ATMO ACCESS
Access to Atmospheric Research Facilities

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Summary

This deliverable presents an analysis of the development, user feedback, iterative improvements, and achievements of cross-RI services implemented under work package 5 of the ATMO-ACCESS project. Throughout the project's lifetime, significant efforts were invested to create a suite of services that are technologically advanced and highly responsive to user needs, ensuring broad scientific applicability and long-term sustainability.

The ATMO ACCESS VA portal is accessible from the ATMO ACCESS web site and through the direct link https://www.atmo-access.eu/virtual-access/#/.

After successful login the user will have the choice for the different services through a set of large icons, guided by a short description of the services. The page also allows the user to directly provide feedback on the VA tool through a link in a highlighted button and a QR code.

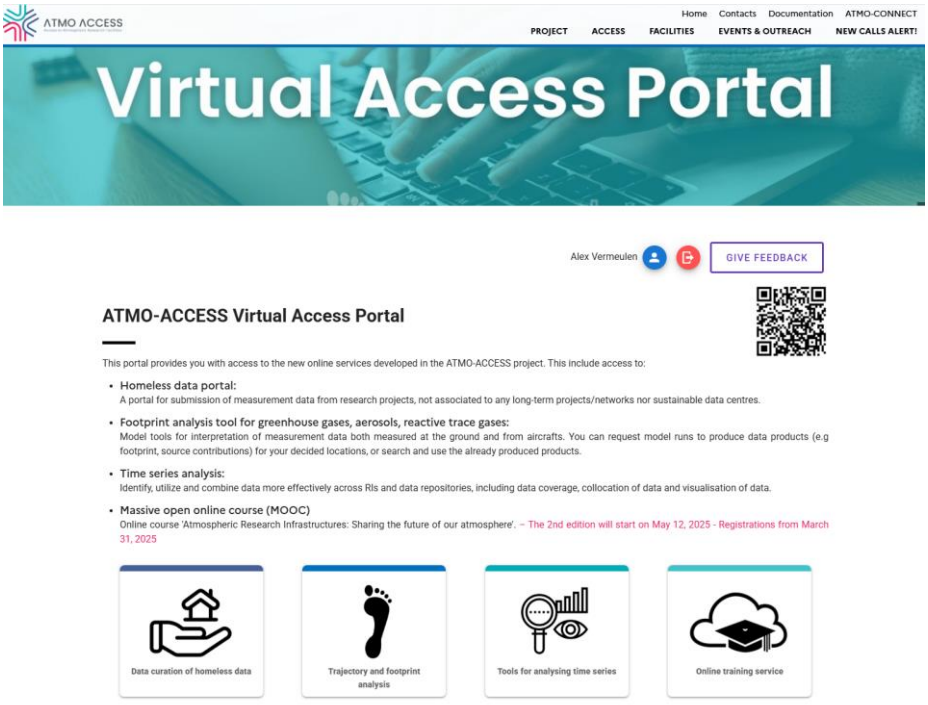

Figure 1 Entry page of the ATMO ACCESS Virtual Access portal

The VA Portal gives access to the following services (more details can be found in ATMO ACCESS Deliverable 5.7):

- **The Homeless Data Portal** is a data curation system providing long-term storage of atmospheric measurement data. The portal is set up to serve scientists producing atmospheric measurements and time series resulting from research campaigns and

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TNA activities that are normally not covered by any data management or data curation system or activity.

- In the **Trajectory and footprint analysis service** a choice of three atmospheric footprint services is offered, each catering to different requirements for the different components measured and the analyses carried out with the data. ICOS provides footprint service for greenhouse gases, IAGOS provides the footprint tool for tropospheric vertical gradients and ACTRIS provided the footprint tool for reactive gases and aerosols.
- The **Time Series Analysis service** provides users with a tool to identify, use and combine data across RIs and data repositories. It provides a dedicated Virtual Research Environment (VRE) that facilitates the exploration of multiple in situ datasets with long time series of different variables. The service provides access to the most used basic metrics (e.g. means, percentiles) and statistical analysis (e.g. trends), as well as visualization tools to view e.g. 2D or 3D scatter plots. The combination of different variables important for climate and air quality recorded by ACTRIS, IAGOS and ICOS allows users to explore relevant cross-cutting issues.
- The **Massive Open Online Course (MOOC)** also offered at the VA portal and not further described in this deliverable, is developed by work package 4, and it introduces atmospheric research infrastructures to a broader audience, enhancing capacity building and promoting open science.

During the project, the footprint analysis services underwent extensive refinement based on continuous user feedback. The ICOS footprint tool expanded to include Flexpart capabilities and methane analysis, enabling source separation and enhancing emission estimates. The ACTRIS footprint tool transitioned to ECMWF meteorological fields and developed a forecast version, widely appreciated for its usability and scientific relevance. The IAGOS footprint tool incorporated advanced temporal filters, improved station search, and additional emission data to support vertical profile analysis. Users valued these updates and suggested further improvements, many of which were implemented in iterative development cycles.

The time series analysis service integrated ACTRIS data and new IAGOS variables, enhancing its capability for multi-dimensional analysis. Enhanced interface features, such as searchable dropdowns and refined filters, addressed user concerns about clarity and ease of use. Requests for downloadable processed data and detailed methodological information shaped the roadmap for future improvements, including comprehensive help materials and tutorials.

The homeless data portal addressed challenges related to storing and curating transient datasets. Feedback emphasized the importance of supporting non-traditional data formats and

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improving metadata quality, leading to updates in workflows and ongoing discussions about future sustainability and funding models.

Feedback meetings were central to WP5. During these meetings, users consistently emphasized the need for clearer citation guidance, data provenance, improved access protocols, and persistent identifiers for outputs. The development team systematically addressed these points through iterative updates and future feature planning, including the integration of ENVRI AAI to simplify authentication and strengthen support for FAIR data principles.

In conclusion, WP5 of ATMO-ACCESS delivered innovative, interoperable, and user-centered services that strengthen European atmospheric research capacities. By integrating user feedback and co-design approaches, the project ensured that its services are robust, accessible, and aligned with real-world scientific workflows. These achievements lay a strong foundation for future integration into European and international open science initiatives.

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Analysis of the activities in provision of the Virtual Access services

Feedback meetings were central to WP5. Four dedicated user feedback meetings were organized and documented as milestones: Meeting 1 in 2023, setting the stage for initial service concepts; Meeting 2 (Milestone 20) in late 2023, where early service versions were demonstrated and discussed; Meeting 3 (Milestone 21) in April 2024, which focused on updates, new functionalities, and intermediate improvements; and Meeting 4 (Milestone 22) in March 2025, which presented final refinements and future strategy discussions. During these meetings, users consistently emphasized the need for clearer citation guidance, data provenance, improved access protocols, and persistent identifiers for outputs. The development team systematically addressed these points through iterative updates and future feature planning, including the integration of ENVRI AAI to simplify authentication and strengthen support for FAIR data principles.

Footprint analysis services

ICOS Footprint Tool (GHG)

Updates and accomplishments:

- Integration of Flexpart service for passive tracers, with customizable receptor points and high-resolution configurations (European domain at 0.25°, global at 1°).
- Addition of methane calculations and separation of natural and anthropogenic contributions.
- Improvements in station preselection, documentation, and in Flexpart support for new meteorological fields.
- Implementation of wildfires and ocean fluxes is in progress, alongside N_2O capabilities.

User feedback:

- Positive reception of the two-model approach (Flexpart and STILT), enabling flexibility.
- Requests for footprint availability in Africa and higher temporal resolution footprints were addressed through special request options.
- Need for improved citation guidance and improved traceability by providing persistent identifiers for the downloaded model datasets.

ACTRIS Footprint Tool (aerosols & BC)

Updates and accomplishments:

- Transition to ECMWF meteorological fields and ongoing update to Flexpart version 11.

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- Forecast capabilities now available.
- Improved clarity on citation requirements, visible directly on the service page.
- High usage documented, contributing to seven research publications.

User feedback:

- High appreciation for service simplicity and documentation.
- Emphasis on securing future funding to sustain and expand the service.

IAGOS Footprint Tool (vertical gradients)

Updates and accomplishments:

- Addition of temporal filters and improved dropdown menus for station selection.
- Integration of SOFT-IO model data and daily data updates.
- Implementation of feedback button and improved user guidance.

User feedback:

- Positive responses to new filtering and usability features.
- Interest in further extending to greenhouse gas modules and improved data download options.

Time series analysis service

Updates and accomplishments:

- Improved integration of ACTRIS and ICOS data and addition of new variables for IAGOS (e.g., RH, water vapor, temperature).
- Ergonomic improvements: keyboard-searchable dropdowns, better temporal filters, aligned y-axes.
- Planned and ongoing features: data download functionality, detailed method documentation, updated help pages, and video tutorial.

User feedback:

- Strongly appreciated by both experienced researchers and new users.
- Requests for ability to select specific months for analysis, download processed data (e.g., aggregated timeseries), and clearer handling of multiple temporal dimensions in ACTRIS data.
- Emphasis on continued development of training materials (interactive webinars, e-learning).

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Homeless data portal

Updates and accomplishments:

- Established to provide long-term curation and access for campaign and TNA data not covered by standard RI data systems.
- Integration with RI data flows and metadata harmonization advanced.
- Early successes reported in first data contributions, with ongoing efforts to support non-traditional and multi-instrument datasets.

User feedback:

- Overall positive user experience; smooth request process.
- Need for improved handling of metadata and harmonization for non-traditional datasets.
- Concerns about sustainability and funding models for future access, including potential cost structures.

Cross-cutting improvements and user-driven refinements

- Repeated user feedback cycles have resulted in tangible service updates and ergonomic enhancements across tools.
- Interoperability among ACTRIS, ICOS, and IAGOS data services has been strengthened, supported by shared APIs and REST endpoints.
- Clearer acknowledgment and citation instructions have been implemented, as they are crucial for service recognition and scientific credit.
- Common challenges such as login and AAI (Authentication and Authorization Infrastructure) issues have been addressed progressively, though further improvements are planned (e.g., adoption of ENVRI AAI).

Future perspectives and sustainability

The developed services are seen as essential by the user community and should be integrated into each RI domain. Continued funding and dedicated technical support would be necessary to maintain a single-entry point to simplify user access and improve it beyond ATMO-ACCESS.

A long-term strategy document and cost analysis in prepared in Work Package 10 (D10.3), outlining options for service maintenance, potential funding schemes, and expanded use cases.

The services demonstrated value in scientific support (e.g., avoiding nuclear contamination in ICOS flask sampling, support for TOAR assessments), and the strong user demand suggests a

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clear need for future operationalization under European and international research frameworks (e.g., EOSC, ENVRI).

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