



ICOS Sweden Strategic Plan

2023-2028

ICOS

National
Network
Sweden



This plan is compiled by the ICOS Sweden Coordination Office and is based on discussions with and recommendations by the ICOS Sweden Steering Committee, the ICOS Sweden Scientific Advisory Committee and the ICOS Sweden Reference Group. The plan was endorsed by the ICOS Sweden Steering Committee on 2022-12-14.

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1. Scientific and societal framing of the infrastructure

Climate is changing faster at higher latitudes than anywhere else on Earth. Because of Sweden's latitudinal extent and topography, many of our sensitive ecosystems will change and some are at risk of being damaged irreversibly. The study of environmental parameters with detailed, long-term measurements is crucial to understanding the environmental system and its responses to changes in climate. The European research infrastructures (RI) ICOS (Integrated Carbon Observation System), ACTRIS (Aerosol, Clouds and Trace Gas Research Infrastructure) and eLTER (European Long-Term Ecosystem Research) focus on better understanding of the ecosystems and climate through observations and research emerging from this. Each of the complementary RIs has a specific focus: ACTRIS is dedicated to high-quality observation of aerosols, clouds, trace gases and exploration of their interactions. It delivers precision data, services and procedures regarding the 4D variability of clouds, short-lived atmospheric species, and the physical, optical, and chemical properties of aerosols to improve capacity, in understanding the past, current, and future evolution of the atmospheric environment. eLTER provides researchers with access to field sites to promote high-quality research through long-term field measurements and field experiments. ICOS produces standardised, high-precision, and long-term observations to understand the Carbon cycle and provides important information on greenhouse gases (GHG). Observations cover GHG concentrations and fluxes in the atmosphere, meteorological parameters, ecological and oceanic parameters. ICOS is the European pillar of the global GHG observation system. It directly addresses the "Essential Climate Variables" (ECVs) developed under the United Nations Framework Convention on Climate Change (UNFCCC) with essential inputs from other worldwide organisations. Since 2015, ICOS has the legal status of European Research Infrastructure Consortia (ERIC), facilitating the establishment and operation of Research Infrastructures of European interest; ACTRIS is expecting to become an ERIC in the beginning of 2023; eLTER is working towards an ERIC.

The overall aim of ICOS is to facilitate research to understand the Earth system and to derive applied knowledge that supports 'climate action'. Scientific knowledge on carbon emissions, sinks and trends advances the UN Sustainable Development Goals and EU Societal Challenges, especially concerning climate change. It also supports efforts to comply with the COP23 Paris Agreement resolutions with targets to reduce the anthropogenic impact on the global climate and, in the Swedish case, compliance with the Swedish Climate Policy Framework. The Framework is decided upon by parliament and aims for net zero emission of GHGs in 2045, and includes a road map to reach that goal, evaluated annually

ICOS enables, better understanding of the annual variations in the GHG exchange processes

that determine the sources and sinks. To quantify these is important for national commitment negotiations in general, and, in Sweden, as an evaluation tool for the emission roadmap stated in the Climate Policy Framework. It is expected that ICOS data from all domains will be used in future information systems on GHGs, e.g., those that combine improved atmospheric transport models, dynamic vegetation models, and inversion frameworks. The development of such top-down methods will improve the accuracy and usefulness of IPCC emission guidelines, based on carbon inventories, for estimating GHG emissions. Such development requires that the ICOS data is not only of high quality but also interoperable with other environmental measurement systems. The ICOS Ecosystem station network also offers calibration and validation capabilities for a variety of remotely sensed variables through constantly monitored uniform areas around each station. Currently, terrestrial photosynthesis and respiration processes, energy exchanges between ecosystems and the atmosphere and additional variables such as the leaf area index, standing biomass, foliage nutrient ratios, soil organic carbon, nitrogen and soil moisture, disturbances and vegetation phenology and life cycle are monitored. Due to their accuracy, temporal consistency and standardization, these data are being increasingly used for calibrating satellite proxies such as fraction of absorbed solar radiation, photochemical reflectance index or fluorescence (solar induced fluorescence, SIF) and other remote sensing products (soil moisture, canopy radiative temperature, standing biomass). The ICOS ocean station network provides information on spatial and temporal variations of GHG exchange between the ocean and atmosphere, and also provides a validation basis for modeling of the marine carbonate system including carbon transports, sinks and sources. Due to the continuous and high quality measurements, ICOS can even quickly respond to extreme events (e.g. consequences of the drought 2018 or high methane concentrations from the Nord Stream gas pipeline leakages 2022).

ICOS Sweden is the Swedish national network within ICOS RI. It is one of the three pillars focusing on detailed, long-term monitoring of climate and ecosystem response in Sweden. Due to Sweden's geography, ICOS Sweden together with SITES and ACTRIS Sweden provides an opportunity - probably unique worldwide - to study climate system interactions and the impact of climate change on these sensitive ecosystems. Thus, ICOS Sweden is essential for the wider ICOS project as it provides data from a number of important ecosystems at high latitudes including one sub-arctic site. ICOS also links to the national freshwater and marine environmental monitoring programs and to the European Marine Biological Resource Center EMBRC that Sweden joined in 2022. The long environmental time series and knowledge on aquatic ecosystems combined with ICOS time series will provide an important basis for studies of the role of freshwater and marine ecosystems in the carbon cycle.

The existence and mission of ICOS Sweden is determined by the European Union's and the Swedish government's strategic investments in research infrastructures. Furthermore, the

Swedish universities, the Swedish Polar Research Secretariat and SMHI (Swedish Meteorological and Hydrological Institute) fund at least 50% of the cost for managing the infrastructure and running their respective stations. The usefulness of the data and locales for science, as well as the societal use of the results is thus a prerequisite for the financing of the infrastructure. The development of the scientific and political outlines for research and infrastructures is framing the strategic decisions for ICOS Sweden.

The long-term vision is that ICOS observations will be an important source for climate policy research in Europe, large cities and regions. The following topics have been identified by ICOS RI to drive the future development of the observational network:

- 1) ICOS has the utility for detecting the temporal and spatial variations of the GHG exchanges between the three earth reservoirs and to understand their drivers and can contribute to the detection of trends and the understanding of the drivers in land and ocean sinks.
- 2) The ICOS network comprises a multitude of ecosystem sites providing long-term data sets for supporting scientists to improve the best practice guidelines for terrestrial ecosystem management between food production, bioenergy and GHG gas mitigation.
- 3) The quantification of GHG emissions and sinks in urban areas require estimates of emission baselines and changes.

For all these uses, long-term data from a multitude of ecosystems are needed, which is provided by the international ICOS RI, of which ICOS Sweden is an important part.

2. Mission

The mission of ICOS Sweden is to make accurate and high-quality long-term measurements of GHG concentrations in water and air as well as surface exchange fluxes of these gases and their drivers. These measurements are relevant to derive understanding of the processes of climate change in this region. All sites within ICOS Sweden are using measurement systems of the same design and adhering to the measurement protocols and quality control procedures decided upon by ICOS RI. The consistent measurement design makes data highly comparable and robust which is key to developing: a) models and estimation methods for characterizing seasonal source/sink distributions from local to global scales and b) assessing and monitoring the effectiveness of climate change mitigation activities. ICOS Sweden is an integral part of ICOS RI providing such data with a focus on Nordic ecosystems. As a member of the European ICOS RI and the ERIC, ICOS Sweden provides access to extensive knowledge in the field of GHG observations from the European ICOS related measurements and research network. ICOS Sweden will develop towards increased collaboration and interoperability with other in-situ environmental networks and satellite measurement programs, in order to widen

the research and societal usefulness of the data.

3. Vision

This vision refers to a period from the present to 10 years and beyond. The vision includes the four major topics: continuation, optimization, usage, and integration. It assumes a stable funding for ICOS ERIC as well as for the member countries and their national networks, including Sweden and the Swedish national network. In 10 years from now, ICOS will have provided 15 years of data. This robust observation-based data will have been used for science on the carbon cycle, and for quantifying GHG emissions and sinks including their uncertainties. ICOS Sweden will still be an active partner within the European ICOS. All three components Ocean, Atmosphere and Ecosystem will be integrated, and a close collaboration with other neighboring countries e.g., with Finland in the Baltic Sea, will have been established. ICOS Sweden has a central role in the support of Swedish biogeochemistry research, providing test sites for national inventory systems, a near-real time monitoring system for atmospheric pollution, as well as sites and databases for advanced research. ICOS Sweden stations are widely used within education (students, PhD, post docs), and as test sites for new instruments and methods within academia and private-sector companies. As per other European ICOS stations, the Swedish stations will be fully incorporated into the Copernicus satellite services. The collaboration with the other environmental national RIs, SITES and ACTRIS, will have been elevated to a new level with joint approaches for outreach and strategic developments and to maximize synergies among these complementary infrastructures. Synergies with the national environmental monitoring programs and with EMBRC have also been identified and exploited. The representativity of ICOS stations for terrestrial and marine ecosystems has been evaluated and a priority list has been established for the inclusion of new stations into ICOS Sweden.

Standardized work certificates for technical staff working at European ICOS stations will facilitate applying for new jobs and foster career possibilities within ICOS. Student workers will receive certificates specified to their skills within ICOS.

4. Strategic objectives

The strategy of ICOS Sweden to meet the goals of the Vision is outlined below.

4.1 Continuation: To perform robust measurements of highest quality by:

- Following the established ICOS protocols and instructions and contributing to the development of these in collaboration with ICOS RI.
- Ensuring the expertise of the station personnel through education at ICOS RI

workshops and courses on handling of data and instruments to increase exchange of knowledge between countries.

- Ensuring governance and coordination of ICOS Sweden to maintain and strengthen internal cooperation and quality of the products, and external contacts and collaborations.
- Actively seeking financial support to ensure the long-term funding of the RI and services provided to the users.

4.2 Optimization: To optimize the geographical network structure:

- Identifying possible extension of measurements to facilitate research within other disciplines (e.g., boundary layer meteorology, physiological ecology, marine ecology and biogeochemistry, atmospheric physics and chemistry) and thereby enable better understanding of related physical and biogeochemical processes.
- Contributing to development and evaluation of new instruments that have potential for superior measurement capabilities, allowing the network measurement systems to evolve with major shifts in technology.
- Providing a better picture of the Arctic, by establishing an ICOS Ocean station onboard the icebreaker Oden or the new Swedish research vessel.
- Observing and assessing needs for measurements in ecosystems/regions complementing the existing ICOS Sweden RI.

4.3 Usage: To strengthen ICOS Sweden's role in Swedish and international research by:

- Promoting, encouraging, and supporting research utilizing and enhancing ICOS data, at the national or Nordic level, and garnering the results as input to synthesis reports. For example, by providing data for an annual GHG index and an emission verification system for Sweden.
- Promoting, encouraging, and supporting research utilizing and enhancing the use of the ICOS Sweden infrastructure and data by national and international scientists within the field of GHG flux studies and outside this community. Promoting, and supporting education that utilize ICOS, e.g., via under-graduate and graduate (MSc, doctoral) courses using the data and sites.
- Engaging in dialogue with other national or international observation networks, by arranging and participating in meetings and workshops, and by establishing long-term collaborations.
- Ensuring high visibility and accessibility of ICOS Sweden and ICOS RI's data products by communicating with users to facilitate and encourage their use in high-profile scientific papers.

- Ensuring and strengthening scientific and societal benefits of ICOS Sweden's activities and output through supporting ICOS RI outreach efforts like information meetings, workshops, webinars, and training courses.
- Encouraging other research groups and industry to utilize the sites to develop and test new environmental measurement technologies.

4.4 Integration: To foster the integration of the Swedish national RIs

- Fostering the developments within ICOS RI to use ICOS stations for validation and ground truth for satellite platforms.
- Together with the other national RIs SITES and ACTRIS establishing a common Scientific Advisory Committee for defining long-term strategic developments within the Swedish environmental RIs.
- Elaborating a common approach within the national ENRIs to reach out to scientists, authorities, media, and public to communicate results based on measurements at the RI stations.
- Co-localizing the Nordic/national workshops with the other national environmental RIs.
- Working towards a central access point for metadata (e.g., through the Swedish National Data Service SND) to simplify the access to all data measured at a station independently of the responsible RI for users from science, stakeholders, and the public.

5. Activities

In mid-2022, the ICOS Sweden organization and most of its functions have moved from the buildup to the operational phase. All ICOS Sweden Atmosphere Stations and all but one Ecosystem Stations are ICOS labelled stations. The remaining Ecosystem Station, and the two Ocean Stations are expected to become certified before the end of the current funding period (end 2024). ICOS data, from the raw data to the elaborated level, are available at the Carbon Portal for the ICOS labelled stations.

ICOS Sweden has a good representation of the Swedish natural environment with a north-south transect of its key terrestrial ecosystems and marine measurements, a north-south profile of atmospheric measurements and an *in-situ* ocean station with a complementary flux and meteorology measurement system.

ICOS Sweden has built-up collaborations within ICOS RI and with other European Environmental Research Infrastructures (ENVRIs), e.g., in the trans-national access program ATMOaccess. To promote the use of ICOS products and sites in the Nordic, ICOS Sweden with

the other Nordic ICOS RIs has taken an active role in the arrangement of Nordic ICOS Symposiums.

Over the coming four-year period (2023-2026), there are three activities that we will focus on in order to fulfill the objectives:

- Maintaining the scientific and technical expertise of the personnel and promoting long-term, continuous measurements of highest quality of the station equipment (Ch. 5.1).
- Working towards an optimization of the geographical representativity (Ch. 5.2)
- Continue stimulating scientific studies and modelling efforts aiming at increasing the knowledge on carbon emissions, sinks and trends to enable evaluation of the Swedish emission targets (Ch. 5.3).
- Continue fostering collaboration and interoperability with other in-situ environmental measurement networks and satellite programs (Ch. 5.4).

The objectives will be described in more detail below.

5.1 Maintaining the scientific and technical expertise of the personnel and promoting highest quality of the station equipment

ICOS Sweden is both a national research resource and a partner of the international ICOS RI. To fulfill our obligations, we will maintain qualified technical personnel and PIs at our sites. We will ensure that they are kept updated on improvements in the measurements and systems by encouraging participation in meetings, courses, and education. We will also continue support functions of scientific and technical expertise concerning measurement systems and use of data by both internal and external users.

To fulfill aims concerning the quality of the network and its management, as well as to strengthen the role of the consortium partners in the scientific development of the RI and connection to the partner universities, we will continue to engage high-profile PIs and Co-PIs from all consortium partners. These members of the reference group are also essential for the outreach and collaboration activities; they also will participate and initiate national and international discourse. They will be all actively involved when applying for funding to maintain the long-term perspective of the RI.

To fulfill our obligations to ICOS RI and maintain the quality of our network, we will continuously follow and participate in ICOS RIs development of instrumentation and protocols, e.g., by participation in research and development projects initiated by ICOS ERIC.

Equal opportunities for all users and employees is sought in all areas of the RI and will be taken into account in dissemination activities of the RI, e.g. by supporting project and

researcher presentations on the homepage and oral presentations at ICOS meetings and conferences. Diversity and gender balance issues are considered for project prioritization. Data usage is openly available and not controlled for gender equality. In the coming years we will monitor gender distribution and take action where needed.

Renewal of the instrumentation and possible extensions of the measurements will also be identified in the light of possible changes in the research community needs of data and information to address societal challenges. This also includes reoccurring evaluations of the importance of the already existing individual stations for the future development of the full network and its usefulness.

5.2 Working towards an optimization of the geographical representativity of the network

To ensure the best use of the RI, the parallels in variables, ecosystems, and geographical extent need to reflect users' needs. A denser network of ecosystem measurement stations and diversity can be achieved to a certain extent by close collaboration with the RI SITES. The representativity of measurement stations for terrestrial and marine ecosystems will be evaluated and a priority list will be established for the future network design of ICOS Sweden

5.3 Stimulating scientific studies and modelling efforts aimed at increasing the knowledge on carbon emissions, sinks, and trends to effectively evaluate Swedish emission targets

Data and elaborated products based on our stations have been delivered through the ICOS Carbon Portal from the date of certification. Outreach activities directed towards the scientific community will be increasingly important for ICOS Sweden. To ensure ICOS' long-term contributions, ICOS Sweden will mainly target information towards the funders - the Swedish Research Council (SRC) and the station hosting universities and institutions, but also to other funding agencies (e.g. Formas) and the Ministry of Climate and Business to increase funding for relevant research and join relevant international research programs. Activities will include continued active support of ICOS RI outreach activities as workshops, webinars, newsletters, and information meetings.

The main task is to engage and motivate the funders while targeting industry and policy makers. Scientific and societal relevance will be addressed by compiling data and synthesis products. This is being done centrally by ICOS RI and the ICOS Carbon Portal. ICOS Sweden may need to work on adapting material for national use. Showcases on how ICOS Sweden data can be used to improve the understanding of ecosystem functioning, carbon budgets and trends in greenhouse gas concentrations will be identified and featured. An example of such showcases are the 2018 drought, the Warm Winter 2020 initiative or the new bulletin "FLUXES" (www.icos-ri.eu/fluxes) published by ICOS RI supported by the community including ICOS Sweden. We expect more of these initiatives in future. Furthermore, ICOS Sweden will

actively promote research contributing to improvements of the carbon emission accounting, and development of adequate methods to evaluate the Swedish emission roadmap stated in the Swedish Climate Policy Framework. Ongoing research using ICOS Sweden and ICOS RI data will be compiled and spread through outreach channels mentioned above.

5.4 Foster collaboration and interoperability with other in-situ environmental measurement networks and satellite programs

5.4.1 General/International level

At the international level, ICOS RI aims at being the European pillar of a global GHG observation system, within the European Research Area and the ENVRIs. In this role it acts towards Global Climate Observing System (GCOS) and global organizations and networks such as UNFCCC, WMO, UNESCO, UNEP, and GEO (Intergovernmental Group on Earth Observations). ICOS also cooperate with similar research infrastructures in other regions, and thus, actively supports global integration of research on GHG and the carbon cycle. Furthermore, the interoperability with satellite data and e.g., the Copernicus program is a prerequisite for the integration of ICOS into a global observational system and for enabling top-down approaches to assess the GHG cycles, sources, and sinks. Such approaches require measurements from ground-based stations or aircraft and remote sensing data. In the aim of widening the use of the data, evaluation of the possible extension of new measurements within the ICOS Sweden measurement program, as well as technical development of the instruments, are taken into account.

ICOS Sweden will continue collaborating with other national and international in situ ENVRIs active in Sweden such as SITES, ACTRIS¹, eLTER², AnaEE³ and NordSpec⁴.

5.4.2 Collaboration among ICOS - ACTRIS - SITES

The national environmental research infrastructures ICOS, ACTRIS and SITES aim to strengthen their collaboration. This has already been done by a strict co-location of ACTRIS stations with ICOS/SITES stations; ICOS stations are within the SITES domain at three locations; Svartberget is even part of all three RIs. The aim of co-location is to make the systems interoperable in order to widen the use of the data, e.g. for earth system modelers,

¹ ACTRIS – the European Research Infrastructure for the observation of Aerosol, Clouds, and Trace gases. <https://www.actris.eu>

² eLTER – the Integrated European Long-Term Ecosystem & Socio-Ecological Research Infrastructure. <http://www.lter-europe.net/elter>

³ AnaEE – AnaEE offers access to experimental platforms on terrestrial and aquatic ecosystems across Europe. <https://www.anaee.com>

⁴ NordSpec - a research network for spectral data collection, inspired by SpecNet. <https://nordspec.nateko.lu.se>

that need a number of variables from a specific site to validate and constrain their models. Both ACTRIS and SITES have been receiving funding as national RI. SITES is actively supporting the European RI eLTER on becoming an ERIC; SITES will work on becoming the Swedish national node of eLTER when that milestone has been reached.

Both national networks from ICOS and ACTRIS strive for co-organising (co-locating and time synchronized) conferences/workshops on the Nordic level to widen the outreach to potential users. A common communication strategy will be elaborated among ICOS, ACTRIS and SITES.

6. Evaluation of the outcome

The outcome of the activities will be quantified in line with the required key numbers from the Swedish Research Council and adapted to the suggested key performance indicators in the ICOS RI Impact report 2018 that will be updated in the coming years. The ICOS Sweden key numbers to report to SRC are already set in the agreement 2021-24 and revised in spring 2021 to identify complementary key numbers useful for internal evaluation. They are collected annually and reported to the SRC in the beginning of each year.

Based on the user numbers for the past years (Table 1 and 2), following targets will be set for the key numbers:

1. Number of publications per year: > 60
2. Number of data repository downloads: national: > 2000; international: > 40000
3. Number of project PIs (=number of projects): national: > 50; international: > 15
4. Number of site days (=number of days projects used the ICOS sites for measurements, visits etc): > 5000

The targets will be revised together with the strategic plan.

Table 1. Summary of the key numbers for the annual reporting of the infrastructure activities 2021. Data downloads include all levels of data products (Level 0: raw data to level 3: elaborated products).

year	general key numbers	Site visitors and project PIs					Data repository downloads	
		international		national			international	national
		male	female	male	female	unknown		
2016	44	140	129	337	270	0	--	--
2017	64	48	12	100	197	56	2	752
2018	60	15	13	72	69	2	3728	1397
2019	26	75	36	166	97	0	10483	2776
2020	87	35	15	143	84	0	50467	2296

Table 2. User numbers for project PIs, Scientific visitors (site visitors through field courses and excursions) and General public visitors (general public and school children).

year	Project PIs		Scientific visitors		General public visitors
	male	female	male	female	not divided by gender
2016	50	19	355	277	245
2017	40	14	166	227	21
2018	42	12	72	67	32
2019	63	25	163	94	14
2020	49	35	129	64	10
2021	40	30	134	92	10

7. Risk analysis

7.1 Risk of failure on European scale

The risk of failure for ICOS RI is probably very little since ICOS RI is now well established and integrated into other European and global research infrastructures on GHG observations and climate change issues. The number of member countries within ICOS is still increasing and therefor strengthening the relevance of the RI. ICOS RI has also demonstrated its usefulness by for instance taking swift actions on analyses of the CH₄ emissions from the leaking gas pipes in the Baltic Sea. Several of the ICOS atmospheric stations (including the Swedish ones) were providing direct observations on atmospheric CH₄ concentrations which formed the basis for the analyses.

7.2 Risk of failure on national scale

On national level, risks can be connected to (a) the management of the infrastructure, (b) funding issues, and performance of the infrastructure in both, (c) fulfilling the tasks for ICOS RI, (d) attracting users to the RI and (e) use of data.

	threat	countermeasures
Risks at the management level of the RI	Mismanagement leading to problems with the operation of stations, delays or errors in reporting etc.	The director of the infrastructure maintains close contact with the steering committee and station PIs. Steering documents are updated regularly in close collaboration with the reference group (PIs).

Risks connected to funding	Funding provided by the SRC and the consortium partners is not sufficient to continue with the RI as it is. This is mainly relevant at the start of new funding periods. Co-locating ICOS with SITES and/or ACTRIS stations provides possibilities for synergies in the basic infrastructure. However, these synergies are at the same time a risk for the other RI: Under the worst-case scenario, where a station cannot be continued within ICOS, this will have direct consequences for ACTRIS as well, setting their activities at risk. This mainly affects the stations that are not part of the SITES RI, i.e. the stations hosted by Lund University and Uppsala University.	The reference group actively engages in finding funding possibilities outside the SRC.
Risks for failure in fulfilling tasks for ICOS RI	Data loss due to instrument damage/ instrument calibration times	ICOS Sweden manages a pool of spare instruments for most of the key variables of the RI to be able to replace damaged instruments during their repair time, resp. during periods of calibration. However, the pool of instruments is limited.
	internet outage	Raw data from the stations is also stored locally to bridge failures in the internet connection.
	extensive power outages	Power outages of several hours can be backed up using batteries at the stations.
	Local network security regulations interfering with ICOS data chain	Close dialogue between network administrators and ICOS station staff to find

		solutions and workarounds to keep the data chain undisturbed
Risks from HR related problems	Lack of staff due to illness/vacations/employments	The co-location of the RI helps to alleviate periods with low staff. In urgent matters, stations can support each other for a limited time.
	High fluctuation of station staff	Involving all personnel involved in ICOS duties in regular meetings/ workshops increases the feeling of togetherness. Giving all staff the possibility to participate in relevant courses and conferences increases the awareness of the meaningfulness of the measurements that are done.
Risks from failure of attracting users	The number of users and the scientific output lacks behind expectations	The management team actively engages in promoting the use of the ICOS RI. This includes the use of data and the use of stations. ACTRIS/ICOS/SITES seek common outreach efforts to reach a larger community, e.g. synchronization of conferences/workshops

8. Revision of the Strategic Plan

The Strategic Plan will be revised annually.