2024

ICOS Handbook

Knowledge through observations

ICOS Integrated Carbon Observation System

ICOS Handbook 2024

Author:

Integrated Carbon Observation System (ICOS) Research Infrastructure

ICOS ERIC
Helsinki 2024

ICOS HANDBOOK 2024

Author: Integrated Carbon Observation System Research Infrastructure

Several dozens of people within the whole research infrastructure have participated in the writing work.

Maps: Ida Storm, Alex Vermeulen, ICOS Carbon Portal

Layout: Inka Kosonen

Published by ICOS ERIC, Helsinki, March 2022

3rd revised edition. The first edition 2019 was funded by the RINGO project, which received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730944.

Printed in Finland by Grano

For copies and information: icos-comms@icos-ri.eu

To reference use https://doi.org/10.18160/28AV-80QR

ISSN 2984-2026 (print)

ISSN 2984-2034 (online)

ICOS HANDBOOK TABLE OF CONTENTS

Foreword

Greenhouse gases are transported in the atmosphere with the winds, even thousands of kilometres. Their mixing and distribution in the atmosphere impact the climate globally. People who have not contributed to the burning of fossil fuels are, and will be heavily affected by the climate crisis.

To take informed climate action, it is key to understand greenhouse gases; their sources, transport, sinks and their balance. Standardised in situ observations with broad geographical coverage are essential for this understanding.

The Integrated Carbon Observation System, ICOS, provides an observational net-work throughout Europe, facilitating science and enabling better knowledge for decisions on climate change mitigation and adaptation.

ICOS was born out of scientists' grand idea back in the 1990s of having a consistent, sustained observation network, which is operating under the same technical and scientific standards. Pursuing the common goal has driven the community forward, often with incredible engagement and tenacity when facing difficulties.

I believe that it has been this unique combination of scientific excellence, technical competence and strong commitment to climate change mitigation that has convinced the European Commission with its bodies, and by now 16 governments to support ICOS during the journey: from the first EU project to an ERIC in 2015, and to today's operational infrastructure. Building a greater ICOS community together with scientists, technicians and our stakeholders has been the base of our success. We are proud of and grateful for this achievement.

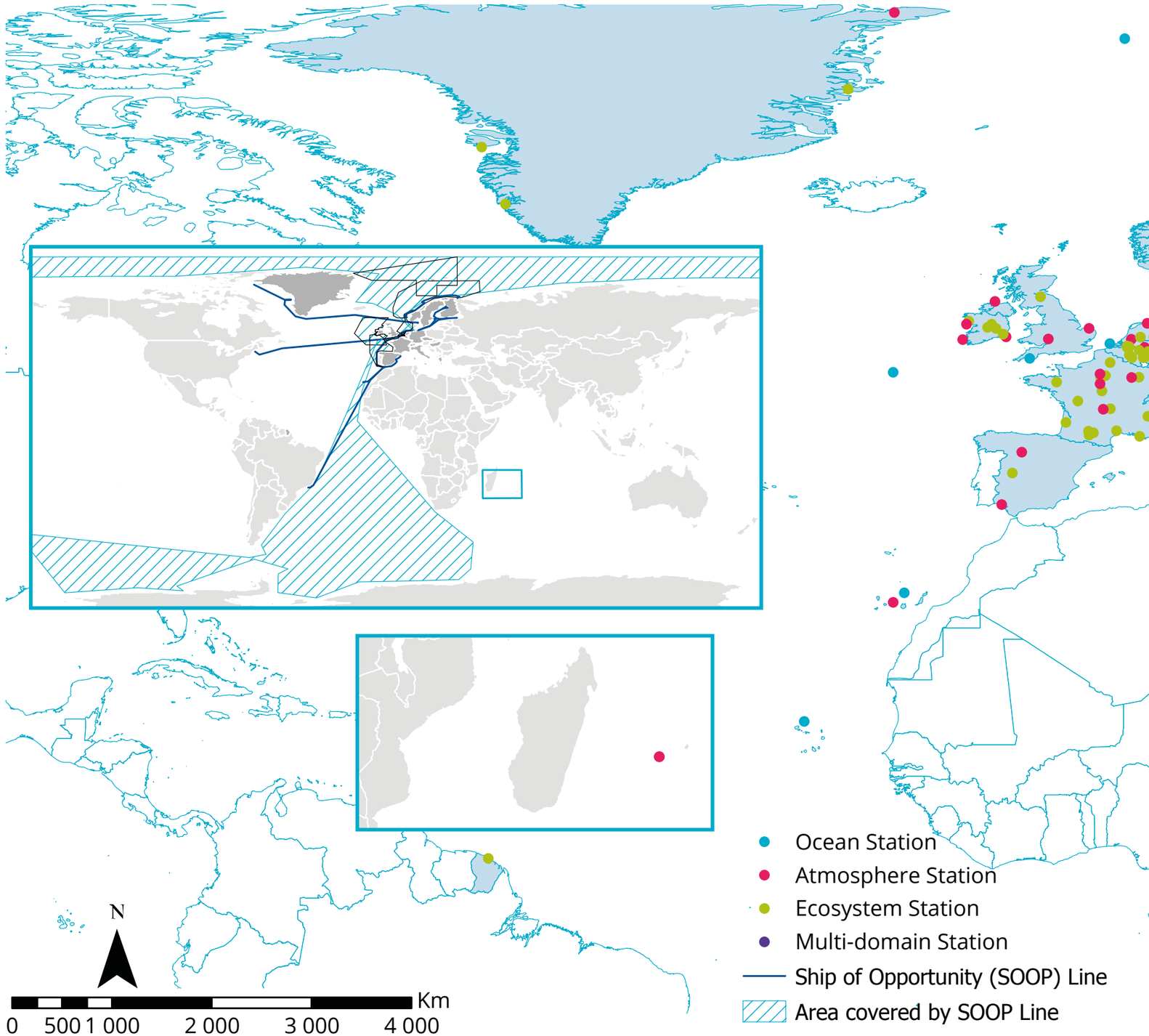
During the years, ICOS has developed solid cooperation beyond Europe: ICOS is an accredited Observer of the UNFCCC, a regional network of the WMO Global Atmosphere Watch Programme, and a strong pillar in the future Global Greenhouse Gas Watch, which will be established by the WMO member countries in 2024. This global operational observing system will support the Paris Agreement with data on greenhouse gases, scientific analyses on carbon-climate feedback and direct observations of anthropogenic emissions.

This handbook gives a comprehensive overview of ICOS research infrastructure: its data processing and data life cycle, organisational structure and technical details about station requirements as well as estimates on funds needed. It also describes the ICOS National Networks and the process a country must undergo to join ICOS.

This is the fourth edition of the ICOS Handbook, and published in 2024. In this regard, I want to thank the ICOS National Networks for their support in compiling the Handbook, as well as the personnel in the Thematic Centres, Carbon Portal and in the Head Office for their efforts in producing this book. As is the matter with the ICOS research infrastructure in general, also here the whole is greater than the sum of its parts.

WERNER KUTSCH
Director General, ICOS ERIC

ICOS Station Network



ICOS – Standardised greenhouse gas observations throughout Europe

The level of greenhouse gases in the atmosphere rises continuously, heating up our planet. Observing the levels of greenhouse gas emissions is essential to predict climate change and mitigate its consequences. ICOS produces standardised and high-precision greenhouse gas data from its Atmosphere, Ecosystem and Ocean stations.

Benefits of being a part of ICOS

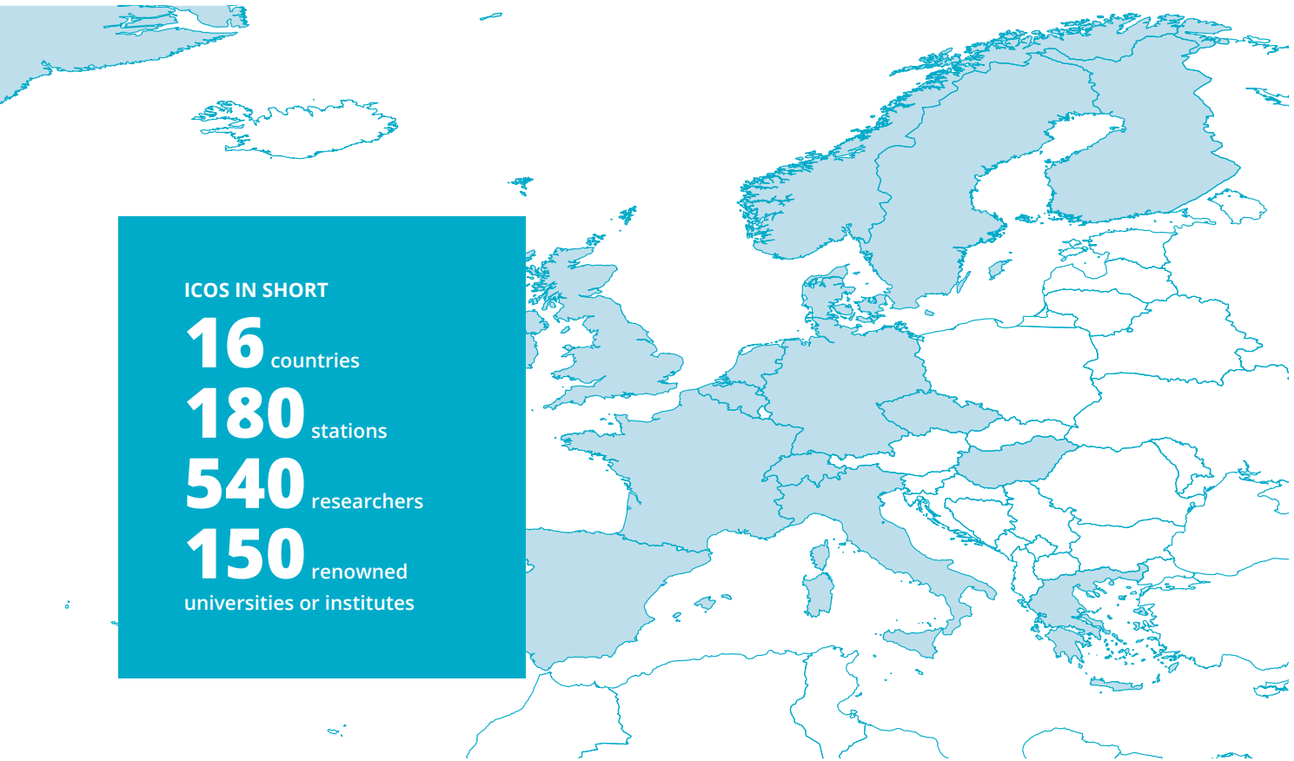
1 we represent a community of scientists distributed over Europe.

2 We strengthen the scientific community by organising training and events.

3 We are well connected to European and global networks.

4 We promote the standardisation and curation of data.

5 We support our members who apply for funding in multidisciplinary consortium projects.



ICOS IN SHORT

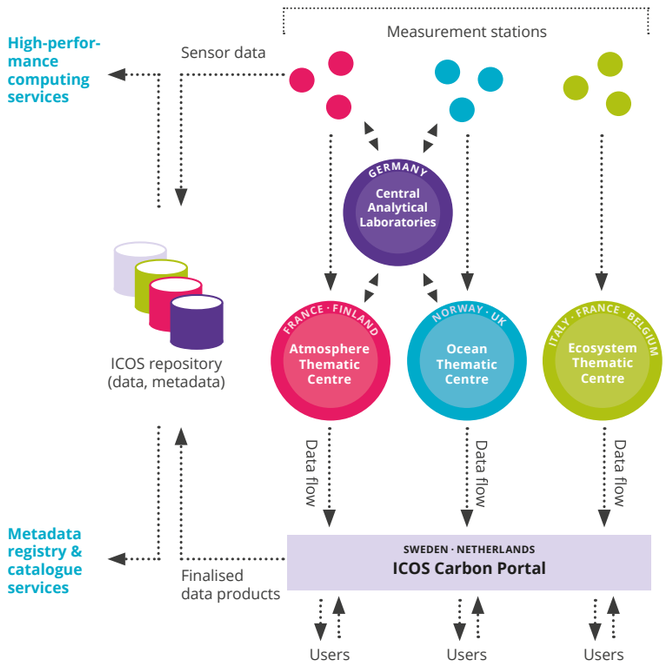
16 countries

180 stations

540 researchers

150 renowned universities or institutes

We produce high-quality greenhouse gas data open for all



Station labelling process ensures common ICOS standards and data quality

The applicant sends a formal application via www.icos-ri.eu

Step **01**

ICOS evaluates the station location and technical requirements.

ICOS Head Office creates links between the station personnel and the respective Thematic Centre, which helps the station in the work.

Step **02**

Constructing and upgrading the station, evaluation and testing.

The station needs to meet ICOS standards, the Thematic Centre personnel can advise.

Step **03**

The ICOS General Assembly awards the ICOS label to the station.

The duration of the labelling process varies depending on the station characteristics.

1 AN OVERVIEW: Purpose, benefits and administration

Climate change brings immense changes to the Earth and to our life. To predict and mitigate this change, it is crucial to have long-term and standardised measurements of greenhouse gas emissions and sinks, as well as their changes. ICOS, which is short for the Integrated Carbon Observation System, is a distributed European research infrastructure (RI) producing these high-precision data on greenhouse gases. It provides standardised and open data from close to 180 measurement stations across 16 European countries. The stations observe greenhouse gas concentrations in the atmosphere as well as carbon fluxes between the atmosphere, land surface and the oceans. Thus, ICOS is rooted in three domains: Atmosphere, Ecosystem and Ocean.

ICOS data helps to give an account of the Earth system and its response to climate change and other environmental challenges. The data generate scientific knowledge, which advances the fulfilment of the United Nations' Sustainable Development Goals and the European Union's Societal Challenges, especially those concerning climate change. ICOS supports efforts to comply with the Paris Agreement resolutions. It actively communicates to society that science-based knowledge is relevant to climate action and decision-making.

ICOS thus supports policy- and decision-making to combat climate change and its impacts. It is also important for ICOS to promote technological developments and demonstrations related to greenhouse gases by linking together research, education and innovation. One of ICOS' key features is the possibility of dynamically implementing technological and state-of-the-art scientific upgrades by introducing new techniques, instruments and observed variables.

The ICOS community consists of more than 540 scientists in its Member countries and beyond. More than 150 renowned universities or institutes are a part of the ICOS community. The ICOS community has strong connections to colleagues and operators outside ICOS.

ICOS is a part of a diverse RI landscape. In Europe, ICOS collaborates with other European Environmental Research Infrastructures (ENVRI) to develop a clearer picture of the landscape, the core competences of each RI and possible cross-RI services. Moreover, ICOS participates in many external projects which in turn help us to be a cutting-edge research infrastructure. Most important ongoing projects are listed in Appendices of this handbook.

Internationally, ICOS participates in global initiatives such as the current development of the Global greenhouse Gas Watch (G3W) of the World Meteorological Organization (WMO). Furthermore, ICOS has since 2019 been an Observer organisation to the United Nations Framework Convention on Climate Change (UNFCCC). Thus, ICOS contributes to the work of the Convention and its Subsidiary Body on Scientific and Technical Advice (SBSTA) and can organise its own side-events in connection with the annual global climate negotiations (COP meetings). As an Observer also to the Intergovernmental Panel on Climate Change (IPCC), ICOS can actively foster the participation of the ICOS community in the writing process of IPCC's various reports.

ICOS has also formed deep connections to global data-integration efforts. ICOS' ecosystem flux data, for example, are well connected to FLUXNET, a global network of micrometeorological tower sites. Ocean data in turn are connected to the Surface Ocean CO_2 Atlas (SOCAT). Atmospheric data are connected to the WMO's Global Atmosphere Watch (GAW) Programme.

ICOS' historical background

Although an ample amount of research and data on greenhouse gases had existed before ICOS, scientists found that the data were often scattered and difficult to find and access. The quality and consistency of measurements were not guaranteed. Nor did the data turn into information that could easily be used by citizens and decision-makers. The scientific community concluded that the measurements of greenhouse gases needed to be harmonised and that the data that were gathered should be shared. That required deeper collaboration and interaction among the scientists and their home institutions.

In 2006, European scientists and their national support networks combined their efforts and initiated the ICOS RI, the Integrated Carbon Observation System Research Infrastructure. In the same year, the ICOS RI entered into the ESFRI (European Strategy Forum on Research Infrastructures) road map. The ESFRI road map identifies the new RIs of pan-Euro-pean interest corresponding to the long-term needs of European research communities, covering all scientific areas, regardless of possible location. From 2008 to 2013, ICOS was designed and prepared in an EU-funded preparatory project. Since 2015, the ICOS RI has been coordinated and integrated by a legal body called the European Research Infrastructure Consortium (ERIC), established by a decision of the European Commission in November 2015. ICOS ERIC has its statutory seat in Finland. ICOS is one of 26 currently existing ERICs. ICOS ERIC has held a Landmark status in the ESFRI roadmap since March 2016.

Benefits of being a part of ICOS

ICOS fosters Europe's scientific competence and competitiveness by strategically pooling available resources linked to greenhouse gas measurements. By cooperating and creating a joint network, it is possible to further scientific excellence cost-efficiently. ICOS has been established to ensure the high-quality measurements of greenhouse gas concentrations and fluxes that are independent, transparent and reliable. In turn, this observational network will support governments in their efforts to mitigate climate change as well as hold them accountable for reaching their mitigation targets. ICOS Member countries receive support for their national inventories and capacity building. ICOS opens new opportunities for its Members to be connected with the European and global community of researchers.

The standardisation carried out in ICOS provides an example of the joint international efforts through which Europe has achieved global influence, and this plainly shows the strategic importance of ICOS. ICOS provides easy access to new methods and instrumentation. The high quality of reliable and comparable data is guaranteed by harmonised practices in the operations at its Thematic Centres and in the Carbon Portal data services used in data processing. These include, for example, Quality Assurance and Quality Control.

The main benefits of being a part of ICOS are summarised below.

Strengthening of scientific communities

ICOS is engaged in enhancing the readiness of scientific communities to tackle the current pressing climate-change-related challenges by organising science events that include, for example, a biennial ICOS Science Conference. In 2019, ICOS took the initiative of forming a drought task force to address the 2018 extreme drought event in Europe. This task force rapidly compiled relevant datasets and the analyses were discussed openly among the wider science community at the European Geosciences Union General Assembly 2019. The initiative resulted in a special issue with 14 papers in the Philosophical Transactions of the Royal Society B journal.

Advancing the standardisation and curation of data

ICOS has developed a broad range of standardisation protocols in order to ensure the highest observational standards for each ICOS station. One component of this standardisation for ICOS Atmosphere measurements is that the stations are centrally served with reference gases. The protocols are implemented during the ICOS station labelling process (described in detail in Chapter 2). This guarantees that all ICOS stations collect data that meet the agreed quality requirements. By going through the labelling procedure, the ICOS stations increase their reliability, participate in a near-real-time (NRT) data flow via the Carbon Portal and benefit from the curation and dissemination of the data.

Guidance, training and knowledge exchange

The ICOS Central Facilities (CFs) and Carbon Portal provide training, for example for stations' Principal Investigators, managers and technicians on any necessary issues. The aim is to stimulate better use of ICOS-certified instruments and involve station staff in working groups for protocol development. Training also acts as a platform for exchanging ideas and knowledge on cutting-edge innovations and technologies related to the ICOS RI.

Funding opportunities

ICOS supports its partners applications for multi-disciplinary consortium projects by providing timely information on the financial and administrative process as well as on the scientific and technical prerequisites and developments. For example, ICOS partners have participated in several successful EU Horizon 2020 and Horizon Europe projects, and the partnership with ICOS is explicitly mentioned in several Horizon Europe calls. All ongoing ICOS projects are listed in the Appendices.

Increasing international scientific networking

ICOS is well connected to European and global networks that are in charge of coordinating greenhouse gas observational activities or collecting and curating data. Its voice is increasingly being acknowledged in international forums. ICOS has, for example, established a deep connection to domain-wise global data-integration efforts such as FLUXNET, SOCAT and GAW. During the past years, ICOS has become a respected and active participant in the advocacy work of climate change policy and management carried out in international organisations, such as the SBSTA of the UNFCCC. In 2019, ICOS became an observing Intergovernmental Organization to UNFCCC and has since then organised official side-events at the annual COP meetings.

Technology and innovation

ICOS' effectiveness in unifying the European climate science field has already had effects on technology and innovation. The wider the ICOS network is, the bigger its impact is on technology and innovation. ICOS is a single large procurer with high demands. Its industrial partners indicate that high ICOS standards drive them to develop new or improved measurement methods and hardware innovations and to increase their product quality. Suppliers of sensors and measurement instrumentation mention that having ICOS as their client counts as a quality certificate.

ICOS' mission

ICOS is a distributed RI conducting standardised, high-precision and long-term observations and facilitating research to understand the carbon cycle and to provide necessary information on greenhouse gases. ICOS-based knowledge supports policy- and decision-making to combat climate change and its impacts. ICOS is the European pillar of a global greenhouse gas observation system. It promotes technological developments and demonstrations related to greenhouse gases by linking research, education and innovation.

ICOS' vision for 2025 and beyond

Today and through the late 2020s, ICOS will produce highly standardised, robust ground-based data and elaborated data products for science on the carbon cycle and for quantifying greenhouse gas emissions and sinks across Europe.

ICOS data are integrated into major global data systems and networks and meet the needs of international requirements, principles and agreements. ICOS Thematic Centres are established as centres of excellence in their domains and provide stable support for European and international networks.

The ICOS data are near-real-time and compliant with FAIR principles (meaning that the data are Findable, Accessible, Interoperable and Reusable). They are being utilised by a broad spectrum of users who employ them both for making scientific breakthroughs and for producing knowledge for climate action, as evidenced by ICOS' data-citation statistics. ICOS also has a vibrant user community and an active dialog with it, which helps ICOS to improve its state-of-the-art data and to provide multiple services for science and society. Based on these services, ICOS is also able to quantify and separate fossilfuel-related emissions, sources and sinks from natural greenhouse gas fluxes.

ICOS represents a strong European community of institutions investing in ground based observations, and it has established itself as an organisation from which relevant stakeholders seek advice. ICOS acts as a mediator between the greenhouse gas science community and the agencies that work on national inventories and the global stocktake. The biennial ICOS Science Conference is a hub for presenting the outcomes and impacts of observations. It also functions as a development, prioritisation and mediator forum. ICOS drives technical developments in order to improve analytical capacities, supporting industry partners to fulfil its high-quality needs.

Within the ensemble of ENVRI, ICOS is a strong European building block and supporter of a recently established global RI. This role, the benefits of ICOS to science and society, and an increased number of member countries have resulted in obtaining stable and sufficient resources to further sustain and develop the RI.

Organisational structure

The basis of ICOS' operations is the measurement network that comprises of close to 180 standardised stations across Europe. The stations are directly supported by national funding and are called Station Networks. The ICOS Station Networks are coordinated and run by the ICOS National Networks, of 16 Member countries. The number of stations varies greatly between member countries. The age of the stations also varies, as some of them have been working for decades and others are newly established. All the stations have been substantially re-equipped to comply with ICOS standards.

Besides running the stations and working for labelling, the National Networks organise a number of other activities, such as a significant number of national or regional scientific events. These include conferences, training courses, workshops and annual meetings combined with seminars.

The stations in the National Networks operate in three distinct domains: Atmosphere, Ecosystem and Ocean. A handful of ICOS stations are classified as multi-domain, meaning they collect observation data from more than one ICOS domain. Each of the three fields have their own Monitoring Station Assembly (MSA) in which the Principal Investigators of the stations are represented to discuss, develop and improve the scientific and technical bases of the observations. The MSAs monitor, develop and improve the scientific and technical abilities of the station networks, working closely with ICOS Central Facilities, which include the Thematic Centres and Central Analytical Laboratories. The MSAs are also represented in the ICOS RI Committee by the Chair and Vice-Chair to communicate and discuss the views and recommendations of the stations' operators.

Within each domain (Atmosphere, Ecosystem, Ocean), a Thematic Centre coordinates the observations and supports the stations. In addition to the Thematic Centres, there are Central Analytical Laboratories (CALs) that provide gas analyses and calibration gases.

The Central Facilities coordinate and lead operations within their fields and process the data coming from the stations. They play key roles in specialised analyses, metrology and the technology watch, and support the measurement stations by offering additional instruments, training and technical assistance. The Central Facilities also have frequent interactions with one another for coordination, sensor interoperability and the standardisation of data archiving, data formats and processing methods. The Central Facilities are hosted by universities or research institutions in the Member countries.

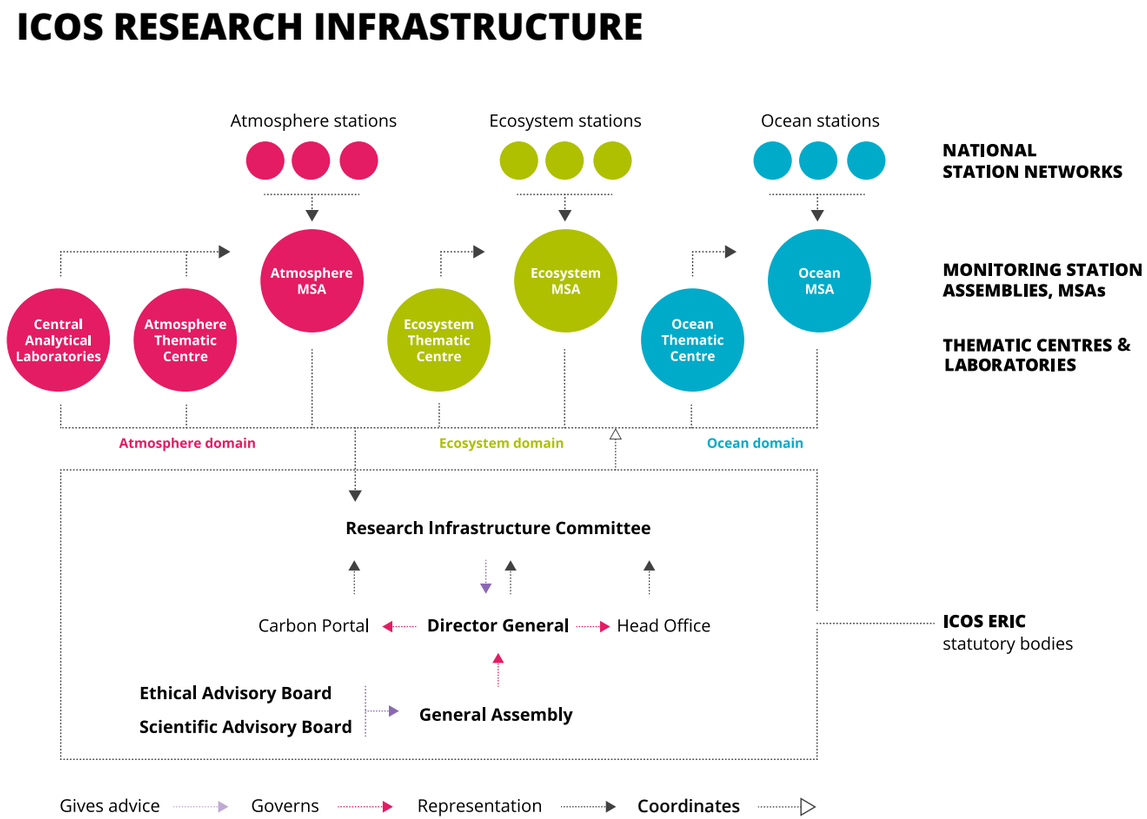
ICOS operations are coordinated by ICOS ERIC, which is a specific legal entity for European RIs created by the European Commission. ICOS ERIC consists of the Head Office, coordinating the RI operations, and the Carbon Portal, collecting and distributing ICOS data and derived products. In addition to coordinating, the Head Office is responsible for administration, management and development of the RI as well as for communication.

The Carbon Portal in turn acts as the platform for the observational data and elaborated data products of the ICOS RI. It is a 'one-stop shop' for all ICOS data products, a place where ICOS data, along with ancillary data, can be openly accessed by anyone. All ICOS data available in the Carbon Portal are quality controlled by the ICOS Thematic Centres.

ICOS ERIC is governed by its General Assembly. It appoints the Director General, who carries out the day-to-day management of ICOS ERIC and is responsible for the implementation of the decisions of the General Assembly. The Director General is responsible for managing the staff and activities of the Head Office and the Carbon Portal.

The representatives of the Head Office, Carbon Portal, Central Facilities and MSAs form a high-level advisory body called the RI Committee, which advis-

Figure 1. ICOS RI governance and structure.



es the Director General and the General Assembly on scientific and organisational matters concerning the RI. The ICOS RI Committee uses both face-to-face and online meetings to develop and discuss the ICOS RI's operations and strategic issues.

The General Assembly has established two external bodies to provide advice on scientific and ethical matters: the Scientific Advisory Board (SAB) and the Ethical Advisory Board (EAB). The role of the SAB is to give feedback and make recommendations to develop ICOS RI activities on the scientific level, to advise ICOS ERIC on objectives in achieving the scientific goals of the ICOS RI, to provide programmatic support by commenting on the overall science plans and directions as well as to analyse the scientific results and impact of the ICOS RI. The names of the members in SAB are listed in the Appendices. The role of the EAB is to advise and periodically report on ethical issues, such as scientific ethics, data-related ethical issues, discrimination issues or any kind of conflict of interest.

The overall structure of the ICOS RI is shown in Figure 1. A more detailed description of each operating part is given in Chapter 4 of this handbook.

ICOS RI financial principles and membership contributions

ICOS' financial structure follows the general policy of ESFRI: The RIs receive stable and sustainable national funding from their host countries to ensure their operations. In some countries, the funding has not been harmonised with the ICOS five-year planning period. Additionally, new developments and innovations are supported through external funding, for example, by the European Commission's Horizon funding for Research and Innovation.

ICOS has three levels of funding, mirroring the basic organisational structure of a distributed RI. The Member countries pay the *membership contribution* to ICOS ERIC. Additionally, ICOS ERIC receives *host premium contributions* from Finland, Sweden, the Netherlands and France. These cover the core operations of ICOS ERIC Head Office and Carbon Portal. Part of the membership contribution to ICOS ERIC is calculated based on the number and type of stations in the country. ICOS ERIC transfers this *station-based contribution* to the Central Facilities, which also receive *host or in-kind contributions* (80% of total funding) from their host institutions. National Networks receive funding from their governments or in-kind contributions from their host institutions.

Calculating Member contributions

Annual membership contributions to ICOS ERIC as well as host premium contributions by the hosting countries, cover activities that are of general benefit to the whole ICOS RI community: users and Members. ICOS ERIC statutes and the Internal Financial Rules of the ICOS RI set the principles for the calculation of the annual Member contributions to ICOS ERIC.

The General Assembly approves annual membership contributions every year. It determines the membership contributions of the potential intergovernmental organisations, which become Members on a case-by-case basis. The annual membership contribution of a Member country is based on the following three variables: Common basic contribution, Common Gross National Income (GNI)-based contribution and Station-based contribution.

The ICOS ERIC budget

The participating countries have agreed on the financial plan determining the ICOS ERIC budget for the third five-year period, from 2025 to 2029. The General Assembly also decides the Common basic and Station-based contributions covering all years of a five-year period, and has decided them for the period 2025–2029. The Station-based contributions are shown in Table 1.

How Common Basic, Common Gross National Income and station-based contributions are calculated

The Common Basic contribution for members and observers is calculated by sharing 50 % of the total common costs equally between the Members and Observers.

The common Gross National Income (GNI)-based contribution for members and observers is calculated by sharing 50% of the total common costs as follows:

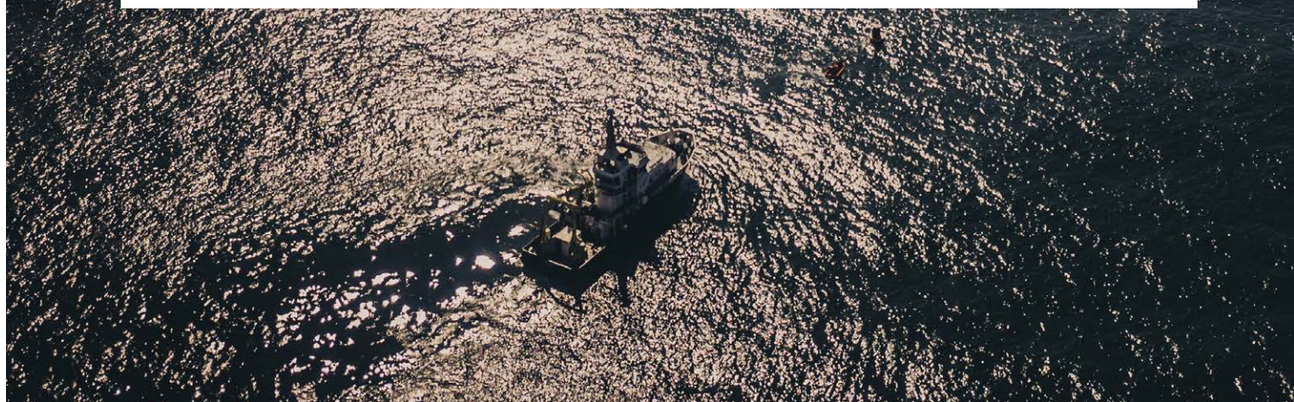
The GNI-based contributions are based upon the country's three-year aggregate national GNI (according to OECD) expressed as a percentage of the three-year aggregate GNIs of all countries in ICOS RI.

The GNI for each country will be calculated for three consecutive years and updated with every five-year Financial Plan.

The General Assembly approves annual membership contributions every year.

When a new country joins ICOS, the total ICOS ERIC revenue will increase with the Common Basic Contribution and the GNI of the acceding country.

Membership contributions related to the number and type of stations joining the ICOS network are calculated based on information from the Members, Observers and ICOS Central Facilities and are approved by the General Assembly. The current station contributions for all station classes are listed in Table 1.



The ICOS ERIC annual budget consists of host premium contributions received from the hosting countries of Head Office and Carbon Portal. A second part of ERIC budget consists of membership contributions from all Member and Observer countries.

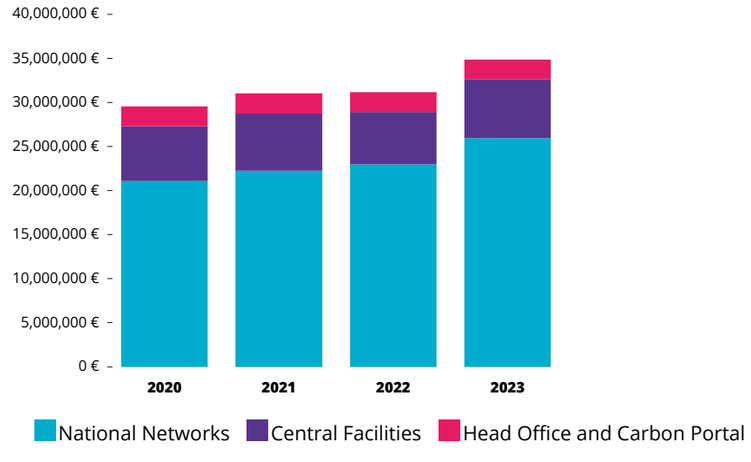
The annual budget of ICOS ERIC is decided annually by the General Assembly. Figure 2 shows the ICOS ERIC revenue structure for 2020–2023, which includes all components of membership contributions and the host premium contributions by the countries hosting the Head Office (Finland and France) and the Carbon Portal (Sweden and the Netherlands).

Over the past five years ICOS ERIC has also been very successful in getting funding from the EU Horizon funding instruments.

Table 1. Annual station-based contribution by station type for the period 2025–2029. Atmosphere Class 1 stations receive a full set of analytical services from the Central Analytical Laboratories, including calibration services and radiocarbon analysis. Atmosphere Class 2 stations receive basic calibration services. Ocean station fee includes calibration services as well.

STATION TYPE	ANNUAL STATION CONTRIBUTION, €
Atmosphere Class 1	38,750
Atmosphere Class 2	14,150
Ecosystem Class 1	9,600
Ecosystem Class 2	4,700
Ecosystem associated	2,100
Ocean Class 1 and 2	11,420

Figure 2. ICOS ERIC revenue structure for years 2020–2023.



2 ICOS STATION LABELLING PROCESS: A quality assurance

Detailed labelling procedures for each domain are described in documents published on ICOS website at www.icos-cp.eu/about/join-icos/process-stations

The compliance of the stations to ICOS standards is of utmost importance to the users of ICOS data. To guarantee data reliability and quality across the stations, ICOS has designed a unique quality-assurance process called station labelling. The process has tight criteria that each station has to fulfil, both for the measurements at the stations and for data production. Once the station fulfils all the criteria set for an ICOS station, it receives an ICOS label as a guarantee that the data produced are of the highest quality.

To start the process, a country representative, Focal Point (a national coordinator) or General Assembly delegate officially announces the new station to the Head Office. Each ICOS station must be approved by its host institution and national government. However, before formally applying to become a labelled ICOS station, the interested party is advised to contact the appropriate Thematic Centre to discuss the station in terms of network design and station characteristics.

Benefits of ICOS labelling for the stations and their staff

- ICOS stations will take part in the latest developments of cutting-edge greenhouse gas measurement techniques and updated data-processing routines, which reduces the amount of work at the stations once they are labelled.
- ICOS stations will get substantial technical support for station operations in order to assure data quality. ICOS stations' staff will be involved in training activities organised by the Thematic Centres and Carbon Portal on the best and most updated practices for data acquisition and data use.
- The standardisation of the measurements and harmonised data processing, quality control and archiving are guaranteed through the Thematic Centres and the Carbon Portal data services to ensure the highest quality, comparability and credibility for the data.
- The provision of elaborated data products, such as advanced visualisations and flux maps in time and space, will increase the impact of the data.
- ICOS will provide support through contacts with equipment manufacturers and negotiates group prices for official ICOS stations.
- The global visibility of ICOS stations will increase due to the high-quality data provided and the large number of users. This will also have a strong positive effect on the host institution in terms of attractiveness.
- ICOS stations' data use will be professionally tracked and cited in peer-reviewed articles, which will increase the visibility of the station's staff and institution.
- ICOS stations will get support from the Head Office in searching for funding opportunities at the national and international levels using the well-developed ICOS brand in supporting proposals.

Steps towards ICOS station labelling

The ICOS station labelling process (Figure 3) includes a testing period and a training to ensure familiarity with the ICOS methodology. When ICOS receives an application for a station to be labelled, the *first step* is to evaluate the site, the location of the measurement infrastructure and other characteristics of the station. These are evaluated by the Thematic Centres.

After the Director General has approved the station evaluation, the approved station is eligible to begin *step two*. This includes a thorough analysis of its compatibility with the ICOS measurement protocols and standards, measurement setup, data transfer and data quality. The Thematic Centres control the process and support the station's Principal Investigators in fulfilling the requirements for ICOS stations, and they also provide support for new incoming stations in the planning phase.

Finally, in *step three*, the General Assembly approves the station on the basis of the evaluation report prepared by the Thematic Centre and the recommendation of the Director General.

Figure 3. The steps of the ICOS station labelling process.

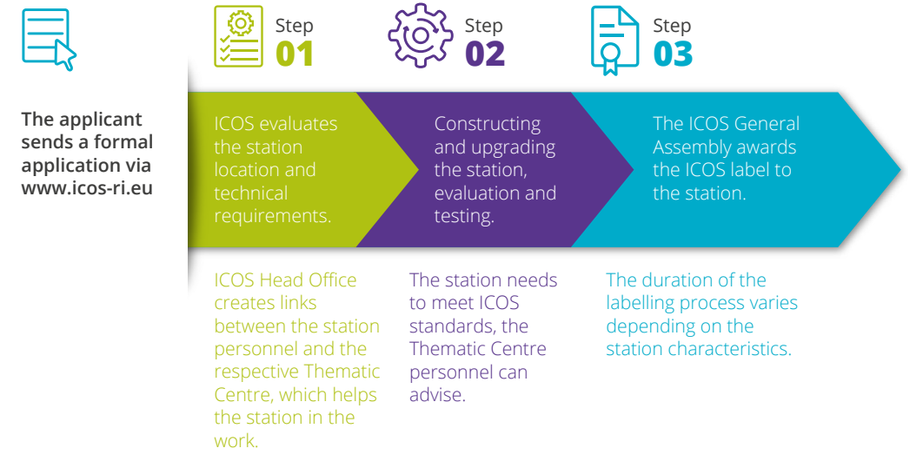
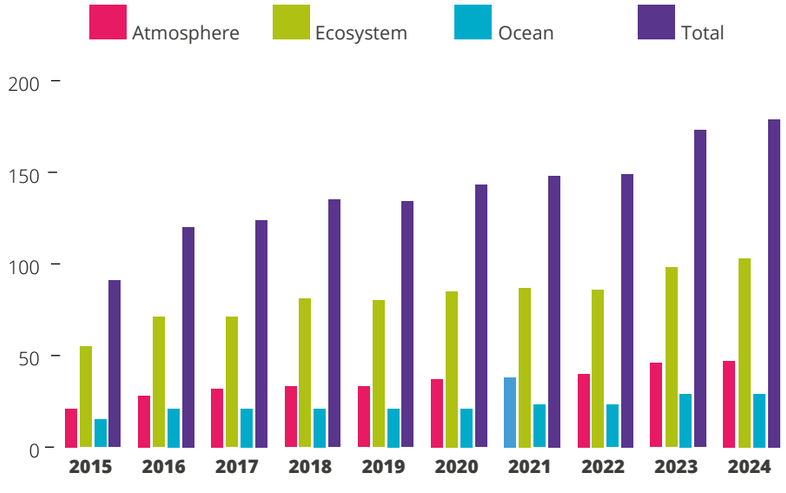


Figure 4. Number of ICOS stations in 2015–2024. The total number of stations was 179 in 2024.



After receiving the ICOS label, the station accepts the ICOS RI data policy and commits to be compliant with the station specifications, protocols and data-quality criteria used in its component (Atmosphere, Ecosystem, Ocean) under the authority of the Thematic Centre concerned. The ICOS Station network currently consists of close to 180 stations (Figure 4). These stations have officially been included in the ICOS RI by the Member countries. Two stations were brought into the network by the European Joint Research Centre through a specific contract. By March 2024, 126 stations had received an official ICOS label.

3 ICOS DATA: How they are produced and managed

ICOS data follow the so-called FAIR (Findable, Accessible, Interoperable, Reusable) principles. In practice, the FAIR principles aim at giving the user sufficient tools to understand the meaning of the data before and after downloading them. For this purpose, the ICOS Carbon Portal utilises linked open-data technology, which is a modern, advanced technology within the field of data management. It allows ICOS to distribute the data via internet links, which the user can simply click to view and/or download the data. It also makes machine-to-machine communication of data possible. Metadata and other descriptions are associated.

ICOS uses Creative Commons Attribution 4.0 International (CC BY 4.0) as its data-licence format. The licence gives the user extensive rights to use, redistribute and derive products from the data, under the condition that the data ownership is passed along and that proper attribution to the data provider is given. The user agrees to the licence when downloading the data.

To attach the data ownership, ICOS utilises Persistent Identifiers (PIDs) based on the Handle system for all the data objects. On top of these, it uses DataCite Digital Object Identifiers (DOIs) for datasets and collections. These uniquely identify each data object and can be cited, for example, in scientific publications. The PID is created automatically and immediately when the data are submitted, and mathematical encryptions are utilised to ensure the validity of the data. The PID is a World Wide Web address (URL: Uniform Resource Locator) that resolves into a so-called landing page where the metadata can be viewed or accessed by either humans or machines. In the case of the ICOS Carbon Portal, accessing the link will trigger the user-license acceptance check. The usage is counted at the download. A ready-made citation text is provided for use in publications

The whole process guarantees that the original data and downloaded data are exactly identical and are always available together with the associated metadata and that the user accepted the user licence. Other portals can use the PID and associated link to the data and give seamless access to the data object through the ICOS Carbon Portal.

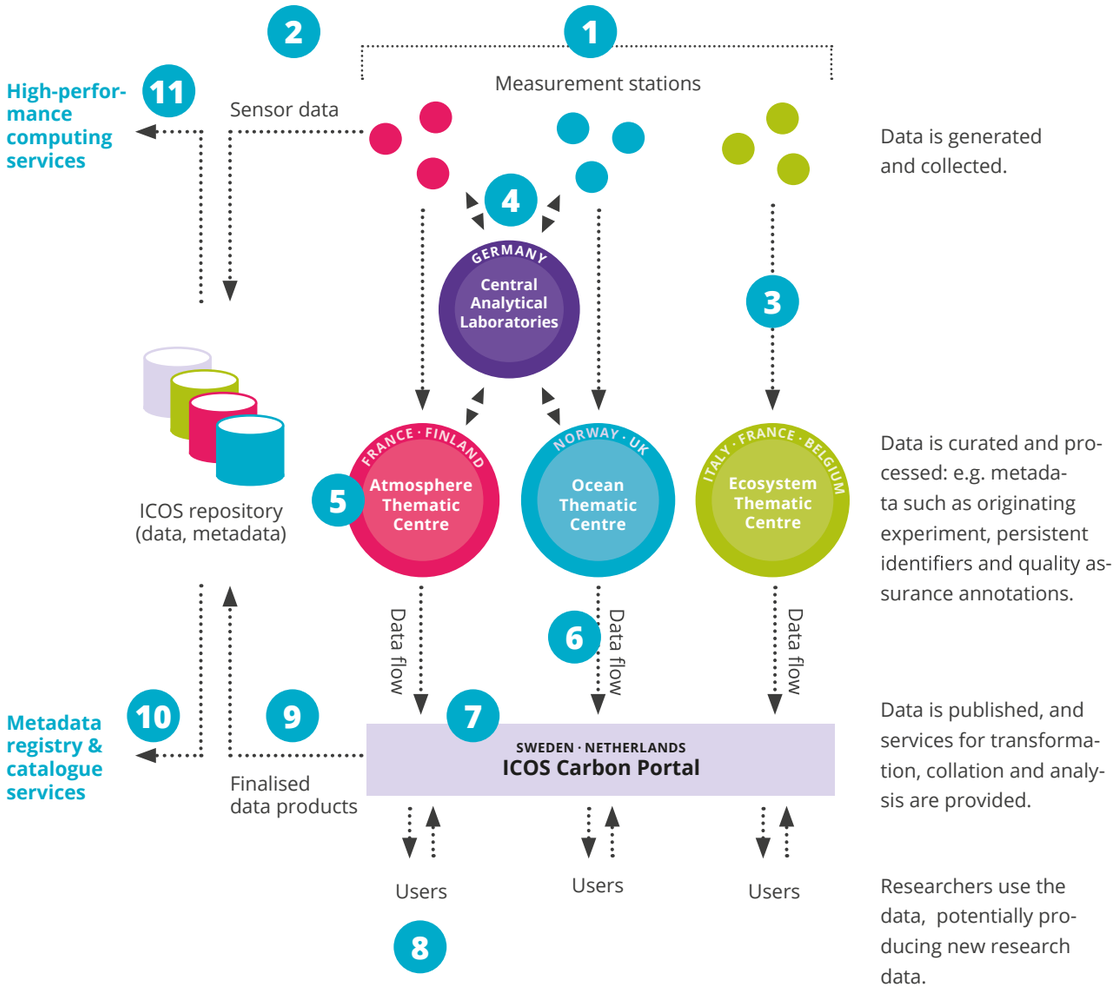
The ICOS data-production process

The following schematic diagram (Figure 5) shows the standardised ways of handling data within ICOS.

1. Data are collected at ICOS measurement stations. There are close to 180 sites in 16 countries, making up three networks of Atmosphere, Ecosystem and Ocean stations. Some sites or stations are equipped with up to 100 data-collecting instruments and sensors.

2. The ‘raw’ data are stored in a safe repository as soon as possible. Environmental observation data are very precious because if the data are lost, it is not possible to go back and remeasure. Therefore, copies of all the ‘raw’ data are transferred to safe, long-term storage at a trustworthy data centre. Typically, this is done within 24 hours of collecting the data.

Figure 5. Schematic diagram of the ICOS data-production process.



3. The observation data are then passed on to the Thematic Centres for expert processing. Each station sends its sensor data to the relevant Thematic Centre – Atmosphere, Ecosystem or Ocean – for processing and quality control.

4. In addition to the three Thematic Centres, the Central Analytical Laboratories (CAL) are a part of the ICOS Central Facilities. CAL consists of Flask and Calibration Laboratory and the Central Radiocarbon Laboratory. They provide gas analyses and calibration gases.

5. The ICOS Thematic Centres take care of and process the observations following standardised procedures. At the Thematic Centres, the data are checked, quality controlled and, if needed, gap-filled. Some data types, for example, fluxes, require quite extensive processing. Finally, the data are aggregated into half-hourly or hourly averages.

6. Quality-controlled data are delivered by the Thematic Centres. When ready to be released, the finalised observation data are transferred to the Carbon Portal. How often new data become available varies, but the aim is to reduce as much as possible the time between collection and release.

7. The Carbon Portal is responsible for organising and taking care of all ICOS datasets. The Carbon Portal is the 'one-stop shop' for ICOS data products and offers advanced search, visualisation and downloading services. The portal is also responsible for all ICOS data management (such as assigning identifiers, DOIs, to make them easily cited), for tracking how ICOS data are used and for long-term archiving. Finally, it also provides user support.

8. Users can freely and openly access the ICOS data and may also contribute. Everyone who wants to access, view or download ICOS data products is welcome to do so. Any use of data should be properly referenced and acknowledged, and citation guidelines are provided with the downloaded data. Some ICOS data users, including atmospheric and ecosystem modellers, also use the Carbon Portal to distribute their research results. If you have a data product that is based on ICOS data, you are invited to make your data product available through the Carbon Portal.

9. All ICOS data products are safely stored in the ICOS repository. Copies of all data products that are handled by the Carbon Portal are stored in a safe, long-term manner in the ICOS repository. This also includes all metadata that are necessary to make sense of the data themselves. The repository is based on the B2SAFE service provided by the European Data Infrastructure (EUDAT) Collaborative Data Infrastructure (CDI), which is part of the European Open Science Cloud (EOSC). Data is replicated in the trusted repositories at two separate instances, one in Finland and one in Germany, next to the copy at the Carbon Portal and, in most cases, also at the Thematic Centres.

10. Descriptions of the ICOS data products and their contents must be easily found. ICOS is operating its own data catalogue, but we also share information about all the ICOS data products and how to access them with other data providers, including environmental and climate-data portals.

11. ICOS data can be effectively and quickly sent to other computing centres. Our collaboration with European e-infrastructure providers that are part of EOSC, such as EUDAT and EGI, makes it easy to transfer ICOS data to and from high-performance computing centres.

Data product levels

ICOS data are quantitative or qualitative attributes of variables or sets of variables that have been gathered using ICOS RI-recommended sensors at validated ICOS stations in an ICOS ERIC Member or Observer country. The measurements are standardised due to protocols mutually agreed upon by the Thematic Centres and Monitoring Station Assemblies (MSAs). The Principal Investigators of the ICOS stations are responsible for Quality Assurance at the station and for the first-order Quality Control of the data. Quality Assurance protocols, developed by the Atmosphere Thematic Centre (ATC), Ecosystem Thematic Centre (ETC) and Ocean Thematic Centre (OTC) in cooperation with the associated MSAs, must be used.

Level 0 data

Level 0 data, or so-called 'raw data', are information or objects directly obtained from human measurements or automated sensors that have not undergone any transformation. They may provide quantitative or qualitative information about physical variables of the environment and may be of various forms, such as images, text files or physical samples. For the sake of transparency and reproducibility, all ICOS Level 0 data are, in principle, available through the ICOS data licence.

Level 1 data

Level 1 Near Real Time data (L1_NRT): NRT data are generally developed for fast distribution using automated quality control within 24 hours of the measurement. NRT data are defined as a high-quality dataset that will be distributed in the default way through the Carbon Portal. These datasets have their own provenance metadata that describe the raw data used, the versions of the software and the scripts, the settings and the results of the automatic quality control.

Level 1 Internal or Intermediate Working data (L1_IW): Internal Working data are data that are generated as intermediate steps in the data processing of NRT or Level 2 data preparation, and for this reason they are not handled as persistent data and not shared outside the ICOS RI. Level 1 data are used for internal quality checks, as in the communication between Central Facilities and Principal Investigators. During the production of internal working data and following quality checks, important provenance information is generated that needs to become a part of the provenance metadata of Level 2 data.

Level 2 data

Level 2 data are the final, quality-checked ICOS RI dataset, published by the Central Facilities, to be distributed through the Carbon Portal.

Level 3 data

Elaborated data products or Level 3 data products are data that rely partly or completely on ICOS observations. The Carbon Portal helps users in the production and publication of these data or data services in the same FAIR and reproducible way as ICOS data. Through publication at Carbon Portal and sharing through ICOS Head Office dissemination channels the reach of the data products are increased significantly.

4 THE OPERATIONS OF ICOS RESEARCH INFRASTRUCTURE

The ICOS RI operates in three domains: Atmosphere, Ecosystem and Ocean. ICOS-related local cooperation is being led and carried out by a national coordinator who also serves as a so-called Focal Point in relation to ICOS ERIC. In many cases, an assistant has been nominated to share the workload and take care of practical matters. These tasks are usually performed as an in-kind contribution by one of the participating institutions.

Each observational network (Atmosphere, Ecosystem or Ocean) is coordinated and supported by a Thematic Centre through data services such as processing and quality control; training and technical assistance for site management; developing and testing new measurement sensors; instrument setups and methods; and developing new methods for data processing. France and Finland host the Atmosphere Thematic Centre (ATC), Italy, Belgium and France the Ecosystem Thematic Centre (ETC), Norway and the UK the Ocean Thematic Centre (OTC) and Germany the Central Analytical Laboratories (CAL).

The Central Facilities ensure that all data are treated and quality controlled with the same algorithms and are properly archived. The ATC, ETC and OTC receive online data from the ICOS stations, typically on a daily basis and in near-real-time. They interact with the Monitoring Station Assemblies, which consist of the stations' Principal Investigators, researchers and technicians, on matters related to the coordination and improvement of the ICOS National Networks.

In addition to having frequent interaction with one another, the Thematic Centres interact with research institutions and industrial partners to stimulate new measurement methods and sensor development for maintaining the state-of-the-art technology within the ICOS RI. The Central Facilities promote technology transfer, in particular towards local spin-off companies. Detailed descriptions of each Thematic Centre are given below.

Atmosphere observations

The greenhouse gas concentrations in the atmosphere integrate all natural and anthropogenic fluxes, atmospheric chemistry and transport processes. ICOS has established a network of tall towers, coastal and mountain stations where data on greenhouse gas concentrations in the atmosphere are collected. The ICOS Atmosphere network covers a large part of the European continent. The data feed, for example, informs inverse modelling approaches describing the sources and sinks of greenhouse gases.

How an Atmosphere station operates

Each ICOS Atmosphere station is an observatory established to continuously measure the dynamics in the concentration of greenhouse gases (CO_2, CH_4) and other trace gases (for example, CO), which are the result of regional and global surface fluxes as well as of complex atmospheric transport mechanisms.

A site chosen for installing an Atmosphere station will typically be representative of a footprint area of more than 10,000 km^2. The ICOS Atmosphere stations are equipped with commercially available instruments integrated into a digital control system run by ICOS ATC custom-made software. ICOS Atmosphere stations' modular character allows for various configurations, which manifest in two classes of stations: Class 1 and Class 2. Class 1 stations include complete equipment for measuring the full set of ICOS atmospheric parameters. Class 2 stations include equipment for measuring a pre-defined subset.

The addition of novel instruments to the existing ICOS Atmosphere station structure, for measuring additional gas species (for example, N_2O), or the replacement of the existing instruments with more advanced ones at a later date may occur. The mandatory parameters that each category of station in the ICOS Atmosphere network measures are listed in Table 2. The requirements for data quality and compatibility are the same for ICOS Class 1 and Class 2 stations.

In the future, additional stations with a more local footprint and with the same precision requirements as the main ICOS stations, for instance, stations located in areas of high local emissions (for example large cities), might be incorporated into the network. The estimated equipment cost and staffing requirements for the establishment and operation of ICOS Atmosphere stations are provided in Tables 3 and 4, respectively.

Table 2. List of parameters measured at ICOS Atmosphere stations.

CATEGORY	GASES, CONTINUOUS SAMPLING	GASES, PERIODICAL SAMPLING	METEOROLOGY, CONTINUOUS	EDDY FLUXES
Class 1 Mandatory parameters	CO_2, CH_4, CO: at each sampling height	CO_2, CH_4, N_2O, SF_6, CO, H_2, ^{13}C and ^{18}O in CO_2: sampled every three days at highest sampling height ^{14}C (radiocarbon integrated samples): at highest sampling height	Air temperature, relative humidity, wind direction, wind speed: at highest and lowest sampling height* Atmospheric Pressure Planetary Boundary Layer Height**	
Class 2 Mandatory parameters	CO_2, CH_4: at each sampling height		Air temperature, relative humidity, wind direction, wind speed: at highest and lowest sampling height* Atmospheric Pressure	
Recommended parameters***	^{222}Rn, N_2O, O_2/N_2 ratio CO for Class 2 stations	CH_4 stable isotopes, O_2/N_2 ratio for class 1 stations: weekly sampled at highest sampling height		CO_2: at one sampling height

* Atmospheric temperature and relative humidity recommended at all sampling heights.
** Only required for continental stations.
*** Recommended for its scientific value but support from ATC in terms of protocols, database, spare analyser will not be ensured as long as the parameters are not mandatory.

Table 3. Estimated equipment cost (k€) for the ICOS Atmosphere station. Sums depend on e.g. local taxes and markets.

CATEGORIES	DESCRIPTION	EQUIPMENT COST (k€)		
		Class 2	Class 1	Class 1 'Extended'*
Meteorological parameters	At 3 tower heights	15	15	15
CO_2, CH_4 continuous in situ measurement		70	70	70
CO continuous in situ measurement			+ 20 (in addition to CO2/CH4 cost)	+ 20 (in addition to CO2/CH4 cost)
CO/N_2O continuous in situ measurement				150
Periodic air sampling for CO_2, CH_4, N_2O, SF_6, CO, H_2 and CO_2 isotopes	Flask sampler with dryer + 100 flasks with shipment cases		70+30	70+30
Radiocarbon ($^{14}CO_2$) periodic sampling	Integrated sampler (NaCl)		15	15
Boundary Layer structure	Ceilometer or Lidar		30–80	30–80
^{222}Rn				50
CO_2 flux by eddy covariance	Fast in situ CO2 analyser associated with a 3D wind sensor			60
Tubing, valve, pumps…		25	25	25
Calibration				
Tanks, pressure regulators…		12	12	12
Electrical and computing systems, data acquisition, storage and transmission, integration parts (indicative cost; prone to important variation depending on technical choice and station configuration)		10–50	10–50	10–50
TOTAL		**130–170**	**300–390**	**560–650**

* The column Class 1 'Extended' indicates equipment costs for Class 1 stations extended with some recommended but not mandatory parameters (see Table 3 for details).

Atmosphere Thematic Centre: Coordinating observations and processing data

The ICOS Atmosphere observations are coordinated by the ATC in close cooperation with the Atmosphere Monitoring Station Assembly and Central Analytical Laboratories. The ATC is composed of a data centre and a metrology lab and is complemented by an in situ station quality-control mobile lab (Figure 6). The ATC is coordinated and operated by the French Laboratoire des Sciences du Climat et de l´Environnement, supported by the Finnish Meteorological Institute.

The ATC has the following long-term objectives:

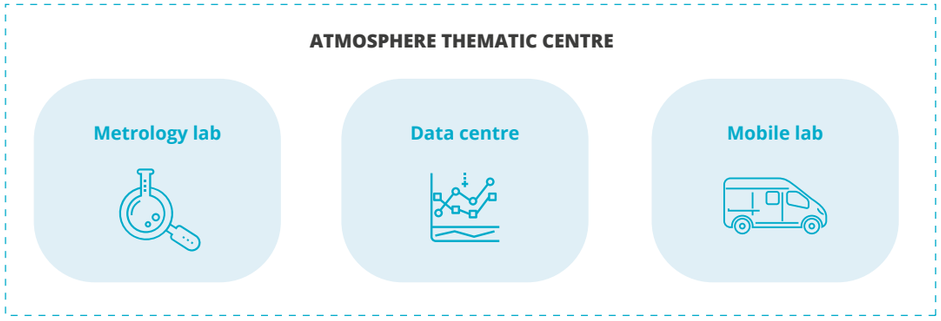
- Develop and operate the atmospheric data-processing chains, from the data transmission from stations to the routine delivery of the quality-checked data-stream used by modellers.
- Carry out a regular measurement-technology survey and analysis and enable the development of new sensors and their testing, for instance, through research and development programmes.
- Service the network with spare instruments, training and high-level technical assistance.
- Link the ICOS atmospheric data-collection programme with other ICOS Central Facilities within the framework of European and international monitoring programmes.

Table 4. Estimated annual labour force requirement (person month, PM) for the operation of an ICOS Atmosphere station.

CATEGORIES	ANNUAL WORKFORCE (PM)		
	Class 2	Class 1	Class 1 'Extended'
Maintenance in situ gas analyser	1.5	1.5	2
Maintenance Meteo	0.5	0.5	0.5
Flask sampling and handling		1	1
Radiocarbon sampling		0.5	0.5
Maintenance Ceilometer or Lidar		1	1.5
Maintenance ^{222}Rn monitor			0.5
CO_2 flux			1.5
Station maintenance, data transmission, power etc.	1.5	1.5	1.5
TOTAL	**3.5**	**6**	**9**

* The column Class 1 'Extended' indicates workforce needed for Class 1 station extended with some recommended but not mandatory parameters

Figure 6. Structure of the ICOS Atmosphere Thematic Centre.



By meeting these goals, the ATC organises the Atmosphere network for optimal long-term operations. In the ATC, harmonisation in procedures and equipment with the appropriate Quality Assurance/ Quality Control plan ensures the robustness and reliability of the collected atmospheric dataset.

The **ATC metrology lab** carries out regular measurement-technology surveys, tests and analyses for the greenhouse gas and isotope instruments of tomorrow. It facilitates the development of new sensors through research and development programmes at the national and international levels. The lab is the central labelling and training centre for ICOS atmospheric measurements, and it coordinates the development of atmospheric measurement protocols. It also provides high-level support to the network and loans replacement instruments in case of a major failure.

The **ATC data centre** develops and maintains in-house software to centrally process and quality control the data from ICOS Atmosphere stations. It provides near-real-time data products and other data products for stations' Principal Investigators.

The main task of the **ATC mobile lab** is to conduct quality control by parallel measurements at the Atmosphere stations. Its aim is to improve measurement compatibility and the development of competent quality assurance in the ICOS Atmosphere station network that ensures the credibility of the measurements. The mobile lab is hosted by the Finnish Meteorological Institute in Helsinki, Finland. The mobile lab operates a van equipped with state-of the-art analysers and standard gases, which are traceable to the WMO Central Calibration Laboratory and the ICOS CAL. Atmosphere station visits lasts for 1–2 months. During the visit, the standard gases of the station are cross-checked, and parallel monitoring of ambient air is conducted to validate the quality of the greenhouse gas monitoring of the station.

Ecosystem observations

The ICOS Ecosystem observation network is a setup of instruments, usually on a tower, that measures the flux of relevant greenhouse gases, energy and momentum representing the local surface (for example, bare soil, vegetation, water) surrounding the measurement sites, typically within 100m–1km.

Additional measurements of ancillary parameters on air, plants and soil (or water body) are also made within this footprint area. The purpose of the ancillary measurements is to support process studies and to help in understanding the physical and biotic factors controlling the greenhouse gas fluxes. The ICOS Ecosystem observation network adheres to the monitoring principles of the Global Climate Observation System (GCOS) and Global Terrestrial Observing System (GTOS).

How an Ecosystem station operates

ICOS Ecosystem stations are based on instrumentation, partly commercial, embedded into an integrated system for ecosystem monitoring. As the ecosystem observing involves human intervention in field activities (such as plant and soil sampling), an ICOS Ecosystem station follows a set of rigorously standardised protocols developed for field ecosystem measurements.

The ICOS Ecosystem station network includes two classes of Ecosystem stations, referred to as Class 1 (complete) and Class 2 (basic) stations. They differ in costs of construction, operation and maintenance due to the reduced number of variables measured at the Class 2 stations. This strategy enhances flexibility and ensures a high level of participation. A list of variables that each category of stations in the ICOS Ecosystem network measures is presented in Table 5.

The estimated cost and workforce required for operating an Ecosystem station are provided in Tables 6 and 7. The costs reported include all the investments and are calculated on the basis of a seven-year lifetime of all the equipment except the tower.

There is a possibility of establishing ICOS Ecosystem station-associated sites. The requirement is to submit at least one full year of data, which must include a set of key variables with full descriptions and meta-information, with the acceptance of the ICOS data policy. The data from these stations are processed within the ETC database. The associated sites receive an ICOS-associated status.

Table 5. List of variables that are collected at the various ICOS Ecosystem stations (Class 1 and Class 2) for the various ecosystem types.

VARIABLES	FOREST	GRASS-LAND	CROP-LAND	WET-LAND*	MA-RINE**	LAKES**
CO_2, H_2O and H fluxes (eddy covariance, including profile for storage)	1 & 2	1 & 2	1 & 2	1 & 2	1 & 2	1 & 2
CH_4 and N_2O fluxes (eddy covariance, including profile for storage)	1	1	1	1	1	1
Air H_2O concentration	1	1	1	1	1	1
Incoming, outgoing and net SW and LW radiations	1 & 2	1 & 2	1 & 2	1 & 2	1	1
Incoming SW radiation (high quality)	Fac	Fac	Fac	Fac	Fac	Fac
Incoming PPFD	1 & 2	1 & 2	1 & 2	1 & 2	1 & 2	1 & 2
PPFD below canopy + ground reflected	Fac	Fac	Fac	N.R.	N.R.	N.R.
Outgoing PPFD	1 & 2	1 & 2	1 & 2	1 & 2	Fac	Fac
Diffuse PPFD and/or SW radiation	1	1	1	1	Fac	Fac
Spectral reflectance	Fac	Fac	Fac	Fac	Fac	Fac
Soil heat flux	1 & 2	1 & 2	1 & 2	1 & 2	N.R.	N.R.
Air temperature and humidity profile	1 & 2	1 & 2	1 & 2	1 & 2	Fac	Fac
Backup meteo station (TA, RH, SW_IN, precipitation)	1 & 2	1 & 2	1 & 2	1 & 2	1 & 2	1 & 2
Total high-accuracy precipitation	1 & 2	1 & 2	1 & 2	1 & 2	1 & 2	1 & 2
Snow height	1 & 2	1 & 2	1 & 2	1 & 2	Fac	Fac
Soil water-content profile	1 & 2	1 & 2	1 & 2	1 & 2	N.R.	N.R.
Soil temperature profile	1 & 2	1 & 2	1 & 2	1 & 2	N.R.	N.R.
Air pressure	1 & 2	1 & 2	1 & 2	1 & 2	1 & 2	1 & 2
Trunk and branches temperature	Fac	N.R.	N.R.	N.R.	N.R.	N.R.
Water-table depth	1 & 2	1 & 2	1 & 2	1 & 2	N.R.	N.R.
Tree diameter (continuous)	1	N.R.	N.R.	N.R.	N.R.	N.R.
Phenology/camera	1	1	1	1	N.R.	N.R.
Soil CO_2 automatic chambers	1	1	1	1	1	1
CH_4 and N_2O fluxes by automatic chambers	1	1	1	1	1	1
Wind speed and wind direction (additional to 3D sonic)	1	1	1	1	1	1
GAI	1 & 2	1 & 2	1 & 2	1 & 2	N.R.	N.R.
Above-ground biomass	1 & 2	1 & 2	1 & 2	1 & 2	N.R.	N.R.
Soil carbon content	1 & 2	1 & 2	1 & 2	1 & 2	N.R.	N.R.
Litterfall	1	1	1	1	N.R.	N.R.
Leaf nutrients content	1 & 2	1 & 2	1 & 2	1 & 2	N.R.	N.R.
Soil-water N content	Fac	Fac	Fac	Fac	N.R.	N.R.
DOC concentration	Fac	Fac	Fac	Fac	N.R.	N.R.
C and N import/export by management	1 & 2	1 & 2	1 & 2	1 & 2	N.R.	N.R.
Oxygen and pCO_2 surface concentration	N.R.	N.R.	N.R.	Fac	2	2
Oxygen, pCO_2 and pN_2O concentration profile	N.R.	N.R.	N.R.	Fac	1	1
Salinity	N.R.	N.R.	N.R.	N.R.	1 & 2	N.R.
Wave properties	N.R.	N.R.	N.R.	N.R.	Fac	Fac
Water-temperature profile	N.R.	N.R.	N.R.	N.R.	1	1
Management and disturbances information	1 & 2	1 & 2	1 & 2	1 & 2	1 & 2	1 & 2

Fac = Facultative variable; N.R. = Not Relevant for the ecosystem.
* Wetland includes all distinct water-inundated or saturated ecosystems according to Joosten and Clark 2002.
** List of variables for Lake, Marine and Urban sites under discussion.

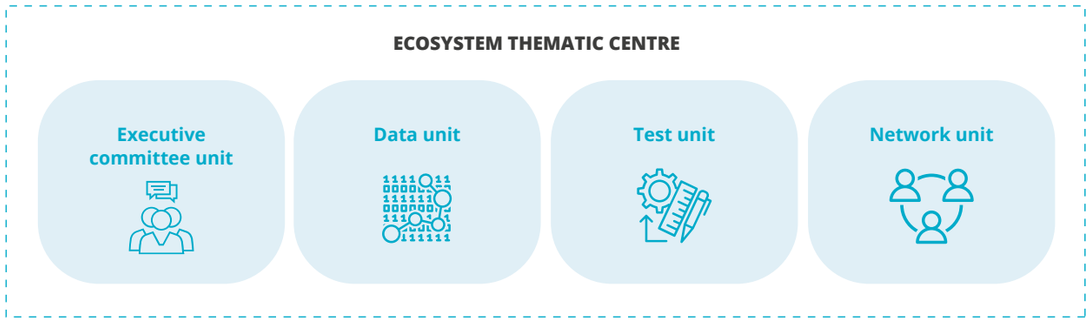
Table 6. Estimated equipment cost (k€) for the ICOS Ecosystem station

CATEGORIES	FOREST		CROP		GRASS		MIRE	
	Class 1	Class 2	Class 1	Class 2	Class 1	Class 2	Class 1	Class 2
Infrastructure	30–200	30–200	20–30	20–30	20–30	20–30	20–30	20–30
CO_2, H_2O energy EC	60–70	60–70	60–70	60–70	60–70	60–70	60–70	60–70
Storage CO_2 and H_2O	20–30	20–30	0–10	0–10	---	---	---	---
CH_4 EC	50–70	---	50–70	---	50–70	---	50–70	---
N_2O EC	100–150	---	100–150	---	100–150	---	100–150	---
Storage CH_4	25–50	---	0–40	---	---	---	---	---
Storage N_2O	25–50	---	0–40	---	---	---	---	---
Radiations	10–30	10–15	10–30	10–15	10–30	10–15	10–30	10–15
Soil meteorology	20–30	14–20	20–30	14–20	20–30	14–20	20–30	14–20
Basic meteo	25–50	20–30	25–35	15–25	25–35	15–25	25–35	15–25
Precipitations	7–13	4–7	7–13	4–7	7–13	4–7	7–13	4–7
Phenology-Camera	2–3	2–3	2–3	2–3	2–3	2–3	2–3	2–3
Soil CO_2 automatic chambers	60–75	---	60–75	---	60–75	---	60–75	---
Ancillary data	12–18	4–10	10–15	10–15	10–15	10–15	6–15	6–10
Tree diameter	4–5	---	---	---	---	---	---	---
Leaf nutrients content								
Soil carbon content								
Management, disturbances, C & N import and export								
Site characterization								
Dataloggers, other costs	10–25	6–20	10–25	6–20	10–25	6–20	10–25	6–20
TOTAL	**460–865**	**170–405**	**375–635**	**140–215**	**375–635**	**140–215**	**370–545**	**135–200**

Table 7. Estimated annual labour force requirement (PM) and maintenance cost (k€) for the operation of an ICOS Ecosystem station. Sums depend on e.g. local taxes and markets.

CATEGORIES	FOREST		CROP		GRASS		MIRE	
	Class 1	Class 2	Class 1	Class 2	Class 1	Class 2	Class 1	Class 2
Installation (PM)	3-10	3-8	2-5	1.5-4	2-5	1.5-4	2-5	1.5-4
Maintenance and sampling (PM)	24-36	18-30	22-34	18-30	24-36	20-34	24-36	15-24
CATEGORIES	**FOREST**		**CROP**		**GRASS**		**MIRE**	
	Class 1	Class 2	Class 1	Class 2	Class 1	Class 2	Class 1	Class 2
Maintenance costs	3-6	3-5	8-12	6-10	8-12	6-10	8-12	6-10

Figure 7. Structure of the ICOS Ecosystem Thematic Centre.



Ecosystem Thematic Centre: Coordinating observations and processing data

The ICOS Ecosystem observations are coordinated by the ETC. The ETC offers continuous support to the Ecosystem stations and organises additional training activities. It performs the centralised data processing and quality control and provides technical assistance to the stations. The ETC collaborates closely with the Ecosystem MSA and the broader scientific community to develop and test new data processing methods, measurement techniques and instruments to evaluate their potential use and implementation in the Ecosystem network. As part of the labelling process, the ETC evaluates the quality of the Ecosystem stations before they are included in the ICOS Ecosystem station network. The ETC manages the international collaborations of the Ecosystem network to increase its visibility and oversees the activities that enhance the data interoperability across different terrestrial Ecosystem networks and Research Infrastructures.

The ETC processes the data on net ecosystem fluxes and their components, carbon stocks and ancillary data. Diverse processing hierarchies are used for the production of the various data levels. Near-real-time datasets are released for data users that need fast access to recent data and for continuous data quality control. Ancillary information about the stations (for example: vegetation and soil characteristics; disturbances; management) are processed, often starting from raw measurements, to guarantee a high standardisation between the various stations. All the data and metadata are delivered to the Carbon Portal for further user distribution.

The ETC is coordinated and operated by the Euro-Mediterranean Centre on Climate Change (CMCC) in collaboration with the University of Tuscia (UNITUS) in Viterbo, Italy, the University of Antwerp (Research group Plants and Ecosystems, PLECO) in Antwerp, Belgium and the French National Research Institute for Agriculture, Food and Environment (INRAE), France.

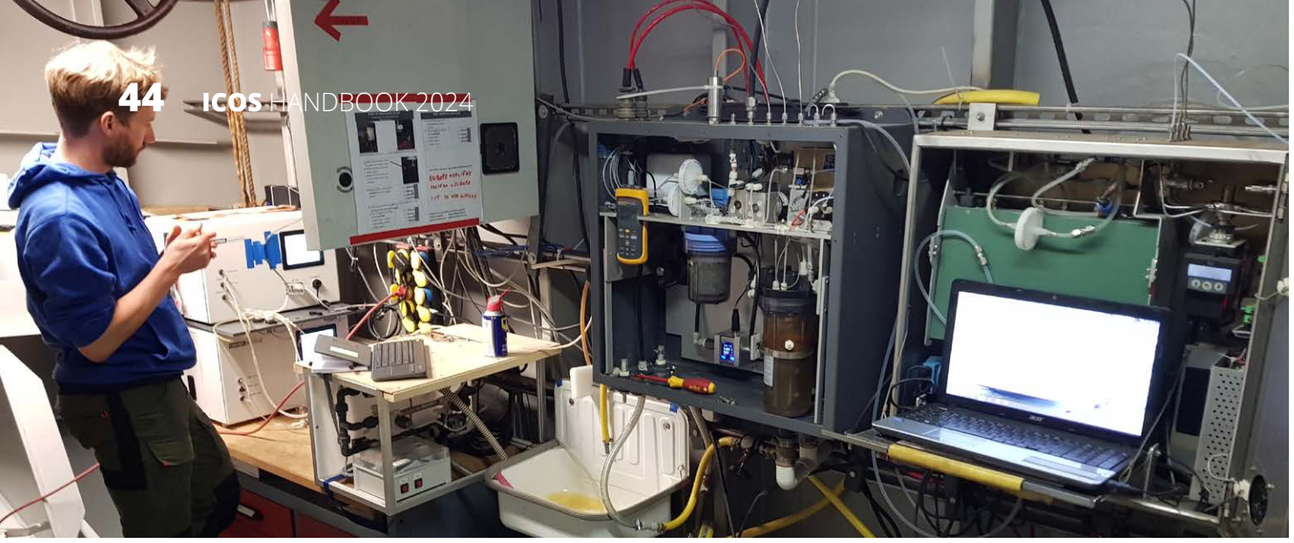
Although the ETC has been organised to maximise the interchangeability of the members to increase its robustness and share its competencies, the groups involved have distinct fields of expertise and main responsibilities. The Italian partners, UNITUS and CMCC, coordinate the ETC and the processing of ecosystem fluxes and meteorological data, the University of Antwerp is responsible for the ancillary vegetation data collection and treatment, while INRAE receives, analyses and stores the soil and vegetation samples. The ETC is organised in four main units with specific tasks (Figure 7).

Unit 1: The Executive Committee Unit's main tasks include communication and interaction with the ICOS community and other Central Facilities. The unit also organises annual assessments of ETC operations and plans its medium- and long-term activities. It is also responsible for the international collaborations.

Unit 2: The Data Unit's main tasks include Level 2 and NRT data production and metadata collection as well as automatic data quality assistance, quality control and processing. The unit shares, distributes and archives data and develops tools for data exploration and validation. This unit also maintains an alert service in case of data problems and inconsistencies.

Unit 3: The Test Unit's main tasks include the evaluation of new sensors and prototypes and the development of new processing and quality control methods. The unit is responsible for interactions with instrument manufacturers and research centres.

Unit 4: The Network Unit's main tasks include providing assistance to the ICOS Ecosystem stations, evaluation of station performances and the labelling activities. The unit organises training sessions for site managers and technicians and forms workgroups for protocol development. This unit also analyses soil and vegetation samples and takes care of their storage.



Ocean observations

ICOS provides long-term observations from 23 Ocean stations in eight countries, monitoring carbon uptake and fluxes in the North Atlantic and the Nordic, Baltic and Mediterranean Seas. The measuring methods include sampling from research vessels, moorings, buoys and commercial vessels, so called Ships of Opportunity (SOOP). They all have been equipped with state-of-the-art carbonate system sensors.

The ICOS Ocean observation network is also enhancing and actively seeking, developing and exploring new methodologies. For example, in addition to the core platforms mentioned above, the ICOS Ocean network cooperates with the wider community to develop new sensors for the carbon system for autonomous platforms, such as Argo floats and gliders, to provide better coverage of more remote areas. It also works with the hydrographic community to provide full-depth carbon observations.

The linear coverage along ship tracks is integrated with satellite-based observations and modelled data to provide extrapolation across the surface of the ocean. The satellite data are also used to assist in the interpolation of the data between passages of ships. Carbon flux estimates are based on ships' and satellite measurements of the surface temperature, the winds and the output of real-time ocean forecasting models. This provides the comprehensive assessment that is required to monitor and understand the present state of the oceans. ICOS Ocean observations aim to better understand the complex interplay between oceans and the atmosphere.

How an ocean station operates

ICOS Ocean stations are based on instrumented Ships of Opportunity (SOOP) and Fixed Ocean Stations (FOS). The SOOP are either research vessels or commercial ships operating on regular, repeated ship routes on the European shelf and marginal seas and those of cargo vessels on open ocean routes.

The FOS are fixed sites in the ocean. They are able to provide near-real-time data that also might contain information from greater depths, for example, about temperature anomalies. FOS observations are recorded by means of moorings. These platforms require visits from well-equipped research vessels, preferably 2–12 times per year. Coastal FOS can be equipped with shore-based towers for direct flux measurements called Marine Flux Towers (MFT). Such mixed stations, by nature, serve both the Ocean and Ecosystem community. FOS can also be fixed

sites in the ocean, from where primarily discrete water samples are collected, which is less common.

The SOOP and FOS are equipped with a suite of automated instrumentation to measure ocean-surface pCO_2, sea surface temperature, salinity and related variables. On SOOP lines, measurements are repeated along the same transects at intervals of days to months; they cover only the marine surface.

SOOP and MFT typically measure semi-continuously, while the temporal coverage of FOS ranges from semi-continuous to annual. For each category of Ocean stations, ICOS defines two classes of stations according to the set of parameters measured (see Tables 8a, b). The labelling of ICOS Ocean stations is based on two key motivations: 1. Quantifying air-sea CO_2 fluxes and 2. Assessing variability and drivers of the carbonate system. The resulting uncertainty requirements for the various variables can be related to the motivations.

The current Ocean station setup consist of 13 SOOP lines and 10 FOS where one of the FOS has a Marine Flux Tower connected to it. The coverage includes repeated East–West and North–South transects of the Atlantic Ocean, Baltic Sea and the North Sea, as well as a transect sampling that reaches out to the Barents Sea and all the way to the Arctic Ocean. FOS are situated in the Baltic, the Atlantic Ocean, as well as in the Mediterranean Sea.

Table 8a. List of required variables measured at ICOS SOOP stations.

VARIABLE	FREQUENCY	ACCURACY	REQUIRED FOR CLASS
Sea surface fCO_2	Quasi-continuous	± 2 µatm	2
Intake temperature (SST)	Continuous	± 0.05 °C	2
Equilibrator temperature	Continuous	± 0.05 °C	2
ΔT (Intake/Equilibrator temperature difference)	Continuous	< 1.5 °C (normal) < 3 °C (ice-edge)	2
Water vapour pressure*	Continuous	± 0.5 mbar	2
Equilibrator pressure	Continuous	± 2.0 mbar	2
Atmospheric pressure/sea level pressure	Continuous	± 1.0 mbar	2
Sea surface salinity (SSS)	Continuous	± 0.1 PSU	2
Dissolved oxygen	Continuous	± 2%	1
Total alkalinity (TA)**	***	± 10 µmol kg^{-1}	1
Dissolved inorganic carbon (DIC)**	***	± 5 µmol kg^{-1}	1

* If the analysed headspace gas is not dried completely prior to measurement.

** At least one of these variables must be provided.

*** The frequency of these additional variables will be decided on during the labelling process based on the area where the station is operating.

Table 8b. List of required variables measured at ICOS FOS stations with continuous/quasi-continuous measurements.

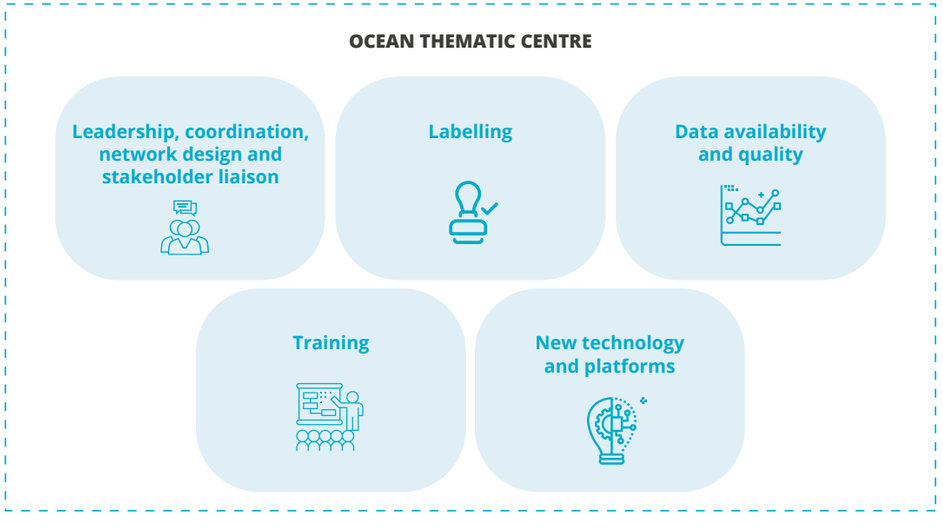
VARIABLE	FREQUENCY	ACCURACY	REQUIRED FOR CLASS
Sea surface pCO_2	> 1/day (open ocean) > 3/day (coastal)	± 10 µatm	2
Sea surface temperature	> 1/day (open ocean) > 3/day (coastal)	± 0.02 °C	2
Sea surface salinity	> 1/day (open ocean) > 3/day (coastal)	± 0.1 PSU	2
Pressure (depth)	> 1/day (open ocean) > 3/day (coastal)	± 3 dbar	2
Total alkalinity (TA)*	**	± 4 µmol kg^{-1}	2
Dissolved inorganic carbon (DIC)*	**	± 2 µmol kg^{-1}	2
pH***	**	± 0.003	2
Dissolved oxygen	> 1/day (open ocean) > 3/day (coastal)	± 2%	1
Dissolved nutrients ****	**	± 1-3%*****	1

* At least one of these variables must be provided.
** The frequency of these additional variables will be decided on during the labelling process based on the area where the station is operating.
*** pH (together with TA or DIC) is only required for validation of the pCO_2 data and is not needed as a regular variable. pH should not be used together with pCO_2 to calculate the full carbonate system due to high resulting uncertainty. OTC will assist with the supply of sampling material and measurement of pH samples.
**** At least two out of the three dissolved nutrients nitrate (NO_3), phosphate (PO_4), and silicate ($Si(OH)_4$) must be provided.
***** The accuracy refers to samples without conservation. If conservation is used (freezing is the most used method) the accuracy might decrease, especially for silicate.

Ocean Thematic Centre: Coordinating long-term ocean observations

The ICOS Ocean observations are coordinated by the Ocean Thematic Centre (OTC). OTC currently coordinates 22 ocean stations in seven countries, monitoring carbon uptake and fluxes in the North Atlantic and the Nordic, Baltic and Mediterranean Seas. The measurement methods include sampling from research vessels, moorings, buoys, and commercial vessels, so called Ships of Opportunity (SOOP). They all have been equipped with state-of-the-art carbonate system sensors.

Figure 8. Structure of the ICOS Ocean Thematic Centre.



OTC is coordinated and operated by Norwegian Research Centre (NORCE) and University of Bergen in Norway, and University of Exeter and National Oceanography Centre in the UK.

The OTC is organised in five main units with specific tasks (Figure 8.)

The Executive Unit is in charge of leadership, coordination of Ocean Thematic Centre, network design and stakeholder liaison. OTC leadership is a shared responsibility between the OTC director and the deputy director.

The Labelling Unit is in charge of the station labelling process. The unit's task is also the development of station labelling reports. The reports include the evaluation of the stations undergoing the labelling procedure.

The Data Unit is in charge of the data collection, availability and quality. The unit tracks the data collection, flow, processing, quality and availability for all the stations that are part of the ICOS Ocean network. They ensure the contribution to the relevant global data collections, as well as prompt actions in order to solve potential critical situations.

The Training Unit's task is to optimise and standardise performance of the network instrumentation and calibration. They provide guidance, technical support for installations at individual stations and organise training events for the ICOS Ocean community.

New Technology and Platforms Unit is in charge of new sensors and new platforms. Its task is to invite early adopters as collaborators or partners in future research grants to explore new technologies.

Table 9a. Estimated investment cost (k€) for an ICOS Ocean station. Sums depend on e.g. local taxes and markets.

CATEGORIES	DESCRIPTION	SOOP		FOS		
		Class 1	Class 2	Class 1	Class 2	Flux tower
CO_2 in situ measurements	UW equilibrator based system	100	100			
CO_2 in situ measurements	Membrane based system			35	35	
LICOR Sensor	To accompany Equilibrator	25	25			
Temperature, Salinity	Essential Addition-al Data	40	40	40	40	
Dissolved Oxygen		20		10	10	
Nutrients				40		
Deployment platform	Buoy, highly variable			80	80	
CO_2 flux measurements (incl. Tower, data aquisition)						60
One off cost to visit the station for set up and data aquisition		20	20	20	20	20
Total Alkalinity/Dissolved Inorganic Carbon (TA/DIC)		35				
Tubing, valve, pumps…		10	10	10	10	
Calibration of sensors on deployment		10	10	10	10	
Tanks, pressure regulators…		5	5	5	5	
Capital cost of electrical and computing systems, data acquisition, storage and trans-mission, integration parts (indicative cost; prone to important variation depending on technical choice and station configuration)		20	20	20	20	
TOTAL		**285**	**230**	**270**	**230**	**80**

NB Flux tower estimates assume full flux tower is in place already

Table 9b. Estimated annual workforce requirement (PM) and maintenance cost (k€) for the operation of an ICOS Ocean station. Sums depend on e.g. local taxes and markets.

CATEGORIES	SOOP		FOS		
	Class 1	Class 2	Class 1	Class 2	Flux tower
Maintenance (pCO_2, Sal, Temp) (PM)	1	1	1	1	
Maintenance DO (calibration included) (PM)	1		1	1	
Maintenance (TA/DIC) (PM)	1	1			
Maintenance CO_2 (PM)	1	1	1	1	4
Maintenance nutrients (calibration included) (PM)			1		
Sampling/analysis (PM)	3	3	3	3	
Station maintenance, data transmission, power etc. (PM)	3	3	3	3	6
Data reduction, validation and QC (PM)	3	3	3	3	3
TOTAL (PM)	**13**	**12**	**13**	**12**	**13**
Maintenance CO_2 (k€)	1	1	1	1	5
Maintenance Temp, Sal (k€)	1	1	1	1	
Maintenance DO (calibration included) (k€)	1		1		
Maintenance nutrients (calibration included) (k€)	1	1	1		
Sampling/analysis (k€)	5	5	5	5	
Station maintenance, data transmission, power etc. (k€)	5	5	5	5	10
Consumables (pCO_2, Sal, Temp)	5	5	5	5	
Consumables DO (calibration included)	5		5	5	
Consumables (TA/DIC)	5				
Travel and subsistence for Station maintenance	10	10	10	10	
TOTAL MAINTENANCE COSTS (K€)	**39**	**28**	**34**	**32**	**15**

Interoperability among Central Analytical Laboratories, Thematic Centres and Observation networks

Sample logistics

The role of the FCL and CRL is the analysis of air samples collected at ICOS stations. The FCL serves the Atmosphere network in maintaining their sampling equipment (flasks). CO_2-free NaOH solution is supplied to Class 1 stations by the CRL for radiocarbon sample collection. Sample logistics and sampling information will be handled centrally in the CAL database. The CAL database system documents the sample processing, starting with collection at the sites, sample preparation, analysis steps and sample container maintenance.

Data processing

The analysis of several thousands of samples per year on various instruments in the FCL and CRL generates a large amount of raw data that need to be processed, evaluated and archived. For this, an elaborate database system, suited for the task, is in place and being further developed by the FCL and the CRL. The CAL database application has an interface to the ATC database, providing the analysis results and comprehensive metadata information for all samples. The data management strategy allows for measurement data to be reprocessed at any time should calibration corrections be necessary by hindsight.

Central Analytical Laboratories use the following instrumentation:

- Isotope ratio mass spectrometer (Thermo Scientific MAT 253) and CO_2 extraction line for stable isotope analysis of atmospheric CO_2
- Isotope ratio mass spectrometer (Thermo Scientific DELTA V) for CO_2/O_2/N_2 analysis of air samples
- Gas chromatograph (Agilent 7890A) for CO_2, CH_4, N_2O, H_2, CO and SF_6 concentration analyses in flask samples (detector types: FID, ECD, PDD, RGD)
- Oil-free compressor (Rix) combined with a Zero Air Generator and a depletion/spiking system for selective adjustment of tracers to produce real air calibration gases
- Cavity ringdown spectrometer (Picarro G2301) for CO_2 and CH_4 measurements
- Off-Axis Integrated Cavity Output Spectroscopy spectrometer (Los Gatos) N_2O/CO analyser
- FTIR Spectrometer (Ecotech Spectronus FTIR) for CO_2, N_2O, CO and CH_4 analyses
- ^{14}C low-level gas proportional counting facilities for high-volume samples
- Semi-automated CO_2 extraction and graphitisation devices to produce graphite targets for subsequent AMS analysis

Table 10. List of the specific tasks of the Flask and Calibration Laboratory (FCL) and the Central Radiocarbon Laboratory (CRL).

TASKS OF THE FCL		
Flask samples	**Standard gases**	**Quality control**
• Analysis of the following parameters in air samples from the ICOS stations: trace gas concentrations (CO_2, CH_4, N_2O, H_2, CO, SF_6) stable isotopes of CO_2 ($\delta^{13}C$ and $\delta^{18}O$) • O_2/N_2 ratios • Initial conditioning of air-sample containers (flasks) to achieve long-term stability of the CO_2-$\delta^{18}O$ signature • Routine leak test of flasks • Sampler development and production	• Production of real air reference gases for ICOS atmosphere stations and observing ships • Initial conditioning of high-pressure cylinders • Calibration of reference gases (CO_2, CH_4, N_2O, CO) relative to the established WMO scales (maintained by the Central Calibration Laboratory at NOAA-ESRL) • Provision of standard gases as temporary replacement sets for stations	• Maintenance of comprehensive internal quality-assurance procedures • Active maintenance of the link to the WMO scales by regular recalibration of ICOS lab standards by the WMO Central Calibration Laboratory • Organisation of ongoing international comparison programmes for flask and high pressure cylinder analysis
TASKS OF THE CRL		
$^{14}CO_2$ analysis	**ICOS network support**	**Fossil fuel CO_2 estimation**
• Analyses of up to 500 samples per year via gas proportional counting • Extraction of CO_2 from flask and high-volume samples with subsequent graphitisation for AMS analysis for up to 1,500 samples per year • Comprehensive quality management from an internal to an international level	• Serve the atmospheric ICOS sampling network with CO_2-free NaOH solution for high-volume CO_2 absorption • Build integrated, high-volume $^{14}CO_2$ samplers for the conventional gas-counting method • Develop new $^{14}CO_2$ sampling equipment	• Operation of an atmospheric pilot station measuring all major greenhouse gases and isotopes in CO_2 as well as ^{222}Rn progeny • Assessment of new sampling strategies or surrogate tracers

Central Analytical Laboratories ensure observation accuracy

The building of single central laboratories as ICOS CAL was based on earlier findings that differences between laboratories analysing flasks or producing calibration gases can substantially reduce the accuracy of a whole observational network. The aim of the CAL is to ensure the accuracy of ICOS atmosphere measurements.

The CAL is located in Germany and consists of two laboratories: the **Flask and Calibration Laboratory (FCL) in Jena**, which is hosted by the Max Planck Institute for Biogeochemistry, and the **Central Radiocarbon Laboratory (CRL) in Heidelberg**, which is operated by the Institute of Environmental Physics of the Heidelberg University.

The FCL does analyses of greenhouse gas concentrations and of other tracers that carry auxiliary information on the origin of the air samples (CO_2 stable isotope composition, O_2 / N_2 ratio, additional gases). It also produces calibrated real air reference gases to ensure the compatibility of the ICOS atmospheric greenhouse gas observations with data from other global monitoring networks, such as WMO GAW, and provides support on the material involved. The tasks of the FCL are listed in Table 9.

The CRL quantifies the radiocarbon (^{14}C) content of CO_2 in air samples and develops methods to derive the fossil-fuel contribution to atmospheric CO_2 ($ffCO_2$). The tasks of the CRL are listed in Table 10.

Carbon Portal

The ICOS Carbon Portal offers access to research data as well as easily accessible and understandable science and education products. The Carbon Portal is hosted by the University of Lund in Sweden and also one person in Wageningen University in the Netherlands. Carbon Portal is the data repository for all ICOS and elaborated data, including all raw measurement data. All higher level measurement data available from the Carbon Portal are quality controlled through the ICOS Thematic Centres: the ATC, ETC, OTC and the CALs. The Carbon Portal has the ability to address all the requirements stemming from those aspects, including data security, enforcement of the ICOS data policy and user-friendly (and machine-friendly) internet-based and other computer-network-based interfaces.

The Carbon Portal is an integrative access point for all ICOS users and stakeholders, ranging from experts to the general public, and it supports standardised data-exchange protocols and techniques. Organising the long-term archiving of ICOS data products, with the aim of guaranteeing their safe storage and future access (including after a possible cessation of the research infrastructure itself), is an important task of the Carbon Portal. The Carbon Portal's activities and features are as follows:

Long-term data archiving and (back-up) storage

An important task of the ICOS Carbon Portal is to organise the long-term archiving of ICOS data products, with the aim of guaranteeing both safe storage and future access long after the cessation of the RI itself. This activity complements the data storage and backups routinely performed by the Thematic Centres. Decisions regarding the archiving strategy used are to be taken by the ICOS RI in consultation with the Thematic Centres and MSA Principal Investigators.

Data mining, data extraction, collocation

In order to facilitate the interactions of a wide spectrum of user categories, the Carbon Portal acts as the main access platform for any and all parties interested in ICOS data products. In addition, the Thematic Centres may operate their own data-access interfaces, mainly for use by principal investigators in the quality control process. The Carbon Portal de-

velops efficient search capabilities that allow users to locate and retrieve data of interest, e.g. restricted to specific variable types, geographical areas or time periods. To this end, the Carbon Portal maintains an up-to-date collection of metadata of the data provided by the Thematic Centres.

Maintaining ICOS data and metadata standards

The harmonisation of data and metadata standards, together with graphical formats and links to new products, are coordinated within the ICOS RI under the responsibility of the Carbon Portal. Concerning data formats, the Carbon Portal may offer various options to meet user needs with online/offline automatic conversion tools (for example, ASCII for time-series point measurements, NetCDF for spatial data). Metadata that adhere to the relevant standards (for example, ISO 19115, Dublin Core, DIF) are provided by the Carbon Portal.

Providing web services for users

The overall architecture of the Carbon Portal software for publishing data and metadata is based on Web service solutions. Web services have been developed for publishing metadata, searching within metadata repositories, visualising data and retrieving data.

Traceability of downloaded ICOS data

The traceability and citability of ICOS data products are ensured by applying a system of unambiguous data identifiers, for example, handle PID or DOI. The Carbon Portal has the overall responsibility for coordinating and ensuring the implementation of (internal and external) data identifiers for all ICOS data products. The citation and referencing of DOIs and data publications offer a bibliometric means of tracing and measuring the data usage through its referencing in the scientific literature.

Tracking of publications based on ICOS data

ICOS data users are encouraged to submit copies of any publications that report studies using ICOS data when they are published. The Carbon Portal keeps track of this record and completes the list by conducting searches using bibliometric tools (for example, ISI, Scopus) in order to make it exhaustive. Links to publications based on ICOS data available on the internet are provided by the Carbon Portal. Any other outcome of the use of ICOS data is also documented on the Carbon Portal. Relevant information on data usage and ICOS visibility is collected, including the number of downloads, the number of visits to the portal, the number of papers and media coverage of ICOS.

User registration and traceability

In accordance with the ICOS data policy, the Carbon Portal tracks what data or information users have accessed or downloaded. This allows for the assessment of which data are most interesting to users or for establishing user profiles. Download tracking also contributes to showing the interest of users in the ICOS network to the funding agencies of ICOS' infrastructure and to improving the effectiveness and efficiency of the system. Access to ICOS data follows the ICOS data-use policy, which in turn complies with GEOSS (Global Earth Observation System of Systems) data-sharing principles.

Coordinating ICOS data descriptions and releasing publications

Processed and quality-controlled datasets offered via the Carbon Portal may be frozen on a periodic basis and subsequently published in specialized journals, for example, *Earth System Science Data*. The frozen datasets, also known as Data Releases, are also available through the Carbon Portal in parallel with the continuously updated 'live' datasets. With

the Thematic Centres, the Carbon Portal coordinates the peer-reviewed publication of descriptions of the ensemble of the databases. The publication may be done regularly with each 'freezing' of the database, for example, annually. This publication ensures bibliometric recognition of the work performed by the Monitoring Station Assembly Principal Investigators and the Thematic Centres.

Display of and access to elaborated data products

Level 3 data products increase the scientific impact of ICOS, and an important task of the Carbon Portal is therefore to act as a clearinghouse that will offer access and proactive publicity to Level 3 products that are based on ICOS observational data, including, but not limited to, flux production efforts. The Level 3 products may be generated within ICOS (for example, by the Carbon Portal) or by external users (mostly modellers), both from the large scientific community within the ICOS consortium or outside of it. Comparisons between products may be developed by the Carbon Portal. Contributions are open to any product of high scientific quality, but contributions should ideally be extensively based on work published in the international peer-reviewed literature by the contribution team.

Interfaces with other data portals in and outside of Europe

Interfaces with relevant data portals were established by the Carbon Portal team. This involved, at minimum, liaising with those other initiatives for visible links between the portals. Links with external, specific thematic data centres (Atmosphere, Ecosystem and Ocean) are managed by the Thematic Centres with technical support from the Carbon Portal. Whenever possible, the interfacing can be stronger. The Carbon Portal team collaborates with these data portals to ensure mutual or unilateral discoverability and accessibility (within the respective portal search engines) that are technically feasible and respect intellectual property rights (IPRs), notably with the GEO/GEOSS-related portals. In doing so, the Carbon Portal ensures that ICOS data will remain accessible under the authentication and authorization schemes defined for ICOS data by the Carbon Portal.

IT services for the ICOS community

ICOS ERIC supports the scientific ICOS community with some useful IT tools to facilitate the cooperation.

NextCloud Fileshare: document sharing & editing in the cloud. A cloud-based service to store and share your documents (text, spreadsheets, presentations, any data file) with colleagues. The fileshare offers a cooperative document editor like Google Docs (highly compatible with MS Office), so that you can work with many persons simultaneously on manuscripts, data and presentations, with guaranteed privacy. We assign you the permissions to the right group shares when you register. Beware that processing your registration can take a few working days.
Main link: fileshare.icos-cp.eu
Further info and help: bit.ly/2Vp6oVk

Mailing lists. Email lists offer both moderated and unmoderated discussions, and possibility to archive and search for messages. Users can subscribe or unsubscribe themselves. You can join published lists through lists.icos-ri.eu. You can request to have your own mailing lists for an ICOS related activity at www.icos-cp.eu/emaillist_request.
Main link: lists.icos-ri.eu
Further info and help: bit.ly/3eGoEBt

Curation of research data products. Our curation specialists can help in finding a good place for sharing your research data, just send a mail to info@icos-cp.eu. ICOS Carbon Portal can be the right repository to long-term preserve your data. You can mint your own DOI and set the right metadata at our DOI minting interface and then we can help you in transferring the data to out trusted repository. We expect to receive the CoreTrustSeal certificate in spring 2024.
Main link: doi.icos-cp.eu

Websites. ICOS can host the website for National Networks or other facilities. Currently, four NNs and several EU projects use this service. Carbon Portal uses the CMS Drupal V10 system and helps to make sure that the website follows the ICOS visual guidelines.
Main contact point for these services:
info@icos-cp.eu

Jupyter notebook services and Python Data Access Library. Jupyter notebooks are a modern and interactive way to work together on scientific workflows and to improve the reproducibility of science when working with (large) datasets. Carbon Portal provides a Jupyter Hub that gives a free access to a large number of demonstration notebooks. Through the easy-to-use ICOSCP Python Library, you can access directly to all the ICOS time series and many other data and metadata at the ICOS repository.
Further info & access to ICOS Jupyter Hub:
www.icos-cp.eu/data-services/tools/jupyter-notebook
Further info on ICOS Python Data Access Library:
icos-carbon-portal.github.io/pylib

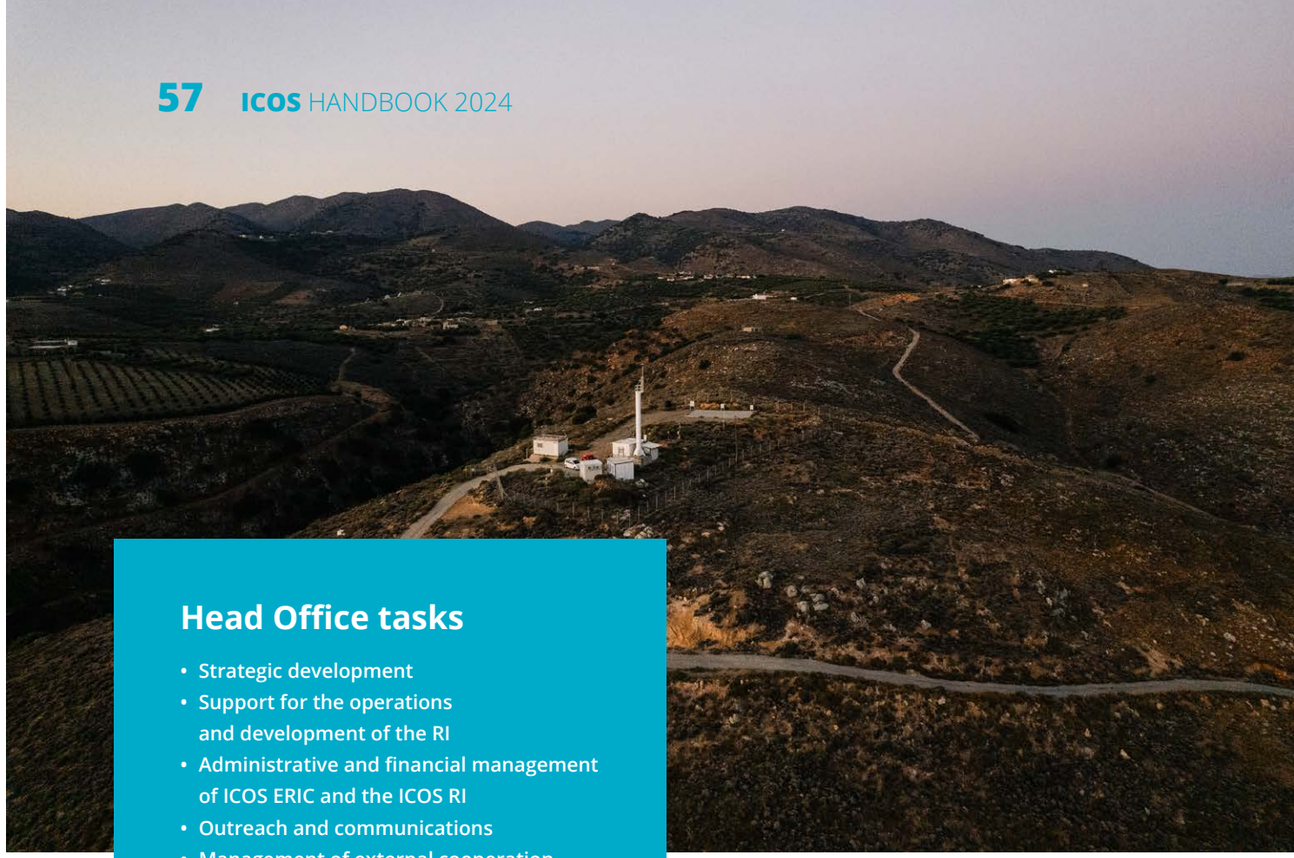
Head Office

The Head Office (HO) is the organisational hub of the entire ICOS RI. It supports and connects all the bodies of ICOS ERIC. Furthermore, the HO coordinates the operations of ICOS RI in close cooperation with the Research Infrastructure Committee (RI COM) which has representatives from other bodies of the RI. The Head Office is led by the Director General (DG).

The Head Office prepares the meetings of the overall governing body, the General Assembly (GA), and implements its decisions. The HO prepares and monitors the annual work plans and budgets, and it oversees the implementation and updates of ICOS strategy. DG and the HO have developed a broad network for international cooperation and effective communication, including videos and exhibitions during the past years and will even increase these efforts in the future.

The Head Office works together with the Central Facilities to coordinate overall activities and develop the ICOS RI. The activities and deliverables are discussed, and possible problems solved together when needed. The Head Office coordinates and supports the Monitoring Station Assemblies, stations, and National Networks and is responsible for managing the contracts with the hosts of ICOS Central Facilities and stations. Furthermore, the Head Office coordinates and facilitates future network development and extension in cooperation with the ICOS Central Facilities and Monitoring Station Assemblies.

The administrative areas within the Head Office include, for example: Acting as the General Secretariat for the General Assembly, Chair and Vice-Chair and providing support to the Financial Committee, the SAB, EAB and the GA delegates; Human-resource management of the ERIC; Financial management of the ERIC and planning and coordinating the ICOS RI financial management as specified in the ICOS Financial Rules, as well as supporting the procurement and managing the service providers of the ERIC.



Head Office tasks

- Strategic development
- Support for the operations and development of the RI
- Administrative and financial management of ICOS ERIC and the ICOS RI
- Outreach and communications
- Management of external cooperation
- Management of ICOS ERIC's participation in externally funded projects

The Head Office is also tasked with communications and outreach. Through its actions and through supporting the National Networks and Central Facilities' communications, the HO aims to increase the awareness and perceived value of ICOS and its data among key external stakeholders and to strengthen the sense of belonging among its own community. Educating the general public about importance and methods of greenhouse gas measurement is also within the scope. Actions include a unified ICOS brand: producing online and printed materials and managing communications channels as well as marketing and events.

The amount of work needed in the areas described above has varied over the years. In the beginning, community building and design needed much efforts, then construction and now operation. Consequently, the number of personnel in the HO, and the funding of the tasks have developed throughout the ICOS RI life cycle, with project funding providing the important extra resources for the development. In the future, we expect that basic funding will cover the resources needed, while potential projects will continue to fund and develop ICOS RI in the future.

ICOS makes a significant contribution to the European and the global climate-science community by:

- Increasing the volume of available data.
- Greatly enhancing the measurement and data quality of many measurement sites that lacked knowledge, funds or instruments to meet ICOS standards.
- Improving access to data and data uniformity throughout its network.
- Developing measurement standards and protocols.
- Providing reference samples through the CALs.
- Bringing greenhouse gas scientists across Europe together as a community, increasing collaboration and the sharing of results.

5 ICOS' IMPACTS: Better science, better knowledge, better world

More accurate greenhouse gas information enables better science, provides important background information for decision-makers and helps to avoid costly mistakes. ICOS has become the base of a scientific value-chain supporting global policy- and decision-making to combat climate change and its impact, as stated by the external evaluators in the Five-Year Evaluation Report in 2021. The ESFRI monitoring report, in 2023, states that 'the standardized and scientifically interpreted measurement data provided by ICOS RI play an essential role as a rationale for European climate policy, significantly contributing to global policy action'.

The benefits of ICOS are spreading across society. Decisions are based on many standpoints, with science being only one of them, and results can be seen within very different timescales. Defining the socio-economic impact of environmental research infrastructures such as ICOS is challenging, since they observe long-term environmental phenomena requiring a long time series of data. The data provide knowledge for societal mitigation and adaptation processes that often take decades or even centuries.

The impacts of ICOS result from its interlinked strategic activities: sustainability, scientific excellence, societal impact, international cooperation, and innovation.

The ICOS Science Conference, for example, contributes to all of the impacts in this chapter. The biennial conference endorses the scientific impact by providing a platform for scientists to discuss about their discoveries and learn from each other. Technological impact is nourished at the conference's Vendor Expo, which provides opportunities for sensor and instrument manufacturers as well as hands-on users, especially scientists, to innovate together. The conference alternates special sessions and events, for example on high-level dialogues and climate communication, to interact with the decision- and policy makers as well as society.

ICOS' impacts on science

ICOS improves the quality, spatial resolution and time-series length of greenhouse gas observations in several ways. For example:

1. ICOS methods and standards enable the production of high-quality data, which leads to more reliable scientific results. The high-quality certification and associated services by Thematic Centres continue to be an attractive value proposition to new member countries, seven of which joined after the initial establishment of the ERIC. Having the data openly available accelerates research outcomes and supports efforts to mitigate climate change.
2. ICOS enables the combination of diverse datasets from various countries and across the Atmosphere, Ecosystem and Ocean domains. Combining data from the different domains, as

well as the combination of the communities itself, provides added value for the scientists, for instance by allowing for cross-comparisons of data and for sprouting original research ideas.

3. ICOS provides financial stability for the operation of over 180 measurement stations, extending the time horizons from often project-based funding to a more long-term model.
4. ICOS collaborates with research projects, other research infrastructures, and international networks and initiatives, which amplifies its impact.

ICOS started to provide data from ICOS-labelled stations in 2017, and today ICOS datasets are downloaded more than 400,000 times per year. The data is being used not only by European researchers but also globally, as shown by the global coverage of IP addresses accessing ICOS data.

The ICOS community of researchers produces around 200 scientific publications annually, the accumulated number being about 2000 at the end of 2023, including more than 140 in the high-impact journals of Nature.

Analyses show that ICOS-originated papers are widely cited (Figures 9 and 10). The citations are based on the DOIs minted by Carbon Portal. However, the DOIs are a rather new development in data use, and thus not yet as widely used as ICOS would hope for.

Additionally, ICOS-originated publications cover several journals, up to 64 different journals by the end of 2023.

Figure 9. ICOS-related publications, 2010–2023.

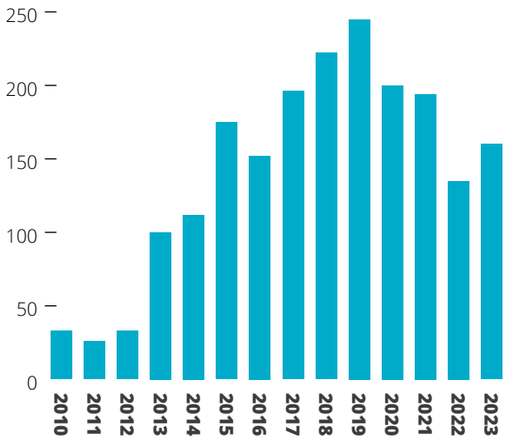
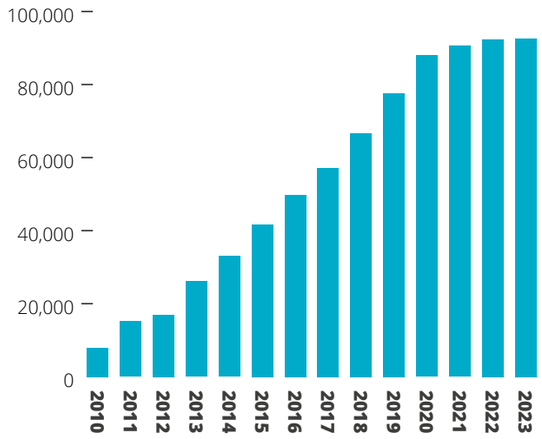


Figure 10. Cumulative citations of ICOS-related publications, 2010–2023.



ICOS' impact is also amplified by its role as the analytics and synthesis service provider for the wider scientific community. ICOS is the main Eu-ropean provider to the global atmospheric, ecosystem and oceanic datasets of, for instance, GLODAP, SOCAT, FLUXNET and the National Oceanic and Atmospheric Administration's (NOAA) Observation Package. These products are integrally used in (inverse) modelling by the global climate modelling community. ICOS also provides physical services through the Thematic Centres and the Central Analytical Laboratories (CAL). These are widely used, and the CAL is an important part of the glob-al reference-sample network, being second to only NOAA, which has performed this role for decades.

ICOS also works together with many other RIs to facilitate science. Some of the ICOS stations are co-located, while some of them provide an access via various EU-funded projects. As one of the oldest ERICs, ICOS is also working in cross-RI projects such as the ERIC Forum 2 project, and the Research Infrastructure Training Plus (RItrainPlus) to share its lessons learned with less experienced RIs.

The recent ESFRI evaluation of ICOS considers that ICOS offers value to the climate change science: "The role of ICOS in the international landscape has gained high relevance with integration, expertise and service provision to international programs or organizations like Copernicus, WMO, IPCC."

The ESFRI evaluation also concludes: "The scientific activity, research advances and engagement with the community is supported by several research project participation, including with other RIs in the European landscape, a conference series which adapted to include online participation, and support through data and resources to graduation and post-graduation programs."

The socio-economic impacts of ICOS

According to ESFRI, when evaluating the socio-economic impact of an RI, there are two important aspects to consider: Firstly, reaching a broad audience, since this helps spread knowledge and benefits beyond the scientific community. And secondly, using the RI produced reliable data in both economic and political decision-making.

ESFRI concludes that "Undoubtedly, ICOS RI has documented its excellent activity in disseminating the obtained results."

Using ICOS-generated knowledge in decision-making is more difficult to measure since decisions affecting society and the economy are made outside the RI. The ICOS evaluators reasoned as follows: *if the RI makes due efforts to disseminate the obtained measurement data and knowledge, and if policy- and decision-makers are open to using this evidence, then RI's social and economic impact reflects the public relevance of the RI.*

Hence, the ESFRI evaluation committee states: "The standardized and scientifically interpreted measurement data provided by ICOS RI play an essential role as a rationale for European climate policy, significantly contributing to global policy action".

Dissemination and communication of ICOS's results and greenhouse gas science

ICOS uses communications to increase the awareness and perceived value of ICOS and its data products among key external stakeholders, and to increase the community's engagement in ICOS. The third general goal is to increase general awareness of greenhouse gas measurements. For this, a wide pallet of tools is being used.

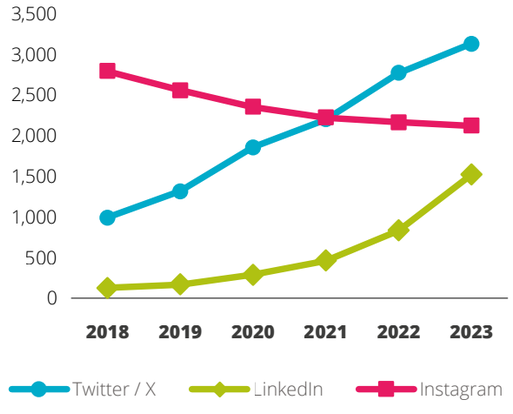
Social media is the most important external communication channel; particularly X, Instagram and LinkedIn. The number of followers on these channels has increased constantly, as shown in Figure 11.

ICOS HO works actively with the media to promote ICOS-related topics, as shown in the increasing numbers of media articles mentioning ICOS Figure 12. The Nord Stream methane pipe explosion in September 2022 explains the high number of mentions in 2022. During the incident, the real-time methane data from ICOS stations was highly interesting for the general media.

National Networks and Central Facilities also actively promote the importance of greenhouse gas research: They participate in science days and climate events, produce educational materials and work together with ICOS HO to highlight research results in the media.

ICOS has also created series of webinars to share complicated topics: Since spring 2021, the Carbon Portal Webinar series has trained users to access and visualise ICOS data and to use Jupyter Notebooks and other Virtual Research Environments (VREs). The ICOS Cities Talks webinar has raised awareness on greenhouse gas measurements and climate change in urban landscapes since 2021.

Figure 11. ICOS social media followers 2018–2023



ICOS Cities Talks webinars are part of the ICOS Cities (PAUL) EU- project.

Use of ICOS data and knowledge in decision-making

ICOS contributes timely information relevant to greenhouse gas decision-making, thus supporting efforts towards the fulfilment of the Paris Agreement. Since 2019, ICOS has been an Observer to the United Nations Framework Convention on Climate Change (UNFCCC). This allows ICOS to easily contribute to the scientific cycle of the UNFCCC, to the IPCC reports as well as to impact the parties in COP meetings through own events, for example.

However, greenhouse gas measurements and the related reports influence decisions only indirectly. Covering the whole range of essential climate variables requires cooperation between diverse organisations. Additionally, ICOS and the other organisations need collaborate closely with the societal end-users in order to base climate policy and decisions on the best available science. As the Global Stocktakes of the Paris Agreement become a norm, actors in all levels are interested to map not only the emissions and their changes, but also how the emission reduction actions affect concentrations in the atmosphere and the entire carbon cycle. Data provided by ICOS is essential for this.

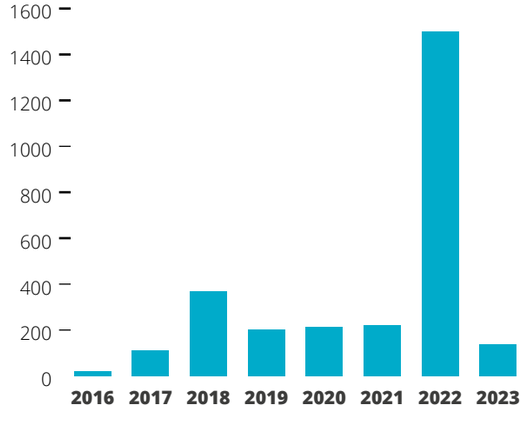
The Global Greehouse Gas Watch is one of the global initiatives aimed at supporting the Stocktake process. This measurement network, to be established by World Meteorological Organization (WMO) member countries, will use both remote sensing and on-the-ground network. ICOS is actively involved in building the Watch, being the European pillar of ground-based measurements.

The Global Climate Observing System (GCOS) defines the essential climate variables that must be systematically observed. Together with the World WMO and its Integrated Global Greenhouse Information System (IG3IS), ICOS already provides the necessary data on the situation of greenhouse gas concentrations and fluxes in Europe.

Contacts between ICOS and WMO are active at many levels. The Director of the ICOS Carbon Portal chairs the scientific advisory group for greenhouse gases of the WMO Global Atmosphere Watch Programme (GAW) and is a member of the executive steering group of the IG3IS initiated by the WMO. This allows a fertile interaction to constantly improve the ICOS data processing and the concepts used for data portals. IG3IS uses atmospheric observations and inverse modelling to provide information on the national emissions and subnational mitigation options. The system is an important monitoring tool for the Paris Agreement.

ICOS is a Participating Organization in the Group on Earth Observations (GEO), a network of over 100 member countries and 120 participating organisa-

Figure 12. The number of media articles mentioning ICOS in 2016–2023. The Nord Stream methane pipe explosion in September 2022 explains the abnormally high number of media articles in 2022.



tions that aims to promote the importance of comprehensive and sustained Earth observations and information for the political decision-making process. The GEO framework allows ICOS to share experiences and measurement protocols on data acquisition, and to increase the use of ICOS data and data products.

In Europe, ICOS actively cooperates with Copernicus, through different projects as well as directly to in regards to ICOS data. The data in the Copernicus service will be utilised, for example, by national weather services or private companies to improve air-pollution predictions and also to develop other data products based on ICOS data, such as maps of fossil-fuel emissions.

Finally, ICOS has a unifying impact at the governmental level by means of science diplomacy. An international collaboration such as ICOS brings to-gether not only scientists but also representatives of the research- and environment-related ministries who participate. The states from the European Union have successfully come together to make a joint observation facility and that should not be underestimated as getting people on the same page is very important and not trivial.

ICOS' impact on technology and innovation

In addition to the innovative ICOS data approach – using FAIR principles in environmental research data – ICOS also drives technical innovation. Scientists at ICOS create new instrumentation set-ups and are measuring greenhouse gases in novel places. The ICOS community comprise a crucial and large knowledge network, which collaborates with companies to improve the instruments.

The industrial partners have indicated in the Impact Assessment in 2018 that ICOS' high standards drive them to increase their product quality, induced by the testing and calibration conducted at ICOS sites as well as different meetings and events. Many also advertise their equipment as fulfilling the ICOS standards, itself being an evidence of the value of ICOS to the industry.

Examples of cooperation between the industry and ICOS can be found in all domains. The ATC metrology lab has built collaborations with industrial companies to test emerging technologies. The ETC and Carbon Portal cooperated with private companies in the development of a specific logger for the automatic data-submission process. The OTC has partnered with Saildrone, a private company to validate the ICOS ocean data from fixed ocean stations using a wind-powered, fully autonomous ocean drone. OTC is also engaging instrument suppliers to an intercomparison campaign to reach a high level of standardisation. Ongoing dialogue and competition between companies as well as manufacturers drives for production of even more accurate and improved sensors and measurement instruments. In this regard, ICOS' technological readiness and impact also rely on the research and innovation carried out in companies which produce the equipment, such as Picarro, LI-COR, Pro-Oceanus Systems and Vaisala.

It is worth emphasising that ICOS RI has become a coordinated and unified observation system covering most EU Member States. It makes ICOS a key partner for the European Commission, cooperating with WMO and IPCC in activities towards a Monitoring, Verification and Support system for recording anthropogenic emissions of GHGs on a global scale.
– ESFRI Evaluation of ICOS, 2023

6 HOW TO BECOME AN ICOS ERIC MEMBER OR OBSERVER

A country can be either a Member or an Observer of ICOS ERIC. Both pay an annual contribution and have different rights and obligations. The main difference is that Members can attend and vote at the General Assembly, while Observers can attend without a vote.

Member rights and obligations are listed in the ICOS ERIC statutes and are the same for all Members, whereas the rights and obligations of Observers are negotiated individually between the Observer and ICOS ERIC.

ICOS ERIC Members currently include Belgium, the Czech Republic, Denmark, Finland, France, Germany, Hungary, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland and the United Kingdom.

Requirements for becoming a Member or an Observer

Member States of the European Union, associated countries, countries other than associated countries and intergovernmental organisations may become Members or Observers. An additional requirement for membership is that the Member must contribute to the operation of ICOS ERIC and/or host an ICOS Central Facility and/or a National Network. Figure 13 summarises the process of becoming a Member or Observer.

Member and Observer applications

When a country or intergovernmental organisation is interested in joining ICOS ERIC as a Member or as an Observer, it should contact the Head Office of ICOS ERIC to further discuss its plans. ICOS will help the applicant by providing information and a contact person to assist with the preparation and application phases.

The applicant should as soon as possible, and at least six months before submitting its application, describe how it wishes to participate and how many and what kind of stations it is willing to bring to ICOS RI.

The applicant should name its national Focal Point, who will act as a contact person for ICOS and ensure the organisation of its national consortium.

The application should also include information on the representing entities and the name(s) of the applicant's representative(s) to the General Assembly. A Member is entitled to appoint up to three representatives, whereas an Observer is entitled to appoint one representative.

The applicant should also state which organisations will be its representing entities in accordance with the ICOS ERIC statutes, Article 3(5).

The admission of a new Member or an Observer requires the approval of the ICOS ERIC's

General Assembly. The applicant will be invited to join the General Assembly meeting. When approved, the Membership/Observership always starts at the beginning of the next financial year.

The application to become a **Member** should describe how the applicant will be involved in the ICOS RI and how it will participate in the realisation of the tasks and activities of ICOS ERIC according to the ICOS ERIC statutes, Article 2. It is especially important to list how many and what kind of stations the applicant is ready to bring to the ICOS RI. The application should also include a statement that the applicant fulfils the Membership obligations stated in the ICOS ERIC statutes, Article 6(2).

The application to become an **Observer** should describe how the applicant will be involved in the ICOS RI and whether it will participate in the realisation of the tasks and activities of ICOS ERIC according to the ICOS ERIC statutes, Article 2. It is especially important, if such is intended, to list how many and what kind of stations the applicant is ready to bring to the ICOS RI.

Figure 13. Steps towards ICOS membership.

Preparing phase

- The applicant contacts the ICOS Head Office.
- The Head Office provides the applicant with more information and contacts.
- Discussions between the applicant and ICOS: How you wish to participate and which stations to include.
- ICOS will calculate the membership costs and plan the integration of stations.
- The applicant is invited to participate in ICOS General Assembly meetings as a guest.

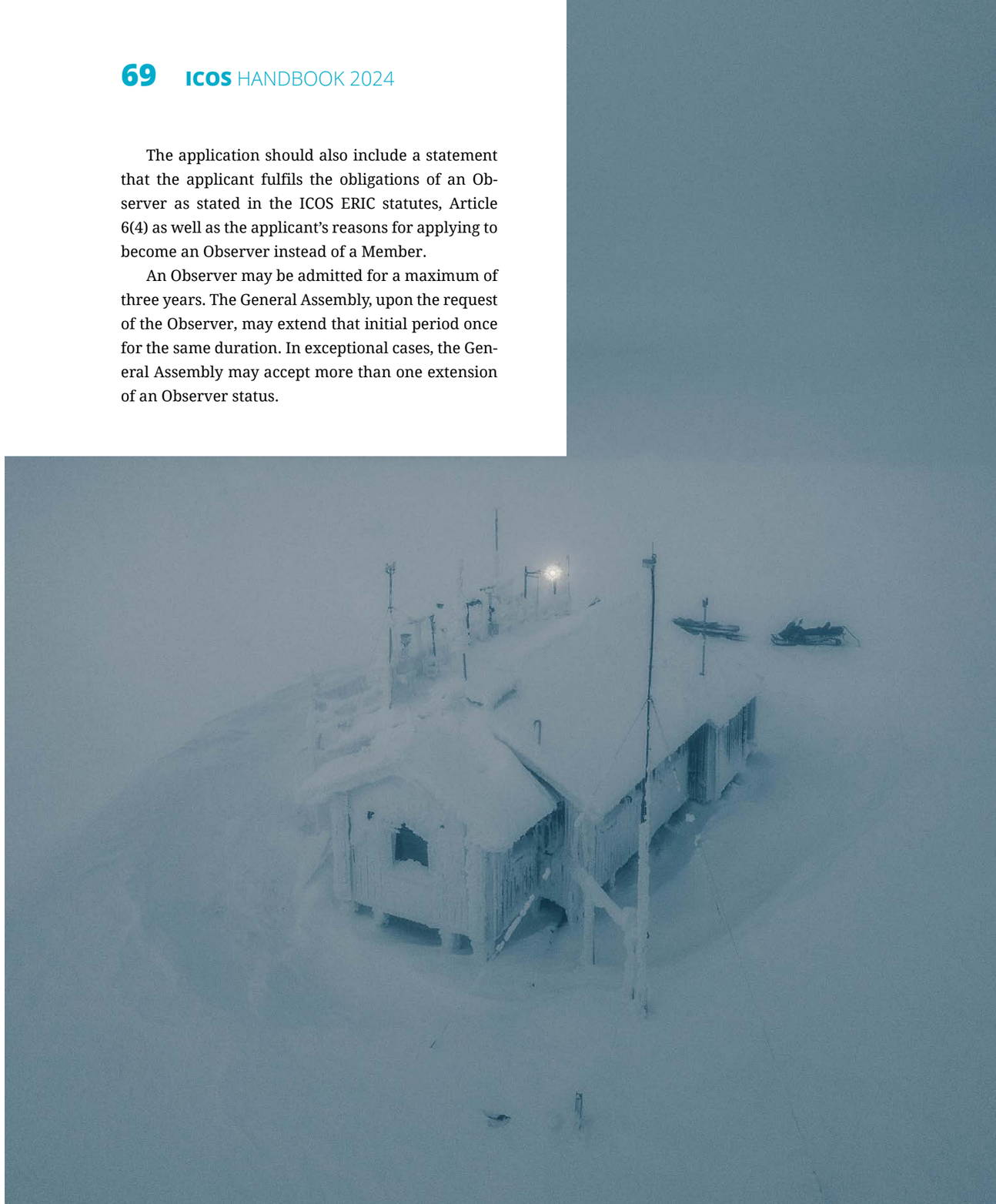
Application phase

- The country writes an application.
- The ICOS General Assembly approves the new Member country.
- The membership starts from the beginning of the next financial year.

Send to:
Director General / ICOS ERIC
Erik Palménin aukio 1
00560 Helsinki, Finland

The application should also include a statement that the applicant fulfils the obligations of an Observer as stated in the ICOS ERIC statutes, Article 6(4) as well as the applicant's reasons for applying to become an Observer instead of a Member.

An Observer may be admitted for a maximum of three years. The General Assembly, upon the request of the Observer, may extend that initial period once for the same duration. In exceptional cases, the General Assembly may accept more than one extension of an Observer status.



7 ICOS COUNTRIES: Cooperation for better data

The ICOS RI network consists of 179 (in 2024) measurement stations across sixteen countries in Europe. ICOS member countries include Belgium, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland and the United Kingdom. Together, these countries form a station network reaching all the way from the Arctic to the equator. All the stations produce high-quality data on greenhouse gases that are accessible by anyone through the ICOS Carbon Portal. A comprehensive standardised network guarantees that the data is precise and reliable, which is crucial both for high-quality research and for effectively mitigating climate change.

The number of stations varies between member countries from over thirty stations to fewer than five. The oldest operating stations have been collecting data for decades. However, all these stations were re-equipped to meet the high ICOS standards and some stations have been built from scratch for ICOS RI. Stations operate in three different domains: Atmosphere, Ecosystem and Ocean.

The Atmosphere, Ecosystem and Ocean networks include two classes of stations: Class 1 stations are equipped with complete equipment for measuring a full set of predetermined ICOS variables, and Class 2 stations are equipped for measuring a predefined subset of the ICOS variables. Importantly, the standardisation and quality of the data are at the same level in both station categories. In addition, the ICOS Ecosystem network is supplemented by a set of Associated stations in which the requirements, in terms of the variables examined and the standards followed, are different from the Class 1 and Class 2 stations.

Each National Network is managed and coordinated by a number of national research institutes. The number of partner organisations and the funding structures vary between member countries.

This chapter describes the ICOS member countries; that is, the National Networks, their role in the European network, the stations and how the operation is funded. The contact information for each National Network is provided, together with a comprehensive list of partners and funders.

The station network maps in the following pages are illustrations and rather simple snapshots of the network in 2024. For up-to-date and more detailed maps with adjustable layers, please visit www.icos-ri.eu.

ICOS Belgium

ICOS BELGIUM FOCAL POINT
Ivan Janssens
Professor
Plants and Ecosystems, PLECO
University of Antwerp, Belgium

contact-belgium@lists.icos-ri.eu
+32 3 265 50 51
www.icos-belgium.be

Simon Stevin: An Ocean station of ICOS Belgium

The role of ICOS Belgium

Belgium hosts 12 stations in total and is involved in all three observation networks. The University of Antwerp is hosting the Ecosystem Thematic Centre (ETC) together with INRAE (France) and CMCC (Italy). Despite Belgium's diverse landscape and high human density, the ICOS-BE network covers well the typical land-uses and economically important North Sea. The Belgian network also comprises two overseas stations located in the Democratic Republic of Congo and Réunion Island.

The forest sites of Brasschaat and Vielsam are two of the longest-running and most complete flux stations in the world. The two most recent cropland sites in Westmalle evaluate effects of farming techniques on carbon uptake. Thanks to its location near the Thornton wind farm, the Thornton buoy is one of the few fixed Ocean stations in the world that can rely on a Wi-Fi and mobile connection for data transmission. Maasmechelen is constructed in Belgium's first national park and is the first European heathland site where greenhouse gases are monitored. The station is closely linked to the Ecotron of Hasselt University (AnaEE), providing the necessary data to control the Ecotron's chamber environment. In a similar way, the Lonzée station located in a cropland is closely linked to the AneEE Ecotron of the University of Liège. The Belgian network further contributes to carbon observations in Africa through the Yangambi station. This state-of-the-art tower is the first one to record flux measurements in Central Africa.

The Belgian stations have strong links with other international research infrastructures. The research vessel Simon Stevin is also used in LifeWatch, Brasschaat and Maasmechelen are proposed as eLTER master sites, and Vielsalm and the Atmosphere station Maido observatory are proposed as co-located ICOS-ACTRIS supersites. The Observatoire de l'Atmosphère du Maïdo at Réunion Island is also contributing to the global Total Carbon Column Observing Network (TCCON).

The ICOS Belgium Infrastructure

The current ICOS Belgium network (Figures 14a, b) consists of 12 observation stations (Table 11) operated by seven different research institutes. The University of Antwerp acts as the national Focal Point, representing and coordinating the Belgian network. The University of Antwerp is also co-hosting the Ecosystem Thematic Centre, and is particularly responsible for the collection and processing of ancillary data, one of the three pillars of the ETC.

The Ecosystem network consists of four agricultural sites (Dorinne, Lonzée and two Westmalle stations), two forest sites (Brasschaat and Vielsalm) and one heathland site (Maasmechelen). An eighth Ecosystem station (Yangambi) is located in the Congo Basin, and jointly operated by Ghent University and INERA (Institut National pour l'Etude et de la Rercher Agronomique) since 2021. Located in the UNESCO Man and Biosphere reserve in Yangambi, the station will contribute to the understanding of the global carbon cycle in undersampled and critical zones. The two cropland stations in Westmalle, constructed in 2023, are the most recent addition to the Belgian network. Both sites will be proposed as ICOS Associated stations and will be the very first flux stations evaluating the effects of carbon farming techniques.

The Ocean network consists of the RV Belgica, a multidisciplinary oceanographic research vessel the RV Simon Stevin, a research vessel deployed for coastal oceanographic research in the Southern Bight of the North Sea and the eastern part of the English Channel, and the Thornton buoy, located in the Thorntonbank wind turbine farm.

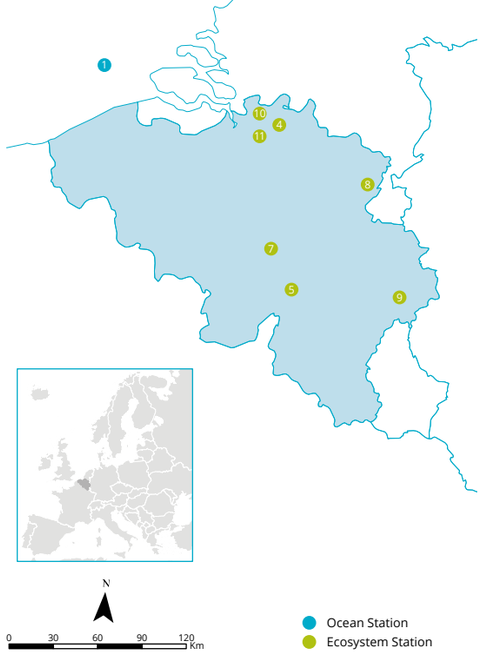
The Atmosphere station at Ile de La Réunion is a Belgian-French collaboration (between BIRA and the French partners of LSCE and the Université de La Réunion) performing background measurements

of greenhouse gases in the Indian Ocean. The Observatoire de l'Atmosphère du Maïdo consists of two observational stations: one close to sea level and one at about 2,100 m above sea level.

The ICOS Belgium Funding Structure

The current ICOS Belgium Consortium involves two Walloon, three Flemish and two Federal institutes. Each institute is funded by its respective government. The Federal government represented by the Belgian Science Policy Office (BELSPO) carries the cost of membership and station fees.

Figure 14a



Until 2023, no structural funding existed for the involvement of the Flemish partners in ICOS, but a yearly subsidy was provided since 2012. Since 2018, the Research Foundation – Flanders (FWO) has launched a call every two years for structural funding for international research infrastructures. The Flemish partners have successfully secured a four year (2021–2024) funding in the 2020 FWO call. Equipment, logistic and governance support for the Yangambi station is provided by the Belgian Federal Public Service Foreign Affairs, Foreign Trade and Development Cooperation, MD8: Environment and Climate.

The Walloon partners received funding in 2013 from the Service Public de Wallonie to finance three Ecosystem stations. The project, called ICOS Wallonia-Brussels, lasted eight years. By a decision of the Walloon Minister of Economy, Research and Innovation and Agriculture in October 2020, the Walloon partners of the ICOS Belgium Consortium (ICOS-WB) received funding for five years for Phase 2 of the ICOS-WB infrastructure project, which started in July 2021.

BIRA has received financial support from BELSPO through the ministerial decree for ICOS for a period of 6 years since December 2014 for running the Observatoire de l'Atmosphère du Maïdo at Réunion Island. The RV Belgica, operated by RBINS-OD Nature, is funded by BELSPO via yearly renewed grants. The federal partners received an extension of the actual financial support until the end of November 2021. They were successful in winning a project, "ICOS-BE" that started in December 2021 and will last for four years, submitted to BELSPO in a competitive call in the frame of the ESFRI-FED research infrastructure.

Figure 14: The ICOS Belgium station network. Figure 14a primarily covers Ecosystem and Ocean station around mainland Belgium, Figure 14b shows the area covered by the SOOP line, while Figure 14c shows the Atmosphere station that is located at Réunion Island in the Indian Ocean and the Yangambi Ecosystem station located in the Congo basin. The numbers in the maps correspond to the numbers in Table 11.

Figure 14b

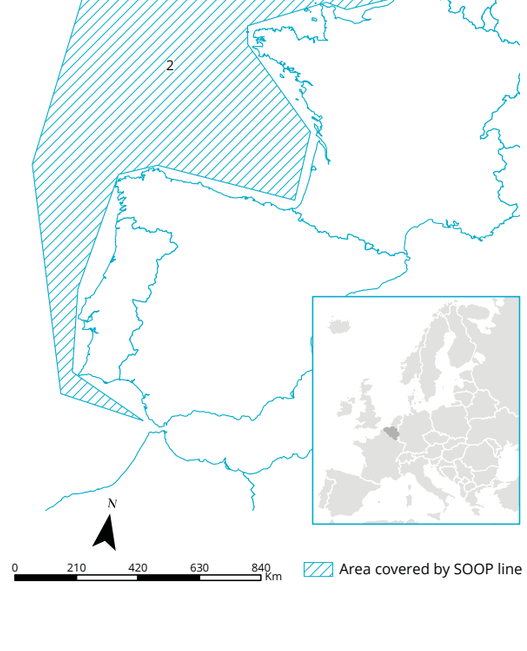
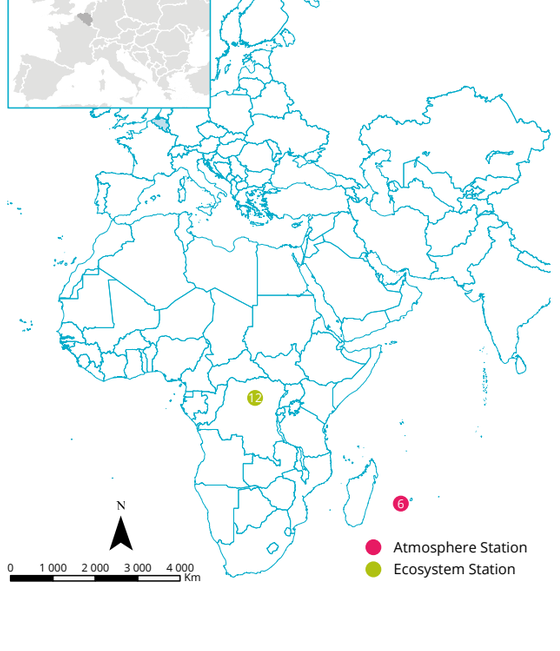


Figure 14c



ICOS BELGIUM PARTNERS AND FUNDERS

Belgian Science Policy Office (BELSPO)
www.belspo.be/belspo

Flanders Marine Institute (VLIZ)
www.vliz.be/en

Research Foundation – Flanders (FWO)
www.fwo.be/en

Royal Belgian Institute for Space Aeronomy (BIRA-IASB)
www.aeronomie.be/en

Royal Belgian Institute of Natural Sciences (RBINS)
www.naturalsciences.be

Service Public de Wallonie (SPW)
spw.wallonie.be

University of Antwerp (UAntwerpen)
www.uantwerpen.be/en

Université catholique de Louvain (UCLouvain)
uclouvain.be

University of Liège (ULiège)
www.uliege.bea

Ghent University (UGent)
www.ugent.be

Table 11. ICOS Stations in Belgium

MAP NUMBER	STATION NAME	STATION ABBREVIATION	STATION TYPE	SITE TYPE	STATION CLASS	HOST INSTITUTE	LABELING DATE
1	BE-FOS-Thornton Buoy	1199	Ocean Station	Buoy in the North Sea	Class 1	Flanders Marine Institute	30.11.2018
2	BE-SOOP-Belgica	11BE	Ocean Station	Ship of Opportunity in the North Sea	Class 1	Royal Belgian Institute of Natural Sciences	
3	BE-SOOP-Simon-Stevin	11SS	Ocean Station	Ship of Opportunity in the North Sea	Class 1	Flanders Marine Institute	25.5.2021
4	Brasschaat	BE-Bra	Ecosystem Station	Coniferous forest	Class 1	University of Antwerp	17.11.2020
5	Dorinne	BE-Dor	Ecosystem Station	Grassland	Class 2	University of Liege	23.11.2022
6	La Réunion	RUN	Atmosphere Station	Mountain	Class 2	Royal Belgian Institute for Space Aeronomy	21.11.2019
7	Lonzée	BE-Lon	Ecosystem Station	Cropland	Class 2	University of Liege	17.11.2017
8	Maasmechelen	BE-Maa	Ecosystem Station	Heathland	Class 2	University of Antwerp	27.5.2020
9	Vielsalm	BE-Vie	Ecosystem Station	Mixed forest	Class 2	UCLouvain	17.11.2020
10	Westmalle1	BE-Wm1	Ecosystem Station	Cropland	Associated	University of Antwerp	
11	Westmalle2	BE-Wm2	Ecosystem Station	Cropland	Associated	University of Antwerp	
12	Yangambi	CD-Ygb	Ecosystem Station	Tropical forest	Associated	Ghent University	23.11.2022

ICOS Czech Republic

ICOS CZECH REPUBLIC FOCAL POINT

Jiří Kolman

Scientific Secretary of CzechGlobe

Czech Republic

contact-cz@list.icos-ri.eu

+420 511 192 299

www.icos-infrastructure.cz/english

Lanžhot: an Ecosystem station of ICOS Czech Republic

The role of ICOS Czech Republic

The main goal of the ICOS Czech Republic, which operates within the national research CzeCOS (Czech Carbon Observation System) infrastructure, conducts long-term research on the greenhouse gases and carbon cycles in the atmosphere and the main Czech ecosystem types. Combining measurements of the atmosphere and ecosystems, the infrastructure enables the effects of land use, climate variability and changes in the territory of the Czech Republic to be determined.

Apart from ICOS infrastructure itself, CzeCOS operates supportive complementary infrastructure, such as an aircraft laboratory providing remote sensing instruments and ecosystem experimental sites that are used in conjunction with ICOS infrastructure (e.g. multifactorial experiments in ecosystems and remote sensing research methods).

Thanks to its experience of multi-source funding, especially using EU structural funds, ICOS Czech Republic's CzechGlobe institution can serve as a model institution for ICOS candidate countries that are constructing ICOS infrastructure.

The ICOS Czech Republic infrastructure

ICOS Czech Republic is hosted and operated by a single institution: CzechGlobe – Global Change Research Institute of the Czech Academy of Sciences. The Czech ICOS stations are included in the national CzeCOS project. The Czech ICOS comprises one Atmosphere station and three Ecosystem stations (Figure 15; Table 12), and represents different ecosystem types: floodplain forest, evergreen needle leaf forest and a wetland to represent a mosaic of ecosystem types in the Czech Republic.

The Atmosphere station Křešín u Pacova is situated in the middle of the Czech Republic. It has been in operation since 2013 and it serves as a national monitoring point for both the occurrence and remote transmission of greenhouse gases, selected pollutants and basic meteorological characteristics. The station consists of a 250-metre-high meteorological research mast, at the various height levels of which atmospheric concentrations of greenhouse gases (CO_2, CH_4, CO, N_2O, SF_6), pollutants (tropospheric ozone, gaseous mercury and aerosols) as well as basic meteorological characteristics (air temperature, pressure and humidity, wind speed and direction) and the height of the atmosphere boundary layer are monitored.

The ICOS Czech Republic funding structure

The ICOS Czech Republic is part of the Czech national research infrastructure road map, which is managed by the Ministry of Education, Youth and Sports of the Czech Republic. It also provides the main funding for the operational costs of the ICOS Czech Republic infrastructure. The construction of the research infrastructure was made possible by EU structural funding for the Czech Republic in 2011–2014.

ICOS CZECH REPUBLIC PARTNERS AND FUNDERS

Global Change Research Institute of the Czech Academy of Sciences
www.czechglobe.cz/en

Ministry of Education, Youth and Sports
www.msmt.cz

Figure 15: The ICOS Czech Republic station network. The numbers in the map correspond to the numbers in Table 12.

Table 12. ICOS Stations in the Czech Republic

MAP NUMBER	STATION NAME	STATION ABBREVI-ATION	STATION TYPE	SITE TYPE	STATION CLASS	HOST INSTITUTE	LABELING DATE
1	Bílý Kříž forest	CZ-BK1	Ecosystem Station	Forest	Class 2	CzechGlobe	18.5.2022
2	Křešín u Pacova	KRE	Atmosphere Station	Tall tower	Class 1	CzechGlobe	31.5.2018
3	Lanžhot	CZ-Lnz	Ecosystem Station	Forest	Class 1	CzechGlobe	18.5.2022
4	Třeboň	CZ-wet	Ecosystem Station	Wetland	Associated	CzechGlobe	25.5.2021

ICOS Denmark

ICOS DENMARK FOCAL POINT
Thomas Friborg
Professor
University of Copenhagen
Denmark
contact-denmark@lists.icos-ri.eu
+45 3532 2574
www.icos-denmark.dk

Zackenberg Fen: an Ecosystem station of ICOS Denmark

The role of ICOS Denmark

The role of ICOS Denmark is to contribute to the ICOS RI with stations in the characteristic ecosystems of Denmark and Greenland. In addition, ICOS Denmark runs an Atmosphere station at the north-eastern tip of Greenland. The Greenlandic stations make an important arctic contribution to ICOS RI. If funding can be obtained, ICOS Denmark would like to include an Atmosphere station on the Danish west coast and contribute to the Ocean network, especially in the arctic seas.

The Ecosystem stations of the Danish network all had multi-year data records before entering the ICOS RI. Furthermore, the universities running the stations all have long experience of measuring the concentration and fluxes of greenhouse gases.

The ICOS Denmark Infrastructure

The ICOS National Network of Denmark (ICOS-DK) is a consortium of four universities: the University of Aarhus (AU), the University of Copenhagen (KU) and the Technical University of Denmark (DTU). KU acts as the national Focal Point, representing and coordinating the Danish network of ICOS partners.

ICOS Denmark contributes to two ICOS observation domains: Atmosphere and Ecosystem. The ICOS Denmark network consists of seven stations (Figures 16a, b; Table 13), of which one is an Atmosphere station and six are Ecosystem stations. The network includes stations officially labelled by ICOS according to the three classes: Class 1, Class 2 and Associated. Four of the stations are in typical ecosystems in Greenland, and one is an Atmosphere station in Greenland at a location that frequently encounters air masses from Europe and Siberia.

The stations on the Danish mainland cover typical beech forest and energy crop ecosystems. Each station performs a set of measurements according to common specifications and under the control of the Thematic Centre concerned. This ensures the standardisation of measurements, their interoperability and the relevance of the ICOS network as a whole.

The ICOS Denmark funding structure

The financing of the operation depends on support from the technical university of Denmark (DTU). Additional funding for the logistics of the stations in Greenland is obtained from the Danish Ministry of Energy, Utilities and Climate and from private foundations.

ICOS DENMARK PARTNERS AND FUNDERS

Aarhus University
www.international.au.dk

Danish Ministry of Climate, Energy and Utilities
en.kefm.dk

Technical University of Denmark
www.dtu.dk/english

University of Copenhagen
www.ku.dk/english

Figure 16: The ICOS Denmark station network. Figure 16a shows Ecosystem stations located in mainland Denmark, while Figure 16b depicts both Atmosphere and Ecosystem stations situated in Greenland. The numbers in the maps correspond to the numbers in Table 13.

Figure 16a

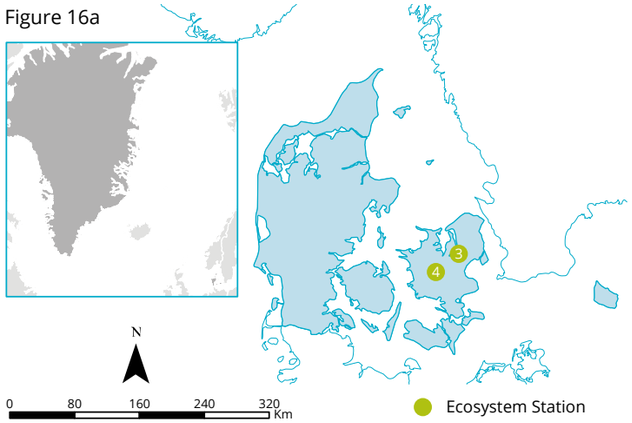


Figure 16b

Table 13. ICOS Stations in Denmark

MAP NUMBER	STATION NAME	STATION ABBREVIATION	STATION TYPE	SITE TYPE	STATION CLASS	HOST INSTITUTE	LABELING DATE
1	Disko	GL-Dsk	Ecosystem Station	Heathland	Associated	University of Copenhagen	25.5.2021
2	Nuuk Fen	GL-NuF	Ecosystem Station	Mire	Associated	University of Copenhagen	17.11.2021
3	Risoe	DK-RCW	Ecosystem Station	Forest	Associated	Technical University of Denmark	
4	Soroe	DK-Sor	Ecosystem Station	Deciduous forest	Class 1	Technical University of Denmark	17.11.2021
5	Station Nord	SNO	Atmosphere Station	High arctic, dry and cold	Class 2	Aarhus University	25.5.2021
6	Zackenberg Fen	GL-ZaF	Ecosystem Station	Wetland	Class 2	Aarhus University	23.11.2022
7	Zackenberg Gras	GL-ZaH	Ecosystem Station	Grassland	Associated	Aarhus University	23.11.2022

ICOS Finland

ICOS FINLAND FOCAL POINT

Annalea Lohila

Professor

Institute for Atmospheric and Earth System Research (INAR), University of Helsinki and Finnish Meteorological Institute

Finland

contact-finland@lists.icos-ri.eu

+358 50 366 32 42

www.icos-finland.fi

Pallas Sammaltunturi: an Atmosphere station of ICOS Finland

The role of ICOS Finland

ICOS Finland stations provide ICOS RI with useful representation of boreal and subarctic Eurasian environments in a transition zone from a marine to a continental climate. The Finnish network produces data on sinks and sources of greenhouse gases in typical boreal and subarctic ecosystems, focusing on coniferous forests and peatlands but also including the unique sites of lake, urban, agricultural and Baltic environments. Finland hosts 18 stations and is involved in all three domains (Atmosphere, Ecosystem, Ocean). Five of the stations are located north of the Arctic Circle, providing valuable information on the impacts of fast proceeding warming on subarctic ecosystems, particularly peatlands with high carbon storage.

The Atmosphere station network covers a latitudinal gradient from 60°N (Utö) to 68°N (Pallas). All four Atmosphere stations, except one (urban Pujo SMEAR IV station) are in remote locations. The twelve Ecosystem stations (two of Class 1, three of Class 2, and seven Associated) cover varying land-cover types: unmanaged and managed forests, pristine and forestry-drained peatlands, agricultural field, and lake. One of the very few urban Ecosystem stations in whole ICOS (Kumpula/SMEAR III station in Helsinki) is part of the Finnish network. Finland contributes to the Ocean domain of ICOS with two Ocean stations, Tvärminne FOS, which is also an Ecosystem associate station, producing CO_2 and CH_4 flux data on Baltic coast, and Silja Serenade SOOP Line which is travelling between Helsinki and Stockholm.

The ICOS Finland infrastructure

ICOS Finland network consists of 18 stations operated by five institutes. University of Helsinki (UHEL) acts as a national focal point and coordinates the national network. The two other long-term partners are the Finnish Meteorological Institute (FMI) and the University of Eastern Finland (UEF), and the network has recently been expanded by two new institutes, the University of Oulu (UO) and the Natural Resources Institute Finland (Luke). ICOS Finland station network consists of four Atmosphere stations, two Ocean stations (SOOP and FOS), and twelve Ecosystem stations, one of which is co-located with the coastal FOS site.

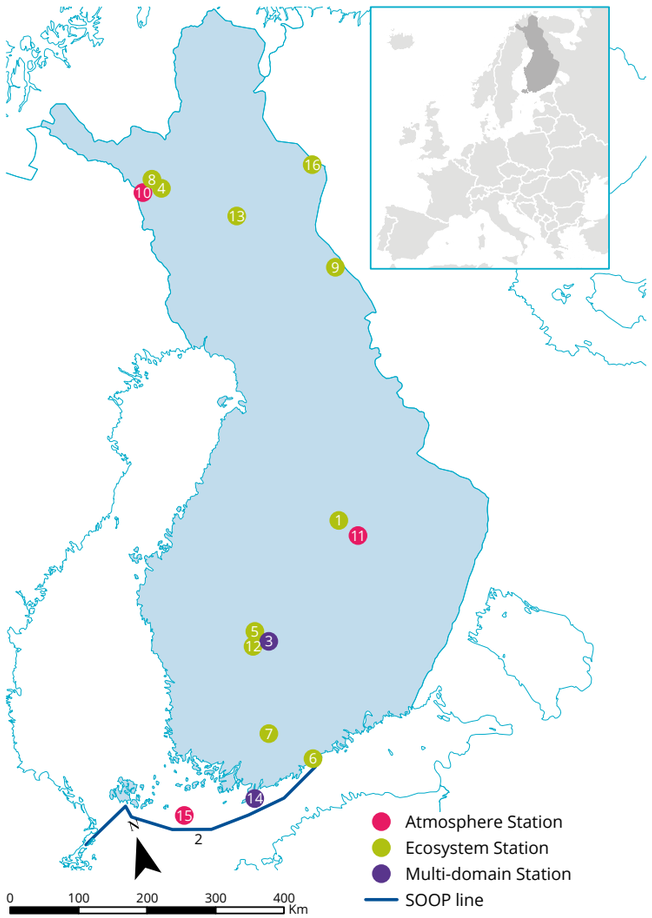
Seven of the stations belong to the SMEAR (flagship site of the Stations for Measuring Earth Surface–Atmosphere Relations) network run by UHEL and UEF. The CO_2 and CH_4 flux data from the SMEAR II forest and peatland sites Hyytiälä and Siikaneva are among the longest-running and most utilised in the biogeochemistry research community. Four stations operated by FMI are part of the Pallas-Sodankylä Atmosphere-Ecosystem supersite, one of these (Pallas) also belonging to the Global Atmosphere Watch (GAW) of the WMO. The agricultural site (Anttila) of ICOS Finland measures atmosphere-ecosystem CO_2, CH_4 and N_2O exchange on grass-crop rotation on a mineral soil.

The Finnish Meteorological Institute is hosting the ICOS Mobile Laboratory, a subunit of the ICOS RI Atmosphere Thematic Centre. The main task of the MobileLab is to conduct quality control by parallel greenhouse gas measurements at Atmosphere stations. Its aim is to improve measurement compatibility and development of quality assurance of the Atmosphere station network that ensures credibility of the measurements. The ICOS RI's head office is in Finland, in Helsinki, in the same building with the FMI.

The ICOS Finland funding structure

The ICOS Finland network is funded by the Ministry of Education and Culture (through the Academy of Finland), Ministry of Transport and Communication and Ministry of Agriculture and Forestry. Further funding is provided in-kind by the member institutions.

Figure 17: The ICOS Finland station network. The numbers in the map correspond to the numbers in Table 14. The multi-domain station number 3 (Hyytiälä) includes atmosphere and ecosystem observations, while the multi-domain station number 14 (Tvärminne) consists of ocean and ecosystem observations.



ICOS FINLAND PARTNERS AND FUNDERS

Research Council of Finland
www.aka.fi/en

Finnish Meteorological Institute (FMI)
en.ilmatieteenlaitos.fi

Natural Resources Institute Finland
luke.fi/en

Ministry of Agriculture and Forestry
mmm.fi/en

Ministry of Education and Culture
www.minedu.fi/en/front-page

Ministry of Transport and Communications
www.lvm.fi/en/home

University of Eastern Finland (UEF)
www.uef.fi/en

University of Helsinki (UHEL)
www.helsinki.fi/en

University of Oulu
oulu.fi/en

Table 14. ICOS Stations in Finland

MAP NUMBER	STATION NAME	STATION ABBREVIATION	STATION TYPE	SITE TYPE	STATION CLASS	HOST INSTITUTE	LABELING DATE
1	Anttila	FI-Ant	Ecosystem Station	Cropland	Class 2	Natural Resources Institute Finland	
2	FI-SOOP-Silja Serenade	FI-SER	Ocean Station	Ship of Opportunity in Baltic Sea	Class 2	Finnish Meteorological Institute	
3	Hyytiälä/SMEAR II	SMR	Atmosphere Station	Tall tower / forest	Class 1	University of Helsinki	17.11.2017
3	Hyytiälä/SMEAR II	FI-Hyy	Ecosystem Station	Southern boreal pine forest	Class 1	University of Helsinki	30.11.2018
4	Kenttärova	FI-Ken	Ecosystem Station	Northern boreal pine forest	Associated	Finnish Meteorological Institute	25.5.2021
5	Kuivajärvi/ SMEAR II	FI-Kvr	Ecosystem Station	Boreal lake	Associated	University of Helsinki	27.5.2020
6	Kumpula/SMEAR III	FI-Kmp	Ecosystem Station	Urban environment	Associated	University of Helsinki	21.11.2019
7	Lettosuo	FI-Let	Ecosystem Station	Drained peatland forest	Associated	Finnish Meteorological Institute	30.11.2018
8	Lompolojänkkä	FI-Lom	Ecosystem Station	Permanent wetland	Class 2	Finnish Meteorological Institute	
9	Oulanka	FI-Ouk	Ecosystem Station	Permanent wetland	Associated	University of Oulu	
10	Pallas	PAL	Atmosphere Station	Subarctic hill	Class 1	Finnish Meteorological Institute	30.11.2018
11	Puijo/SMEAR IV	PUI	Atmosphere Station	Tall tower / urban	Class 2	Finnish Meteorological Institute and University of Eastern Finland	25.5.2021
12	Siikaneva/SMEAR II	FI-Sii	Ecosystem Station	Permanent wetland	Class 2	Finnish Meteorological Institute and University of Eastern Finland	17.11.2017
13	Sodankylä	FI-Sod	Ecosystem Station	Nothern boreal pine forest	Class 1	Finnish Meteorological Institute	23.5.2023
14	Tvärminne	FI-Tvm	Ecosystem Station	Coastal	Associated	University of Helsinki	15.11.2023
14	FI-FOS-Tvärminne	FI-TVA	Ocean Station	FOS	Class 2	University of Helsinki	
15	Utö - Baltic sea	UTO	Atmosphere Station	Non-forested island in Baltic Sea	Class 2	Finnish Meteorological Institute	22.5.2019
16	Värriö/SMEAR I	FI-Var	Ecosystem Station	Subarctic pine forest	Associated	University of Helsinki	30.11.2018

ICOS France

ICOS FRANCE FOCAL POINT

Leonard Rivier

French Alternative Energies and Atomic Energy Commission, CEA

France

contact-france@lists.icos-ri.eu

+33 678 197 399

www.icos-france.fr

Grignon: An Ecosystem station of ICOS France

The role of ICOS France

Within ICOS RI, the French network aims to provide the data flow required for quantifying and understanding the exchange of greenhouse gases between the continental surface, atmosphere and superficial ocean waters. The country network of stations covers the main land use types (crops, grasslands, temperate and tropical forests, and peatlands) and spans over temperate, alpine, Mediterranean and tropical climates.

The ICOS France network includes a range of management practices from annual crops to grazed or mowed meadows, fast growing pine forest plantations to managed broadleaved forests, peatland and unmanaged pristine forests. Innovative measurement methods and techniques are developed and tested at ICOS French stations; for example, the total carbon column with Fourier transform spectrometers, atmospheric profiles of greenhouse gases by AirCore, N_2O, CH_4, NHy, NOx and ozone flux measurements, and ultra-light spectrometers on drones. The Ocean network includes a merchant ship, sailing from France to Brazil, crossing different ocean biogeochemical provinces and measuring the surface fugacity of CO_2 during the journey by infrared detection.

ICOS France manages the Atmosphere Thematic Centre (ATC) located at Saclay and a part of the Ecosystem Thematic Centre (ETC) at the French National Research Institute for Agriculture, Food, and Environment (INRAE).

ICOS France infrastructure

The French ICOS consortium includes the main national research partners concerned with the carbon and greenhouse gas cycles: the National Radioactive Waste Management Agency (ANDRA), the Alternative Energies and Atomic Energy Commission (CEA), the National Centre for Scientific Research (CNRS-INEE and INSU), the French National Research Institute for Agriculture, Food, and Environment (INRAE), the University of Versailles-Saint-Quentin-en-Yvelines (UVSQ), among others. The partners are involved in international research programmes on climatology, environment, ecology, oceanography, agronomy, and forestry, among them the IPCC, the Global Carbon Project, Fluxnet.

The ICOS France network encompasses three ICOS observation domains: Atmosphere, Ecosystem and Ocean. The French network consists of 23 stations (Figures 18 a, b, c, d.) of which five are Atmosphere stations, 17 are Ecosystem stations and one is an Ocean station (SOOP). Each station performs a set of measurements according to common specifications and under the control of the corresponding Thematic Centre. Class 1 and 2 stations form the main framework of the infrastructure and are committed for a period of 20 years.

In addition to the stations, France hosts the Atmosphere Thematic Centre at Saclay (CEA-CNRS-UVSQ) and co-shares the Ecosystem Thematic Centre (INRAE) in coordination with Italy (CMCC) and the University of Antwerp. Furthermore, France is in charge of the ICOS plant and soil analysis laboratories in Bordeaux and Arras, respectively, and the European Soil Conservatory in Orléans.

The ICOS France funding structure

The ICOS France network is mainly funded by voluntary contributions from the host institutions: the National Radioactive Waste Management Agency, the Alternative Energies and Atomic Energy Commission, the National Centre for Scientific Research, the National Research Institute for Agriculture, Food, and Environment and the University of Versailles-Saint-Quentin-en-Yvelines.

Altogether, the host institutions employ 90 permanent staff devoted to the station network, and Thematic Centres employ a manpower equivalent of 12 full-time employees. They also support the stations with funds covering equipment, consumables, travel and other expenses. The French station network receives additional grants directly from the Ministry of Research and Higher Education for either Research-Observation networks or the Future Investment Plan (PIA) from regional fundings, and from the national (French) ANR for international research projects.

Figure 18a

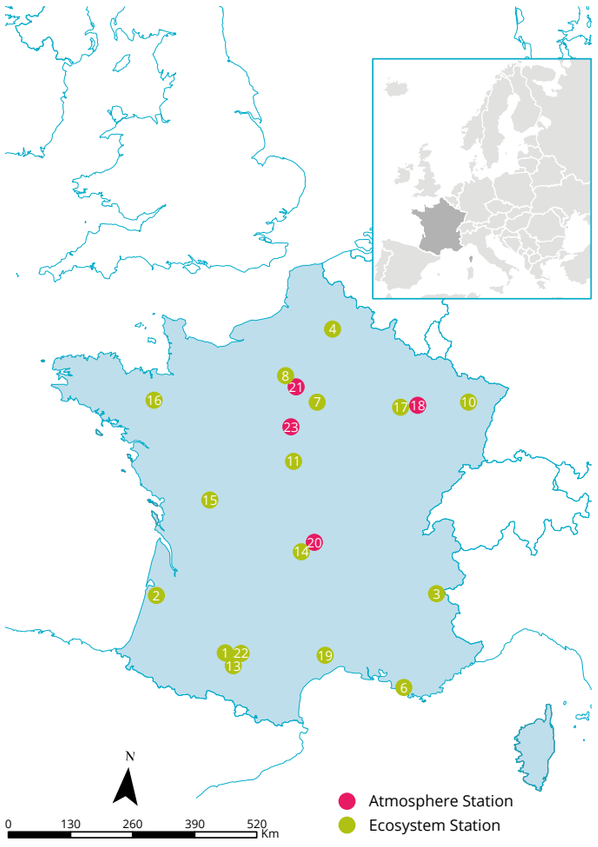


Figure 18: The ICOS France station network. Figure 18a shows stations located in mainland France, Figure 18b depicts Ecosystem stations in French Guiana, and Figure 18c shows the trajectory of the France-Brazil SOOP route. Figure 18d shows the Franco-Belgian Atmosphere station in La Réunion. The numbers in the maps correspond to the numbers in Table 15.

Figure 18b

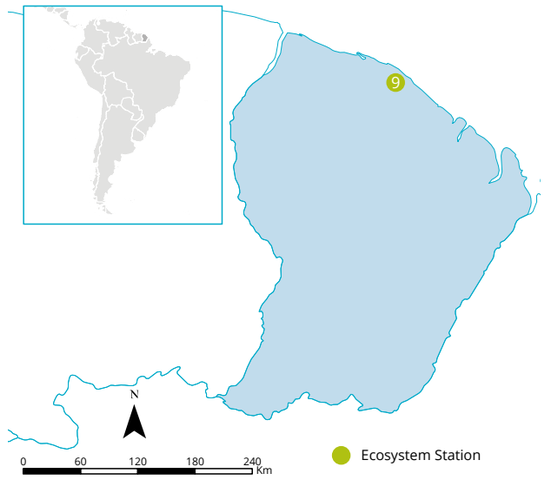
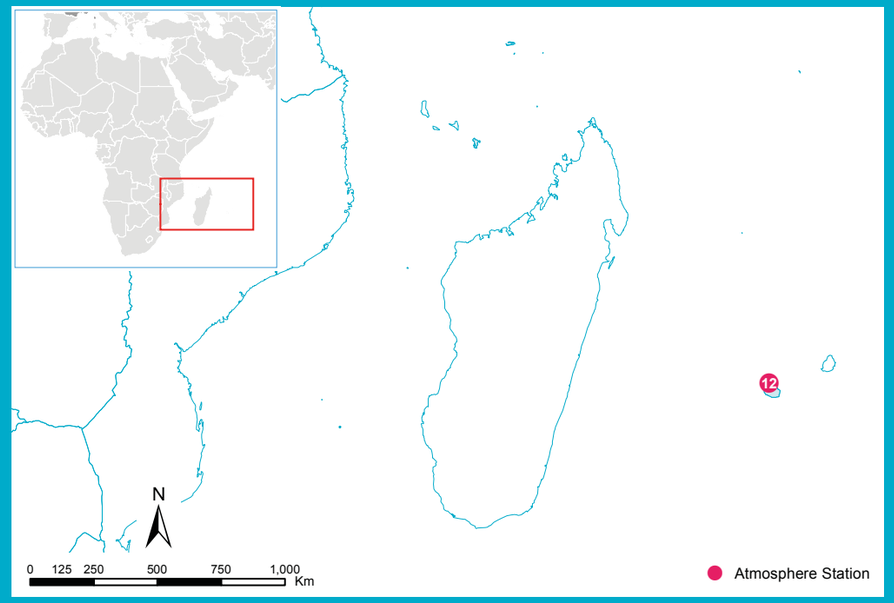


Figure 18c

Figure 18d



ICOS FRANCE PARTNERS AND FUNDERS

Ministry of Higher Education, Research and Innovation
www.enseignementsup-recherche.gouv.fr

The National Centre for Scientific Research (CNRS; INSU and INEE)
www.cnrs.fr

French National Research Institute for Agriculture, Food, and Environment (INRAE)
www.inrae.fr/en

French Alternative Energies and Atomic Energy Commission (CEA)
www.cea.fr/english

French National Radioactive Waste Management Agency (ANDRA)
www.andra.fr

University of Versailles-Saint-Quentin-en-Yvelines (UVSQ)
www.uvsq.fr

Agro-ParisTech – Paris Institute of Technology for Life, Food and Environmental Sciences
www2.agroparistech.fr

Aix-Marseille University
www.univ-amu.fr/fr

Bordeaux-Sciences-Agro
www.agro-bordeaux.fr

French Geological Survey (BRGM)
www.brgm.eu

French Meteorological Institute
www.meteofrance.com

French National Museum of Natural History
www.mnhn.fr

French Polar Institute (IPEV)
www.institut-polaire.fr/language/en

French Research Institute for Development (IRD)
www.en.ird.fr

French Space Agency (CNES)
www.cnes.fr/en

Montpellier SupAgro, International Centre for Higher Education in Agricultural Sciences
www.montpellier-supagro.fr

National University of Ireland, Galway (Ireland)
www.nuigalway.ie

University of Abidjan (Côte d'Ivoire)
www.uniabidjan.com

University of Avignon
www.univ-avignon.fr

University of Clermont-Ferrand
www.en.uca.fr

University of Crete, Heraklion (Greece)
www.en.uoc.gr

University of French West Indies and Guiana
www.univ-ag.fr

University of Grenoble-Alpes
www.univ-grenoble-alpes.fr

University of La Paz, Bolivia

University of La Réunion Island
www.univ-reunion.fr

University of Lorraine
welcome.univ-lorraine.fr

University of Montpellier
www.umontpellier.fr

University of Orléans
www.univ-orleans.fr/en/international

University Paris-Saclay
www.universite-paris-saclay.fr/en

University Paul Sabatier, Toulouse
www.univ-tlse3.fr

University Paul Valéry of Montpellier III
www.univ-montp3.fr

University of Reims Champagne-Ardenne
www.univ-reims.eu

University Sorbonne, Paris
www.lettres.sorbonne-universite.fr

Table 15. ICOS stations in France

MAP NUMBER	STATION NAME	STATION ABBREVIATION	STATION TYPE	SITE TYPE	STATION CLASS	HOST INSTITUTE	LABELING DATE
1	Auradé	FR-Aur	Ecosystem Station	Cropland	Associated	The National Centre for Scientific Research	27.5.2020
2	Bilos - Salles	FR-Bil	Ecosystem Station	Forest	Class 2	French National Research Institute for Agriculture, Food, and Environment	21.11.2019
3	Col du Lautaret	FR-CLt	Ecosystem Station	Grassland	Associated	The National Centre for Scientific Research	23.5.2023
4	Estrées-Mons	FR-EM2	Ecosystem Station	Cropland	Associated	French National Research Institute for Agriculture, Food, and Environment	30.11.2018
5	FR-SOOP-France-Brazil	65DK	Ocean Station	SOOP	Class 1	CNRS-IRD-U. Paris-Sorbonne	31.5.2018
6	Font-Blanche	FR-FBn	Ecosystem Station	Forest	Class 2	French National Research Institute for Agriculture, Food, and Environment	23.11.2022
7	Fontainebleau-Barbeau	FR-Fon	Ecosystem Station	Forest	Class 1	The National Centre for Scientific Research	21.11.2019
8	Grignon	FR-Gri	Ecosystem Station	Cropland	Class 2	French National Research Institute for Agriculture, Food, and Environment	17.11.2021
9	Guyaflux	GF-Guy	Ecosystem Station	Forest	Associated	French National Research Institute for Agriculture, Food, and Environment	21.11.2019
10	Hesse	FR-Hes	Ecosystem Station	Forest	Class 1	French National Research Institute for Agriculture, Food, and Environment	18.5.2022
11	La Guette	FR-LGt	Ecosystem Station	Peatland	Associated	The National Centre for Scientific Research	21.11.2019

Table 15. ICOS stations in France

MAP NUMBER	STATION NAME	STATION ABBREVIATION	STATION TYPE	SITE TYPE	STATION CLASS	HOST INSTITUTE	LABELING DATE
12	La Réunion	RUN	Atmosphere Station	Tall tower	Class 2	University of La Réunion	21.11.2019
13	Lamasquère	FR-Lam	Ecosystem Station	Cropland	Class 1	The National Centre for Scientific Research	17.11.2020
14	Laqueuille	FR-Lqu	Ecosystem Station	Grassland	Class 2	French National Research Institute for Agriculture, Food, and Environment	23.11.2022
15	Lusignan	FR-Lus	Ecosystem Station	Grassland	Class 2	French National Research Institute for Agriculture, Food, and Environment	23.11.2022
16	Méjusseaume	FR-Mej	Ecosystem Station	Grassland	Associated	French National Research Institute for Agriculture, Food, and Environment	17.11.2020
17	Montiers sur Saulx	FR-MsS	Ecosystem Station	Forest	Associated	French National Radioactive Waste Management Agency	
18	Observatoire Pérenne de l'Environnement	OPE	Atmosphere Station	Tall tower	Class 1	French National Radioactive Waste Management Agency	17.11.2017
19	Puechabon	FR-Pue	Ecosystem Station	Forest	Class 2	The National Centre for Scientific Research	17.11.2021
20	Puy de Dôme	PUY	Atmosphere Station	Mountain	Class 2	CEA-CNRS	31.5.2018
21	Saclay	SAC	Atmosphere Station	Tall tower	Class 1	CEA-CNRS-UVSQ	27.5.2020
22	Toulouse	FR-Tou	Ecosystem Station	Grassland	Associated	CNRM, University of Toulouse, Météo-France, CNRS	17.11.2021
23	Trainou	TRN	Atmosphere Station	Tall tower	Class 1	CEA-CNRS	30.11.2018

ICOS Germany

ICOS GERMANY FOCAL POINT

Christian Brümmer

Senior Researcher

Thünen Institute of Climate-Smart Agriculture

Braunschweig, Germany

contact-germany@lists.icos-ri.eu

+49 531 596 2614

www.icos-infrastruktur.de

Berlin-Rothenburgstrasse: an Ecosystem station of ICOS Germany

The role of ICOS Germany

The ultimate goal of ICOS Germany is the long-term consolidation of the world's leading observation networks on atmospheric greenhouse gas concentrations and exchange fluxes within terrestrial and marine ecosystems. A dense station network covering important land-use types and the most common terrestrial ecosystems assure a high level of representative data sets and products for central Europe. These are complemented by crucial marine observations on different platforms for example in the Baltic Sea and in the North Atlantic Ocean.

Germany's featured station within the ICOScapes photo campaign was the Ecosystem site Fendt. Its location and site management represent the most typical farmland for the northern slopes of the Alps in Germany, Austria and Switzerland. These mountain regions are important for measurements because they are especially vulnerable to climate change. Over the last 50 years, the temperature in the Fendt station area has already risen twice as much as in the rest of Germany.

Germany also hosts one of the Central Facilities: the ICOS Central Analytical Laboratories. It is an ideal location due to its specific expertise in the high-precision analysis of trace gases, the provision of calibration standards for the observation networks, and in the analysis of the radioactive carbon isotope ^{14}C in air samples.

The tasks of the ICOS Germany coordination unit, the Thünen Institute of Climate-Smart Agriculture, include data integration, reporting and knowledge transfer among scientists, policymakers and the public.

The ICOS Germany infrastructure

ICOS Germany comprises 39 stations (Figures 19a, b; Table 16), and they are categorised into three station/observation networks: Atmosphere, Ecosystem and Ocean. The network is operated by 19 national research centres, universities and federal research institutions.

The Atmosphere station network covers the continuous monitoring of atmospheric greenhouse gas concentrations (CO_2, CH_4 and N_2O) combined with flask samples for their isotopic composition, radiocarbon sampling and tracer measurements (CO and ^{222}Rn) from a network of 12 observation stations at tall towers, and mountain and coastal stations distributed across Germany.

Continuous measurement of greenhouse gas fluxes (H_2O, CO_2, partly CH_4 and N_2O) between various ecosystems and the atmosphere are carried out in the Ecosystem station network of 21 stations with the use of the eddy covariance technique. The flux stations are mainly arranged in clusters, with different ecosystems being exposed to similar climatic conditions.

Measurements of greenhouse gas concentrations in the surface water and air-sea fluxes are carried out in the Ocean station network from two SOOP (Ship of Opportunity) lines in the North Atlantic Ocean and Baltic Sea in addition to the SOOP 'Polarstern' and at two oceanic time-series observatories at the polar (Hausgarten) and tropical (Cape Verde) extremes of the North Atlantic. In 2023, a FerryBox station measuring carbon dynamics in Cuxhaven, at the outflow of the Elbe estuary to the North Sea, has been added to the network. This novel station type provides important information on the land-ocean interactions, which so far had been missing in the observation network.

The ICOS Germany funding structure

ICOS Germany is funded by the German Federal Ministries for Digital and Transport (BMDV) and Education and Research (BMBF). Further funding is provided in-kind by the member institutions.

ICOS GERMANY PARTNERS AND FUNDERS

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung (AWI)
www.awi.de/en.html

Technische Universität Dresden
www.tu-dresden.de

Federal Ministry of Education and Research (BMBF)
www.bmbf.de/en/index.html

Federal Ministry for Digital and Transport (BMDV)
www.bmvi.de/EN/Home/home.html

GEOMAR Helmholtz Centre for Ocean Research
www.geomar.de/en

Georg-August-University Göttingen
www.uni-goettingen.de

Deutscher Wetterdienst (DWD)
www.dwd.de/EN/Home/home_node.html

Heidelberg University
www.uni-heidelberg.de

Helmholtz Centre for Environmental Research, Leipzig (UFZ)
www.ufz.de

Helmholtz Center Hereon
https://www.hereon.de/index.php.en

Forschungszentrum Jülich (FZJ)
www.fz-juelich.de

Karlsruhe Institute of Technology (KIT)
www.kit.edu/english

Max-Planck-Institute for Biogeochemistry (MPI)
www.bgc-jena.mpg.de

University of Münster
https://www.uni-muenster.de/en/

The Leibniz Institute for Baltic Sea Research (IOW)
www.io-warnemuende.de

Technische Universität Berlin
www.tu.berlin/en

Thünen Institute
www.thuenen.de/en

Weihenstephan-Triesdorf University of Applied Sciences
www.hswt.de

University of Freiburg
www.uni-freiburg.de

Landesbetrieb Forst Brandenburg
forst.brandenburg.de/lfb/de

Umweltbundesamt (UBA)
www.umweltbundesamt.de/en

Figure 19: The ICOS Germany station network. Figure 19a shows the stations in mainland Germany, while Figure 19b depicts remote Ocean stations and areas covered by SOOP lines. The numbers in the maps correspond to the numbers in Table 16.

Figure 19a

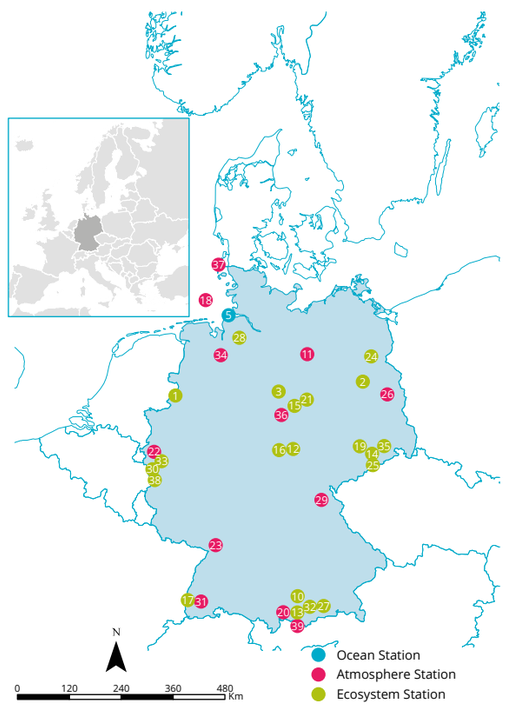


Figure 19b

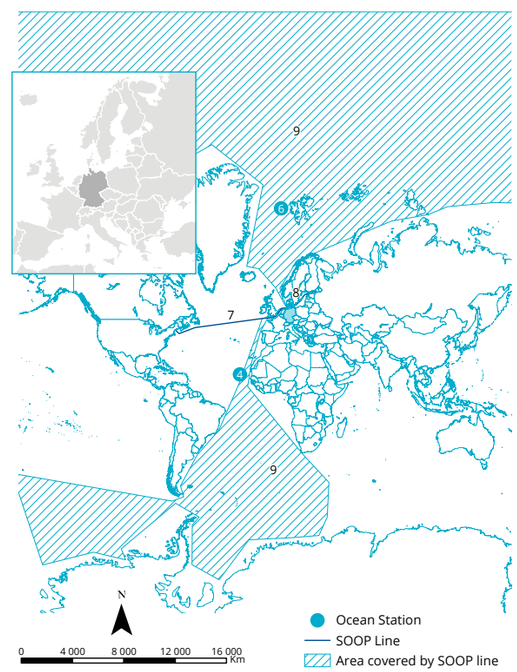


Table 16. ICOS Stations in Germany

MAP NUMBER	STATION NAME	STATION ABBREVIATION	STATION TYPE	SITE TYPE	STATION CLASS	HOST INSTITUTE	LABELING DATE
1	Amtsvenn	DE-Amv	Ecosystem Station	Wetland	Associated	University of Münster	
2	Berlin-Rothenburgstrasse	DE-BeR	Ecosystem Station	Urban	Associated	Technische Universität Berlin	23.11.2022
3	Braunschweig	DE-Brs	Ecosystem Station	Cropland	Associated	Deutscher Wetterdienst (DWD)	
4	Cape Verde Ocean Observatory	DE-FOS-CVOO	Ocean Station	Profiling station	Class 1	GEOMAR – Helmholtz Centre for Ocean Research Kiel	
5	Cuxhaven Stationary FerryBox Platform	CUXHAVEN	Ocean Station	Stationary FerryBox platform	Class 2	Helmholtz Center Hereon	
6	DE-FOS-Hausgarten	DE-HGT	Ocean Station	Profiling station	Class 1	Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung (AWI)	
7	DE-SOOP-Atlantic Sail	74WX	Ocean Station	SOOP line	Class 1	GEOMAR – Helmholtz Centre for Ocean Research Kiel	18.5.2022
8	DE-SOOP-Finnmaid	34FM	Ocean Station	SOOP line	Class 2	Leibniz Institute for Baltic Sea Research Warnemünde	23.5.2023
9	DE-SOOP-Polarstern	06AQ	Ocean Station	SOOP line	Class 2	Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung (AWI)	27.5.2020
10	Fendt	DE-Fen	Ecosystem Station	Grassland	Associated	Karlsruhe Institute of Technology	
11	Gartow	GAT	Atmosphere Station	Tall tower	Class 1	Deutscher Wetterdienst (DWD)	17.11.2017
12	Gebesee	DE-Geb	Ecosystem Station	Cropland	Class 1	Thünen Institute of Climate-Smart Agriculture	17.11.2020
13	Graswang	DE-Gwg	Ecosystem Station	Grassland	Associated	Karlsruhe Institute of Technology	
14	Grillenburg	DE-Gri	Ecosystem Station	Grassland	Associated	Technische Universität Dresden	30.11.2018
15	Grosses Bruch	DE-GsB	Ecosystem Station	Grassland	Associated	Helmholtz Centre for Environmental Research	
16	Hainich	DE-Hai	Ecosystem Station	Deciduous forest	Associated	Georg-August-University Göttingen	27.5.2020
17	Hartheim	DE-Har	Ecosystem Station	Coniferous forest	Associated	University of Freiburg	18.5.2022
18	Helgoland	HEL	Atmosphere Station	Tall tower	Class 2	Deutscher Wetterdienst (DWD)	17.11.2020
19	Hetzdorf	DE-Hzd	Ecosystem Station	Plantation forest (oaks)	Associated	Technische Universität Dresden	23.5.2023
20	Hohenpeissenberg	HPB	Atmosphere Station	Tall tower	Class 1	Deutscher Wetterdienst (DWD)	17.11.2017
21	Hohes Holz	DE-HoH	Ecosystem Station	Deciduous forest	Class 1	Helmholtz Centre for Environmental Research	22.5.2019
22	Jülich	JUE	Atmosphere Station	Tall tower	Class 2	Deutscher Wetterdienst (DWD)	17.11.2021
23	Karlsruhe	KIT	Atmosphere Station	Tall tower	Class 1	Deutscher Wetterdienst (DWD)	21.11.2019
24	Kienhorst	DE-Kie	Ecosystem Station	Coniferous forest	Associated	Landesbetrieb Forst Brandenburg	
25	Klingenberg	DE-Kli	Ecosystem Station	Cropland	Associated	Technische Universität Dresden	22.5.2019
26	Lindenberg	LIN	Atmosphere Station	Tall tower	Class 1	Deutscher Wetterdienst (DWD)	30.11.2018

Table 16. ICOS Stations in Germany

MAP NUMBER	STATION NAME	STATION ABBREVIATION	STATION TYPE	SITE TYPE	STATION CLASS	HOST INSTITUTE	LABELING DATE
27	Mooseurach	DE-Msr	Ecosystem Station	Coniferous bog forest	Associated	Weihenstephan-Triesdorf University of Applied Sciences	18.5.2022
28	Oberklenkendorf	DE-Okd	Ecosystem Station	Grassland	Associated	Thünen Institute of Climate-Smart Agriculture	
29	Ochsenkopf	OXK	Atmosphere Station	Tall tower	Class 1	Deutscher Wetterdienst (DWD)	21.11.2019
30	Rollesbroich	DE-RuR	Ecosystem Station	Grassland	Associated	Forschungszentrum Jülich (FZJ)	25.5.2021
31	Schauinsland	SSL	Atmosphere Station	Mountain	Class 1	Umweltbundesamt (UBA)	18.5.2022
32	Schechenfilz Nord	DE-SfN	Ecosystem Station	Coniferous bog forest	Associated	Karlsruhe Institute of Technology	
33	Selhausen Jülich	DE-RuS	Ecosystem Station	Cropland	Class 1	Forschungszentrum Jülich (FZJ)	22.5.2019
34	Steinkimmen	STE	Atmosphere Station	Tall tower	Class 1	Deutscher Wetterdienst (DWD)	21.11.2019
35	Tharandt	DE-Tha	Ecosystem Station	Coniferous forest	Class 1	Technische Universität Dresden	17.11.2020
36	Torfhaus	TOH	Atmosphere Station	Tall tower	Class 2	Deutscher Wetterdienst (DWD)	30.11.2018
37	Westerland	WES	Atmosphere Station	Coastal station	Class 2	Umweltbundesamt (UBA)	17.11.2021
38	Wüstebach	DE-RuW	Ecosystem Station	Coniferous forest	Associated	Forschungszentrum Jülich (FZJ)	18.5.2022
39	Zugspitze	ZSF	Atmosphere Station	Mountain	Class 2	Umweltbundesamt (UBA)	25.5.2021

ICOS Greece

ICOS GREECE FOCAL POINT
Ioannis Gitas
National Research Council (CNR)
Professor
Aristotle University of Thessaloniki
igitas@for.auth.gr
+30 2310992699

Finokalia an atmosphere station of ICOS Greece

The Role of ICOS Greece

Recognizing the Mediterranean region's heightened vulnerability to climate change, particularly its significantly fast rate of temperature rise compared to other parts of the world, ICOS Greece aims to address the lack of monitoring stations in this area. ICOS Greece contributes to the ICOS RI with 4 stations in the characteristic ecosystems of Greece. More specifically, there is one ecosystem station in a high-altitude fir forest in Central Greece, two ecosystem-associated stations in Heraklion city, and one atmospheric station in Finokalia, Crete. The main goal of ICOS Greece is to expand the geographical coverage of the network in other ecosystems, facing severe threats due to manmade and natural disturbances.

The ICOS Greece infrastructure

The ICOS Greece network is currently comprised of 4 sites: 1 Atmospheric and 3 Ecosystem.

The Finokalia environmental research station, located on the north coast of Crete Island, has been operated continuously by the University of Crete since 1993, focusing on aerosol characterization measurements. Its strategic position in the Eastern Mediterranean, far from major urban centers, allows for sampling of air masses unaffected by local sources, offering a picture representative of the background conditions of the Eastern Mediterranean.

The Pertouli Ecosystem Station, situated in the Pertouli University Forest in northern Greece, was established in 2021 according to ICOS Ecosystem Thematic Center protocols. The station's location was selected based on the particular characteristics of the area and to minimize disturbance to the ecosystem as much as possible. The station consists of a telescopic mast, 24 meters high, equipped with all the necessary instruments for CH4 and CO2 monitoring above the canopy of a naturally regenerated forest.

Additionally, Greece hosts two other Ecosystem stations in Heraklion: the Heraklion City Center Station (HECKOR) and the Heraklion Residential Area Station (HECMAS). Both equipped with an Open Path Eddy Covariance system and a 4-component net radiometer, HECKOR captures characteristic urban diurnal and seasonal patterns reflecting emissions from traffic and commercial activities in the northern area, and residential activities in the southern part. Similarly, HECMAS monitors CO2 fluxes, providing insights into residential emissions in the surrounding area.

The ICOS Greece funding structure

The common basic and GNI-based contributions are paid by the Greek Ministry of the Environment and Energy. The annual station-based contributions, development, and running costs of each station are covered by the host institutes (Aristotle University of Thessaloniki, University of Crete, and Foundation for Research and Technology – Hellas).

Figure 20: The ICOS Greece station network. The numbers on the map correspond to the numbers in Table 17.

ICOS GREECE PARTNERS AND FUNDERS

Aristotle University of Thessaloniki (AUTh)
www.auth.gr/en/

University of Crete (UoC)
https://en.uoc.gr

Foundation for Research and Technology – Hellas
www.forth.gr/en/home/list/

Ministry of the Environment and Energy
https://ypen.gov.gr

Table 17. ICOS Stations in Greece

MAP NUMBER	STATION NAME	STATION ABBREVIATION	STATION TYPE	SITE TYPE	STATION CLASS	HOST INSTITUTE	LABELING DATE
1	Finokalia	FKL	Atmosphere Station	Mountain	Class 2	University of Crete	
2	HECKOR – Heraklion Kornarou	GR-HeK	Ecosystem Station	Urban and built-up lands	Associated	The Foundation for Research and Technology (FORTH)	15.11.2023
3	HECMAS – Heraklion Mastabas	GR-HeM	Ecosystem Station	Urban and built-up lands	Associated	The Foundation for Research and Technology (FORTH)	15.11.2023
4	Pertouli	GR-Prt	Ecosystem Station	Evergreen needle-leaf forests	Class 2	Aristotle University of Thessaloniki	

ICOS Hungary

ICOS HUNGARY FOCAL POINT

László Haszpra

Professor, Scientific Advisor

HUN-REN Institute for Nuclear Research (ATOMKI)

Hungary

haszpra.laszlo@atomki.hu

+36 30 454 3309

Hegyhátsál: An Atmosphere station of ICOS Hungary

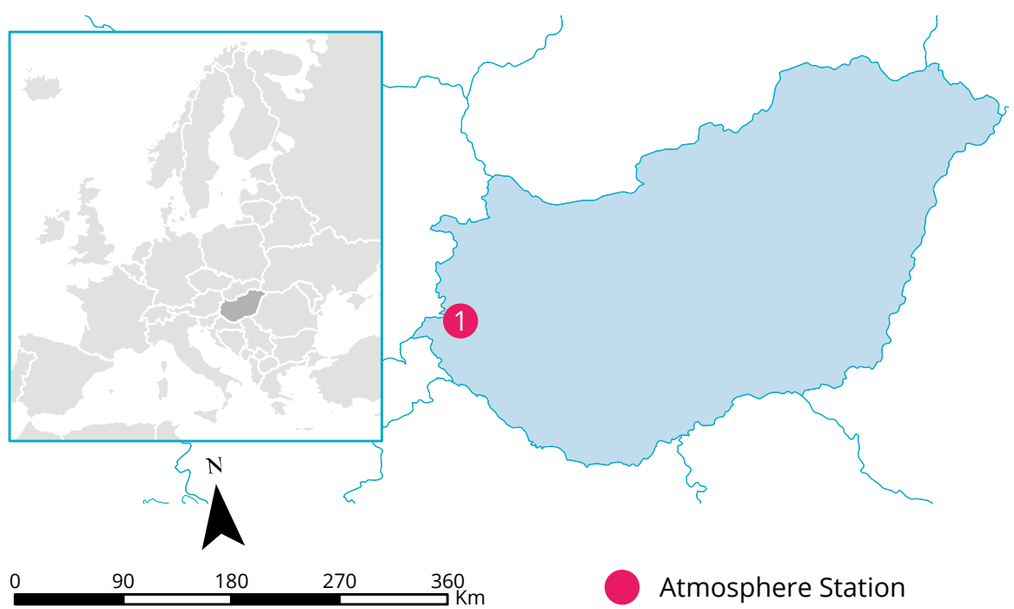
The role of ICOS Hungary

The main goal of ICOS Hungary is to expand the geographical coverage of the ICOS network towards the east. As Hungary is located in the zone of westerlies winds in Europe, adding measurement stations east of the existing ICOS network may significantly reduce the uncertainty of the continental atmospheric budget models. Hungary expands the long-term data series with its in situ atmospheric carbon dioxide measurements that date back to as early as 1981. Hungary has joined ICOS in January 2022.

The ICOS Hungary infrastructure

ICOS Hungary network consists of one Atmosphere Class 2 station, Hegyhátsál (Figure 21; Table 18). The instrumentation in this station, established in 1993, is mounted on a 117 m tall TV/radio transmitter tower owned by Antenna Hungária Corporation. ICOS Hungary activities are coordinated by Hungarian Research Network the (HUN-REN) Institute for Nuclear Research (ATOMKI) that has a long tradition in environmental monitoring.

Figure 21: The ICOS Hungary station network. The numbers in the map correspond to the numbers in Table 18.



Hegyhátsál's monitoring program has been gradually expanded, and it has participated in several EU-funded international research projects throughout the years. The station also belongs to the global cooperative flask air sampling network of the US National Oceanic and Atmospheric Administration, and is a member of the Global Atmosphere Watch program of the World Meteorological Organization. Hegyhátsál measures in situ carbon dioxide and methane concentrations as well as basic meteorological variables. In addition, the station measures radiocarbon, carbon monoxide and vertical fluxes of nitrous oxide.

ICOS Hungary consortium will be developed gradually to involve university departments, the Hungarian Meteorological Service, and other institutions that are active in the field of atmospheric and ecosystem monitoring. In the coming years, two or more Ecosystem stations will also join the Hungarian network. The potential Ecosystem stations will focus on measuring the greenhouse gas budget of temperate climate zone grasslands. After that, the network will expand to include a second Atmosphere tall-tower in the eastern part of Hungary.

The ICOS Hungary funding structure

The common basic and GNI-based contributions, as well as the station-based contribution are paid by the National Research, Development and Innovation Office of Hungary (NKFIH). The development and running costs of the Hegyhátsál Atmosphere measurement station are covered by the HUN-REN Institute for Nuclear Research (ATOMKI).

ICOS HUNGARY PARTNERS AND FUNDERS

HUN-REN Institute for Nuclear Research (ATOMKI)
www.atomki.hu

Eötvös Loránd University
nimbus.elte.hu/research.html

HungaroMet Hungarian Meteorological Service
www.met.hu/en

Hungarian University of Agriculture and Life Sciences
uni-mate.hu

HUN-REN Institute of Earth Physics and Space Science
epss.hu/en

Table 18. ICOS stations in Hungary

MAP NUMBER	STATION NAME	STATION ABBREVIATION	STATION TYPE	SITE TYPE	STATION CLASS	HOST INSTITUTE	LABELING DATE
1	Hegyhátsál	HUN	Atmosphere Station	Tall tower	Class 2	Institute for Nuclear Research (ATOMKI)	

ICOS Ireland

ICOS IRELAND FOCAL POINT
Frank McGovern
Environmental Protection Agency

ICOS@epa.ie
+353 (1) 260-1000
ICOS Ireland | ICOS (icos-cp.eu)

Mace Head: An atmosphere station of ICOS Ireland.

The Role of ICOS Ireland

The atmosphere over the North Atlantic Ocean is highly impacted by human activities on the surrounding continents, its islands, and by emissions along its trade and transport routes. Ireland's location in the mid-latitude western boundary of Europe means that it is ideally suited for observations of how these activities are impacting on the composition of the Atlantic atmosphere as well as hemispheric and global influences. These attributes have led to the Mace Head site on the west coast of Ireland becoming a leading global site for atmospheric observations, including those carried out under ICOS.

Atmospheric observations of greenhouse gases at Mace Head are complemented by data from sites at Carnsore Point, on the south east coast and Malin Head, the most northerly point in Ireland as well as the historic Valentia Island Observatory on the south west coast. Together data from these sites allow for studies of how Ireland is impacted by air masses from the North Atlantic and Europe and also how Ireland is influencing these. Grass and peatland dominate Ireland's land cover, and a series of ecosystem sites has been established to observe GHG exchanges between these ecosystems and the atmosphere. Ireland also has a long-term forest ecosystem site. Five ecosystem sites are included in its ICOS network.

The island of Ireland is surrounded by ocean areas. As well as being a key part of Ireland's economy, society and nature the oceans are an important sink for carbon dioxide. The Marine Institute research vessels are actively exploring exchanges of carbon dioxide and other gases between ocean areas and atmosphere. This work is also included in the ICOS network.

Ireland has developed an extensive range of measurements which allows for detailed studies of GHG emissions and removals to support policy and actions on climate change. The size, geography and ecosystems of Ireland, provide opportunities for the provision of scientific analysis of emissions and removals at national, regional and local scales. These are scientifically and technically challenging. Working with our European ICOS partners in addressing these challenges and realising the potentials of advanced observation systems to provide science-based analysis of GHG emissions and removals across a range of temporal and spatial scales is a shared goal.

The ICOS Ireland infrastructure

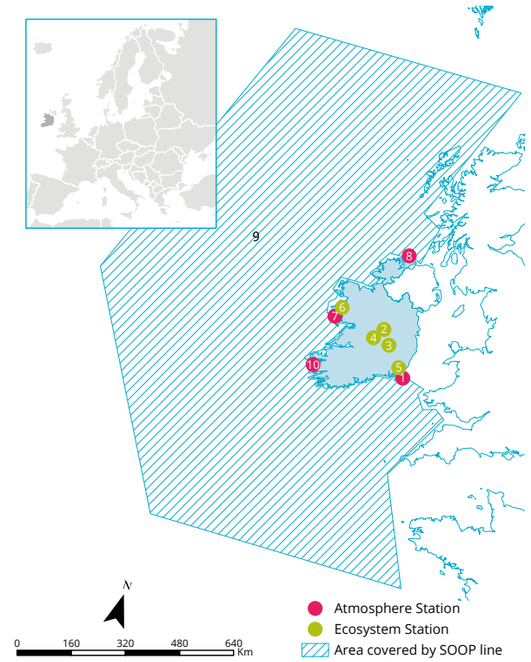
ICOS Ireland contributes to the three ICOS observation domains, those being Atmosphere, Ecosystem and Ocean. The ICOS Ireland network consists of 10 sites, of which four are Atmospheric stations, five are Ecosystem stations and one is an Ocean station. These stations are officially labelled by ICOS as either Associated or Class 2. Ecosystem sites have been established at grassland, peatland, and forest locations. The ocean site is based on the Celtic Explorer RV, a registered "Ship of opportunity" (SOOP) station. The ICOS Ireland network is run by several partners and universities: The University of Galway, Trinity College Dublin, the Marine Institute Foras Na Mara, Met Éireann, Teagasc, The National Parks and Wildlife Services and the Department of Agriculture, Food and the Marine. The Environmental Protection Agency, Ireland acts as the focal point for ICOS Ireland.

The ICOS Ireland funding structure

The ICOS network in Ireland is owned and operated by a number of bodies including third level institutions and state bodies and agencies, which are listed below. Funding is provided by each of these through their own operational budgets or via research awards or grants. Funding for the atmospheric sites is provided by the EPA and Met Eireann,

with the EPA supporting the operation of three of these sites on contractual basis with the University of Galway. The Ecosystem sites are owned, managed and funded by state bodies which have responsibility for these areas. These are Teagasc for grasslands, National Parks and Wildlife Service (NPWS) for peatland, and the Department of Agriculture and Coillte for the Forest site. These are operated in cooperation with third level institutions such as Trinity College Dublin, and University College Dublin. The Marine Institute operates ocean observations. Data analysis and research using these data are funded via national and European research projects. At a national level these are supported by the Environmental Protection Agency, Science Foundation Ireland, Teagasc, National Parks and Wildlife service and the Department of Agriculture, Food and the Marine.

Figure 22: The ICOS Ireland station network. The numbers in the map correspond to the numbers in Table 19.



ICOS IRELAND PARTNERS AND FUNDERS

Environmental Protection Agency
epa.ie

The University of Galway
www.universityofgalway.ie

Trinity College Dublin
tcd.ie

Marine Institute Foras Na Mara
www.marine.ie

Met Éireann – The Irish Meteorological Service
www.met.ie

Teagasc
teagasc.ie

The National Parks and Wildlife Services
npws.ie

Department of Agriculture, Food and the Marine
www.gov.ie

Table 19. ICOS Stations in Ireland

MAP NUMBER	STATION NAME	STATION ABBREVIATION	STATION TYPE	SITE TYPE	STATION CLASS	HOST INSTITUTE	LABELING DATE
1	Carnsore Point	CRP	Atmosphere Station	Coastal	Class 2	University of Galway and Environmental Protection Agency	
2	Clara Raised Bog	IE-Cra	Ecosystem Station	Permanent wetland	Associated	National Parks and Wildlife	
3	Dooary	IE-Doa	Ecosystem Station	Deciduous broadleaf forests	Class 2	University College Dublin	
4	Doorey	*	Ecosystem Station	Grassland	Associated	Teagasc	
5	Johnstown Castle	IE-JtC	Ecosystem Station	Grassland	Class 2	Teagasc	
6	Leam West	IE-LmW	Ecosystem Station	Permanent wetland	Associated	National Parks and Wildlife	
7	Mace Head	MHD	Atmosphere Station	Coastal	Class 2	University of Galway and Environmental Protection Agency	
8	Malin Head	MLH	Atmosphere Station	Coastal	Class 2	University of Galway and Environmental Protection Agency	
9	RV Celtic Explorer	45CE	Ocean Station	SOOP	Class 2	Marine Institute	
10	Valentia Island	VTO	Atmosphere Station	Coastal	Class 2	University of Galway and Met Éireann	

*Will be assigned later

ICOS Italy

ICOS ITALY FOCAL POINT
Carlo Calfapietra
National Research Council (CNR)
Director
Institute of Research on Terrestrial Ecosystems Italy

info@icos-italy.it
+39 0763 3749 17
www.icos-italy.it

Lampedusa: A multi-domain station of ICOS Italy

The role of ICOS Italy

The international scientific community has shown that in the different domains (Atmosphere, Ecosystem and Ocean) of ICOS, the impacts, the responses and the mitigation capacity may differ from what has been assumed so far. For example, a significant impact of climate change on the biodiversity of natural ecosystems and/or on the productivity of agro-ecosystems can be assumed. In Italy, this problem appears particularly important given the multiplicity and diversity of its ecosystems, the circulation of air masses and seas in the various climatic zones and the vulnerability of most of them.

ICOS Italy hosts three urban stations (Capodimonte, Osservatorio Ximeniano and Sassari) and one peri-urban site (Castelporziano). This vast environmental variety is extremely important, as it can portray a comprehensive overview of GHG exchanges in different conditions.

For example, Castelporziano hosts several forest ecosystems. One of these is the holm oak forest, which is, from the research perspective one of the most relevant types of ecosystems in the lower Mediterranean areas. ICOS observations at the Castelporziano station help in understanding how this type of forest is behaving in response to changes caused by rising temperatures. In addition, the station's closeness to the centre of Rome gives a better understanding of complex interactions between the urban environment and the plants.

Moreover, the national network also includes the typical agroecosystems (e.g. vineyards and crops), which represent an important component of the Mediterranean landscape. Furthermore, Italy now hosts the first integrated observatory between atmospheric, ecosystemic and marine components.

Italy also leads the Ecosystem Thematic Centre (ETC).

The ICOS Italy infrastructure

ICOS Italy Joint Research Unit is coordinated by the National Research Council (CNR). ICOS Italy includes stations belonging to the three domains: Atmosphere, Ecosystem, and Ocean. In particular, ICOS Italy network consists of 24 stations (Figure 23; Table 20a), four of them are Atmosphere stations (two Class 1 and two Class 2), fifteen are Ecosystem stations (two Class 1, two Class 2 and eleven Associated) and five are Ocean stations.

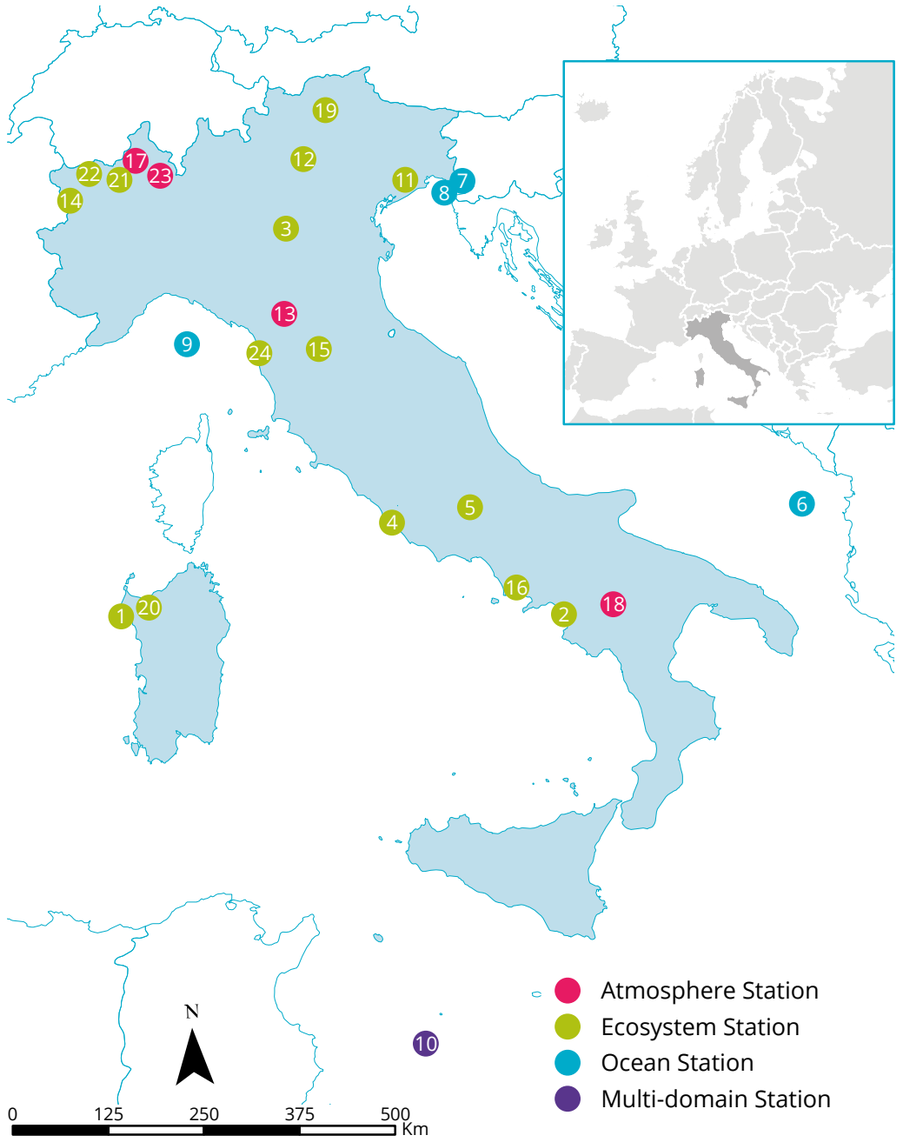
The Euro-Mediterranean Center on Climate Change and the University of Tuscia host the Ecosystem Thematic Centre (ETC) together with the University of Antwerp in Belgium and the French National Research Institute for Agriculture, Food and Environment (INRAE).

Thanks to the project 'Upgrading ICOS Italy Observation Network in the Mediterranean (PRO-ICOS_MED)', many stations, especially those based in the South of Italy, are being upgraded with state-of-the-art instrumentation and with the aim of linking ICOS protocols with advanced related measurements in line with the ICOS 2.0 strategic plan. As part of PRO-ICOS_MED, new Atmosphere (Potenza) and Ecosystem (Collelongo) stations have been built, while the Atmosphere station of Lampedusa has been implemented to become the only station in which all three domains of the ICOS network (Atmosphere, Ecosystem, Ocean) can be monitored simultaneously. In addition, hub of sensors and mobile units for the three domains are under construction to support the entire national network in the event of failures or maintenance / calibration operations, ensuring continuity and quality of the surveys over time.

The ICOS Italy funding structure

The main Italian funds derive from the Ministry of University and Research, which funds the Joint Research Unit through the Coordinator, CNR. Single partners receive funds for the various stations through international, national and local projects. Each partner institution supports ICOS through in-kind funding, mainly characterised by personnel and owned instrumentation.

Figure 23: The ICOS Italy station network. Atmosphere station Ispra (IPR) and Ecosystem station San Rossore 2 (IT-SR2) are run by the EU Joint Research Centre. The numbers in the map correspond to the numbers in Tables 20a and 20b. The multi-domain station number 10 (Lampedusa) includes atmosphere, ecosystem and ocean observations.



ICOS ITALY PARTNERS AND FUNDERS

Autonomous Province of Bolzano-Alto Adige/Bozen-Südtirol
www.provinz.bz.it/de/default.asp

Catholic University of the Sacred Heart of Brescia
www.unicatt.it

Council for Agricultural Research and the Analysis of the Agrarian Economy (CREA)
www.crea.gov.it/it

Edmund Mach Foundation
www.fmach.it

Environmental Protection Agency of Aosta Valley (ARPA Valle d'Aosta)
www.arpa.vda.it

Euro-Mediterranean Center on Climate Change (CMCC)
www.cmcc.it

Free University of Bozen-Bolzano
www.unibz.it

Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA)
www.enea.it

National Research Council (CNR), Department of Earth System Sciences and Environmental Technologies
www.dta.cnr.it/index.php/it

Ministry of University and Research (MUR)
www.mur.gov.it/it

National Institute of Oceanography and Applied Geophysics (OGS)
www.ogs.trieste.it/en

Research on Energy Systems - RSE S.p.A
www.rse-web.it

University of Chieti-Pescara
www.unich.it

University of Genoa
www.unige.it

University of Padova
www.unipd.it/en

University of Sassari
www.uniss.it

University of Udine
www.uniud.it

University of Tuscia
www.unitus.it

Table 20a. ICOS Stations in Italy

MAP NUMBER	STATION NAME	STATION ABBREVIATION	STATION TYPE	SITE TYPE	STATION CLASS	HOST INSTITUTE	LABELING DATE
1	Arca di Noe - Le Prigionette	IT-Noe	Ecosystem Station	Shrubland	Associated	University of Sassari	23.5.2023
2	Borgo Cioffi	IT-BCi	Ecosystem Station	Cropland	Class 1	National Research Council – Institute for Agricultural and Forest Systems in the Mediterranean (ISAFOM)	23.5.2023
3	Bosco Fontana	IT-BFt	Ecosystem Station	Oak-hornbeam forest	Associated	Catholic University of the Sacred Heart of Brescia	25.5.2021
4	Castelporziano2	IT-Cp2	Ecosystem Station	Mediterranean forest	Class 1	Council for Agricultural Research and Economics (CREA)	25.5.2021
5	Collelongo	IT-Col	Ecosystem Station	Deciduous broadleaf forests	Associated	National Research Council - Institute of BioEconomy (IBE)	
6	IT-FOS-E2M3A	IT-E2M	Ocean Station	Surface buoy	Class 2	National Institute of Oceanography and Applied Geophysics (OGS) - Section of Oceanography	
7	IT-FOS-Miramare	IT-MIR	Ocean Station	Surface buoy	Class 2	Oceanography and Applied Geophysics (OGS) - Section of Oceanography	23.11.2022
8	IT-FOS-PALOMA	48MB	Ocean Station	Beacon	Class 1	National Research Council-Institute of Marine Science (ISMAR)	30.11.2018
9	IT-FOS-W1M3A	IT-W1M	Ocean Station	Surface buoy	Class 2	National Research Council – Institute for the Study of Anthropic Impact and Sustainability in the Marine Environment (IAS)	18.5.2022
10	Lampedusa	LMP	Atmosphere Station	Open ocean	Class 1	National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA)	27.5.2020
10	Lampedusa	IT-Lmp	Ocean Station	Buoy open sea	Class 2	National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA)	
10	Lampedusa Ecosystem Observatory	IT-Lpd	Ecosystem Station	Forest	Associated	National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA)	
11	Lison	IT-Lsn	Ecosystem Station	Vineyard	Associated	University of Padova and University of Udine	17.11.2020
12	Monte Bondone	IT-MBo	Ecosystem Station	Grassland	Class 2	Edmund Mach Foundation	23.11.2022
13	Monte Cimone	CMN	Atmosphere Station	Mountain peak	Class 2	Italian Air Force and National Research Council – Institute of Atmospheric Sciences and Climate (ISAC)	30.11.2018
14	Nivolet	IT-Niv	Ecosystem Station	Alpine grassland	Associated	National Research Council – Institute of Geosciences and Earth Resources (IGG)	18.5.2022
15	Osservatorio Ximeniano Firenze	IT-OXm	Ecosystem Station	Urban	Associated	National Research Council – Institute of BioEconomy (IBE)	

Table 20a. ICOS Stations in Italy

MAP NUMBER	STATION NAME	STATION ABBREVIATION	STATION TYPE	SITE TYPE	STATION CLASS	HOST INSTITUTE	LABELING DATE
16	Parco Urbano di Capodimonte	IT-PCm	Ecosystem Station	Urban forest	Associated	National Research Council – Institute of Research on Terrestrial Ecosystems (IRET)	
17	Plateau Rosa	PRS	Atmosphere Station	Mountain peak	Class 2	Research on Energy Systems – RSE S.p.A	25.5.2021
18	Potenza	POT	Atmosphere Station	Continental	Class 1	National Research Council – Institute of Methodologies for Environmental Analysis	
19	Renon	IT-Ren	Ecosystem Station	Subalpine forest	Class 2	Forest Services of the Autonomous Province of Bolzano	17.11.2021
20	Sassari	IT-Sas	Ecosystem Station	Urban	Associated	University of Sassari, Department of Agricultural Sciences; CNR IBE	
21	Torgnon	IT-Tor	Ecosystem Station	Alpine grassland	Associated	Environmental Protection Agency of Aosta Valley (ARPA VdA)	17.11.2017
22	Torgnon-LD	IT-TrF	Ecosystem Station	Deciduous needleleaf forests	Associated	Environmental Protection Agency of Aosta Valley (ARPA VdA)	

20b: Stations run by the EU Joint Research Centre (JRC)

MAP NUMBER	STATION NAME	STATION ABBREVIATION	STATION TYPE	SITE TYPE	STATION CLASS	HOST INSTITUTE	LABELING DATE
23	Ispra	IPR	Atmosphere Station	Tall tower	Class 2	Joint Research Centre	30.11.2018
24	San Rossore 2	IT-SR2	Ecosystem Station	Forest	Class 2	Joint Research Centre	21.11.2019

ICOS Netherlands

ICOS NETHERLANDS FOCAL POINT

Paula Bronsveld

The Netherlands Organisation
for Applied Scientific Research (TNO)

The Netherlands

contact-netherlands@lists.icos-ri.eu

+31 611 49 70 94

www.icos-infrastructure.nl

Loobos: an Ecosystem station of ICOS Netherlands

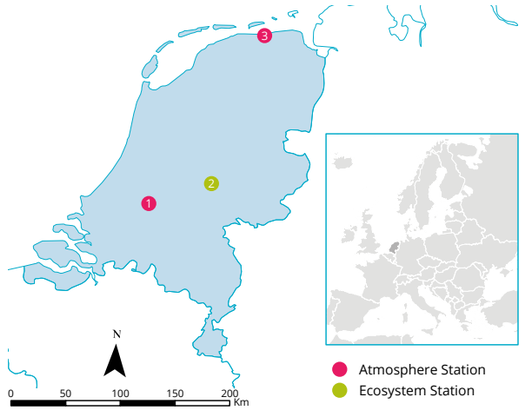
The role of ICOS Netherlands

The Netherlands is unique in Western Europe in its situation as a lowland delta, with high population density, intense agricultural and strong spatial clustering of urban and rural areas. ICOS Netherlands aims to ultimately establish high observational density and high-resolution inversion modelling, enabling the area-wide verification of greenhouse gas exchange.

The three ICOS stations in The Netherlands comprise one Ecosystem flux station and two Atmosphere stations with established long records. Together, they serve as anchor points in the European network, covering the greenhouse gas exchange of a characteristic forest type as well as concentration fields that represent a region wider than the Netherlands. At the same time, they are key stations in the country-wide Ruisdael Observatory focused on greenhouse gas budgets, cloud formation, extreme weather and air pollution.

ICOS Netherlands also plays an important role in the Carbon Portal, providing a multitude of data services for all of Europe.

Figure 24: The ICOS Netherlands station network. The numbers in the map correspond to the numbers in Table 21.



The ICOS Netherlands infrastructure

Two universities and two knowledge institutes are actively involved in the Dutch ICOS Netherlands (ICOS-NL) consortium: Wageningen University (WUR), University of Groningen (RUG), the Royal Netherlands Meteorological Institute (KNMI) and The Netherlands Organisation for Applied Scientific Research (TNO).

The ICOS-NL network consists of three stations (Figure 24; Table 21): two Atmosphere stations (Cabauw and Lutjewad) and one Ecosystem station (Loobos). In addition, ICOS-NL makes a strong contribution to the ICOS Carbon Portal.

Loobos, in the heart of the Veluwe forest, is a flux tower facility in an over 100-year-old Scots pine (Pinus sylvestris) forest. It was primarily developed to determine the long-term uptake and release of CO_2 and evapotranspiration of the forest, using the eddy covariance method and supporting observations. Serving as a vital research hub, this station facilitates studies on carbon sequestration and the effects of forest management practices on carbon cycling.

Located amidst the Groningen salt marshes, Lutjewad specializes in studying carbon dynamics within coastal wetland ecosystems. Its coastal position enables the collection of data on carbon exchanges between land, sea, and atmosphere. Currently the site provides a high-quality record of all relevant greenhouse gases, as well as advanced tracers, such as carbon isotopes, ^{222}Rn, O_2/N_2, COS. These allow to derive regional greenhouse gas emissions and estimates of biospheric and oceanic uptake of CO_2.

In the central Netherlands, Cabauw stands as an indispensable urban-terrestrial interface station. The 213-meter-high mast at the Cabauw site was built for meteorological research, specifically to establish relations between the state of the atmospheric boundary layer, land surface conditions and the general weather situation for all seasons. The nearby region is agricultural, and surface elevation changes are at most a few metres over 20 km. The existing Cabauw greenhouse gas profile measurements (CO_2, CH_4, N_2O, CO) are ICOS level 1 standard. Monitoring carbon dynamics across a diverse landscape encompassing urban areas, agricultural fields, and natural vegetation, Cabauw plays a pivotal role in studying urban carbon emissions, atmospheric transport processes, and the impacts of land use changes on carbon fluxes.

The ICOS Netherlands funding structure

ICOS-NL is financially supported by the Ministry of Economic affairs and Climate Policy (EZK). The ICOS Netherlands infrastructure is funded for a large part through the large-scale Netherlands 'Ruisdael observatory' and the EU ATMO-ACCESS project 2021–2025, supplemented by matching funding from the host institutes.

The Ruisdael observatory (https://ruisdael-observatory.nl/) is a national initiative, a nationwide observatory for measurements of the atmosphere. It was set up to enable more concrete, detailed forecasts of the weather and air quality. The funding of the Ruisdael observatory is provided by the Dutch Research Council (NWO) and will provide parts of the material and technical support for the network until about 2028.

ICOS NETHERLANDS PARTNERS AND FUNDERS

Ministry of Economic affairs and Climate Policy (EZK)
https://www.government.nl/ministries/ministry-of-economic-affairs-and-climate-policy

The Netherlands Organisation for Applied Scientific Research (TNO)
https:/www.tno.nl/en

The Dutch Research Council (NWO)
https://www.nwo.nl/en

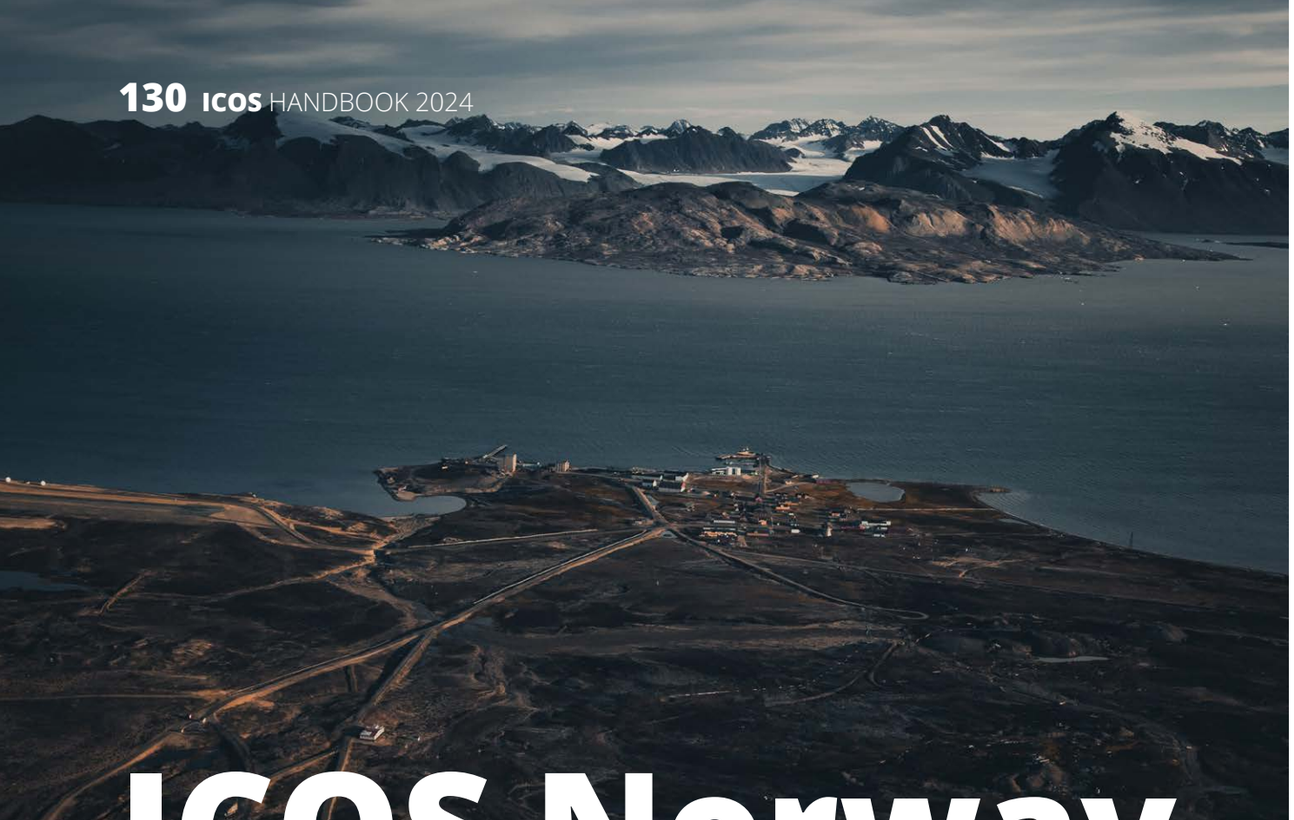
The Royal Netherlands Meteorological Institute (KNMI)
https://www.knmi.nl/over-het-knmi/about

Wageningen University (WUR)
https://www.wur.nl/en.htm

University of Groningen (RUG)
https://www.rug.nl/?lang=en

Table 21. ICOS Stations in the Netherlands

MAP NUMBER	STATION NAME	STATION ABBREVIATION	STATION TYPE	SITE TYPE	STATION CLASS	HOST INSTITUTE	LABELING DATE
1	Cabauw	CBW	Atmosphere Station	Tall tower	Class 1	KNMI/TNO	23.5.2023
2	Loobos	NL-Loo	Ecosystem Station	Pine forest	Class 2	University of Wageningen	23.5.2023
3	Lutjewad	LUT	Atmosphere Station	Coastal/continental	Class 2	University of Groningen	22.5.2019



ICOS Norway

ICOS NORWAY FOCAL POINT

Stephen Matthew Platt

Senior Scientist

The Climate and Environmental Research Institute, NILU

Norway

contact-norway@lists.icos-ri.eu

+47 63 89 81 33

no.icos-cp.eu

Ny-Ålesund and Kongsfjorden seen from the Zeppelin Observatory, an atmosphere station of ICOS Norway

The role of ICOS Norway

The long-term goal of ICOS Norway is to establish and operate an infrastructure that will allow for a complete accounting of carbon sources and sinks in the Arctic, North Atlantic, Norwegian and adjacent oceans. Measurements in the atmosphere, in the ocean and over land are combined to provide a basis for comprehensive carbon budgeting and to form a basis for the science underpinning policy actions.

ICOS Norway has a particularly strong ocean focus since it operates five of the 23 permanent Ocean stations and, together with the UK, hosts the Ocean Thematic Centre (OTC). Major scientific interests for ICOS Norway include the influence of the ocean on the greenhouse gas balance, and changes in the carbon cycle of the Arctic. Characterisation of the Arctic atmosphere and research on long-range atmospheric transport is facilitated through the uniquely-located Atmosphere station Zeppelin near Ny-Ålesund, Svalbard.

The ICOS Norway infrastructure

The ICOS Norway observation network consists of seven ICOS measurement stations (Figure 25; Table 22): five Ocean stations, two Atmosphere stations and one Ecosystem station. The Ocean domain measures CO_2 concentration in the surface ocean (used for quantifying the air-sea CO_2 flux), man-made CO_2 content and the rate of ocean acidification. The five Ocean stations are operated by the University of Bergen (UiB), the NORCE Norwegian Research Centre, and the Norwegian Polar Institute (NPI).

The Atmosphere domain, operated by the The Climate and Environmental Research Institute NILU,

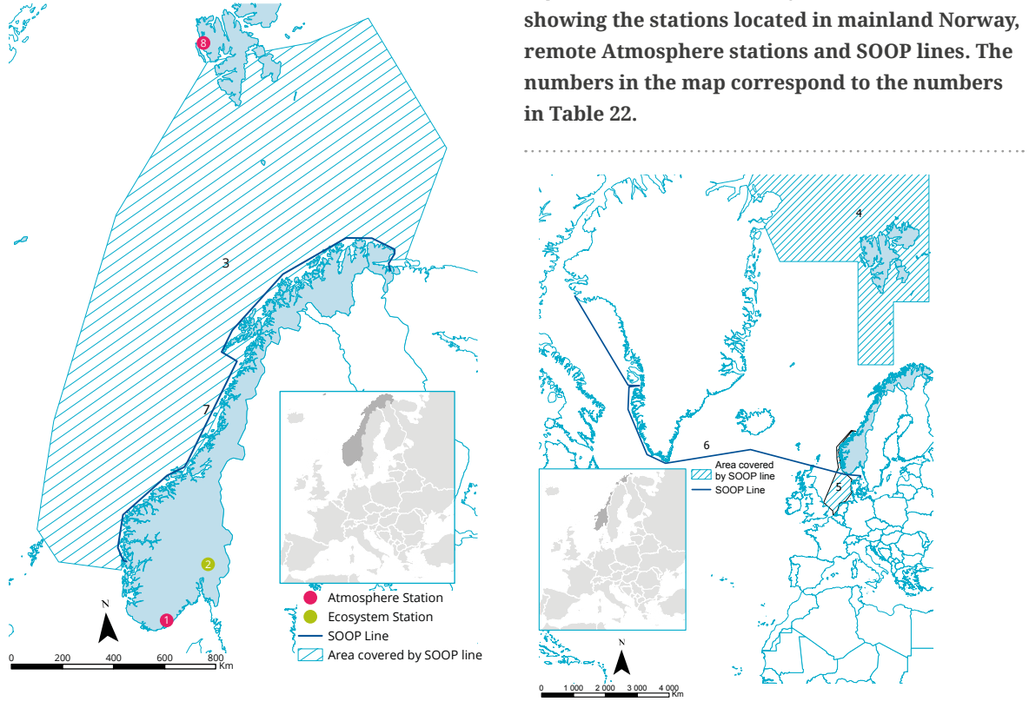


Figure 25: The ICOS Norway station network showing the stations located in mainland Norway, remote Atmosphere stations and SOOP lines. The numbers in the map correspond to the numbers in Table 22.

provides measurements of CO_2, CH_4, CO and N_2O in the atmosphere, which are used for understanding the changes and variations in these components in the long-term as well as at shorter timescales.

The Ecosystem domain measures the exchange and the uptake of carbon by the boreal forests in southern Norway and is operated by the Norwegian Institute of Bioeconomy Research (NIBIO). The ICOS Norway infrastructure, furthermore, carries out semi-operational estimates of CO_2 and CH_4 fluxes in Scandinavia through inverse modelling. Simulations are made by NILU, in collaboration with the Centre for International Climate and Environmental Research (CICERO), using ICOS data from Norway and Northern Europe as input.

The ICOS Norway funding structure

Implementation of the current ICOS Norway station network was funded by the Research Council of Norway (RCN). Upgrades to the station network are being funded via an RCN infrastructure project running from 2021–2024. This project also funds Norway's hosting of the Ocean Thematic Centre. Through this, the RCN has funded the implementation of ICOS methods and standards for Norwegian stations.

For the Ocean and Ecosystem domains, the RCN also funds operating costs, such as maintenance of the instruments, daily operations and data analysis. For the Atmosphere stations, these costs are covered through the institutes involved and various other projects. The main funding agencies for these activities are the Norwegian Ministry of Climate and Environment, the Norwegian Environmental Agency and the Research Council of Norway.

In April 2020, the RCN granted additional funding for the period of 2021–2023. A new proposal for a continuation of ICOS Norway and the Norwegian OTC host status was submitted to RCN in 2023 for the funding period 2025–2029.

ICOS NORWAY PARTNERS AND FUNDERS

Centre for International Climate and Environmental Research (CICERO)
www.cicero.oslo.no/en

Institute for Marine Research (IMR)
www.imr.no/en

NORCE Norwegian Research Centre
www.norceresearch.no/en/

The Climate and Environmental Research Institute NILU
www.nilu.no/

Norwegian Institute of Bioeconomy Research (NIBIO)
www.nibio.no/en

Norwegian Institute for Water Research (NIVA)
www.niva.no/en

Norwegian Polar Institute
www.npolar.no/en/

Royal Norwegian Ministry of Climate and Environment, Department for Nature Management
www.regjeringen.no/en/dep/kld/organisation/departments/department-nature-management/

The Research Council of Norway
www.forskningsradet.no/

University of Bergen
www.uib.no/en

Table 22. ICOS Stations in Norway

MAP NUMBER	STATION NAME	STATION ABBREVIATION	STATION TYPE	SITE TYPE	STATION CLASS	HOST INSTITUTE	LABELING DATE
1	Birkenes	BIR	Atmosphere Station	Hilly forest, meadow, lakes	Class 2	NILU	25.5.2021
2	Hurdal	NO-Hur	Ecosystem Station	Norway spruce forest	Class 2	Norwegian Institute of Bioeconomy Research	15.11.2023
3	Norwegian Coastal Steamer – Bergen Kirkenes	NO-SOOP-Bergen Kirkenes	Ocean Station	SOOP, Norwegian Sea	Class 1	Norwegian Institute for Water Research	
4	NO-SOOP RV G.O. Sars	58G2	Ocean Station	SOOP, Nordic seas	Class 1	NORCE Norwegian Research Centre	30.11.2018
5	NO-SOOP-Kronprins Haakon	58US	Ocean Station	SOOP, Arctic Ocean	Class 2	Norwegian Polar Institute	17.11.2020
6	NO-SOOP-Trans Carrier	BHNQ	Ocean Station	SOOP, North Sea	Class 1	NORCE Norwegian Research Centre	
7	NO-SOOP-Tukuma Arctica	26RA	Ocean Station	SOOP	Class 1	University of Bergen	31.5.2018
8	Zeppelin	ZEP	Atmosphere Station	Remote arctic, mountainous	Class 1	NILU	31.5.2018

ICOS Spain

ICOS SPAIN FOCAL POINT

Carlos Torres

Head of the Izaña Atmospheric Research Centre, State Meteorological Agency of Spain (AEMET)

ctorresg@aemet.es

+34922151718

Melchor González-Dávila

Professor

Institute for Oceanography and Global Change (IOCAG), University of Las Palmas de Gran Canaria (ULPGC)

melchor.gonzalez@ulpgc.es

+34 928 452 914

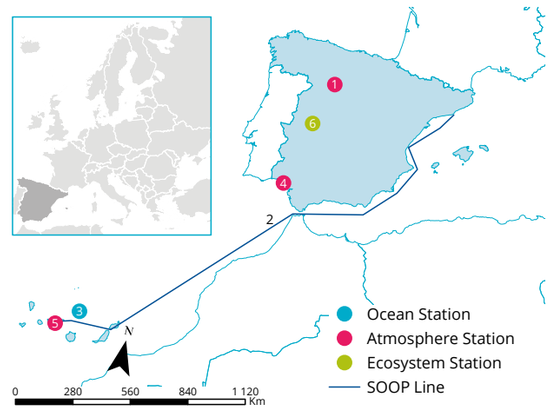
Izaña Observatory: An Atmosphere station of ICOS Spain

The role of ICOS Spain

The main goal of ICOS Spain is to considerably expand the geographical coverage of the ICOS RI observations in all three observation domains. The ICOS Spain station network covers Southwestern Europe, extending the ICOS observations to the subtropical North Atlantic on the Canary Islands. The Spanish infrastructure also provides GHG observations in the Iberian mainland, Mediterranean basin and in the North Atlantic. This includes the Strait of Gibraltar where the connection of the two seas leads to a significant exchange of air and water masses.

At this strategic location, the records of El Arenosillo atmospheric station will allow to study the transport of air masses from the Atlantic Ocean, the Mediterranean Sea or North Africa to the Iberian Peninsula and Europe.

Figure 26: ICOS Spain station network. The numbers in the map correspond to the numbers in Table 23.



In addition, the historical Izaña Atmosphere station, located in Tenerife (Canary Islands), contributes to unique background measurements of GHGs. The station has records of CO_2 and CH_4 measurements since 1984.

The ICOS Spain infrastructure

The national network is composed of the Marine Chemistry (QUIMA) group of the Institute of Oceanography and Climate Change of the University of Las Palmas de Gran Canaria (IOCAG-ULPGC), the National Institute for Aerospace Technology (INTA), the Oceanic Platform of the Canary Islands (PLOCAN), the Spanish Institute of Oceanography of the Spanish National Research Council (IEO-CSIC), the Mediterranean Center for Environmental Studies (CEAM), the University of Valladolid (UVA) and the State Meteorological Agency (AEMET). The Ministry of Science and Innovation (MICIN), through the General Subdirectorate for the Internationalization of Science and Innovation, represents Spain in ICOS RI, and through a bilateral agreement assigns to AEMET the technical coordination. These partners have a leading role in climate modelling and research, and regional greenhouse gas measurements in Spain.

ICOS Spain comprises of six stations, of which three are Atmosphere, two are ocean and one is an ecosystem station. Several of the stations are co-located with other research infrastructures such as the European Research Infrastructure for the observation of Aerosol, Clouds and Trace Gases (ACTRIS) and the European Multidisciplinary Seafloor and water column Observatory (EMSO).

The Izaña Atmosphere station has a long and globally important history of background reference CO2 and CH4 measurements. The station belongs to the WMO GAW programme and runs quality control/assurance audits conducted by the Swiss Federal Laboratories for Materials Science and Technology (Empa).

The atmospheric station of El Arenosillo located in the southwest of the Iberian Peninsula, in the protected area of the Doñana National Park, provides information on the air mass transport and exchange from the Atlantic Ocean and the western Mediterranean basin as well as of the regional greenhouse gas levels and patterns in this coastal and rural environment.

The CanOA VOS-line operates between the Canary Islands and Barcelona through the Strait of Gibraltar and the west Mediterranean Sea.

The Canary Islands Ocean Time Series Station (ESTOC), managed by PLOCAN and IEO-CSIC with QUIMA scientific support, is an instrumented buoy located 60 nautical miles north of Gran Canaria. Since its inauguration in 1994 as a repetitive monthly ship-operated station, it generates and records meteorological and oceanographic time series representative of the central-eastern North Atlantic.

The associated ecosystem station of Majadas de Tiétar has been measuring water vapour and CO2 fluxes continuously since 2003. It is located in the province of Cáceres (Extremadura), in a holm oak forest.

The ICOS Spain funding structure

The main Spanish funds derive from the State Meteorological Agency (AEMET) that is part of the Ministry for Ecological Transition and Demographic Challenge (MITECO). Further funding is provided by the partner institutions, mostly as in-kind voluntary contributions covering personal, equipment, consumables and travel costs.

A LIST OF ICOS SPAIN PARTNERS AND FUNDERS

State Meteorological Agency of Spain (AEMET)
www.aemet.es/en

QUIMA group, Instituto de Oceanografía y Cambio Global – University of Las Palmas de Gran Canaria (ULPGC)
iocag.ulpgc.es/research/research-units/quima

National Institute of Aerospace Technology (INTA)
www.inta.es

Oceanic Platform of the Canary Islands (PLOCAN)
www.inta.es

National Research Council (CSIC), Spanish Institute of Oceanography (IEO)
iocag.ulpgc.es/research/research-units/quima

Mediterranean Center for Environmental Studies (CEAM)
http://www.ceam.es

University of Valladolid (UVA)
https://universityofvalladolid.uva.es/

Ministry of Science, Innovation and University (MICIU)
https://www.ciencia.gob.es/en/

Table 23. ICOS Spain stations network

MAP NUMBER	STATION NAME	STATION ABBREVIATION	STATION TYPE	SITE TYPE	STATION CLASS	HOST INSTITUTE	LABELING DATE
1	CIBA	CIBA	Atmosphere Station	Tall tower	Class 2	University of Valladolid	
2	ES-SOOP-CanOA	ES-SOOP-CanOA	Ocean Station	SOOP	Class 1	University of Las Palmas de Gran Canaria	15.11.2023
3	ESTOC	ES-SOOP-ESTOC	Ocean Station	Buoy	Class 1	Oceanic Platform of the Canary Islands (PLOCAN)	
4	El Arenosillo	ARN	Atmosphere Station	Tall tower	Class 2	National Institute of Aerospace Technology	
5	Izaña	IZO	Atmosphere Station	Mountain	Class 2	State Meteorological Agency of Spain	23.5.2023
6	Majadas de Tiétar	ES-LMa	Ecosystem Station	Savannas	Associated	CEAM Foundation	15.11.2023

ICOS Sweden

ICOS SWEDEN FOCAL POINT
Jutta Holst
Researcher
Lund University
Sweden

contact-sweden@lists.icos-ri.eu
www.icos-sweden.se

Svartberget: a combined Atmosphere and Ecosystem station of ICOS Sweden

The role of ICOS Sweden

ICOS Sweden contributes with a national observation network covering the full latitudinal extent of Sweden, consisting of six Ecosystem stations (three forests, and three mires), three Atmosphere stations, and two Ocean stations. These stations are essential for ICOS, as they provide otherwise scarce data from northern latitudes, which are undergoing the fastest climate change in the world. Climate warming could destabilise the carbon stored in boreal forest soils, accelerate the degradation of the mires and acidification of the seas, with a concomitant impact on Sweden's economy and commitment to enhance carbon sinks.

ICOS Sweden, as a national research infrastructure, aims at having a central role in the support of Swedish biogeochemistry research, at providing test sites for national inventory systems, and at providing sites and databases for advanced research. Furthermore, ICOS Sweden also aims at fostering collaboration and interoperability with other in situ environmental measurement networks and remote sensing programs active in Sweden, and at actively stimulating scientific studies and modelling efforts.

The ICOS Carbon Portal, which is part of the ICOS ERIC, is located in Sweden and it is run by Sweden in conjunction with the Netherlands. Carbon Portal acts as the platform for observational data and elaborated data products of the ICOS RI.

The ICOS Sweden infrastructure

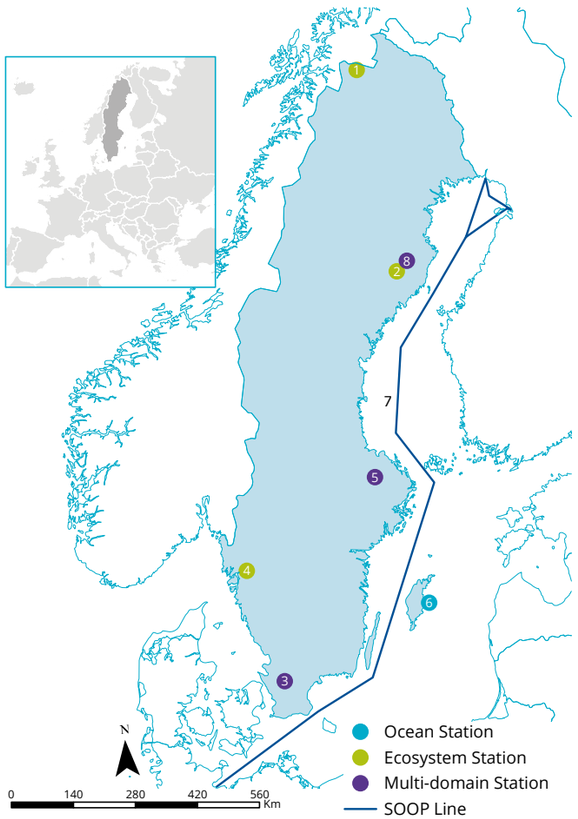
ICOS Sweden is funded as a research infrastructure of national interest and consists at present of a consortium of six partners: Lund University, University of Gothenburg, the Swedish University of Agricultural Sciences, Uppsala University, the Swedish Meteorological and Hydrological Institute, and the Swedish Polar Research Secretariat. Lund University hosts the consortium and the coordination office, with the director of ICOS Sweden also acting as the national Focal Point. All the partners of ICOS Sweden have active roles in many subfields within atmospheric, marine, and earth systems science.

ICOS Sweden contributes to observations in all three ICOS observation networks. The ICOS Sweden network consists of 11 stations (Figure 27; Table 24), of which six are Ecosystem stations representing boreal forests and boreal to subarctic mires, and two are Ocean stations representing the Baltic Sea. The three Atmosphere stations are co-located with the three forest Ecosystem stations, representing a north-south gradient in the country.

The ICOS Sweden research infrastructure has been in operation at most Ecosystem stations since 2014. Three stations have long flux measurement records: Norunda Ecosystem station and Östergarnsholm since 1995, and Degerö since 2001. The Ecosystem stations primarily provide data on greenhouse gas concentrations and fluxes as well as latent and sensible heat fluxes. In addition, several meteorological and soil parameters and complementary ecosystem parameters are measured. The Atmosphere stations include tall-tower measurements of concentrations of greenhouse gases in the well-mixed boundary-layer. The Östergarnsholm Ocean station measures meteorological variables, together with the concentration and fluxes of CO2 and other gases from ocean surface waters and the near-surface atmosphere. The M/S Tavastland SOOP provides continuous data of CO2 and other oceanographic parameters.

All three Atmosphere stations received the ICOS label in 2018. Hyltemossa, Norunda, Svartberget and Degerö Ecosystem stations received the ICOS label in 2018–19, Abisko Stordalen Palsa Bog received the ICOS label in spring 2022. The remaining ecosystem station is expected to be labelled in autumn 2024. All stations are co-located with at least one other RI such as ACTRIS, SITES (a national RI for terrestrial and limnologic field research) and NordSpec (a research network for spectral data collection).

Figure 27: The ICOS Sweden station network. The numbers in the map correspond to the numbers in Table 24. The three multi-domain stations all include atmosphere and ecosystem observations.



ICOS SWEDEN PARTNERS AND FUNDERS

Swedish Research Council
www.vr.se/english.html

Lund University
www.lunduniversity.lu.se

Swedish University of Agricultural Sciences
www.slu.se/en

Uppsala University
www.uu.se/en

University of Gothenburg
www.gu.se/english

Swedish Polar Research Secretariat
polar.se/en

Swedish Meteorological and Hydrological Institute
www.smhi.se/en

The ICOS Sweden funding structure

Funding for the construction and operations of ICOS Sweden is provided by the Swedish Research Council (SRC) and the consortium partners. The Swedish Research Council has covered 40–50% of the costs for the past and current funding period, while the consortium partners together cover 50–60 percent of the costs.

Table 24. ICOS Sweden stations network

MAP NUMBER	STATION NAME	STATION ABBREVIATION	STATION TYPE	SITE TYPE	STATION CLASS	HOST INSTITUTE	LABELING DATE
1	Abisko-Stordalen Palsa Bog	SE-Sto	Ecosystem Station	Sub-arctic fen	Class 2	Swedish Polar Research Secretariat	18.5.2022
2	Degerö	SE-Deg	Ecosystem Station	Boreal fen	Class 2	Swedish University of Agricultural Sciences	21.11.2019
3	Hyltemossa	SE-Htm	Ecosystem Station	Temperate spruce	Class 2	Lund University	31.5.2018
3	Hyltemossa	HTM	Atmosphere Station	Tall tower	Class 1	Lund University	31.5.2018
4	Mycklemossen	SE-Myc	Ecosystem Station	Hemi-boreal fen	Class 2	University of Gothenburg	
5	Norunda	SE-Nor	Ecosystem Station	Hemi-boreal pine/spruce	Class 2	Lund University	30.11.2018
5	Norunda	NOR	Atmosphere Station	Tall tower	Class 1	Lund University	31.5.2018
6	SE-MFT-Östergarnsholm	SE-OES	Ocean Station	MFT and FOS	Class 1	Uppsala University	
7	SE-SOOP Tavastland	SE-TAV	Ocean Station	Ship of Opportunity in Baltic Sea	Class 1	Swedish Meteorological and Hydrological Institute	
8	Svartberget	SE-Svb	Ecosystem Station	Boreal pine/spruce	Class 2	Swedish University of Agricultural Sciences	22.5.2019
8	Svartberget	SVB	Atmosphere Station	Tall tower	Class 1	Swedish University of Agricultural Sciences	31.5.2018

ICOS Switzerland

ICOS SWITZERLAND FOCAL POINT
Nina Buchmann
Professor
ETH Zurich
Switzerland

contact-switzerland@lists.icos-ri.eu
+41 44 632 39 59
www.icos-switzerland.ch

Jungfraujoch: the Atmosphere station of ICOS Switzerland

The role of ICOS Switzerland

The ICOS Switzerland consortium is a member of ICOS RI with two Class 1 stations, Jungfraujoch and Davos. Both of them are unique in terms of their geographical location, site history and relevance for national and international research as well as policy advice. Since the Alpine region will be strongly affected by climate change, information about it is absolutely crucial. A new urban station in Basel city center is supporting urban greenhouse gas emission monitoring and efforts of local climate action plans. Thus, Switzerland, with its exceptional geographic location in the central part of the Alps and its measurement stations, is an outstanding node within the ICOS RI network.

The Swiss consortium builds on long-standing expertise in both atmospheric and ecosystem sciences. Thus, the Swiss ICOS stations are well embedded in various national and international programmes, and ICOS Switzerland is continuously working on increasing the value of its ICOS stations also beyond the ICOS network. For example, synergies with the Aerosols, Clouds and Trace Gases Research Infrastructure (ACTRIS) and the European Long-term Ecosystem Research Infrastructure (eLTER) are pursued, and close interactions with stakeholders are ensured.

The ICOS Switzerland infrastructure

The ICOS Switzerland consortium consists of ETH Zurich (National Focal Point), Empa, WSL, the University of Bern, the University of Basel, and MeteoSwiss. ICOS Switzerland contributes to ICOS RI with one Atmosphere station (Jungfraujoch) and two Ecosystem stations (Davos and Basel, Figure 28; Table 25).

Jungfraujoch (3,572 m a.s.l.) is the highest, permanently manned research station in Europe, and the highest measurement station in the ICOS network. Continuous in situ measurements of reactive gases started in Jungfraujoch in 1973, and measurements of greenhouse gases were initiated in 2000. Due to its elevation and distance from major greenhouse gas sources and sinks, Jungfraujoch station is mainly exposed to air masses representing pristine conditions, but occasionally also to air pollution, especially when air from lower atmospheric layers reaches the station. The information on the background conditions over Central Europe is of key importance in quantifying emission strengths in more polluted environments.

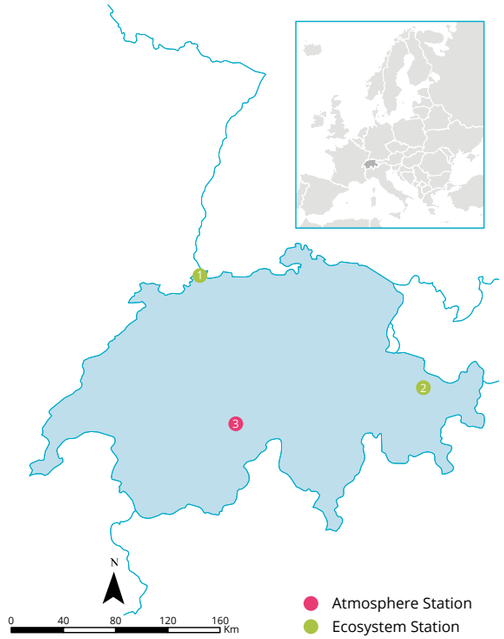
Davos is the only subalpine Norway spruce forest (1,639 m a.s.l.) within ICOS RI, and it is one of the oldest ecosystem flux sites globally. Its record of CO_2 and H_2O vapour flux measurements dates back to 1997. This allows detecting the impacts of slow climate change on the carbon sink capacity of this high elevation forest over time. Moreover, detailed functional, e.g. ecophysiological assessments allow to study how the forest responds to the extreme weather events that are predicted to increase in frequency due to climate change.

The urban station in Basel (264 m a.s.l.), which has one of the longest urban CO_2 flux records worldwide (in operation since 2004), is a significant addition to the ongoing international and national policy and science initiatives to quantify emissions from urban areas using observation-based methodologies. The long-term dataset of the Basel eddy covariance station provides a wealth of information regarding urban emission changes over time.

The ICOS Switzerland funding structure

ICOS Switzerland had been funded by the European Commission (Preparatory Phase, 2008–2012), and since 2013 by the Swiss National Science Foundation, in-house contributions and the State Secretariat for Education, Research and Innovation (Phase 1: 2013–2017; Phase 2: 2017–2021, Phase 3: 2021–2025).

Figure 28: The ICOS Switzerland station network. The numbers in the map correspond to the numbers in Table 25.



ICOS SWITZERLAND PARTNERS AND FUNDERS

Empa – Swiss Federal Laboratories for Material Sciences & Technology
www.empa.ch

ETH Zurich
www.ethz.ch

Federal Office for the Environment (FOEN)
www.bafu.admin.ch/bafu/en/home.html

Federal Office of Meteorology and Climatology (MeteoSwiss)
www.meteoswiss.admin.ch/home.html

International Foundation High Altitude Research Stations Jungfraujoch and Gornergrat (HFSJG)
www.HFSJG.ch

State Secretariat for Education, Research and Innovation (SERI)
www.sbfi.admin.ch/sbfi/en/home/seri/seri.html

Swiss Federal Institute for Forest, Snow and Landscape Research (WSL)
www.wsl.ch/en.html

University of Basel
www.unibas.ch/en.html

University of Bern
www.unibe.ch/index_eng.html

Table 25. ICOS Stations in Switzerland

MAP NUMBER	STATION NAME	STATION ABBREVIATION	STATION TYPE	SITE TYPE	STATION CLASS	HOST INSTITUTE	LABELING DATE
1	Basel Klingelbergstrasse	CH-BaK	Ecosystem Station	Urban	Associated	University of Basel	
2	Davos	CH-Dav	Ecosystem Station	Subalpine forest	Class 1	ETH Zurich, Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), Swiss Federal Laboratories for Material Sciences & Technology (Empa), National Air Pollution Monitoring Network (NABEL/FOEN)	21.11.2019
3	Jungfraujoch	JFJ	Atmosphere Station	Alpine mountain	Class 1	High Altitude Research Stations Jungfraujoch & Gornergrat (HFSJG), University of Bern, Swiss Federal Laboratories for Material Sciences & Technology (Empa), National Air Pollution Monitoring Network (NABEL/FOEN), MeteoSwiss, University of Basel	31.5.2018

ICOS United Kingdom

ICOS UK FOCAL POINT
Andrew Manning
Professor
University of East Anglia
UK

contact-uk@lists.icos-ri.eu
www.icos-uk.org

Weybourne Atmospheric Observatory: an Atmosphere station of ICOS UK

The role of ICOS UK

The Atmosphere Observation network of ICOS United Kingdom (UK) is designed to allow the greenhouse gas budget of the UK to be determined and to quantify the impact of urban landscapes on this budget. The Ecosystem Observation network of ICOS UK is designed to account for the heterogeneity present in UK landscape types and climate, and it aims to sample the uptake of carbon by forests, peatlands and grasslands (the major ecotypes with significant impact on natural and anthropogenic greenhouse gas cycling). The Ocean Observation network of ICOS UK is designed to capture both air-sea gas exchanges and the oceanic sinks of greenhouse gases.

By becoming a full member state within the ICOS network, the UK benefits from and plays its part in the following ways: 1) contributing to developments in cutting-edge greenhouse gas measurement techniques and processes, 2) accessing up-to-date information on the activities within ICOS RI, 3) providing support with station instrumentation, protocols and training, 4) obtaining measurement data in a harmonised and processed pool of open world-class greenhouse gas databases, 5) accessing EU capital funding available through the EU Infrastructure Roadmap, and 6) accessing national capital funding available through the UK RI Roadmap.

ICOS UK also coordinates the Ocean Thematic Centre in conjunction with Norway.

The ICOS UK infrastructure

ICOS UK is divided into three ICOS observation networks: Atmosphere, Ecosystem, and Ocean. The ICOS UK National Network consists of five stations

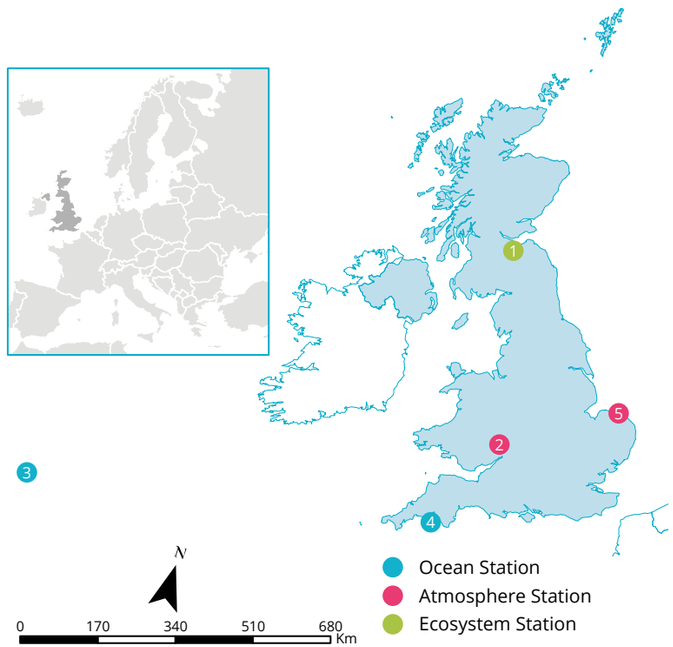


Figure 29: The ICOS UK station network. The numbers in the map correspond to the numbers in Table 26.

(Table 26; Figure 29). At present, ICOS UK has one Ecosystem station (Auchencorth Moss, led by the Centre of Ecology & Hydrology); two Atmosphere stations (Ridge Hill, led by the University of Bristol, and Weybourne, led by the University of East Anglia) and two Ocean stations: the Western Channel Observatory (led by Plymouth Marine Laboratory) and a buoy, the PAP-SO (maintained by the National Oceanography Centre).

Weybourne Atmospheric Observatory is a WMO GAW regional station operated by the University of East Anglia and funded in part by the National Centre for Atmospheric Science (NCAS). In-situ measurements include CO_2, O^2, CH_4, N_2O, SF_6, CO, H_2, Rn, O_3, NO_x, SO_2 and the stable isotopes of CO_2.

The PAP SO buoy (National Oceanography Centre), located at 49° N, 16.5° W, collects high frequency surface and sub-surface CO_2 data.

The Ridge Hill Atmosphere station (University of Bristol) measures greenhouse and ozone-depleting gases from a tall telecommunication tower. High-frequency measurements of all major greenhouse gases are made at Ridge Hill, including CO_2, CH_4, N_2O, SF_6 and a suite of halocarbons. The data from the UK network are used to assess atmospheric trends and UK emissions of these gases.

The Western Channel Observatory is an oceanographic time-series and marine biodiversity reference site in the Western English Channel.

Auchencorth Moss is part of a sensitive peatland ecosystem in central southern Scotland. The latter is a valuable location for long-term monitoring of surface/atmospheric exchange fluctuations and measurements indicating environmental change.

The ICOS UK funding structure

The Natural Environment Research Council (NERC) funds UK institutions via the CLASS programme.

ICOS UK PARTNERS AND FUNDERS

Centre for Ecology and Hydrology
www.ceh.ac.uk

MET Office
www.metoffice.gov.uk

National Centre for Atmospheric Science
www.ncas.ac.uk

National Oceanography Centre (NOC) Southampton
www.noc.ac.uk

Plymouth Marine Laboratory (PML)
www.pml.ac.uk

University of Bristol
www.bristol.ac.uk

University of East Anglia
www.uea.ac.uk

Table 26. ICOS Stations in the United Kingdom

MAP NUMBER	STATION NAME	STATION ABBREVIATION	STATION TYPE	SITE TYPE	STATION CLASS	HOST INSTITUTE	LABELING DATE
1	Auchencorth Moss	UK-AMo	Ecosystem Station	Permanent wetland	Class 1	Centre for Ecology and Hydrology	17.11.2021
2	Ridge Hill	RGL	Atmosphere Station	Tall tower	Class 2	University of Bristol	18.5.2022
3	UK-FOS-PAP	74FS	Ocean Station	Ocean mooring and surface buoy	Class 2	National Oceanography Centre (NOC) and the MET Office	23.5.2023
4	UK-FOS-Western Channel Observatory	UK-WCO	Ocean Station	Ocean mooring and surface buoy	Class 1	Plymouth Marine Laboratory	
5	Weybourne	WAO	Atmosphere Station	Coastal	Class 2	National Centre for Atmospheric Science and the University of East Anglia	17.11.2021

8 APPENDICES

ICOS Terms and definitions

TERMS	DEFINITIONS
Carbon Portal	The combined real and virtual data centre in which ICOS observational and elaborated data products and associated metadata are stored, archived, accessed and curated.
Ethical Advisory Board (EAB)	A group nominated by the General Assembly to advise and periodically report on issues such as science ethics or conflicts of interest.
General Assembly (GA)	The governing and decision-making body of ICOS ERIC. It is composed of representatives of the Member countries of ICOS RI.
Head Office	The ICOS Head Office is the organisational hub of the entire ICOS research infrastructure. The Head Office enables a coherent function of ICOS throughout its highly distributed structure by managing, informing and representing the research infrastructure.
ICOS Research Infrastructure (ICOS RI)	The distributed research infrastructure that is coordinated by ICOS ERIC and involves Central Facilities and ICOS National Networks.
ICOS Central Facilities (CFs)	The centres analysing samples and/or processing data obtained from ICOS NNs, supporting and supervising them and performing technological surveillance on sensors and methods.
ICOS National Networks	ICOS ERIC Member countries' Atmosphere, Ecosystem and Ocean networks of stations.
ICOS Research Infrastructure Committee (ICOS RICOM)	The advisory body for the Director General of ICOS ERIC in all general matters to ensure the consistency, coherence and stability of the Research Infrastructure; it includes one representative from the Head Office, Carbon Portal, each ICOS Central Facility and each Monitoring Station Assembly.

TERMS	DEFINITIONS
ICOS Station	An atmosphere, ecosystem or ocean observatory, as a part of an ICOS national network and either has an ICOS label already or is currently in the process of completing the ICOS labelling. Labelling confirms the station follows the standardised measurement protocols and quality-assurance and data management plans defined in ICOS' internal technical and scientific documents.
ICOS Class 1 Station	An ICOS station which is equipped for measuring the complete set of ICOS parameters with the precision according to the highest ICOS standards.
ICOS Class 2 Station	An ICOS station which measures a reduced set of ICOS variables with the same precision as a Class 1 station (atmosphere and ecosystem domain) or measures the same variables but with a reduced precision (ocean domain) than a Class 1 station.
ICOS Associated Station	(for Ecosystem stations only) An ICOS station which measures a reduced set of parameters and has fewer obligations towards data submission and standards than Class 1 and Class 2 stations.
Monitoring Station Assembly (MSA)	An assembly of scientific and technical experts from the ICOS National Networks; there is one MSA for each thematic area (Atmosphere, Ecosystem and Ocean).
Scientific Advisory Board (SAB)	The group of internationally distinguished independent experts, who analyse and advice ICOS from the scientific perspective.

Abbreviations

ABBREVIATION	FULL NAME
^{14}C	Radiocarbon
$^{14}CO_2$	Carbon dioxide containing a heavy isotope of carbon
ACTRIS	Aerosol, Clouds and Trace Gases Research Infrastructure
ATC	ICOS Atmosphere Thematic Centre
CAL	ICOS Central Analytical Laboratories
CAMS	Copernicus Atmosphere Monitoring Service
CFs	ICOS Central Facilities, i.e., ATC, ETC, OTC, CAL
CH_4	Methane
CMCC	Euro-Mediterranean Centre on Climate Change
CO	Carbon monoxide
COP	The informal name for the Conference of the Parties to the United Nations' Framework Convention on Climate Change (UNFCCC)
CO_2	Carbon dioxide
CRL	Central Radiocarbon Laboratory of CAL
DG	Director General of the ICOS RI
DOI	Digital Object Identifier
EAB	ICOS Ethical Advisory Board
EGU	The European Geosciences Union
eLTER RI	Integrated European Long-Term Ecosystem, critical zone and socio-ecological Research Infrastructure
ENVRI	European Environmental Research Infrastructures
ERIC	European Research Infrastructure Consortium
ESFRI	European Strategy Forum on Research Infrastructures

ABBREVIATION	FULL NAME
ETC	ICOS Ecosystem Thematic Centre
EU	European Union
EUDAT	European Data Infrastructure
FAIR	FAIR data principles: Findable, Accessible, Interoperable, Reusable
FCL	Flask and Calibration Laboratory of CAL
FOS	Fixed Ocean Stations
GA	ICOS General Assembly
GAW	Global Atmosphere Watch programme (WMO programme)
GCOS	Global Climate Observing System
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GHGs	Greenhouse gases
GLODAP	The Global Ocean Data Analysis Project
GTOS	Global Terrestrial Observing System
GNI	Gross National Income
ICOS	Integrated Carbon Observation System
ICOS RI	ICOS Research Infrastructure
ICOS RICOM	ICOS Research Infrastructure Committee
IG3IS	Integrated Global Greenhouse Gas Information System
INRAE	French National Research Institute for Agriculture, Food and Environment
IPCC	Intergovernmental Panel on Climate Change
MFT	Marine Flux Towers

Abbreviations

ABBREVIATION	FULL NAME
MSAs	Monitoring Station Assemblies for ICOS ERIC Member countries' Atmosphere station, Ecosystem station and Ocean station networks
N_2O	Nitrous oxide
NN	ICOS National Network
NOAA	National Oceanic and Atmospheric Administration
NRT	Near-real-time
OTC	ICOS Ocean Thematic Centre
pCO_2	Partial pressure of carbon dioxide in the ocean
PI	Principal Investigator of measurement station(s)
PPFD	Photosynthetic Photon Flux Density
RI	Research Infrastructure
SAB	Scientific Advisory Board
SBSTA	Subsidiary Body for Scientific and Technical Advice
SF_6	Sulphur hexafluoride
SOCAT	Surface Ocean CO_2 Atlas
SOOP	Ship of Opportunity
TCs	Thematic Centres for Atmosphere, Ecosystem and Ocean observations (ATC, ETC and OTC)
UNFCCC	United Nations' Framework Convention on Climate Change
WMO	World Meteorological Organization

The most significant EU projects of ICOS ERIC in 2024

PROJECT NAME	DESCRIPTION
ATMO-ACCESS	The EU Horizon 2020 project "Solutions for Sustainable Access to Atmospheric Research Facilities" (ATMO-ACCESS) is the organised response of distributed atmospheric research facilities for developing a pilot for a new model of Integrating Activities.
ENVRI-Hub NEXT	ENVRI-Hub NEXT aims to expand multidisciplinary environmental sciences by fostering operational synergies between the participating ENVRIs and beyond.
ENVRINNOV	ENVRINNOV aims to co-design, test, and validate a common Innovation Roadmap for the ENVRI community.
ERIC Forum 2	ERIC Forum 2 aims to strengthen the coordination within the ERIC community and enhance collaboration between partners.
ICOS Cities	ICOS Cities (PAUL – Pilot Applications in Urban Landscapes) is an EU Horizon 2020 project that aims to develop a systematic greenhouse gas measurement system for urban areas.
IRISCC	Integrated Research Infrastructure Services for Climate Change Risks (IRISCC) provides scientific and knowledge services to foster cutting-edge research and evidence-based policymaking to improve Europe's resilience to climate change
KADI	Knowledge and climate services from an African observation and Data research Infrastructure (KADI) aims to provide concepts for developing the best available science and science-based services in Africa. KADI is a Horizon Europe project coordinated by ICOS.
NUBICOS	New Users for a Better ICOS (NUBICOS) is a Horizon Europe project coordinated by ICOS. The project aims to strengthen the whole ICOS community by improving data pipelines, welcome a new generation of ICOS community members and further tie ICOS to the RI landscape.
RITrainPlus	The Research Infrastructure Training Plus (RItrainPlus) is an EU Horizon 2020 project which aims to design and deliver a training programme to fulfil the competency requirements for the current and future managers of European Research Infrastructures and Core Facilities.

Members of the ICOS General Assembly

COUNTRY	NAME	AFFILIATION
Belgium	Michele Oleo	Department of Economy, Science and Innovation (EWI), Flemish Government
Belgium	Aline van der Werf	Belgian Science Policy Office (BELSPO)
Czech Republic	Jiří Kolman	Global Change Research Institute of the Czech Academy of Sciences (CzechGlobe)
Czech Republic	Michal Marek	Global Change Research Institute of the Czech Academy of Sciences (CzechGlobe)
Czech Republic	Jiří Švehla	Ministry of Education, Youth and Sports of Czech Republic
Denmark	Mads Rugaard Christensen	Danish Agency for Higher Education and Science
Denmark	Thomas Friborg	University of Copenhagen
Finland	Ritva Dammert (Vice Chair)	University of Helsinki
Finland	Petteri Kauppinen	Finnish Ministry of Education and Culture
Finland	Hannele Korhonen	Finnish Meteorological Institute
France	Thierry Caquet	French National Research Institute for Agriculture, Food, and Environment (INRAE)
France	Gaëlle Decroix	The French Alternative Energies and Atomic Energy Commission (CEA)
France	Jean-Francois Doussin	National Centre for Scientific Research (CNRS)
France	Jean-Marie Flaud	French Ministry of Higher Education, Research and Innovation
Germany	Mathias Herbst	German Weather Service Deutscher Wetterdienst (DWD)
Germany	Christian Plass-Duelmer(Chair)	German Weather Service Deutscher Wetterdienst (DWD)
Greece	Ioannis Gitas	Aristotle University of Thessaloniki
Greece	Michalopoulos Nikolaos	University of Crete
Greece	Nektarios Chrysoulakis	Foundation for Research and Technology Hellas (FORTH)
Hungary	László Haszpra	Institute for Nuclear Research
Hungary	István Bucsi-Szabó	National Research, Development and Innovation Office
Ireland	Frank McGovern	Environmental Protection Agency
Ireland	Micheal Young	Department of Environment, Climate and Communications

Accurate on 1.3.2024

(continues) Members of the ICOS General Assembly

COUNTRY	NAME	AFFILIATION
Ireland	Niamh McCarthy	Environmental Protection Agency
Italy	Cecilia Di Carlo	Italian Ministry of Education, Universities and Research (MIUR)
Italy	Gelsomina Pappalardo	National Research Council (CNR)
Italy	Rosella Marasco	Euro-Mediterranean Center on Climate Change (CMCC)
The Netherlands	Paula Bronsveld	The Netherlands Organisation for Applied Scientific Research TNO
Norway	Jon Børre Ørbæk	Research Council of Norway
Spain	Carlos Torres García	State Meterological Agency of Spain (AEMET)
Spain	Melchor González-Dávila	Institute of Oceanography and Global Change (IOCAG), University of Las Palmas de Gran Canaria (ULPGC)
Spain	María Vallejo	Ministry of Science and Innovation of Spain
Sweden	Ulf Jonsell	Swedish Research Council
Sweden	Sara Moa	Swedish Research Council
Switzerland	Nina Buchmann	ETH Zürich
Switzerland	Maarten Lupker	The State Secretariat for Education, Research and Innovation (SERI)
United Kingdom	Douglas Connelly	National Oceanography Centre
United Kingdom	Thomas Haynes	Natural Environment Research Council (NERC)
United Kingdom	Andrew Manning	University of East Anglia

Accurate on 1.3.2024

Members of the ICOS Scientific Advisory Board

NAME	TITLE AND AFFILIATION
Ankur Desai (Chair)	Professor, Department of Atmospheric and Oceanic Sciences, University of Wisconsin–Madison
John Miller (Co-Chair)	Global Monitoring Division, NOAA Earth System Research Laboratory
Dorothee Bakker	Associate Professor, School of Environmental Sciences, University of East Anglia (UK)
Philippe Ciais	Research Director, Laboratoire des Sciences du Climat et de l'Environment (LSCE)
Eric Kort	Associate Professor, Climate and Space Sciences and Engineering,University of Michigan (USA)

Accurate on 1.3.2024

10 CONTACTS

ICOS ERIC Head Office
Erik Palménin aukio 1
FI-00560 Helsinki
Finland
info@icos-ri.eu

ICOS Carbon Portal
Lund University, Geocentrum II
Sölvegatan 12
22362 Lund
Sweden
info@icos-cp.eu

Atmosphere Thematic Centre (ATC)
Leonard Rivier
LSCE-Orme, point courrier 129, CEA-Orme des Merisiers
F-91191 Gif-sur-Yvette, CEDEX
France
contact-atc@lists.icos-ri.eu

Ecosystem Thematic Centre (ETC)
Dario Papale
DIBAF University of Tuscia, Largo dell'Università – Blocco D
01100 – Viterbo
Italy
contact-etc@lists.icos-ri.eu

Ocean Thematic Centre (OTC)
Richard Sanders
Nygårdsgaten 112
5008 Bergen
Norway
contact-otc@lists.icos-ri.eu

Central Analytical Laboratories (CAL)

ICOS - Flask and Calibration Laboratory (FCL)
Armin Jordan
Technologie Center am Felsenkeller (TCF) – Eingang C
Kahlaische Str. 4
07745 Jena
Germany
contact-fcl@lists.icos-ri.eu

ICOS – Central Radiocarbon Laboratory (CRL), Karl Otto Münnich ^{14}C Laboratory
Samuel Hammer
Heidelberg University
Institute of Environmental Physics
Berliner Straße 53
69120 Heidelberg
Germany
contact-crl@lists.icos-ri.eu

www.icos-ri.eu

instagram.com/icosri

x.com/icos_ri

linkedin.com/company/integrated-carbon-observation-system