A European infrastructure dedicated to high precision monitoring of greenhouse gases

Integrated Carbon Observation System

Stakeholders Handbook

2013

SEVENTH FRAMEWORK PROGRAMME

ICOS – Integrated Carbon Observation System

www.icos-infrastructure.eu

A European research infrastructure dedicated to high precision observations of greenhouse gases fluxes

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Foreword

On a yearly basis, we issue an updated version of the ICOS Stakeholder's Handbook. This is a publication where ICOS stakeholders can find current information on the building of the ICOS RI. This is the last Handbook of the Preparatory Phase Project. ICOS is in rapid evolvement at the moment and the Handbook reflects the current situation. We are please to include here updated sections on ICOS Central Facilities, ICOS National Networks and Data Quality Assurance Strategy. The work done in ISIC and its' working groups to develop the ICOS ERIC organisation is not reported in this Handbook, but it forms another aspect to the work regarding establishing an operative research infrastructure.

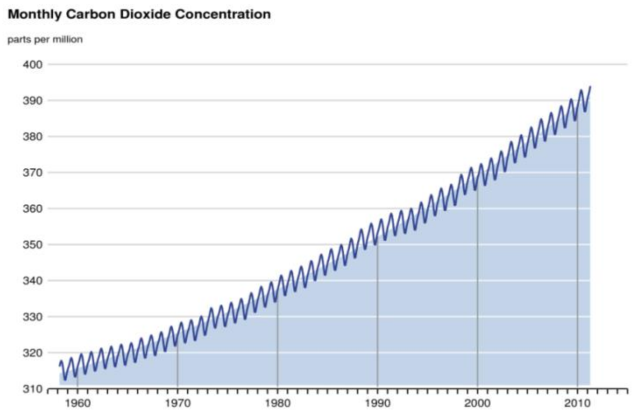
During the preparation of this Handbook the application processes for the Carbon Portal and the Ocean Thematic Centre are in progress. For the other components of the ICOS RI, Stakeholders' Interim Council has made the following decisions among other things:

- *The legal seat of the ICOS ERIC is in Finland; Finland will apply for the ERIC status for ICOS by the end of 2013*
- *The ICOS Head Office is located in Finland, with the secondary node in France*
- *The ATC is located in France, with the Nordic hub and Mobile Lab operated by Finland*
- *The ETC is located in Italy, with operative nodes in Belgium and France*
- *The CAL is located in Germany*

***The mission** of ICOS RI is to enable research to understand the greenhouse gas budgets and perturbations. ICOS RI provides the long-term observations required to understand the present state and predict future behavior of the global carbon cycle and greenhouse gas emissions. Linking research, education and innovation promotes technological development related to greenhouse gases.*

Part 1. ICOS : An Overview

Mission statement: Understanding the greenhouse gas perturbation



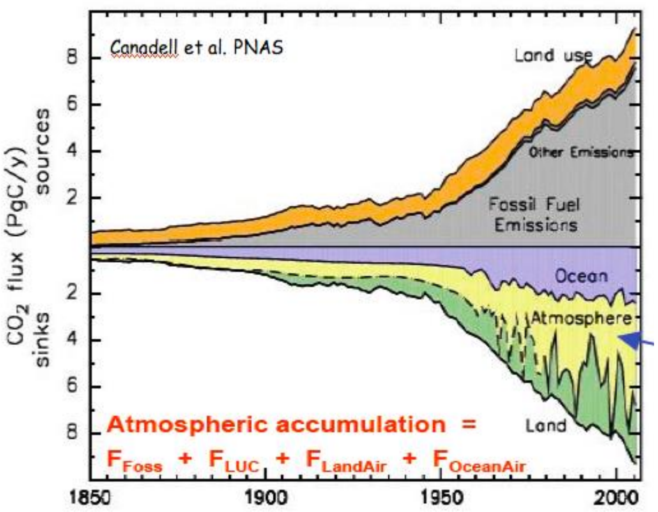
ICOS will provide the long-term observations required to understand the present state and predict future behavior of the global carbon cycle and greenhouse gas emissions.

ICOS will monitor and assess the effectiveness of greenhouse gas mitigation activities on atmospheric composition levels, including attribution of sources and sinks by region and sector.

Climate change is one the most challenging problems that humanity will have to cope with in the coming decades. The Intergovernmental Panel on Climate Change (IPCC) has concluded that the observed rise of global temperatures are very likely due to increasing greenhouse gases in the atmosphere, driven by man-made emissions overtaking the natural cycles of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The perturbed global biogeochemical cycles of these greenhouse gases are a major driving force of current and future climate change.

The concentrations of CO_2 and CH_4 in the atmosphere exceed by far the natural range observed over the last 650'000 years. Current levels of CO_2 have increased by 40% from pre-industrial times and they continue to rise, as fossil fuel emissions are climbing up at a rapid rate. Current levels of CH_4 are nearly two and a half times the pre-industrial value.

These changes are caused by human activities; the primary agents of change are fossil fuel combustion and modifications of global vegetation through land use change, in particular deforestation. The natural carbon cycle offers a discount of 50% by absorbing half of the anthropogenic emissions. It is not clear, however, if these CO_2 sinks will operate in the future under a changing climate and increasing human impacts. At the current atmospheric level of CH_4, the natural oxidizing power of the atmosphere cleans up almost all the CH_4 injected by human and natural sources but expected increases of emissions will further raise CH_4 mixing ratios.



Deeper understanding of the driving forces of climate change requires full quantification of the greenhouse gas emissions and sinks and their evolution. Regional greenhouse gas flux patterns, tipping-points and vulnerabilities can be assessed by long term, high precision observations in the atmosphere and at the ocean and land surface.

"The Mauna Loa curve, simple and unambiguous, thrust itself before humanity's eyes, changing our view of the world. Keeling's work was far ahead of its time. It was the 1970s before other quality-controlled data sets got going. Had we not had his long backrecord, awareness of global change would have come more slowly. Sudden events, such as the marked fluctuations in global CO_2 uptake after the 1991 volcanic eruption of Mount Pinatubo, may have looked very different in the context of a 15-year rather than a 30-year record." *Euan Nisbet, Nature (2008).*

Part 1. ICOS : An Overview

Integrated atmospheric, ecosystem and ocean observations form the basis for advanced carbon cycle research in Europe

It was realized early that, high precision long-term carbon cycle observations form the essential basis for carbon cycle understanding and that these observations must be secured beyond the lifetime of a research project, and must be established at the European level as an infrastructure. ICOS is in the strategic roadmap of ESFRI (European Strategic Forum for Research Infrastructures) for Europe as one of the required Research Infrastructures. ICOS is now on the implementation and construction stage.

The ICOS concept is a high precision long-term network of stations measuring greenhouse gas fluxes from ecosystems and the oceans, and greenhouse gas concentrations in the atmosphere, designed around a set of central facilities. The observations collected by ICOS will enable researchers to gain full understanding of the exchange of greenhouse gases over the European continent, and sources and sinks, using:

- Atmospheric greenhouse gas concentrations of CO_2, CH_4, CO and radiocarbon-CO_2 to quantify the fossil fuel component
- Ecosystem fluxes of CO_2, CH_4, H_2O, and heat together with ecosystem variables needed to understand processes
- Ocean flux observations

The ICOS measurements will be combined using advanced carbon cycle models in an operational information system which permit:

- The detection of systematic changes in regional greenhouse gas fluxes despite their high level of internal variability,
- The reduction of uncertainties in Earth System models
- Early warning of negative developments,
- The timely introduction of mitigation and adaptation measures and the evaluation of their successes.

This system will establish a world class standard for understanding the exchange processes between the atmosphere, the terrestrial surface and the ocean. The routine flux diagnostics will be generated both by research institutes members of ICOS, and by other institutes that will benefit from free access to the observations provided by the infrastructure. Regular assessment and synthesis of the different flux products, and interaction with policy will be organized by ICOS.

The list of variables covered in ICOS matches that of GEOSS (Global Earth Observation System of Systems) recommended to 'support the development of observational capabilities for Essential Climate Variables such as CO_2, CH_4 and other greenhouse gases' according to the 10-years GEOSS implementation Plan. ICOS will also contribute to the WMO Global Atmosphere Watch program, to the Global Terrestrial Observing System (GTOS) and to the international Integrated Global Observing Strategy for Atmospheric Chemistry Observations (IGACO) and for the GEO Carbon Strategy under the GEO umbrella. (http://www.earthobservations.org/index.shtml)

ICOS will strengthen the position of Europe as a global player for in situ observations of greenhouse gases, data processing and user-friendly access to data products for validation of remote sensing products, scientific assessments, modeling and data assimilation.

ICOS and other international research and monitoring programmes

- ICOS-INWIRE (FP7) ICOS Improved sensors, NetWork and Interoperability for GMES
- InGOS (FP7, I3) develops the infrastructure for non-CO_2 greenhouse gases.
- GHG-EUROPE (FP7, IP) will be a prime user of the ICOS data, and provides advanced research tools to use the infrastructure observations.
- CARBOEUROPE (FP6, IP) has developed the scientific case for ICOS, and provides the basic network elements from which ICOS is being built.
- IMECC (FP6, I3) provided key network design tools to the ICOS Preparatory Phase, funding for ecosystem measurement sensors and standard preparation facilities as well as pilot Near-Real-Time concentration data products.
- MACC-II, and GEOLAND2 (FP7,) projects (part of the GMES program) are key users of the high quality, fast delivery atmospheric and ecosystem validation data provided by ICOS.
- GEOMON (FP-6, IP) ensured the link to ICOS with forthcoming satellite observations of column integrated CO_2 (NASA/OCO, JAXA/GOSAT missions) and CH_4 (ESA/SCIAMACHY instrument on ENVISAT) and CO (NASA/MOPITT).
- GEOSS will use the European implementation of the Integrated Global Carbon Observation strategy (IGCO) for atmospheric and biospheric observations, and of the Integrated Global Atmospheric Composition Observation strategy (IGACO) provided by ICOS.
- GEOCARBON is a FP7 project linking the observational data to the end users through advanced products and new knowledge on the carbon cycle.
- IPCC panel members will have access to unique, high precision long term data to understand the carbon cycle and the current perturbation attributed to anthropogenic activities.

Envisaged ecosystem and atmospheric networks

Updated 04/12

Ecosystem level active | Ecosystem level not yet active

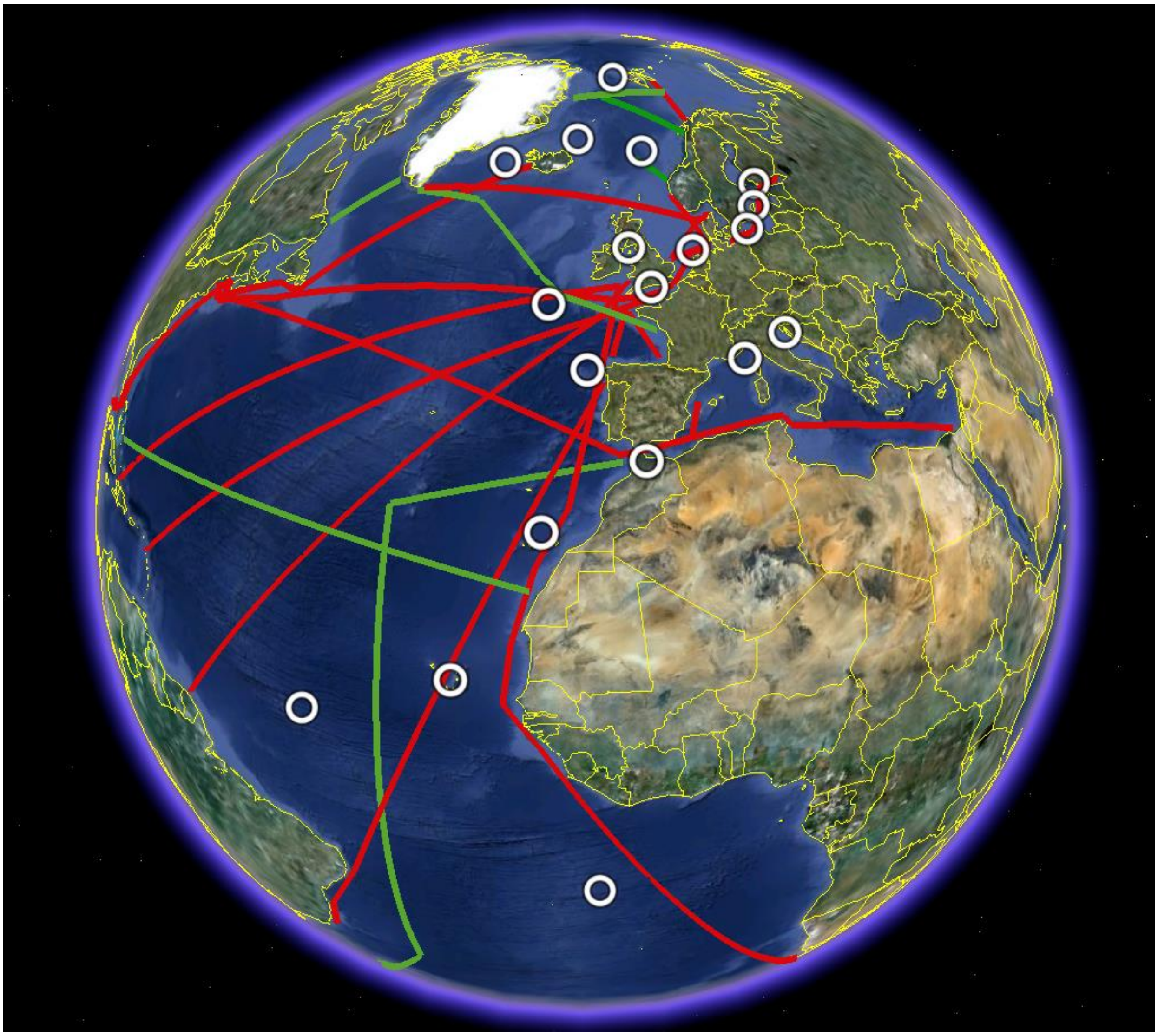
Aircraft active | Aircraft not yet active

Atmosperic ground site active | Atmosperic ground site not yet active

Atmospheric tall tower active | Atmospheric tall tower not yet active

Ocean station

Marine observation routes and stations



The suggested network of stations for the ocean-network: Cicles - Fixed Ocean Stations, Red lines – Ships of Opertunites and Green lines – Repeat Section. In addition, new technologies like floats and gliders will be implement when relaiable and robust autonomious sensors for the purpose is developed.

A distributed infrastructure integrated around a set of central facilities

The ICOS elements, their function and the resources mobilized for their construction and operation are given below, starting from.

- **Head Office** coordinating the research infrastructure at the European level,
- The **ICOS National Networks of atmospheric and ecosystem observation** sites, with more than 30 atmospheric and more than 30 ecosystem primary long term sites located across Europe, with secured funding coverage for 20 years, and additional secondary sites with same analytical precision,
- The **ICOS National Networks of ocean observations** covering the North Atlantic and European marginal seas using “ships of opportunity” and moorings,
- A **Central Analytical Laboratory** for calibration, and air samples analyses including radiocarbon for the entire network,
- An **Atmospheric Thematic Center** responsible for the coordination of atmospheric measurements, instrument development/servicing, and online data processing,
- An **Ecosystem Thematic Center** responsible for total ecosystem flux measurements and component fluxes and carbon pools, including data processing and instrument development,
- An **Ocean Thematic Center**, responsible for co-ordinating continuous marine observations, initial data processing from marine network.

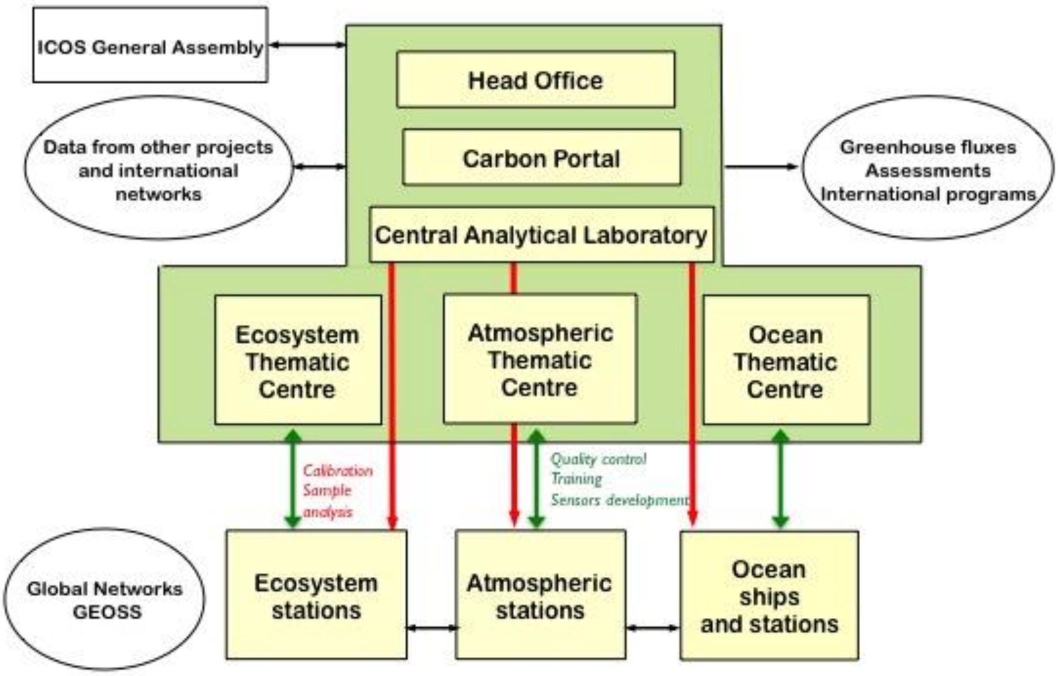


Figure 1. Organizational structure of ICOS

ICOS anticipated users

Once operational, ICOS will provide access to a set of data and products including standards, calibration, protocols, instrumentation, software, information on essential climate and ecosystem variables, and support to environmental policies.

A ICOS user may be a person, organization, program, initiative, protocol, energy utility or business. An ICOS user is any entity, as defined above, that will be interested in using any of the ICOS products. Core users include researchers and students. The main products and services provided for these groups by the ICOS research infrastructure are access to data and access to research infrastructure and training. The users potentially interested in the ICOS products and services belong to a wide variety of entities, ranging from science to policy, from public to the private sector, from mass media to operational monitoring agencies. Additionally any entities that need external independent verification will benefit from the ICOS data. The following categories of potential users can be distinguished:

National and international scientific programmes and environmental agencies that monitor carbon cycle or relevant data

By maintaining a standardized European-wide observation network, ICOS will contribute to monitor the regional carbon cycle in the Earth system. International programmes, like the Global Carbon Project, or the WMO-Global Atmosphere Watch, will integrate ICOS' high precision data for the estimation of key global indicators, like the global budget or the trends of the carbon balance. UN organizations (UNEP, UNESCO, FAO, WMO.), monitoring programmes (GEOSS, GCOS, GTOS), meteorological networks and energy agencies can be included in this group. For the marine component of ICOS, the SOCAT international initiative will be a key integrator of ICOS data.

In the US, NOAA/ESRL's Global Monitoring Division is already seeking to integrate ICOS data into its international collaborative database; and the National Ecological Observing Network (NEON) is seeking data sharing for scientific and validation purpose.

Operational and pre-operational service providers about carbon fluxes

At the continental scale, the products coordinated by the ICOS Atmospheric and Ecosystem Central Facilities will be a key asset for the routine estimation of CO_2 surface fluxes and for data validation. The two main programmes that have expressed interest in ICOS data are the MACC-II Pilot Atmospheric Service and the Geoland2 Land Monitoring Core Service of GMES (both EU Framework 7 programes). The specific data needs and requirements requested from ICOS are established in the GISC report [GMES in-situ coordination, Deliverable 2.1, Report on in-situ data requirements. De Sousa et al., EEA (2011)]. A key institution central to the GMES use of ICOS data is the European Center for Medium range Weather Forecast (ECMWF).
By providing data to the GMES services, ICOS data will extend well beyond the "primary" users (ECMWF, MACC-II, and GEOLAND2 consortia) to a much wider pool of "secondary" users, which include users of products integrating ICOS data into other data sources (including, importantly, space-based Earth observation data). Such secondary users can even be "downstream service providers" themselves in the GMES vocabulary.

Regional authorities

At the country and regional scale, ICOS data and products will be a valuable basis for monitoring the impact of local policies related to the carbon cycle, e.g. in the domain of transport, urbanism, or forestry. Local authorities will likely be involved as well as national governments, governmental agencies, policy makers, and resource management communities.

Protocol verification bodies

ICOS data will provide independent, reliable observations that allow assessment of and, ultimately, verification of various emission reduction measures and associated reporting. Downstream from the flux providers, the ICOS data will be particularly sought after by institutes that monitor the application of international conventions and protocols, like the UNFCCC, the Kyoto protocol and its follow-up or the European Union Emission Trading Scheme. In Europe, institutional bodies, like EEA, are the main actors, but with the set up of binding emission allowances, the private sector will be involved as well.

Scientific communities

The wealth of scientific publications based on the CarboEurope-IP project (2004-2008), one of the precursors of ICOS, highlights the involvement of the scientific communities to fill the gaps of knowledge about the cycle of carbon and associated climate feedbacks through its diverse pools. As a passive atmospheric tracer, CO_2 is also of interest for the validation of atmospheric models. Beyond carbon, ICOS could also provide data to study the nitrogen cycle and all trace gas and aerosol particle exchange between various ecosystems and the atmosphere, and more generally for the atmospheric, terrestrial, and marine communities.

Remote sensing communities

The remote sensing community may benefit from the in-situ atmospheric concentration data. More in particularly, the remote sensing communities deriving land surface properties for calibration and validation of vegetation indices will profit from systematic ecosystem observations as ground truthing. Up to now, in-situ time series have been underexploited as a source of information for land surface products. Atmospheric measurements from space additionally require ground based measurements of ICOS for validation.

Private sector

Industry, and in particular SMEs, are relevant at many level to climate change, renewable energy and GHG related issues. Several companies, (e.g. Earth Networks,Germantown, MD USA) have begun to see the value independent data on greenhouse gas concentrations and fluxes and have expressed strong interest in ICOS data.

Educational organizations

The ICOS data will be essential for studying the carbon cycle and the evolution of greenhouse gases for the education community. The need for GHG data and their implications for global change has been increasingly recognized, even in the early stages of education. Primary and secondary schools increasingly request up-to-date information in order to update their curricula. By making data freely available, ICOS will provide accurate, first hand data to students along with specific products to facilitate the spread of scientific knowledge within the community.

Mass media and the general public

The mass media and the general public seek explanations from scientists but also like to analyse data and facts by themselves; a basis of “citizen science”. As such the interest for ICOS data extends beyond expert communities. Mass media are looking for better, more accurate and up-to-date information about global change news and its implications for communities. The general public (i.e. any individual that wants/needs to know about GHG emissions or absorption in Europe) wants to understand better how our planetary life-support system is evolving over time.

Specific products will be tailored to these different users. For example, respondents to the survey expressed the need for consultation products targeted to policy makers, in order to facilitate environment oriented policy decisions. Similarly, a synthesis of recent findings emerging from ICOS data could be produced every year and distributed to the whole users’ community, considering their implication for all possible uses, such as for policy and education.

Typology of uses of ICOS data

The potential use of ICOS data is related to the following, ranking by importance:

1. comparisons, calibration, and validation (of satellite data and models)
2. monitoring, reporting and verification at both national and international levels
3. assessing carbon fluxes and budgets
4. information and educational purposes
5. synthesis (including maps) and predictions

Overview of users' expectations and needs

Participants in relevant scientific projects are expecting the consolidation of the current European network, and an improved coordination among different EU and international programmes . People not currently involved in ICOS are also keen on developing future cooperation; some users are interested in an enlargement of the ICOS network into new parts of the ocean including coastal areas.

ICOS users express the need for:

- Long term time series of GHG concentrations in the atmosphere, of fluxes over the land, and in the ocean, including associated variables necessary for their interpretation and scaling
- Overcoming the existing substantial problems with regard to continuity and reliability of the current GHG data in Europe due to a lack of QA/QC (Quality Assurance/Quality Control) standards, a lack of reliable calibration facilities and gaps in funding
- Integrating and enabling the availability of new and high-quality observations with ancillary data and elaborated products through the Carbon Portal.

In particular, users would profit from:

- Access to methods and tools
    - QA/QC experience and standard protocols
    - Calibration standards
    - Measurement intercomparisons
    - Instrumental development
- Access to quality-controlled long-term observational data and data products for data assimilation and modelling:
- A set of GHG products processed at levels of varying sophistication where each specific user will find the appropriate answer to their question.
- Access to long-term *in-situ* observation stations for ancillary research
- Training for young scientists and technicians

ICOS will address the problem of data accessibility: very high quality data is useless if not available to the users. As such, this task is one that will be addressed by the ICOS Carbon Portal, a technologically sound and user-friendly web portal with an open access and an open data policy.

Through ICOS, data quality will be improved by an integrated approach at various levels, considering data format, uncertainties, accuracy, QA/QC, and data processing.

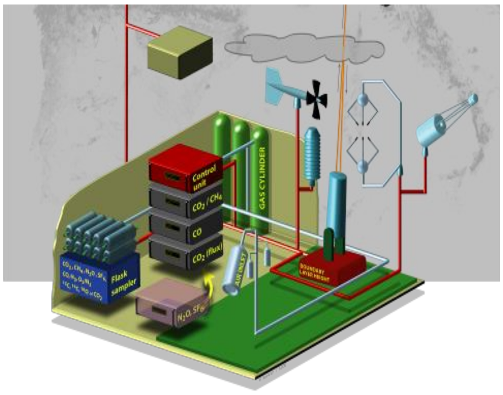
ICOS will implement and promote the use of agreed standards (for data gathering and processing, for example WMO) beyond the ICOS boundaries, promoting the inter-operability of the different systems at global level.

Ad hoc synthesis products for decision makers or educational purposes will be developed. A sound Communication Strategy will be put in place for the ICOS operational phase as a means of achieving maximum visibility of ICOS products outside the scientific community and full promotion of the use of ICOS products for decision makers, students and the general public.

Part 2. Infrastructure elements

Atmospheric Station

Design concept



Atmospheric stations are observatories measuring continuously greenhouse gas concentrations, focusing on the variability due to regional and global fluxes. The ICOS atmospheric network will rely on more than 30 sites distributed across Europe and adjacent regions.
Species of interest include the main anthropogenic greenhouse gases such as CO_2, CH_4 and N_2O, as well as other atmospheric parameters that support the interpretation and analysis of the concentration measurements, such as isotope ratios and meterological parameters. The ICOS Atmospheric Station (AS) consists of commercially available instruments in a computer-controlled integrated system.

Basic ICOS AS characteristics

- standardization of methods and equipment
- modularity including the ability to add the measurments of new parameters
- automatic operation
- local and remote control
- dynamic technological updates (new techniques/gas species)
- less customisation, calibration and maintenance
- lower cost
- continuous air measurements + periodic ”intelligent” air sampling
- two levels of sites (Level 1 and Level 2, Level 2 monitoring less parameters but with the same high precision than for level 1 stations)
- Station ancillary data acquisition (flushing flow rate, room temperature, …) for quality control purpose.

Stations are equipped with dedicated software fulfilling specific requirements:

- Allows the configuration of the AS.
- Provides access and control of the AS (local and remote).
- Allows the display of AS parameters.
- Allows automatic operation of the AS (measurement, calibration).
- Permits to execute measurement sequences.
- Logs the AS state (warnings and alarms) and implements the security routines.
- Handles Station ancillary data
- Handles the data flow and transfer.
- Handles the intra- and extra-AS station communication.
- Allows performing action on all controllable components of the AS.
- Includes a central sequencer for all AS instruments.
- Permits the addition of further instruments to the AS in the future.

Parameters to be measured on Level 1 and Level 2 AS

ICOS AS's modular character will allow for different configurations. However a range of mandatory parameters have been defined to harmonize the stations across Europe. Stations are further divided into two levels. Level 1 stations include a large range of mandatory measurements, whereas Level 2 stations operate only a subset of Level 1 station's mandatory parameters (cf. Table 1).

Table 1: List of parameters measured at ICOS Atmospheric stations

ICOS AS Category	**Gases** Continuous sampling	**Gases** Periodical sampling	**Meteorology**	**Eddy Fluxes**
Level 1 Mandatory parameters	• **CO_2, CH_4, CO** : at each sampling height	• **CO_2, CH_4, N_2O, SF_6, CO, H_2, CO_2 stable isotopes**: weekly sampled 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****	
Level 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 Level 2 stations	• **CH_4 stable isotopes, O_2/N_2 ratio** for Level 1 stations: weekly sampled at highest sampling height		• **CO_2 flux**: at one sampling height

*   Atmospheric temperature and relative humidity recommended at all sampling heights
** Only required for continental stations. PBLH can be retrieved from an appropriate independent dense ceilometers/lidar network.
*** Recommended for its scientific value but support from ATC in terms of protocols, data base, spare will not be assured as long as the parameters are not mandatory.

The list of the mandatory paramaters for ICOS AS Level 1 and Level 2 is to be expanded in the future.
The Atmospheric Thematic Center carries continuous test of new instruments in collaboration with the community (see below). As a result, new instruments can be recommended for addition to the stations. These include new instruments measuring new parameters, justified by both scientific interest and the commercial availability of robust instruments, as well as replacing existing instruments by new ones measuring the same species but with better characteristcs.

The common mandatory parameters measured by ICOS Level 1 and 2 AS (eg. CO_2, CH_4) will be measured using the same equipment and protocol. These observations will have the same level of data quality.

Data transfer and QC

Automated data transfer in ICOS is an important part of the system because it allows, in fine, operational availability of data to the ICOS users.Data will be transfered to the ATC by the AS on a daily basis using SFTP protocol. The data transfer is initiatied by the AS. The protocol for data transmission follows the requirements set up by the ATC.

Metadata characterizing the station will be informed by the station manager using the tools provided by the ATC. The quality control of the data benefits from automatic screening and calculations offered by the ATC, but it will be finalized by the scientist in charge of the station using the ATC tools.

Instrumentation selection and tests

The choice of the instruments to be integrated into the ICOS AS are made based on laboratory and field tests as well as with the feedback from scientific partners. An effort is made to include the scientific community as much as possible in the development process. For this purpose, five ICOS AS instrumentation workshops have been organized in order to exchange information and experience on the instrumentation and thus discuss the ICOS requirements and recommendations. Overall, researchers from more than ten countries and fifteen institutions are participating. The performance and advantages/shortcomings of commercially available and, in some cases, partially customised instruments have been discussed. A web based forum is available (http://icos-infrastructure.eu/forum) in order to promote a more active discussion on the instrumentation and the protocol for the atmospheric station.

Since 2010, several analyzers have been evaluated, both in the central laboratory and in the field during the ICOS Demo experiment (2011) at four stations (Observatoire Pérenne de l'Environnement, Cabauw, Puijo and Mace Head). Based on this work, and on results obtained by other international institutes, the preliminary recommendations have received wide consensus during the fifth Workshop in Arona, Italy (Oct. 20212). These recommendations concern the analyzers for CO_2, CH_4 and CO in-situ measurements, the sensors for the meteorological parameters, and the instruments for PBL height observations. For the later, it has been agreed that a common algorithm is needed to process the raw data from the three systems which have been tested. A first version of the algorithm will be evaluated by the end of 2012. This work will be further developed in the FP7 project, ICOS-INWIRE (http://www.icos-inwire.lsce.ipsl.fr). A first version of the flask sampler has been tested at OPE station during the Demo experiment. More work needs to be done for the automation of this system and to coordinate the sampling with the meteorological parameters and the CO_2/CH_4 and CO measurements in order to sample during favourable conditions to capture significant atmospheric events. This development has also been identified as a task of the European project ICOS-INWIRE.

Working groups have been established during the fourth Atmospheric Workshop (Feb. 2012) in order to provide the measurement guidelines, complete the equipment recommendations and define the ICOS strategy for the quality management within the atmospheric network. The working groups' outcome will lead to the *ICOS Atmospheric Station Specification*.

The demonstration experiment

An ICOS Demonstration Experiment has been initiated in 2011 in order to demonstrate the feasibility of the ICOS infrastructure and its capability to manage properly a network of standardized instruments, with a centralized data processing performed in near real time. For that purpose, the demonstration experiment relied on Demo central facilities (ATC and CAL) and a small demo network made of 4 stations : a Level 1 station at the OPE, a new site in the east of France (operated by ANDRA and LSCE), and 3 Level 2 stations at Mace Head (Ireland), Puijo (Finland) and Cabauw (The Netherlands).

The OPE station has been designed by LSCE/IRFU with the assessment of the ICOS communityin order to likely to constitute the ICOS Atmospheric Station (AS) pattern for the coming construction of new ICOS AS. The Demonstration Experiment aims to test and validate this station design called ICOS AS Demonstrator before deployment.

The level 2 demo stations performed several tests to validate procedures and technical options.

Part 2. Infrastructure elements

In order to take part of the demonstration experiment, these stations must observe the following requirements:

- Use the ICOS standard instrument for the CO2/CH4 measurements (Picarro G1301 or G2301), calibrated with working gases provided by the ICOS-CAL.
- Measure the meteorological parameters: wind direction, wind speed, atmospheric pressure, temperature and relative humidity.
- Send the raw data to the Atmospheric Thematic Center (ATC) in near real time (at least once a day), in a format specified by ATC.
- Perform regular flask sampling in order to compare with the in-situ measurements. For that purpose, the station must have a dedicated sampling line at the same (or highest if several) level as used for the ICOS standard CO2/CH4 instrument.
- Have a dedicated sampling line to receive the travelling ICOS control instrument (closed path FTIR).

The demo experiment is currently in its “extended” phase with more stations (Fig. 1) voluntarily participating (see above for the requirements). This will ultimately implement the envisioned Atmospheric ICOS network described in Section 1 (see network map in that section).

More details on the demo experiment are available on https://icos-atc-demo.lsce.ipsl.fr.

Figure 1: ICOS Extended Demonstration Network

Costs

The preliminary equipment cost and operational manpower estimates for a typical continental station (tall tower with 3 sampling heights) are summarized in Tables 2 and 3 below. While the ICOS AS Level 1 and Level 2 configuration correspond to a station measuring only the mandatory parameters corresponding to its level, the "Extended" configuration of Level 2 stations corresponds to a station equipped for measuring mandatory and additional parameters. The ICOS AS Demonstrator constructed during the project's preparatory phase corresponds to an "Extended" configuration with a higher integration cost due to its advanced control system. The estimates in Table 1 do not include cost for the construction of a tower (if it should be needed) and other infrastructure (eg. Building). The Table 2 do not include manpower cost for the station integration and for data flagging.

Table 2: Estimated equipment cost estimates for the ICOS Atmospheric station (as of Feb. 2013)

Type	Description	Equipment Cost (k€) ICOS AS **Level 2**	ICOS AS **Level 1**	ICOS AS **Level 1 "Extended"**
Parameter measurement				
Meteorological parameters	at 3 tower heights	10	10	10
CO_2, CH_4 continuous in-situ measurement		40-50	40-50	40-50
CO continuous in-situ measurement			+ 25-75 (in addition to CO2/CH4 cost)	+ 25 (in addition to CO2/CH4 cost)
N_2O continuous in-situ measurement				+ 50 (in addition to CO cost)
Periodic air sampling for CO_2, CH_4, N_2O, SF_6, CO, H_2 and CO_2 stable isotopes.	Flask sampler + 100 flasks with shipment cases		40 + 20	40 + 20
Radiocarbon ($^{14}CO_2$) periodic sampling	Integrated sampler (NaCl)		10	10
Boundary Layer structure	Ceilometer or Lidar		30-80	30-80
^{222}Rn				30
CO2 flux by eddy covariance	Fast in-situ CO2 analyzer associated with a 3D wind sensor			30
Air sampling, conditioning and distribution system				
Tubing, valve, pumps, …		15-20	15-20	15-20
Calibration				
Tanks, pressure regulators, …		10	10	10
Integration				
Electrical and computing systems, data acquisition, storage and transmission, integration parts (<u>indicative cost; prone to important variation depending to technical choice and station configuration</u>)		10-50	10-50	10-50
TOTAL		**85-140**	**210-365**	**320-425**

Table 3: **Estimated manpower needs estimate for the operation of the ICOS Atmospheric station**

Manpower Position	**Task**	**Annual Manpower (Man Month)**		
		ICOS AS **Level 2**	ICOS AS **Level 1**	ICOS AS **Level 1 "Extended"**
Technician	Maintenance in-situ gas analyzer	1.5	1.5	2
	Maintenance Meteo	0.5	0.5	0.5
	Flask manipulation		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…	1.5	1.5	1.5
TOTAL		**3.5**	**6**	**9**

Aircraft Profile Site

Design concept

ICOS “aircraft profile sites” are sites where aircraft flights are repeated at regular intervals (e.g. weekly, monthly) to sample the vertical distribution of CO_2, CH_4, and other greenhouse gases and meteorological parameters in the troposphere.

ICOS aircraft profile sites typically complement an ICOS Atmospheric station (tall tower sites) and/or ground based remote sensing sites.

In order to address the main objectives of ICOS, aircraft flights can provide various measurements that are useful in a variety of ways including:

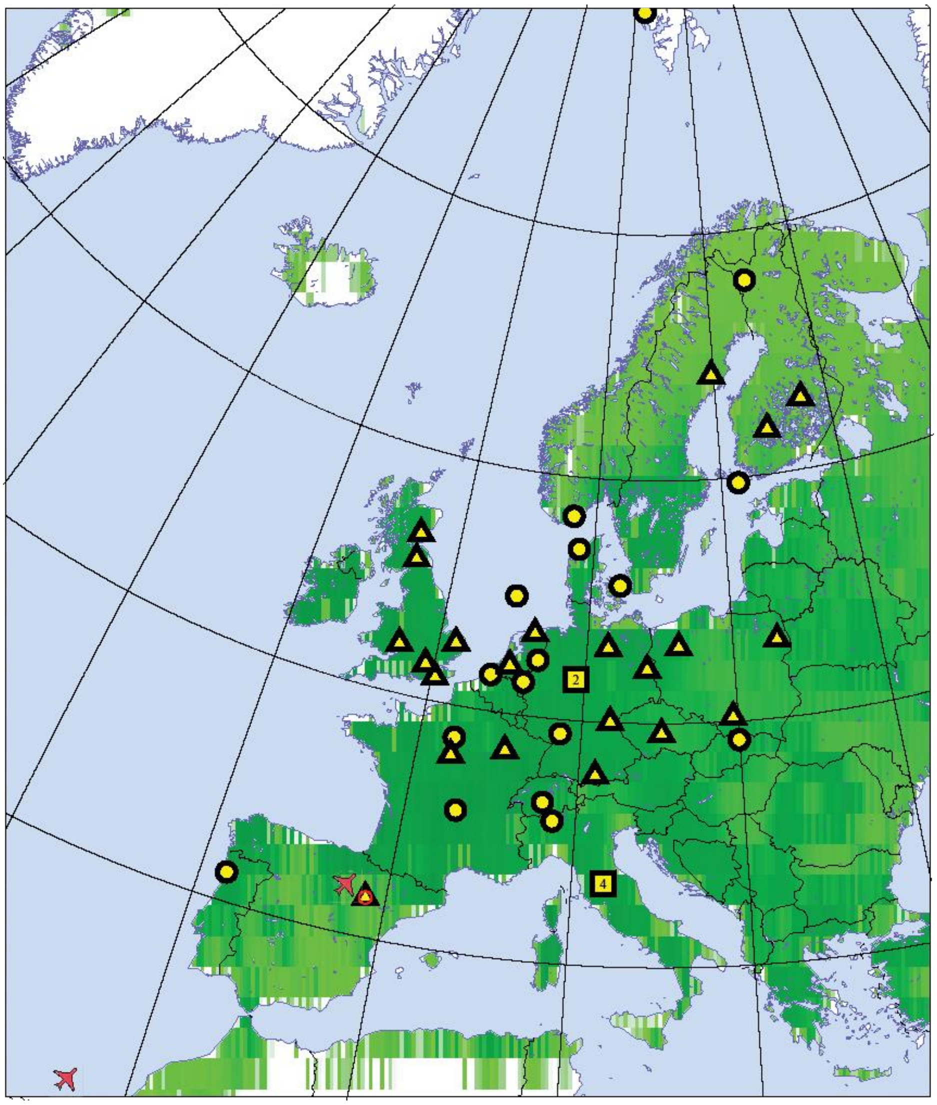
Quantity of interest	Scientific objective	Remark
Vertical profile of CO_2 and CH_4	Providing constraints on vertical distribution and vertical mixing in atmospheric inversions	
Integrated column burden in CO_2 and CH_4	Provide independent information on the total column in order to validate total column observations available in connection with ICOS (TCCON, satellite)	
Vertical and horizontal variability of trace gases	Regional studies, boundary layer budgets	Not to be done regularly, is a by-product of the vertical profiling flight plan

Site selection

An ICOS aircraft site ideally complements an ICOS Atmospheric Station in a rural or background (e.g. large forest) environment.
Very useful values derived from performing vertical profiles over a ground-based remote sensing instrument measuring the integrated column of CO_2 and CH_4 (e.g. FTIR instruments from the TCCON network) as it allows the calibration and validation of this instrument at regular intervals.

Network

The initially planned aircraft network includes 6 locations, each in conjunction with a local ICOS Atmospheric station.



Updated 2013

Flight pattern and frequency

A flight is typically composed of

- A transit phase, during which the aircraft is taking off and flies to the selected profile site;
- A vertical profile, consisting of ascent from the boundary layer into the free troposphere (up to flight ceiling) and descent in the boundary layer, typically performed as a “candle” pattern (spiraling upwards and downwards possibly at distinct locations, to avoid sampling the aircraft’s own exhaust gases)
- A transit phase returning to the airport.

The flight ceiling is generally driven by the aircraft capability (and the associated cost). Charter and research aircraft possibly used in this context have flight ceiling ranging from 3 to 6 km for small and medium propeller aircraft. Higher altitudes (e.g. 9 km, up to the tropopause) can be achieved using jet aircraft, although at a higher cost.

For measurements over surface sites equipped with atmospheric column remote sensing, the highest altitude possible is desirable in order to maximise the description of the atmospheric column.

The return frequency is ideally between 1 week and 1 month, up to 3 months as this would allow adequate sampling of synoptic to seasonal variability.

Data

In-situ data will be processed under the responsibility of the flight PI after each flight, and sent with a common format to the ATC for inclusion in the database:

- Quicklook: 1 week after each flight;
- Validated data: ideally 1 month after each flight, and no later than 6 months after each flight.

The data will be available as atmospheric data in the data centre, and will be covered under the same data policy in use.

Instrumentation

Sampling inlet: type and position

Isokinetic inlets are not needed. Inlets need to be installed far enough to the front of the aircraft to avoid a sampling of its own exhaust.

CO_2/ CH_4

The in-situ measurement of CO_2 and CH_4 follow a calibration strategy that enables traceability of the measurements to the WMO primary scale. For this purpose a simultaneous flask sampling is used for pre- and post-flight calibration on the ground.

The in-situ instrument for CO_2 and CH_4 must follow the same standardization process as for the atmospheric station (all aircraft equipped with the same instrument and perform the same measurement protocol). The choice of instruments can benefit from the experience gained in the IAGOS infrastructure instrumental package selection.

Flasks

The flask sampler being prepared for the ICOS Atmospheric stationsis designed to be reused on aircraft. Adaptation of this flask sampling device may be required for placement in small aircraft. Flasks will conform to the ICOS standard and will be shipped to the CAL (Central Analytical Laboratory) for analysis of the typical ICOS AS species.

Flask sampling will entail a minimum of two flasks (in parallel) at the bottom of the candle (in the boundary layer) and 2 flasks (in parallel) at the top of the candle (in the free troposphere). Ideally, up to 10 flasks are sampled by the aircraft per flight.

Interface with the CAL needs further definition. An approximate estimate for the number of flasks to be analysed and prepared by CAL for the aircraft network is: 6-8 sites x 4 flasks/flights x 6-26 flights/year = between 200 and 1000 flasks annually.

Meteorological parameters

The parameters that are required include: pressure, temperature, humidity. Optional parameters could include wind speed and direction. Boundary layer height should be derived from the measurements with a consistent method across sites.

Other parameters

Other required parameters should include longitude, latitude, pressure and GPS altitudes

Mechanical and electrical integration

Strongly platform-dependent

Costs

Initial equipment costs

- In situ CO_2/CH_4 analysers; potential candidate instruments include for example:
  - In-situ CO_2/CH_4/H_2O instrument ~50k€
  - In-situ CO_2/CH_4/CO/H_2O instrument ~100k€
- Flasks and flasks sampling equipment: 25k€
- Inlet installation and tubing: 5k€
- Racks: 5k€
- GPS : 2 k€
- Meteo probe : 3 k€
- Certification: 5k€
- Total: 90-140k€

Annual costs

(Indicative, strongly dependent on local agreements):

- Example of a charter aircraft rental (small propeller a/c, 3 km flight ceiling, twice a month, sampling site 100 km away from airport): ~1 k€ x 24 = 24k€
- Logistics (transfer from lab to airport, integration in the aircraft): <5k€
- Standard reference gases: 5k€
- Total: ~30k€/year

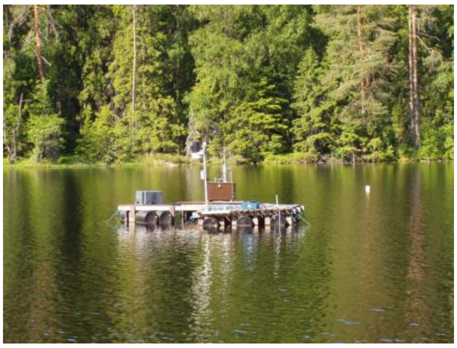
Costs for flask analysis by the CAL must be accounted for.

Required Personnel

Up to 3 person-month per year for a twice a month flight frequency.

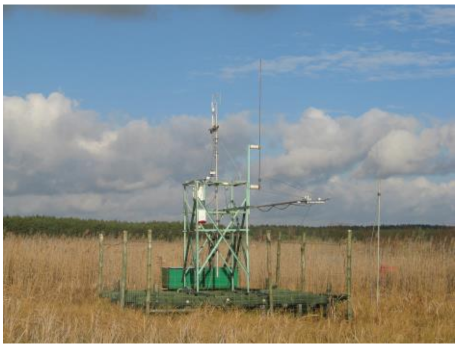
Ecosystem Station

Design Concept

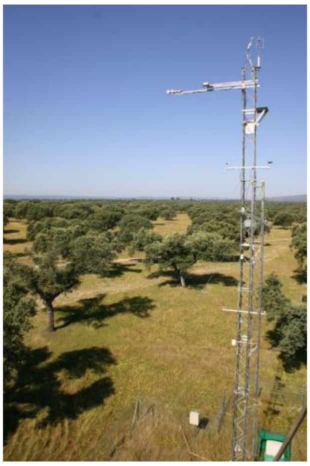


An ecosystem station (ES) is a set-up of instruments, usually on a tower, that measures the flux of relevant greenhouse gases (GHGs), energy and momentum representing local surface surrounding the measurement site, typically within 100 m - 1 km. Additional measurements of ancillary parameters on air, plants and soil (or water body) are also made within this footprint area. The surface can consist of bare soil, vegetation or water. Ideally, the surface around the tower should be homogeneous so that the measured fluxes are representative of the surface irrespectively of the wind direction. Additional data collected at the ES vary depending on type of ecosystem but generally they include continuous measurements of micrometeorological quantities such as temperatures, humidity, radiations, concentration of greenhouse gases and precipitation, and ancillary information such as biomass, vegetation and soil carbon and nutrients, management and disturbance site history. The purpose of the ancillary measurements is to support process studies and to help to understand the physical and biotic factors controlling the GHGs fluxes.

The ICOS operational network adheres to the monitoring principles of the Global Climate and Terrestrial Observing Systems (GCOS and GTOS). These consist of an established set of principles (GCOS Climate Monitoring Principles) that are far from trivial in their practical execution. They concern detailed measurement protocols, quality control and data management plans for secure long-term operation. The instrument setup and measurement protocols of ICOS Ecological Network follow these guidelines, to ensure that the instrumentation yields observations of comparable accuracy and that changes in setups are documented and traceable.



Basic ICOS-ES characteristics include standardization of equipments and procedures, automatic operation as well as local and remote control. As the envisaged life-time of ICOS ecological networks is 20 years, a key feature of ICOS-ES will be the possibility to dynamically implement technological and state-of-the art scientific upgrades, e.g. by introducing new techniques, instruments or observed variables. In order to assure standardization and inter-comparability of measurements among sites across the continent, ICOS will target high standardization for human interventions, such as for calibration and maintenance.



While most of the design of ICOS-ES involves the selection of commercial instruments into an integrated system, a special effort will be paid to the development of measurement protocols The protocols preparation is already ongoing involving the whole scientific community and will give theoretical and practical guidelines to establish and operate an ICOS-ES. In terms of fluxes calculation, the ICOS-ES will ensure a data flow to transfer measurements to the ICOS Ecosystem Thematic Centre (ICOS-ETC) where the data are processed to calculate the fluxes. The ES will have also a dedicated interface at the ETC portal to track the submission status and the site specific agenda for calibrations and specific additional measurements to perform.

One of the main changes in the ES organization occurred in 2012 has been the decision to add also the inland water ecosystems. Inland waters have a significant role in the sequestration, transport and mineralization of organic carbon. Although inland waters are especially important in lateral transporters of carbon, their direct carbon exchange with the atmosphere has also been recognized to be a significant component in the global carbon budget.

The eddy covariance technique has been applied over lakes and it has been demonstrated that it can give important information about these ecosystems. Clearly the list of additional variables needed in these ecosystems is different respect to the terrestrial sites and it is still under refinement, however a first list can be found the following section.

Level 1, Level 2 and Associated Ecosystem Stations

The ICOS ecosystem network will include two levels of ES, referred to as Level1 and Level2 Stations, which will differ for the completeness of the measurements supported and thus for construction, running and maintenance costs. This strategy will enhance flexibility in including ecosystem stations into the network. Nonetheless, as a major characteristic of ICOS is standardization and data quality, all ICOS ES, either Level1 or Level2, will be characterized by a strict standardization of instrumentation and procedures. This implies that costs can be reduced only by reducing the number of instrumentation/procedures supported and variables measured, not their quality. The complete ICOS Level1 Ecosystem Stations (ICOS-ES-L1) will include instruments/equipments for the core measurements listed in Table 1.

However, Stations can be eligible for Level1 ranking even if they do not support all of the core measurements, provided that it can demonstrated (e.g. by means of short term campaigns) that the measurements that are going to be omitted are not relevant for the site into consideration. As an example, a station that does not measure N2O fluxes would be eligible of being an ICOS-ES-L1 if it can be proven that N2O fluxes are negligibly small for that site, e.g. by means of a short-term manual chamber campaigns.

Level 2 sites (ICOS-ES-L2) will feature instrumentations and procedures for the same measurements, with the exception of some high-quality requirements that are relaxed to reduce station realization and operational costs. The complete list of ICOS-ES-L2 variables is also reported in Table 1. As for Level 1, also Level 2 ICOS-ES can be included in the Network even if some variables are not supported, provided they are proved to be negligible for the site.

In the list of the ICOS-ES variables have been included also facultative measurements. These are variables where ICOS will prepare and provide protocols and the ICOS-ETC will accept and process the data, but they are not mandatory (at least in the first ICOS period) to either the L1 and L2 sites.
There will be the possibility also to establish ICOS Associated sites. These sites, that are not part of the ICOS network, will be however hosted in the ETC database. The requirement will be to submit at least one full year of data that must include a set of key variables with full description and meta-information and to accept the ICOS data policy. The associated sites will get the ICOS-Associated status that will be maintained only if the site will continue to submit data. In order to equilibrate the number of L1, L2 and Associated sites at national level the proposal for associated sites must be approved by the National Focal Point.

Table 1: list of variables collected at the different ICOS sites (Level 1 and Level2) for the different ecosystem types

Variable	Forest	Grassland	Cropland	Peatland	Marine	Lakes
CO_2, H_2O and sensible heat fluxes (eddy covariance)	1 & 2	1 & 2	1 & 2	1 & 2	1&2	1&2
Eddy covariance CH4 and N2O	1	1	1	1	1	1
Air CO2 and H2O vertical profile	1	1	1	1	Fac	Fac
Air CO2 vertical profile	2	2	2	2	Fac	Fac
Air H2O concentration	1	1	1	1	1	1
In, Out and Net SW and LW radiation, Surface temperature	1 & 2	1 & 2	1 & 2	1 & 2	1	1
SW incoming radiation high quality	Fac	Fac	Fac	Fac	Fac	Fac
PAR/PPFD incident	1 & 2	1 & 2	1 & 2	1 & 2	1 & 2	1 & 2
PAR/PPFD below canopy + ground reflected	Fac	Fac	Fac	N.R.	N.R.	N.R.
PAR/PPFD reflected	1 & 2	1 & 2	1 & 2	1 & 2	Fac	Fac
Diffuse PAR/PPFD 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 Rh profile	1 & 2	1 & 2	1 & 2	1 & 2	Fac	Fac
Main meteo vars (Ta, Rh, Swin, precipitation)	1 & 2	1 & 2	1 & 2	1 & 2	1 & 2	1 & 2
Total high accuracy precipitation	1	1	1	1	1	1
Rain precipitation	1 & 2	1 & 2	1 & 2	1 & 2	1 & 2	1 & 2
Snow precipitation	1	1	1	1	1	1
Snow heigt	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 temerature	Fac	N.R.	N.R.	N.R.	N.R.	N.R.
Groundwater level	1 & 2	1 & 2	1 & 2	1 & 2	N.R.	N.R.
trees diameter	1	N.R.	N.R.	N.R.	N.R.	N.R.
Phenology-Camera	1	1	1	1	N.R.	N.R.
Soil CO2 automatic chambers	1	1	1	1	1	1
CH4 and N2O fluxes by automatic chambers	1	1	1	1	1	1
Wind speed and wind direction (additional)	1	1	1	1	1	1
LAI	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 N 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 pCO2 surface concentration	N.R.	N.R.	N.R.	Fac	2	2
Oxygen, pCO2 and pN2O 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 distrurbances information	1 & 2	1 & 2	1 & 2	1 & 2	1 & 2	1 & 2

Objectives and time line

The objective goal of the ICOS Preparatory Phase is to put the basis for the construction guidelines of the ICOS ecosystem sites. The strategy is to arrive to a shared set of protocols through the work of focussed working groups with the participation of the ecosystem scientific community. To ensure the comparability with similar initiatives in others continents (e.g. NEON and AmeriFlux in US) the working groups coordinate their activities with the others international efforts. Working groups are open to the participation of all the interested people: to register visit the temporary ETC interface at www.europe-fluxdata.eu/icos.

Status of instrumentation selection and working groups activity

The choice of the instruments to be integrated into the ICOS-ES is made based on scientific literature review, users feedbacks, laboratory and field tests and on the exchange with scientific partners. An effort is made to include the scientific community as much as possible in the development process. The selection criteria are based on accuracy levels of the measurements, reliability in long-term use, user-friendliness, remote control accessibility and automatic functioning features, maintenance requirements, power requirements, initial and running costs. High standardization of the instruments is a crucial ICOS characteristic and objective. The main activity is related to the eddy covariance system; in fact, respect to the meteorological sensors for which international standards exist, the equipments for fluxes measurements (gas analyzer and anemometer) need to be standardized in order to avoid to introduce differences in the data due to the systems used. For this reason they will be exactly the same for all the sites (same company and model). This selection needed and will need great efforts in terms of field and laboratory tests and scientific discussion by the whole ecosystem community.

The ICOS Focal Points during the meeting in Helsinki in 2010 decided to pre-select the LI-7200 as standard ICOS gas analyser for CO2 and H2O requiring additional development by the producer in order to solve issues raised during the field tests. Final decision is expected in 2013 on the basis of the results of the evaluation of the last version of the sensor (currently under test in the ICOS experimental field) and Working Groups discussion.

The sonic anemometer for Eddy Covariance flux measurements has been also pre-selected on the basis of scientific literature review, long-term experiences within the Fluxnet and ICOS Preparatory Phase scientific communities and field tests organized by the University of Tuscia (Italy), taking into consideration robustness, costs, performances and sensor features. The ICOS Focal Point meeting in 2010 pre-selected the Gill HS asking to the company a number of improvements and changes both in the short and long term, including improvement of the temperature linearity and analysis of possible solutions to avoid ice formation on the anemometer in very cold environments. A specific Working Group is focused on this activity.

Given the availability of many commercial meteorological sensors that meet sufficient requirements for the purposes of ICOS and that are under the supervision of WMO, ICOS-ES will defined a set of expected performances rather than a definitive choice of specific firms and models for these sensors. As a consequence, each ICOS-ES station will be allowed to use the sensors that better fit local market conditions provided that the their nominal performances are within the required ranges, thereby assuring a fair and equal competition among sensors producers.

A book of ICOS meteorological sensors has been prepared and includes all the sensors useful to monitor the ICOS variables that meet the required performances. The sensors have been proposed directly by companies and compared with the WMO standards criteria; periodic updates of the book will be released to add new instruments. The final version of the book of sensors will be prepared after the protocol release by the Working Groups.

About the ancillary measurements in addition to the specification of the instruments characteristics requested, detailed protocols are under discussion and will be defined by the ETC on the basis of the results coming from the WG activities ensuring compatibility with others international protocols such the TCO-GTOS or the NEON and AmeriFlux procedures.

Costs

The cost of an ecosystem site is function of the site level and difficult to estimate due to the changes of the single sensor costs, possibility to get discounts from the companies specific for ICOS and different cost of the salaries in Europe. In addition the final cost is also function of the protocols preparation that is still ongoing. To give an approximate estimation based on the list of variables currently under discussion, a L1 site will cost between 90 and 130 keuro and 35 person months per year (depending on which non-CO2 gases are relevant) while a L2 site will require about 60 keuro and 15 person months per year. The costs reported includes all the investment and are calculated on the basis of a 7 years lifetime of all the equipments except the tower.

Fees for the ETC services

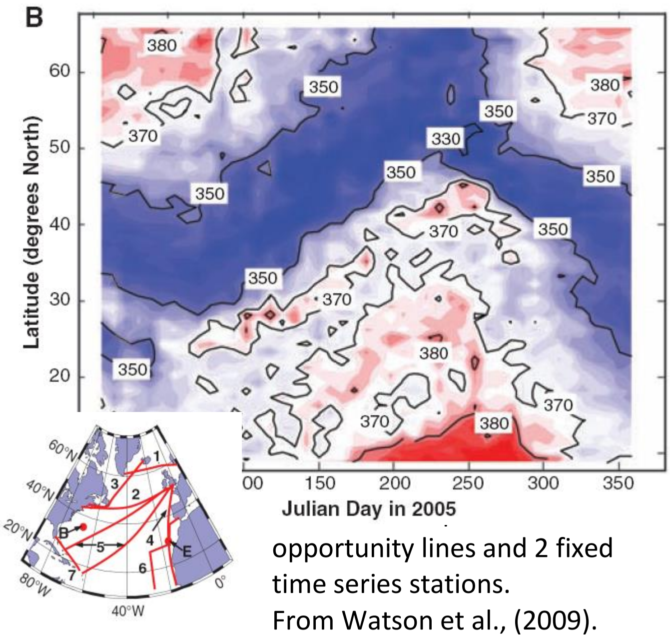
The ES will have to pay an annual fee to the ETC that is function of the site level. The fees for the first years of the ICOS network will be 6000 euro per year for L1 sites and 3000 euro for the L2 sites. These money will cover direct costs for the chemical analysis of the vegetation and soil samples. Also the Associated sites will have to pay an annual fee of 1000-1500 euro as contribution for the infrastructure and these money will be used for the working groups and meetings organization.

Ocean Observations

Prime goals of an ocean observing system in ICOS

Marine ICOS will provide the long-term oceanic observations required to understand the present state and predict future behaviour of the global carbon cycle and climate-relevant gas emissions. The oceanic sink currently offsets approximately 25 % of CO_2 emissions from human activities. Oceanic net air-sea CO_2 fluxes of the Atlantic are a large proportion of the net global marine flux, together with CH_4 and N_2O fluxes.

Quantifying these fluxes are critical for determining the European carbon budget and for accurate accounting of land fluxes. Although the ocea s variable, the variability is much less than for land fluxes. Consequently relative to land-based assessment, marine fluxes can be determined with comparatively simple network of observing ships and other marine platforms to high degree of precision. This has been demonstrated by observations made in 2005 (Watson et al, 2009), see Figure 1.



opportunity lines and 2 fixed time series stations. From Watson et al., (2009).

The oceanic uptake of CO_2 is responsible for ocean acidification, which is expected to have deleterious consequences for marine ecosystems. Marine ICOS observations will also effectively monitor the progress of ocean acidification.

Net marine fluxes of CO_2 vary substantially from year to year and from location to location, and are sensitive to environmental change. Therefore, secure long-term monitoring is crucial for the identification of variability from seasonal to inter-decadal timescales, for the understanding of the underlying causes of this variability, and for the prediction of future variability under expected environmental change.

Carbon exchange between the surface ocean and the atmosphere can not be understood without considering the contribution of the carbon fluxes to the deep ocean. Therefore, global and subsurface measurements must be also taken into account to assess the role of the oceanic compartment in the global carbon cycle. Considering these singularities of the marine ICOS component, the observing system has to deal with other specific aspects of the ocean domain rather than air-sea CO_2 exchange exclusively, which ultimately affect the carbon storage by the ocean. Since the uptake of carbon by the water column is under the influence of several processes of diverse nature subjected to different frequency of variability, the monitoring
program implemented under the ICOS umbrella should guarantee the maintenance and operation of the observational system in the long term.

Sampling strategy

Marine ICOS will support a network of observations in the oceans particularly in the North Atlantic, Nordic Seas, Baltic and Mediterranean. Marine ICOS will build on expertise and results gained during EU-funded science projects (CAVASSOO, CARBO-OCEAN and CARBOCHANGE). In addition, as the observation of CO_2 fluxes is global concern, marine ICOS will work with the global observing community the further the development of network of global observations. Currently this coordination exists through the work of the IOC International Ocean Carbon Coordination Project (IOCCP, http://www.ioccp.org/). Marine ICOS will consequently support appropriate observations in ocean areas other than the North Atlantic as observing platforms extend beyond the core ICOS area (see Figure 2 for the current global network).

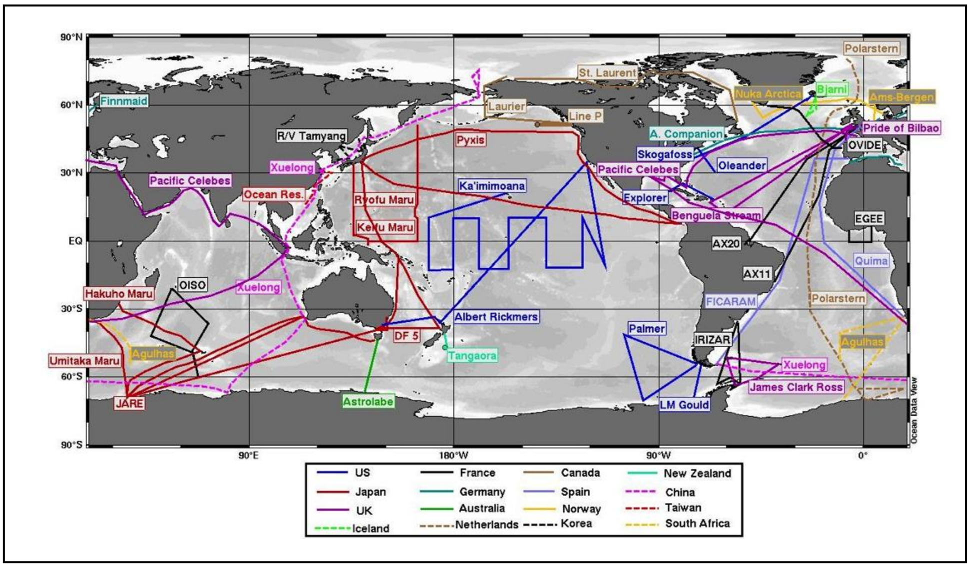


Figure 2: The global network of ships of opportunities currently financed through national funding (from http://www.ioccp.org/).

Figure 3: Examples of some of the ships of opportunity currently in the observing network.

The ICOS marine observation system will consist of approximately 15 major instrumented "ships of opportunity" and 15 fixed time series stations. The ships will usually be commercial ships operating regularly repeated routes, e.g. ferry routes in European shelf and marginal seas, and cargo vessels on open ocean routes. The fixed time series will be points in the ocean at which sustained time series observations are recorded by means of moorings and research ship monitoring.

The ships of opportunity and fixed time series stations will be equipped with a range of automated instrumentation to measure atmospheric and surface ocean pCO2, surface temperature, salinity and related variables. Measurements will be repeated along similar transects at intervals of days to months. Recent work under the FP-6 CARBOOCEAN IP has shown that this coverage is sufficient to constrain air-sea ocean fluxes over the entire regions such as the North Atlantic. To achieve this, the observational data is interpolated to these regions by combining with satellite measurements of surface temperature, winds and the output of real-time ocean forecasting models.

Part 2. Infrastructure elements

In addition to the core platforms used in marine ICOS, ships of opportunity and fixed time series stations, marine ICOS (i) will work 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, (ii) work with the hydrographic community to provide full-depth carbon observations (see below “subsurface measurements”).

Variables to be measured

Type	Parameters	Frequency	Accuracy and precision
Core	Atmospheric pCO_2	Continuous (30 min)	Essential to within 1 µatm Desirable to within 0.1 µatm
Core	Sea surface pCO_2	Continuous (30 min)	To within 1 µatm
Core	Barometric pressure	Continuous (30 min)	To within 0.5 mbar
Core	Sea surface temperature	Continuous (30 min)	To within 0.05 ^oC
Core	Sea surface salinity	Continuous (30 min)	To within 0.1 units
Core	Nutrients ($NO_3 + NO_2$, PO_4, SiO_4)	Periodical, water sampling	To within 1 µM
Core	Dissolved inorganic carbon	Periodical, water sampling	Desirable to within 1 µmol kg^{-1}
Core	Total alkalinity	Periodical, water sampling	Desirable to within 1 µmol kg^{-1}
Additional	Atmospheric flask samples for CO_2, CH_4, N_2O, SF_6, CO, H_2, O_2/N_2, ^{13}C, ^{18}O, ^{14}C in CO_2	As determined by central analytical facility	As determined by the central analytical facility
Additional	Chlorophyll-fluorescence		
Desirable	pH	Continuous (30 min)	To within 0.001 units
Desirable	Total dissolved gas pressure	Continuous (30 min)	
Desirable	Meteorological parameters	Continuous (30 min)	

Spatial and temporal coverage

Whereas the ICOS atmospheric and ecosystem networks cover exclusively European territory, marine ICOS will necessarily hae a more global reach. The focus will be on the oceans adjacent to Europe, but shipping lines will naturally extend further afield.

Area Coverage

Focus will be on the North Atlantic and adjacent seas. The linear coverage along ships tracks will be integrated with satellite based observations and modelled data to provide extrapolation across the surface of the ocean. The satellite data will also be used to assist the interpolation of the data between passages of the ships. Fluxes will be based on ships and satellite measurements of surface temperature, winds and the output of real-time ocean forecasting models.

Temporal coverage

The ships of opportunity will be equipped with automated instrumentation to measure atmospheric and surface ocean pCO2, surface temperature, salinity and related variables. Time series stations will allow more continuous coverage at selected points. Measurements will be repeated along similar transects at intervals of days to a month. Work under the FP-6 CARBOOCEAN IP has shown that this is sufficient to constrain air-sea ocean fluxes over the North Atlantic.

Subsurface measurements

Carbon exchange between the surface ocean and the atmosphere cannot be understood without considering the contribution to the carbon fluxes of mixing from the surface into deeper waters. This requires:-

(1) working with the Argo float community to ensure that information on changes in thermocline and deep water mixing are available.

(2) working with the hydrographic community, e.g. GOSHIP (http://www.go-ship.org/) and in the context of CLIVAR (Climate Variability and Predictability - www.clivar.org/index.php), to ensure that information of transport and storage of carbon within the ocean is linked with surface measurements and air-sea fluxes.

Structure of the network – ships and fixed stations

The Marine ICOS observation network will be based on instrumented "ships of opportunity" and fixed time series stations. Experimental versions of this network have been tested during the EU-funded CARBO-OCEAN project. Marine ICOS will provide the coordination and support required to expand and maintain the network at the required level in the long-term. This will require the liaison of the different national groups within marine ICOS and work with the shipping industry to identify and agree access to ships and routes. The support of the shipping industry is a major factor in this work as they supply ship time worth many millions of euros if the work had to be done by research ships. Effective knowledge exchange with the shipping industry will be achieved through the ICOS ocean thematic centre.

The ship of opportunity network will be complemented by information from fixed time series stations, with 15 such stations capable of providing information currently, this network will be extended through ICOS. The fixed time series will be points in the ocean at which sustained time series observations are recorded by means of moorings and research ship monitoring. Marine ICOS will work with the "Euro-Sites" community to encourage the development of CO_2 related observations where appropriate.

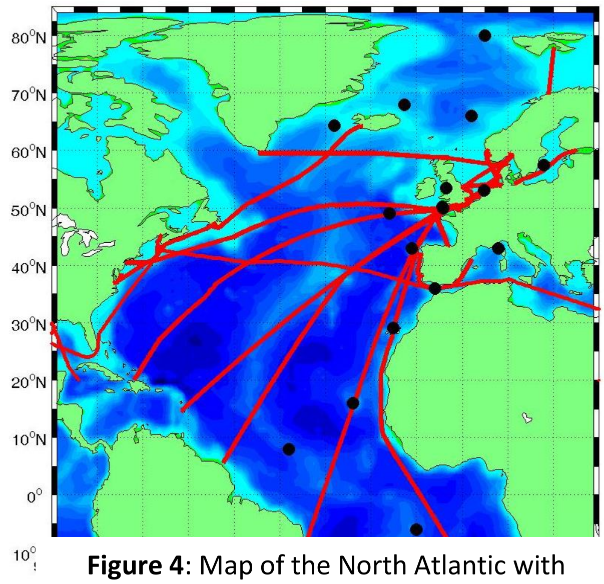


Figure 4: Map of the North Atlantic with Arctic and western Mediterranean, showing ship of opportunity lines (red) and fixed time series stations (black) within marine ICOS.

The Marine ICOS observational network will build on the following lines and stations (Figure 4).

Proposed Ships of opportunity

- Denmark to Greenland line - Norway
- Germany to Canada line - Germany
- UK to Caribbean line - UK
- France to French Guiana line - France
- France to Brazil line - Spain
- UK to South Africa line - UK
- Australia to Canada – Spain
- Tromsø to Svalbard line - Norway
- Iceland to USA line - France

- UK to Spain line – UK
- Nordic Sea –Lines - Norway
- Norway to Netherlands line Norway
- North Sea to Spain line Netherland
- North Sea line UK
- Baltic Sea line from Germany to Finland – Germany
- Iberian Peninsula line Spain
- France-UK line (Western English channel) UK
- France to Spain line (Bay of Biscay) France

Proposed Fixed Time Series Stations

- Hausgarten, Fram Strait - Germany
- Ocean Weather Station M, 66°N / 2°E - Norway
- Irminger Sea, 64.33°N / 28.00°W - Iceland
- Iceland Sea, 68.00°N / 12.67°W - Iceland
- Östergarnsholm, Baltic Sea – Sweden and Finland
- Utö, Baltic Sea – Finland
- Arkona Seas - Finland
- Marsdiep, North Sea – Belgium
- Liverpool Bay, Irish Sea - UK
- L4, western English Channel - UK
- E1, western English Channel- UK
- Station Pap, 49°N / 16°W - UK
- MINAS, off Spain, 43°N / 11°W - Spain
- DYFAMED, Mediterraenean, 43°N / 7.9°E – France
- PALOMA – Italy
- ODAS – Italy
- ENEA – Italy
- GIFT, Gibraltar, 35°N / 5°W - Spain
- ESTOC, Canary Island, 29°10' N / 15°30' W - Spain
- Cap Verde Islands - Germay
- PIRATA 6°S / 10°W tropical Atlantic - France
- PIRATA 8°N / 38°W tropical Atlantic – France

"On the Baltic Sea, the following observations are planned: fixed time series station Östergarnsholm (Sweden) and fixed time series station Utö (Finland)"

Italy added three fixed stations the PALOMA station in the central part of Gulf of Trieste.

Figure 5: Marine activities of Italy

- PALOMA in the Northern Adriatic Sea (coordinates: 45° 37.09 N; 13° 33.913 E)
- ODAS buy (Oceanographic Data Acquisition System) in the Ligurian Sea, deployed in open sea (bottom at about 1400 m) coordinates: 43° 48' 54'' N , 09° 06' 48'' E
  more info at http://www.urp.cnr.it/Boa_Odas/index.html

- ENEA STATION FOR CLIMATE OBSERVATIONS-ROBERTO SARAO Lampedusa Island, coordinates: 35.5° N, 12.6°E more info at http://www.lampedusa.enea.it/index.html

GO-ships Repeat hydrographic sections from the north to the south.

- 75^{o}N - Norway
- Svinøy Section - Norway
- PRIME - UK
- OVIDE - Spain
- 24^{o}N - UK
- A17- Spain
- Weddell- Germay
- More lines might be added at the OTC

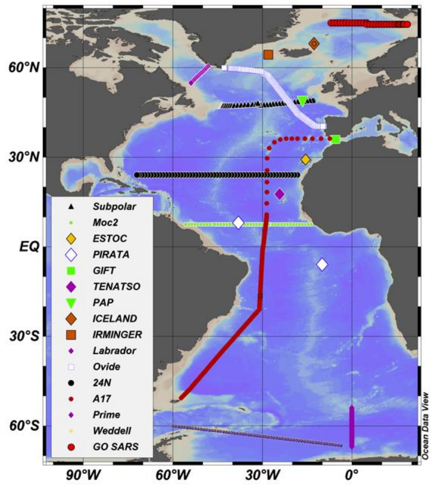


Figure 6: Deep sections: Starting from North. The 75N section with G.O. Sars, Prime Cruise Labrador Sea, the Ovide cruise, 24N section, section A17 and Weddell Section. All sections are measured to full depth and include at least two variables describing the CO2-system Ct and At. The most advance cruise also include chemical tracers as CFC's and variables measuring the organic C-cycle (DOC, POC etc..)

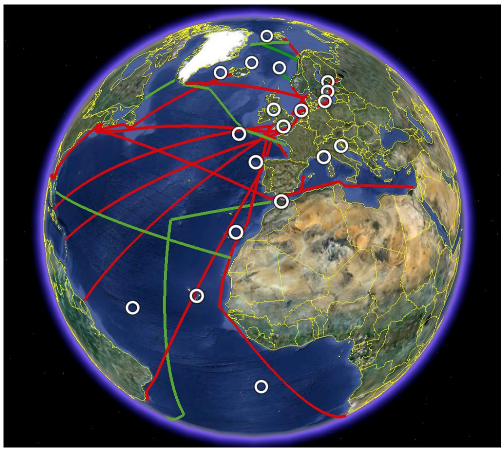


Figure 7: The suggested network of stations for the ocean-network: Cicles - Fixed Ocean Stations, Red lines – Ships of Opertunites and Green lines – Repeat Section. In addition, new technologies like floats and gliders will be implement when relaiable and robust autonomious sensors for the purpose is developed.

Indicative costs of the ICOS ocean observing network

The number of ship of opportunity lines, fixed time series stations and repeat sections potentially maintained by all nations interested in joining the ICOS OTC is at the moment 46. The total cost for Marine ICOS is currently estimated at euros 14628k for set-up excluding shiptime for repeat section and euros about 9850k running costs per year for the first five years. Potentially participating institutions, and the lines or stations to be maintained, are outlined above and visualized in figure 8.

Nations	*VOS*	*Fix Stations*	*Repeat Sections*	*Running Cost*	*Set-up Cost*
Belgium		1		449	690
Iceland		2		895	1380
Italy		3		1347	2070
Finland		1		449	690
France	3	3		1480	2277
Germany	2	2	1	1127	1656
Netherlands	1			45	69
Norway	4	1	2	907	1242
Spain	3	3	2	1760	2553
Sweeden		1		448	690
UK	5	4	2	2296	3381
Total	18	21	7	11203	16698

Figure 8: Nubers in kEURO. The average cost used is: VOS 45kEURO running costs, 69 kEURO set-up cost, fix stations 450 kEURO running cost and 690 set up cost and repeat sections, 138 kEURO pr. line excluding ship time. This is based on average costs.

Products of the ICOS ocean observing network

Marine ICOS data

- An open marine data archive – a joint operation of the ICOS Ocean Thematic Centre, IOCCP, and the Carbon Dioxide Information Analysis Center (CDIAC, http://cdiac.ornl.gov/).
- Measurements of atmospheric and ocean partial pressure of CO_2, sea surface temperature, sea surface salinity, wind speed and atmospheric pressure, and flask measurements of atmospheric CO, CO_2, CH_4, N_2O SF_6, H_2, and N_2/O_2.

Marine ICOS derived products

- Maps of seasonal to annual sea surface pCO_2 and CO_2 air-sea fluxes.
- Annual and seasonal budgets of greenhouse gas exchange over the North Atlantic.
- Regular estimates of the anthropogenic CO_2 inventory in North Atlantic water masses.
- Annual and seasonal budgets of greenhouse gas exchange in other areas such as the Southern Ocean.
- Contribution to annual and seasonal budgets of greenhouse gas exchange over the global ocean.
- Monitoring and assessment of the rate of ocean acidification.
- Variability of the oceanic sink of atmospheric CO_2 under future environmental change.

Users

- EU and National governments for policy development – based on assessments of variability and future scenarios
- Global Carbon Trading organisations
- Research institutions and universities researchers and students;
- More than 20 PhD students per year (a minimum of 1 per participating partner);
- Scientific climate modeling community;
- Global scientific carbon community;
- Met Offices for climate modeling;

A tentative description of the interface with the rest of the infrastructure

- Collaboration with the central analytical laboratory for the analyses of flask samples;
- Collaboration with central analytical laboratory to ensure high quality calibrations of gas standards for oceanic measurements;
- Collaboration with central analytical laboratory for uniform data handling, quality control, and storage;
- Collaboration with all other thematic centres and the central facility for the production of monthly, seasonal, and interannual maps of CO2 sources and sinks in Europe and the adjacent seas.

Rough indication of future implementation

- **2010 to 2013:** All observational lines and stations are operational at the moment. However, some currently have very limited or no financial resources to continue measurements. Hence the first priority is to ensure funding for those lines and stations. Funding must be provided by the stakeholders for a long term operation.
- **January 2013**: The Oceanic Thematic Centre (OTC) proposal submitted.
- **March-June 2013: Evaluation results** and Norwegian-Spain-UK stakeholders discuss the
- **During 2013**: Establishment of the ICOS oceanic thematic centre.
- **2014 to 2016**: The oceanic observational network is brought to full operational status, coordinated by the thematic centre.

- **2016 OTC planned to be in full operation**

Atmospheric Thematic Center

Rationale and general concept

Key to correctly understand and quantify the carbon cycle is to have a long term, high precision and harmonized data set. To that objective, the ATC coordinates the atmospheric measurements in ICOS. The Atmospheric Thematic Center (ATC) is one of the four central facilities of the Infrastructure. It provides a centralized data processing of atmospheric measurements, and a laboratory dedicated to the evaluation of new sensors and instruments to be deployed in the network. It facilitates optimal functioning of the network, provides protocols, procedures and training.

The ATC has the following long-term objectives:

1. Develop and operate the atmospheric data processing chains, going from data transmission from stations to the routine delivery of quality checked data-stream used by modellers;
2. Carry out regular measurement technology survey, analysis and enable development of new sensors and their testing, for instance through R&D programmes;
3. Service the network with spare instruments, training, and high level technical assistance;
4. Link the ICOS atmospheric data collection programme with other ICOS central facilities, in the framework of European and international monitoring programmes.

By meeting these goals, the ATC will help organise the atmospheric network for optimal long term operations. With the ATC, harmonization in procedures and equipment with the appropriate QA/QC plan will greatly improve the robustness and reliability of the atmospheric dataset collected.

Main functions and roles of the ATC

On-line data collection

The first function of the ATC will be to receive online data from all ICOS atmospheric stations on a typical daily basis. The list of parameters measured at an ICOS atmospheric station is given in Table 1 below. The daily raw file will be organized by the local computer of the station, stored on hard disk and transferred to the ATC. Most of the ICOS stations will be located in sites where internet access is available. For remote stations without any link to communication networks, a satellite link will be set-up between the ATC and the station. The station PIs (Principle Investigators) will be responsible for the connection of the ICOS station to the communication network, but the ATC may provide recommendations and possibly technical support. A protocol will be set up at the ATC to check for the correct transfer of the expected daily data files. Automatic emails will be sent to the stations PIs (in case of problem in the data-transmission/gathering process). The raw atmospheric measurement data collected at the ATC will be archived.

Table 1: List of parameters measured at ICOS Atmospheric stations

ICOS AS Category	Gases Continuous sampling	Gases Periodical sampling	Meteorology	Eddy Fluxes
Level 1 Mandatory parameters	• **CO_2, CH_4, CO** : at each sampling height	• **CO_2, CH_4, N_2O, SF_6, CO, H_2, CO_2 stable isotopes**: weekly sampled 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****	
Level 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 Level 2 stations	• **CH_4 stable isotopes, O_2/N_2 ratio** for Level 1 stations: weekly sampled at highest sampling height		• **CO_2 flux**: at one sampling height

* Atmospheric temperature and relative humidity recommended at all sampling heights
** Only required for continental stations. PBLH can be retrieved from an appropriate independent dense ceilometers/lidar network.
*** Recommended for its scientific value but support from ATC in terms of protocols, data base, and spare instruments will not be assured as long as the parameters are not mandatory.

Atmospheric data product levels

- Level 0: Raw data (e.g. current, voltages) produced by each instrument
- Level 1: Data expressed in geophysical units (e.g. ppm-CO_2, m $-s^{-1}$ for wind speed) and useable by modellers to calculate fluxes. Two types of level 1 data will be generated: Rapid Delivery Data (level1a) and Long Term Data (level 1b).
- Level 2: Elaborated time series of concentrations (e.g. gap-filling, combined with meteorological information, source regions, local flux and Boundary Layer Height observations) and other products (e.g. PBL, meteo data, comparaison model-observations)
- Level 3: Higher level products using concentrations and other information (e.g. flux maps, multisensor concentration datasets, data fusion between satellite and in-situ observations ...).

Data processing strategy

The second function will be to ensure a rapid, smooth and traceable processing of the data collected by the atmospheric network. This function incorporates the collection and archiving of all raw data, the establishment of a centralized operational data processing system, and the provision of data to users and the carbon portal. In the data processing, three main steps are foreseen:

- The transmission of stations raw data (level 0 data), ancillary data and all necessary instrument parameters. These data will be archived with the possibility to being re-processed in the future.
- From level 0 data; we will extract the air measurement and the calibration periods, and check the physical parameters provided by the instruments to identify possible periods of failure. In this step, the greenhouse gas and other tracer concentrations will, if needed, be calculated into geophysical units (e.g. ppm for CO_2) based upon Level 0 data, corrected using the calibration information from field standards attached to each station and aggregated in hourly means. Level 1 products will include trace gases concentrations, meteorological parameters, and some information about data quality. On-line quality checks will be performed during this processing stage. An automated quality check will be applied based on the information given by each instrument (e.g. temperature, flow rates …), and on a statistical algorithm to identify suspicious signals. Then, interactive tools will be provided to the station PIs in order to flag the data which correspond to malfunctions of the instruments or to local contaminations. The ATC will be in charge of developing these tools to collect the local expertise. The station PIs will be in charge of making the expert inspection and validation of the dataset.
- Two distinct Level 1 data streams will be generated. The first one is the Rapid Delivery Data (RDD) stream. The maximum delay for RDD (level 1.a product) after in-situ measurement is 24 hours. The second one is the Long Term Data (LTD) stream (level 1.b product). LTD are high precision green house gas (GHG) time series. The precision of the LTD product is increased as compared to RDD data thanks to the a-posteriori calibration information that is included in its computation. Also the LTD has gone through the inspection of the expertise of the station PI.
- Level 2 data products build upon Level 1 data. Using in situ meteorological data collected online at each station, the Level 2 may incorporate information about air masses characteristics collected on an hourly basis, as well as on Lidar Boundary Layer Height measurements and in-situ local CO2 fluxes. Gap filling algorithms will be used in case of missing data intervals. Level 2 data will incorporate information on data representativeness, which is useful for modellers.

Database

The database established at the Atmospheric Thematic Center will be designed to handle the daily input of data from:

1. The stations network involving more than 30 main sites when full operation is in place.
2. The Central Analytical Laboratory (CAL) that will provide regular calibration information, and flask analysis of atmospheric species information

Logistical online information allowing the tracking of the circulation of calibration tanks and flasks between the network and the CAL will be managed by the CAL. The database environment will include software modules enabling remote access to the ICOS atmospheric stations in order to detect instrument failures and launch simple automated diagnostic tests.

The database archiving will be dynamic, complete and robust over time (20 years) to allow for an automatic reprocessing of the whole dataset for instance when primary scale changes will occur (every 3 years on average). Off site backup will be properly dimensioned and operated. The database will ensure fast, dynamic and robust interfacing with user requests. Data and meta-data formats will be enumerated requirements for later requirements flow-down documents. A first estimation of data volume (30 atmospheric assume) amounts to a flow of 500 Go/year.

- Level 0 data will be accessible mostly on request, for research purpose or/and algorithm improvement to update data collection and processing algorithms

- Level 1, 2 data will be accessible to the Carbon Portal of the RI. Level 1, 2 product data will be organized into data collections (versions), resulting from the regular re-processing of level 0 data (raw data).

Sensor development and testing

This function of the ATC concerns the network instrumentation. It will define the requirements needed for the atmospheric network in terms of instrument types, principles, upgrades and maintain interactions with research institutions and industrial partners for stimulating new sensor development. ATC will be testing instruments, and assessing their performances to prepare any decision regarding their deployment in the atmospheric network. Consequently, in order to fulfil this task, the ATC will require a laboratory fully equipped with the instruments routinely used at the network for comparison with new sensors, and with all necessary testing facilities. All instrument tests performed by the ATC will be documented and distributed to the ICOS Partners, in compliance with IPR associated to new sensors or measurement techniques.

In the longer run, the ATC could also organize cooperative research and technological projects, involving partners of the RI, industrial partners and institute outside the RI. The programs will be devoted to fostering the development of new instruments and rigorous testing / qualification procedures.

Monitoring of the atmospheric network

This function of the ATC will be to define with involved partners the standardization of the atmospheric measurements, the instrumental set up, and data collection protocols, taking into account the specificities of each station. The maintenance of the atmospheric stations and instruments will be under the responsibility of the station manager and staff. The data processing chains will help to identify rapidly any drift or anomaly in the quality of the measurements. In such event, staff from the ATC will contact the station manager to outline, identify, understand and help resolve the problem.

The ATC could also manage a small stock of spare instruments to quickly deploy in the network in case of failure of a station where spare instruments are not immediately available. The staff of the ATC will also help the station PI to interact with the instrument manufacturers, and will organize training for the maintenance of the ICOS atmospheric stations.

QA/QC with a mobile laboratory

On site visits performed with a mobile laboratory are part of the QA/QC plan of ICOS. The personnel of the mobile laboratory will examine the site infrastructure and measurement protocols and conduct parallel measurements using its own instruments and standards. The mobile laboratory will produce essential QC documentation of an atmospheric site for internal auditing of the sites. It will also serves ICOS ATC by training visited atmospheric station personnel and providing a useful channel for information exchange between atmospheric station and ATC. It is foreseen that annually about 5 sites will be visited. The sites will be selected to represent all participating countries but prioritizing sites which need data quality improvements according to the ATC on-line and other data quality checks.

Complementarity between ATC, network and other central facilities

As described in the functions of the ATC, there is a built-in complementarity between this central facility and the atmospheric network: Data transmission from stations to the ATC in near real time; quality control of the data by standardized algorithms and the local expertise; support of the network with spare instruments, and training and technical assistance.

Good communication will be needed between the ATC and the Central Analytical Laboratory (CAL). The processing of the atmospheric measurements is based on the raw data gathered from the stations and on the calibration information provided (and regularly updated) by the CAL. Any revision of the calibration scale established by the CAL will have to be propagated down to new versions of the Level 1-2 data processed by the ATC. The ATC will also have frequent interactions with the ecosystem and oceanic thematic centers for coordination, sensors inter-operability, standardization in the data archiving, data formats and processing methods, and sensor development.

ATC in the context of European / international data collection and data management effort

The ATC provides trace gas concentrations and other necessary parameters to the core GMES[1] (Global Monitoring for the Environment and Security) Atmospheric Service via agreed protocols. It will also provide precise GHG concentration for research activities, with information on other trace gas concentrations and boundary layer structure. These data will be archived in the long term and mirrored to the WMO GAW WDCGG (World Data Center on Greenhouse Gases. The data will serve to construct various data products for use by modellers (GLOBALVIEW)

The ATC will implement the IGACO and IGCO strategy within the GEOSS relevant carbon tasks. The ATC will form the backbone of the WMO GAW implementation in European countries for greenhouse gases. The ATC will work in close cooperation with other international measurement networks like NOAA/ESRL and the AGAGE programme.

Organisation and implementation

The functions of the ATC are ensured via several organisational units: the coordination unit has the responsibility to ensure the functioning of the ATC, link to ERIC and participation to the RI committee. The centralised data processing is perfomed via a data unit. The instrumental test and network monitoring units build synergies to perform instrument test and to organize network optimal functioning. The QA/QC mobile laboratory works in close link with the ATC.

[1] http://www.gmes.info/

An open call to set up the ICOS ATC was produced in 2010. An international review of the application sent in by France and Finland was perfomed. Formal approval of the attribution of the ATC to France with Finnish collaboration was done via a letter of intent signed at ministerial level by now fifteen countries in Europe.

Technical implementation of the ATC has started with the atmospheric demo experiment of ICOS in mid 2011. First version of the data processing chains have been put in place for some GHG analysers. As of February 2013, some fifteen stations are now participating to the extended demo experiment for ICOS atmosphere. Also a beta version of graphical application for station configuration management and manual quality control has been developed. More than twenty commercial instruments have been tested for validation under ICOS requirements. A quality insurance program is in place following the ISO 17025 norm on testing and calibration laboratories. During the ICOS Demo experiment, a travelling FTIR instrument was used to test and develop QA/QC procedure. The ATC implementation plan shedules full operation of the center in 2015.

In terms of infrastructure in Saclay, France: an office place platform of 340 m2 has been constructed in 2012. New laboratory space for instrument testing (80 m2) is being constructed and will be finalized mid 2013. It is equipped with a high level air conditioning that guaranties temperature drift less than 1 degree per hour.

In 2012, a van has been purchased and equipped by Finland to host the mobile lab.

The funding agencies for the ATC are CEA, CNRS and UVSQ for France and UHEL and FMI for Finland.

Ten persons are presently working for ATC in France (2 for coordination, 4 in the data unit, 4 for instrument test and network implementation) and 3 persons in Finland.

Central Analytical Lab

Rationale

The mission of ICOS is to run a long-term monitoring network that produces harmonized sets of high precision globally compatible observational data. The atmospheric data sets will be interpreted using high resolution transport modelling. It is likely that progress in this field will continue to be significant, which will result in decreasing model errors. Accuracy and compatibility of observational data hence may emerge as the limiting factor, and even today calibration offsets between stations possibly bias flux estimates. Information on changing emissions and associated carbon cycle responses will be reflected in long-term trends and changing continental gradients. This makes it particularly important to have available highly consistent experimental records over decades.

The demand for highest accuracy and long-term data consistency can best be met with Central Analytical Laboratories, which are currently being established for ICOS. The central Flask and Calibration Laboratory (FCL) will close a still existing gap in providing consistently calibrated reference gases for the European ICOS atmospheric station network, and, through its centralised analysis of flask samples, will eliminate measurement offsets between air samples taken at the stations; this will improve the emerging data sets considerably. Furthermore, a Central Radiocarbon Laboratory (CRL) will provide, through dedicated $^{14}CO_2$ analyses, the necessary high-precision input data to separate the fossil component in the regional CO_2 offset measured at the European ICOS stations.

Concept

Centralised calibration of station standards

For quantitative analysis, instrumental raw data have to be converted to atmospheric concentrations by comparing sample signals with reference standard signals on the same instrument. Therefore, the backbone for comparability of greenhouse gas (GHG) measurements is a clearly defined calibration scale, common to all individual monitoring stations. Measurements generally refer to the calibration scale generated and maintained by the WMO Central Calibration Laboratory (WMO-CCL). However, errors in transferring the calibration have proven to constitute a major cause for inconsistent datasets. Such deficits are partly caused by analytical errors made when calibrating working standards in the laboratories relative to the standards purchased at the CCL. Also for some stations it has been difficult to obtain suitable clean natural air standards as "working" standards for instrument calibration. Instead, synthetic gas mixtures often have been used. These differ in their gas composition from real natural air, which induces different spectroscopic properties, and such can create a systematic bias in the measured data. The CAL will supply calibrated natural air working standards for the entire ICOS atmospheric station network from its Flask and Calibration Laboratory.

Centralised flask analysis

Concentrations of atmospheric CO_2 are affected by the complex interplay of natural and anthropogenic processes. To reveal the actual processes driving the observed changes of atmospheric CO_2, additional tracers can be used that characterize different processes. These additional parameters include:

- other chemical species that are indicative for emissions from selective anthropogenic sources (e.g. CO, H_2 for combustion sources, N_2O from agriculture, SF_6, N_2O for industrial emissions)
- isotopic ratios of CO_2 (and CH_4), which are influenced differently by the diverse processes. As net changes of atmospheric CO_2 concentrations are small compared to gross fluxes through the various natural carbon reservoirs, these processes introduce time-dependent modifications of the atmospheric isotope composition of CO_2. Thus, this signal contributes to our understanding of global and regional carbon budgets.
- O_2/N_2 ratios are linked in different stoichiometric ways to CO_2 emissions from combustion sources and natural terrestrial processes (photosynthesis and respiration), but are not altered by ocean CO_2 uptake. The analysis of O_2/N_2 ratios thus complements CO_2 concentration data and provides additional information on the underlying processes.

A key component of an improved monitoring system will include observations of these tracers. However, the procedures for analyzing these species require stable laboratory environments and a high degree of control, including regular maintenance and supply of consumables like liquid nitrogen, dry ice, etc. These conditions cannot be offered at most monitoring stations. Therefore, the continuous ICOS GHG monitoring is complemented by regular collection of discrete air samples in flasks that will be analysed by the Flask and Calibration Laboratory for the ICOS parameters for periodical sampling (CO_2, $^{13}CO_2$, $CO^{18}O$, CH_4, N_2O, SF_6, O_2/N_2 and eventually CH_4 isotopes). Regular comparison of flask results for CO_2, CH_4 and potentially other trace components with the respective in situ continuous measurements at the monitoring stations will furthermore provide an essential independent quality control of the station measurements.

Centralised Radiocarbon Analysis

Among the tracers providing additional quantitative information on the processes contributing to the CO_2 variations in a polluted region such as Europe, $^{14}CO_2$ measurements are particularly important. CO_2 emissions from fossil fuel burning are the largest single net source over Europe; their contribution can be quantitatively determined by $^{14}CO_2$ observations. However, measuring the very low $^{14}C/C$ ratio in atmospheric CO_2 of order 10^{-12} at the highest possible precision requires dedicated laboratory techniques. Moreover, measuring regional differences which are used to estimate the regional fossil fuel CO_2 component are only small; these analyses will therefore be made by a Central Radiocarbon Laboratory.

Procedure selecting the institutions to set up the CAL

A call for setting up the ICOS CAL in Europe was opened in April 2011. The following requirements to possible applicants had been specified in the CAL concept paper:

(1) Long-term experience in running a laboratory for high-precision analysis of the relevant parameters; (2) an excellent track record in international inter-comparison activity results, (3) maintenance of elaborate laboratory QA/QC procedures, (4) regular publication in international peer-reviewed journals, as well as (5) active contribution to defining measurement requirements at WMO-GAW CO_2 Experts' Meetings. Only one country (Germany) with two laboratories, the Max-Planck Institute for Biogeochemistry (MPI-BGC) in Jena and the Institut für Umweltphysik, Heidelberg University (UHEI-IUP), applied. The German Ministry for Education and Research offered to cover the costs for the complete laboratory set-up (2012-2015) while the

German Federal Ministry of Transport, Building and Urban Development agreed to support the CAL during its operation from 2016-2031.

The MPI-BGC (PI: Dr. Armin Jordan) laboratories for stable isotope and trace gas analysis have played a leading role in quality control and calibration activities of atmospheric measurements in several European research projects in recent years. They have gained international recognition for their methodological contribution to high precision measurements and standardization. This has resulted in their selection as WMO Central Calibration Laboratory for stable isotopes of CO_2 in air and for H_2.

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UHEI-IUP (PI: Dr. Ingeborg Levin) is operating a high-precision radiocarbon laboratory since many decades and is running a cooperative global network of $^{14}CO_2$ measurements to be used for global carbon cycle research. They also pioneered the method of determining the regional fossil fuel CO_2 component through precise $^{14}CO_2$ measurements at a number of German stations and could show that this method will be able to detect fossil fuel CO_2 emissions changes in urban areas of less than 10% within a time period of 5-10 years.

The German application was positively reviewed by two internationally acknowledged experts of the field, the ICOS Interim Stakeholder Council (ISIC) thus decided to give the mandate to Germany for setting up the ICOS CAL in two parts, the Flask and Calibration Laboratory (FCL) to be located in Jena and the Central Radiocarbon Laboratory (CRL) to be located in Heidelberg.

Main functions of the Central Analytical Laboratories

Flask and Calibration Laboratory (FCL)

Standards production. Calibration of field instruments has to cover the full range of atmospheric mole fractions that can be expected at a monitoring site considering diurnal, seasonal, and inter-annual variability. The FCL will run a facility to produce real air calibration gas mixtures. This includes a compressor unit to fill dried air into high pressure cylinders as well as equipment to modify the standard composition by increasing or reducing the content of specific trace gases. The FCL tasks will also include testing and conditioning of the high pressure cylinders before the filling.

Calibration. The FCL will have analytical instruments that permit utmost accuracy in the calibration of reference standards. It will ensure that these calibrations are traceable to the respective WMO scales by maintaining a suite of standard gases purchased from the WMO-CCL in compliance with the Expert Groups' Recommendations of the WMO/IAEA.

Analytical tasks. The FCL will analyse flask air samples collected by the ICOS network for the core parameters specified in the ICOS Preparatory Phase work plan. For this purpose a gas chromatography and a mass spectrometry laboratory are currently set up with a capacity that meets the demand of the currently envisaged ICOS network (outlined under the "Resource and Implementation section" below). Part of this task is work on improving and developing new analytical methods, also for new tracers serving the ICOS goals.

Flask maintenance. A precondition for the use of flask samples for monitoring is that the air composition does not alter between sampling of atmospheric air and its analysis. Potential error sources include leaks and humidity in the flask. To make sure that no deficient flasks are used for air sampling, the FCL sets up routine procedures for leak checking and conditioning of all flasks before being sent to the sampling stations. A sufficient number of flasks thus need to be available for each sampling station.

Quality Control. The success of the FCL will be gauged by its ability to assure and document that the required data quality of the analysis results is met. Therefore, a comprehensive quality control strategy is being developed, including inter-comparison activities with other international flask laboratories and monitoring networks (like NOAA-GMD, AGAGE and others).

Quality Control of the ICOS station network. The implementation of homogeneous calibration scales at all monitoring stations enables a harmonized data set. Yet, instrumental problems may evolve over time at individual stations. Any significant bias should be revealed by the accompanying flask sample program at Level 1 monitoring stations, but regular inter-comparison activities are needed to help detecting small offsets. The FCL will support these activities by providing the respective high-pressure standard gases.

Central Radiocarbon Laboratory (CRL)

Analytical tasks. The CRL will set up and operate dedicated instrumentation for the routine measurement of two-weekly integrated air samples from the whole ICOS station network at the highest possible precision (better than 2‰ which will allow to detect 1 ppm fossil CO_2 in a single sample), mainly using conventional counting techniques. In addition, for episodic or diurnal cycle experiments and calibration of CO as tracer of fossil fuel CO_2 at selected stations, small volume Accelerator Mass Spectrometer (AMS) samples will also be analyzed. The CRL will, thus, have direct access to an AMS facility (Tschira-Labor, Mannheim close to Heidelberg) with sufficient capacity and a single sample precision of better than 3‰.

Sampling instrumentation. The dedicated equipment required for integrated $^{14}CO_2$ sampling will be provided by the CRL, together with absorber solutions for high-volume sampling. Episodic or event samples will be collected with the automated ICOS flask sampler but into dedicated large volume flasks. Samples will be analyzed first in the FCL for trace gases and possibly stable isotopes, before $^{14}CO_2$ analysis in the CRL. All flasks will be transferred back to the FCL for routine pre-conditioning and maintenance.

Improvement of methodology to estimate fossil fuel CO_2. The CRL will continue to run its pilot monitoring station in Heidelberg, in order to develop and test new methodologies to “measure” fossil CO_2. For example, new and better suited pollution tracers (other than CO) may become available in the future. These need to be tested before implementation in the ICOS network.

Quality control. As for the FCL, one key task is to assure and document that the required data quality of the analysis results is met. This includes an elaborate internal quality control strategy as well as inter-comparison activities, tightly linking the laboratory to the international standards used for ^{14}C analyses (distributed by the IAEA).

Interoperability between Central Analytical Laboratories, the monitoring networks and Thematic Centers

Sample logistics. As described in the functions of the laboratories, the role of the FCL and CRL laboratories is the analysis of air samples collected at ICOS observatories. The monitoring networks will also be supplied by the FCL and CRL with maintained sampling equipment (flasks and, in the case of CRL samplers). Sample logistics and sampling information will be handled centrally in the CAL database. The CAL database system will document the sample processing starting with collection at the sites, and including every shipment, sample preparation and analysis step.

Data processing. The analysis of several thousands of samples per year on different instruments in the FCL and the CRL generates a large amount of raw data that needs to be processed, evaluated and archived. For this an elaborate database system, suited for the task, is being jointly developed by the CRL and FCL. The CAL database will be automatically linked to the ATC database, providing the analysis results and comprehensive metadata information for all samples. The data management strategy will allow that measurement data can be re-processed at any time, selected, analyzed, and transferred to the Atmospheric Thematic Centre. This allows for updates of the calibration scales for the greenhouse gases by the WMO-

CCL, which have occurred repeatedly in the past. The related re-calculation of in situ measurement results based on such re-assignments will then be made by the Atmospheric Thematic Center.

Resources for the CAL set-up and implementation of the laboratories

The current laboratory capacities are planned to meet the demands of the ICOS monitoring network. The initial station number is expected to increase as ICOS aims to further increase the density of the network. Depending on this development an adjustment of the resources might become necessary in the future.

Flask and Calibration Laboratory

The projected sample load is based on weekly flask pair sampling at 30 ICOS core sites, with potentially additional sampling at ship-based and aircraft profiling sites. This can be accommodated by a capacity of 5000-7000 atmospheric samples per year (for trace gas analysis, about half the capacity for stable isotopes) plus additional quality control measurements.

The construction of the FCL has been started in 2012 with initial funds of 2.8 million Euro for two years from the German Ministry of Education and Research (BMBF), to be complemented in a second two-year funding period (2014-2015) by an additional 2.1 million Euro. Within this period all operations of the FCL will be brought to routine. First services (e.g. reference standard production, glass flask pre-conditioning, flask sample analysis) are expected to become available to the ICOS community gradually starting in 2014.

First steps of this implementation by March 2013 are

- renting of suitable laboratory space (700 m²) and installation of the required technical infrastructure
- build-up of the laboratory team
- selection, acquisition and testing of the first analytical instruments
- design of logistics routines and draft of the data-base structure in cooperation with the ATC and CRL teams
- development of the standard ICOS flask sample instrument

The staff of the FCL comprises the following positions:

- 2 Scientists (lab heads of the trace gas and stable isotope laboratories)
- 2 laboratory engineers
- 1-2 database programmer
- 1 IT manager
- 1 workshop technician
- 1 engineer for flask sample development
- 0 - 5 laboratory technicians (to be hired when routine operation is started)

Central Radiocarbon Laboratory

The projected analytical capacity of the CRL is based on two-week integrated $^{14}CO_2$ collection at 40 ICOS stations (in total 1000 analyses) plus another 1000 analyses for episodic or event flask analysis. About 25% of all samples will be analyzed by conventional counting technique, whereas the remaining 1500 samples will be measured by AMS.

The German Ministry of Education and Research (BMBF) is currently funding in a pilot project (Jan. 2012 – Dec. 2013, 376 000 Euro) the modernization of the existing counter electronics at the UHEI-IUP ^{14}C-Laboratory, the preparation of the database system, as well as the planning and preliminary tests for the new sample preparation for AMS analysis. The grant for the set-up of the new CRL laboratory instrumentation (April 2013 – Dec. 2015, 1.3 million Euros) is still pending; it shall cover the following items:

- Extraction, purification and metering line for conventional ^{14}C samples
- Flask extraction and AMS target preparation line
- Development and implementation of standard laboratory procedures, including QA/QC

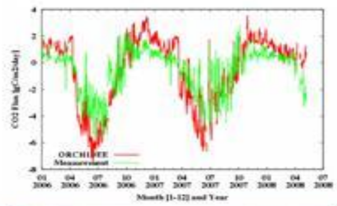
- Development and construction of systems for integrated CO_2 sampling
- Improvement of methodology at the Heidelberg pilot station to estimate fossil fuel CO_2

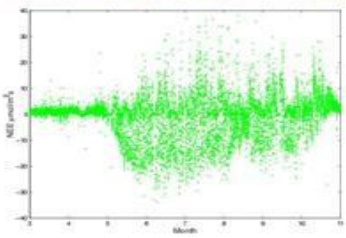
This requires the following human resources:

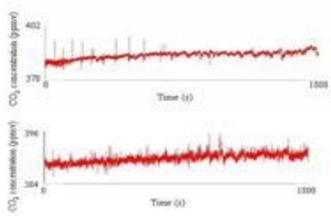
- 1 Scientist (PI and chief of CRL)
- 1 PhD student
- 1 database engineer
- 1 mechanical workshop technician (construction of instrumentation)
- 1.5 – 2.5 laboratory technicians (instrument testing and sample preparation)

The construction of instrumentation shall be finalized in June 2015, which will then allow the laboratory to serve a limited number of ICOS stations (20) with ^{14}C analyses of integrated samples. The second half of 2015 will be used as test phase of the CRL operational procedures, including sample logistics and data processing and transfer. Operation of the CRL with full capacity will be possible when the new laboratory instrumentation has moved to its final space (ca. 165 m^2 & ca. 50 m^2 for storage), envisaged in a new building to be finally constructed in 2016 (Mathematicon, located close to the current IUP building).

Ecosystem Thematic Center







Rationale

The Ecosystem Thematic Center (ETC) is one of the four centralized facilities of the Research Infrastructure. The aim of the ICOS Research Infrastructure is to build a network of observation points that are highly standardized and coordinated. The ETC, together with the other Thematic Centers, is fundamental to ensure that these characteristics of the network will be respected and maintained. The role of the ETC is to coordinate the Ecosystem Network providing assistance with instruments and methods, testing and developing new measurement techniques and associated processing algorithms. The ETC will also ensure a high level of data standardization, data quality control, uncertainty analysis and database services in coordination with the ICOS carbon portal. A strong and robust ETC is crucial for the success of the ICOS infrastructure and the coordination with other initiatives in the other continents.

Concept and roles

There are different tasks that will be covered by the ETC, starting from what has been developed in the last 10 years in terms of methods, techniques and infrastructures during different European Research Projects (e.g. Carboeurope-IP and IMECC). In particular:

a. Coordination, provide protocols, training and technical assistance for the Ecosystem network
b. Development and testing of new measurement methods and instruments
c. Data calculation, correction and processing
d. Development of new methods for data processing
e. Database development and maintenance

Coordination, provide protocols, training and technical assistance for the Ecosystem network

The Ecosystem network will consist of a number of sites (between 40 and 60) fully standardized in terms of measurement techniques and instruments, located in different European countries. To ensure standardized measurements, the ETC will coordinate the development of protocols and of the modus operandi for each variable that is included in the list of mandatory measurements. A large network, such as the ICOS Infrastructure, will need an important coordination and assistance service from the ETC to ensure correct data acquisition and transmission, support in case of problems with the instruments as well as training for the personnel that will work at the sites for maintenance and data transfer.

Development and testing of new measurement methods and instruments

During the Demonstration Experiment of the preparatory phase a prototype of the standard Ecosystem Station equipment has been developed and tested. However it is clear that in the long-term perspective of the infrastructure new instruments and new methods will be developed and proposed by companies as well as by the scientific community. It is fundamental that the ICOS Ecosystem Infrastructure will be continuously upgraded with the best methods and sensors available. However, it is also important that only consolidated and fully tested equipment/methods are included and used in the Ecosystem network. Therefore, the ETC will be responsible for the testing, validation and development of new instruments and technologies with the aim to maintain the Ecosystem sites updated.

Data quality control, calculation, correction and processing

Data acquired at the Ecosystem sites are not immediately ready to be used and interpreted. These measurements need additional processing that includes flux quality control, calculations, filtering and corrections. One of the main activities that will be under the ETC responsibilities will be to centrally apply all the processing schemes available and used in the international community.

The raw data that are collected at the Ecosystem Sites have a 10 Hz time resolution. These data need to be quality controlled as a first processing step to calculate fluxes with a typical time resolution of 30 min. Then, also the 30 min fluxes need to be corrected, filtered, gap-filled and processed to retrieve additional important variables. Clearly, different processing, correction and calculation schemes can easily lead to different results for the same dataset. It will therefore be important to process the raw data centrally at the ETC using all the most updated and accepted methods. The difference due to the processing will serve as an estimate of the uncertainty.

The Ecosystem sites will submit the raw data to the ETC at a monthly time step. In addition preliminary half-hourly fluxes and meteorological data will be automatically submitted to the ETC in Near Real Time (NRT - one day). These data are not corrected and can thus not be used for scientific purposes. However, they can be useful for overall outreach purposes. The raw data will then be processed and each step will be fully documented. As for the Atmospheric Thematic Center and following what has been developed within the ecosystem network community, different processing levels will be used to identify the datasets in relation to the processing applied (from the measured values to the final products).

Similarly, the ancillary information about the sites, as metadata, vegetation and soil characteristics, disturbances and management, will be quality controlled to ensure high standardization between the different sites. All ancillary information will be collected at the Ecosystem sites according to the developed protocols, and where necessary after the necessary training.

Development of new methods for data processing

As for the instruments, also the data processing is continuously evolving, proposing new calculation, correction and processing techniques. The ETC will play a pivotal role in this topic, working directly in the development of new correction schemes to apply to the data acquired at the different sites. Standard quality control tools and uncertainty analysis will be two topics where major efforts will be requested at the start. In addition, common software for data acquisition at the site level was prepared during the preparatory phase; the ETC will be responsible for the development and upgrade of this software and for the technical assistance.

Database development and maintenance

Both the NRT data and the corrected data processed centrally will be freely available to the ICOS users. The ETC will ensure a database structure able to store all the data, track all the changes in the data and in the processing using versioning systems. In addition the database will contain all the meta information about the sites, the variables, the instruments and the processing methods applied. The ETC will maintain a direct link between the site PIs and the users, and provide, through the Carbon Portal, a clear and robust interface for the users, where the data access is at the same time simple and containing all the information for a correct use of the data. The ETC will establish and lead strong collaborations with other databases containing similar data from other networks to enhance cross network standardization. The ETC will provide and maintain a backup system and a mirror server to ensure the data access and storage throughout the duration of the project.

Organization of the Ecosystem Thematic Center

The ETC is organized in four main units, i.e. Coordination Unit, Data Unit, Test and Development Unit and Network Unit. Each unit has specific responsibilities, but the personnel employed in the ETC will work in transversally different units to ensure redundancy of competences and optimal exchange of information.

The ETC Coordination Unit has the responsibility to ensure the functioning of the ETC, to interact as ETC with various institutions and companies, and to serve as the reference interface for the ICOS governance bodies.

The Data Unit is responsible for all the issues related to the ICOS data, from submission to data processing and QAQC (Quality Assessment & Quality Control), to storing and distribution.

The Test and Development Unit is responsible for checking, testing and developing new instruments, new methodologies and new tools. The Unit will also run one or more ICOS test fields for long-term sensor comparisons.

The Network Unit is devoted to assist the network, providing information and protocols, organizing training courses, analyzing the samples and store them for long term.

List of tasks performed by the ETC through the different Units:

In this section the list of the services offered by the ETC to the network are reported. Although the exact definition of all the activities is still under discussion within the ecosystem community in order to optimize the services, the list gives a general overview of what will be done by the ETC.

ETC Coordination Unit

- To perform the overall coordination and supervision of the ETC and the ETC components and Units;
- To organize the annual Ecosystem sites assembly;
- To prepare the annual report to the ICOS General Assembly and the workplan for the upcoming years;
- To coordinate / collaborate with other RI networks related to ICOS Ecosystem (e.g. NEON, Ameriflux)
- To negotiate with instrument manufacturers and external providers special conditions on behalf of the entire ICOS ecosystem consortium for instrument purchasing, calibration, maintenance, customisation, spare sensors etc.

Data Unit

- To create and to maintain an “Ecosystem site agenda” with all due dates for sample collections, instrument calibrations, periodic measurements, notifications for training sessions and Ecosystem site meetings specific for each single ICOS Ecosystem site. This tool will help the site managers to respect all the deadlines agreed upon and to be continuously informed about the ecosystem related activities;
- To create and to maintain web tools for data uploading and real time monitoring of site submission status, including data accesses and users information. The tool includes an interface to upload the main data (GHG concentrations, micrometeorology, vegetation, hydrology and soil variables) but also to communicate all the management operations (soil preparation, vegetation management etc.) and other compulsory or noteworthy observations related to the site. This will constitute an organized log-book that can be easily used in data processing and evaluation;
- To produce an automatic alert system if a due date for data upload or sampling or calibration in the agenda has not been respected (including a pre-alert message when the deadline is approaching). To send an immediate alert when NRT data fails to pass QAQC;
- To receive and to store all data (including NRT data, consolidated continuous data, periodic data, metadata), to track their submission status, to validate the formal correctness, to ensure their traceability;

- To apply simple automated QAQC to NRT data and publish them in a specific section of the ETC portal in coordination with the Carbon Portal;
- To process consolidated raw data following protocols (including QAQC and uncertainty quantification) and to calculate higher levels products;
- To generate site specific reports for site PIs with information on calculated fluxes and products, with possible data problems highlighted by the multiple constraint QAQC (e.g. consistency between radiation sensors). This will facilitate scientific feedback by PIs in case of unexpected results;
- To guarantee the data streaming to the Carbon portal for publication/distribution and elaboration of further ICOS level 3 products;
- To ensure continuity in the server accessibility through a mirror system and data security through periodic full back-ups;
- To trace in text documents all the algorithms and calculation steps used for checking, analysing and processing the data and update them according to the scientific progress in order to maintain full traceability of the calculation and data processing steps throughout the entire ICOS life;
- To organise and maintain an instrument database at the ETC level for keeping track of the most important sensors and analysers used in the ICOS stations (GHG analysers, sonic anemometer, dataloggers). This is an essential component of ICOS Ecosystem data traceability and quality;

Test and Development Unit

- To organize and maintain test stations to evaluate and develop instruments and techniques and test performances of new sensors or new instrument setups;
- To run accepted ICOS Ecosystem sensors in parallel over extended periods;
- To provide possibilities to ICOS participants to run specific comparisons at the ICOS test stations. Possibility to open the access to SME, providing agreement with the ICOS assembly;
- To test and develop new data processing schemes and tools, including new QAQC;
- To develop and operate a roving test system to be run in parallel at the ICOS sites for QAQC *(funding to be raised, but progress has been made).*

Network Unit

- To coordinate the development of the protocols for site installation and measurement of all accepted ICOS variables, together with specific WGs and the scientific community;
- To distribute protocols to ICOS and the scientific community in a clear and uniform form through a web tool in coordination with the data unit;

- If requested, to organize training workshops for staff at the European level in coordination with other ICOS thematic centers when necessary;
- To develop and apply standard routines for objective evaluation of site performances (e.g. number of gaps, calibration of the instruments, deadlines respect etc.). The results will be reported to the site PI and to the ETC coordination in preparation of the annual report for ICOS-RI
- To assist the network in specific questions related to protocols application, sensors, sampling etc., through email, chat and telephone (if needed) by dedicated technical staff;
- To perform the chemical analyses of soil and vegetation samples in a certified laboratory;
- To store for 20 years all pooled samples of soil and vegetation for potential future re-analysis with new techniques or analysis of new variables;
- To manage spare instruments.

Resources and state-of-the-art of the establishment / set up the ETC

A call for setting up the ICOS ETC in Europe was opened beginning of 2010. Only one application has been submitted and reviewed by external experts in US and Canada; after a process of evaluation of the comments and answers to the reviewers the ETC construction has been assigned to the groups and countries leading the proposal: Italy (University of Tuscia – Viterbo and Euro-Mediterranean Center for Climate Change CMCC), Belgium (University of Antwerp) and France (INRA).

Part 2. Infrastructure elements

On 11 April 2012 a Memorandum of Understanding was signed between the three institutions involved in the ETC construction and operation, i.e. Euro-Mediterranean Center for Climate Change; University of Antwerp; and INRA-Bordeaux. This Memorandum of Understanding confirms the collaboration between the three institutions to jointly establish and operate the ETC. The Memorandum relates to the people involved/employed in the ETC and it also defines the organization that is explained further below.

Significant process has been made in the establishment of the ETC and part of the ETC is already fully set up. The financial contribution by the stakeholders in the three countries has been used to firstly employ the first group of people in the different units (see below the description), that are added to people already employed in the institutions and dedicated part-time to the ETC. Larger part of the recruited people have been dedicated to the Data Unit, in order to establish as soon as possible all the technical infrastructures needed to receive and process data (two scientists, three database technician); the scientists of the Data Unit participate also to the Network Unit (one scientist employed) for the activities related to the protocols preparation. One scientist and two technician have been also dedicated full time to the Technical Unit in order to collect the measurements needed for the eddy covariance protocol discussion and to set up the first ETC Field Test Site. Finally two people are working in the Coordination Unit. In terms of laboratories needed in particular for the chemical analysis, INRA approved the agreement with three different labs: USRAVE (INRA Bordeaux) for the plant analysis, LAS (INRA Arras) for the soil analysis and INFOSOL (INRA Orléans) for the soil archive. In all the three labs a person responsible for the ICOS samples management has been identified.

To follow the development of the internal activities, a number of management meetings have been organized within the ETC to streamline work and actions, and to plan the establishment and development of the ETC. The ETC is expected to be fully operational and ready to receive and process the first data in the second half of 2013.

The first drafts of a number of protocols have been written up and are being sent out for review to the institutions participating in the Ecosystem stations network. Frequent meetings have been organized in 2012 and are being intensified in 2013 to finalize the data protocols.

In terms of financial contribution, all the costs are covered by the countries involved. The fees that the ecosystem sites will pay to the ERIC and that will be transferred to the ETC are needed to cover direct costs of the chemical analysis; for this reason the ETC functions are ensured and independent of the number of sites participating, in particular in the first years of ICOS when a small network is expected. The actual interface of the ICOS ETC is hosted in the ICOS Demonstration Experiment page available at www.europe-fluxdata.eu/icos.

Ocean Thematic Center

Goal

The goal of this document is to provide a description of the Oceanic Thematic Centre of the ICOS infrastructure. This description will address the concept, the role, the functions, and the requirements needed to build and run the Oceanic Thematic Centre of the ICOS infrastructure, in the context of the European research area and international landscape.
The ICOS Ocean Thematic Centre will provide comprehensive co-ordination of the marine carbon cycle observing network, including:

- technical support for the observations,
- archiving of the marine data,
- regular quality assessment of the network,
- processing and integration of data from ships and stations into products such as
    - maps and regional budgets of CO_2 fluxes and transports,
    - assessment of changes in pH (“acidification”),
    - interpretation and comparison with marine models and processes.

All these are important tools for identifying changes in marine sources and sinks of carbon, the progress of ocean acidification, and biogeochemical cycles, crucial for projecting future climatic and environmental changes.

Concept

The OTC is one of the four centralized infrastructure facilities within ICOS. It will be the coordinating body for activities measuring the carbon cycle within the ocean in the context of ICOS. It will provide support to the marine network in the form of information and technical backup on the state of the art instrumentation and analytical methods. It will provide of data storage, data reduction techniques, quality control, and network-wide integration of data to into useful products, such as maps of CO_2 fluxes, carbon transport, and the assessment of ocean acidification.
The OTC will be the main European facility within global marine activities, providing secure, long term base for European components of a global observing network. The marine components of ICOS, will be:

- existing and new components of the network of Voluntary Observing Ships (VOS) for underway measurements of ΔpCO_2 that are used to produce global flux maps (Takahashi et al. 2009) and to measure changes in major ocean sources as sinks (Watson et al, 2009),
- existing and new ocean time series such as that those near Canary Islands, Bermuda, Station M, etc., focusing on annual to interannual variability of carbon fluxes,
- selected repeated hydrographic sections focusing on the storage and transport of anthropogenic carbon in the ocean,
- development of novel monitoring platforms such as floats and gliders and the required carbon sensor technologies.

All these essential network components will enable ICOS to produce robust carbon budgets across Europe and the adjacent oceans and seas. Data analyses, quality control, and storage, as well as the assistance to and co-ordination of further instrument/sensor development will be a key issue of the centre.

Roles

The ocean carbon observing community has an excellent record in co-ordinating observational networks through national and international programmes. This has been within Europe and through international organizations, particularly through IOC's International Ocean Carbon Coordination Project (IOCCP) and also IGBP projects e.g. SOLAS, IMBER. There is a strong recommendation and good practice by the international community to store data in central, international databases like CDIAC and PANGEA. However, there is currently no organization in Europe that co-ordinates actual observations and no central co-ordination or standardization.

Overall there are seven components of work that the OTC would provide for the marine ICOS community:

- technical assistance and coordination of training for tasks within the observational network including
  - installing and maintaining instrumentation on Voluntary Observing Ships,
  - installing and maintaining instrumentation on Time Series Stations,
  - measurements on selected repeat hydrographic sections,
  - assessing the usefulness of new instrumentation and platforms,
  - co-ordinating flask sampling and analysis for atmospheric parameters;

- high level quality control, ensuring unified data reduction techniques;
- archiving of ancillary information;
- development of new methods for data processing;
- maintaining a database and linkage with associated data centres;
- production of network-wide data products;
- interface of the marine network with the atmospheric and ecosystem components of ICOS.

Requirements for OTC

The ocean thematic centre will provide critical leadership for the observational network, technological development, data handling and data storage. It would be expected that institutions applying to provide the OTC must be able to demonstrate expertise in the following fields:

- A well supported track record in previous international collaborations and in project co-ordination.
- A track record in the delivery of highly precise and accurate marine measurements of the carbon system variables.
- Transferable skills for ensuring best practice in measurements and data quality control in the other laboratories.
- A sound and transferable knowledge associated instrumentation.
- The knowledge to encourage the development of new related technologies
- A sound and transferable knowledge of data synthesis, quality control and storage;

OTC resources and costs assessment

The location(s) of the ICOS OTC has not been decided upon, yet. The exact cost of the OTC will depend on the institution(s) being selected to host this facility, hence no costs are given here. However, the following OTC staff are required:

- 1 OTC coordinator,
- 3 scientists to co-ordinate the marine observing network, and to lead and promote new sensors and platforms development, testing and maintenance,

- 6 technicians for the co-ordination of the marine observing network, and the promotion of new sensors and platforms development, testing and maintenance,
- 2 scientist for producing maps of carbon fluxes and transports,
- 3 programmers,
- 2 data managers for data archiving, data reduction, and quality control,
- 1 person for the web-site and daily communication in the network.
- 1 office manager
- secretary
- Public communicator and web. operator

The total costs for the OTC is assessed to become about 3 mill. EURO's that will be approximately the same as for the other central facilities.

To implement the OTC work plan there are at the moment three nations making a joint proposal: Norway, Spain and UK. Each of these nations has considerable expertise and interest in marine carbon observations, with an emphasis on fluxes of CO_2 from oceans to atmosphere. They each have specialities within that broad field, which they will bring to the operation of the OTC. Thus the OTC will benefit from some of the most experienced investigators in Europe in the marine carbon cycle and marine GHG fluxes.

At present funding has not been firmly committed for the OTC: currently only the UK has an agreed pathway to funding its proportion of the work, which will be via the Natural Environment Research Council (NERC) at its Institute the National Oceanographic Centre, Southampton (NOCS). The outcome of further approaches and proposals to provide such funding, being made by all three nations, will be known during 2013. However, it seems highly unlikely in the present financial climate that any one European nation will offer the ~3M euros per year required to fund all the OTC's proposed functions. Hence we believe that a multi-national consortium to back the OTC is the only practical way forward.

A suggested split of responsibilities is given in table 1 and a structure for managing the OTC is visualized in figure 1:

Table 1: Proposed sharing of tasks required in the OTC between the potential host nations (Norway, Spain and UK)

The operative network	New developments	Training	Lead country	COSTS (kEUROS)
Management 3 Directors (One from each country) Project manager (One from each country) Secretary Time Office equipment Computers Webpage			NO, SP, UK	450 kEuro
VOS-network for GHG observations Ship liaison officer	Defining the ICOS VOS approved standard for GHG observation	VOS-system, best practices for maintaining, calibrating and operating the system.	UK UK, SP, NO	450 kEuro including services provided for other platforms 130kEuro
Time Series – network of fixed point observations	Defining the ICOS ocean fixed point	Time series, best practices for	SP	450 kEuro

Mention role of EUROFLEETS	observatory	maintaining, calibrating and operating time series.		
European network of repeated sections Mention role of EUROFLEETS	Defining the number of variables and best practices for ICOS-repeated section observations	Repeated sections, best practices for measuring, calibrating and operating on research vessels	NO	450kEuro
Data management Routines for data submission and transfer, QC, flagging, metadata and data achieving	Develop more efficient and simplified routines for data submission and transfer, Near-realtime (NRT) data access, QC, flagging, metadata and data achieving	Best practices for data submission and transfer, QC, flagging, metadata and data achieving. Interoperability	NO	235kEuro
Products i.e. flux maps on a seasonal, annual, interannual and decadal basis	Improve mathematical and statistical procedures, data assimilations techniques, models for generating maps of fluxes etc.	Best practices for mathematical and statistical procedures, data assimilations techniques, models for generating maps of fluxes etc.	UK	220kEuro
Other platforms – promising approaches for observations	Gliders, floats, cable based observatories	In the use of gliders, floats, cable based observatories	SP, NO, UK, Ge	190kEuro
Sensor developments	pH, NO_3, N_2O, CH_4, O_2, pCO_2	Sensor development	SP, UK, NO, Ge	250kEuro
Sea water and gas standards	Provide a European CMR		NO, SP, UK	175kEuro

Table 1: Total costs: The general costs operating the OTC are estimated to be 1 mill. Euros per. Nation per. year: in sum 3 mill. Euros pr. year. OTC board of directors (One scientist from UK, SP, NO) Lead 3 first years will depend on national funding and in kind contribution from the different countries. Germany (Ge) will be associated member, with contributions towards new technologies and new sensor development. Numbers given here are harmonized in the sense that we use average European salaries and costs.

Assuming a multi-national OTC, a local leader will be appointed at each of the national sites, responsible for the individual teams of 4- 6 people in each country. Deputy leaders will also be identified. One of these leaders will be designated Director OTC, responsible for the overall management of the OTC, and this post will be rotated between the leaders, nominally every two years. The director will be a part of the ICOS executive board and management teams.

A monthly teleconference will be held between the leaders and their deputies, scientists and technicians. Representatives of the groups will also meet in person at least twice per year. To these teleconferences and meetings, we will also invite representatives of the ICOS coordination office, the Carbon Portal, and the Atmospheric Thematic Centre.

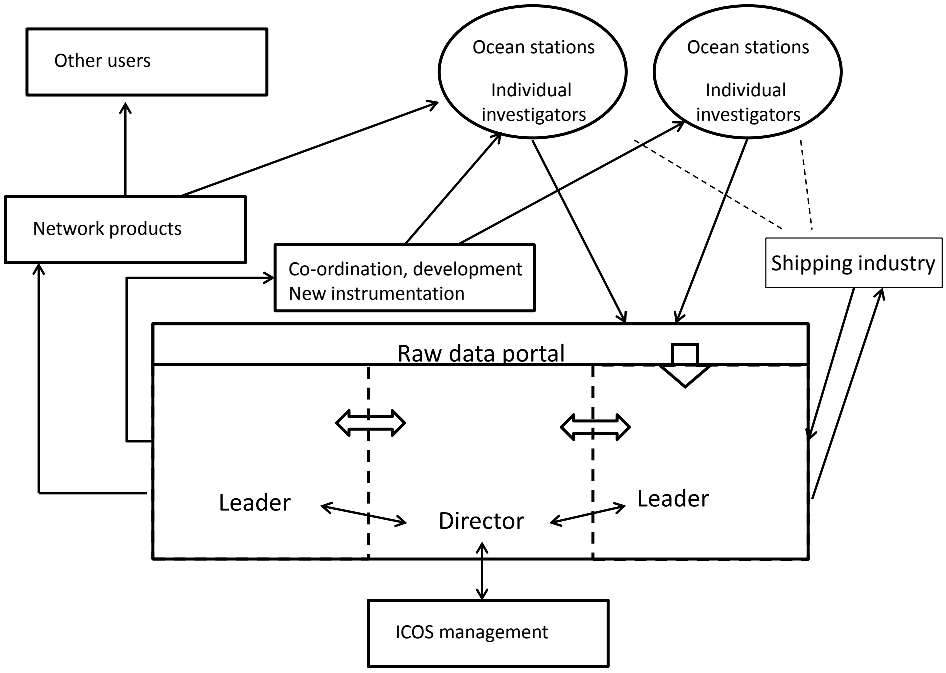


Figure 1: The diagram shows a schematic of the management and operation of the OTC

ICOS *Head Office*

Tasks and duties of the Head Office

The Head Office (HO) support the ICOS ERIC (European Research Infrastructure Consortium) governance in planning, integrating, developing and coordinating the ICOS activities under the supervision of the Director General. The HO assists the planning and promoting of scientific and technical objectives. The HO will have the responsibility to support the coordination of the infrastructure at the European level, its construction, commissioning and transition to full operational mode. The HO coordinates and facilitates the network extension, and supports ICOS RI's science and technological development. As the main guardian of ICOS legal entity, the HO also works for building ICOS general identity, securing that ICOS as a distributed RI, will operate as a strong productive actor both at European and Global level.

The HO facilitates outreach, training and mobility for participants. Engagement of a wide scientific and public community and building the partnerships with stakeholders makes it necessary to have a central user community facilitation task.

The HO is directed by the ICOS ERIC Director General (DG). The DG has the responsibility that General Assembly (GA) meetings are well supported with preparation and follow-up actions. For this purpose the HO will have to employ sufficient staff that the DG manages. Envisaged responsibilities are listed below:

Managing the ICOS legal entity

Before the ICOS legal entity exists:
The country that will host the ICOS legal entity will take care of the following issues for the legal entity set up. These tasks are:

- Lead the negotiation process for setting up the legal entity including statutes
- Start the legal process for registering the legal entity in Finland and consequently in the EU
- Prepare a detailed ICOS budget plan based on the information from the Central Facilities (CFs) and decisions made by ICOS Stakeholder Interim Council.
- Draft a general implementation plan for ICOS based on the implementation plans of each CF and HO.
- The plans are needed for the first General Assembly to commission the Research Infrastructure into the operational phase

During the operational phase with an ICOS legal entity in place:

- gather and prepare the balanced budget estimates along the work programs to be approved by the GA;
- manage the funds for common operations of ICOS, incl. HO, CF, Carbon Portal (CP) and other common activities according to the budget agreed by the GA
- calculate and invoice countries' contributions
- gather and prepare annual finance reports and follow the realisation of the global budget of ICOS utilizing the quarterly finance reports from the CFs and HO; any statutory financial and fiscal reporting

- organize accounting and auditing of the accounts of ICOS once a year by an external auditor
- process transactions related to income, expenditure and financing
- secure long term funding and lead the fund raising on the international (European) level
- gather and prepare the working documents and meeting minutes
- organize meetings for the ICOS bodies and others as deemed appropriate for the management of ICOS RI
- manage guidance and plans for:
  - human resource management including recruitment strategy
  - user community management including communications, outreach and education, done in cooperation with the Carbon Portal
  - data policy
  - infrastructure risk management at the European level; analyze risks and provide solutions to minimize them
  - organization of the decommissioning in terms of selling the properties or instruments of ICOS ERIC, preparing an exit plan for the ICOS ERIC staff, and planning alternative operations
  - manage the intellectual property right (IPR) issues that may arise from the activities in the ICOS RI

Strategic scientific and technical planning

- serve as an information node and contact point of the European ICOS infrastructure towards other European RIs, other observing systems and global networks as well as European and national institutions
- help to improve the integration and coordination of environmental and atmospheric research and exchange of knowledge at the European and global levels
- manage the quality for ICOS operations in monitoring; developing a quality management system for continuous improvement of operations
- monitor together with Carbon Portal and CFs, the consistency and inter-operability of the different networks of ICOS, in synergy with national research institutions and programs, and in compliance with the mandate agreed upon by the GA
- prepare periodic scientific and technical strategies for ICOS and organize and ensure coordinated implementation of set common strategic plans, organizing revisions to them, with a general aim of contributing to the European Research Area
- support the work on network assessment and quality control on system level
- seek opportunities and funding for potential expansion of the infrastructure to regions adjacent to Europe, in close cooperation with existing or new (inter)national initiatives and the central facilities
- seek and promote new opportunities within the ERA for the development of the RI and the research related to it, as well as for expanding and upgrading the infrastructure
- promote future expansion of relevant in situ stations for calibration/validation of satellite observations
- monitor the data collection program, management and operations of the CFs, follow up the agreed data policy and prepare reports on activities
- monitor user access to ICOS data based on an agreed access policy, and researcher visits in the form of activity reports from CFs and CP
- monitor the performance of the RI in regular intervals in terms of contentment of the users, scientific results and technical solutions, education, utilization of the RI and impacts on policy

- support a supply/procurement management plan for the CFs to phase costly acquisitions and to ensure continuous operations
- coordinate dismantling plans at the central facility level at the same time as new procurements are done

Community building, outreach, promotion and training

- employ modern social media tools for ICOS community building and management
- promote and organize the communication and outreach at the RI level by delivering timely information to the end user community in professional and scientific journals, brochures, information sheets, demo CDs, newsletters, announcements, press releases, web pages, and other promotional tools and manage the general ICOS web site in coordination with CP
- facilitate the development of new potential services to end users (policy makers, as well as researchers) to serve as broad an end user communities as possible (enhancing the diffusion of data and products, and outreach papers at the European level, for example) in close cooperation with the CFs, CP and national ICOS secretariats/competence centres
- translate ICOS findings to policy relevant messages that will significantly benefit the European Union countries and its institutions (European Commission, European Environmental Agency, etc)
- develop web tools in close cooperation with CP for decision makers to use ICOS data for making scientifically-based decisions related to climate change
- increase general awareness of the ICOS and the opportunities it provides, its products and services and highlight the benefits for current and potential users
- coordinate the training of new researchers and technicians
- organize general ICOS training courses, workshops and seminars for both early-career and advanced researchers and technicians to provide training and learning experiences for individuals to maximize the use of ICOS output
- support the organization of joint training in cooperation with the CFs for the researchers and technicians
- coordinate a visiting grant program and seek and promote other funding to increase the mobility within ICOS RI and the usage of the facilities and data provided by ICOS RI

Organization of the work

Location and partner organizations

The HO will have a multinational structure. The human resources and employment policies will follow the ERIC host country’s legislation according to other rules adopted by the GA. ICOS RI HO is located in Helsinki, Finland with a secondary node in Paris, France. ICOS RI HO in Finland is the statutory seat of the ICOS ERIC.

Organigram of the HO

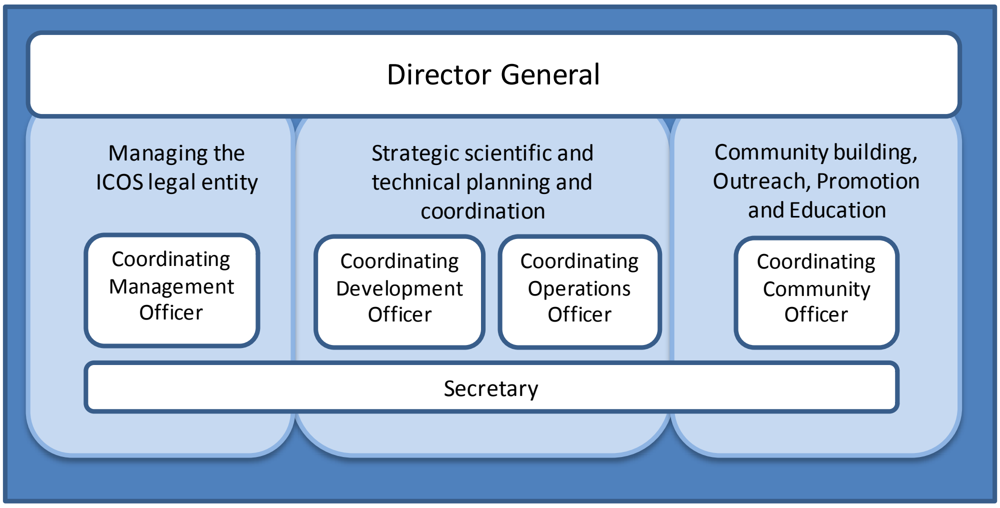


Figure 1. Main task groups of the Head Office and its personnel.

Personnel

HO will start with four full time employees in Finland and one in French HO node. The number of staff may increase gradually when ICOS RI is running in full operative mode. In addition to below listed staff, the HO may recruit researchers and project managers related to forthcoming ICOS RI projects (with external funding from various science funding sources).

1. Director General
2. Coordinating Development Officer
3. Coordinating Operations Officer
4. Coordinating Management Officer
5. Coordinating Community Officer
6. Secretary 50%

Budget

HO will be financed by host contributions (FI and FR) and by contributions from ICOS ERIC member and observer countries.

Carbon Portal

Concept

The Carbon Portal shall provide a "one-stop shop" for all ICOS data products. As such, the CP is envisioned as a virtual data center, i.e. a place where ICOS data can be discovered and accessed along with ancillary data and where users can post elaborated data products that are obtained from ICOS data. The CP will also have the ability to address all the requirements stemming from these aspects, including:

- data security,
- enforcement of the ICOS data policy,
- user-friendly (and machine-friendly) internet-based and other computer-network interfaces.

In this document, the “Carbon Portal” term refers equivalently to:

- the combination of the teams, equipment and intellectual assets within ICOS, and
- the web portal that materializes it for the end users.

The CP is the data platform of ICOS. All relevant ICOS data and ancillary data sets from external sources will be published and be accessible through the facilities of the Carbon Portal.

The CP shall be developed based on standard data interfaces and be an integrative access point for all ICOS users, ranging from experts to stakeholders and the general public. The CP shall support standardized data exchange protocols and techniques.

The Carbon Portal shall be responsible for the following aspects of handling ICOS data products:

- user registration,
- bibliometrics,
- publishing of the data monitoring data usage and citation,
- developing an integrated metadata system, maintaining metadata consistency inside the RI and proving a device for external metadata systems (e.g. DataCite),
- ensuring long-term archiving and
- setting up and operating suitable web-based interfaces for data discovery, visualization and access.

The CP shall also provide the capability of advanced service composition techniques for web-based distributed processing of ICOS data to generate useful information (e.g. risk maps, alarm maps, and integration and analysis with other types of datasets) for research, public users and decision-makers.

Role of the carbon portal within ICOS

This section describes the role, functions within ICOS and technical functionalities of the Carbon Portal.

Table 2. An overview of the roles and tasks of the Carbon Portal.

Overview of the roles of the Carbon Portal	
1	to organize and ensure back-up storage and long-term archiving of published ICOS data sets
2	to generate and provide effective tools to publish, discover, access and retrieve observations according to user needs
3	to ensure basic semantic interoperability by maintaining a full copy of the standard metadata and data description documents (ontologies) held at the ICOS TCs, including the compilation of the vocabularies in use within ICOS
4	to define and implement advanced web services and procedures for web-based data visualization, retrieval and processing
5	to organize the traceability of downloaded ICOS data
6	to record relevant bibliometric information and establish indicators about the use of ICOS data
7	to implement a common user registration, authentication and tracking system for ICOS
8	to coordinate regular publication of the ensemble of the ICOS data, with the TCs and the ICOS community of PIs
9	to encourage, coordinate, facilitate and ensure the operational provision of elaborated products and synthesis efforts based on ICOS data
10	to offer user-friendly, web-based access to products elaborated from ICOS data
11	to establish interfaces with other relevant data portals

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

Organizing the long-term archiving of ICOS data products, with the aim to both guarantee safe storage and future access long after the cessation of the Research Infrastructure itself, will be an important task of the CP. This activity will complement the data storage and backups routinely performed by the TCs. Decisions regarding the archiving strategy should be taken by ICOS RI in consultation with the TCs and monitoring station assembly PIs.

The 1st proposed role of the CP is to organize and ensure back-up storage and long-term archiving of published ICOS data sets

Data mining, data extraction, collocation

In order to facilitate the interaction with a wide spectrum of user categories, the ICOS Carbon Portal (CP) shall be the main access platform for any and all parties interested in ICOS data products. In addition, the TCs may operate their own data access interfaces provided authentication control is provided through the CP (see section “User registration and traceability” below). The web design, data traceability, download and usage statistics, as well as the enforcement of the ICOS data policy of such TC interfaces shall be closely coordinated with the CP.

The CP shall develop efficient search capabilities that allow users to locate and retrieve data of interest, for example restricted to specific variable types, geographical areas or time periods. *[See e.g. solutions developed in the frame of the INSPIRE GEOPORTAL, at http://inspire-geoportal.ec.europa.eu/]* To this end, the CP will maintain an up-to-date collection of metadata about data provided by the TCs, see Section below.

The 2nd proposed role of the CP is to generate and provide effective tools to publish, discover, access and retrieve observations according to user needs.

Maintaining ICOS data and metadata standards

The harmonization of data & metadata standards, together with graphical formats and links to new products, shall be coordinated within ICOS-RI under responsibility of the CP. Concerning data formats the CP could offer different options to meet user needs with online/offline automatic conversion tools (e.g. ASCII for time series point measurements, NetCDF for spatial data).

Relevant metadata standards (e.g. ISO 19115, Dublin Core, DIF) shall be provided by the CP as well as application of the standard of the INSPIRE directive *[http://www.inspire-geoportal.eu/]*. An agreement on metadata exchange format shall be made to facilitate exchange with other data centers. Metadata will be structured and updated at every TC, but the CP shall maintain its own metadata database according to the above stated metadata standards.

The 3rd proposed function of CP to ensure basic semantic interoperability by maintaining a full copy of the standard metadata and data description documents (ontologies) held at the ICOS TCs, including the compilation of the vocabularies in use within ICOS.

Providing web services to users

The overall architecture of the CP and TCs side software for publishing data and metadata shall be based on Web service solutions. Web services shall be developed for publishing metadata, searching within metadata repositories, visualizing data and retrieving data. Further services (e.g. processing services) as well as procedures and techniques (such as Web service composition) shall also be developed on cloud and the CP environments to offer special services to public users and decision-makers, to generate their favorite information (e.g. risk, alarm or emergency maps) from ICOS and/or with integration with other external data resources. Special interactive Web interfaces (e.g. Web mapping interfaces) could be developed allowing users to manage and/or process data at a basic level and creating their own simple tables and graphs.

The 4th proposed function of CP is to define and implement advanced web services and procedures for web-based data visualization, retrieval and processing.

Traceability of downloaded ICOS data

Traceability and citability of ICOS data products can be ensured by applying a system of unambiguous data identifiers, for example DOI numbers as well as ICOS-internal data set identification schemes. The CP shall have the overall responsibility for coordinating and ensuring the implementation of (internal and external) data identifiers for all ICOS data products.

Citation and referencing of DOI numbers and data publications (see section “Coordinating ICOS data description and releases publications” below) will offer a simple bibliometric means of tracing and measuring the data usage through its referencing in the scientific literature.

The 5th proposed role of the CP is to organize the traceability of downloaded ICOS data.

Tracking of publications based on ICOS data

ICOS users should be encouraged to send in copies of any publications that will report studies using ICOS data, when they are published. The CP will keep track of this record and complete the list by searches using bibliometric (ISI, Scopus…) tools in order to make it exhaustive. Links to publications based on ICOS data available on the Internet are provided by the CP. Any other outcome of the use of the ICOS data shall also be documented on the CP. Relevant information on data usage (and ICOS visibility) is collected: the number of downloads, the number of visits on the portal, the number of papers, the media coverage of ICOS.

The 6th proposed role of the CP is to record relevant bibliometric information and establish indicators about the use of ICOS data.

User registration and traceability

The Carbon Portal shall track what data or information users do access or download, in accordance with the ICOS Data Policy. This allows assessing which data are most interesting to users or establishing user profiles. Download tracking also contributes to showing to funding agencies of ICOS infrastructure the interest of users in the ICOS network and to improve the effectiveness and efficiency of the system. Access to ICOS data will follow the ICOS Data Use Policy (that in turn shall comply with the GEOSS Data Sharing Principles).

The 7th proposed role of the CP is to implement a common user registration, authentication and tracking system for ICOS.

Coordinating ICOS data description and releases publications

Processed and quality controlled data sets offered via the CP may be frozen on a periodic basis and subsequently published in specialized journals *[e.g., Earth System Science Data, http://earth-system-science-data.net]*. The frozen datasets will be available through the CP, in parallel to the continuously updated ‘live’ datasets. The CP shall coordinate with the TCs the peer-reviewed publication of descriptions of the ensemble of the databases. The publication could be done regularly with each “freezing” of the database, e.g. annually. This publication ensures bibliometric recognition of the work performed by the monitoring assembly PIs and the TCs.

The 8th proposed role of the CP is to coordinate regular publication of the ensemble of the ICOS data, with the TCs and the station PIs community.

To coordinate, facilitate and ensure production of elaborated products based on ICOS data

Level-3 data products, such as GHG fluxes on a grid, which are derived from ICOS observational data, have the potential to significantly increase the scientific impact of ICOS. Encouraging the production of Level-3 products and making them readily available to downstream users is a key goal of ICOS. To ensure a broad participation of different modeling groups and to accommodate uncertainty, the CP shall take a proactive role in initiating synthesis and upscaling efforts based on ICOS Level-1 and Level-2 data.

To try and make a wide and representative range of Level-3 products available to stakeholders, the CP shall coordinate external ensemble modeling activities and synthesize their results. The CP shall include research-trained staff with background in all relevant areas who maintain scientific watch on the evolution of user needs and the scientific developments. The production of operational Level-3 products may be done by external groups that commit to the required tasks according to the specifications set by the CP. In addition, the CP research staff should maintain the capacity to produce a limited but consistent base set of Level-3 data products on an annual basis throughout the entire life span of the ICOS RI.

The 9th proposed role of the CP is to encourage, coordinate, facilitate and ensure the operational provision of elaborated products and synthesis efforts based on ICOS data.

Display and access to elaborated data products

Level-3 data products, such as GHG fluxes on a grid that are derived from ICOS observation data, increase the scientific impact of ICOS, and an important task of the CP is therefore to act as a clearing house that will offer access and proactive publicity to all Level-3 products that are based on ICOS observational data, including but not limited to flux production efforts.

The flux products may be generated within ICOS (by the carbon portal) or by external users (modelers), both from the large scientific community among the ICOS consortium and outside. Eligible Level-3 products should be standalone self-consistent products. Example of candidate Level-3 products from future ICOS GHG concentration data are for instance maps of European high-resolution CO2 or CH4 fluxes obtained by atmospheric inversion modelers in Europe , or by the TransCom inversion modelers over the globe, as well as bottom-up ecosystem model-based datasets. Comparisons between products can be developed by the Carbon Portal such as the comparison established by Carboscope (www.carboscope.eu) linked from the current ICOS web-site. Contributions will be 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.

The 10th proposed role of the CP is to offer user-friendly, web-based access to products elaborated from ICOS data.

Interfaces with other data-portals in and outside Europe

Interface with relevant data portals will be established by the CP team. This involves at minimum liaising with these other initiatives for visible links between the portals. Link with external, specific thematic data centers (atmosphere, ecosystem, and ocean) are managed by the TCs with technical support of the CP. Whenever possible, the interfacing can be stronger. The CP team will collaborate with these data portals to ensure technically and IPR-wise (IPR: Intellectual Property Rights) mutual or unilateral discoverability and accessibility within the respective portal search engines, notably with the GEO/GEOSS related portals. While doing so the CP will ensure that ICOS data will remain accessible under the authentication and authorization schemes defined for the ICOS data by the CP.

The 11th proposed role of the CP is to establish interfaces with other relevant data portals.

Interface between the thematic centers and the CP

Data collection and distribution

The TCs will collect all the measurements, from raw data to ancillary data and associated metadata and descriptions for the sites including information on the instrumentation. The data collected and processed with different time resolutions from Near Real Time (daily) to annually will be quality controlled and stored in the respective TC databases. The TCs are responsible for the relations and communications with their related site PIs including for data quality issues and delays in the delivery, in addition to the support activity for methods and protocols. The CAL maintains an archive of calibration tanks.

The CP will build on the work of the TCs and provide access to the Level-1 and Level-2 data produced by the thematic centers, jointly implementing with the TCs technical solutions for easy and straightforward access to the TCs databases after user authentication. The user-accessible data sets may be stored physically at the TCs (Level-1 and Level-2) and at the CP (Level-3) to avoid duplications. Web-services between TCs and CP will be implemented to get access easily to the different data from a single interface.

Metadata associated with the various ICOS data sets will also be made available through the CP, see section “Maintaining ICOS data and metadata standards” above.

Determination & display of data uncertainty

The CP must report and explain the uncertainties in the observation and flux products, in order to minimize the risks of misinterpretation of the data.

Uncertainties pertain to the different data shall be produced and provided by the respective TCs, and subsequently be made available through the CP:

- ICOS data
- Ancillary data
- Flux products

The uncertainty of the ICOS measurements related to data correction, data processing and post-processing is estimated by the relevant thematic centers. The uncertainty of ancillary data is not a priority for the CP but shall be reported if available. For flux products, the CP collects the information provided by the proponents. The CP shall provide to these users clear recommendation on how to document and to report uncertainties for the model results to be displayed on the CP. The display of several products on the CP will also allow users to assess product uncertainty.

Data security (archiving, protection)

Data security involves two different aspects: backup (archiving) of the data and protection against external attack by hackers that could manipulate or damage the system and the data. Data security shall be managed separately by the TCs and the CP. Safe backups, necessary for the day-to-day operations of the Thematic Centers will be secured by the TC. Long-term archiving, with the aim to guarantee both safe storage and potential future access to ICOS data long after the cessation of the RI itself, will be the task of the CP.

Carbon portal & outreach

By its nature the CP contributes directly and actively to the dissemination of the ICOS results. ICOS will provide easily accessible and understandable science and education products through the CP. The CP may prepare and organize outreach actions focused on the various ICOS data products at the European level. The Head Office (HO) organize general ICOS outreach actions on the basis of the scientific material (advanced data plots and visuals) provided by the CP.

Good communication and collaboration with the HQ is essential for being successful in outreach and publicity. To ensure this, a set of “communication principles” shall be identified and applied, at the beginning approved by the ICOS RI Committee. The HQ coordinating communication officer will work on outreach activities in close cooperation with the CP, setting up short and mid-term priorities in the field. The ICOS RI Committee will monitor and evaluate the implementation and success of priority activities.

Carbon portal within the ICOS governance

The CP is a virtual data center which is hosted by one or more institutions and located within ICOS ERIC. As such it will be under the direction of the Director of ICOS ERIC. It will have a representation within the ICOS RI Committee which is an advisory body to the Director of ICOS ERIC. The budget of the CP will be partly supported by ICOS at the European level. The ICOS RI Committee will decide about strategies concerning the Carbon Portal. The CP web interface shall be an integral part of the ICOS ERIC web interface.

Interaction of the CP with the ICOS community of PIs is facilitated through the so called monitoring stations’ assemblies. The CP can technically assist the HQ for liaising with e-infrastructures.

Resources, contributions

The CP will build a system based on the data available at the different facilities and external modelers, and make all these data available to external users. This means that the CP requires a significant storage capacity and a fast and reliable internet connection. Linkage to an important internet hub and a powerful physical link to this are prerequisite. The computer, database and networking capacity could be part of an existing large infrastructure, in that case it would be required that this infrastructure is non-commercial, flexible, easily extendable, based on open systems and research oriented.

System engineers and operators could be held to a minimum of 2 FTE (full time equivalent). The overall scientific coordination and integration of the CP requires 2 scientists and the manager, including an expert in visualization and web application building. The activities related to elaborated Level-3 data products is estimated to require 4 FTE staff, including both data services to external groups as well as consistency checks and product generation. Half FTE is required for secretarial and (financial) reporting support.

The annual personnel budget would amount to around 1000 k€, depending on location and conditions of the hosting institute(s). To this come other operational costs, and the total annual budget of the CP is estimated to approximately 1270 k€ per year.

ICOS Data Quality Assurance Strategy

Introduction

This document outlines a data quality management policy for ICOS. It is important that a dedicated ICOS Quality Management Committee (IQMC) is formed within ICOS (coordinated by the ICOS Head Office (HO)), that oversees and implements this policy, in co-operation with all ICOS Central Facilities.

Definitions used

Quality assurance: all planned and systematic actions necessary to provide adequate confidence that a product, process or service will satisfy given requirements for quality

Internal quality control: operational techniques and activities that are used to maintain and assure given requirements for quality

External quality control: all actions/measurements performed referencing to an external body that verify quality objectives

In this process of quality management two types of auditing are required: auditing by an external certification body (external audits/QC) and audits by internal staff trained for this process (internal audits/QC). The aim is a continual process of review and assessment, to verify that the ICOS Research Infrastructure (ICOS-RI) is working as envisioned, find out where it can be improved and to correct or prevent identified problems. In particular with the case of CFs or the HO, it is considered more productive for internal auditors to audit outside their usual management line, so as to bring a degree of independence to their judgments (see e.g. ISO: http://en.wikipedia.org/wiki/ISO_9000).

Strategy

The QA/QC strategy of the Central Facilities (CFs) and the Head Office (HO) should be guided by ISO 9001 standards (note that ISO certification is not sought for ICOS-RI at this moment in time). In particular the HO, but also the CFs should follow the eight quality principles, which are (from ISO webpage):

- Principle 1: User focus
- Principle 2: Leadership
- Principle 3: Involvement of people
- Principle 4: Process approach
- Principle 5: System approach to management
- Principle 6: Continual improvement
- Principle 7: Factual approach to decision making
- Principle 8: Mutually beneficial supplier relationships

In other words this implies that:

- The data quality management policy of ICOS-RI is a formal statement from the management *of the CFs and HO*, closely linked to the business plan and to user needs. The quality policy is understood and followed at all levels and by all partners. Each partner needs measurable objectives to work towards.

- Decisions about the quality system are made based on recorded data and the system is regularly audited and evaluated for conformity and effectiveness (i.e. ICOS internal QC/audits).

- Records should show how and where products were processed (ICOS *samples analyzed or measurements calibrated*), to allow products and problems to be traced to the source.

- The involved ICOS-RI bodies (e.g. CF's (Central Facilities), MSAs (Monitoring Station Assemblies), ICOS Research Infrastructure Committee) need to determine ICOS *users* requirements and create systems for communicating with users about product information, inquiries, contracts (*e.g. data disclaimers*), and complaints.

- When developing new products, the involved ICOS bodies (i.e. the CFs) need to plan the stages of development, with appropriate testing at each stage. They need to test and document whether the product meets design requirements, regulatory requirements and user needs.

- Regular review of ICOS performance through internal audits and meetings (*by MSAs and CFs*) is required. These determine whether the quality system is working and what improvements can be made. They deal with past and potential problems, keep records of those activities and the resulting decisions, and monitor their effectiveness (note: a documented procedure for internal audits needs to be designed by the ICOS Quality Management Committee (IQMC)).

- Documented procedures also need to be developed by the IQMC for dealing with actual and potential non-conformances (problems involving suppliers (ICOS stations) or customers (ICOS users), or internal problems). The involved ICOS bodies need to make sure no one uses substandard products (i.e. not quality-assessed data), determine what to do with these products, deal with the root cause of the problem (e.g. what to do with poorly performing ICOS-certified stations), seeking and keeping records to use as a tool to improve the system.

ICOS Data quality policy

There are three steps in data quality management for which different responsibilities are assigned:

- **Quality assurance and first order** quality control at the site: This is the responsibility of the PI. Protocols developed by Thematic Centers in cooperation with the associated Monitoring Station Assemblies.

- **ICOS internal quality control**: This is the responsibility of station PI, Thematic Centre, CAL and IQMC: Sampling and measurement system performance checks at the stations, standardized data processing and flagging, calibration.

- **External quality control**. This is done by an independent organization (i.e. external to ICOS). Responsible for organizing this is the ICOS Quality Management Committee in consultation with MSAs, CFs and CAL

Critical issues to ensure quality assurance are (1) the use of standardized equipment (2) training of station personnel and (3) measurement guidelines (MGs) and standard operating procedures (SOPs). The description of **data quality objectives (DQOs)** is important for instrument selection and development of MGs and SOPs.

These DQOs are qualitative and quantitative statements that clarify the objectives of observations, define the appropriate type of data, and specify tolerable levels of uncertainty. DQOs are, thus, used as the basis for establishing the quality and quantity of data needed. An example for CH_4 measurements from WMO-GAW is given in GAW Report No. 185 Guidelines for the Measurement of Methane and Nitrous Oxide and their Quality Assurance, WMO, Geneva, section 3.

The Thematic Centers (with help of MSAs) need to ensure that the selected instrumentation is appropriate, measurement guidelines and standard operating procedures are developed and the protocols are written down in a clear and unambiguous way. The required auxiliary information (e.g. ecosystem sites) must also be clearly stated. Formats of data need to be specified. PI's need to ensure that their equipment is operating properly and according to the protocols (i.e. internal quality control) and that data is submitted regularly to the data centers.

DQOs for ecosystem, ocean and atmospheric sites specify targets for accuracy and precision of mole fractions and flux measurements, or derivatives of those. The same is true for auxiliary variables, like meteorological data, ocean parameters, biomass or soil carbon, where appropriate and possible. If not possible, or DQOs are not existing, protocols need to be developed that prescribe measurement methodologies and DQOs defined for specific parameters, etc. Important is that there is an agreed list of variables with stated target accuracy and precision. These protocols are ideally submitted to WMO for acceptance as official international standards.

The Thematic Centers collect data and process it in a standardized way. The way they process data must be standardized and written up in data processing protocols according to latest scientific standards. This step makes it possible to **minimize differences between site data** and produces various levels of quality assured data. The key responsibility is with the Thematic Centers in consultation with site PIs. During this process site visits are planned for stations to check compliance to the ICOS standards and determine ways to improve quality. This is called **internal auditing.**

When the data is made public, external quality control comes into play. External quality audits **generate credibility** to the ICOS data. It is assessed by an independent organization that is not associated to ICOS. This is like a controller's statement on a financial bill. If ICOS data is used for verifying treaties and emission reductions, this is a key step to be taken into account. It would involve two things: a thorough evaluation of the protocols and methodologies ICOS deploys, and site checks to ensure that the protocols are followed. This is external auditing. As for some of the GCOS Essential Climate Variables, in the future ICOS may want to obtain ISO standards.

These three steps in quality management are fundamentally different and are organized in different ways. Step one and 2 are part of the station PI's, the Thematic Center's and the CAL's responsibility. Concerning the third step, the ICOS Quality Management Facility is critical for ensuring independence of the quality audit to achieve credibility with the outside world.

Part 3: Implementation

Preparatory Phase

The **Preparatory Phase** started in 2008 to develop the strategic plan for constructing the Infrastructure, and to obtain the funding commitments by national agencies and stakeholders. The technical aspects of the project have been developed in the demonstration of full operation with a reduced number of observational sites. The preparatory phase has received funding by the EU from 2008 until 2013. The figure 1 illustrates the scientific and institutional communities and projects related to work in ICOS Preparatory Phase Project.

The preparatory phase of the ICOS workplan is supported by the European Commission under Framework Programme 7. It is organised around eight complementary work packages:

- *WP 1 corresponds to the consortium organization and management of the project,*
- *WP 2 provides legal and governance models,*
- *WP 3 coordinates the financial/fund raising work,*
- *WP 4 considers the integration of essential external datasets into ICOS, and involves data providers, in particular for fossil fuel emission data and biomass and soil carbon inventories,*
- *WP 5 corresponds to the technical work associated with the distributed network of field sites, including network design, equipment selection, testing and optimisation,*
- *WP 6 carries out the preparation for building the atmospheric and ecosystem thematic centers, as well as the central analytical laboratory,*
- *WP 7 applies the technical solutions retained in WP 5-6, to execute the Demonstration Experiment, a six month to one year test run where the infrastructure will be operated with a small number of sites,*
- *WP 8 organizes the project-level outreach, the definition of the web based Carbon Portal, as well as training and capacity building necessary for the future operational phase.*

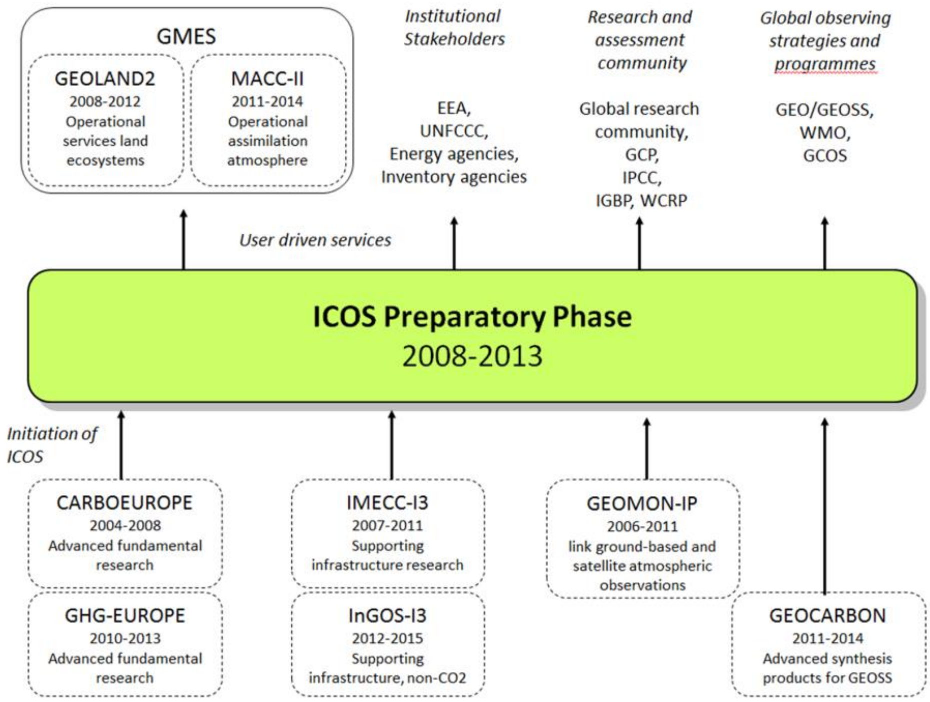


Figure 1. The scientific and institutional communities and projects related to work in ICOS Preparatory Phase Project.

Construction and Implementation Phase

The **Construction Phase** starting between 2011 and 2013 in the different countries, will build and commission the ICOS Central Facilities, and complete the development according to the strategic plan.

The general timeline for implementing the ICOS (see also Figure 2 below):

- Establishment of the ERIC legal entity: present - early 2014
- Co-ordination of the implementation and construction of ICOS RI: Jan 2013 – until all components are constructed, including the OTC and CP
  - Integrated ICOS RI implementation plan 2014

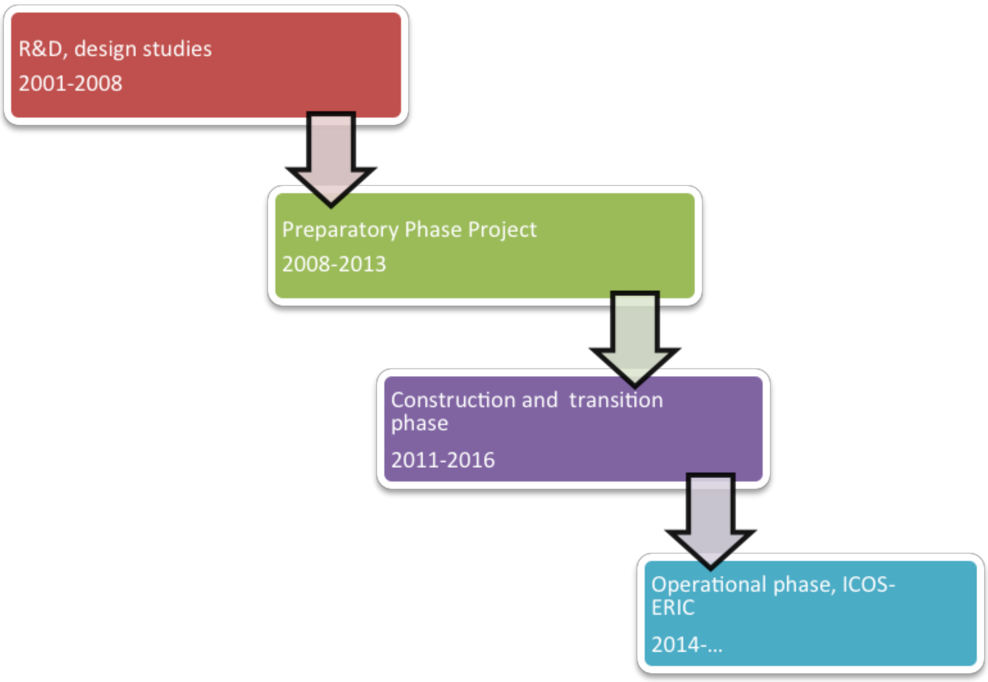


Figure 2. The general timeline for implementing the ICOS.

Implementation of the ICOS Central Facilities

Most of the technical and scientific planning as well as the demonstration of the functions of the ICOS RI components (national measurement sites and Central Facilities) have been accomplished during the ICOS Preparatory Phase Project. The PPP ends in March 2013. The construction of the ICOS RI (networks and CFs) started in 2011. The transition from ICOS RI construction phase to full RI operational phase will take place in 2013-2016. One of the main tasks of the transitional HO will be to coordinate the commissioning and implementation of the ICOS RI. The fully operative phase is planned for 2016.

Figure 3 shows the timelines for the construction of the CFs and the HO. The implementation timeline of the ICOS RI will be more precise when the legal process and construction of the CFs will be accomplished.

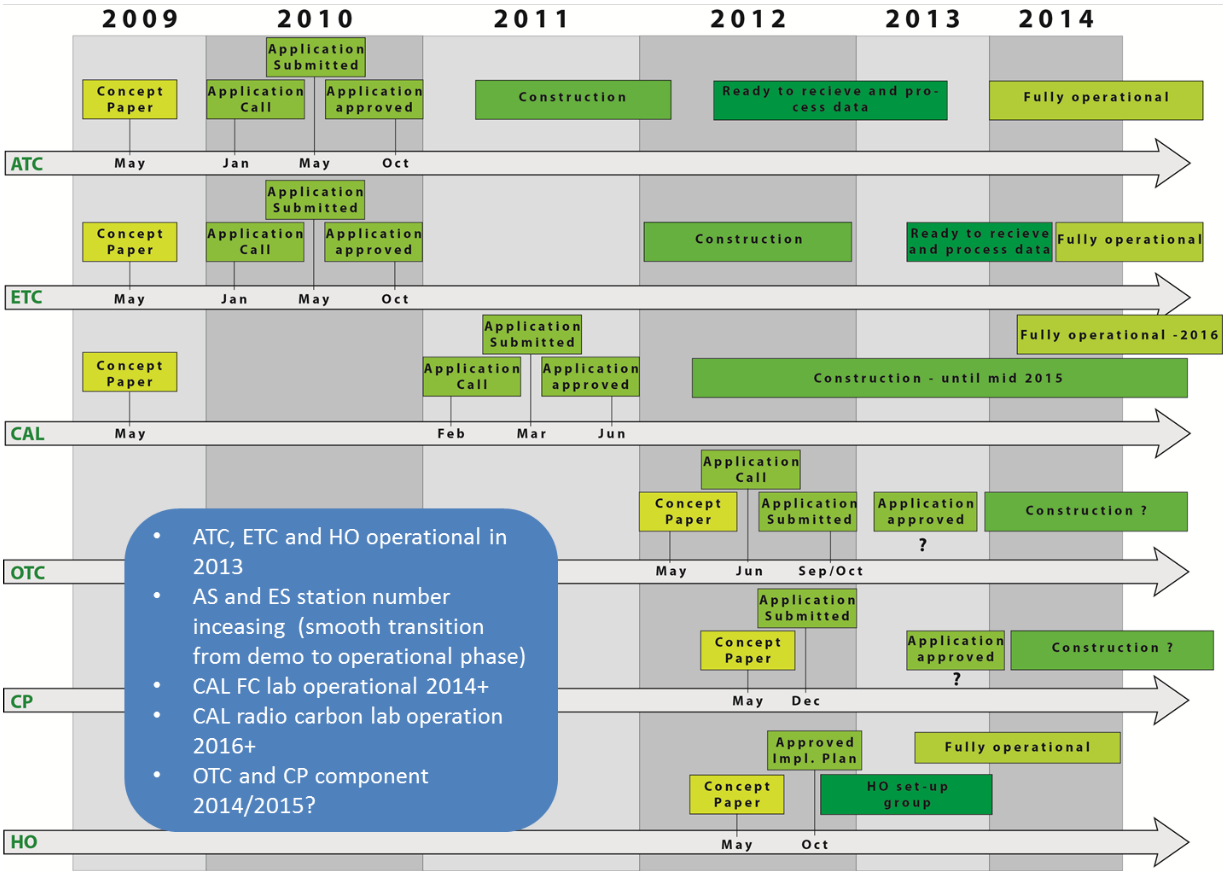


Figure 3. The scheduled timelines of the ICOS RI Central Facilities and Head Office from concept paper to full operative mode. The abbreviations: ATC – Atmospheric Thematic Centre, ETC – Ecosystem Thematic Centre, CAL – Central Analytical Laboratories, OTC – Ocean Thematic Centre, CP – Carbon Portal and HO – Head Office.

Implementation of the ICOS National Networks

Section describing the Financial implementation of ICOS RI and Table 2 (below) give an overview of the potential stations that the countries related to the PPP are upgrading to ICOS standards, planning to run or trying to seek funding for. It gives a view of the potential ICOS National Network size in the future in Europe, which is according to plans in table 2 approximately 150 in total. At the moment countries are building up the stations, finding solutions for funding their ICOS activities and signing in ICOS ERIC. Therefore, initially, smaller set of stations are integrated into ICOS, total amount of stations of different levels being approximately 80.

Operational Phase

The **Operational Phase** will start in 2014 and is scheduled to last for 20 years. After the full scale deployment of the ICOS National Networks and the ICOS Central Facilities, it will run in an operational mode, collecting and processing greenhouse gas concentrations and fluxes on a routine basis, providing greenhouse gas data for the researchers, providing elaborated data products as necessary, giving training, and setting the standards for producing high quality GHG-data and European added value. Periodic upgrades of the infrastructure will be established along with a regular review process of assessment of the network performances.

Financial implementation of ICOS RI

The approximated yearly costs of the whole ICOS RI is shown in Table 1.

Table 1. General estimates of the construction and running costs of different components of ICOS RI.

	Construction Costs, approx, Meur		Running Costs, Meur/per year[3]
ICOS ERIC[1]	2011-2013	2	2.7
ICOS Central Facilities[2]	2011-2015	40	10
ICOS National Networks	2011-2013	125	23
Total costs		167	35.7

[1] Includes Head Office and Carbon Portal, Carbon Portal is not constructed yet, construction costs of Head Office include costs from the ERIC negotiation process
[2] ICOS Central Facilities: ca. 30-40 Meur, OTC is not constructed yet
[3] ICOS ERIC includes estimations for Head Office, Carbon Portal and common activities

A substantial part of the total costs of ICOS Central Facilities is covered by contributions of the hosting country/ies (host premium contribution) of the Central Facilities, Head Office and Carbon Portal.

Member countries and Observers of ICOS ERIC shall pay annual membership contributions. Total membership contribution is formed by the following elements: common basic contribution, common GNI based contribution, and number and type of stations. The latter part of the membership contribution is redistributed to the activities in the ICOS Central Facilities. ICOS ERIC will actively seek funding opportunities from European Commission and other sources.

The implementation of the ICOS National Networks has started already in 2009. The anticipated list for the overall ICOS National Networks is shown in Table 2. The participating countries will bring the stations into the network gradually during the first years of operation. The approximated yearly running costs per station depend on the station type and are described in Part 2.

The development of the total costs of ICOS National Networks, and transition from the construction phase to operational phase is shown in Figure 4.

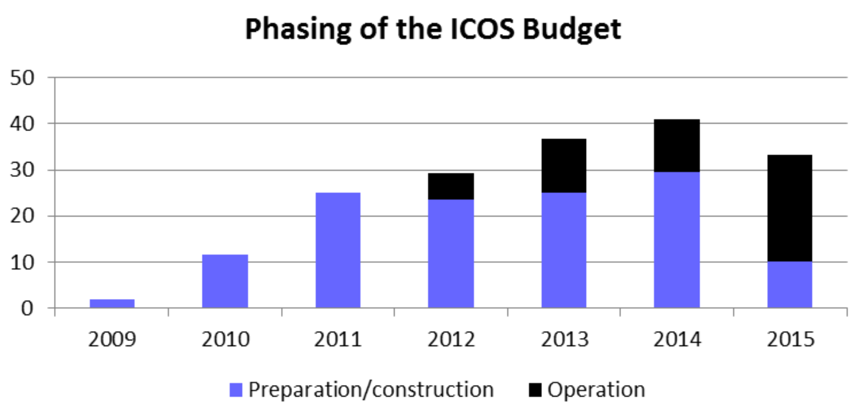


Figure 4. The development of ICOS National Networks budget 2009-2015 in Meuros for preparation/construction (blue) and transition towards operational phase (black).

ICOS ERIC budget will consist of the host premium contributions from HO and CP hosting countries and membership contributions. The anticipated development of the ICOS ERIC annual budget is described in Figure 5.

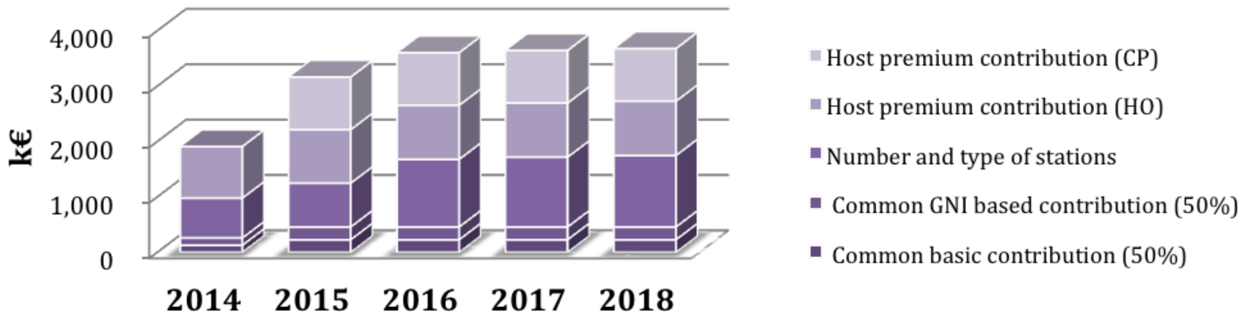


Figure 5. The estimated development of the annual budget of ICOS ERIC 2014-2018. It is assumed that the Carbon Portal is operational in 2015.

Table 2. List of ICOS atmospheric and ecosystem stations possibly operated by each country. The future ocean observing system contribution to ICOS is currently being defined.

COUNTRY	ECOSYSTEM				ATMOSPHERE				OCEAN			
	N° OF SITES	NAMES OF SITE	OP DATE	TYPE SITE	N° OF SITES	NAMES OF SITE	OP DATE	TYPE SITE	N° OF SITES	NAMES OF SITE	OP DATE	TYPE SITE
BELGIUM	6	Brasschaat	2011	Forest coniferous	1	La Réunion	2014	Tall tower	2	Simon Stevin	2013	North Sea
		Lochristi	2011	Short Rotation Coppice Culture						Belgica	2014	North Sea
		Maasmechelen	2013	Heathland								
		Vielsalm	2013	Mixed Forest								
		Lonzée	2013	Young Diverse Forest								
		La Robinette	2013	Agricultural								
CZECH REPUBLIC	4	Bílý Kříž forest	2011	Forest coniferous	1	Křešín u Pacova	2013	Tall tower				
		Třeboň	2013	Wetland								
		Lanžhot -	2014	Forest deciduous								
		Křešín u Pacova	2014	Agricultural								
DENMARK	2	Lille Bøgeskov	2014	Forest deciduous	2	Risø Meteorological Mast	2014	Mixed agricultural				
		Energipil Risø	/	Short Rotation Coppice Culture		Østerild Wind Test Station	/	Agricultural				
FINLAND	10	Hyytiälä	2013	Boreal pine forest (Scots pine)	4	Hyytiälä	2013	Tall tower				
		Sodankylä	2013	Northern boreal pine forest		Pallas-Sodankylä GAW station	2013	Mountain				
		Siikaneva	2013	Southern boreal fen		Puijo-Koli-Eastern Finland	2013	Tall tower				
		Värriö	2013	Subarctic pine forest		Utö - Baltic sea	2013	Non-forested island on sea				
		Kumpula, Helsinki	2013	Urban environment								
		Lettosuo	2013	Forestry-drained peatland								
		Lompolojänkkä	2013	Northern boreal fen								
		Kaamanen	2013	Subarctic fen								
		Kenttärova	2013	Northern spruce forest								
		Kuivajärvi	2013	Boreal lake ecosystem								
FRANCE	15	Grignon	2015	Cropland	4	Observatoire Pérenne de l'Environnement	2013	Periurban				
		Auradé	2015	Cropland		Trainou	2013	Mountain				
		Lamasquère	2014	Cropland		Puy de Dôme	2013	Tall Tower				
		Hesse 1	2014	Dbf		Gif-sur-Yvette	2013	Coastal				
		Barbeau	2014	Dbf								
		Puéchabon	2014	Evergreen oak								
		Fontblanche	2014	Coniferous+evergreen oak								
		Lusignan	2014	Grassland								
		Laqueuille	2014	Grassland								
		Mons	2013	Cropland								
		Guyaflux	2015	Rainforest								
		Bilos	2014	Coniferous								
		Osnes	2015	Grassland								
		Mauzac	2015	Fallow								
		Montiers	2014	Dbf								
GERMANY	19	Gebesee	2014	Cropland	9	Ochsenkopf	2012	Tall tower	5	Polarstern Voluntary Observing Ship	2013	Voluntary observing shipocean
		Tharandt	2014	Forest coniferous		Hohenpeißenberg	2013	Tall tower		North Altantic Voluntary Observing Ship	2012	Voluntary Observing Ship
		Fendt	2014	Grassland		Lindenberg	2014	Tall tower		Finnmaid Voluntary Observing Ship	2013	Voluntary observing ship
		Hohes Holz	2014	Forest deciduous		Gartow 2	2015	Tall tower		Cape Verde Ocean Observatory	2013	Mooring + sampling program
		Selhausen	2014	Cropland		NA	2016	Tall tower		Hausgarten	2014	Profiler
		Hainich	2014	Forest deciduous		NA	2016	Tall tower				
		Mooseurach	2014	forest coniferous (wetland)		NA	2016	Tall tower				
		Meppen 1	2016	Cropland		NA	2016	Tall tower				
		Bourtanger Moor	2016	Wetland		Heidelberg	/	30 m a.l.g.				
		Meppen 2	2016	Grassland (wetland)								
		Wüstebach	2016	Forest coniferous								
		Rollesbroich	2016	Grassland								
		Wulferstedt	2016	Grassland								
		Schlanstedt	2016	Cropland								
		Klingenberg	2016	Cropland								
		Grillenburg	2016	Grassland								
		Spreewald	2016	Forest deciduous (wetland)								
		Schechenfilz	2016	Wetland								
		Graswang	2016	Grassland								

/ = No communicated or tbc
NA = No Available

Table 2. continues

COUNTRY	ECOSYSTEM				ATMOSPHERE				OCEAN			
	N° OF SITES	NAMES OF SITE	OP DATE	TYPE SITE	N° OF SITES	NAMES OF SITE	OP DATE	TYPE SITE	N° OF SITES	NAMES OF SITE	OP DATE	TYPE SITE
IRELAND	7	Dripsey Farm,Co. Cork	2013	Eco	4	Mace Head	2013	Ground				
		Johnstwon Castle, ARC	2012	Eco		Mace Head Atmosphere Research Station	2013	Ground				
		Glencar peatland site, Co. Kerry	2013	Eco		Carnsore Point EMEP monitoring Station	2013	Ground				
		Oakpark Agriculture Research Centre	2013	Eco		Malin Head Synoptic Meteorological Station	2013	Ground				
		Laois Forest	2014	Eco								
		Pius x Tempelogue	/	Eco								
		Marrowbone Lane	/	Eco								
ISRAEL	1	Yatir	/	semi-arid, pine								
ITALY	5	NA	2014	Eco	2	NA	2014	Ground				
		NA	2014	Eco		NA	2014	Ground				
		NA	2014	Eco								
		NA	2014	Eco								
		NA	2014	Eco								
NETHERLAND	6	Cabauw-2	2014	Cropland	6	Hengelo	2014	Grassland				
		Haastrecht	2014	Grassland		Goes	2014	Grassland				
		Horstermeer	2014	Peat		Peel	2014	Crops				
		Langerak	2014	Semi-natural		Noordzee	2014	Sea				
		Loobos	2014	Coniferous		Cabauw	2012	Grassland				
		Molenweg	2014	Grassland		Lutjewad	2014	Crops				
NORWAY	1	Andøya	2013	Peatland	3	Birkenes Observatory	2013	Ground				
						Andøya Observatory	/					
						Zeppelin Observatory	2013	Remote Arctic				
POLAND	11	Tuczno	2016	Coniferous Forest	4	Kasprowy Wierch	2016	Ground				
		Rzecin	2016	Wetland		Katowice Kosztowy	2016	Tall tower				
		Bialowieska Forest	2016	Coniferous Forest		Piła Rusionow	2016	Tall tower				
		Notecka Forest	2016	Coniferous Forest		Białystok Krynica	2016	Tall tower				
		Spala	2016	Coniferous Forest								
		Lublin	2016	Crops								
		Bydgoszcz	2016	Grassland								
		Bebrzanski National Park	2016	Wetland								
		Mazury Lake (Śniardwy)	2016	Lake								
		Miedzyzdroje	2016	Coast								
		Brody	2016	Crops								
PORTUGAL	3	Montado	/	Evergeen oak woodland	1	Urban	2013	Urban				
		Eucalyptus	/	Eucalyptus globulus plantation								
		Pine	/	Maritime pine								
SPAIN	4	Las Majadas	2015	Savanna	4	Izaña	2015	Mountain	4	Estoc	2016	Fixed station
		Balsa Blanca	2015	Shrubland		La Muela	2015	Tall tower		Gift	2016	Fixed station
		La Africana	2015	Orchard crop		Izaña-Aircraft	2015	Aircraft		Quima	2016	VOS-line
		Quintos de Mora	2015	Forest		La Muela	2015	Aircraft		Trancos	2016	VOS-line
SWEDEN	4	Svartberget	2013	Forest coniferous	1	Svartberget	2013	Tall tower				
		Stordalen	2013	Arctic wetland								
		Lanna	2013	Cropland								
		Degerö	2013	Boreal wetland								
SWITZERLAND	1	Davos	2013	Forest coniferous	1	Jungfraujoch	2013	Mountain				
UNITED KINGDOM	2	Alice Holt	2013	Dbf	6	Angus	2013	Grassland				
		Griffin	2013	Enf		Ridge Hill	2013	Grassland				
						Tacolneston	2013	Grassland				
						Selkirk	2014	Grassland				
						Heathfield	2014	Grassland				
						Egham	2013	Urban				

/ = No communicated or tbc

NA = No Available

Part 4. Country Profiles

Belgium

Focal Point: Reinhart Ceulemans, UA

Main scientific organisations

Present scientific organisations

- University of Antwerp, Research Group of Plant and Vegetation Ecology - Research Center of Excellence ECO (Prof. Reinhart Ceulemans and Prof. Ivan Janssens)
- University of Liège – Gembloux Agro-Biotech, Unit of Biosystem Physics (Prof. Marc Aubinet)
- Hasselt University, Center for Environmental Sciences (Prof. Jaco Vangronsveld)
- Flanders Marine Institute VLIZ (Director Jan Mees)
- Research Institute for Nature and Forestry (Director Jurgen Tack)

Scientific organisations to be involved in the future

- Belgian Institute for Space Aeronomy (Director General Martine De Mazière)
- Management Unit of the North Sea Mathematical Models and the Scheldt estuary (MUMM) at the Royal Belgian Institute of Natural Sciences (RBINS) (General Director Camille Pisani)

- Université de Liège, Unité MARE (Dr. Alberto V. Borges)

Stakeholders and possible funding organisations

- For the Government of Flanders:
  - Flanders Authority, Department of Economy, Science and Innovation (EWI)
  - Flemish Hercules Foundation with specific ESFRI financial support from the Flemish Government, Vice Minister-President, Minister for Innovation, Government investment, Media and Poverty Reduction

- For the Communauté Française / Région Wallonne:
  - Service Public de Wallonie, DG06 Économie, Emploi et Recherche

- At the Federal level:
  - Belgian Science Policy Office (BELSPO)

Experience

The Research Group of Plant and Vegetation Ecology (PLECO) has been established in 1975 and has since been growing until 45 scientists and technical staff at present. The research group has been involved in ecological and ecophysiological research (at the plant, vegetation, ecosystem, regional scales) for more than three decades. Based on its size, its output in terms of publications and citations, and its international recognition (Honorary Doctorate degrees, Francqui Chair, international awards, publications in Nature and Science), the research group has been formally recognized – and funded – as the Research Center of

Excellence ECO in 2007. Flux measurements of carbon, water and energy of plants and ecosystems have been at the core of the research, including fluxes between ecosystems and the atmosphere using the eddy covariance methodology. This expertise has been primarily on mixed forest ecosystems including bioenergy plantations. Furthermore the research group has a very large expertise with the collection, analysis and synthesis of ancillary ecological parameters. The group has also acquired international recognition for its research on short-rotation coppice crops for bio-energy over the last four decades.

The Unit of Biosystem Physics has been working since 1996 on ecosystem - atmosphere exchanges. The group has 15 scientists and technical staff at present. The research group has been involved in ecophysiological research at ecosystem scale and managed three eddy covariance sites on forest, crop and grassland ecosystems. The Unit has an international recognition in micrometeorology, in flux measurement and analysis and in eddy covariance methodology. Especially, it has coordinated the publication of "Eddy covariance; a guide to measurement and data analysis" which will be used as a handbook by the ecosystem network.

The Flanders Marine Institute (VLIZ) acts as the coordination and information platform for marine and coastal-related scientific research in Flanders and serves as an international contact point. The data centre of VLIZ is a world leader in managing marine biodiversity data. It is the National Oceanographic Data Centre (NODC) for Flanders, and is actively involved in several initiatives of the UNESCO/IOC/IODE. VLIZ is also coordinating part of the EU marine strategy roadmap towards an integrated maritime policy and is involved in EuroFleets. VLIZ is active in the other ESFRI projects LifeWatch and EMBRC.

The Centre of Environmental Sciences (**CMK**) of Hasselt University is an interdisciplinary research institute in which five research teams focus on environmentally related fundamental and applied research questions. Their combined expertise is now concentrated in three main research fields, where biologists, chemists, economists and lawyers focus on environmentally and biodiversity related research questions. CMK has currently a staff of more than 95 scientists and technicians. Since late 2010 CMK-UHasselt also has a formal agreement with the only National Park in Belgium to perform biodiversity and climate change related research in this National Park and surroundings. CMK is also a partner in the Centre of Excellence ECO, intensely collaborating with PLECO.

Implementation timeline

- 2008-2012: Participation in the EU ICOS project
- 2009-2012: Preparatory phase; funding secured in 2012 for Flemish ICOS participation
- 2011: Construction and installation of two L1 ICOS measuring towers (poplar plantation and Scots pine forest)
- 2012: Establishment of the Ecosystem Thematic Center part in Antwerp. Operational with 4 persons since October 2012.

Station Name	Station Type	Site Level	Site type	Estimated date when the site will be ICOS operational
Brasschaat	eco	1	Coniferous Forest	mid-2011
Lochristi	eco	1	Short Rotation Coppice Culture	early 2011
Maasmechelen	eco	2	Heathland	mid 2013
Vielsalm	eco	2	Mixed Forest	late 2013
Lonzée	eco	2	Young Diverse Forest	late 2013
La Robinette	eco	2	Agricultural Crop	late 2013
Simon Stevin	ocean		North Sea	late 2013
To be confirmed				
Belgica	ocean		North Sea	late 2014
La Réunion	atm			late 2014

Users of the infrastructure and anticipated gains

- The six ecosystem stations and the ships of opportunity provide a broad window of opportunities for researchers from many different research fields as remote sensing, hydrology, ozone and aerosols, microbiology, ecology….
- In combination with the atmospheric tower network, they also offer ample possibilities for earth system modellers, regional climate modellers, for support to policymakers in the domain of climate change;
- Scientists that study the bio-geochemical cycles (a.o. the C cycle) in view of enhancing climate models for better predictions towards regional and decadal scales;
- Academic education and training of young scientists;
- Institutions that have a responsibility with regard to greenhouse gas emission inventories within the framework of the UNFCC, Federal Interregional Cell for Environment and Air Quality…
- Public and non-governmental (environmental and climate) organizations;
- Private sector: companies that want to test newly developed instruments against the internationally established ICOS standards, carbon management companies, carbon markets, trade of emissions, insurance companies;
- Local and regional authorities;
- International organizations: IPCC, GCOS, JPI Oceans, JPI Climate...

Role in the infrastructure; Network Update

- The UA Research Center of Excellence is one of the three partners of the Ecosystem Thematic Center (ETC), responsible for the ancillary ecological data (parameters, coordination, standardization of data flow and protocols for collection of ecological and supporting ancillary data in the field). As of 1 October 2012 the ETC part in Antwerp has been established. Four full-time persons are now employed to run and operate the ETC. These include one project manager (for the overall management and support of the Belgian Focal Point), two post-doctoral scientists (in early phases responsible mainly for preparation of the protocols and training) and one database developer (for the informatics and development of the database).
- Two ICOS ecosystem stations have been established and are operational as ICOS sites since 2011, i.e. a Scots pine forest in the Antwerp Campine region (Brasschaat) and a short-rotation coppice culture of poplar and willow (Lochristi, East-Flanders).
- Support has been received from the Hercules Foundation for the construction of a third ecosystem tower that is being established in 2013 in a dry heathland ecosystem in the National Park Campine region (Limburg) and to equip a ship of opportunity that will be monitoring the Southern Bight of the North Sea.
- Financial support has been received for the operation of the three ecosystem stations, the oceanic station and the Ecosystem Thematic Center in 2013, with a promised continued funding for the period of 2014-2018.
- In the Fédération Wallonie-Bruxelles three operational ecosystem stations have been approved for inclusion in ICOS, i.e. a mixed forest (Vielsalm), an agricultural crop (Lonzée) and a young diverse forest (La Robinette). Funding is secured for the coming eight years. The three stations will be ICOS operational by late 2013.
- An atmospheric station at Ile de la Réunion of the Belgian Institute for Space Aeronomy is being considered for approval and funding by BELSPO in the course of 2013.
- A second oceanic observatory on the research vessel BELGICA is also being considered for approval and funding by BELSPO in the course of 2013.

National Roadmap Update

Flanders' particular interest is focused on the contribution to the ICOS Ecosystem Thematic Center and on the establishment and operation of (at least) three ecosystem stations and one oceanic station. The Flemish government is supporting the participation of the research group of Plant and Vegetation Ecology (PLECO) / Research Center of Excellence ECO (University of Antwerp), the Research Institute for Nature and Forestry (INBO) and Flanders Marine Institute (VLIZ) as participant in the ICOS ecosystem network, and of PLECO / ECO in the Ecosystem Thematic Center. The Research Center of Excellence ECO also acts as Belgian focal point for the ecosystem stations.

In the Région Wallonne an ICOS contact group has been created, supported by the National Science Foundation-FRS. This ICOS contact group involves research teams of the Université de Liège (Agro-Biotech-Gembloux and MARE), the Université Catholique de Louvain, and the Centre Wallon de Recherches Agronomiques (CRA-W). The group is being coordinated by the Unité de Physique des Biosystèmes. The Walloon Ministry council approved the establishment of three ecosystem stations in 2013 in the Walloon region.

Network participants

Universiteit Antwerpen

inbo

Met steun van de Vlaamse overheid

HERCULES STICHTING

belspo

Université de Liège

VLIZ

universiteit hasselt

Avec le soutien de la Wallonie

EWI

Czech Republic

Focal Point: Jiří Kolman, CVGZ

Main scientific organisations

Present scientific organisations

Centrum výzkumu globální změny AV ČR, v. v. i. (Global Change Research Centre AS CR, v. v. i, project CzechGlobe): Michal V. Marek, Dalibor Janouš, Marian Pavelka, Manuel Acosta, Alice Dvorska, Kateřina Havránková, Radek Czerný, Radek Pokorný, Jiří Dušek, Pavel Sedlák, Eva Dařenová, Romana Slípková, Ladislav Šigut, Jan Trusina, Vlastimil Hanuš.

The main project of the Center is Operational Programme R&DI - European Centre of Excellence "CzechGlobe - Center for Global Climate Change Impacts Studies".

Stakeholders and possible funding organisations

- Ministry of Education, Youth and Sports of the Czech Republic and Czech Grant Agencies
  National programmes (e.g. Projects of Large Infrastructures of R&DI): project CzeCOS (national carbon stock investigation)

Experience

Network of ecosystem stations (mountain spruce and beech forest, mountain grassland, spruce forest in highlands, wetland, agroecosystem) unified under the umbrella of the Bílý Kříž Experimental Research Station - basic funded body by CzechGlobe for the long-future, technical support, training centre: former Research Infrastructure under FP5.

Implementation timeline

- 2008-2011 Preparatory phase: Focused attention to the finalisation of the technical quality of the National Observation Site (NOS) Bílý Kříž and implementation of the CzechGlobe contribution to the WP3, WP7 and WP8, further focus on setting up new ecosystem stations.
- 2012-2014 Construction phase – full sets of equipment to all ecosystem stations, building of atmospheric station
- 2014-2031 Operational phase

Users of the infrastructure and anticipated gains

- CZ users of the infrastructure:
  1/ Agency for the environmental Protection – Carbon emission budget unit
  2/ Czech Institute for Meteorology and Climatology
  3/ Czech national Climatic Program
  4/ Czech State Forests
  5/ Ministry of Environment

6/ Ministry of Agriculture
7/ Ministry of Education
8/Mendel University in Brno

- Scientific community: National grant agencies, Academy of Sciences, Academic Universities bodies
- Czech State Forests
- Approximately 10 PhD and 5 Thesis & post-docs expected to be using the infrastructure network, data or facilities
- 30 scientific publications

Role in the infrastructure; Network Update

The Czech Republic has been involved in EU Carbon projects since 1995. Under the umbrella of the projects national network (i.e. Carboeurope IP), eddy towers were constructed and the national observation site of Bily Kříž was established. The carbon observation programme is completed with the impact studies (long-term experiments with elevated CO_2 on the forest stand level). Thus this type of proposed research plan is of great importance in the Czech governmental research priorities.

CzechGlobe is a partner in the 4 PhD. programmes at 2 universities:

- Univ. of South Bohemia Č. Budějovice: Applied and Landscape Ecology and Biophysic
- Mendel Agric. and Forestry University Brno: Applied and Landscape Ecology and Forest Ecology

Future participation of PhD students within the ICOS project will be part of the CzechGlobe – Ministry of Education pre- agreement on the national founds support of the ICOS programme.

ICOS was incorporated into the Czech National Roadmap of Large Research Infrastructures as “CzeCOS”.

National Roadmap Update

ICOS was incorporated into the Czech National Roadmap of Large Research Infrastructures as “CzeCOS”.

Network Participants

CzechGlobe

Denmark

Focal Point: Kim Pilegaard, DTU

Main scientific organisations

Present scientific organisations

- Technical University of Denmark, DTU: Kim Pilegaard, Andreas Ibrom, Ebba Dellwik
- University of Roskilde: Eva Bøgh
- University of Aarhus: Lise Lotte Sørensen, Camilla Geels, Morten Rasch, Mikkel Tamstorf

Stakeholders and possible funding organisations

- Ministry of Science Technology & Innovation, Danish Agency for Science, Technology & Innovation.
- Ministry of Climate and Environment
- Private funds

Experience

The *Technical University of Denmark*, DTU (and the former Risø National Laboratory for Sustainable Energy) has since 1996 participated in EU-projects such as Euroflux, CarboEurope, CarboEurope-IP, and IMECC. Participation in FLUXNET. DTU has established a number of ecosystem flux sites as part of their long-term research programme. DTU has the technical skills and staff to provide national support for the infrastructure.
The Institute of Geography, *University of Copenhagen*, has taken part in CarboEurope-IP and has carried out flux measurements of greenhouse gases in Africa, Siberia and Greenland.

The research area and infrastructure are very important to consolidate current research activities at the new environmental institute, ENSPAC, at *Roskilde University*. It is also strongly supportive to the strategic research planning of ENSPAC which includes spatial environmental dynamics as a core research area.

The National Environmental Research Institute at the *University of Aarhus* has a long tradition for monitoring of atmospheric pollutants. The institute is also doing research in Greenland and operates the Zackenberg Research Station in northeast Greenland.

The members of the research team behind this application have all been active within the research areas supported by the infrastructure. Apart from participation in the EU-projects, the present research team has formed the national part of the Nordic centre of excellence NECC (Nordic Centre for Studies of Ecosystem Carbon Exchange and its Interactions with the Climate System). The research team has published a large number of papers utilizing results from the research driven measurement stations. Thus the existing team has demonstrated a high quality and productivity in research utilizing data of the type that the ICOS infrastructure can provide in the future.

Implementation Timeline

- 2008 to 2009: Danish pre-project
  1) Identification of localities for atmospheric concentration stations and for flux measurement stations

2) Establishment of research network
3) Outlining of research associated to the infrastructure
4) Model for practical implementation in Denmark and Greenland
5) Models for financing

- 2008-2011: Participation in ICOS/EU pre-project
- 2013-2014: Establishment of ecosystem and atmospheric stations according to ICOS standards
- 2014-?: Running phase for stations.

Users of the infrastructure and anticipated gains

- Scientific user groups: 10
- 3 PhD students per user group
- Danish citizens (scenarios of future impact on climate change)
- 2-5 publications/group/year
- Private enterprise (technical development within sensor development and systems)

Role in the infrastructure; Network Update

Operation of:

- 2 ecosystem stations in Denmark (Sorø beech forest and short rotation willow crop)
- 2 atmospheric concentration stations in Denmark (Risø and Østerild)
- 1 ecosystem station in high arctic Greenland (Zackenberg/Zackenberg Valley) (Funded by EU-project SCANNET)

National Roadmap Update

A roadmap for Danish Research Infrastructure was presented December 2010. ICOS is highly prioritized in the Roadmap and listed for funding on the short term (3-5 years).

Network Participants

DTU

Finland

Focal Point: Marjut Kaukolehto, UHEL

Main scientific organisations

Present scientific organisations

- University of Helsinki (UHEL): Timo Vesala, Sami Haapanala, Eija Juurola, Marjut Kaukolehto, Pasi Kolari, Janne Levula, Eero Nikinmaa, Mari Pihlatie, Toivo Pohja, Jukka Pumpanen, Janne Rinne, Ivan Mammarella
- Finnish Meteorological Institute (FMI): Tuomas Laurila, Tuula Aalto, Mika Aurela, Juha Hatakka, Mika Komppula, Lauri Laakso, Ari Laaksonen, Sanna Sorvari, Yrjö Viisanen
- University of Eastern Finland (UEF): Kari Lehtinen, Sami Romakkaniemi

Stakeholders and possible funding organisations

- The Ministry of Education and Culture
- The Ministry of Transport and Communications
- The central administration of each research organisations UHEL, FMI and UEF form part of the stakeholder board

UHEL, FMI and UEF are working closely together in building the ICOS Finland. Finnish stakeholders meet regularly at the ICOS Finland stakeholder board meetings to hear of the latest progression and to have discussions on current and future issues and needs. The government and the ministries make decisions regarding the funding and make recommendations on the organisation of ICOS Finland.

The Ministry of Education and Culture is coordinating the ERIC preparations in Finland and has an important role in the preparations of all potential ESFRI projects.

Experience

The Finnish partners have been working together actively for several years in the field of greenhouse gas research in tens of projects, such as Nitroeurope, IMECC, GHG-Europe and InGOS projects. The partners have solid scientific and technical knowledge and expertise in atmospheric research. The technical innovations and knowledge is transferred among the partners without barriers due to close cooperation. The organisations are members in the Finnish Centre of Excellence appointed by the Academy of Finland and three Nordic Centre of Excellences (CRAICC, DEFROST and SVALI). In several sites the institutes come together to share information on measurement results and quality control or complement the facilities and equipment. The Finnish ICOS measurement sites have long records and data have been utilized much in international networks. The sites have synergies with several other disciplines and environmental research infrastructures.

The SMEAR (stations for measuring forest ecosystem - atmosphere relations) stations I-IV are unique entities in the world with their comprehensive measurements on their respective locations (www.atm.helsinki.fi/SMEAR). Particularly SMEAR II is a leading station due to its comprehensive research program and to its unique time series. All SMEARs have open access to facility and data.

FMI is strongly committed to continuing long term greenhouse gas studies and is actively searching and implementing new technologies and methodologies. FMI has demonstrated its capability in committing to high quality continuous greenhouse gas atmospheric mixing ratio measurements. FMI participates in the GEOMON-Integrated project, and is part of the World Meteorological Organization's Global Atmospheric Watch-programme (GAW) through measurements at Pallas global background site. The site also belongs to other international monitoring and evaluation programmes, such as AMAP, EMEP and Forest Focus networks. Pallas-Sodankylä GAW station forms a satellite calibration-validation test area. Being a remote site, Pallas makes a valuable contribution to the global network showing the northern boreal zone atmospheric background. At Sodankylä, there is a high-resolution spectrometer for column CO_2 measurements and it belongs to the TCCON network. The flux measurements are carried out also at Tiksi in Northern Siberia.

Implementation Timeline

ICOS Finland

- Completed 2012: National structure and contractual agreement of ICOS Finland.
- Completed 2012: ICOS network/site construction and upgrade.
- - 2031: Routine operation of the ICOS Finland: continuous data submission to ICOS Central Facilities.
- 2013: Contractual agreement of ATC operations (Fr-Fi).
- 2013: ATC structures and equipment ready needed to fulfil the shared tasks.

ICOS ERIC

- 2013: leading the work on ICOS ERIC negotiations and submission of ICOS ERIC application to the EC.
- 2013: Implementation of the Head Office together with France.
- 2014 - : Hosting the ICOS ERIC.

Users of the infrastructure and anticipated gains

- User groups of the research infrastructure include research institutes and university researchers, students, and high schools. Number of PhD students and post-docs expected to be using the infrastructure network, data or facilities is about 75 per year. Estimation for the total amount of users from the scientific community from Finland and abroad is in the beginning 100 per year, and later several 100 per year.
- The services and products provided by ICOS will be used by ministries, policy makers, regional authorities, carbon inventory agencies, media, NGOs and general public.
- Publications on greenhouse gases about 50 per year.

Role in the infrastructure station network

Below are listed the measurement stations in Finland that will be provided for ICOS. The Finnish sites will complement the ICOS network with the boreal and sub-arctic environments in the vicinity of the Eurasian land mass. The special focus is on coniferous forests, wetlands and the Baltic Sea.

Stations included

2 Level 1 Atmospheric stations
SMEAR II Hyytiälä in Southern Finland (in operation)
Pallas-Sodankylä in Northern Finland (in operation)

2 Level 2 Atmospheric stations
Puijo-Koli SMEAR IV in Eastern Finland (in operation)
Utö - Baltic Sea in Costal Finland (in operation)

2 Level 1 Ecosystem stations
SMEAR II Hyytiälä - Southern boreal pine forest (in operation)
Sodankylä - Northern boreal pine forest (in operation)

1 Level 2 Ecosystem station
Siikaneva - Southern boreal fen (in operation)

7 associate Ecosystem stations (all in operation)
Lompolojänkkä - Northern boreal fen
SMEAR I Värriö - Subarctic pine forest
SMEAR III Helsinki - Urban environment
Lettosuo - Forestry-drained peatland
Kaamanen - Subarctic fen
Kenttärova - Northern spruce forest
Kuivajärvi – Boreal lake ecosystem

The two ministries in Finland have committed to funding the construction phase in 2013. The partners in Finland are additionally funding the network from their institutional budgets. The negotiations to secure the long term national financial commitments for the operational phase are on the way.

Role in the European level organisation

Finland is preparing to host the forthcoming ICOS ERIC and responsible for the legal processes in setting up ICOS ERIC and tasks related to ERIC application. The HO in Finland, with secondary HO node in France, is responsible for ICOS ERIC governance and legal issues, coordination of strategic scientific and technical planning, community building, outreach and education. Finland has a role in the ATC, coordinated by France, related to field testing, and serving as a Boreal-Arctic regional hub for technical assistance, servicing and station training.

Roadmap Update

ICOS is included in the research infrastructure roadmap 2009 of Finland with high priority. ICOS is also on top priority lists on the strategies of the partner institutions. The national infrastructure roadmap is being updated in 2013.

Network Participants

HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

UNIVERSITY OF
EASTERN FINLAND

France

Focal Point: Léonard Rivier, CEA ; Denis Loustau, INRA

Main scientific organisations

Present scientific organisations

- Climate and Environment Sciences Laboratory (LSCE, a joint research unit of CEA, CNRS and UVSQ), Philippe Ciais, Leonard Rivier
- 10 different laboratories in the French National Institute for Agricultural Research (INRA) and CNRS, INEE, OVSQ. Denis Loustau, Richard Joffe
- Observatoire de Haute Provence, Observatoire de Physique de l'Atmosphère de la Réunion
- CNRM-Meteo France
- ICOS France Ocean Network

Stakeholders and possible funding organisations

- Commissariat à l'Energie Atomique et aux Energies Alternatives (CEA)
- Centre National de la Recherche Scientifique-Institut National des Sciences de l'Univers (CNRS-INSU)
- Centre National de la Recherche Scientifique- Institut Ecologie et Environnement (CNRS-INEE)
- Institut National de Recherche Agronomique (INRA)
- Ministère de l'enseignement supérieur et de la recherche (MESR)
- Ministère de l'Ecologie, de L'Energie, du Développement Durable et de la Mer, General Directorate for Energy and Climate Change (MEEDEM-DGEC)
- Université Versailles Saint Quentin (UVSQ), Observatoire de Versailles Saint Quentin (OVSQ)
- National Radioactive Waste Management Agency (ANDRA)

Experience

The LSCE is a renowned laboratory that operates the largest network of atmospheric greenhouse gases measurements in Europe. The oldest site (Amsterdam Island) has been collecting data for the past 25 years. As for ecosystem research, most of the laboratories involved are accredited by COFRAC (Comité français d'accréditation) and ISO for the soil and plant material analysis proposed by INRA. They are already included in European projects such as the ICP Forest observatory and others.

Implementation timeline

The timeline for ICOS implementation in France is the planed as follows:

- Nov 2009: Statement of support from the Ministry of Education received for France's participation in the ICOS RI
- Feb 2010: Ministerial Letter of support for the ATC received
- Nov 2010: Stakeholders reviewed positively ETC and ATC applications
- Apr 2011: Coordination of the atmospheric Demonstration experiment
- End 2012**:** Extended Demonstration experiment: continued operation of ATC data processing
- 2015: ATC Operational

The Preparatory Phase (2008-2013) has begun establishing the Research Infrastructure, obtaining the funding commitments and establishing the building of the central facilities.
The follow-up Construction phase and Operational Phase spanning 2013-2031, will build the central facilities and the network, and then run it in operational mode, with greenhouse gas fluxes determined on a routine basis.

Users of the infrastructure and anticipated gains

- Number of researchers users In France, approximately 200 researchers at LSCE and other laboratories
- Approximately 25 PhD and postdocs per year
- Ecosystem researchers: about 25 researchers
- A total of 10 publications per year during the preparatory phase

Role in the infrastructure; Network Update

Stations included

Atmosphere: 16 sites

- **Gif-sur-Yvette**
- **Observatoire Pérenne de l'Environneme**
- **Puy de Dôme**
- **Trainou**
- Guyane
- Biscarrosse
- Observatoire de Haute Provence
- OPAR La Réunion
- Amsterdam Island
- Mace Head
- Ivittuut
- Finokalia
- Cap Corse
- Roc Tredudon
- Lamto
- Pic du Midi
- Trainou (aircraft)

Ecosystem: 15 sites

- **Bilos (forest, 2014)**
- **Hesse1 (forest, 2014)**
- **Barbeau (forest, 2014)**
- **Laqueuille (grassland, 2014)**
- Grignon (crop, 2015)

- **Lusignan (grassland, 2014)**
- **Lamasquère (crop, 2014)**
- **Puéchabon (forest, 2014)**
- **Montiers (forest, 2014)**

- **(Fontblanche) (forest 2014**)
- (Guyaflux) (forest 2015)
- (Touget) (fallow 2016)
- **(Mons) (crop 2014)**
- (Osnes) (grassland 2015)
- Auradé (crop, 2015)

Among atmospheric stations, we plan to launch 2 level-1 and 2 level-2 stations (both in bold) by the official start of the RI (2014). Additional stations may join the RI at level 1 or 2 subsequently. The other stations are organized within the national atmospheric branch of ICOS.

For Ecosystem stations, we plan to launch 4 level-1 (bold) and 4 level-2 stations by the official launching the RI. Additional stations may join the RI at level 1 or 2 subsequently. The other stations are organized also within the national Ecosystem branch of ICOS and will propose datasets as auxiliary sites (level3).

Contributions include

- Contribution to ecosystem network (INRA, CNRS, ANDRA)
- Contribution to atmospheric network (CEA, CNRS, ANDRA)
- Coordination of the ICOS Preparatory phase FP7 project

- France already operates the Atmospheric Thematic Centre for the purpose of the Demonstration experiment. In the future, it should be operated with a contribution from Finland.
- France will host a secondary node of the ICOS Head Office in the construction phase specifically linking with international programs, coordinating the greenhouse gas information systems in relation to international treaties, and supervising optimized-network design.
- France (Inra) contributes to the Ecosystem Thematic Center Coordinating team.
- France (Inra) managed the soil analysis, plant analysis and archives for the entire Ecosystem network.

National Roadmap Update

In the 2008 edition of the French Roadmap for the Very Large Research Infrastructures, ICOS was classified as high priority for funding.

In June 2010, we have received a strong support letter from the Ministry of the Environment and the Ministry of Research ensuring France's participation in the ICOS research infrastructure.

This support was renewed in 2013 through the funding of atmospheric (SOERE GReatGases) and ecosystem (SOEREs ACBB and F-ORE-T) observation networks. SOERE are national services labelled by the French Minister of Research. SOERE stands for Service for the Observation and Experimentation supporting Research in Environment

Network Participants

http://icos-infrastructure-france.lsce.ipsl.fr/

Germany

Focal Point: Werner Kutsch, TI-AK

Main scientific organisations

Present scientific organisations

- Thünen-Institute for Climate-Smart Agriculture (TI-AK), Braunschweig: W. Kutsch, C. Brümmer, A. Freibauer;
- Max-Planck-Institute for Biogeochemistry (MPI-BGC), Jena: M. Heimann, C. Gerbig, A. Jordan, W. Brand;
- University of Heidelberg, Institute of Environmental Physics (UHEI-IUP), Heidelberg: I. Levin, S. Hammer;
- German Weather Service, Hohenpeißenberg Observatory: W. Fricke, C. Plass-Dülmer
- Alfred-Wegener-Institute Helmholtz-Centre for Polar and Marine Research (AWI), Bremerhaven: M. Hoppema;
- GEOMAR Helmholtz-Centre for Marine Research, Kiel: A. Körtzinger, T. Steinhoff;
- Leibniz Institute for Baltic Sea Research, Warnemünde, G. Rehder, W. Gülzow;
- Georg-August Universität of Göttingen, Department of Bioclimatology, Göttingen: A. Knohl;
- Helmholtz-Centre for Environmental Research (UFZ), Leipzig: C. Rebmann;
- Helmholtz Forschungszentrum Jülich, Institute of Bio- and Geosciences (IBG-3), Jülich: H. Bogena, H. Vereecken;
- Hochschule Weihenstephan-Triesdorf (HSWT), Lehrstuhl für Vegetationsökologie, Freising: M. Drösler;
- Karlsruhe Institute of Technology, Institute for Meteorology and Climate Research, Atmospheric Environment Research Division, Garmisch-Partenkirchen: H. P. Schmid;
- Technische Universität Dresden (TUD), Chair for Meteorology: C. Bernhofer, T. Grünwald.

Stakeholders and possible funding organisations

- Bundesministerium für Bildung und Forschung (BMBF);
- Bundesministerium für Verkehr, Bau und Stadtentwicklung (BMVBS) via Deutscher Wetterdienst (DWD);
- Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz (BMELV) via Thünen-Institute (TI);
- Helmholtz Association;
- Leibniz Association.

Experience

Scientific institutes in Germany have been internationally active in global and regional carbon cycle research since several decades. The longest European CO_2 and $^{14}CO_2$ records stem from the Schauinsland station operated by the German Umweltbundesamt in cooperation with the Institute of Environmental Physics of the Heidelberg University (UHEI-IUP). UHEI-IUP is running several other European $^{14}CO_2$ observations with the aim to determine the regional fossil fuel CO_2 component. The German Weather Service starts operation of an atmospheric network at tall towers and brings in experience from running a GAW global station at Hohenpeissenberg since the mid 90-ies. The Max-Planck-Institute for Biogeochemistry has been the coordinator of the FP6 integrated project CarboEurope-IP. TI-AK is currently coordinating the FP7 integrated project GHG Europe. Several of the longest European flux measurements and best studied sites with regard to carbon and greenhouse gas fluxes are located in Germany. The national research initiative TERENO is connecting GHG observations with regional water relations and biodiversity observations. The German ocean component is building on long-standing experience with voluntary observing ships (VOS) in various EU projects (CAVASSOO, CarboOcean IP, CarboChange IP) and local observatories (EuroSITES) and is well connected to international initiatives.

Implementation timeline

Funding for a pilot phase (2012-2013) and a build-up phase (2013-2015) as well as a 20 year commitment for the support of the operational phase starting in 2016 have mostly been secured and partly promised from the funding organizations. Funding covers the German contributions to the atmospheric, ecosystem and ocean networks of ICOS as well as the Central Analytical Laboratories.

Users of the infrastructure and anticipated gains

- Carbon and GHG modellers
- Atmospheric, ocean, ecosystem and climate researchers
- Universities for education of graduate and post-graduate students
- Environmental monitoring: German Weather Service – interested in producing products e.g. CO_2 and GHG flux and concentration maps,
- Agencies involved in the establishment of the German contribution to the Global Earth Observing System of Systems (GEOSS), (a.o. BMVBS, BMELV, DLR, DWD)
- Secondary schools, e.g. those now involved in the European project CarboSchools.

Role in the infrastructure; Network Update

Network elements operated as part of the national German branch of ICOS:

Atmosphere:
- Four tall towers as level-1 sites (Ochsenkopf, DWD Observatories Hohenpeißenberg and Lindenberg, Gartow), one more level-1 site is currently in negotiation for funding;
- Three level-2 sites are in negotiation for funding (site selection is still open). In addition one polluted urban site (CRL pilot station Heidelberg) only as associated station. The existing UBA atmospheric stations (Zugspitze, Schauinsland, Neuglobsow, and Westerland) will not be part of the German ICOS network but closely linked;
- Associated extra-European stations: Koldewey (Svalbard), ZOTTO (central Siberia), Cape Verde Atmospheric Observatory, Neumayer Station (Antarctica).

Ecosystems:
- Five to six ecosystem clusters, each consisting of a group of sites with similar climate but varying degree of land use management. Each site will cover all GHG fluxes and provide the necessary links to nitrogen cycling and biodiversity;

Ocean:
- Three VOS lines for regular marine observations (North Atlantic, Baltic Sea) and regular meridional transects with R/V Polarstern
- Deep-sea long-term time series observatory in the eastern Fram Strait (Hausgarten);
- Oceanic long-term time series observatory in the subtropical Atlantic (Cape Verde Oceano Observatory - CVOO)

Contribution to central ICOS functions

Germany contributed to the design of the ICOS Central Analytical Laboratories during the Preparatory Phase. In the operational phase of ICOS, Germany will host the Central Analytical Laboratories consisting of the:

- Flask and Calibration Laboratory (FCL) for standard production, calibration and flask analyses
- Central Radiocarbon Laboratory (CRL) for ^{14}C analyses

National Roadmap Update

A National Competence Centre (NCC) for data evaluation, public relations and political consulting will coordinate all national activities and will be the national resource for other research programmes and scientific users of the research infrastructure. All data streams from national and international activities within ICOS will flow into the NCC and will be combined with additional information (e.g. remote sensing data, models) in order to obtain an integrated assessment of the trace gas fluxes and concentrations over Germany and Europe.

Network Participants

http://www.icos-infrastruktur.de

Ireland

Focal Point: Frank McGovern, EPA and Phillip O'Brien, EPA

Main scientific organisations

Present scientific organisations

Atmospheric Monitoring
- Environmental Protection Agency (EPA): Dr. Frank McGovern, Mr. Phillip O'Brien, Mr. David Dodd
- Met Eireann : Dr Eoin Moran
- NUI, Galway: Prof. S. Gerard. Jennings, Prof. Colin O'Dowd, Dr. Michael Geever

Ecosytem sites
- Teagasc: Dr. Gary Lanigan, Prof. Frank O'Mara
- University College Cork: Prof. Gerard Kiely
- Trinity College Dublin: Prof. Mike Jones
- University College Dublin: Dr. Bruce Osbourne, Dr. Matt Saunders
- University of Limerick: Dr. Ken Byrne
- NUI, Maynooth: Dr Ronan Fealy

Ocean activitities
- NUI, Galway, Dr. Brian Ward
- Marine Institute, Glenn Nolan

Stakeholders and possible funding organisations

EPA, Department of Environment, Heritage, Local Government (DEHLG), Department of Agriculture, Food and Marine (DAFM).

Experience

Significant technical expertise exist in the fields of trace gas concentration and flux measurements at both ecosystem and atmospheric sites across various university and governmental research institutions.

NUI. Galway owns and manages activities at the Atmospheric Research Station at Mace Head. Mace Head is a Global Atmospheric Watch station and a key location for background marine observations for the north Atlantic. The EPA will support ICOS activities at the Mace Head site.

The EPA also operates EMEP air quality stations at two other locations in Ireland in collaboration with Met Eireann. These have been equipped with ICOS compliant CO_2 and CH_4 measurement systems. The EPA and Met Eireann currently operate EMEP monitoring stations at these sites.

At least two primary ecosystem stations are proposed. Decisions regarding optimum location and institutional support will be made by based on agreed assessment of national need among the research groups activity in the area. The principle research group engaged in ICOS-ecosystem activities will be based in Teagasc, the national agriculture research agency. During the initial phase of ICOS, grassland sites in, Wexford and Cork will be supported, as well as peatland site in Kerry and a forestry site in Laois. A number of secondary/associated ecosystem sites will also be supported in order to achieve representative coverage of priority landscapes, i.e grassland, peatland and forestry. The existing ecosystem sites are operated by the independent research groups indicated above. Long term funding commitment to these sites will be based on stakeholder institutional arrangements and assessment of national need.

There is national research interest in the characterisation of GHG fluxes from larger urban centres. NUI. Maynooth have established an urban flux measurement site has been installed to monitor GHG associated with the greater Dublin area (pop. 1.2m).

There is national interest in engaging with the activities of the ICOS Ocean infrastructure. NUI. Galway, in associate with the Marine Institute have initiated CO_2 flux measurements on a marine based platform off coast of Co. Galway, near Mace Head.

Implementation timeline

2008-2011 : Involvement and funding commitments of stake-holders and further national groups organized by the national focal point. Final decision on primary and secondary/associated sites.

2012-2015 : Involvement and funding commitments of stake-holders and further national groups organized by the national focal point. Additional installation with required equipment according to ICOS recommendations. Maintenance of primary sites as well as secondary/associated sites. Regular updates on equipment. Continuous improvement of measurements.

Users of the infrastructure and anticipated gains

- Researchers from universities, research institutions, weather service, national and local authorities.
- National GHG emissions inventory verification by EPA.
- DEHLG and DAFF in development of mitigation and adaptation policy related to land use.
- Research, insurance companies, small enterprises for environmental consulting, NGOs, policy advice committees

Role in the infrastructure; Network Update

Ireland is uniquely located to provide key background atmospheric observations of marine air masses from the north Atlantic towards Western Europe. A relatively high density of regional initial boundary conditions should result in better constrains of the inverse model output.

Ireland shares a common interest in quantification of trace gas fluxes/budgets and emissions to comply with international conventions understand consequences of climate change, investigate the role of land-climate and land-use interactions. Also, ICOS will provide information to support sustainable resource use in

Ireland, data for validation of terrestrial greenhouse gas budgets for land management activities of specific national interest (forest, peatland and grasslands).

Long term continuation and operation of ICOS and associated sites will benefit both science and policy in Ireland. Detailed spatial and temporal knowledge of processes will lead to independently verification of the changes of fluxes, trends and emissions of relevant greenhouse gases. It is likely that greater emphasis will be place on soil and biomass as potential pools for additional carbon sequestration. The validity of these sinks will require rigorous validation and verification if they are to be considered acceptable under the terms of reporting and accounting rules of any future GHG reductions agreements. Ireland views ICOS activities as essential to this process.

The focal point will organize a working group covering both ecosystem and atmospheric research, with probably about 20-25 scientists and institutional representatives contributing to national consortium.

The EPA is chair organisation of the Climate Change Research Coordination Committee, CCRCC, in Ireland which holds regular briefings of national funding agencies and government departments. The CCRCC discusses research requirements, funding and co-funding arrangements in areas of common interest, emerging issues of scientific and policy relevance.

National Roadmap Update

Not available at this time.

Network Participants

Israel

Focal Point: Dan Yakir, Weizmann Institute

Main scientific organisations

Present scientific organisations

- Weizmann Institute of Science (WIS)

Stakeholders and possible funding organisations

- Ministry of Environmental Protection
- Ministry of Science
- Jewish National Fund, KKL

Experience

Research group from different universities, research institutions (such as the Volcani Center; Hebrew University of Jerusalem, Israel Institute of Technology) and national and regional technical agencies (such as the National forestry, KKL) and the National LTER system will cooperate together, contributing according to their respective capacities and funds availability.

Implementation timeline

Israeli timeline will follow the funding projections. Existing Ecosystem station will continue to operate based on Weizmann Institute funding (secured for another 6 years). The construction phase of new stations or upgrade of existing ones will depend on funding commitments by the relevant Ministries and may go beyond the preparatory phase. The full operational phase will follow the construction phase.

Users of the infrastructure and anticipated gains

- Universities and Research Institutes
- National Forestry (KKL)
- National LTER and MAARAG networks
- Ministries
- Public Agencies for environment
- NGOs
- Approximately 5 graduate students/Postdocs per year
- 5-10 publications per year
- Linked to NOAA greenhouse gas observation network

Role in the Infrastructure; Network Update

The main role shall be to support, and share with the ICOS infrastructure, the Israeli monitoring network. The main interest is to provide data from semi-arid environment, and extend the European geographical observational range. Main station is Ecological and LTER, substation atmospheric, greenhouse gas station linked to NOAA network

A detailed national organization structure, with specific role has not been defined up to now. The consortium size will include probably about 6 Israeli institutions (considering universities, research institutes, funding agencies, regional agencies, and Ministries).

Efforts are on-going to recruit the active involvement and financial support of all relevant Ministeries and the National Academy.

National Roadmap Update

Not available at this time.

Network Participants

WEIZMANN INSTITUTE OF SCIENCE

Collaborating participans :
Technion, Israel Institute of Technology
Hebrew University of Jerusalem
Ben Gurion University of the Negev
The Volcani Center, Bet-Dagan

Italy

Focal Point: Riccardo Valentini, UNITUS/CMCC

Main scientific organisations

Present scientific organisations

- University of Tuscia
- National Council of Research (CNR)
- National Agency for New Technologies (ENEA)
- Euro-Mediterranean Centre for Climate Change (CMCC)
- Fondazione Edmund Mach

Stakeholders and possible funding organisations

- Ministry of University and Research
- Ministry of Environment
- Ministry of Agriculture
- National Council of Research (CNR)
- Euro-Mediterranean Centre for Climate Change (CMCC)
- National Agency for New Technologies (ENEA)
- National Agency for Environment Protection

Experience

Different Universities, research institutions (such as the above mentioned CNR, ENEA and CMCC) and national and regional technical agencies are cooperating in order to contribute according to their respective capacities and funds availability.

Implementation timeline

The construction phase should last 3 years after the preparatory phase. The full operational phase will follow the establishment of the Ecosystem Thematic Center that is currently under construction while for the sites the funding is still under discussion to it is not possible to set precise deadlines. Some sites already existing and funded with structural budgets are however ready to join ICOS and follow the data policy and requirements of the project.

Users of the infrastructure and anticipated gains

- Universities and Research Institutes
- Italian Local Administrations
- Ministries
- Public Agencies for environment (APAT, ARPA)
- NGOs
- Small and medium enterprise

- Approximately 10 PhD students per year
- 5-10 publications per year

Role in the Infrastructure; Network Update

The main actual effort of Italy is the construction and establishment of the Ecosystem Thematic Center that will be based in Viterbo under the responsibility of CMCC. Search for extra funding to cover new tasks not considered in the original proposal and added after the review processes is still ongoing with contacts with others institutions, in particular Regional Administrations.

ICOS is one of the Italian priorities as concerns the infrastructures for environmental research in Italy.

There have not been budgets assigned to build sites however there are existing sites with long term funding coming from others institutions that are available to join ICOS following the requirements, protocols and data policy and there is a discussion ongoing with the Italian Ministry of Research to get financial support for the sites..

National Roadmap Update

Not available at this time.

Network Participants

Netherlands

Focal Point : A.T. Vermeulen, ECN

Main scientific organisations

Present scientific organisations

- Prof. dr. A.J. Dolman, VU Amsterdam (coordinator),
- Dr. F. Bosveld, KNMI – Netherlands Royal Meteorological Institute
- Dr. S. Houweling, SRON – Netherlands Institute for Space Research
- Prof. dr. M. Krol, Wageningen University and Research centre
- Prof. dr. H.A.J. Meijer, University Groningen
- Ir. E.J. Moors, Alterra
- Prof. dr. T. Röckmann, University Utrecht
- Ir. A.T. Vermeulen, ECN - Energy research Centre of the Netherlands (focal point)

Stakeholders and possible funding organisations

- NWO, National science foundation of the Netherlands
- IenM, ministry of Infrastructure and Environment

ICOS-nl has been selected on the national ESFRI roadmap as one of the 8 priority projects for support by the Netherlands to the ESFRI platform. The ESFRI process has been delegated to NWO. Summer 2011 The Netherlands signed the Letter of Intent for support of ICOS to enter the ERIC phase and became member of the ICOS ISIC.

Unfortunately the overall budget for ESFRI support in NL was inadequate in the first round to support all priority projects. The ministry for Infrastructure and Environment (IenM) is supporting the ICOS-nl proposal and recognised it in a recent inventory on climate monitoring needs for the Netherlands.

In the second round for proposals on the national ESFRI roadmap (September 2011) again the ICOS-nl proposal was recognized as scientifically excellent and very relevant for society. The decision was made to keep ICOS-nl on the scientific infrastructure roadmap of the Netherlands. Nevertheless the proposal was not selected for funding. From the 25 proposals only budget was available for five. Main criticism from the selection committee was the lack of prognosed funding after the initial five years.

At the end of 2012 it was decided to support ICOS-nl by providing funds covering the fees of the ICOS ERIC for a limited number of stations for the first five years of the ICOS ERIC, which will guarantee the ICOS membership of The Netherlands.

September 2013 there will be another call for proposals at which ICOS-nl will apply for actual support for an extended network of observations and a high resolution regional modelling system.

Experience

- The foundations for the observational capability of the consortium around ICOS-NL were laid by participation in European projects (FP4-FP7) and later the Climate changes Space Planning (CcSP) and Knowledge for Climate Research (CfCR) programmes, while model development also took place at Ispra and NOAA/US.
- Dutch researchers (Alterra, VUA, ECN) led the first European projects with emphasis on regional aspects of the carbon cycle and implemented the first set of tall towers, now the backbone of this proposal. Installation of a network of ceilometers to determine the atmospheric boundary layer height was a key innovation in the experimental capability (WUR, KNMI), helping the regional modelling and data assimilation.
- The development of the modelling capability took place at SRON, NOAA, UU, and Ispra and now WUR. TM5, a zoomed atmospheric chemistry transport model is considered to be world leading and was largely developed by Dutch researchers; it forms the basis of CarbonTracker.
- The group as whole, has over the years of collaborating together in various projects, developed a strong coherence and complementarity. ECN is coordinating the InGOS FP7 infrastructure project that serves to prepare non-CO_2 observations techniques for inclusion into the future ICOS network and to integrate the different communities with expertise in these measurements.

Implementation Timeline

In 2013 a new round for proposals will be launched for national support of ESFRI projects. The ICOS-nl consortium then plans to apply again with an updated but smaller proposal. In the mean time other support options will continue to be applied to acquire parts of the required infrastructure.

Users of the infrastructure and anticipated gains

The current atmospheric observatories Cabauw and Lutjewad and the ecosystem observatories Loobos and Horstermeer are operating on funding from national and EU projects and partly institutional budgets. Cabauw station is part of the ICOS atmospheric demonstration network. The observations of current stations date back to the early nineties of the last century and were and still are being used in a large number of scientific studies, related to national and European RTD projects but also in GMES (MACC, MACC2) and international studies (NOAA, WMO).

Role in the infrastructure network update

Currently the national support for ICOS-nl allows to support only one atmospheric site and one ecosystem site and for the actual running institutional and other external support is required.

Tall tower	Lon	lat	Name	ID
X	4.9264	51.9703	Cabauw	CBW

Tall tower Cabauw has been operational since 1992.

1 ecosystem station:

lon	Lat	name	ID
5.74396	52.1679	Loobos	Loo

ICOS-nl would like to contribute to the QA/QC of the ecosystem component and the Carbon portal, and will work on development of high resolution regional inversion systems.

Roadmap Update

ICOS-nl was again selected in 2012 on the national ESFRI roadmap as one of the 15 priority projects for support by the Netherlands to the ESFRI platform.

Network Participants

VU-A	RUG	ECN	WUR	Alterra	UU	KNMI	SRON

http://www.icos-infrastructure.nl/

Norway

Focal Point : Cathrine Lund Myhre, NILU

Main scientific organisations

Present scientific organisations

- Ecosystem stations: Norwegian Institute for Agricultural and Environmental Research: (BIOFORSK): Daniel Rasse,
- Atmospheric stations: NILU -Norwegian Institute for Air Research: Cathrine Lund Myhre (atmosphere)
- Oceanic station and OTC: BCCR / University of Bergen (UiB): Truls Johannessen, Are Olsen, and Ingunn Skjelvan (ocean)

Our other partners:

- University of Life Sciences (UMB):
- Norwegian Institute for Nature Research (NINA)
- Polar Institute (NP)
- Nansen Environmental and Remote Sensing Centre (NERSC)
- Norwegian Institute for Water Research (NIVA)
- Institute of Marine Research (IMR)

Stakeholders and possible funding organisations

- The Research Council of Norway
- Norwegian Pollution Control Authority
- Potentially other Ministries such as the Agriculture Ministry (LMD)

Experience

Our goal is to develop a national infrastructure for continuous monitoring of GHG emissions in Norway in association with the ICOS Preparatory Phase. We aim at integrating the three carbon cycle observational activities currently operated by Norwegian institutions into one integrated operational infrastructure in order to meet societal and scientific needs for precise measurements and integrated assessments of carbon cycle parameters. It will consist of 5 subsystems: 1. Atmospheric, 2. Marine, 3. Terrestrial, 4. Integrating activities, 5. An Ocean Thematic Centre (OTC) within ICOS as part of the European ESFRI road map.

The long-term goal of the Norwegian contribution is to implement and operate an infrastructure that will allow for a complete accounting of carbon sources and sinks in the North Atlantic, Norway and adjacent oceans. This will provide the basis for comprehensive carbon budgeting and the science underpinning policy actions required to avoid dangerous climate change. We will establish a network for observations of the three carbon reservoirs that are mobilisable on the relevant time scales—the atmosphere, the terrestrial biosphere and the oceans—and will ensure harmonisation and integration of the data streams for assessment of the exchange fluxes between these reservoirs.

Terrestrial ecosystems: the Research Network is between BIOFORSK, NILU and the Smithsonian Environmental Research Center (SERC, MD USA; Dr Bert Drake as leading scientist for SERC). In 2008, we have installed the very first eddy covariance (EC) monitoring system in mainland Norway for CO_2 (and

CH_4) emission from the largest arctic mire on the Norwegian Atlantic Coast: Andøya (69 16 42 N, 16 00 31 E). The coastal site of Andøya was chosen to be complementary of more continental sites of Sweden and Finland, and is therefore geared especially towards ICOS participation. We propose to develop an additional super site on the western coast, a potential site being the peat formation of Smøla island.

Ocean component. Regular measurements of ocean CO2 are carried out by the Bjerknes Centre for Climate Research using a combination of Voluntary Observing Ships (VOS surface measurements) and research cruises (whole water column). The VOSs are the container carriers Nuka Arctica and Transcarrier and the R/V G. O. Sars. They are part of a global network of ships equipped with sensors for surface ocean pCO2 measurements. The data have been used for the aforementioned global ocean pCO2 climatology as well as for regional North Atlantic assessments. It is funded mostly though European union framework programs. Water column carbon measurements are carried out every 3-5 years as part of research projects at a European level. They are used for assessment of ocean uptake of anthropogenic CO2.

Atmospheric component. Measurements are carried out at two sites: 1) Birkenes Observatory: Rural background site surrounded mainly by forests, located downwind from Europe, 2) Zeppelin Observatory: Arctic remote site at the Zeppelin mountain, close to Ny-Ålesund, Svalbard representative for hemispheric background levels. These monitoring sites will be further developed in the framework of ICOS. Both sites have long term measurements of a wide range of atmospheric variables are available with open access to data and the facilities itself. Both sites are included in the EMEP program (European Monitoring and Evaluation Programme under the Convention on Long-Range Transboundary Air Pollution) and further developed in EU projects like CREATE, EUSAAR, and ACTRIS. Zeppelin is also included in InGOS. Thus there are comprehensive measurement programs including various aerosol properties and trace gases in addition to GHGs ongoing at both locations. Both sites are currently further developed in accordance with the ongoing projects ACTRIS and InGOS.

Implementation timeline

Uncertain, national ICOS proposal under review, decision tentatively autumn 2013 with update of national roadmap.

Users of the infrastructure and anticipated gains

There is a wide range of stakeholders with interest in the results from the infrastructure. With this in mind we aim to form national user groups, which will be used to design the infrastructure and its measurement and monitoring programme, and to disseminate results.

- Science user group: Earth System Modelling community, CO_2-mitigation research community, including CCS research community, climate policy researchers.
- Government agencies: Ministries (Environment, Finance, Oil and Energy, Fisheries and Coastal Affairs, Foreign Affairs, Food and Agriculture), Climate and Pollution Directorate (KLIF), Fisheries Directorate
- NGOs, oil and gas industry (OLF), carbon trading companies, e.g. Point-Carbon.

Role in the infrastructure; Network Update

Norway is interested in developing two ICOS ecosystem super sites, three atmospheric sites, and a large ocean component, which would include a proposal to develop and host the ICOS ocean thematic center. The Bjerknes Centre intends to become the Thematic Centre for Ocean measurements within ICOS.

The long term operation of ICOS Norway will be dependent on funding from the government after 5 years. This platform will be vital to understand the development of GHG's in the atmosphere related to changes in sources and sinks of such, and direct emission from fossil fuel burning, cement production and changes in land use. In addition the consortium will seek funding from EU and NRC also in the future that will fund part of the activity.

ICOS Norway will utilize already existing platforms like ships and observatories already established in Ny-Ålesund, Birkenes, Andøya and ships own by the University of Bergen and Institute of Marine Research and use laboratories already present at the different institution. In this sense, task of ICOS Norway will be an added value to already invested infrastructure.

Roadmap Update

ICOS-Norway is not on the national ESFRI roadmap as of the last update (Spring, 2011). update of national roadmap is expected in autumn 2013.

Network Participants

Poland

Focal Point: Janusz Olejnik, PULS

Main scientific organisations

Present scientific organisations

- Poznan University of Life Sciences (PULS)
- Systems Research Institute, Polish Academy of Sciences (IBS)
- University of Lodz (UL)
- The Institute for Land Reclamation and Grassland Farming (IMUZ)
- West Pomeranian University of Technology (ZUT)
- Institute for Agricultural and Forest Environment, Polish Academy of Science (IAFE)
- Wroclaw University of Environmental and Life Sciences (WU)
- Interdisciplinary Centre for Mathematical and Computational Modelling (ICM)
- University of Sciences and Technology (AGH)
- Warsaw University of Life Sciences (SGGW)
- University of Warmia and Mazury (UWM)
- Institute of Meteorology and Water Management (IMGW)
- Institute of Agrophysics, Polish Academy of Science (IA PAN)
- AeroMeteo Service Company (AMS)
- University of Szczecin (US)

Stakeholders and possible funding organisations

Not available at this time.

Experience

Measurements of GHG fluxes exchanged between surface area of different ecosystems (wetland, forest, arable) and the atmosphere are carried out in Poland mainly by the Meteorology Department of PULS within FP6 & FP7 EU founded projects (CARBOEUROPE-IP, NITROEUROPE-IP, GHG-EUROPE, GREENFLUX-TOK) and projects of Polish Ministry of Environment. PULS has performing such measurements from 2003 and has a leader position in Poland having currently, at national level, the highest experience in operation of Eddy Covariance, Relaxed Eddy Accumulation and chamber systems. These different measurement techniques are applied to continuously monitor fluxes of CO_2, H_2O and CH_4 on wetland ecosystem (Rzecin site), Scots Pine forest (Tuczno site) and cropland (Brody site).

Additionally, the concentration of GHG in the higher troposphere is monitored by AMS company by means of aircraft observations and profile sampling carried out on 250 m tower in Bialystok-Krynica (eastern Poland). The unique at the national scale and long term GHG measurements in the Tatra Mountains are carried out by the AGH Krakow research team. New “ecosystems” and “atmospheric” measurement sites, where GHG concentrations and fluxes can be permanently monitored, are planned to be established over different regions in Poland within the frame of ICOS-PL.

Implementation timeline

1. Preparatory phase - formation of ICOS-PL scientific operational group and the financing proposal preparation for the Ministry of Science and Higher Education (2013),
2. Construction phase - equipment purchase (2014), modernization of already existed stations and construction of new measurement sites (2015), equipment and data base testing, ICOS-PL infrastructure/network ready to start (2016-17), courses for administrative and research personnel (2017),
3. Operational phase - further personnel courses, fully operated measuring system (from 2018 to 2030), transfer of the fully operative ICOS-PL infrastructure to the National Environment Monitoring Services (2031).

Users of the infrastructure and anticipated gains

Foreseen users of the ICOS infrastructure, beside the ICOS-PL network community will be: national and international scientific community (GHG fluxes and balances), Ministry of Science and Higher Education (scientific projects), Ministry of the Environment (politics of GHG emission reduction, GHG national inventory), Ministry of Economy and National State Forest Holding (the GHG units trade).

Development of the ICOS infrastructure in Poland will enhance the integration process of polish research groups dealing with a “climate” research topics and make their position much stronger on a international arena. Moreover, among direct and indirect anticipated benefits coming from the ICOS-PL has to be mentioned:

- quantification (estimation) of GHG fluxes exchanged between different ecosystems and the atmosphere at a national scale,
- estimation of the interaction between terrestrial ecosystems and the atmosphere,
- integration of scientific community in the frame of European Research Community,
- development of innovative measuring techniques and methods.

Additionally, the ICOS-PL infrastructure will be a crucial element in the ecological education related to the human impacts on natural ecosystems and processes which take place in the atmosphere. From the economical point of view, ICOS-PL will create a strong basis for long term political and economical actions related to environment protection in Poland and across Europe.

Role in the infrastructure; Network Update

15 measuring stations are planned to be established in the frame of ICOS-PL. Such network will ensure the proper measurements of GHG concentrations and fluxes on the whole territory of Poland:
- 4 atmospheric towers (Pila-Rusinowo, Katowice-Koszowy and Bialystok-Krynica),
- 11 ecosystems towers at wetland, forest and cropland ecosystems (Olsztyn, Spala, Bydgoszcz, Tuczno, Rzecin, Notecka Forest, Trzebciny Forest, Lublin, Biebrza wetland, Miedzyzdroje).

Additionally, one of the atmospheric tower will be located on the top of the Kasprowy Wierch in Tatra Mountains. Moreover the periodic aircraft measurements of GHG concentrations in the troposphere under Bialystok-Krynica station are planned to be performed within ICOS-PL.

Roadmap Update

The National Interdisciplinary Advisory Board for Research Infrastructure and Research Politics of EU in the Ministry of Science and Higher Education of Polish Government, on the 23th of July 2010, has officially

approved the ICOS-PL to be one of the ESFRI project included to the Polish Roadmap for Research Infrastructure. The ICOS-PL Consortium, which was set up on the 20th of April 2011, consist of the 15 national scientific units (universities, institutes, and private companies) which will be coordinated by the Meteorology Department from Poznan University of Life Sciences. On the 2nd of January 2012 the Vice-Secretary of State from the Polish Ministry of Science and Higher Education signed the European Letter of Intent (LoI). Furthermore, the Polish delegate for the Stakeholder ICOS Interim Council have been nominated. Presently, the ICOS-PL Consortium is preparing the proposal for the National Centre of Research and Development, which will be the most probable an institution financing the ICOS-PL network.

Network Participants

Not available at this time.

Portugal

Focal Point: João Santos Pereira, ISA

Main scientific organisations

Present scientific organisations

- University of Lisbon : João Santos Pereira, Sofia Cerasoli, Margarida Tomé (Instituto Superior de Agronomia), Gabriel Pita (Instituto Superior Técnico).
- University of Aveiro, CESAM & Department of Environment: Casimiro Pio
- Instituto Nacional de Investigação Agraria e Veterinaria (INIAV) , Ministerio da Agricultura, do desenvolvimento Rural e das Pescas: Abel Martins Rodrigues, Teresa Soares David.
- New University of Lisbon, Faculdade de Ciências e Tecnologia, DCEA - Departamento de Ciências e Engenharia do Ambiente: Júlia Seixas, Nuno Carvalhais.

Stakeholders and possible funding organisations

- Ministry for Education and Science
- Ministry For Agriculture, Sea, Environment and Spatial Planning

Stakeholders will participate actively in the creation of the national network, contributing to the identification of national objectives and priorities within ICOS. They will also collaborate in the promotion of the national network close to other governmental agencies as well as to the scientific community and general public.

Experience

The group of Portuguese universities involved in the Carboeurope network, helped to develop the pan-European system of carbon balance observation and gained technical expertise, providing a good data basis – almost 10 years of data on carbon fluxes between the ecosystem and the atmosphere as well as scientific knowledge necessary to fulfill the needs for the proposed "integrated carbon observation system" (ICOS). We studied three ecosystem types. Two of them quite unique, (1) evergreen oak savannas (4 years (Mitra site) + 3 years (Machoqueira – Coruche site, with a younger cork oak savanna); (2) eucalypt plantation (8 years – extremely fast growth on an yearly basis). The 3rd type was annual grassland (5 years, discontinued in 2008). We also expanded our research area in the field of ecosystem/vegetation remote sensing. Biophysical vegetation properties acquired from satellite remote sensing are ancillary variables helpful to diagnose in situ ecosystem states and fluxes. Our research activities also comprise the evaluation of satellite remote sensing products and the integration of different data streams (ecosystem carbon fluxes, meteorological measurements and satellite remote sensing) in a modeling framework.
Our team has also experience in the measurements of GHG emissions other than CO_2 in different environments.

Implementation Timeline

2009-2011: Preparatory phase: Creation of a national coordination centre for Portuguese participation in ICOS.

2009-2013: Full set-up of the equipment, including remote control for 3 ecosystem stations, according to standard proposed by ICOS-ETC.

From 2014: Operational phase.

Users of the infrastructure and anticipated gains

- Scientific community in general, including researchers interested in links between carbon and water cycle, modelers, also for validation of satellite data. 3Phd/year and 3post-doc/year, graduate students in general

- Public sector: National Committee for Climate Change which compiles the National budget of GHG emissions ("Plano Nacional para as Alterações Climáticas")
- Private sector interested in quantifying their own emissions and mitigation capacity, in particular the forest sector: The cork industry as well as other forest based industries need to get certification to maintain their positions in their markets and therefore need to estimate the carbon sequestration levels in stands that follow good-practice rules or are certified for sustainability. All sites are certified forests

Role in the infrastructure; Network Update

We are interested in participating in the network of ecosystem (ICOS-ETS)and atmospheric stations (ICOS-ATM). Three stations are planned, for the three most important forests in the country:

- a cork oak woodland with agro-silvicultural management (trees+ pasture).
- an eucalypt plantation
- a maritime pine forest (with measurements at level of the canopies and of the understorey).

Atmospheric measurements of carbon fluxes in an important urban area will be implemented soon.

ICOS will be crucial to inform the national GHG inventory and help defining the National Plan for Climate Change. Furthermore the data on carbon fluxes associated with other environmental observation data is needed as a basis for forest management certification.

National Roadmap Update

Portugal did not define yet the national roadmap for research infrastructures. Stakeholders and researchers involved collaborate to promote the inclusion of ICOS in the national roadmap. Presenting the network at national public conferences and to the competent autorities.

Network Participants

Spain

Focal point : Melchor González Dávila, La Universidad de Las Palmas de Gran Canaria

Main scientific organisations

Present scientific organisations

- Centro de Estudios Ambientales del Mediterráneo (CEAM): M. J. Sanz, A. Carrara
- Consejo Superior de Investigaciones Científicas (CSIC)
  - Instituto de Ciencias Marinas de Andalucía (ICMAN): E. Huertas
  - Instituto de Investigaciones Marinas (IIM): A. Fernández Ríos
  - Unidad de Tecnología Marina (UTM): J. Piera
  - Estación Experimental de Zonas Áridas (EEZA): F. Domingo
- Agencia Estatal de Meteorología, CIAI (AEMET-CIAI): E. Cuevas, A. Gómez Peláez
- Institut Català de Ciències del Clima (IC3): X. Rodo, J.A. Morguí
- Universidad de Castilla La Mancha (UCLM): J-M. Moreno
- Universidad de Granada (UGR): A. Kowalski
- Universidad de Las Palmas Gran Canaria (ULPGC): M. Gonzáles
- Plataforma Oceánica de Canarias (PLOCAN): E. Delory

Stakeholders and possible funding organisations

- Ministry of Economy and Competitiveness (MINECO)
- Ministry of Agriculture, Food and Environment (MAGRAMA)
- Consejo Superior de Investigaciones Científicas (CSIC)
- Regional Governments through various public organisms.

The MINECO is currently the main interlocutor at national level for the implementation of ICOS in Spain. The General Secretariat of Science, Technology and Innovation, of MINECO, is responsible for organising open calls regarding international infrastructures that include ESFRI projects. Both MINECO and MAGRAMA may support ICOS in Spain. National and regional public research organisms (e.g. CSIC, AEMET, Universities) will support ICOS-Spain by local in-kind contributions.

Experience

Regarding atmospheric component, the renowned Izaña observatory (AEMET-CIAI) is one of the oldest atmospheric monitoring station operated by European institution, collecting GHG data since 1984 under international standard programs (WMO-GAW, NOAA-GlobalView). IC3 has experience in capacity building and operating continuous CO_2 observations in the network of Tall Towers and airborne platforms within European projects.
Regarding ecosystem component, CEAM and UGR are pioneers in Spain in monitoring carbon balance at ecosystem level and have robust and extensive experience in eddy covariance and participated in many FP6/FP7 European projects related to carbon cycle. EEZA and UCLM have experience in operating flux-towers, and specific experience in drought-prone ecosystems processes (EEZA) and plant ecophysiology (UCLM).

Regarding oceanic component, ICMAN, IIM, and ULPGC have long historical of international collaborations (e.g. related EU FP projects), with extensive experience in marine carbon cycle research , development of innovative instrumentation, and in operating marine monitoring stations (VOS-lines and fix stations). UTM has very robust experience in technical aspects of marine observation systems, being responsible for operation and management of various marine research infrastructures, including research vessels "*BIO Hespérides*", "*Sarmiento de Gamboa*" and "*García del Cid*".

Implementation Timeline

2014-2016: Construction of Spanish ICOS monitoring stations according to ICOS standards. Individual stations implementation timeline will depend on the respective institutions capacities and funds availability.
2015: First ICOS Spanish stations operational.

Users of the infrastructure and anticipated gains

- National institutions with reporting commitments to international institutions, such as to EC and UNFCCC regarding GHG emission inventories: Ministry of Agriculture, Food and Environment, Climate Change Spanish Office, Department of Forest Protection Service against Pest Protection, General Directorate of Natural Environment and Forest Policy, General Directorate of Air Quality, etc…
- Regional Councils related to Environment, Forestry and Agriculture.
- Researchers from Spain, Europe and rest of the world (>50 publications/year using data).
- Academic education and training of young scientists on state-of-the-art infrastructure
- International organizations: IPCC, GMES, GCOS, GEOSS, WMO …
- European Research Area: JPI Oceans, FACCE-JPI, JPI-Climate...

Role in the infrastructure; Network Update

- Contribution to ecosystem stations network (CEAM, UGR, EEZA-CSIC, UCLM)
- Contribution to atmospheric stations network (AEMET-CIAI, IC3)
- Contribution to oceanic stations network (CSIC, ULPGC, PLOCAN)
- Spain (PLOCAN + CSIC) may present a joint-candidature (with UK and Norway) to host part of the Ocean Thematic Center (OTC). PLOCAN (Plataforma Oceánica de Canarias, www.plocan.eu) will coordinate operational and technical aspects of the Spanish component of the OTC and CSIC (ICMAN and UTM) and ULPGC support on science.

Core network of Spanish ICOS stations is expected to include 2-3 Atmospheric stations, 2-4 ecosystem stations and 4-5 oceanic stations/VOS lines. This core network is foreseen to enhance to improve ICOS-Spain observing network capacities in all components. Timeline will largely depend on economical aspects (raised funds and opportunities,

National Roadmap Update

The Science and Innovation Ministry (MICINN) organized in 2010 a specific procedure for prioritization of ESFRI projects.The resulting 2010 ESFRI Spanish roadmap consider ICOS as "High Priority". The Spanish roadmap is foreseen to be updated in 2013 or 2014.

Network Participants

Sweden

Focal Point: Maj-Lena Linderson

Main scientific organisations

Present scientific organisations

- Lund University: Anders Lindroth and Meelis Mölder
- University of Gothenburg: Leif Klemedtsson
- Swedish University of Agricultural Sciences: Mats Nilsson and Mikaell Ottosson-Löfvenius
- Swedish Polar Research Secretariat/Abisko Scientific Station: Thomas Friborg and Christer Jonasson
- Stockholm University: Patrick Crill

Stakeholders and possible funding organisations

- The Swedish Research Council (VR)

The Swedish Research Council together with the Universities involved (see below) has decided to fund Swedish ICOS with Lund University (LU) as the host. The collaboration between the host and Gothenburg University, the Swedish University of Agricultural Sciences, Stockholm University and the Swedish Polar Research Secretariat/Abisko Scientific Research Station is regulated through a consortium agreement. ICOS Sweden is formally governed by a board of external experts from academia, authorities and industry, chaired by Prof. Terry Callaghan.

Experience

Scientists from the member institutes have been involved with flux measurements from the beginning of the 'fluxnet' era and have therefore a very good competence within this field, and within this community we also have the required competence to run the atmospheric stations. There exists a longstanding fruitful collaboration built up within the framework of the Nordic Centre for Studies of Ecosystem Carbon Exchange and its interactions with the climate system, NECC (by and its successor NORDFLUX (both funded by the Nordic Council of Ministers and the joint organisation of the national Nordic research councils, NOS-N). This collaboration between practically all Nordic groups active in this type of studies will continue to be beneficial for ICOS.

Implementation Timeline

- November 2009: Funding approved
- June 2010: Formal establishment of ICOS Sweden and contract signing
- June 2011: First meeting of the ICOS Sweden board
- Spring 2011: Procurement of Svartberget high tower (new installation)

- Autumn 2011: Construction of Svartberget high tower finished
- December 2011: ICOS Sweden site coordination group inaugurated
- Spring 2012: Procurement and installation of ecosystem station equipment and instrumentation
- Summer/autumn 2012-Spring 2013: Startup and testing of ICOS Sweden ecosystem stations
- May 2013: Formal start of ICOS Sweden ecosystem station operations
- August 2013: Formal start of ICOS Sweden atmospheric system station operations
-

Users of the infrastructure and anticipated gains

- Users of information and data:
  - The National Environmental Protection Board
  - Swedish County Administrative Boards
  - The Swedish Meteorological and Hydrological Institute (SMHI)
  - The Swedish National Forest Survey
- Users of the infrastructure (ancillary projects):
  - The Swedish Environmental Research Institute (IKL)
  - Consortium for Aerosol Science and Technology at Lund University (CAST)
  - Other Swedish and European universities and research institutes
- Publications in peer-reviewed journals
- Students (undergraduate and postgraduate)
- Information portal about Swedish and Nordic greenhouse gas emissions aimed to the wider community (schools, press, general public etc.)

Role in the infrastructure; Network Update

Nine stations are currently part of ICOS Sweden:

- Norunda eco (ecosystem station; forest)
- Norunda atmo (atmospheric station 102 m tower)
- Hyltemossa eco (ecosystem station; forest)
- Hyltemossa atmo (atmospheric station 150 m tower)
- Svartberget eco (ecosystem station; forest)
- Svartberget atmo (atmoispheric station 150 m tower)
- Lanna (ecosystem station; agricultural site)
- Degerö (ecosystem station; boreal wetland site)
- Stordalen (ecosystem site; arctic wetland)

National Roadmap Update

Concerning the next step for ICOS Sweden, i.e., to join ICOS-ERIC, ICOS Sweden is presently included in Sweden's roadmap and this window of opportunity is open until end of 2013. If ICOS-ERIC is not ready by then, a new decision have to be made by the Swedish stakeholder. Sweden has applied for hosting the ICOS Carbon Portal together with the Netherlands.

Network Participants

Lund University

University of Gothenburg

Stockholm University

Swedish Polar Research Secretariat

Swedish University of Agricultural Sciences

http://www.icos-sweden.se/

Switzerland

Focal point: Prof. Nina Buchmann, ETH Zurich

Main scientific organisations

Present scientific organisations

- ETH Zurich: Prof. Nina Buchmann, Prof. Sonia Seneviratne, PD Dr. Werner Eugster
- Uni Basel: Dr. Christian Feigenwinter
- WSL: Dr. Roman Zweifel, NN
- Empa: Dr. Lukas Emmenegger, Dr. Brigitte Buchmann
- University Bern: Prof. Markus Leuenberger
- MeteoSwiss: Dr. Gabriela Seiz, Dr. Saskia Willemse, Dr. Andrea Rossa

Stakeholders and possible funding organisations

- State Secretariat for Education, Research, Innovation SERI (= Staatssektretariat für Bildung, Forschung, Innovation SBFI)
- Federal Office for the Environment FOEN (= Bundesamt für Umwelt BAFU), Division Climate
- Swiss National Science Foundation SNF (=Schweizer Nationalfonds)

The first two stakeholders will participate in the use/implementation of the new data and scientific information originating from ICOS Switzerland into political processes at cantonal and federal levels. The SNF will be the funding organization distributing the funds. Close contacts between scientists involved in ICOS-CH and the stakeholders will ensure fast and direct dialogue. Since FOEN is responsible for the national Kyoto reporting, the data acquired within ICOS can contribute to validate the inventory based methods. Both SERI and FOEN stakeholders are participating in the ICOS Council, thus, direct exchange of information on ICOS issues is ensured and also sought for actively by the stakeholders themselves.

Experience

- ETH Zurich: biospheric-atmospheric trace gas exchange measurements, plant/soil/ecosystem responses to environmental change, biogeochemistry, regional/continental/global earth system modelling
- Uni Basel: biospheric-atmospheric trace gas exchange measurements, regional modelling
- WSL: basic to applied forest research, long-term ecosystem monitoring program (LTER)
- Empa: atmospheric trace gas measurements of pollutants, greenhouse gases and isotopes, long-range transport modelling, Word Calibration Centre (WCC-Empa) for Surface Ozone, CH_4, CO und CO_2 of the Global Atmosphere Watch Programme (GAW) of WMO.
- University Bern: high-precision combined atmospheric CO_2 and O_2 measurements within the Global Climate Observing System program (GCOS-Switzerland),
- MeteoSwiss: meteorological and climatological monitoring, coordination of the Swiss GCOS and GAW programmes, numerical weather prediction, climatological analyses

Implementation Timeline

February 2012: Federal Council Dispatch (“BFI-Botschaft”) 2013-2016 discussed in the “Nationalrat” and in the “Ständerat”
September 2012: Decisions of parliament on Federal Council Dispatch 2013-2016 (“BFI-Botschaft”) as well as decisions on its funding (Bundesbeschluss 12.033). Discussions on procedures to access Swiss funds took place in December 2012 and January 2013. Start of ICOS-CH funding is anticipated for May 2013.

On-going: Discussion on legal issues about participation of Switzerland in an ERIC. To be finalized in 2013/2014.

Users of the infrastructure and anticipated gains

- Scientists from universities and research institutions in Switzerland, Europe and globally
- Stakeholders like SER, FOEN as well as MeteoSwiss
- Student training on state-of-the art scientific equipment and protocols, international contacts
- Anticipated gains: quantification of trace gas fluxes/budgets and emissions to comply with international conventions, understand consequences of climate change, investigate the role of land-climate and land-use interactions, leading role in advancement of science, information to support sustainable resource use in Switzerland, data for validation of terrestrial greenhouse gas budgets for sites of specific national interest (subalpine forest, high altitude observations), estimate national and European emissions

Role in the infrastructure; Network Update

Two primary sites are proposed: one ecosystem station at Davos (since 1985 focal site for air chemistry/tree physiology [NFP14+] and since 1997 a flux-site) and one atmospheric station at Jungfraujoch, a long-term site within the Global Atmosphere Watch Program (GAW) as well as within the atmospheric monitoring program of the WMO (since the early 70ties).

Funding is sought for from SER and FOEN as well as from the participating institutions.

National Roadmap Update

ICOS is prominently mentioned in the Swiss BFI-Botschaft which has been discussed and decided upon during 2012. Currently (Janl. 2013), funding procedures are being clarified, after which upgrades of site installations as well as hiring of personnel can commence in early summer 2013.

Network Participants

UNIVERSITÄT BERN
OESCHGER CENTRE
CLIMATE CHANGE RESEARCH

WSL

EMPA
Materials Science & Technology

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

UNI BASEL

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Eidgenössisches Departement des Innern EDI
Bundesamt für Meteorologie und Klimatologie MeteoSchweiz

United Kingdom

Focal Point: John Grace, UEDIN and Andrew Watson, UEA

Main scientific organisations

Present scientific organisations

- University of Edinburgh: Mat Williams, Paul Palmer, John Moncrieff and John Grace
- University of East Anglia: Parv Suntharalingen, Andrew Manning and Andrew Watson
- Royal Holloway College: Euan Nisbet
- Centre for Ecology and Hydrology: Peter Levy
- University of Bristol: Simon O'Doherty
- Met Office: Alistair Manning
- Forest Research: James Morison; Northern Research Station: Mike Perks

Stakeholders and possible funding organisations

- Natural Environmental Research Council (NERC)
- Department of Energy and Climate Change (DECC)
- Forestry Commission
- Rural & Environment Research and Analysis Directorate, Scotland

It is expected to include five atmospheric stations on UK mainland: Angus in Fife, Scotland; Tacolneston in Norfolk, East England; Ridge Hill in Herefordshire, West England; Selkirk in Scotland; Heathfield in Sussex. There is a possibility of another one to cover urban emissions, Egham in Surrey on the outskirts of London.. One of these (Fife) was already established in Carboeurope-IP but now faces funding difficulties. Most of these are likely to be Level 2. A network of marine sites mounted on ships is being prepared by Andrew Watson. Aspirations for two other stations in overseas territories (eg Ascension Island), from Euan Nesbit and Andrew Manning. Two ecosystem flux stations on UK mainland are also expected, again Level 2 unless additional funding can be found for upgrade.

Additionally the University of Edinburgh has a small research aircraft currently operated for concentration and flux measurements at ecosystem and landscape scale; and NERC operates a much larger aircraft which can be used for national concentration measurements.

Experience

The technical expertise in the UK for flux and atmospheric measurement is at Edinburgh, Penicuik, East Anglia, London ; technical expertise for atmospheric modelling is at Leeds, Met Office and Edinburgh; technical expertise for land-surface ecosystem fluxes is Edinburgh, Penicuik, Durham, Lancaster and Sheffield; technical expertise for data assimilation modelling is Exeter, Wallingford,, Edinburgh.

Implementation timeline

Bids for the 10 million Euro funds for NERC's Greenhouse Gas Programme (including terrestrial, atmospheric and ocean ICOS-relevant projects) were successful, but as the call was for an experimental and infrastructural programme there is still a deficit for running the towers at Level 1.

Users of the infrastructure and anticipated gains

- DECC is the government agency that reports UK greenhouse gas emissions based on inventory analysis.

- Directorate in Scotland oversees environmental affairs in Scotland and the Environment Agency Wales may also have an interest.

There is a large academic community interesting in all aspects of climate change, for research and teaching purposes (assume 2000 academics plus their research students) with several centres such as the National Centre for Earth Observation (NCEO) and the Tyndall Centre based at the University of East Anglia. There are pressure groups and newspaper correspondents: An estimate of 1000 individuals- these people would be interested in 'surprises' like an unusual rise in a GHG in one year versus the rest. There are many carbon management companies that have sprung up in the last ten years, interested in carbon trading opportunities.

- Field and community of users:
  - Scientific community between 1000-3000
  - Non-scientific public sector between 100-300
  - Private sector between 100-300

- Total number of users: Between 1200 and 4000
- 50-200 PhD Thesis & post-docs expected to be using the infrastructure network, data or facilities
- 500 publications over the next 5 years

Role in the infrastructure; Network Update

The UK Government has accepted the Royal Commission on Environmental Pollution's longer term recommendation that the UK must put itself on a path towards a reduction in emissions of some 60% from current levels by 2050 in order to mitigate the effects of Climate Change. It is accepted now that this will require some further nuclear power stations to be built, and heavier penalties for driving high emission motor vehicles.

The national inventory, drawn up by DEFRA, is the estimate used by government, and is 'state-of-the-art' being based on inventory and models. ICOS is seen as 'validation'.

In regards to a national organisational structure, several possible models could be envisioned, based upon existing patterns. Probably the most likely is a distributed 'Centre' which has a Director, tight reporting guidelines, annual reports, funding in five-year instalments. The scientists are distributed between a numbers of institutions. An alternative model would be something like the Met Office, a government agency with a specific mission, all on one site, closely linked to national needs but with an element of research subcontracted to universities and other institutions.

In environmental sciences, the agency with the responsibility of contributing to *ESFRI* discussions is NERC.

National Roadmap Update

At the large scale, a new Capital Investment Roadmap will replace the existing RCUK Large Facilities Roadmap (on which ICOS was an 'emerging project'), which was designed to

provide a national overview of large (typically over £25M) facilities projects that could be considered as priorities for investment from the Government Large Facilities Capital Fund (LFCF).
Currently this is out for consultation, and the effects of this change are not likely to be felt for several years.

Network Participants

University of Edinburgh University of Bristol University of East Anglia

Natural Environment Research Council

Part 5. Abbreviations

^{14}C	radiocarbon
$^{14}CO_2$	carbon dioxide containing heavy isotope of carbon
ACTRIS	Aerosols, Clouds, and Trace gases Research InfraStructure Network
AS	ICOS Atmospheric Station
Associated sites	(only for ecosystem stations) station not formally a part of the ICOS network, will be however hosted within the ETC database
ATC	ICOS Atmospheric Thematic Centre
CAL	ICOS Central Analytical Laboratory
CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
COPAL	COmmunity heavy-PAyload Long endurance Instrumented Aircraft for Tropospheric Research in Environmental and Geo-Sciences
CP	ICOS Carbon Portal
CRL	Central Radiocarbon Laboratory of CAL
Data Level 0	Raw data
Data Level 1	Data expressed in physical units
Data Level 2	Elaborated time series of concentrations for atmospheric data and gap filled time series for ecosystem data
Data Level 3	Higher level products using concentrations and other information (e.g. flux maps and multi-sensor concentration datasets for atmospheric data and spatially explicit datasets for ecosystem data)
Data Level 4	(only for ecosystem data) variables derived from combination of measurements
DG	ICOS ERIC Director General
DQO	Data Quality Objectives
EC	European Commission
ECMWF	European Center for Medium range Weather Forecast
ECV	Essential Climate Variables
ERA	European Research Area
ERIC	European Research Infrastructure Consortium
ES	ICOS Ecosystem Station
ESFRI	European Strategy Forum on Research Infrastructures
ETC	ICOS Ecosystem Thematic Centre
FCL	Flask and Calibration Laboratory of CAL
FP7	Seventh Framework Programme (running 2007-2013)
FWG	ICOS Financial Working Group (valid during the transition phase)
GA	ICOS ERIC General Assembly
GAW	Global Atmosphere Watch program

GCOS	Global Climate Observing System
GEOSS	Global Earth Observation System of Systems
GHG	Greenhouse gas
GTOS	Terrestrial Observing System
HO	ICOS Head Office
IAGOS	In-service Aircraft for a Global Observing System
ICOS	Integrated Carbon Observation System
ICOS Central Facilities	ATC, ETC, OTC, CAL and CP
ICOS National Networks	ICOS ERIC Member countries' AS, ES and ocean networks of stations
ICOS RI Committee	ICOS Research Infrastructure Committee
InGOS	Integrated non-CO_2 Greenhouse gas Observation System
IOCCP	International Ocean Carbon Coordination Project
IPCC	Intergovernmental Panel on Climate Change
ISIC	ICOS Stakeholders' Interim Council (valid during the transition phase)
JPI	Joint Programming Initiative (e.g. JPI Climate, JPI Ocean and JPI Urban)
Level 1 station	(for ecosystem and atmospheric stations) complete equipment for measuring the full set of ICOS core parameters
Level 2 station	(for ecosystem and atmospheric stations) same analytical precision thank Level 1 station but less physical parameters measured
LWG	ICOS Legal and Statutes Working Group (valid during the transition phase)
MG	Measurement Guidelines
MSA	Monitoring Station Assemblies for ICOS ERIC Member countries' AS, ES and ocean networks
N_2O	nitrous oxide
NRT	Near-Real-Time
OTC	ICOS Ocean Thematic Centre
PI	Principal Investigator of a measurement station
QAQC	Quality Assurance and Quality Control
RI	Research Infrastructure
RoP	Rules of Procedures
SAB	Scientific Advisory Board
SF_6	sulfur hexafluoride
SME	Small and medium enterprises
SOP	Standard Operating Procedures
TC	Thematic Centers for atmosphere, ecosystem and ocean observations (ATC, ETC and OTC)
UNFCCC	United Nations' Framework on Climate Change
WMO	World Meteorological Organisation

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