ICOS INTEGRATED CARBON OBSERVATION SYSTEM

Knowledge Through Observations

Climate Change

GLOBAL TEMPERATURES ARE RELATED TO GREENHOUSE GASES

Climate change is one the most challenging problems that humanity will have to cope with in the coming decades and it is happening now: global average surface temperatures have increased by almost 1°C relative to 1951–1980 average temperatures. In its Fifth Assessment Report, the IPCC, a group of 1,300 independent scientific experts under the auspices of the United Nations, has concluded that the observed rise of global temperatures is extremely likely due to increasing greenhouse gases in the atmosphere.

RISING CONCENTRATIONS OF GREENHOUSE GASES

Today's atmospheric concentrations of the main greenhouse gases carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O) are unprecedented in the last 800,000 years. CO, concentration has increased by 40% from pre-industrial times and continues to rise. Human activities have been the major contributor to the increasing concentrations. There is a global consensus that climate change can only be mitigated by a drastic cut of anthropogenic emissions.



Image: NOAA & NASA

WERNER L KUTSCH

ICOS is an important answer of European scientists, national governments and the European Commission to the Grand Challenge of Climate Change. We have joined efforts to provide knowledge through observations on the complex interactions that are behind atmospheric greenhouse gas variations. Better understanding will result in better action." **Director General, ICOS ERIC**

Knowledge through observations

ICOS – INDEPENDENT OBSERVATIONS

Standardised high-precision observations of greenhouse gases enable scientists to support the societies in their efforts to mitigate climate change. Knowledge on greenhouse gases requires a wide span of methods and instruments covering in-situ observations, satellites, data integration and modeling. The pan-European Research Infrastructure ICOS RI is a cornerstone of these global observations. ICOS will also contribute to the Global Climate Observation System (GCOS) by monitoring essential variables in order to ensure the best available science for The United Nations Framework Convention on Climate Change (UNFCCC).

ICOS IS ESSENTIAL IN BOTTOM-UP AND TOP-DOWN APPROACHES

THE DUAL PERSPECTIVE APPROACH **TO INTEGRATE KNOWLEDGE**

Scientists have developed and applied two complementary approaches to disentangle the combined effects of anthropogenic emissions, natural fluxes and atmospheric transport of greenhouse gases. The bottom-up perspective summarizes information on all kinds of surface fluxes. The top-down perspective analyses the concentrations in the atmosphere measured at atmospheric stations or by satellites and use weather information to analyze transport. In combination, the two approaches build a powerful tool to provide knowledge on the complex fabric woven of natural and anthropogenic greenhouse gas fluxes that drives the atmospheric concentrations.



Quality, transparency and open data

HIGHEST OUALITY DATA FOR FREE

One of the most important impacts of ICOS is the development of standardized and harmonized methodologies. All data from over 30 atmospheric stations, 60 terrestrial ecosystem sites, and roughly 20 oceanographic observation platforms, including volunteer observing ships are going through standardized central processing and rigorous quality control performed by the station operators and the three ICOS Thematic Centres. In that way, observations from different stations and regions can be readily compared.

THE ICOS CARBON PORTAL

The ICOS Carbon Portal provides free access to all ICOS observational data. In addition, the Carbon Portal offers elaborated products based on ICOS data and a platform where all users can publish their products. The ICOS Carbon Portal is located in Lund (Sweden) and is hosted by the University of Lund and Wageningen University (Netherlands).

MAPS, GRAPHS AND EDUCATION MATERIAL

The portfolio comprises data visualisation tools, easily accessible and understandable education products and services for integration of different models. ICOS has agreed on the Creative Commons 4.0 BY data license that enables the widest possible usage.

STATE-OF-THE-ART DATA SERVICES

The FAIR principles are used to make sure that data are Findable, Accessible, Interoperable and Reusable for both human to machine and machine to machine communication. All data usage is tracked which enables attribution to the data providers through accurate data citation. All raw data and higher level data products are stored through a long-term trusted repository together with the relevant metadata to ensure transparency and future (re-)processing of all data.

The Carbon Portal is the 'one stop shop' for all ICOS data. Easy and open access are the key criteria for all our developments, be it for the general public, stakeholders or advanced users like COPERNICUS services and modellers."

ALEX VERMEULEN Director of ICOS Carbon Portal

The ICOS data life cycle

BEST PRACTICES FOR DATA PROCESSING

ICOS data are generated from sensors at stations distributed over currently 12 European countries. Several hundred scientists and technicians assure the quality according to the best practice defined in protocols and station descriptions. From the stations the data are transmitted to Thematic Centres where highly specialized scientists run standardized data processing and quality checks. The basic principle for processing ICOS data is transparency, achieved through comprehensive description of the data and all processing steps.



ICOS PROVIDES DIFFERENT DATA PRODUCTS

- Near Real Time (NRT) data for specific users who need immediate information e.g. to run forecast models
- Final quality checked ICOS RI data
- Elaborated data products based on observational data, enriched with model and/or other observational data. Examples of these are flux maps for Europe, prognostic concentrations or fossil fuel emission estimates for one or more region

The ICOS Atmosphere observational network

WIDE GEOGRAPHICAL COVERAGE

A network of atmosphere stations monitors regional changes in greenhouse gas concentrations. Each of the stations observes an area hundreds of kilometers wide around the station thanks to the mixing property of the atmospheric circulation. Thus the network covers most of the participating countries.

MINDSET FOR THE BEST POSSIBLE DATA

Atmosphere stations continuously measure varying concentrations of CO., CH., CO and radiocarbon-CO.. These data, together with meteorology parameters, from all stations are processed in a dedicated facility, the Atmosphere Thematic Centre (ATC). The performance of the stations is further assessed by the ICOS Atmosphere Mobile Lab, capable of independent GHG observations campaign-wise carried out in parallel to the stations' in-situ observations.

TRAINING AND R&D

The ATC Metrology Laboratory carries out regular research for providing the instruments of tomorrow. Joint R&D projects with the industry lead for example to new, more capable sensors. In the ATC scientists are also trained for ICOS atmospheric measurements.

COMMITTED COUNTRIES

ATC is coordinated and operated by the French Laboratoire des Sciences du Climat et de l'Environnement supported by the Finnish Meteorological Institute. The preparation of calibration material and flask sample analysis is done in the Flask and Calibration Laboratory of the Central Analytical Laboratories in Germany.

Radiocarbon (¹⁴C)

SEPARATING FOSSIL FUEL FROM NATURAL CARBON DIOXIDE

Fossil fuels contain specific ratios of carbon isotopes, which are different from those in the atmosphere or in renewable energy sources. In particular, fossil fuels do not contain radioactive carbon (¹⁴C). A contribution of fossil fuel CO₂ therefore reduces the atmospheric ¹⁴C/C ratio at the measurement site. If the measured ¹⁴C/C ratio is lower than in the clean atmosphere, this is a clear indicator of fossil fuel CO₂ at the site. Another characteristic of fossil fuel burning is the production of carbon monoxide (CO) and nitrogen oxides (NO₂). These gases can, therefore, be used as indicators or even quantitative tracers of fossil fuel CO₂.

PERCENTAGE OF TOTAL GHG EMISSIONS

GIGATONNES OF CO, EQUIVALENT Anthropogenic **GHG emissions** in 2010

GHG emitted at the surface are transported in the atmosphere. Measurements of varying atmospheric concentration of GHG therefore inform on GHG emission over areas several hundred km wide. But because atmospheric mixing is strong over large scales, only precise measurement can bring accurate information."

LEONARD RIVIER Director of the ATC

Source: IPCC

GROUND-BASED OBSERVATIONS ARE COMPLEMENTED WITH SATELLITES

Radiocarbon is measured at several ICOS sites. The ¹⁴C/C ratio is directly related to the presence of fossil fuel use. By adding meteorological measurements, such as wind speed and direction, and modelling, the emissions can be tracked to their sources. This data can then be used to estimate the magnitude of emissions and usage of fossil fuels. On the other hand, satellites can detect the total amount of CO and NO, in the air column. These measurements provide another means to estimate the magnitude of fossil fuel CO₂ emissions.

25% Electricity and heat production

21% Industry

15% Agriculture

14% Transport

9,6% Other energy

9.0% Land use change and forestry

6,4% Buildings



The annual national CO, emission from fossil fuel burning are very well known from bottom-up statistics. With ¹⁴C we can provide the needed information to improve and validate the spatial and temporal resolution of those emission estimates."

SAMUEL HAMMER

Head of the Central Radiocar bon Laboratory (CRL)

The ICOS Ocean observational network

OCEANS ARE AN IMPORTANT SINK FOR CO.

The ICOS long-term oceanic observations are essential to understand the present state and to predict future behaviour of the global carbon cycle. Presently the oceanic sink offsets approximately 25% of anthropogenic CO, emissions and the annual net marine fluxes of CO, can vary substantially from year to year and location to location.

ALL MEANS ARE USED TO COVER THE VAST OCEAN

ICOS ocean network of observations covers particularly the North Atlantic, Nordic Seas, Baltic and the Mediterranean. Ships, floats, gliders and other platforms are equipped with state of the art carbonate system sensors. The ambition is to make the ocean platforms autonomous and to provide near real time ocean data to the ICOS RI.

ORIENTATION TOWARDS THE FUTURE

The measurements from the ocean network are coordinated and processed by the Ocean Thematic Centre (OTC). OTC also focuses on the development of best practise guidelines and protocols, training, and liaising with industry.

COMMITTED COUNTRIES

The Ocean Thematic Centre is coordinated and operated by Uni Research and the University of Bergen, Norway, as a joint effort in the Bjerknes Centre for Climate Research.



The earth surface consists of 71 per cent ocean and the deep ocean stores about 60 times more carbon than the atmosphere. Changes in climate caused by the human emitted GHGs can cause changes in ocean climate and circulation. The ocean is in addition a critical factor damping the effect of human emission of GHG by air sea gas exchange and for this reason a must to understand. ICOS therefore takes into account the important interplay between ocean, land and atmosphere."

TRULS JOHANNESSEN Director of the OTC

The ICOS Ecosystem observational network

WIDE COVERAGE OF BIODIVERSITY

Earth is covered by a multitude of terrestrial ecosystems. These have varying contribution to the global carbon balance. ICOS observes processes where they occur, and therefore all major European ecosystems are represented in the ecosystem network. GHG fluxes and contributing factors are observed in forests, wetlands, grasslands, fields and aquatic ecosystems.

HARMONIZED METHODS FOR COMPLEX SYSTEMS

Understanding ecosystem scale greenhouse gas dynamics needs the observation of tens of parameters. This brings together scientists from different fields and various methodologies for data collection and analysis. ICOS provides harmonized protocols how these observations should be conducted. This vastly increases the usability of the data and facilitates understanding of GHG cycles.

Continental ecosystems are hosting complex biogeochemical processes which produce and transform greenhouse gases. A large set of observations is necessary to monitor these processes and understand the dynamics of greenhouse gases exchanges. For this reason, a strong interaction is needed among different fields of expertise and this has been at the basis of the decision to involve institutes from three countries in the Ecosystem Thematic Centre (ETC)."

BERT GIELEN (BE), DARIO PAPALE (IT) AND DENIS LOUSTAU (FR) the Executive Committee of the ETC

CENTRALIZED DATA PROCESSING

The measurements over the continental ecosystems are coordinated by the Ecosystem Thematic Centre (ETC). ETC is responsible for the online processing of all the ecosystem data and instrument development in co-operation with the wider community.

COMMITTED COUNTRIES

ETC is coordinated and operated by the Euro-Mediterranean Centre on Climate Change (CMCC) in collaboration with the University of Tuscia in Italy, by the University of Antwerp in Belgium and the National Institute for Agricultural Research in France.



Under permanent development

PREPARING FOR FUTURE NEEDS

The Paris Agreement has introduced new requirements for ICOS. ICOS is developing its readiness for upcoming tasks in a permanent innovation process. Supported by the European Commission we are exploring new technologies, better data analysis tools and innovative concepts to support the observation and verification of the national Greenhouse Gas Inventories and the stocktaking process of the Intended Nationally Determined Contributions (INDCs) in the **UNFCCC** framework.

GOVERNANCE

ICOS is a distributed Research Infrastructure. It is organized as a European Research Infrastructure Consortium (ICOS ERIC), a legal entity under European Law hosted by Finland. ICOS ERIC coordinates the operations, distributes information from ICOS to user communities and establishes integrated data and analysis from GHG observation systems.

STRUCTURE

ICOS ERIC comprises the Head Office and the Carbon Portal, whereas the other Central Facilities and the Observational Networks are run under the auspices of the participating nations. The cooperation is defined in agreements between ICOS ERIC and the respective research institutions.

CROSS-INFRASTRUCTURE COOPERATION

ICOS ERIC is a landmark on the European Roadmap for Research Infrastructures (ESFRI Roadmap). In this context, ICOS is strongly cooperating with other environmental Research Infrastructures in order to find shared solutions on observational methodologies, data interoperability, access to infrastructures, societal aspects and dissemination. ICOS is coordinating the environmental cluster project ENVRIplus, where 21 ESFRI research infrastructures and emerging communities are cooperating.



ICOS is for the challenges of today and tomorrow. As there is uncertainty in future climate and societal needs, we need to be adaptive. This is achieved by constantly developing governance and our operations. Wide cooperation is essential for global best practices."

EIJA JUUROLA Head of Operations

The international role of ICOS

ESSENTIAL INFORMATION FOR UNFCCC

ICOS cooperates internationally to provide comprehensive information on the Earth's climate system. Our activities are a European contribution to the Global Climate Observation System (GCOS), a joint undertaking of UN and science organisations. GCOS has defined essential variables to address the total climate system including physical, chemical and biological properties, and atmospheric, oceanic, terrestrial, hydrologic, and cryospheric components. Through GCOS vital and continuous support to the United Nations Framework Convention on Climate Change (UNFCCC) is provided.

SPECIAL FOCUS IN AFRICA

Through GEO-C and IG³IS and the H2020 projects RISCAPE and SEACRIFOG we are deepening our connections to Research Infrastructures in other regions. We are doing this with a special focus on African countries. We want actively contribute to global observations and share our technical experiences.



GLOBAL NETWORKS WITH GEO AND WMO

ICOS is participating organization in the Group on Earth Observations (GEO) and actively supports the GEO Initiative on Carbon and Greenhouse Gases (GEO-C). GEO-C is complementary to the Integrated Global Greenhouse Gas Information System (IG³IS) developed by the World Meteorological Organisation (WMO). We support the two missions with the open supply of our data and meet the demand for comprehensive information about the Earth.



Climate Change is global; greenhouse gases do not stop at national borders. For us it is important to share our knowledge as part of a global observation svstem."

IOUNI HEISKANEN Scientific Integration and Liaison Officer at ICOS Head Office



Get involved



ICOS NATIONAL NETWORKS

Belgium
Czech Republi
Denmark
Finland
France
Germany

reinhart.ceulemans@uantwerpen.be kolman.j@czechglobe.cz kipi@env.dtu.dk philippe.ciais@lsce.ipsl.fr christian.bruemmer@thuenen.de

Italy Netherlands Norway Sweden Switzerland

carlo.calfapietra@ibaf.cnr.it eddy.moors@wur.nl director@icos-sweden.se nina.buchmann@usys.ethz.ch **United Kingdom** and rew.watson@exeter.ac.uk

ICOS INTEGRATED CARBON OBSERVATION SYSTEM

ICOS ERIC HEAD OFFICE

Erik Palménin aukio 1, FI-00560 Helsinki info@icos-ri.eu | www.icos-ri.eu Twitter: @ICOS_RI