ATMO ACCESS
Access to Atmospheric Research Facilities

Report on the long-term strategy of training and TNA related to the three access modalities

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1. Introduction

Growing concerns over air pollution and greenhouse gas emissions have spurred a significant need for advanced research and effective monitoring strategies to address these global challenges. Training both early career and experienced scientists on air pollution measurements and greenhouse gas assessments is therefore vital to ensure the success of ongoing research initiatives and the long-term sustainability of environmental research.

In recent years, the landscape of scientific training has evolved, particularly in response to the constraints posed by the COVID-19 pandemic. Remote access and hybrid training formats have emerged as viable alternatives to traditional week-long in-person training schools, enabling wider participation and greater international outreach, reducing costs, and offering greater flexibility. These methods present a unique opportunity to make training more accessible, particularly for those who may be geographically distant or face other barriers to attendance.

However, while remote and hybrid formats offer clear benefits, the question arises as to whether physical attendance at training is still necessary. Physical presence can facilitate hands-on experience, provide networking opportunities, and enable direct collaboration with peers and mentors. Therefore, it is essential to assess the balance between the advantages of digital training options and the irreplaceable value of in-person interactions, particularly in fields that require complex hands-on measurements and data analysis.

This report will examine the different training modes related to trans-national access (TNA) access (physical, remote, hybrid, and virtual) in the context of European research infrastructure projects related to air quality and greenhouse gas measurements. The pilots performed within ATMO-ACCESS have been analyzed to identify factors that contribute to the long-term sustainability of training programs. The reasons why physical attendance may still be required are examined, and recommendations are provided on how to best integrate innovative, flexible training solutions while preserving the core benefits of traditional in-person training.

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2. Pilot TNAs for the three access modes, including hybrid access

Figure 1 summarizes the three access modes (physical, remote, virtual) and illustrates the pilot test cases discussed in this report. These cases are related either to campaign-based training or mix of access modes or cross-RI training schools.

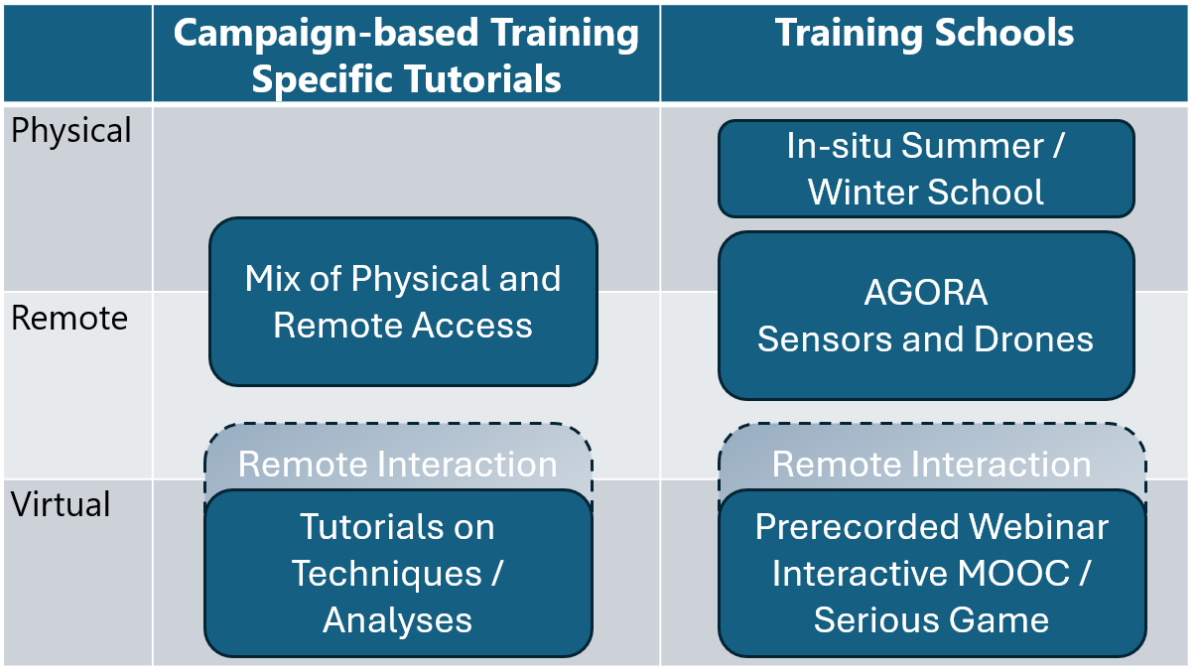

Figure 1: Trainings related to TNA can be performed in physical, remote and virtual modes or as a combination in hybrid format. Shown are individual trainings, which were performed in ATMO-ACCESS during TNA-related campaigns and training schools. In addition, the potential for extending the value of virtual training with an additional remote interaction is shown, which is discussed under the recommendations in section 3.

2.1. Campaign-based training (CBT)

In campaign-based training, trainees participate in experimental campaigns at observation sites (National Facilities) or exploratory platforms (mobile platforms or atmospheric simulation chambers). Additionally, training at Central Laboratories is also discussed under CBT.

2.1.1 Training related to TNA at observation sites, mobile platforms and chambers

TNA at observation sites, mobile platforms and chambers offers a wide variety of possibilities for training, from hands-on instrument training and software to data management knowledge transfer. The user groups are typically students or early-career scientists.

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TNA during campaigns is nowadays often performed in hybrid mode, as a mix of physical, remote and/or virtual access. Scientists are usually only on-site for the installation and deinstallation of instruments, and sometimes the instruments are shipped to the sites without accompanying scientists, with local researchers taking care of the instruments on-site. As no travel is included, this access mode has some ecological advantages. In addition, this could also be cost-efficient in terms of the number of days spent on site. However, it generally requires additional resources from the providers and facility staff. Therefore, overall costs have to be evaluated carefully. Furthermore, a lot of downtime, during which a significant amount of time is spent unproductively on site, can now be used more productively. However, this approach poses a challenge in terms of training. With less time spent on site, it is practically impossible to receive on-the-job training and learn about the instrumentation of other groups. Furthermore, establishing personal networks for future scientific collaboration is substantially hindered.

In the past, training related to TNA-specific user groups has been provided to teachers and students (e.g. at the Finokalia site). Considering ecological sustainability, the transnational component of these accesses only makes sense in cases, such as when cross-border stations are located near users' places of residence. Furthermore, in ATMO-ACCESS, TNA was originally intended to invite policy stakeholders to visit an observation site and learn about the instrumentation and air quality guidelines. In the end, this activity was ultimately performed remotely, so it is advised that a physical TNA activity is not offered for this purpose in the future, except in situations where, for example, a new network is intended to be started, and no equivalent sites are close enough for stakeholders to visit ahead of the activities.

2.1.2 Training related to TNA at Central Laboratories

TNA-related training at the Central Laboratories follows the same purpose as the campaign-based training. Here, scientists take advantage of instruments being shipped to the Central Laboratories (e.g. for recalibration) and receive physical training in instruments and data handling. Experts in a specific technique or instrument can transfer their knowledge on an individual basis. This results in a very intensive training experience for the trainee. However, in terms of efficiency, it is recommended to combine training-related TNAs at the Central Laboratories with either several users or different instruments, or to perform training remotely. Within WP4, the virtual mode has also been tested using videos for technological knowledge transfer. Three pilots have been conducted: First, on the use of an X-act instrument for the online analysis of metals in aerosols (ACTRIS CAIS-ECAC) together with IMT (see below); second, on the application of an online quality assessment tool for analyzing potential errors in VOC data (ACTRIS); and third, on explaining the databases for atmospheric data (EBAS).

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The corresponding videos are available through the following links:
https://www.youtube.com/watch?v=IcAF8oVRrro&ab_channel=ATMO-ACCESS
https://polybox.ethz.ch/index.php/s/uI9WdN81AluL7gO
https://www.youtube.com/watch?v=F18tegyCr-g

Within ATMO-ACCESS, IMT (France) produced three tutorials: First, on the X-act instrument, together with ACTRIS CAIS-ECEC (analysis of metal in particles, 183 views); second, on timeseries analysis service (125 views); third. on analyzing volcanic plumes (released on June 30, 2025).
All three tutorials can be accessed from here: https://www.atmo-access.eu/tutorial-videos/

These tutorials have been done in a very professional manner. Additionally, the interaction between trainees and trainers is still an untapped resource for knowledge transfer. Therefore, to increase interaction and encourage community-building around a training topic or area of study, additional remote interactions would be favorable.

2.2 Training Schools

Training schools are a very common, well-established way for training young scientists. There are several long-established training schools in atmospheric sciences (such as the Hyytiäla summer and winter schools), where both trainers and trainees are physically present. Within ATMO-ACCESS, we have tested new training modalities, in which some trainers participated remotely, or by remotely connecting two independent training workshops. This approach allowed training that was beneficial for both parties to be shared. An important innovation and novelty in trainings schools related to atmospheric sciences was introduced with a cross-RI MOOC (Massive Open Online Course) on Research Infrastructures connected to ATMO-ACCESS. Along with an additional webinar on cross-RI training, these trainings served as successful pilots to test the virtual TNA.

2.2.1 Physical Winter / Summer Schools

Physical training schools are a traditional method of training young scientists in measurement and sampling techniques, data analysis and scientific writing. During the COVID-19 pandemic, this form of training was not possible and was partly replaced by remote formats. After the restrictions ended, physical training schools resumed. While the added value of physical interactions is evident, the environmental impact of travel to the site is a concern in view of environmental sustainability.

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2.2.2 Hybrid Schools (combined physical and remote TNA)

The hybrid format was tested using two different approaches. First, the AGORA (Andalusian Global ObseRvatory of the Atmosphere) training school covered the characterization of atmospheric aerosols using in-situ and remote sensing techniques, and second, a hybrid workshop on sensors and drones was jointly organized by EMPA (Switzerland) and the Cyprus Institute (Cyprus).

In AGORA, the summer school began with remote interactions between students, who were organized into work teams, and their respective research project supervisors. After this initial phase, the students moved to the AGORA observatory, where they attended the main part of the course. This included lectures given in person or remotely by the lecturers, as well as practical activities involving hands-on work with the observatory's instrumentation. This hybrid approach allows the participation of remote lecturers who otherwise might not have the possibility of traveling to the facilities. The final phase of the summer school was conducted remotely. Students worked remotely, from their home institutions, with their team members, under the supervision of their respective tutors, within the framework of scheduled remote meetings. The training school concluded with the remote presentation and defense of the work developed by each team, with the participation of all students and tutors online. This format significantly limited the period of travel for both the trainers and the trainees. Additionally, some of the trainers, who only participated in the theoretical lectures, connected remotely. The students principally approved of this format, although they expected a higher quality of remote lectures. Therefore, remote lectures should be limited to experienced, and highly motivated lecturers. The first edition of AGORA has already been repeated once and will be rerun in a bi-annual mode.

Second, a hybrid workshop on sensors and drones was organized. It combined training on sensors for measuring atmospheric trace gases at a Central Laboratory in Switzerland with a workshop on using drones to measure these compounds at a mobile platform in Cyprus. In this case, almost all the trainers participated remotely, and the lectures that covered common ground for both topics were shared across both locations. Additionally, hands-on work was performed independently at both sites. This format proved to be a successful approach for linking the two communities in a very straightforward way.

2.2.3 Virtual Access

Prerecorded webinars have become an excellent, low-level way to acquire knowledge about a new field. Within the greenhouse gas community, ICOS provides an excellent series of webinars on various topics. Topics include training on ICOS atmospheric measurements and

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guidance on finding and using ICOS data through its web services. More information is available here:
https://www.icos-cp.eu/science-and-impact/education/recorded-workshops-and-webinars

Within ATMO-ACCESS, IMT (France) was primarily responsible for the virtual training component and provided the following pilot virtual training sessions:

A MOOC (massive open online course) on "Atmospheric Research Infrastructures: Sharing the Future of Our Atmosphere" was launched as an innovate and very successful training tool. The first edition took place from January to February 2025, with 811 learners enrolled and the second improved edition took place in May – June 2025, with 518 learners enrolled. The second and third highest number of trainees came from China and India for this second edition, demonstrating the global attractiveness of this type of resource and its ability to enhance the influence and visibility of European RIs. Finally, a "serious game" titled "What's going on in the air?", will be released in July 2025 and will cover aerosol properties via remote sensing.

Additionally, within ATMO-ACCESS, NAOK (Czech Republic) provided an excellent multiday cross-RI webinar (featuring ACTRIS, ICOS, EIRENE), with 16 lectures and 33 practical videos. Over 100 trainees from 39 countries attended this event, which was distributed over the globe. Again, this demonstrates the impact of virtual training. The course is available at the following link:
https://www.atmo-access.eu/atmospheric-and-environmental-research-infrastructure-online-training/

The global accessibility and the continuous availability of these virtual training tools are attractive means of knowledge transfer and strengthens the impact of the project beyond its end date. Interaction with trainees is enforced by quizzes at the end of the training sessions. However, as for the virtual tutorial, interactions between trainees and trainers could be further encouraged by single or regular remote exchanges.

3. Recommendations

3.1 Recommendations for Campaign-based TNA

A campaign-based TNA with a training component should include a certain number of on-site days to discuss instrumentation and data analysis with other on-site scientists. Travel should be limited to fewer but longer stays, to minimize negative ecological impact, although this may affect inclusiveness and gender balance, especially for scientists with family obligations.

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Physical campaign-based TNA related training for non-scientists (e.g. schools and stakeholders) should only be granted under well-defined constraints. Access should be granted either within a short distance of the country where the visit takes place or remotely using state-of-the art IT tools such as virtual reality glasses.

Physical TNA-related training at the Central Laboratory should combine several access modes to be more efficient in terms of trainers and travel. Combining several trainees on-site will provide additional value.

Physical TNA-related training at the Central Laboratory should be replaced, at least partially, by virtual tools such as instructional videos, to reach users more efficiently.

When virtual access is provided, an additional benefit could be the option of remote access for interaction between trainers and trainees. This could include regular remote meetings (e.g. once or twice per year in different time zones as a Q&A session) to build a specific community of users.

3.2 Recommendations for Training Schools

Physical training schools remain the foundation for educating the next generation of scientists. Working alongside other scientists can hardly be replaced by remote access alone. However, to increase international outreach, and for environmental and economic reasons, including remote and virtual access modes should be considered.

For example, training schools that are purely based on physical access can use remote access to attract high-impact researchers in the field to act as trainers.

Hybrid access has great potential for training schools and allows for flexibility. It also promotes sustainability in economic and environmental terms.

Remote access in combination with virtual training, before or after the training, reinforces the training topics and builds community.

Cross-RI training has a big potential to connect different RIs from neighbouring scientific disciplines. Virtual or remote access is recommended as an efficient way to perform this novel type of training.

An unused possibility for reducing the environmental impact of training related to TNA is to use the hybrid mode with physical and remote access for spatially shared meetings. Trainees could meet at regional focus points throughout Europe and use remote access to share the

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meeting. This could also be used to jointly visit conferences on other continents with other students remotely.

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