Title	**Multidisciplinary MOOC implemented and publicly available**
Work package n°	4. Developing and integrating joint training services
Deliverable / Milestone n°	D 4.3: Development and application of training through Virtual Access
Lead beneficiary	2 - IMT
Author(s)	Antonia Zogka, Véronique Riffault
Deliverable Type	DEM
Dissemination Level	Public
Estimated delivery date	M 24
Actual delivery date	M 46 (20 Jan 2025 – 16 Feb 2025)
Version	V1
Reviewed by	Ariane Dubost (ATMO-ACCESS Project Office)
Accepted by	
Comments	

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ATMO ACCESS
Access to Atmospheric Research Facilities

Table of Content

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Introduction

The main objective of the task 4.3 'Development and application of training through Virtual Access' is to test new ways of training beyond the remote and/or physical access via Trans National Access (TNA). In this way, the basis for innovative trainings related to TNAs are built and could be enhanced in the future within the atmospheric research community.
The pilot resources and specifically the MOOC (Massive Open Online Course) aim to add the training dimension to RI accesses, by using virtual access and show how tools for training and education can be further developed and applied within the RIs for different user communities in a sustainable framework.

General information

The 1st session of the pilot MOOC 'Atmospheric Research Infrastructures: Sharing the future of our atmosphere' has opened on Jan 20, 2025 until Feb 16, 2025, on the FUN (France Université Numérique) MOOC platform on this **page.**

The course consisted of a 2-week self-paced session, with a commitment of approximately 2 hours per week. The MOOC was open for a duration of 4 weeks in total, allowing more flexibility for registered participants.
At the beginning of each of the 1st two weeks, new content is released. Participants joining on the 3rd and 4th weeks have all the material readily accessible.

Topic	Atmospheric observations in European Research Infrastructures (RI)
Goal	Provide knowledge and skills to optimise the use of Atmospheric Research Infrastructures
Target user groups	➢ Young scientists ➢ Broader community of users concerned by climate change and air quality issues ➢ Operators of atmospheric RI facilities

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Communication (related to WP2)

Ahead of the MOOC release, several resources have been produced and actions taken for communication purposes (related to *WP2: Integrated modalities for engaging users, enhancing awareness and monitoring the success of access strategies*), such as a **teaser** and a **flyer**.

The teaser was shown ahead of time at several scientific conferences such as the EGU General Assembly 2023, the ACTRIS Science Conference, and specific events relative to each RI, such as the ACTRIS weeks 2023 and 2024, training activities such as the 'ACTRIS training on organic tracers and aerosol constituents' and 'Training school related to sensor applications on the ground'.

It was also presented for a wider audience on the YouTube pages of the ATMO-ACCESS project and the RIs ACTRIS and IAGOS, and published on the FUN MOOC platform during the registration period, as well as on social media, such as LinkedIn and X.

Once registrations were opened (beginning of December 2024), the MOOC was further promoted at the AGU Annual Meeting 2024, on social media (see *Annex | Examples of the use of social media to communicate about the MOOC*), by the three RI newsletters, and by the FUN MOOC platform itself through a dedicated **article**. It was also shared with wider networks notably in the ENVRI community website and newsletter and in the Global Atmosphere Watch (GAW) newsletter.

The flyer was also distributed, mostly by IMT staff, at meetings and events which they attended such as the European Research Course on the Atmosphere (ERCA) winter school in January 2025, or various PhD defenses during the month of December 2024.

MOOC content

Video specifications

The 2-week course consisted of 8 **interactive videos.** These interactions allow viewers to actively engage with the video through clickable areas, transforming passive video watching into a more dynamic experience. They are ideal for e-learning since they enhance learning by providing more effective learning outcomes and better retention of information. They can be true false or multiple-choice questions, buttons to access more information, images and activities. The following screenshot shows how interactions keep learners engaged and facilitate knowledge acquisition.

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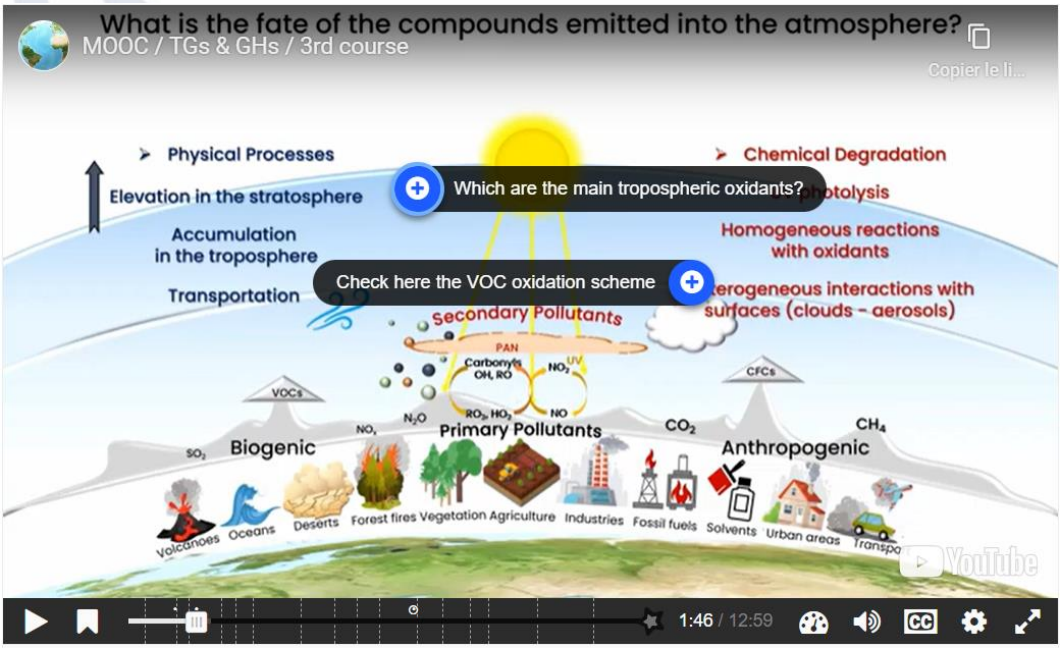
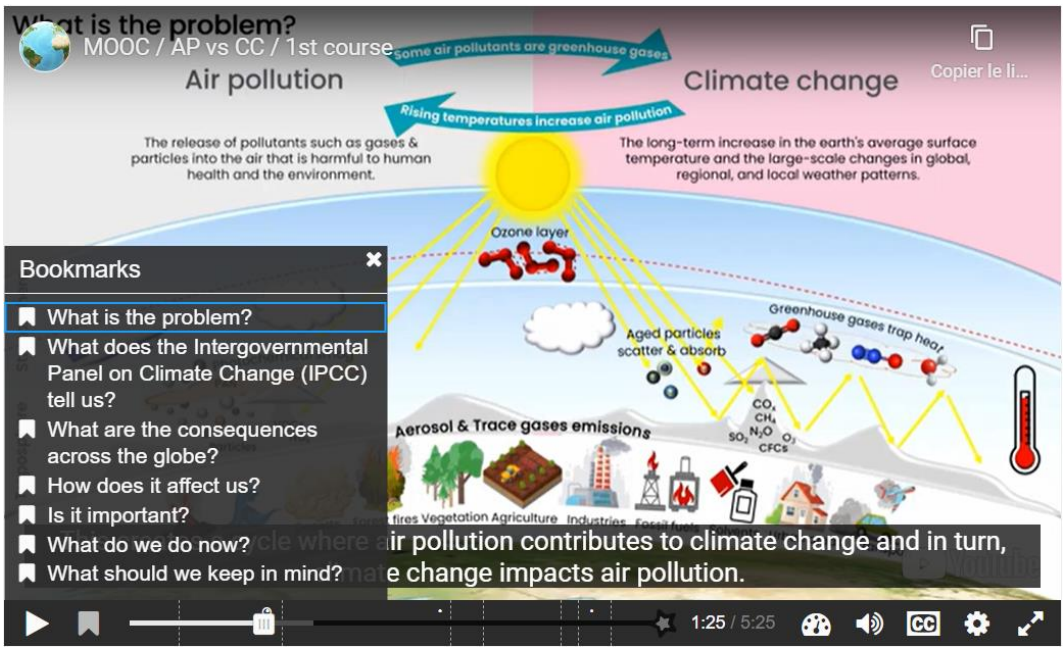


These interactive videos possess bookmarks. By clicking a selected bookmark, the participants can quickly access to the specific chapter. Thus, the bookmarks direct the learners immediately to the part of their interest. The screenshot below illustrates how bookmarks create a structured video course and facilitate access to relevant information.



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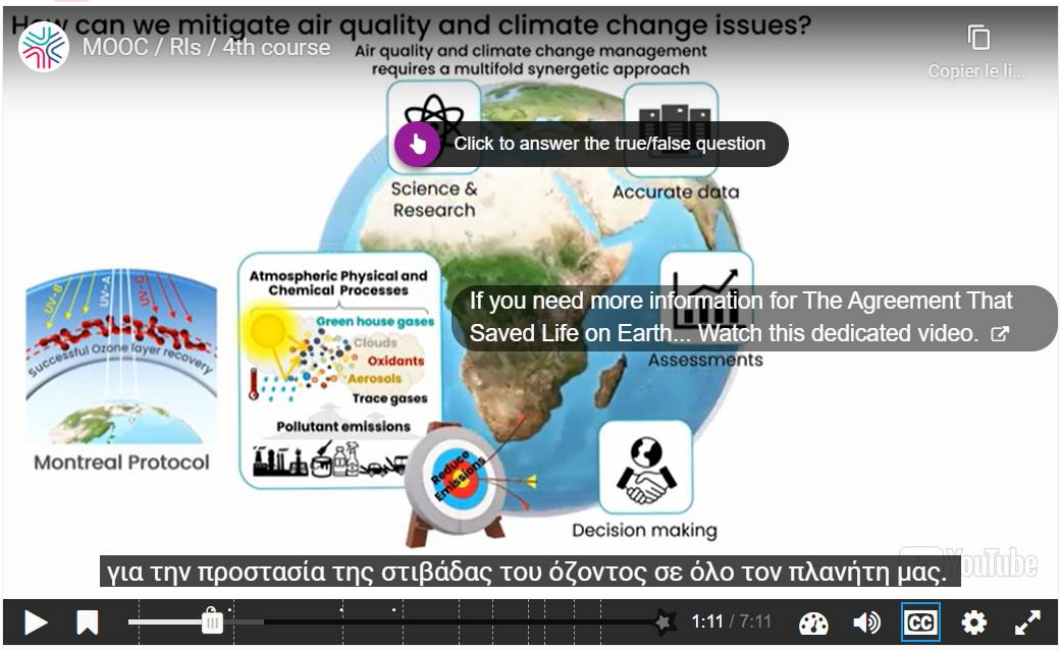
For the benefit of non-native English speakers and people with some disabilities, the 8 interactive videos are provided with **subtitles** in English, French, German, Greek, Portuguese, and Spanish. Here are some examples of how interactions provide access to additional resources and facilitate understanding through native-language subtitles.



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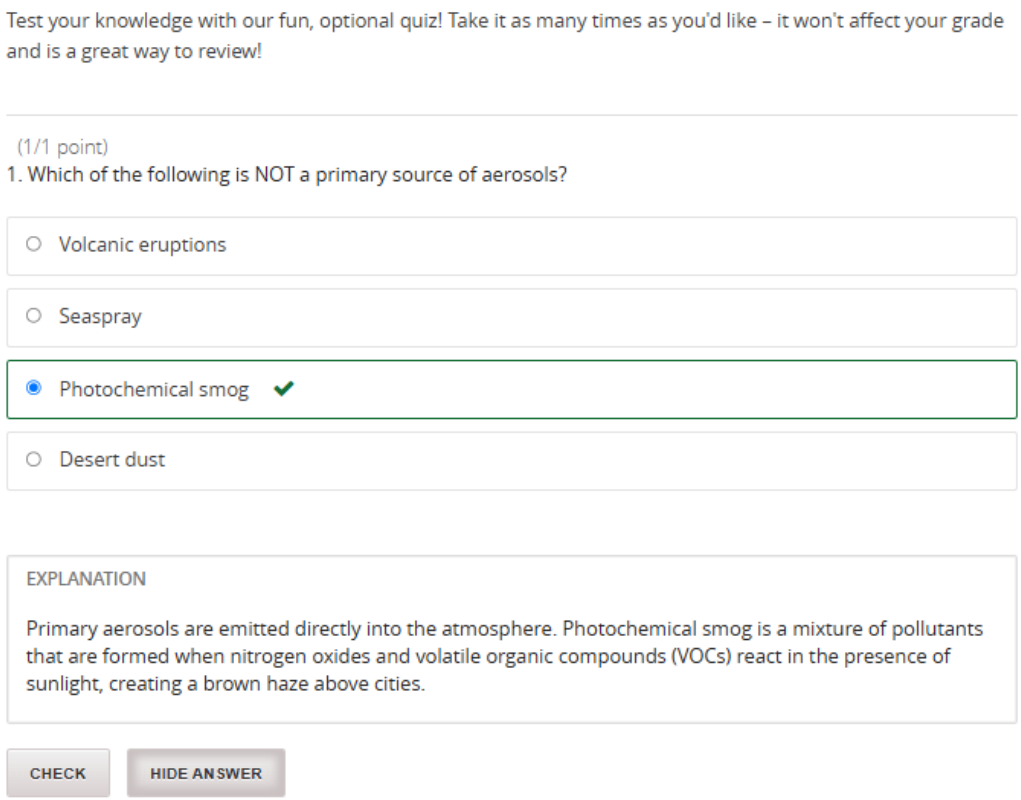
First week

The **first week** 'Air pollution and climate change, what is happening in our atmosphere and what should we do?' contains **4 interactive videos of 36 minutes** of material in total. The videos are designed to build upon concepts presented in earlier sections. Therefore, watching them in the correct sequence is crucial for effective learning.

Video topic	Length (min)
Air pollution vs. Climate change	5:25
Aerosols and Clouds	10:58
Trace gases and Greenhouse gases	12:59
Atmospheric Research Infrastructures	7:11

At the end of each interactive video, participants can consult a brief **summary** and test their knowledge with an **optional quiz of 5 questions**. This optional quiz is used for practising and preparation for the final quiz. Participants can take these quizzes as many times as they want since they're a great way to reinforce learning. Below is an example of an optional quiz question.



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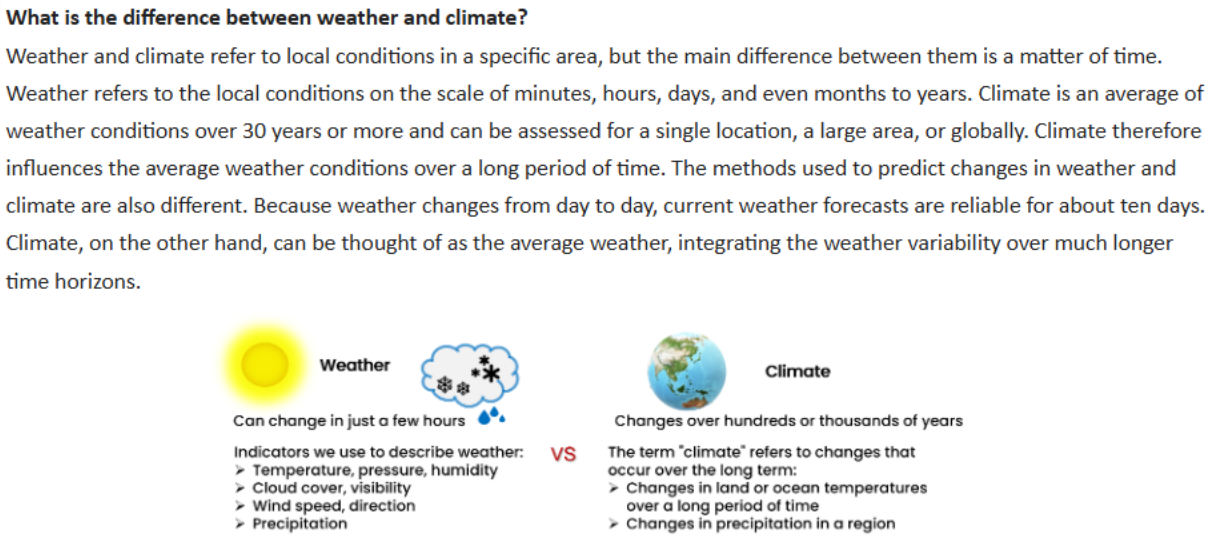
At the end of the first week, participants can go further and explore **8 critical questions and answers** on air pollution and climate change. The screenshot below offers an example of one of these questions. The list of all the questions addressed can be found in *Annex | MOOC content, 1st week: To go further*.



Second week

The **second week** 'Three Atmospheric Research Infrastructures on the way to addressing atmospheric issues' incorporates **3 interactive videos of 32 minutes** of material in total. Participants are free to choose the order in which they watch the 3 RI videos.

Video topic	**Length (min)**
ACTRIS (Aerosol, Clouds and Trace Gases Research Infrastructure)	10:28
IAGOS (In-service Aircraft for a Global Observing System)	8:43
ICOS (Integrated Carbon Observation System)	9:09
The workflow and benefits of a coordinated approach	3:22

Similar to the first week, each interactive video concludes with a brief **summary** and **an optional quiz of 5 questions** for participants to assess their knowledge. This screenshot illustrates the concluding summary of an interactive video.

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The eighth ATMO-ACCESS video concludes the two-week online course and emphasises the critical workflow that ensures the collection, processing, and dissemination of accurate and high quality data. Key steps in this workflow include:

- Standardisation of experimental methods: Techniques and instrumentation are harmonised across each research infrastructure (RI) to ensure consistent and reliable measurements.
- Calibration and intercomparison: Instruments undergo rigorous calibration and cross-checking to maintain accuracy.
- Data collection: Data are collected from a variety of facilities, including mobile and fixed platforms, aircraft, and ground stations, in different environments.
- Data processing and evaluation: Collected data are subjected to quality control and thorough evaluation to ensure they meet the required scientific standards.
- Data access: The processed data are made openly available in accordance with the FAIR principles (Findable, Accessible, Interoperable, Reusable) principles, enabling further research and policy-making.

The data generated by these infrastructures benefit a wide range of users, from researchers and policy makers to the private sector and the general public. These initiatives foster interdisciplinary collaboration across different scientific fields. However, ensuring data interoperability remains a key challenge, with efforts needed to standardise data formats and vocabularies across disciplines.

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At the end of the week, participants can watch **staff interviews** of about **20 minutes of material in total** to further explore the three RIs.

Interviews	Interviewees	Length (min)
Meet ACTRIS	Eija Juurola, Suzanne Crumeyrolle, Stefan Reimann	8 :30
Meet IAGOS	Hannah Clark, Thibaut Lebourgeois, Romain Blot, Julie Patuel	4:13
Meet ICOS	Elena Saltikoff	6:34

More information about the interviewees is presented in *Annex | MOOC content, 2nd week: Interviews*.

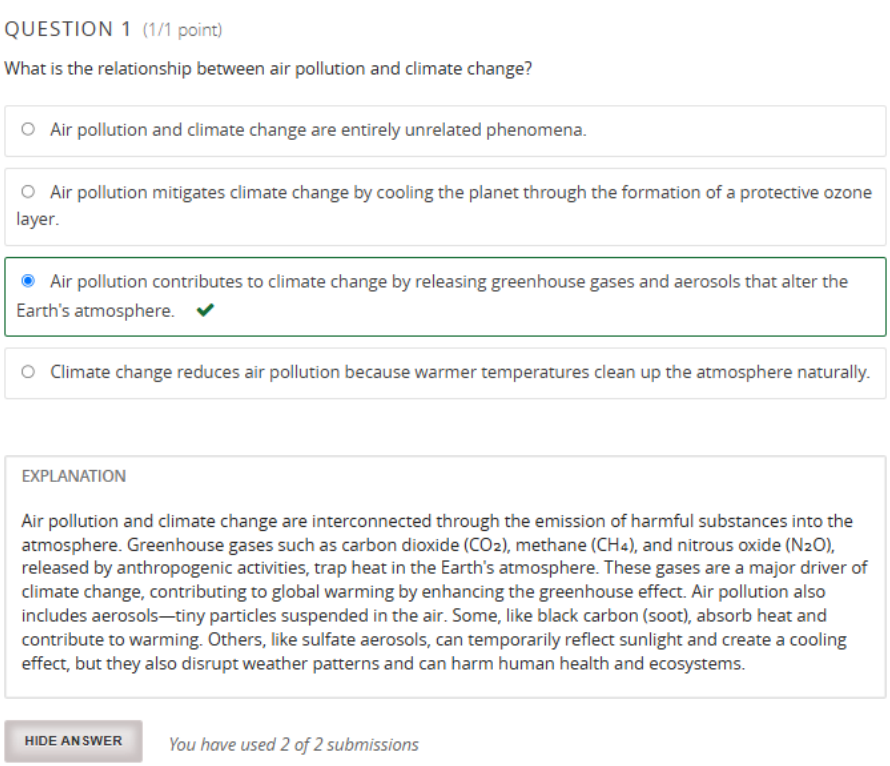
Additional material

In addition to the weekly content, a section '**Additional material'** on this **page** contains useful information such as a glossary (41 entries), a list of abbreviations and nomenclature (chemical families, chemical compounds, ATMO-ACCESS facilities), and a selection of recent scientific publications and websites related to the three atmospheric research infrastructures ACTRIS, IAGOS and ICOS.

All the additional material present on the FUN platform is listed in the *Annex | Additional material*.

Final Graded Quiz (evaluation)

The final quiz consists of 15 questions and counts for 100% of the final grade. In order to successfully complete the course and obtain the open badge, an average grade of 67% or higher is required (10 out of 15 correct answers). The screenshot below presents the first question of the quiz and its answer.



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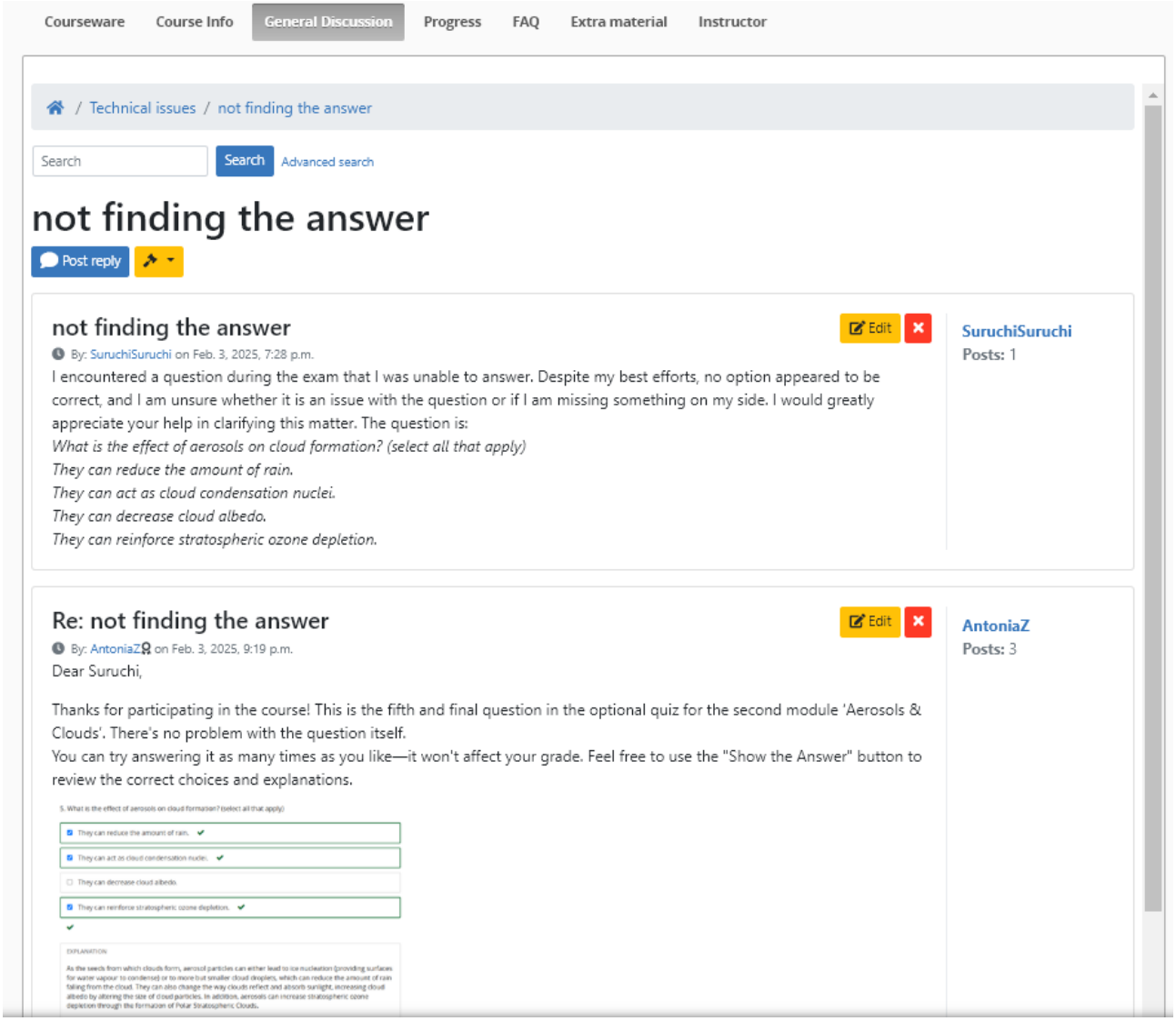
General discussion & Technical issues

The platform provides a forum, which is, in the case of this MOOC, dedicated to **questions about the course or technical aspects of the FUN platform** in order to reply to possible participant issues. Participants can post and have further information and help. The following screenshot shows an example of the General discussion page.



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Other motivational resources

Weekly messages

At the beginning of each week, a motivational message is sent to all registered participants, aiming at encouraging them to complete the MOOC. As of Feb. 10, 2025, four weekly messages have been sent and can be found below.

Release date **Title**	**Message content**
January 20, 2025 Welcome!	Hello everyone, Thank you for joining us for a self-paced session of this online course focused on Atmospheric Research Infrastructures. Our course starts today! The content of each chapter is described on this page. At the end of each chapter, you can test your knowledge with an optional quiz. You will receive a free badge if you pass the final quiz with 10 out of 15 correct answers. We would also like to know more about your motivations. Please answer our short survey to help us learn more about you. We will begin by introducing you to the basics of air pollution and climate change. Your main instructors will be Prof. Veronique RIFFAULT and Dr. Antonia ZOGKA, who are introduced on this page. Enjoy this course, we are thrilled to have you there! The 'MOOC Atmospheric Research Infrastructures: Sharing the Future of Our Atmosphere' Team
January 27, 2025 Week 2	Dear all, If you have successfully completed Week 1 – Well done! If you have just joined us – a warm welcome! You still have plenty of time to catch up and finish this 2-week course, as it will remain open until February 16. In Week 1, we covered the crucial topics of air pollution and climate change. By now, you should feel confident in explaining the difference between these two issues, understanding the complex interactions within the atmosphere, and recognizing the importance of data sharing and experimental results in advancing atmospheric research. Now, let's dive into Week 2! This week, we will explore three major European research infrastructures focused on atmospheric monitoring: ACTRIS, IAGOS, and ICOS. By the end of the week you will be able to:

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	• Understand how these 3 RIs operate and how they support policy makers and global efforts to tackle environmental challenges, • Get an overview of the technical aspects of these RIs, including data collection principles, • Evaluate the essential contribution of these RIs to atmospheric research, air quality, climate change, civil aviation, weather and climate predictions, and future mitigation strategies. • Explore a virtual journey through atmospheric simulation chambers and field measurement stations, through a selection of representative photos, • Watch interviews with scientists from each RI, where they discuss their roles, motivations, and the importance of atmospheric research ********* A quick reminder: If you have not completed our introductory survey yet, please take a moment to fill it out. Your feedback is invaluable for improving future sessions. ********** Finally, looking ahead: At the end of the course, you will have the opportunity to fill out two brief surveys. These will help us improve the course content for future learners and also contribute to the ATMO-ACCESS project yourself, by providing invaluable feedback on the value and limitations of virtual resources for training on the topics of research infrastructures and atmospheric issues. Enjoy Week 2, and thank you for your engagement! The ATMO-ACCESS MOOC team
February 3, 2025 (none)	Dear all, A huge congratulations to everyone who's already completed the first two weeks of the course! And a warm welcome to those just joining us. If you're just getting started or still catching up, don't worry – the course materials will be available until February 16th, so there's plenty of time to get up to speed. This course highlights the importance of atmospheric science in tackling climate change and explores how research infrastructures help scientists monitor the atmosphere, share data, and coordinate global efforts. In Week 1, we cover air pollution, climate change, and their connections, while Week 2 focuses on three key European research infrastructures: ACTRIS, IAGOS, and ICOS. By the end of this course, you'll be able to: • assess the complex interactions within the atmosphere,

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	• recognise the importance of data sharing and experimental results in advancing atmospheric research, • describe different means of monitoring the atmosphere, • summarise the goals, the framework and the workflow of three Research Infrastructures (RIs): ACTRIS, IAGOS and ICOS, You can test your knowledge with the "Final Graded Quiz" of 15 questions. Once you've achieved a passing grade of 67%, you can claim your badge by submitting the Open Badge request. In the "Ending this MOOC" section, you'll find two short surveys. Your feedback will help us improve the course for future learners and contribute valuable insights to the ATMO-ACCESS project, particularly on the effectiveness of virtual resources for training in research infrastructures and atmospheric science. And don't forget to relax and enjoy our behind-the-scenes "making of" video! 😊 Thank you all for your dedication and engagement! We wish you a productive and enjoyable learning experience.
February 10, 2025 Last week	Dear all, A huge congratulations to those of you who've already completed the course and earned your badge — well done! 🎉! Welcome aboard for those of you just joining us! The course is officially closing soon — February 16th is your last chance to wrap things up. Don't worry, there's still time! In just 4 hours, you can discover the world of atmospheric research and the workflows behind Research Infrastructures. Once you hit a 67% passing grade on the Final Graded Quiz, you'll earn your badge! 🏅 Don't forget to claim it — just click here to submit your open badge request. But that's not all — your feedback matters! If you haven't already, please take a moment to complete our short surveys. ✍ Your insights are crucial to making future courses even better, and we'd love to hear from you. Thank you for your participation throughout. We can't wait to see you cross that finish line! Cheers, The ATMO-ACCESS MOOC Team

Making of video

A short behind-the-scenes "making of" video of about 2 min was released after two weeks, to relax and cheer up the participants.

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Feedback assessment

An introductory and two final surveys are proposed to the participants to get their feedback and provide material for *WP10: VA01 - Implementing virtual access to on-line data, computing and training service*.

The **introductory survey** consisted of 20 questions. Among the goals of this survey, there are questions:

- to know more about the participant motivations.
- to understand better the participant educational level and experience.
- to identify different groups of learners with varying needs and preferences.
- to tailor the course to better meet the needs of all participants.
- to enhance learner experience, and achieve better learning outcomes.
- to ensure the course remains relevant and engaging.

Below is a short part of this initial survey.

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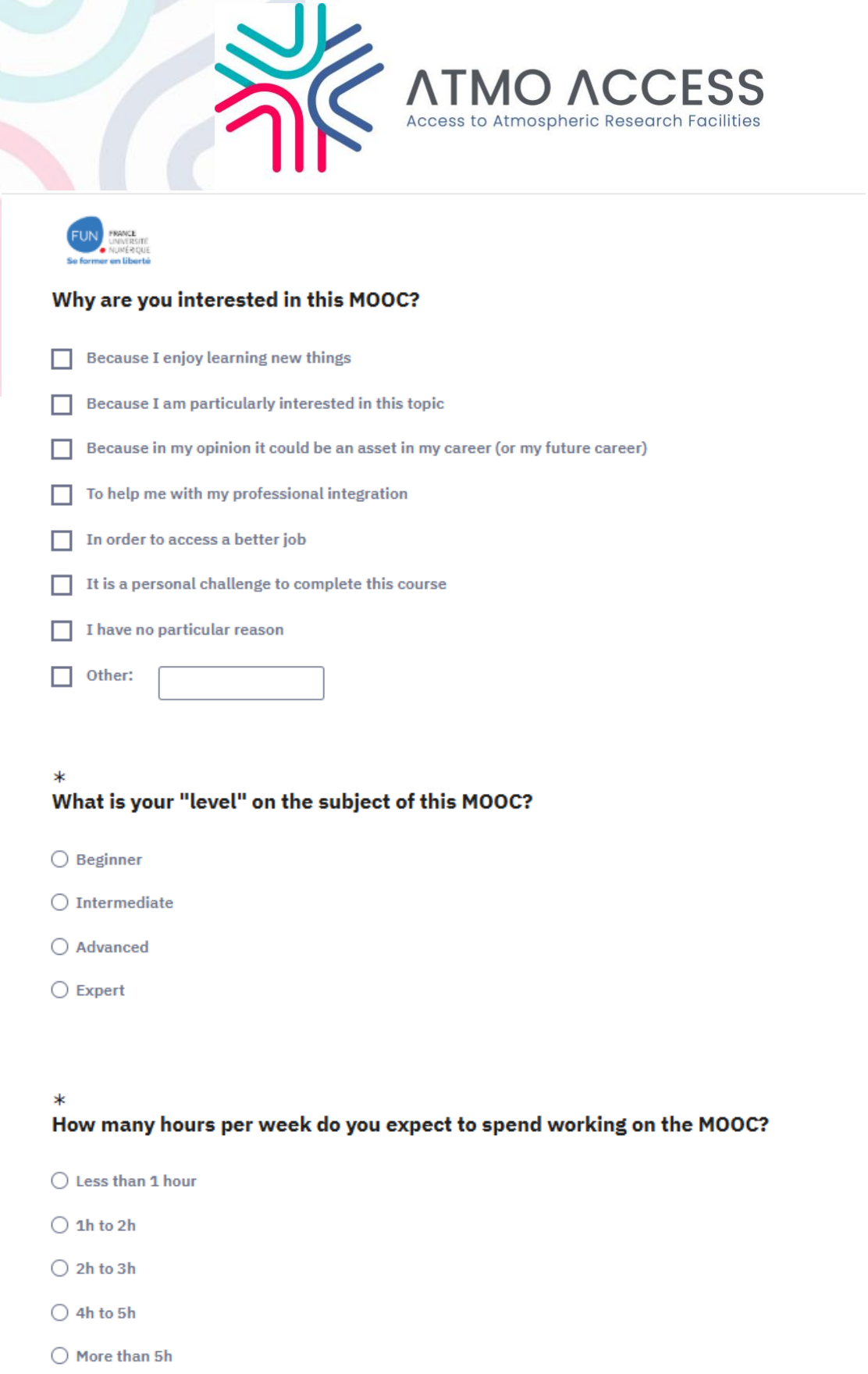

FUN FRANCE UNIVERSITE NUMERIQUE
Se former en liberté

Why are you interested in this MOOC?

- [ ] Because I enjoy learning new things
- [ ] Because I am particularly interested in this topic
- [ ] Because in my opinion it could be an asset in my career (or my future career)
- [ ] To help me with my professional integration
- [ ] In order to access a better job
- [ ] It is a personal challenge to complete this course
- [ ] I have no particular reason
- [ ] Other:

*
What is your "level" on the subject of this MOOC?

- ○ Beginner
- ○ Intermediate
- ○ Advanced
- ○ Expert

*
How many hours per week do you expect to spend working on the MOOC?

- ○ Less than 1 hour
- ○ 1h to 2h
- ○ 2h to 3h
- ○ 4h to 5h
- ○ More than 5h

At the end of the MOOC, participants were invited to answer **two final surveys**: one was the follow-up survey dedicated to the **ATMO-ACCESS** project consisting of 15 questions; the second

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was part of the FUN platform and consists of 17 questions. **Participant feedback is crucial in improving the quality of the course in future sessions.** It is an essential tool for any course to continuously be refined and improved based on learner feedback. Some of the main goals were:

- to pinpoint what aspects of the course worked well and which ones need improvement. This includes content, delivery methods, materials, assignments, and overall organisation.
- to determine if the course effectively achieved its learning objectives. Thus, if the participants gain the intended knowledge and skills.

The list of the ATMO-ACCESS questions can be found in *Annex | Final survey*. The survey is still ongoing and the analysis of the replies will be done in D10.6 "Third report with feedback from users and statistics on use of the services".

For the moment (as of Feb. 10), 759 participants are registered, and more than 85 of them have already completed the course successfully and obtained their free badge. In addition, we count about 1820 total views for the interactive videos and the teaser.

Video topic	**Views** **(as of Feb. 6, 2025)**
Teaser	185
Air pollution vs. Climate change	361
Aerosols and Clouds	296
Trace gases and Greenhouse gases	190
Atmospheric Research Infrastructures	183
ACTRIS (Aerosol, Clouds and Trace Gases Research Infrastructure)	134
IAGOS (In-service Aircraft for a Global Observing System)	123
ICOS (Integrated Carbon Observation System)	106
The workflow and benefits of a coordinated approach	77
Meet ACTRIS	68
Meet IAGOS	32
Meet ICOS	34
Making of	28

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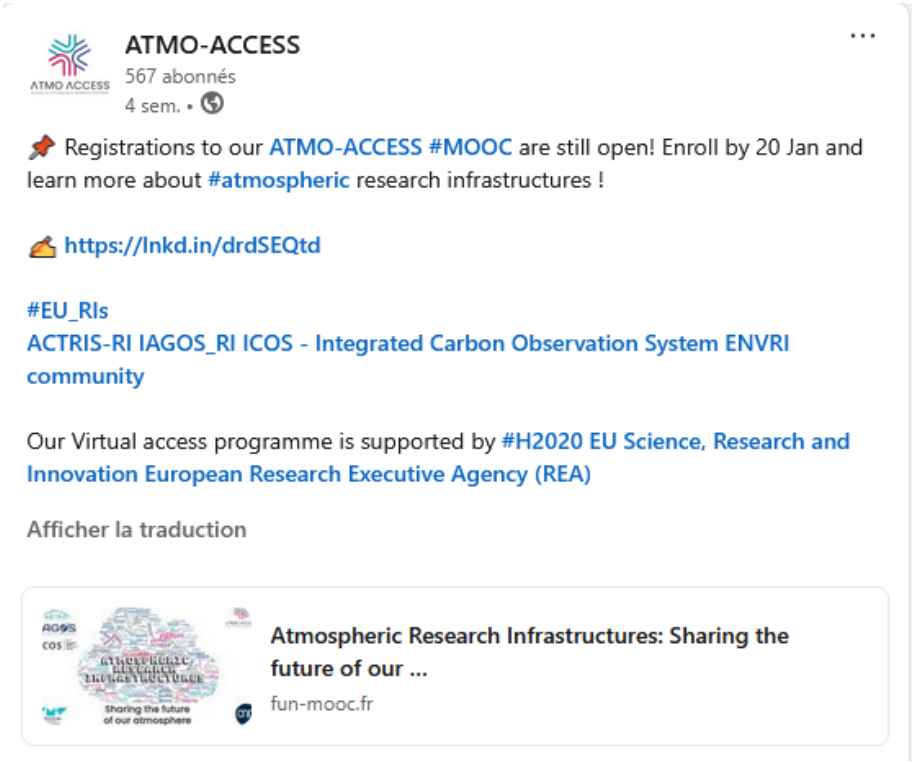
Annexes

Examples of the use of social media to communicate about the MOOC

- LinkedIn post of the ATMO-ACCESS project



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- LinkedIn post of IMT Nord-Europe (in French)

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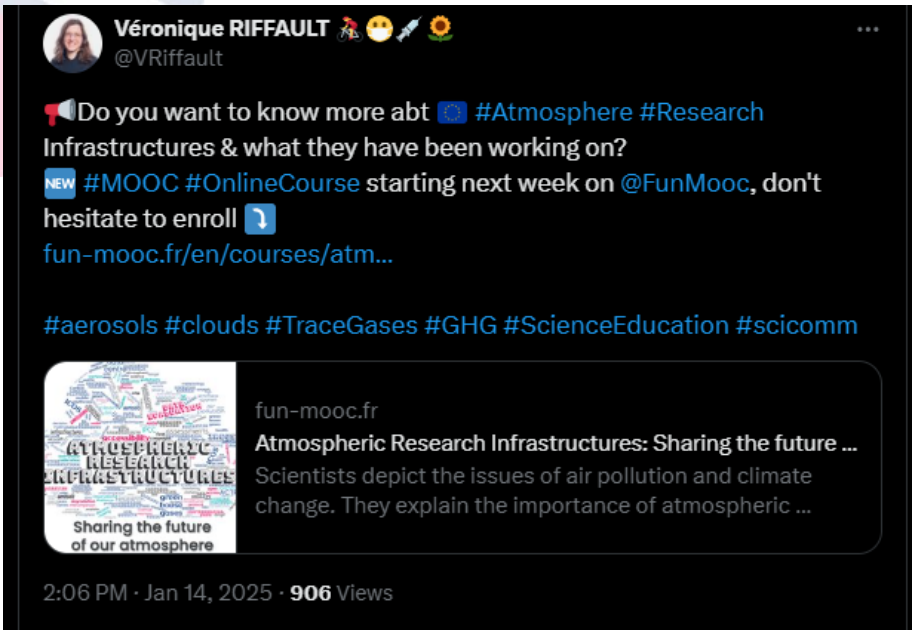
- X post from the Project leader, primary instructor



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MOOC content, 1st week: To go further

List of the 8 critical questions and answers on air pollution and climate change to go further and explore.

- How do the concentrations and distributions of aerosols and trace gases vary in space and time?
- How do clouds, aerosols and trace gases affect the Earth's radiation balance and atmospheric chemistry?
- What is the difference between weather and climate?
- How do climate feedback mechanisms affect atmospheric composition and chemistry?
- What is driving climate change? Are there other factors causing climate change?
- How do scientists predict the future climate? What is a climate model?
- Could global warming be beneficial?
- Can aerosols be beneficial for climate change mitigation? Should we explore increasing their levels as a possible strategy?

MOOC content, 2nd week: Interviews

The following table summarizes key information about the interviewees.

RI	Interviewee	Gender	Actual position	Institution
ACTRIS	Eija Juurola	F	General Director	ACTRIS ERIC Head Office
	Suzanne Crumeyrolle	F	Associate Professor	University of Lille, LOA
	Stefan Reimann	M	Principal Investigator	EMPA, Climate Gases
IAGOS	Hannah Clark	F	Executive Secretary	IAGOS AISBL
	Thibaut Lebourgeois	M	PhD Student	IAGOS, LAERO
	Romain Blot	M	Technical Manager	IAGOS, LAERO

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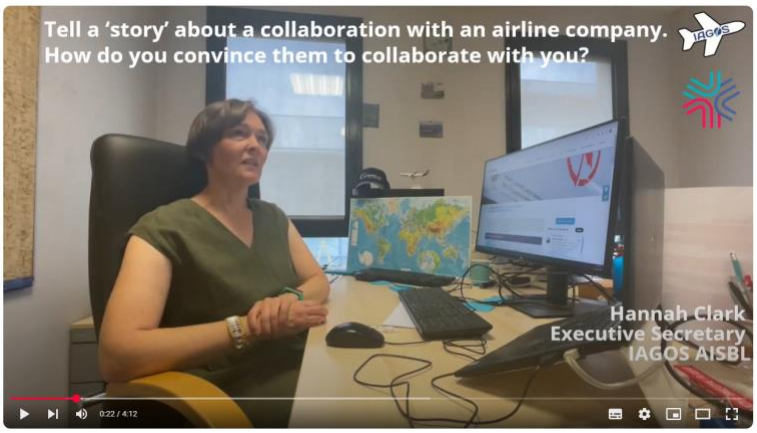
	Julie Patuel	F	Scientific Researcher	IAGOS, LAERO
ICOS	Elena Saltikoff	F	Head of Operations	ICOS Head Office

The following screenshots provide illustrations of the 3 RIs interviews.



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Additional material

- Glossary (41 entries)

Aerosols
Solid or liquid particles (in the nanometre to micrometre range) suspended in the air, which can scatter or absorb the Sun's radiation. They may be harmful when inhaled.

Air monitoring station
A site at which the concentration of one or more pollutants is monitored.

Aitken particles
Aerosol particles between 10 and 100 nanometers in diameter. These are generally the most numerous among all particles in the air. However, due to their small size, Aitken particles contribute little to the total mass concentration of all aerosol particles, which is mostly determined by particles of diameter above 100 nm.

Anthropogenic
Produced by human activities.

Boundary layer
The well-mixed region close to the ground in the lower atmosphere, in which convection induced by the upward heat flux originating from the solar-heated Earth's surface creates turbulences. During the afternoon it can often extend from 1 to 5 km in height.

Calibration gas mixture
A gas mixture of known composition, generally comprising one or more calibration components and an inert gas.

Carbon Footprint
The amount of carbon dioxide (or its equivalent if other greenhouse gases are concerned) released into the atmosphere as a result of the activities of a particular individual, organisation or community.

CFCs (Chlorofluorocarbons)
This class of molecules has been used extensively since the 1950s in refrigeration, "aerosol" spray cans, the manufacture of insulation, etc. The lifetime of many chlorofluorocarbons is very long in the troposphere. For example, the lifetime of $CClF_3$ and CCl_2F_2 is a few hundred years. The major destruction of these species occurs in the stratosphere where photodecomposition of the halocarbons produces Cl atoms which are involved in pathways to deplete stratospheric ozone. They were banned in 1987 according to the Montreal Protocol.

Cloud
An atmospheric aerosol which is made of enough water droplets or ice crystals in the micrometre range to be visible to the eye.

Deposition
A process by which aerosols and gases in the air are deposited on the Earth's surface (soil, water, rock, plants, etc.). Wet deposition involves the scavenging of chemicals by water droplets or snow crystals as they form and fall through the atmosphere. Dry deposition occurs through turbulence, diffusion, impaction, and sedimentation.

Diel variations
Variations that follow a distinct pattern in a 24-hour cycle.

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Diurnal variation
Variations occurring in the daytime.

Emission
The total rate at which a solid, liquid, or gaseous pollutant is emitted into the atmosphere from a given source; usually expressed as mass per unit of time. Primary emissions are substances emitted directly into the atmosphere (e.g., NO, SO_2). Secondary emissions are formed from the primary emissions through thermal or photochemical reactions (e.g., ozone, aldehydes, ketones, sulfuric acid, nitric acid).

Flux
The number or mass of particles or molecules which pass through a given unit surface area per unit time. The net vertical flux of a species is the difference between the downward and upward flux of that species.

Fossil fuels
Fuels such as coal, oil, and natural gas that have formed over many years by the decomposition of deposited vegetation under the extreme pressure of an earth overburden.

Greenhouse gas
A gas that absorbs and emits thermal radiation, contributing to the greenhouse/blanket effect.

In situ measurements
Measurements that are performed directly on site. In the context of ACTRIS, in situ measurements of aerosol, cloud, and reactive trace gas properties refer to techniques that characterise a sampling point. They can be performed from observational platforms near the surface, mobile surface-based or airborne platforms, atmospheric simulation chambers and laboratories.

IPCC
The Intergovernmental Panel on Climate Change (IPCC) is a scientific body that reviews and assesses scientific, technical and socioeconomic information on climate change.

IR
The infrared spectrum refers to the range of wavelengths where the absorption of radiation is associated with vibrational transitions in molecules, typically cited in wavenumbers between 200 and 4000 cm^{-1}.

Keeling curve
The Keeling curve presents the trend of increasing carbon dioxide concentration with time, which began in the 1950s. The original record is made on a volcano in Hawaii (Mauna Loa), and the measurements are made by non-dispersive infrared spectroscopy. Levels are over 410 ppm (parts per million) in the year 2024.

Lifetime
The period of time required for the decay of a given species of initial concentration $[A]_o$ to $[A]_o/e$ (e = 2.7183).

Monitoring
Repeated and regular measurements of pollutants to follow their changes over a period of time. Usually in relation to some standard or in order to assess the effectiveness of a system of regulation and control.

NASA
The National Aeronautics and Space Administration is the United States of America's civil space program and the global leader in space exploration.

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NO_x

NO_x refers to the sum of nitric oxide (NO) and nitrogen dioxide (NO_2), the two oxides of nitrogen that are most significant in atmospheric chemistry near the ground level. The term specifically does not include nitrous oxide (N_2O).

Observational platform

In the context of ACTRIS, an observational platform represents a fixed ground-based station that acquires reliable high-quality data.

Oxidant

In the context of atmospheric chemistry, the term oxidant includes all trace gases having an oxidation potential greater than oxygen (ozone, peroxyacetyl nitrate, hydrogen peroxide, organic peroxides, NO_3, etc.). They are natural detergents, responsible for removing the majority of trace gases emitted into the atmosphere either via natural processes or human activities. The hydroxyl radical (OH), a neutral species containing one hydrogen and one oxygen atom, is the main one. It has one unpaired electron (hence by definition a radical) and is highly reactive.

Particle (atmospheric)

A small discrete mass of solid or liquid matter.

Particulate matter

A general term used to describe airborne solid or liquid particles of all sizes. The term aerosol is recommended for general use in describing airborne particulate matter.

Pollutant (atmospheric)

A gaseous substance or particulate material that has been introduced into the air, either by human activity or natural processes, in sufficient concentration to produce a measurable negative effect on humans, animals, vegetation, or materials.

Photochemical reaction

A reaction which occurs following light absorption of sufficient energy per quantum (usually ultraviolet or visible radiation) by a molecule or an atom, leading to an electronically excited state. In electronically excited species, one or several types of photochemical reaction may occur: photodecomposition into molecular fragments or radicals, photodecomposition into stable, smaller products, photoisomerization, intersystem crossing (a singlet to triplet state, etc.), internal energy conversion (e.g., excited singlet to vibrationally excited, singlet ground state), fluorescence, phosphorescence, electronic or vibrational energy quenching, etc.

Photochemical smog

The resulting mix of ozone, peroxyacetyl nitrate, aldehydes and other oxidation products of hydrocarbons, oxides of nitrogen, aerosols, etc., which form in highly polluted urban atmospheres under conditions of stagnation and high sunlight intensity. Large cities frequently show some degree of photochemical smog. The characteristics of photochemical smog include eye irritation, visibility reduction, damage to certain sensitive plants and trees, and possible pulmonary and other health-related problems in humans and animals.

Primary pollutant

A pollutant emitted directly into the air from identifiable sources (e.g., SO_2, NO, hydrocarbons). Secondary pollutants, such as ozone, are generated within the atmosphere through chemical changes in primary pollutants.

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Radiation

General term for electromagnetic waves which reach the Earth's atmosphere from space, or are reflected/scattered by Earth and its atmosphere. Wavelengths stretch from radiowaves (very long wavelengths) through microwaves, infrared, visible, ultraviolet, X-rays and gamma radiation.

Radiative forcing

The difference between energy from the Sun absorbed by the Earth and energy from the Sun reflected by the Earth, given in W/m^2.

Remote sensing measurements

Measurements from a distance, by means of instruments not in immediate physical contact with the sample being examined, typically using satellites or radars. In the context of the ARIs, remote sensing measurements refer to active and passive atmospheric remote sensing techniques for the observation of aerosols, clouds, and trace gases. They can be applied at observational sites and on mobile platforms.

Sample probe

A sample probe is a sampling device that penetrates a gaseous environment to obtain a sample. It features a connection point for attaching a sampling line or a container for collecting the extracted gas.

Sink

In atmospheric chemistry, the sink is the receptor for material which is removed from the atmosphere. Because of long-range transport of many pollutants, the sink region can be many hundreds of kilometres from the source region of the pollutants.

Smog

The term originated in Great Britain as a popular derivation of "smoke-fog" and appears to have been in common use before World War I. It originally referred to the heavy pollution derived largely from coal burning. Nowadays in the 2020s, it corresponds to an oxidising atmosphere containing ozone and other oxidants, appearing in cities.

Solar radiation

The electromagnetic radiation emitted by the Sun. The total range of wavelengths of light emitted by the Sun (99.9% in the range from 150 to 4000 nm) is filtered on entering the Earth's atmosphere, largely through absorption by oxygen, ozone, water vapour, and carbon dioxide. Near sea level only light of wavelengths longer than 290 nm is present. The light from 290-400 nm is effective in inducing important photochemical processes since absorption by important trace gases, such as ozone, nitrogen dioxide, aldehydes, ketones, etc., is significant in this region.

Source

In atmospheric chemistry, a source is any process or mechanism that releases gases or particles into the atmosphere. It can be also a place, places, or group of sites or areas where a pollutant is released.

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Tracer

A foreign substance mixed with or attached to a given substance, enabling the distribution or location of the latter to be determined subsequently. For example, the composition of aerosols in the troposphere has been used as a qualitative tracer of air masses. There are several types of tracers which are used: a) physical tracers are attached by physical means to the object being traced; b) chemical tracers have properties similar to those of the traced substance with which it is homogeneously mixed; c) isotopic tracers are unique isotopes, either radioactive or an enriched, uncommon stable isotope, of the element to be traced; d) radioactive tracers are physical or chemical tracers having radioactivity as their distinctive property, which allows their detection at small concentrations and hence after large transport distances.

- Abbreviations and nomenclature

This section of the platform contains a list of chemical families (7 entries) and chemical compounds (22 entries) mentioned in the MOOC, the ATMO-ACCESS facilities included in the project (split into observational platforms – 29 entries, atmospheric simulation chambers – 14 entries, mobile exploratory platforms – 5 entries, central laboratories – 13 entries, and IAGOS facility members – 8 entries), and a list of general abbreviations (57 entries).

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Chemical families

Name	Abbreviation	Comments or external links
Chlorofluorocarbons	CFCs	EEA* glossary: https://www.eea.europa.eu/help/glossary/eea-glossary/chlorofluorocarbon https://earthdata.nasa.gov/topics/atmosphere/chlorofluorocarbons
Hydrofluorocarbons	HFCs	EEA glossary: https://www.eea.europa.eu/help/glossary/eea-glossary/hydrofluorocarbon
Non-Methane HydroCarbons	NMHCs	Compounds with the molecular formula C_xH_y, excluding methane (x=1, y=4)
Nitrogen oxides	NO_x	Corresponds to the sum of nitric oxide (or nitrogen monoxide, NO) and nitrogen dioxide (NO_2)
Oxygenated Volatile Organic Compounds	OVOCs	VOCs (see definition below) containing one or more oxygen atoms
Volatile Chemical Products	VCPs	Anthropogenic (human-made) VOCs (see definition below)
Volatile Organic Compounds	VOCs	European Union official definition (art. 3 (45)): https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:02010L0075-20240804%20 EEA glossary: https://www.eea.europa.eu/help/glossary/other-eea-terms/volatile-organic-compound US EPA definition: https://cdxapps.epa.gov/oms-substance-registry-services/substance-details/1846415

* EEA: European Environmental Agency, https://www.eea.europa.eu/

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Chemical compounds

Molecular formula	Name	Link to the NIST Webbook of Chemistry
CH_4	Methane	https://webbook.nist.gov/cgi/cbook.cgi?Name=Methane
C_2H_6	Ethane	https://webbook.nist.gov/cgi/cbook.cgi?Name=Ethane
C_2H_4O	Acetaldehyde	https://webbook.nist.gov/cgi/cbook.cgi?Name=Acetaldehyde
C_3H_6O	Acetone	https://webbook.nist.gov/cgi/cbook.cgi?Name=Acetone
C_4H_6O	Methacrolein	https://webbook.nist.gov/cgi/cbook.cgi?Name=Methacrolein
C_5H_8	Isoprene	https://webbook.nist.gov/cgi/cbook.cgi?Name=Isoprene
C_6H_6	Benzene	https://webbook.nist.gov/cgi/cbook.cgi?Name=Benzene
C_7H_8	Toluene	https://webbook.nist.gov/cgi/cbook.cgi?Name=Toluene
CO	Carbon monoxide	https://webbook.nist.gov/cgi/cbook.cgi?Name=Carbon+monoxide
CO_2	Carbon dioxide	https://webbook.nist.gov/cgi/cbook.cgi?Name=Carbon+dioxide
CS_2	Carbon disulphide	https://webbook.nist.gov/cgi/cbook.cgi?Name=Carbon+disulfide
C_2H_6S	Dimethyl sulphide (DMS)	https://webbook.nist.gov/cgi/cbook.cgi?Name=Dimethyl+sulfide
H_2O	Water	https://webbook.nist.gov/cgi/cbook.cgi?Name=Water
H_2S	Hydrogen sulphide	https://webbook.nist.gov/cgi/cbook.cgi?Name=Hydrogen+sulfide
HCHO	Formaldehyde	https://webbook.nist.gov/cgi/cbook.cgi?Name=Formaldehyde
N_2O	Nitrous oxide	https://webbook.nist.gov/cgi/cbook.cgi?Name=Nitrous+oxide
NO	Nitrogen monoxide	https://webbook.nist.gov/cgi/cbook.cgi?Name=Nitric+oxide
NO_2	Nitrogen dioxide	https://webbook.nist.gov/cgi/cbook.cgi?Name=Nitrogen+dioxide
O_3	Ozone	https://webbook.nist.gov/cgi/cbook.cgi?Name=Ozone
OCS	Carbonyl sulphide	https://webbook.nist.gov/cgi/cbook.cgi?Name=Carbonyl+sulfide
SF_6	Sulphur hexafluoride	https://webbook.nist.gov/cgi/cbook.cgi?Name=Sulfur+hexafluoride
SO_2	Sulphur dioxide	https://webbook.nist.gov/cgi/cbook.cgi?Name=Sulfur+dioxide

ATMO-ACCESS Facilities

(https://www.atmo-access.eu/facilities/)

Observational platforms (fixed ground-based stations)

Acronym	Facility	Location
AGORA	Andalusian Global ObseRvatory of the Atmosphere	Granada, Spain
ATMOS	AThens MOnitoring Supersite	Athens, Greece
ARN	Atmospheric Sounding Station El Arenosillo	Mazagón, Huelva, Spain
BNC	Barcelona Cluster	Barcelona, Spain
CAO	Cyprus Atmospheric Observatory	Agia Marina Xyliatou, Cyprus
CESAR	Cabauw Experimental Site for Atmospheric Research	Lopik, the Netherlands
CIAO	CNR-IMAA Atmospheric Observatory	Tito (Potenza), Italy
CMN-PV	Monte Cimone – Po Valley	Monte Cimone
CO-PDD	Cézeaux-Aulnat Opme Puy de Dôme	Clermont-Ferrand, France
CVAO	Cape Verde Atmospheric Observatory	Calhau, Cape Verde Island
EVASO	EVora Atmospheric Science Observatory	Evora, Portugal
FKL	Finokalia	Finokalia, Crete, Greece.

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FMI PAL-SOD	Pallas-Sodankylä Atmosphere-Ecosystem Supersite	Muonio, Finland
HTM	Hyltemossa Research Station	Forest in southern Sweden; Nearest small town: Perstorp
JFJ	High Altitude Research Station Jungfraujoch	Jungfraujoch, Switzerland
ISAF	Izana Subtropical Access Facility	La Orotava, Tenerife, Spain
MHD	Mace Head Atmospheric Research Station	Carna, county Galway, Ireland
MEL	TROPOS Research Station Melpitz	Melpitz, Germany
NAOK	National Atmospheric Observatory Košetice	Košetice, Czech Republic
OPAR	Observatoire de Physique de l'Atmosphère à la Réunion	La Réunion Island, France
PANGEA	PANhellenic GEophysical observatory of Antikythera	Island of Antikythera, Greece
RADO	Romanian Atmospheric 3D research Observatory	Magurele, Romania
SBO	Sonnblick Observatory	Salzburg, Austria
SIRTA	Site Instrumental de Recherche par Télédétection Atmosphérique	Plateau de Saclay (Paris), France
SMEAR II	Station for Measuring Ecosystem – Atmosphere Relations II	Juupajoki, Finland
SMEAR EE	Station for Measuring Ecosystem – Atmosphere Relations Estonia	Järvselja, Estonia
VRS	Villum Research Station	North Station, Greenland, Denmark
WOPAS	Wrocław Observatory Platform for Atmospheric Studies	Wrocław, Poland
WOS	Warsaw Observatory Station	Warsaw, Poland

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Atmospheric simulation chambers

Acronym	Facility	Location
AIDA	Aerosol Interaction and Dynamics in the Atmosphere	Karlsruhe, Germany
ACD-C and LACIS-T	Aerosol Chamber of the Atmospheric Chemistry Department (ACD-C) and Turbulent Leipzig Aerosol Cloud Interaction Simulator (LACIS-T)	Leipzig, Germany
AURA	Aarhus University Research on Aerosols chamber	Aarhus, Denmark
CESAM	Experimental Multiphasic Atmospheric Simulation Chamber	Créteil, France
ChAMBRe	Chamber for Atmospheric Modelling and Bio-Aerosol Research	Genoa, Italy
ESC-Q-UAIC	Environmental Simulation Chamber from the "Alexandru Ioan Cuza" University of Iasi	Iași, Romania
EUPHORE	European PHOtoreactor	Valencia, Spain
HELIOS	Outdoor Atmospheric Simulation Chamber of Orléans	Orléans, France
IASC	Irish Atmospheric Simulation Chamber	Cork, Ireland
KASC	Kuopio Atmospheric Simulation Chambers	Kuopio, Finland
MAC	Manchester Aerosol Chamber	Manchester, United Kingdom
PACS-C2	PSI Atmospheric Chemistry Simulation Chambers	Villigen, Switzerland
QUAREC	Quartz Reactor	Wuppertal, Germany
SAPHIR/SAPHIR-PLUS	Simulation of Atmospheric Photochemistry in a Large Reaction Chamber	Jülich, Germany

Mobile Exploratory platforms

Acronym	Facility	Location
AMP Poland	ACTRIS-Poland Mobile Platform	Sosnowiec, Poland
FCoMLab	Finland Combined Mobile Laboratory	Finland
FORTH-MSC	FORTH Mobile atmospheric Simulation Chamber	Patras, Greece
LACROS	Leipzig Aerosol and Cloud Remote Observations System	Leipzig, Germany
USRL	Unmanned Systems Research Laboratory	Nicosia & Orounda, Cyprus

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Central Laboratories

Acronym	Relevant Research Infrastructure | Facility	Location
ACMCC	ACTRIS | Aerosol Chemical Monitor Calibration Centre	Plateau de Saclay (Paris), France
CARS-CNR	ACTRIS | CNR Lidar calibration centre	Tito (Potenza), Italy
CARS-ES-ISAF	ACTRIS | Centre for Aerosol Remote Sensing at Izaña Subtropical Facility	Tenerife Island, Spain
CCRES-FR	ACTRIS | Centre for Cloud Remote Sensing – France	Plateau de Saclay (Paris), France
CCice	ACTRIS | Centre for Cloud Ice Nucleation	Karlsruhe, Germany
CCRES-NL	ACTRIS | Centre for Cloud Remote Sensing – NL	Lopik, The Netherlands
CiGAS-CH	ACTRIS | Centre for Reactive Trace Gases In Situ Measurements	Dübendorf, Switzerland
ICOS-ATC	ICOS | Atmospheric Thematic Center	Plateau de Saclay (Paris), France
ICOS-Lab	ICOS | Mobile laboratory	
Isolab – UU	ICOS | Isotope laboratory at Utrecht University	Utrecht, The Netherlands
LiCAL – INOE	ACTRIS | Lidar Calibration Centre	Magurele, Ilfov, Romania
PACC	ACTRIS | Prague Aerosol Calibration Centre	Prague, Czech Republic
WCCAP	ACTRIS | World Calibration Center for Aerosol Physics	Leipzig, Germany

IAGOS FACILITY MEMBERS
https://www.iagos.org/organisation/members/

Facility	Location
Forschungszentrum Jülich GmbH	Jülich, Germany
Centre National de la Recherche Scientifique	Paris, France
Max-Planck-Gesellschaft zur Förderung der Wissenschaften e.V.	München, Germany
Météo France	Toulouse, France
University of Manchester	Manchester, U.K.
Deutsches Zentrum für Luft- und Raumfahrt e.V.	Köln, Germany
Leibniz-Institut für Troposphärenforschung e.V.	Leipzig, Germany
Karlsruher Institut für Technologie	Karlsruhe, Germany

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General abbreviation table

ACTRIS	Aerosol, Clouds and Trace Gases Research Infrastructure
AP	Air Pollution
ARIs	Atmospheric Research Infrastructures
BCP	Backscatter Cloud Probe
CARIBIC	Civil Aircraft for the Regular Investigation of the Atmosphere Based on an Instrument Container
CC	Climate Change
CCN	Cloud Condensation Nuclei
CFCs	ChloroFluoroCarbons
CTMs	Chemical Transport Models
CiGAS	Centre for Reactive Trace Gases In Situ Measurements
EASA	European Aviation Safety Agency
EMEP	European Monitoring and Evaluation Programme
ENVRI	Environmental Research Infrastructure
ERA	European Research Area
ERF	Effective Radiative Forcing
ERIC	European Research Infrastructure Consortium
ESA	European Space Agency
ESFRI	European Strategy Forum on Research Infrastructures
EU	European
FAIR	Findable, Accessible, Interoperable, Reusable
GAW	Global Atmospheric Watch programme
GHGs	GreenHouse Gases
GSAT	Global mean Surface Air Temperature
HTAP	Hemispheric Transport of Air Pollution
IAGOS	In-service Aircraft for a Global Observing System
ICOS	Integrated Carbon Observation System
IPCC	Intergovernmental Panel on Climate Change
IR	InfraRed
LiDAR	Light Detection and ranging
MOOC	Massive Open Online Course
MSA	Monitoring Station Assembly
NASA	National Aeronautics and Space Administration
NFs	National Facilities
NMHCs	Non-Methane HydroCarbons
NOAA	National Oceanic and Atmospheric Administration
OVOCs	Oxygenated Volatile Organic Compounds
PBL	Planetary Boundary Layer
PM	Particulate Matter
ppm	Part per million
ppb	Part per billion
ppt	Part per trillion
PTR-MS	Proton-Transfer-Reaction Mass Spectrometry
RF	Radiative Forcing
RI	Research Infrastructure
SATCOM	Satellite Communication datalink
SIA	Secondary Inorganic Aerosols
SOA	Secondary Organic Aerosols
STC	Supplemental Type Certificate

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TGs	Trace Gases
UAVs	Unmanned Aerial Vehicles
UFPs	UltraFine Particles
UNFCCC	United Nations' Framework Convention on Climate Change
UTLS	Upper Troposphere Lower Stratosphere
UV	UltraViolet
VCPs	Volatile Chemical Products
VOC	Volatile Organic Compound
WMO	World Meteorological Organisation

- Useful articles and websites

The article page features selected scientific publications (all open access, from 2015 to 2024), as well as a link to databases collecting the published literature related to the three RIs.
The website page advertises the webpages of the project and the three RIs, their data portals, and a few external partners at the global scale

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ATMO ACCESS
Access to Atmospheric Research Facilities

All the scientific publications listed on this page are open access. Additional publications (some open access, others not) are available via the links to the relevant databases.

Related to Atmospheric Research Infrastructures

Petzold et al. (2024) "*Opinion: New directions in atmospheric research offered by research infrastructures combined with open and data-intensive science*" - link

Related to ACTRIS

- Pandolfi et al. (2018) "*A European aerosol phenomenology – 6: scattering properties of atmospheric aerosol particles from 28 ACTRIS sites*" - link
- Laj et al. (2024) "*Aerosol, Clouds and Trace Gases Research Infrastructure (ACTRIS): The European Research Infrastructure Supporting Atmospheric Science*" - link
- Doussin et al. (2024) "*A Practical Guide to Atmospheric Simulation Chambers*" - link
- Database of ACTRIS/EARLINET scientific publications
- Database of ACTRIS/Cloudnet scientific publications

Related to IAGOS

- Petzold et al. (2015) "*Global-scale atmosphere monitoring by in-service aircraft – current achievements and future prospects of the European Research Infrastructure IAGOS*" - link
- Bundke et al. (2015) "*The IAGOS-CORE aerosol package: instrument design, operation and performance for continuous measurement aboard in-service aircraft*" - link
- Cohen et al. (2024) "*Multi-model assessment of climatologies in the upper troposphere–lower stratosphere using the IAGOS data*" - link
- Database of IAGOS scientific publications

Related to ICOS

- Ramonet et al. (2020) "*The fingerprint of the summer 2018 drought in Europe on ground-based atmospheric CO_2 measurements*" - link
- Saunois et al. (2020) "*The Global Methane Budget 2000–2017*" - link
- Heiskanen et al. (2022) "*The Integrated Carbon Observation System in Europe*" - link
- Database of ICOS scientific publications

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ATMO ACCESS
Access to Atmospheric Research Facilities

ATMO-ACCESS Project

- Website: https://www.atmo-access.eu/
- Virtual Access Portal: https://www.atmo-access.eu/virtual-access/

ACTRIS

- Website: https://www.actris.eu/
- Data Portal: https://dc.actris.nilu.no/

IAGOS

- Website: https://www.iagos.org/
- Data Portal: https://iagos.aeris-data.fr/

ICOS

- Website: https://www.icos-cp.eu/
- Data Portal: https://data.icos-cp.eu/portal/

European Research Infrastructures (ESFRI)

Website: https://www.esfri.eu/

External institutions

- European Environmental Agency - https://www.eea.europa.eu/en
- Intergovernmental Panel on Climate Change (IPCC) - https://www.ipcc.ch/
- World Meteorological Organisation (WMO)
  - Website: https://public.wmo.int/en
  - Global Atmosphere Watch Station Information System: https://gawsis.meteoswiss.ch/GAWSIS/#/

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Final survey

(1/1 point)
Do you find this course useful for learning about state-of-the-art facilities and services in atmospheric RIs?

- 1 - Not at all
- 2 -
- 3 -
- 4 - ✔
- 5 - Very much
- unanswered

CHECK

(1/1 point)
Does this course help you explore the multidisciplinary use of atmospheric research facilities to address relevant scientific questions?

- 1 - Not at all
- 2
- 3
- 4
- 5 - Very much ✔
- unanswered

CHECK

Did you find that the following aspects of the course matched your needs?

(1/1 point)
Calendar (number of weeks)

- 1 - Not at all
- 2
- 3
- 4
- 5 - Very much ✔
- unanswered

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(1/1 point)
Grading (things to do in order to pass the course)

- 1 - Not at all
- 2
- 3
- 4
- 5 - Very much ✔
- unanswered

CHECK

Did you appreciate the following elements?

(1/1 point)
Pedagogical design of each course section

- 1 - Not at all
- 2
- 3
- 4
- 5 - Very much ✔
- unanswered

CHECK

(1/1 point)
Quality of videos

- 1 - Not at all
- 2
- 3
- 4
- 5 - Very much ✔
- unanswered

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atmo-access.eu

(1/1 point)
Interest of interactions and questions

- 1 - Not at all
- 2
- 3
- 4
- 5 - Very much ✔
- unanswered

CHECK

(1/1 point)
Interest of interviews

- 1 - Not at all
- 2
- 3
- 4
- 5 - Very much ✔
- unanswered

CHECK

(1/1 point)
Utility of additional materials

- 1 - Not at all
- 2
- 3
- 4
- 5 - Very much ✔
- unanswered

CHECK

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(1/1 point)
Quality of quizzes

- 1 - Not at all
- 2
- 3
- 4
- 5 - Very much ✔
- unanswered

CHECK

(1/1 point)
The MOOC videos and the interviews are subtitled in additional languages. On a personal level, did you find this:

- Useless, my English is good enough.
- Useful, I was not sure to understand everything and it motivated me to enroll.
- Extremely useful, I would not have been able to understand the course without them. ✔

CHECK

(1/1 point)
After exploring the multidisciplinary aspect of the RIs, would you be interested in getting involved with an atmospheric RI?

- 1 - Not at all
- 2
- 3
- 4
- 5 - Very much ✔
- unanswered
- I am already involved with an RI

CHECK

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(1/1 point)
Which part of the MOOC did you like most and why?

Interactive videos + interviews

✔

CHECK

(1 point possible)
Would you like to propose ideas to improve the course? For example, by expanding/emphasising a specific subject, or by offering more activities? We welcome your suggestions!

CHECK

(1 point possible)
Would you like to add any general remarks?

CHECK

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