought tolerance under controlled conditions. In contrast, results from the first year of the field experiment, where a one-time inoculation was applied at flowering, showed no significant improvement in gas exchange or yield under water-limited conditions. However, under full irrigation, inoculated plants showed increased A and stomatal conductance during advanced fruiting. Additionally, leaf area index and plant height significantly increased in MIX-treated plants in both water treatments. Consequently, water availability remained the primary determinant of physiological and productivity responses, as the low fitness of the inoculated PGPR likely limited their persistence in the field. To address this constraint, a second-year experiment is underway using repeated PGPR applications throughout the crop cycle to assess the effects of inoculation frequency and timing. These findings underscore the complexity of translating PGPB efficacy from controlled to field conditions, where environmental variability and microbial fitness strongly determine outcomes.

The research was conducted using the advanced digital technological platforms made available through the Itineris project. We gratefully acknowledge the skilled and professional contributions of the following researchers, whose efforts made this study possible: Francesca Alderotti, Cecilia Brunetti, André Daccache, Donatella Danzi, Adriano Conte, Maddalena Grieco, Matthew Haworth, Valentina Lazazzara, Giovanni Marino, Vincenzo Montesano, Valeria Palchetti and Aida Raio.

Keywords: Sustainable agriculture; drought; PGPR

DiSSCo–ITINERIS: Digitizing Foraminiferal Collections for Biodiversity and Environmental Monitoring in the Mediterranean

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Within the DiSSCo infrastructure and ITINERIS project, two reference benthic foraminiferal (BF) collections from the Institute of Marine Science have been harmonized and digitized: the *Linosa Sicily Channel Collection* (LiCSiC) and the *North Adriatic Foraminifera Collection* (NAdFC). As BF are key bioindicators, these collections with their FAIR digital datasets, serve as valuable archives for Mediterranean biodiversity monitoring, environmental quality assessment, and the reconstruction of ecological baselines.

LiCSiC comprises 13 micropaleontological slides containing BF from sediment samples collected around Linosa Island, an ecological area featuring a variety of benthic habitats designated as a priority area under the EU Directive. With a total of 2,755 catalogued specimens, 140 identified BF species, plus a digital image dataset of selected taxa linked to the seabed texture and lithology, LiCSiC reflects the high biodiversity of this marine region. Notably, the collection includes the Indo-Pacific invasive alien species *Amphistegina lobifera*, thriving in shallow waters below 20 meters at temperatures above 14°C, introduced into the Mediterranean via the Suez Canal and whose spread is linked to climate change.

NAdFC originated from benthic ecosystem biomonitoring conducted since 2016 at the LTER Site "Delta del Po e Costa Romagnola" in the North Adriatic, a region shaped by the interplay of natural drivers and anthropic impacts. Digitization, and taxonomic revision produced ~6,000 catalogued specimens across ~100 taxa, including *Virgulinella fragilis*, a non-indigenous species associated to oxygen fluctuations and introduced via shipping. Integration of BF and environmental data revealed that BF diversity is strongly influenced by sediment depositional events (e.g., riverine discharge, storm episodes), offering insight into ecosystem monitoring in this impacted coastal zone.

These case studies demonstrate how the digitization and standardization of BFcollections under DiSSCo-ITINERIS enhance data interoperability and reusability. This facilitates the analysis of biodiversity trends, identification of environmental drivers, and detection of invasive species, ultimately supporting marine biodiversity research, environmental health assessment and conservation efforts. Moreover, they highlight the pivotal role of data infrastructures in guiding policy-making and ecological management.

Keywords: Marine Biodiversity, Foraminifera, Environmental Assessment

Mobilising biodiversity data: results and outputs

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The ITINERIS project (WP6 6.4 activity) supported DiSSCo's vision by prioritising digitisation of Natural History Collections to enable access to biodiversity data.

The resources were primarily allocated to infrastructural works and acquisition of equipment to carry out and support digitisation activities. Three fixed-term technicians were hired to handle the digitisation of both zoological and botanical specimens, focusing mainly on the collections of Florence University Museal System (UNIFI-SMA) and then on a major entomological collection at the University of Naples Federico II through a digitisation campaign. The photographic tools have also been made available to interested institutions holding natural history collections by means of loan agreements, in order to extend digitisation activities throughout Italy. Furthermore some equipment was shared with four fellowship holders involved in a parallel digitisation project funded by the National Biodiversity Future Center (NBFC), leading to the digitisation of a further quota of botanical and zoological collections at UNIFI-SMA.

As part of the project, free training courses on the digitisation of natural history collections were offered to curators from other institutions, with the aim of promoting and encouraging digitisation.

The target of 300,000 digitised specimens and 90,000 transcribed labels has been reached and exceeded, specifically 397,496 biological specimens have been imaged by internal staff and filed at Minimum Information on Digital Specimen level 1 (MIDS1) and partially 2 (MIDS2). This process brings "collateral benefits" to the collections and will make the work of the curators easier.

Thanks to CNR-IBBR-BA as a host, we were able to start the publication of the datasets arranged in Darwin Core standard according to the guidelines for the "Occurrences-type" dataset in the GBIF portal. The publication on GBIF continues, making a wealth of data on specimens truly open and fair.

Keywords: natural history collections, digitisation, open data

A vegetation survey on woody species encroachment of abandoned pastures in the Alps

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The research focuses on the investigation on how climatic and socio-economic shifts drive woody species encroachment into mountain grasslands, altering carbon sequestration patterns and contributing to ecosystem changes.

In recent decades, the investigated area in the Aosta Valley region has seen the transition towards the abandonment of pastures by grazing livestock, below the forest line (~1500 meters asl), a widespread occurrence in the alpine region.

The dynamics of the regrowth of shrub and tree vegetation on this mountainous terrain is inevitably influenced by climate change and therefore it represents an observatory and sentinel of the impacts of global climate change in the transition towards the restoration of a pre-anthropic state.

The activities were carried out at the ICOS associated site Torgnon (IT-Tor), an abandoned subalpine pasture located at about 2100 m asl. An area of 15000 square meters was selected in the pasture, which is undergoing recolonization by larches (*Larix decidua*) and shrubs. Since 2015, periodic surveys (2015, 2018, 2021, and 2024) were conducted to monitor vegetation dynamics. Employing a *GNSS system* we mapped larch tree locations, measured trunk diameters, heights, and crown dimensions, and documented associated shrub growth. Also, *UAV aerial images* of the area were collected annually through drone images.

Moreover, continuous measurements of CO_2, water fluxes, and meteorological variables are available at the site since 2008. To further evaluate ecosystem fluxes, an additional eddy covariance station was installed in October 2024 in the encroached area and preliminary flux measurements will be presented.

Overall, results highlight an ongoing shift from grassland to woody vegetation, that affect carbon and water dynamics.

This research underscores the critical role of *LCLU* changes in shaping present and future global vegetation dynamics and carbon sinks, that need to be considered to improve our understanding and modelling of ecosystem carbon cycle.

Keywords: abandoned mountain grasslands, woody species encroachment, Larix decidua

Monitoring of GHGs fluxes at "Le Viote" alpine peatland (Italy) by smart chamber system in a climate change context.

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The aim of this study is to determine the temporal and spatial variation of fluxes of two greenhouse gases (GHGs), CH_4 and CO_2, at "Le Viote" alpine peatland (Trentino, Italy) using a closed dynamic chamber-based system consisting in a smart dark chamber (LiCor 8200-01) and gas analyser (LiCor 7800), characterizing their response to their main climatic and anthropogenic drivers. Climatic trends were retrieved from local stations of the Meteotrentino network and analysed at different scales (daily, monthly, seasonal and annual). Air temperature and precipitation showed great scale-dependent variability, with an increasing trend on an annual scale: 0.06 °C/year for air temperature ($P<0.0008$) and 9.68 mm/year for precipitation, yet not significative. Regarding GHG fluxes, the peatland showed a great spatial variability among the 6 examined different vegetation types, which generally correspond to differences in soil moisture and microtopography. Flux measurements were performed in August 2024 and continued since May 2025. All plots were found to act as GHG sources with great variability based on vegetation type: GHG emissions ranged from a minimum of 12.21 $\mu gCO_2eqm^{-2}s^{-1}$, which corresponds to a tussock (*Carex fusca* and *Deschampsia caespitosa*) coverage, to a maximum of 1448.63 $\mu gCO_2eqm^{-2}s^{-1}$ in a predominantly grassland covered (*Sieversio-Nardetum strictae*) plot. CO_2 fluxes ranged from 0.27 $\mu molm^{-2}s^{-1}$ in a tussock plot to 32.97 $\mu molm^{-2}s^{-1}$ in a grassland plot. CH_4 fluxes instead ranged from a minimum of -3.75 $nmolm^{-2}s^{-1}$ over grassland, denoting its GHG sink activity, to a maximum of 1350.48 $nmolm^{-2}s^{-1}$ in a *Caricetum rostratae* plot. This strong CH_4 source is located in one of the wettest areas of the peatland, where CH_4 emissions reach up to 60% of total CO_2eq fluxes. Soil moisture is highly variable across plots and impacts the ratio between CH_4 and CO_2 fluxes with lower CO_2 flux contributions to GHG emissions associated to higher soil moisture levels.

Keywords: GHG fluxes, climatic variables, alpine peatland

Topic 5

Geosphere / Landsurface domain

Enhanced workflows and algorithms for rock mass characterization: the Passo della Morte test site

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The main goal of the ATLAS IR (Advanced Technologies for Landslides Research Infrastructure), developed within the ITINERIS project, is to implement workflows, algorithms and a data management platform capable of integrating multiple heterogeneous datasets to support operations during emergency situations related to geo-hazards. Among the various types of landslide phenomena, this study focuses on recent activities related to rock mass characterization. To enhance ATLAS IR's capabilities in assessing and monitoring potential rockfall events, all instruments acquired during the ITINERIS project were tested at the Passo della Morte test site (Udine). Several datasets, including displacement maps, point clouds, images and meteorological data, were collected using both passive and active sensors. These datasets have been integrated and visualized within the ATLAS platform. In terms of rock mass characterization, we implemented methodologies to generate three-dimensional models of the studied area, from outdoor slopes to indoor spaces, by merging ground-based and mobile mapping data. These models serve as a foundation for more advanced analyses typical of engineering geological studies. Furthermore, we are developing algorithms to extract geometric properties of the rock mass, with a focus on fracture trace detection and characterization of open fractures. These include measurements of discontinuity aperture such as area, perimeter and width, which are automatically extracted from two-dimensional images and subsequently draped onto the previously created three-dimensional models.

Keywords: Rock mass characterization, geomatic survey, 2D image processing

Scientific drilling infrastructure: improved access and progress in digital archiving of samples and data

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The Italian scientific community can access scientific drilling and coring data mainly through the participation in two long lived international programs that are part of the Piano Nazionale Infrastructure di Ricerca (PNIR 2021-2027): The International Ocean Drilling Programme (IODP[3] and its precursors), through the European Consortium for Ocean Research Drilling (ECORD), and the International Scientific Continental Drilling Program (ICDP).

ITINERIS has boosted the access of Italian researchers (among which many early career researchers) to both the ECORD and the ICDP infrastructures. This has resulted in increasing the national participation in terms of proposal writing, participation in drilling expeditions/projects, initiatives to use legacy samples/data, and training activities. Italy has become the fourth contributor in ECORD after Germany, UK, and France.

All samples and data produced by the two companion drill programs are archived through a Mobile Drilling Information System (mDIS) developed by ICDP and adopted by ECORD. Since the earliest expeditions, all data are openly accessible by the global scientific community following a 1-year moratorium period for ocean drilling. ITINERIS has addressed two urgent needs that are of relevance for the Italian scientific community: 1) Identification of vintage samples from earlier studies, which produced a wealth of scientific data, and remained uncatalogued in various storage facilities across Italian universities and research centres 2) collection of shallow coring records acquired onshore and offshore, also through the present Italian research vessels Gaia Blu and Laura Bassi, which lack an equally effective data archiving system.

In Italy, ITINERIS has promoted the archiving of thousands of existing sub-samples and data in the disciplines of biostratigraphy, structural geology, sedimentology, petrology, borehole geophysics, and paleomagnetism, and it has promoted the development of an ITINERIS version of mDIS that should be adopted for a nationally managed archive of terrestrial and marine core and drilling data.

Keywords: drilling, coring, data

Advances in Seismic Risk Assessment of the city of Potenza (Southern Italy)

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The overall objective of this study is to improve the seismic risk assessment of the city of Potenza (southern Italy, selected because it is already the subject of several national and international research projects) based on a multidisciplinary approach that considers the seismic hazard of soils in the urban area, the interaction effect between soils and buildings, and the seismic capacity of buildings. 453 (300 on soils and 153 on buildings) single-station ambient noise measurements analysed through Horizontal-to-Vertical Spectral Ratio technique have been performed to assess the main characteristics of the most representative litho-stratigraphic and mechanical conditions of the urban soil and built environment in the city of Potenza. Thanks to experimental relationship between period, height and building area, derived by experimental results on buildings, made it possible estimating the fundamental frequency for all the Potenza's buildings. By comparing the frequency ranges of buildings with those of foundation soils, it was possible to spatially determine the areas and probabilities of highest occurrence of the soil-building resonance effect in the elastic field throughout the city of Potenza.

Furthermore, capacity curves of buildings were obtained based on the geometric and typological characteristics and on the vibrational frequencies of the measured building. Firstly, the buildings were grouped into homogeneous classes. Based on previous and well-established principles and studies, they were distinguished by construction year (pre-1971, post-1971), presence of soft stories, and number of stories. The capacity curves for each typology were defined in terms of the top displacement – base shear relationship. The values for the yield displacement (δy) and the ultimate displacement (δu) were calculated based on the values obtained from numerical modelling of previous studies. For each of the considered typology, a mean capacity curve was obtained by averaging the values of the buildings belonging to each class. The capacity curves obtained can be used as valuable tools to assess the vulnerability of these buildings and define a seismic risk map for the city of Potenza including the urban soil amplification and the soil-building interaction effect.

Keywords: HVSR, Resonance effects, Capacity curves.

A Distributed System for Near Real-Time Forecasting of Shallow Landslides at Regional Scale

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The present research activity aligns with one of the main objectives of the ATLaS research infrastructure: the development of forecasting models and quantitative risk assessment methods for geo-hydrological hazards. The work focused on the development and maintenance of a forecasting system for shallow rainfall-induced landslides that works continuously providing daily outputs in near real-time at a regional scale. The research activities dealt with i) the optimisation of a selected slope stability model considering purposes and framework of the project; ii) the calibration of the system based on the hydrological, geotechnical, morphological and climatic characteristics of the study area; iii) the development of routines and algorithms aimed to enabling the system to operate continuously using weather forecasts and producing spatially aggregated (sub-basins) outputs along with the distributed outputs.

The final forecasting system is based on a distributed slope stability model (HIRESSS), it has been operational since June 2024, and it is currently deployed over Alert Zone B of the Aosta Valley Region, using precipitation forecasts from the ICON-CH2 weather prediction model as dynamic input. The system provides landslide initiation susceptibility maps (in terms of failure probability) at 10-meter spatial resolution and 3-hour temporal resolution, generating forecasts for both the current and the following day, available daily by 09:30 AM. In addition to this, the system simultaneously provides failure probabilities for each sub-basin of the area based on a calibrated system of thresholds, generating outputs ready for operational use in an early warning system. Last activities aimed to optimize the real-time dissemination of model outputs through an open data platform designed by ATLaS within the Itineris project.

Keywords: Regional landslide forecasting; Distributed modelling; Shallow landslides

Integrated Geophysics and Data Science for Soil Moisture Characterization and Hydrogeological Risk Assessment in Urban and Peri-Urban Areas

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Extreme events such as prolonged drought periods and high-intensity rainfall episodes intensify a cascade of hydrological problems. These range from difficulties in securing agricultural water supplies and managing water in urbanized areas, to the critical domain of hydrogeological risk, where ensuring slope stability and preventing landslides become particularly tricky challenges. Effectively addressing these hydrological problems hinges on understanding soil moisture behavior across various soil types, a task for which hydrogeophysics is essential, particularly as its effectiveness is amplified by detailed hydrological and environmental analyses.

A multiparametric strategy using longitudinal multisensory monitoring systems is highly effective for modeling soil moisture. Recent advancements have optimized these systems to include time-lapse Electrical Resistivity Tomography (ERT) alongside various hydrologic and environmental sensors. This combination allows for sophisticated 2-3D dynamic thermo-hydro-geomechanical modeling of the subsurface, providing unique insights into soil moisture and landslides mechanisms.

Our work focuses on a slow-moving peri-urban landslide in the southern Apennines of Basilicata (Italy), an area historically affected by hydrogeological issues. We are setting up an open-air laboratory with a monitoring station that combines a time-lapse ERT system with an array of hydrological sensors (tensiometers, soil moisture sensors, piezometers) and meteorological sensors (thermometers, hygrometers, anemometers, pyranometers). In parallel we've developed a complementary laboratory methodology that unifies and adapts specific instruments to create a customized experimental environment for integrated data acquisition that replicates the coupled ERT plus hydrological field measurements.

Substantial data will undergo innovative processing, including advanced machine learning. These techniques will facilitate efficient analysis and integration of geophysical, hydrogeological, and environmental datasets across laboratory and landslide scales, significantly improving our ability to model and understand soil moisture behavior. Results will not only provide reliable insights for hydrological risk management but will also offer broader applications across the entire spectrum of water resource challenges.

Keywords: soil moisture, hydrogephysics, landslides.

Parallel implementation of Time-Domain airborne SAR focusing

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Airborne Synthetic Aperture Radar (SAR) systems offer high-resolution imaging, rapid deployment, and operational flexibility, making them particularly suitable for time-critical applications such as environmental monitoring and emergency response. Compared to satellite-based systems, their lower flight altitudes enable improved azimuth resolution and shorter revisit times. However, accurate focusing of airborne SAR data must account for motion errors resulting from attitude instabilities and deviations from the planned linear trajectory. Airborne SAR data focusing can be carried out in the Frequency-Domain (FD) or in the Time-Domain (TD). While Frequency-Domain algorithms are computationally efficient, Time-Domain focusing achieves higher accuracy in producing Single Look Complex (SLC) images, at the cost of higher computational demand.

In this work, we present a performance assessment of two Time-Domain SAR focusing strategies—pixel-wise and matrix-wise—implemented using the airborne SAR infrastructure operated by IREA-CNR (Naples, Italy), which includes a SAR sensor named MIPS and a multi-node, multi-thread Information Technology (IT) platform for storage and processing. To leverage these parallel computing capabilities, both strategies are further extended to parallel execution frameworks.

Experimental results indicate that the pixel-wise strategy outperforms the matrix-wise approach in terms of computing time. Moreover, parallel processing significantly accelerates computation, which is critical for scenarios requiring prompt data turnaround such as emergency response and environmental monitoring.

Current developments are focused on migrating the parallel implementation to GPU-based architectures. This aligns with the ITINERIS project's mission, as the IT platform was recently enhanced with GPU-equipped servers to fully exploit their parallel processing power. Implementing the presented TD focusing strategies on GPUs is expected to further improve processing time efficiency, enabling faster generation of high-quality SAR imagery. Such advancements will support near real-time monitoring capabilities, enhancing rapid decision-making in environmental management and emergency scenarios, and thereby reinforcing ITINERIS's objective to strengthen Italy's research infrastructure through cutting-edge technological innovation.

Keywords: Airborne Synthetic Aperture Radar (SAR), airborne infrastructure, parallel Time-Domain SAR focusing.

3D subsurface imaging from UAV-based GPR and magnetic data

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Ground Penetrating Radar (GPR) and magnetometric technologies are widely used as they are rapid, cost-efficient, versatile and non-destructive techniques. Thanks to the development of Unmanned Aerial Vehicle (UAV), several UAV-suitable miniaturized/lightweight GPR and magnetometers were released, opening new potentialities but also new challenges. UAV, indeed, allows fast data collection over large and inaccessible areas. However, the acquired data quality may deteriorate because of the UAV electromagnetic disturbances, the limited coupling of electromagnetic energy into the soil, the increased clutter caused by multipath signals and instability of the flight trajectory. Therefore, the use of UAV-based GPR and magnetometric technologies and the effective interpretation of their results is still challenging.

This abstract proposes innovative workflows for the 3D geophysical imaging through commercially available UAV-based GPR and magnetometer. For GPR, the adopted workflow exploits standard time-domain operations, as zero time, time gating, background removal and gain. Thereafter, a specifically designed microwave tomography approach, facing the GPR imaging as a linear inverse scattering problem and accounting for the presence of the air-soil interface, is applied. This approach needs for an accurate UAV positioning data, which are obtained through Differential Global Navigation Satellite System (DGNSS) technique. Magnetic data are processed considering spectral and wavelet analyses, low-pass and directional filtering to mitigate the effect of the heading errors, oscillation artifacts and electromagnetic disturbances. Depth from Extreme Points (DEXP) method is then applied for imaging purposes by considering the scaling laws of potential field sources.

The effectiveness of both the workflows is assessed in real conditions at the test-site of the Altopiano di Verteglia (Southern Italy), where experimental data were collected. The results provided by both the workflows allow the correct identification and reconstruction of buried targets and represent a proof of the potentialities offered by the two UAV-technologies, when their data are properly processed.

Keywords: UAV, GPR, magnetometry, microwave tomography, imaging methods.

Strengthening of the geophysical facility PiTOP for seismic characterization and monitoring purposes in the ECCSEL-ERIC consortium

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The Italian geophysical test site PiTOP is part of ECCSEL, the distributed Research Infrastructure with the aim to enhance European science, technology development, innovation and education in the field of Carbon Dioxide Capture, Utilisation, Transport and Storage (CCUS). PiTOP offers five wells of different depths, is equipped with seismic and geoelectric instrumentation and allows to perform many types of geophysical/seismic experiments. This infrastructure has been strengthened thanks to the ITINERIS project, enhancing the services offered by the site, improving the operative capabilities and the provision of Transnational Accesses.

The site has been enhanced through the purchase of 800 wireless seismic nodes NuSeis (for a total of 1600 channels), mono and three-component, a borehole receiver Avalon GSR-1, a borehole Distributed Acoustic Sensing (DAS) cable, a Carina® (DAS) interrogator and a mobile laboratory/office (Ford Transit). This exceptional upgrade of instrumentation required personnel to its management and maintenance and the project paid 3 technologists and 3 technicians with a fixed-term contract. All purchased equipment has been tested and has already been used in many experiments and projects, including collaborations with SMINO.

The long-term sustainability of the improved infrastructure is a focal point that was considered at the beginning of the investment. PiTOP, thanks to the new instrumentation, hosted 3 Transnational Accesses (TA), in which the performance of different DAS fibre types and interrogators was evaluated. Following the TA, PiTOP has gained visibility, OGS has strengthened international collaborations and collected a big amount of data that will be shared on a FAIR basis with the scientific community. We have also improved the knowledge on DAS, and the outcomes will be published.

The main fields of application are CO_2 and H_2 storage site seismic characterization/monitoring and seismic studies on geothermal fields or water resources, to boost the way to a sustainable environment and to geoenergy.

Keywords: Seismic, NuSeis nodes, DAS

Fiber-optic seismic and geodetic monitoring network of Friuli Venezia Giulia: implementation and first results from the ITINERIS project

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The ITINERIS project has supported the deployment of the first operational Distributed Acoustic Sensing (DAS) network as part of the existing Seismic Monitoring in North-Eastern Italy (SMINO) network, which operates within the Near-Fault Observatory (NFO) of the Friuli Venezia Giulia region.

Five permanent DAS interrogators, each monitoring up to 50 km of publicly owned dark fiber optics managed by INSIEL and the regional government, collectively provide continuous seismic coverage over approximately 250 km of optical backbone. This configuration creates an unprecedented spatial density of virtual seismic channels, complementing and enhancing the capabilities of the conventional SMINO network.

The permanent deployment enables real-time detection and continuous surveillance of seismic activity across the NFO area, improving earthquake localization and characterization. By incorporating DAS data into SMINO, the system delivers higher-resolution spatial insights into ground-motion patterns and extends monitoring capabilities toward multi-hazard applications such as geodetic deformation, landslides, infrastructure stability, and environmental vibrations.

This initiative represents Italy's first large-scale DAS-based seismic monitoring network and one of the earliest in Europe, offering a replicable and scalable model for regional integration of DAS technology into existing research infrastructures.

Keywords: DAS, fiber optic, seismic monitoring

Topic 6

Virtual Research Environments and Cross-disciplinary Activities

The VRE Carbon and related research

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The Virtual Research Environment on Carbon has been one of the successful outcomes of the Itineris programme. The VRE hosts multiple datasets, code, reference documents, and communication material useful for a broad community of researchers, stakeholders, and end users interested in the carbon cycle and related research. An operative version of the VRE Carbon, focused on the Italian territory, has been released at the end of 2024 and includes several sections, specifically on: (i) Above Ground Biomass: with products related to above ground carbon stocks for Trento province, Tuscany, and maps for the pantropical biome; (ii) Amospheric_Inversion_Models: with sample products from 6 models, infographics, and R code; (iii) Carbon_Fluxes_Models: with products from 3 families of models plus infographics and R code; (iv) GHG_Emissions_Italy: with products from EDGAR and ISPRA families with code and infographics (v) Local Eesearch: examples of local level research and data (e.g. grassland carbon and ecosystem functional properties); (vi) SOCAT_ocean_data: with data sample and references to this data type; (vii) Test_isoscape: a folder related to isotope data and code. In addition the (viii) Instruction folder provides information on how to manage and upload contents in the VRE. In this presentation, considerations about the improvement and the potential of the VRE carbon are discussed in more detail. Furthermore, an example of carbon related interdisciplinary research is here illustrated, with the title: 'Ecosystem Functional Properties estimated from satellite PRISMA hyperspectral and Sentinel-2 multispectral data over different European sites and plant functional types'. The research supports the use of Ecosystem Functional Properties (EFPs) derived from the ICOS flux tower network as a way to monitor ecosystems functions and health. Estimates of EFPs are produced in different plant functional types using innovative satellite hyperspectral ASI PRISMA data and Sentinel-2 multispectral data, comparing the results and highlighting advantages and issues in the different approaches.

Keywords: VRE, Carbon, Itineris

Downstream VRE: Land and Marine domain toolboxes

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As part of the ITINERIS project (2022–2025), funded by NextGenerationEU, a Virtual Research Environment (VRE) has been developed to investigate the impacts of climate and environmental change. Hosted on the D4Science infrastructure, the VRE (Assante et al., 2021) offers tools for data visualization, analysis, and sharing, with dedicated toolboxes for marine and land domains.

In the marine domain, the toolbox focuses in carbon cycling and acidification data available in the North Adriatic Sea mainly pH, pCO2, fCO2, temperature and salinity within the different RIs in the ITINERIS project in particular data from the National Institute of Oceanography and Applied Geophysics. Three user driven tools have been made available based on different users skills and the most common tools for marine domain users: WebODV access for the extraction, analysis, exploration and visualization of oceanographic and other environmental data restricted for Argo (TS & BGC) and SeaDataNet (TS) products, jupyter notebooks to access ICOS data and the ERDDAP-navigator, an open-source web application to navigate within different ERDDAP servers giving the freedom of exploring, merge, load, edit and manually assign a quality control (QC) flag to datasets by exploiting the ERDDAP RESTful API.

In the land domain, the toolbox focuses on areas affected by landslides. A GeoServer and a GeoNetwork have been added to host geospatial data, including regional-scale maps of the Friuli Venezia Giulia region and local-scale maps of the Passo della Morte area (Forni di Sotto). For Passo della Morte site, drone-derived products have been acquired and are available for visualization and download. A monitoring system has been deployed at the site, including GB-InSAR, one GPS station, two extensometers, two inclinometers, and a data coordinator. Interferograms and GB-InSAR time series can be visualized directly through the platform. Additionally, a dedicated application enables quick time series analyses and automatic plot generation.

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Keywords: Land domain, Marine domain, Downstream

A Virtual Research Environment-based analysis of the influence of atmospheric circulation types on seasonal carbon fluxes in a Mediterranean beech forest

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Beech forests (*Fagus sylvatica* L.) are important carbon sinks due to their ability to accumulate biomass and sequester atmospheric carbon. However, their dynamics are strongly influenced by seasonal biotic and abiotic factors, particularly in Mediterranean climates, where frequent droughts and heatwaves negatively affect photosynthesis, growth, respiration rates, and tree mortality. These regional extreme weather events are, in turn, influenced by large-scale meteorological patterns (cyclonic, anticyclonic, and zonal circulations). Despite their relevance, the influence of seasonal atmospheric circulation types on forest carbon fluxes remains largely unexplored. Accordingly, this study aimed to investigate how the seasonal frequency of each circulation type affected the seasonal variability of carbon dynamics in beech forests. The analysis was conducted using the programming facilities provided by the Virtual Research Environment for Essential Variables (EVs VRE), an open-access platform that supports ecological monitoring through the FAIR data principles and tools for reproducible research. Seasonal estimates of Gross Primary Production (GPP), Net Ecosystem Exchange (NEE), ecosystem respiration (RECO), and tree diameter (DBH) were derived using linear regression models applied to data collected from 1995 to 2014 at the Collelongo - Selva Piana forest LTER-Italy site (https://deims.org/9b1d144a-dc37-4b0e-8cda-1dda1d7667da). This 3000-hectare, over-125-year-old beech forest in central Italy is a founding site of the ICP Forests network and part of major European ecological research infrastructures (e.g., eLTER, ICOS). Preliminary results showed that atmospheric circulation types significantly influence seasonal trends of GPP, NEE and RECO. These insights demonstrate the potential of integrating atmospheric circulation data to better understand and anticipate seasonal carbon flux responses in beech forests. Combined with climate projections, this programming approach may support adaptive forest management strategies aimed at mitigating the effects of climate change in Mediterranean ecosystems.

Keywords: Virtual Research Environment, forest growth, large-scale weather

First data from CO2 fluxes from glacier forelands: data access and analysis through the CZ VRE

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Accelerated glacier retreat trends, mainly driven by human-induced climate change, are causing important changes in mountain landscapes. In the European Alps, over a century of glacier retreat has left new vast areas open for biotic colonization (mainly driven by plants and microbes).

Increasing time since deglaciation usually involves an increase in structural diversity and provides fundamental ecosystem services, including mountain slope stabilization, control of surface runoff and soil erosion.

Increasing in plant diversity, facilitating animal colonization, also involves an increase in ecological diversity leading to the establishment of complex biotic communities and the development of new ecosystems.

In order to provide new data on the balance between gross primary production and ecosystem respiration, and to understand if these systems indeed act as either sinks or sources of greenhouse gases, field campaigns aimed to collect data on carbon dioxide fluxes has been carried on in the summer seasons in five study areas distributed across the European Alps (273 sampled points for ER and GPP). Sampled points were collected from a total of 24 sites representing different positions (dated lines) reached by these five glaciers in the recent past.

An R routine, accompanied by metadata, was developed to analyse CO_2 fluxes from glacier forelands, summarizing data, calculating GPP and visualizing trends in ER and NEE from the investigated glacier forelands. Following Open Science principles, data and the R code have been made accessible in the CZ VRE, allowing users to analyse trends, explore relationships and to adapt the code for their own datasets.

By combining data on deglaciation time, aboveground productivity, green fractional cover, plant diversity and climate from five Alpine glacier forelands, we aim at identifying the main drivers and trends of primary production and respiration along the chronosequence at local and regional scales.

Keywords: Critical Zone VRE, Alpine glacier foreland, CO_2 fluxes

ISOTOPE STUDIO: A FAIR-Compliant VRE for Harmonized Isotope Data and Modelling within the ITINERIS Framework

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Isotope Geochemistry plays a pivotal role in exploring the natural variability of isotope ratios in Earth materials. The application of stable, noble gases, non-conventional stable, and radiogenic isotopes is fundamental across a wide range of Earth System disciplines, including geology, biology, archaeology, agronomy, ecology, up to medicine, food provenance studies, and climate change

In this light, as part of the ITINERIS Project, Task 8.9 focuses on developing a Virtual Research Environment (VRE) dedicated to environmental isotopes. The ISOTOPE VRE has been developed within the D4Science e-Infrastructure, adhering to the principles of Open Science by promoting transparency, collaboration, and inclusivity throughout the entire research workflow. To further these objectives, we introduce ISOTOPE STUDIO, a web-based application hosted within the ISOTOPE VRE and designed for acquiring, managing, standardizing, and processing a wide range of geochemical data, including major and trace elements, intensive parameters, and isotopic compositions. A standout feature of ISOTOPE STUDIO is its data homogenization engine, which integrates and categorizes heterogeneous inputs, allowing seamless integration of diverse datasets into a unified, queryable structure. This ensures the reliability of modelling performed by this web application.

ISOTOPE STUDIO supports various modelling functionalities for interpreting natural processes. Practical applications include binary diagrams, ternary plots, normalized spider diagrams and mixing processes. The outcomes produced align closely with established literature, validating the platform's analytical robustness and scientific utility; selected examples will be presented to demonstrate the quality and reliability of the underlying database.

Keywords: ISOTOPE VRE; ISOTOPE STUDIO; MODELLING

Enhancing Aerosol characterization through a Virtual Research Environment

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The Virtual Research Environment (VRE) serves as a collaborative platform designed to facilitate research activities across various scientific domains. By integrating diverse data sources, analytical tools, and computational resources, the VRE aims to enhance the accessibility and usability of data generated by research infrastructures (RIs). This environment fosters collaboration among researchers, enabling them to share knowledge and tools effectively, while promoting interdisciplinary studies.

In this talk, the results of the activities performed in the AERO VRE focused on the atmosphere domain are presented. Within the AERO VRE new software and tools have been developed specifically aimed at studying aerosol properties obtained by lidar measurements. This work involves the adaptation of existing algorithms and the creation of new analytical frameworks to process and interpret lidar data. Additionally, the properties of dust have been investigated by exploiting model simulations and satellite data. By leveraging the capabilities of the VRE, the codes specifically designed not only enhance the analytical capacity for aerosol typing and dust characterization but also promote the sharing of methodologies and findings within the research community. This collaborative effort is essential for advancing our understanding of atmospheric phenomena and their implications for climate and air quality.

Keywords: Virtual Research Environment, Lidar Observations, Aerosol properties, Typing, Dust

Topic 7

e-Science

Ecological effects of mitochondrial dysfunction in pancreatic cancer

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Tumors can be described as evolving ecosystems, where cancer cells act as invasive species that increase their fitness compared to non-tumoral cells. In this framework, ecological fitness refers to the ability of tumor cells to survive, proliferate, evolve within the TME, and adapt to selective pressures. One of the most aggressive and early metastatic neoplasia is the pancreatic ductal adenocarcinoma (PDAC), the most common type of pancreatic cancer, known for its high mortality rate and poor prognosis. In the fitness of PDAC cells, mitochondrial metabolism plays a fundamental role. Indeed, dysfunctions in metabolic pathways lead to alterations in tumor progression and therapeutic resistance.

We investigated how mitochondrial dysfunction affects the ecological fitness of PDAC cells by silencing *NDUFS3*, a gene coding for an essential subunit of mitochondrial complex I, in YAPC and MIA PaCa-2 cell lines. Decreased levels of NDUFS3 affected mitochondrial function and led to reduced proliferation, migration, and invasion. These functional effects were associated with a less aggressive phenotype.

From an ecological-evolutionary perspective, our results reflect how mitochondrial dysfunctions introduce an energetic impairment that modifies cancer cell behavior. Interpreting these findings through the lens of ***Resource Allocation Theory***, less energy availability may obligate a redistribution of resources in the cell, reducing investment in invasion and survival. Therefore, according to ***Performance Theory***, these mitochondrial dysfunctions may be translated into lower ecological fitness, making tumor cells less competitive.

Overall, mitochondrial alterations emerge as a vulnerability of PDAC cells, suggesting that targeting mitochondrial metabolism could represent a strategy to decrease cancer cell fitness, limiting tumor progression and opening new therapeutic perspectives.

Keywords: pancreatic cancer, ecological fitness, metabolic dysfunction.

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